

TC1728

32-Bit Single-Chip Microcontroller

User's Manual

V1.0 2011-12

Microcontrollers

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1 Introduction

This User's Manual describes the Infineon TC1728, a 32-bit microcontroller DSP, based on the Infineon TriCore Architecture. This document covers the features of package variants TC1728 and TC1724.

1.1 About this Document

This document is designed to be read primarily by design engineers and software engineers who need a detailed description of the interactions of the TC1728 functional units, registers, instructions, and exceptions.

This TC1728 User's Manual describes the features of the TC1728 with respect to the TriCore Architecture. Where the TC1728 directly implements TriCore architectural functions, this manual simply refers to those functions as features of the TC1728. In all cases where this manual describes a TC1728 feature without referring to the TriCore Architecture, this means that the TC1728 is a direct implementation of the TriCore Architecture.

Where the TC1728 implements a subset of TriCore architectural features, this manual describes the TC1728 implementation, and then describes how it differs from the TriCore Architecture. Such differences between the TC1728 and the TriCore Architecture are documented in the section covering each such subject.

1.1.1 Related Documentations

A complete description of the TriCore architecture is found in the document entitled "TriCore Architecture Manual". The architecture of the TC1728 is described separately this way because of the configurable nature of the TriCore specification: Different versions of the architecture may contain a different mix of systems components. The TriCore architecture, however, remains constant across all derivative designs in order to preserve compatibility.

This User's Manuals together with the "TriCore Architecture Manual" are required to understand the complete TC1728 micro controller functionality.

1.1.2 Text Conventions

This document uses the following text conventions for named components of the TC1728:

- Functional units of the TC1728 are given in plain UPPER CASE. For example: "The SSC supports full-duplex and half-duplex synchronous communication".
- Pins using negative logic are indicated by an overline. For example: "The external reset pin, $\overline{\text{ESR0}}$, has a dual function."
- Bit fields and bits in registers are in general referenced as "Module_Register name.Bit field" or "Module_Register name.Bit". For example: "The

Introduction

Current CPU Priority Number bit field CPU_ICR.CCPN is cleared". Most of the register names contain a module name prefix, separated by an underscore character "_" from the actual register name (for example, "ASC0_CON", where "ASC0" is the module name prefix, and "CON" is the kernel register name). In chapters describing the kernels of the peripheral modules, the registers are mainly referenced with their kernel register names. The peripheral module implementation sections mainly refer to the actual register names with module prefixes.

- Variables used to describe sets of processing units or registers appear in mixed upper and lower cases. For example, register name "MSGCFGn" refers to multiple "MSGCFG" registers with variable n. The bounds of the variables are always given where the register expression is first used (for example, "n = 0-31"), and are repeated as needed in the rest of the text.
- The default radix is decimal. Hexadecimal constants are suffixed with a subscript letter "H", as in 100_H. Binary constants are suffixed with a subscript letter "B", as in: 111_B.
- When the extent of register fields, groups register bits, or groups of pins are collectively named in the body of the document, they are represented as "NAME[A:B]", which defines a range for the named group from B to A. Individual bits, signals, or pins are given as "NAME[C]" where the range of the variable C is given in the text. For example: CFG[2:0] and SRPN[0].
- Units are abbreviated as follows:
 - **MHz** = Megahertz
 - **μs** = Microseconds
 - **kBaud, kbit** = 1000 characters/bits per second
 - **MBaud, Mbit** = 1,000,000 characters/bits per second
 - **Kbyte, KB** = 1024 bytes of memory
 - **Mbyte, MB** = 1048576 bytes of memory

In general, the k prefix scales a unit by 1000 whereas the K prefix scales a unit by 1024. Hence, the Kbyte unit scales the expression preceding it by 1024. The kBaud unit scales the expression preceding it by 1000. The M prefix scales by 1,000,000 or 1048576, and μ scales by .000001. For example, 1 Kbyte is 1024 bytes, 1 Mbyte is 1024 × 1024 bytes, 1 kBaud/kbit are 1000 characters/bits per second, 1 MBaud/Mbit are 1000000 characters/bits per second, and 1 MHz is 1,000,000 Hz.
- Data format quantities are defined as follows:
 - **Byte** = 8-bit quantity
 - **Half-word** = 16-bit quantity
 - **Word** = 32-bit quantity
 - **Double-word** = 64-bit quantity

1.1.3 Reserved, Undefined, and Unimplemented Terminology

In tables where register bit fields are defined, the following conventions are used to indicate undefined and unimplemented function. Furthermore, types of bits and bit fields are defined using the abbreviations as shown in [Table 1-1](#).

Table 1-1 Bit Function Terminology

Function of Bits	Description
Unimplemented, Reserved	Register bit fields named 0 indicate unimplemented functions with the following behavior. <ul style="list-style-type: none"> Reading these bit fields returns 0. These bit fields should be written with 0 if the bit field is defined as r or rh. These bit fields have to be written with 0 if the bit field is defined as rw. These bit fields are reserved. The detailed description of these bit fields can be found in the register descriptions.
rw	The bit or bit field can be read and written.
rwh	As rw, but bit or bit field can be also set or reset by hardware.
r	The bit or bit field can only be read (read-only).
w	The bit or bit field can only be written (write-only). A read to this register will always give a default value back.
rh	This bit or bit field can be modified by hardware (read-hardware, typical example: status flags). A read of this bit or bit field give the actual status of this bit or bit field back. Writing to this bit or bit field has no effect to the setting of this bit or bit field.
s	Bits with this attribute are “sticky” in one direction. If their reset value is once overwritten by software, they can be switched again into their reset state only by a reset operation. Software cannot switch this type of bit into its reset state by writing the register. This attribute can be combined to “rws” or “rwhs”.
f	Bits with this attribute are readable only when they are accessed by an instruction fetch. Normal data read operations will return other values.

1.1.4 Register Access Modes

Read and write access to registers and memory locations are sometimes restricted. In memory and register access tables, the terms as defined in [Table 1-2](#) are used.

Table 1-2 Access Terms

Symbol	Description
U	Access Mode: Access permitted in User Mode 0 or 1.
	Reset Value: Value or bit is not changed by a reset operation.
SV	Access permitted in Supervisor Mode.
R	Read-only register.
32	Only 32-bit word accesses are permitted to this register/address range.
E	Endinit-protected register/address.
PW	Password-protected register/address.
NC	No change, indicated register is not changed.
BE	Indicates that an access to this address range generates a Bus Error.
nBE	Indicates that no Bus Error is generated when accessing this address range, even though it is either an access to an undefined address or the access does not follow the given rules.
nE	Indicates that no Error is generated when accessing this address or address range, even though the access is to an undefined address or address range. True for CPU accesses (MTCR/MFCR) to undefined addresses in the CSFR range.

1.1.5 Abbreviations and Acronyms

The following acronyms and terms are used in this document:

ADC	Analog-to-Digital Converter
AGPR	Address General Purpose Register
ALU	Arithmetic and Logic Unit
ASC	Asynchronous/Synchronous Serial Controller
BCU	Bus Control Unit
BROM	Boot ROM & Test ROM
CAN	Controller Area Network
CMEM	PCP Code Memory
CISC	Complex Instruction Set Computing
CPS	CPU Slave Interface
CPU	Central Processing Unit

CRC	Cyclic Redundancy Code
CSA	Context Save Area
CSFR	Core Special Function Register
DAP	Device Access Port
DAS	Device Access Server
DCACHE	Data Cache
DFLASH	Data Flash Memory
DGPR	Data General Purpose Register
DMA	Direct Memory Access
DMI	Data Memory Interface
ECC	Error Correction Code
EMI	Electro-Magnetic Interference
FADC	Fast Analog-to-Digital Converter
FAM	Flash Array Module
FCE	Flexible CRC Engine
FCS	Flash Command State Machine
FIM	Flash Interface and Control Module
FPI	Flexible Peripheral Interconnect (Bus)
FPU	Floating Point Unit
GPIO	General Purpose Input/Output
GPR	General Purpose Register
GPTA	General Purpose Timer Array
ICACHE	Instruction Cache
I/O	Input / Output
JTAG	Joint Test Action Group = IEEE1149.1
LBCU	Local Memory Bus Control Unit
LDRAM	Local Data RAM
LFI	Local Memory-to-FPI Bus Interface
LMB	Local Memory Bus
LTC	Local Timer Cell
MLI	Micro Link Interface
MMU	Memory Management Unit

MSB	Most Significant Bit
MSC	Micro Second Channel
NC	Not Connected
NMI	Non-Maskable Interrupt
OCDS	On-Chip Debug Support
OVRAM	Overlay Memory
PCP	Peripheral Control Processor
PMU	Program Memory Unit
PLL	Phase Locked Loop
PFLASH	Program Flash Memory
PMI	Program Memory Interface
PMU	Program Memory Unit
PRAM	PCP Parameter RAM
RAM	Random Access Memory
RISC	Reduced Instruction Set Computing
SBCU	System Peripheral Bus Control Unit
SCU	System Control Unit
SFR	Special Function Register
SPB	System Peripheral Bus
SPRAM	Scratch-Pad RAM
SRAM	Static Data Memory
SRN	Service Request Node
SSC	Synchronous Serial Controller
STM	System Timer
WDT	Watchdog Timer

1.2 System Architecture of the TC1728

The TC1728 combines three powerful technologies within one silicon die, achieving new levels of power, speed, and economy for embedded applications:

- Reduced Instruction Set Computing (RISC) processor architecture
- Digital Signal Processing (DSP) operations and addressing modes
- On-chip memories and peripherals

DSP operations and addressing modes provide the computational power necessary to efficiently analyze complex real-world signals. The RISC load/store architecture provides high computational bandwidth with low system cost. On-chip memory and peripherals are designed to support even the most demanding high-bandwidth real-time embedded control-systems tasks.

Additional high-level features of the TC1728 include:

- Efficient memory organization: instruction and data scratch memories, caches
- Serial communication interfaces – flexible synchronous and asynchronous modes
- Peripheral Control Processor – standalone data operations and interrupt servicing
- DMA Controller – DMA operations and interrupt servicing
- General-purpose timers
- High-performance on-chip buses
- On-chip debugging and emulation facilities
- Flexible interconnections to external components
- Flexible power-management

The TC1728 is a high-performance microcontroller with TriCore CPU, program and data memories, buses, bus arbitration, an interrupt controller, a peripheral control processor and a DMA controller and several on-chip peripherals. The TC1728 is designed to meet the needs of the most demanding embedded control systems applications where the competing issues of price/performance, real-time responsiveness, computational power, data bandwidth, and power consumption are key design elements.

The TC1728 offers several versatile on-chip peripheral units such as serial controllers, timer units, and Analog-to-Digital converters. Within the TC1728, all these peripheral units are connected to the TriCore CPU/system via the Flexible Peripheral Interconnect (FPI) Bus and the Local Memory Bus (LMB). Several I/O lines on the TC1728 ports are reserved for these peripheral units to communicate with the external world.

1.2.2 System Features

The TC1728 has the following features:

Packages

- PG-LQFP-176 package (TC1728)
- PG-LQFP-144 package (TC1724)

1.2.3 CPU Cores of the TC1728

The TC1728 includes a high Performance CPU and a Peripheral Control Processor.

1.2.3.1 High-performance 32-bit CPU

This chapter gives an overview about the TriCore 1 architecture.

TriCore (TC1.3.1) Architectural Highlights

- Unified RISC MCU/DSP
- 32-bit architecture with 4 Gbytes unified data, program, and input/output address space
- Fast automatic context-switching
- Multiply-accumulate unit
- Floating point unit
- Saturating integer arithmetic
- High-performance on-chip peripheral bus (FPI Bus)
- Register based design with multiple variable register banks
- Bit handling
- Packed data operations
- Zero overhead loop
- Precise exceptions
- Flexible power management

High-efficiency TriCore Instruction Set

- 16/32-bit instructions for reduced code size
- Data types include: Boolean, array of bits, character, signed and unsigned integer, integer with saturation, signed fraction, double-word integers, and IEEE-754 single-precision floating point
- Data formats include: Bit, 8-bit byte, 16-bit half-word, 32-bit word, and 64-bit double-word data formats
- Powerful instruction set
- Flexible and efficient addressing mode for high code density

Integrated CPU related On-Chip Memories

- Instruction memory: 24KB total. After reset, configured into:¹⁾
 - 24 Kbyte Scratch-Pad RAM (SPRAM)
 - 0 Kbyte Instruction Cache (ICACHE)
- Data memory: 120 KB total. After reset, configured into:¹⁾
 - 120 Kbyte Local Data RAM (LDRAM)

1) Software configurable. Available options are described in the CPU chapter.

- 0 Kbyte Data Cache (DACHE)
- On-chip SRAMs with ECC protection

1.2.3.2 High-performance 32-bit Peripheral Control Processor

The PCP is a flexible Peripheral Control Processor optimized for interrupt handling and thus unloading the CPU.

Features

- Data move between any two memory or I/O locations
- Data move with predefined limit supported
- Read-Modify-Write capabilities
- Full computation capabilities including basic MUL/DIV
- Read/move data and accumulate it to previously read data
- Read two data values and perform arithmetic or logical operation and store result
- Bit-handling capabilities (testing, setting, clearing)
- Flow control instructions (conditional/unconditional jumps, breakpoint)
- Programmable write protection for Code Memory and Parameter Memory
- Programmable limit of FPI addresses than can be written by the PCP
- Dedicated Interrupt System
- PCP SRAMs with ECC protection
- PCP/FPI clock mode 1:1 and 2:1 available
- High Integrity Operation support

Integrated PCP related On-Chip Memories

- 24 Kbyte Code Memory (CMEM)
- 8 Kbyte Parameter Memory (PRAM)

1.3 On-Chip System Units

The TC1728 microcontroller offers several versatile on-chip system peripheral units such as DMA controller, embedded Flash module, Flexible CRC Engine, System Timer Unit, System Control Unit, Overlay Control module, interrupt system and ports.

1.3.1 Flexible Interrupt System

The TC1728 includes a programmable interrupt system with the following features:

Features

- Fast interrupt response
- Hardware arbitration
- Independent interrupt systems for CPU and PCP
- Programmable service request nodes (SRNs)
- Each SRN can be mapped to the CPU or PCP interrupt system
- Flexible interrupt-prioritizing scheme with 255 interrupt priority levels per interrupt system

1.3.2 System Timer

The TC1728's STM is designed for global system timing applications requiring both high precision and long range.

Features

- Free-running 56-bit counter
- All 56 bits can be read synchronously
- Different 32-bit portions of the 56-bit counter can be read synchronously
- Flexible interrupt generation based on compare match with partial STM content
- Counting starts automatically after a reset operation
- STM registers are reset by an application reset if bit ARSTDIS.STMDIS is cleared. If bit ARSTDIS.STMDIS is set, the STM registers are not reset.¹⁾
- STM can be halted in debug/suspend mode

Special STM register semantics provide synchronous views of the entire 56-bit counter, or 32-bit subsets at different levels of resolution.

1) "STM registers" means all registers except STM_CLC, STM_SRC0, and STM_SRC1.

1.3.3 System Control Unit

The following SCU introduction gives an overview about the TC1728 System Control Unit (SCU) For Information about the SCU see chapter 3.

1.3.3.1 Clock Generation Unit

The Clock Generation Unit (CGU) allows a very flexible clock generation for the TC1728. During user program execution the frequency can be programmed for an optimal ratio between performance and power consumption.

1.3.3.2 Features of the Watchdog Timer

The main features of the WDT are summarized here.

- 16-bit Watchdog counter
- Selectable input frequency: $f_{FPI}/256$ or $f_{FPI}/16384$
- 16-bit user-definable reload value for normal Watchdog operation, fixed reload value for Time-Out and Prewarning Modes
- Incorporation of the ENDINIT bit and monitoring of its modifications
- Sophisticated Password Access mechanism with fixed and user-definable password fields
- Access Error Detection: Invalid password (during first access) or invalid guard bits (during second access) trigger the Watchdog reset generation
- Overflow Error Detection: An overflow of the counter triggers the Watchdog reset generation
- Watchdog function can be disabled; access protection and ENDINIT monitor function remain enabled
- Double Reset Detection: If a Watchdog induced reset occurs twice, a severe system malfunction is assumed and the TC1728 is held in reset until a System Reset occurs. This prevents the device from being periodically reset if, for instance, connection to the external memory has been lost such that even system initialization could not be performed

1.3.3.3 Reset Operation

The following reset request triggers are available:

- 1 External power-on hardware reset request trigger; \overline{PORST} , (cold reset)
- 2 External System Request reset triggers; $\overline{ESR0}$ and $\overline{ESR1}$ (cold/warm reset)
- Watchdog Timer (WDT) reset request trigger, (warm reset)
- Software reset (SW), (warm reset)
- Resets via the JTAG interface
- Flash Tuning Protection (TP) (warm reset)
- EVR13 reset triggering a power-on reset (cold reset)
- EVR33 reset triggering a power-on reset (cold reset)

- EVR5 reset triggering a power-on reset (cold reset)

There are two basic types of reset request triggers:

- Trigger sources that do not depend on a clock, such as the $\overline{\text{PORST}}$ or the EVR13/33. This trigger force the device into an asynchronous reset assertion independently of any clock. The activation of an asynchronous reset is asynchronous to the system clock, whereas its de-assertion is synchronized.
- Trigger sources that need a clock in order to be asserted, such as the input signals ESR0, ESR1, the WDT trigger, TP trigger, or the SW trigger.

1.3.3.4 External Interface

The SCU provides interface pads for system purpose. Various functions are covered by these pins. Due to the different tasks some of the pads can not be shared with other functions but most of them can be shared with other functions. The following functions are covered by the SCU controlled pads:

- Reset request triggers
- Reset indication
- Trap request triggers
- Interrupt request triggers
- Non SCU module triggers

The first three points are covered by the ESR pads and the last two points by the ERU pads.

1.3.4 Development Support

Overview about the TC1728 development environment:

Complete Development Support

A variety of software and hardware development tools for the 32-bit microcontroller TC1728 are available from experienced international tool suppliers. The development environment for the Infineon 32-bit microcontroller includes the following tools:

- Embedded Development Environment for TriCore Products
- The TC1728 On-chip Debug Support (OCDS) provides a JTAG port for communication between external hardware and the system
- Flexible Peripheral Interconnect Buses (FPI Bus) for on-chip interconnections and its FPI Bus control unit (SBCU)
- The System Timer (STM) with high-precision, long-range timing capabilities
- The TC1728 includes a power management system, a watchdog timer as well as reset logic

2 CPU Subsystem

The TC1728 processor contains a TriCore 1.3.1 CPU. This chapter describes the implementation-specific options of the CPU, and should be read in conjunction with the TriCore Architecture Manual, which describes the complete TriCore Architecture including the register and instruction set.

2.1 TC1728 Processor Subsystem

The diagram below shows the block diagram of the processor subsystem.

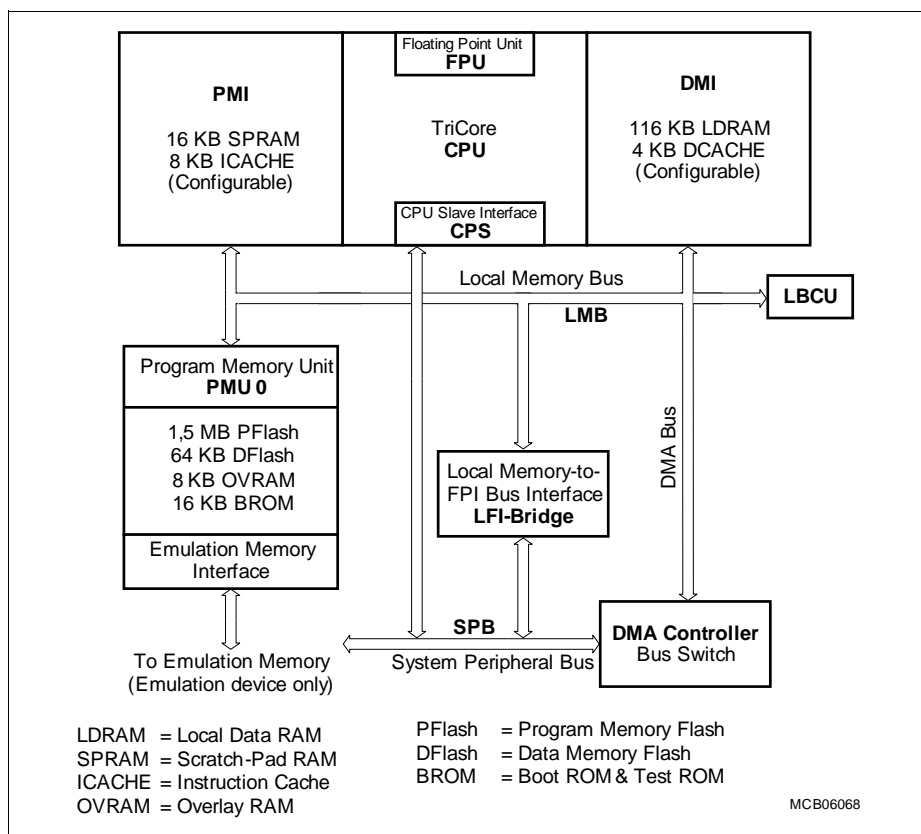


Figure 1 TC1728 Processor Subsystem Block Diagram

2.2 Central Processing Unit Features

The 133MHz TriCore TC1728 CPU includes:

Architecture

- 32-bit load store architecture
- 4 Gbyte address range (2^{32})
- 16-bit and 32-bit instructions for reduced code size
- Data types:
 - Boolean, integer with saturation, bit array, signed fraction, character, double-word integers, signed integer, unsigned integer, IEEE-754 single-precision floating point
- Data formats:
 - Bit, byte (8-bits), half-word (16-bits), word (32-bits), double-word (64-bits)
- Byte and bit addressing
- Little-endian byte ordering for data, memory and CPU registers
- Multiply and Accumulate (MAC) instructions: Dual 16×16 , 16×32 , 32×32
- Saturation integer arithmetic
- Packed data
- Addressing modes:
 - Absolute, circular, bit reverse, long + short, base + offset with pre- and post-update
- Instruction types:
 - Arithmetic, address arithmetic, comparison, address comparison, logical, MAC, shift, coprocessor, bit logical, branch, bit field, load/store, packed data, system
- General Purpose Register Set (GPRS):
 - Sixteen 32-bit data registers
 - Sixteen 32-bit address registers
 - Three 32-bit status and program counter registers (PSW, PC, PCXI)
- Core Debug support (OCDS):
 - Level 1, supported in conjunction with the CPS block
 - Level 3, supported in conjunction with the MCDS block (Emulation Device only).

Implementation

- Most instructions executed in 1 cycle
- Branch instructions in 1, 2 or 3 cycles (using branch prediction)
- Shadow registers for fast context switch
- Automatic context save-on-entry and restore-on-exit for: subroutine, interrupt, trap
- Four memory protection register sets
- Dual instruction issuing (in parallel into Integer Pipeline and Load/Store Pipeline)
- Third pipeline for loop instruction only (zero overhead loop)
- Optional Floating Point instruction set implemented
- Optional Memory Management Unit (MMU) instruction set not implemented (Memory management configuration registers are always read as MMU not present)

2.2.1 CPU Diagram

The Central Processing Unit (CPU) comprises of an Instruction Fetch Unit, an Execution Unit, a General Purpose Register File (GPR), a CPU Slave interface (CPS), and Floating Point Unit (FPU).

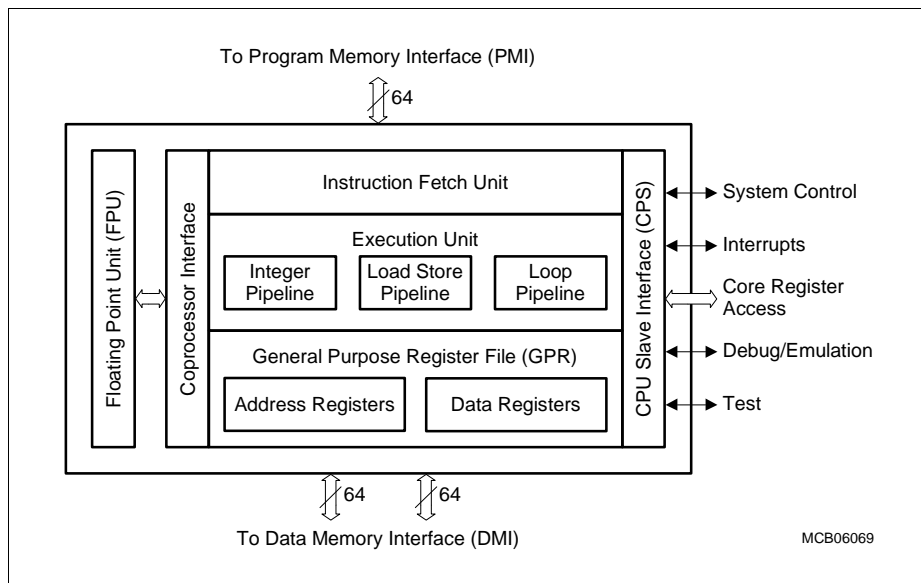


Figure 2 CPU Block Diagram

2.2.2 Instruction Fetch Unit

The Instruction Fetch Unit pre-fetches and aligns incoming instructions from the 64-bit wide Program Memory Interface (PMI). It contains an instruction pre-fetch buffer which may contain up to 128-bits of instructions linearly pre-fetched ahead of the current program counter. The Issue Unit directs the instruction to the appropriate pipeline.

The Instruction Protection Unit checks the validity of accesses to the PMI and also checks for instruction breakpoint conditions. The Program Counter Unit (PC) is responsible for updating the program counters.

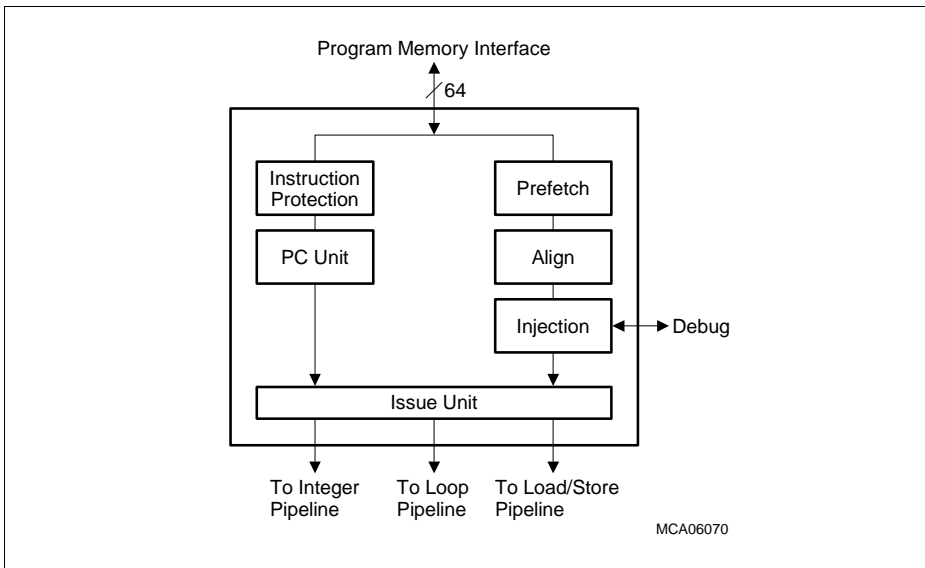


Figure 3 Instruction Fetch Unit

2.2.3 Execution Unit

The Execution Unit contains the Integer Pipeline, the Load/Store Pipeline and the Loop Pipeline.

The Integer Pipeline and Load/Store Pipeline have four stages: Fetch, Decode, Execute, and Write-back. The Execute stage may extend beyond one cycle to accommodate multi-cycle operations such as load instructions.

The Loop Pipeline has two stages: Decode and Write-back.

All three pipelines operate in parallel, permitting up to three instructions to be executed in one clock cycle.

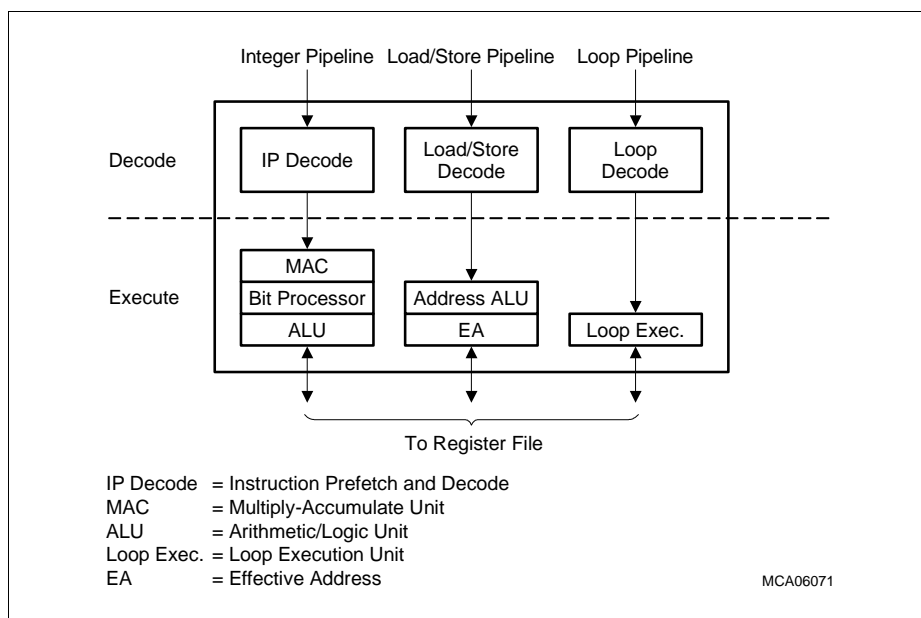


Figure 4 Execution Unit

2.2.4 General Purpose Register File

The CPU has a General Purpose Register (GPR) file, divided into an Address Register File (registers A0 through A15) and a Data Register File (registers D0 through D15).

The data flow for instructions issued to the Load/Store Pipeline is steered through the Address Register File.

The data flow for instructions issued to/from the Integer Pipeline and for data load/store instructions issued to the Load/Store Pipeline is steered through the Data Register File.

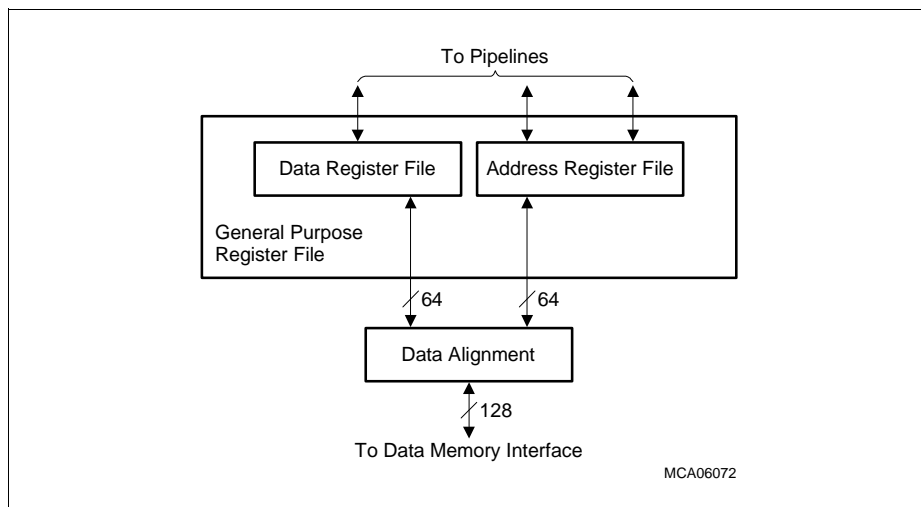


Figure 5 General Purpose Register File

2.3 CPU Implementation-Specific Features

This section describes the implementation-specific features of the CPU. For a complete description of all registers, refer to the TriCore Architecture Manual.

2.3.1 Context Save Areas

Context Save Areas (CSA) may be placed in LDRAM.

The CPU uses a uniform context-switching method for function calls, interrupts and traps. In all cases the Upper Context of the task is automatically saved and restored by hardware. Saving and restoring of the Lower Context may be optionally performed by software.

Fast context switching is enhanced by the unique memory subsystem design and the usage of shadow registers for the Upper Context. Shadow registers are automatically stored to and restored from memory when required and the presence of these registers is transparent to software.

The actual timing of context operations is dependent upon the state of the shadow registers.

CSA Placement in LDRAM

When they are not full, the shadow registers allow a complete Upper Context to be saved in as few as two clock cycles. When the shadow registers are full, the upper context save takes up to five cycles. On average an upper context save takes ~2.7 cycles.

2.3.2 Program Counter Register - PC

The Program Counter (PC) holds the address of the instruction that is currently fetched and forwarded to the CPU pipelines. The CPU handles updates of the PC automatically. Software can use the current value of the PC for various tasks, such as performing code address calculations. Reading the PC through software executed by the CPU must only be done with an MFCR instruction. Explicit writes to the PC through an MTCR instruction must not be done due to possible unexpected behavior of the CPU.

The CPU must not perform Load/Store instructions to the mapped address of the PC in Segment 15. A MEM trap will be generated in such a case. Bit 0 of the PC register is read-only and hard-wired to 0.

2.3.3 Interrupt System

An interrupt request can be generated by the on-chip peripheral units, or it can be generated by external events. Requests can be targeted to either the CPU, or to the Peripheral Control Processor (PCP).

The interrupt system evaluates service requests for priority and to identify whether the CPU (or PCP) should receive the request. The highest-priority service request is then presented to the CPU (or PCP) by way of an interrupt.

The term “interrupt” is used generally to mean an event directed to the CPU, while the term “service request” describes an event that can be directed to either the CPU or the PCP.

2.3.4 Trap System

The following traps have implementation-specific properties.

UOPC - Unimplemented Opcode (TIN 2)

The UOPC trap is raised on optional MMU instructions, coprocessor two and coprocessor three instructions.

OPD - Invalid Operand (TIN 3)

The CPU does not raise OPD traps.

DSE - Data Access Synchronous Error (TIN 2)

The Data Access Synchronous Bus Error (DSE) trap is generated by the DMI module when a load access from the CPU encounters certain error conditions, such as an LMB Bus error, or an out-of-range access to LDRAM. When a DSE trap is generated, the exact cause of the error can be determined by reading the DMI Synchronous Trap Flag Register, DMI_STR. For details of possible error conditions and the corresponding flag bits in DMI_STR, see [“DMI Trap Generation” on Page 2-85](#).

DAE - Data Access Asynchronous Error (TIN 3)

The Data Access Asynchronous Error Trap (DAE) is generated by the DMI module when a store or cache management access from the CPU encounters certain error conditions, such as an LMB Bus error, or an out-of-range access to LDRAM. When a DAE trap is generated, the exact cause of the error can be determined by reading the DMI Asynchronous Trap Flag Register, DMI_ATR. For details of possible error conditions and the corresponding flag bits in DMI_ATR, see [“DMI Trap Generation” on Page 2-85](#).

PIE Program Memory Integrity Error (TIN 5)

The PIE trap is raised whenever an uncorrectable memory integrity error is detected in an instruction fetch from a local memory. The trap is synchronous to the erroneous instruction. The trap is of Class-4 and has a TIN of 5.

Program memories are protected from memory integrity errors on a per-halfword basis. As such the error is localised to a specific instruction, and a PIE trap is raised when an attempt is made to execute an instruction containing a memory integrity error.

The PIEAR and PIETR registers may be interrogated to determine the source of any error more precisely.

DIE Data Memory Integrity Error (TIN 6)

The DIE trap is raised whenever an uncorrectable memory integrity error is detected in a data access to a local memory. The trap is of Class-4 and has a TIN of 6.

DIE traps are always asynchronous independent of the operation which encountered the error.

A DIE trap is raised if any memory halfword accessed by a load/store operation contains an uncorrectable error. The DIEAR and DIETR registers may be interrogated to determine the source of any error more precisely.

2.3.5 Memory Integrity Error Handling

The TriCore 1.3.1 contains integrated support for the detection and handling of memory integrity errors. The handling of memory integrity errors for the various memory types in TriCore 1.3.1 is as follows:

2.3.5.1 Program Side Memories

The program side memories of the TriCore 1.3.1 core support a programmable split between Scratchpad RAM (SPRAM) and Instruction Cache (ICACHE). Both SPRAM and ICACHE are unified within a single memory structure, known as Program Memory (PMEM). The PMEM of TriCore 1.3.1 is protected from memory integrity errors on a per-halfword basis. Any byte write access to the SPRAM from the LMB interface is converted to a halfword Read-Modify-Write sequence by the PMI module.

Scratchpad RAM (SPRAM)

The Scratchpad RAM of TriCore 1.3.1 is protected from memory integrity errors on a per-halfword basis. The SPRAM is ECC protected, six ECC bits are required per half-word stored. ECC protection of SPRAM is enabled by setting MIECON.PMIEE to one. When MIECON.PMIEE is zero all uncorrectable memory integrity errors are ignored.

For instruction fetch requests from the TriCore CPU to SPRAM, the ECC bits are read along with the data bits and an error signal is generated for each half-word. The error

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signals are passed to the core along with their corresponding instruction half-words. Whenever an attempt is made to issue an instruction containing an uncorrectable memory integrity error a synchronous PIE trap is raised. The trap handler is then responsible for correcting the memory entry and re-starting program execution.

For SPRAM read operations from the LMB interface, either from the DMI module or another LMB master agent, an access that results in the detection of an uncorrectable memory integrity error in the requested data half-words causes a bus error to be returned for the bus transaction. Since the TriCore CPU may not be involved in the transaction, a separate error is also flagged to the SCU module to optionally generate an NMI trap back to the core.

Writes to program scratchpad memory are only ever performed from the bus interface. For write operations of half-word size or greater, the ECC bit values are pre-computed based on the 16-bit granularity and written to the scratch memory in parallel with the data. For byte write operations the memory transaction is transformed into a half-word read-modify-write sequence inside the PMI module. As such, byte write operations may result in the detection of uncorrectable memory integrity errors, which are handled as standard read operations.

Instruction Cache (ICACHE)

Since the instruction cache shares the same physical memory as the Scratchpad RAM, it is similarly configured for memory integrity error protection: six ECC bits are stored per half-word. ECC protection of the instruction cache is enabled by setting MIECON.PMIEE to one. When MIECON.PMIEE is zero all uncorrectable memory integrity errors are ignored.

For instruction fetch requests from the TriCore CPU to ICACHE, the ECC bits are read along with the data bits of both cache ways, and an uncorrectable error signal generated for each half-word of each cache way. In the case of a tag hit, the uncorrectable error signals for the corresponding cache way are passed to the core along with their corresponding instruction half-words. The corresponding program tag entry is invalidated such that the next attempt to fetch the instruction cache line will result in a refill. Whenever an attempt is made to issue an instruction containing an uncorrectable error a synchronous PIE trap is raised. The trap handler is then responsible for checking the source of the memory integrity error, and, in the case of the instruction cache, may immediately return to re-fetch the now invalidated cache line.

Program Tag (PTag)

The program tag stores a 22-bit tag address and 1-bit valid field for each of the two cache ways in a set. As such the program tag is written with 23-bit granularity and six ECC bits are associated with each 23-bit tag way. ECC protection of the program tag is enabled by setting MIECON.PTIEE to one. When MIECON.PTIEE is zero all uncorrectable memory integrity errors are ignored.

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For instruction fetch requests from the TriCore CPU to ICACHE, the program tag ECC bits are read along with the data bits and an error flag is computed. A way hit is triggered only if the tag address comparison succeeds, the valid bit is set and no ECC error in the associated tag way is detected, any other result is considered a miss. In the normal case where no error is detected in either cache way then the cache line is filled/refilled as normal. In the case where an error is detected the cache controller replacement algorithm forces the way indicating an error to be replaced. Since such errors are otherwise transparent to the TriCore CPU, the CCPIE_R counter is incremented to allow counting of such error corrections if required. In the case where one cache way flags a cache hit, and the other cache way detects an uncorrectable ECC error, the error condition is masked and has no effect on the memory integrity error handling mechanisms.

2.3.5.2 Data Side Memories

The data side memories of the TriCore 1.3.1 core support a programmable split between Local Data RAM (LDRAM) and Data Cache (DCache). Both LDRAM and DCache are unified within a single memory structure, known as Data Memory (DMEM). The DMEM of TriCore 1.3.1 is protected from memory integrity errors on a per-halfword basis. Any byte write access to either LDRAM or DCache is converted to a halfword Read-Modify-Write sequence. The transformation of such byte accesses to atomic sequences is performed within the DMI rather than the CPU core itself. In normal operation isolated byte write transactions to the data memories result in no additional stall cycles.

Local Data RAM (LDRAM)

The Local Data RAM of TriCore 1.3.1 is protected from memory integrity errors on a per-halfword basis. The LDRAM is ECC protected, six ECC bits are required per half-word stored. ECC protection of LDRAM is enabled by setting MIECON.DMIEE to one. When MIECON.DMIEE is zero all uncorrectable memory integrity errors are ignored.

For data load requests from the TriCore CPU to LDRAM, the ECC bits are read along with the data bits and an uncorrectable error signal is generated for each half-word. If an error is detected associated with any of the data half-words passed to the core an error is flagged to the core. If such an error condition is detected an asynchronous DIE trap is raised. The trap handler is then responsible for correcting the memory entry, or for taking alternative action (such as system soft reset) if correction of the data is not possible.

For LDRAM read operations from the LMB interface, either from the PMI module or another LMB master agent, an access that results in the detection of an uncorrectable error in the requested data half-words causes a bus error to be returned for the bus transaction. Since the TriCore CPU may not be involved in the transaction, a separate error is also flagged to the SCU module to optionally generate an NMI trap back to the core.

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For write operations to LDRAM of half-word size or greater, the ECC bits are pre-calculated and written to the memory in parallel with the data bits. For byte write operations the memory transaction is transformed into a half-word read-modify-write sequence inside the DMI module. As such, byte write operations may result in the detection of uncorrectable memory integrity errors, which are handled as per standard read operations.

Data Cache (DCache)

Since the data cache shares the same physical memory as the Local Data RAM, it is similarly configured for memory integrity error protection: six ECC bits are stored per half-word. ECC protection of the data cache is enabled by setting MIECON.DMIEE to one. When MIECON.DMIEE is zero all uncorrectable memory integrity errors are ignored.

For data load requests from the TriCore CPU to DCache, the ECC bits are read along with the data bits of both cache ways, and an uncorrectable error flag computed for each half-word of each cache way. In the case where an error is detected with any of the requested data half-words in a cache way which has a corresponding tag hit, an error is flagged to the core. If such an error condition is detected an asynchronous DIE trap is raised. The trap handler is then responsible for correcting the memory entry, or for taking alternative action (such as system soft reset) if correction of the data is not possible.

For write operations of half-word size or greater, the check bits are pre-calculated and written to the memory in parallel with the data bits. For byte write operations the memory transaction is transformed into a half-word read-modify-write sequence inside the DMI module. As such, byte write operations may result in the detection of uncorrectable memory integrity errors as for read operations.

For cache line writeback, uncorrectable error detection is performed as dirty data is transferred to the bus. In all cases (normal cache line eviction, cachex.xx instruction) where an error condition is detected in a valid cache line a DIE trap is raised. The trap handler is then responsible for taking corrective action (such as system soft reset) since correction of the data is not possible. Since the uncorrectable error may not be detected until the bus transaction is in progress, no attempt is made to abort the bus transaction.

Data Tag (DTag)

The data tag stores a 22-bit tag address for each of the two cache ways in a set. As such the data tags are written with 22-bit granularity and six ECC bits are associated with each 22-bit tag address. ECC protection of the data tag is enabled by setting MIECON.DTIEE to one. When MIECON.DTIEE is zero, all uncorrectable memory integrity errors are ignored.

For data load or store requests from the TriCore CPU to DCache, the data tag ECC bits are read along with the data bits and an uncorrectable error flag is computed. A way hit is triggered only if the tag address comparison succeeds, the tag location is valid and no

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uncorrectable error in the associated tag way is detected, any other result is considered a miss. In the normal case where no error is detected in either tag way then the cache line is filled/refilled as normal. In the case of a cache miss where an error is detected in one of the tag ways and the cache line does not contain dirty data the cache controller replacement algorithm forces the way indicating an error to be replaced when the refill operation returns. Since such errors are otherwise transparent to the TriCore CPU, the CCDIE_R counter is incremented to allow counting of such error corrections if required. In the case where one cache way flags a cache hit, and the other way detects an uncorrectable error, the error condition is masked and has no effect on the memory integrity error handling mechanisms. If a cache miss occurs, with an uncorrectable error detected on the associated data tag way and dirty data detected, then an asynchronous DIE trap is signalled to the core and any writeback / refill sequence aborted. The trap handler is responsible for invalidating the cache line and processing any associated dirty data if possible, or taking other corrective action. Similar action is taken for forced cache writeback using the cache manipulation instructions.

2.3.5.3 TriCore 1.3 Compatibility

In order to allow code written for existing TriCore 1.3 based devices to be utilised without modification, a compatibility mode is included for both the program and data side memory integrity error handling. This compatibility mode is enabled by setting the COMPAT.PIE/DIE bit(s) to one.

When the COMPAT.PIE/DIE bit is set, the memory integrity error handling is modified. Memory integrity errors are never flagged directly to the TriCore 1.3.1 core, such that:

- PIE/DIE traps are not generated
- LMB bus errors are not generated for SPRAM/LDRAM accesses
- The CCPIE_R/CCDIE_R counters are not updated

When COMPAT.PIE/DIE is set along with the corresponding MIECON bit(s), any memory integrity error detected results in an error being flagged to the SCU module to optionally generate an NMI trap back to the core.

2.4 CPU Subsystem Registers

This section describes the implementation-specific features of the CPU Subsystem registers listed in [Table 1](#). For complete descriptions of all registers refer to the TriCore Architecture Manual.

Table 1 CPU Subsystem Registers

Registers	Purpose	Description
CPU Core Special Function Registers (CSFRs)	Program state information, context and stack management, interrupt and trap control, system control	see Page 2-16
CPU General Purpose Registers (GPRs)	General Purpose Address and Data Registers	see Page 2-23
CPU Memory Protection Registers (CSFRs)	Memory protection control and mode selection	see Page 2-26
FPU Registers (CSFRs)	Support for the standard floating point instructions.	see Page 2-32
Memory Integrity Registers (CSFRs)	Integrity and Protection Core Special Function Registers.	see Page 2-34
CPU Slave Interface (CPS) Registers	Software break control and software service request control	see Page 2-51
Core Debug Registers (CSFRs)	Debug control	see Page 2-55
Implementation Specific Reset Values	Reset values for CPU registers not defined in this chapter	see Page 2-57
Program Memory Interface Registers (PMI)	PMI instruction cache control and status	see Page 2-75
Data Memory Interface Registers (DMI)	DMI status and trap flags	see Page 2-87

2.5 CPU Core Special Function Registers (CSFR)

Figure 6 shows the CSFR registers of the TC1728.

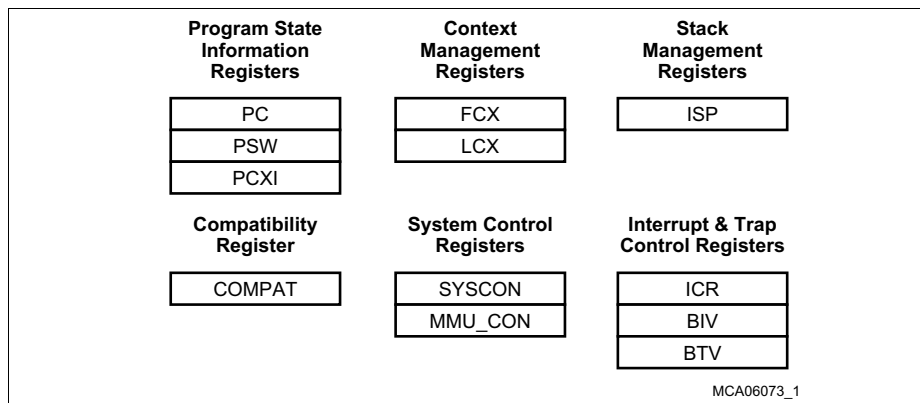


Figure 6 CSFR Registers

Table 2 Core Special Function Registers

Short Name	Description	Offset Address	Access Mode		Reset Value
			Read	Write	
MMU_CON	MMU Configuration Register	8000 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 8000 _H
PCXI	Previous Context Information Register	FE00 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
PSW	Program Status Word Register	FE04 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0B80 _H
PC	Program Counter Register	FE08 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
SYSCON	System Configuration Register	FE14 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
BIV	Interrupt Vector Table Pointer Register	FE20 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
BTV	Trap Vector Table Pointer Register	FE24 _H	U, SV, 32	SV, E, 32	Class 3 Reset A000 0100 _H
ISP	Interrupt Stack Pointer Register	FE28 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0100 _H

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Table 2 Core Special Function Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset Value
			Read	Write	
ICR	ICU Interrupt Control Register	FE2C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FCX	Free Context List Head Pointer Register	FE38 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
LCX	Free Context List Limit Pointer Register	FE3C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
COMPAT	Compatibility Control Register	9400 _H	U, SV, 32	SV, E, 32	Class 3 Reset FFFF FFFF _H

2.5.1 Registers

The implementation-specific Program Status Word Register (PSW) is an extension of the PSW description in the TriCore Architecture Manual. The status flags used for FPU operations overlay the status flags used for Arithmetic Logic Unit (ALU) operations.

Program Status Word Register

PSW

Program Status Word Register (F7E1 FE04_H)

Reset Value: 0000 0B80_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
C or FS	V or FI	SV or FV	AV or FZ	SAV or FU	FX	RM		0							
rwh	rwh	rwh	rwh	rwh	rwh	rw		r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		PRS		IO		IS	GW	CDE	CDC						
r		rwh		rwh		rwh	rwh	rwh	rwh						

Field	Bits	Type	Description
RM	[25:24]	rw	FPU Rounding Mode Selection
FX	26	rwh	FPU Inexact Flag
SAV	27	rh	Sticky Advance Overflow Flag
FU		rwh	FPU Underflow Flag
AV	28	rwh	Advance Overflow Flag
FZ			FPU Divide by Zero Flag
SV	29	rwh	Sticky Overflow Flag
FV			FPU Overflow Flag
V	30	rwh	Overflow Flag
FI			FPU Invalid Operation Flag
C	31	rwh	Carry Flag
FS			FPU Some Exception Flag

Note: The non-shaded areas in the register description define the implementation-specific bits/bit fields. The shaded areas are defined in the TriCore Architecture Manual.

Interrupt Control Register

The Interrupt Control Register (ICR) is an implementation-specific CFSR. Its Arbitration Cycle Control implementation-specific details are defined in bits 24 to 26.

ICR

Interrupt Control Register (F7E1 FE2C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0					CONECYC	CARBCYC		PIPN							
r					rw	rw		rh							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							IE	CCPN							
r							rw	rwh							

Field	Bits	Type	Description
CARBCYC	[25:24]	rw	Number of Arbitration Cycles CARBCYC controls the number of arbitration cycles used to determine the request with the highest priority. 00 _B 4 arbitration cycles (default) 01 _B 3 arbitration cycles 10 _B 2 arbitration cycles 11 _B 1 arbitration cycles
CONECYC	26	rw	Number of Clocks per Arbitration Cycle Control The CONECYC bit determines the number of system clocks per arbitration cycle. This bit should be set to 1 only for system designs utilizing low system clock frequencies. 0 _B 2 clocks per arbitration cycle 1 _B 1 clock per arbitration cycle

Note: The non-shaded areas in the register description define the implementation-specific bits/bit fields. The shaded areas are defined in the TriCore Architecture Manual.

MMU Configuration Register

The MMU Configuration Register (MMU_CON) register indicates the non-availability of the TriCore Memory Management Unit (bit NO MMU is always set).

MMU_CON

MMU Configuration Register (F7E1 8000_H) **Reset Value: 0000 8000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0																
r																
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
NO MMU	0			TSZ								SZB		SZA		V
r	r			r								rw		rw		rw

Field	Bits	Type	Description
NO MMU	15	r	MMU Exists 0 _B MMU is available. 1 _B MMU is not available. All other bits of MMU_CON are undefined. <i>Note: The MMU is not available in TC1728.</i>

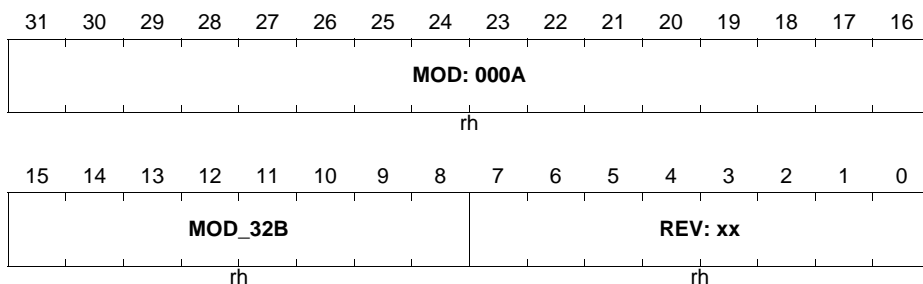
Note: The non-shaded areas in the register description define the implementation-specific bits/bit fields. The shaded areas are defined in the TriCore Architecture Manual.

CPU Identification Register

CPU_ID

CPU Identification Register

(F7E1 FE18_H)

Reset Value: 000A C0XX_H


Field	Bits	Type	Description
MOD_REV	[7:0]	rh	Revision Number 01 _H For version numbering. The value of the revision starts with 01 _H (first revision) up to FF _H FF _H Last revision
MOD_32B	[15:8]	rh	32-Bit Module Enable C0 _H A value of C0 _H in this field indicates a 32-bit module with a 32-bit module ID register.
MOD	[31:16]	rh	Module Identification Number 0A _H For module identification

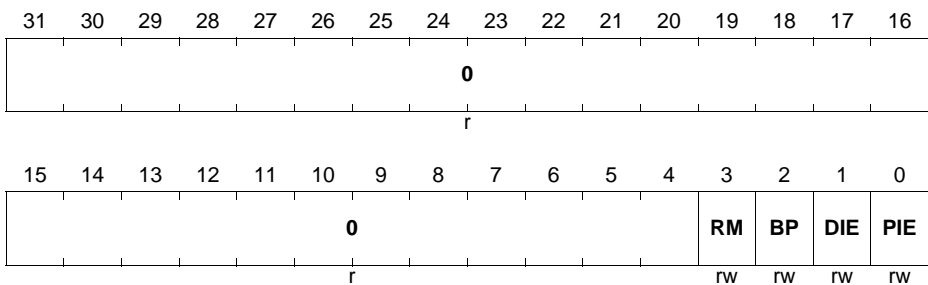
Compatibility Control Register

The Compatibility Control Register (COMPAT) is an implementation-specific CSFR which allows certain elements of backwards compatibility with TriCore 1.3 behaviour to be forced. The reset value of the COMPAT register ensures that backwards compatibility with TriCore 1.3 is enabled by default.

COMPAT

Compatibility Control Register

(F7E1 9400_H)

Reset Value: FFFF FFFF_H


Field	Bits	Type	Description
PIE	0	rw	Program Integrity Error Compatibility 0 _B Errors handled by CPU. 1 _B Errors flagged off-core. TriCore 1.3 backwards compatibility.
DIE	1	rw	Data Integrity Error Compatibility 0 _B Errors handled by CPU. 1 _B Errors flagged off-core. TriCore 1.3 backwards compatibility.
BP	2	rw	Branch Predictor Compatibility 0 _B Bi-model branch prediction. 1 _B Static branch prediction. TriCore 1.3 backwards compatibility.
RM	3	rw	Rounding Mode Compatibility 0 _B PSW.RM not restored by RET. 1 _B PSW.RM restored by RET. TriCore 1.3 backwards compatibility.
0	[31:4]	r	Reserved Read as 0; should be written with 0.

2.6 CPU General Purpose Registers

Figure 7 shows the General Purpose Registers (GPRs) of the TC1728.

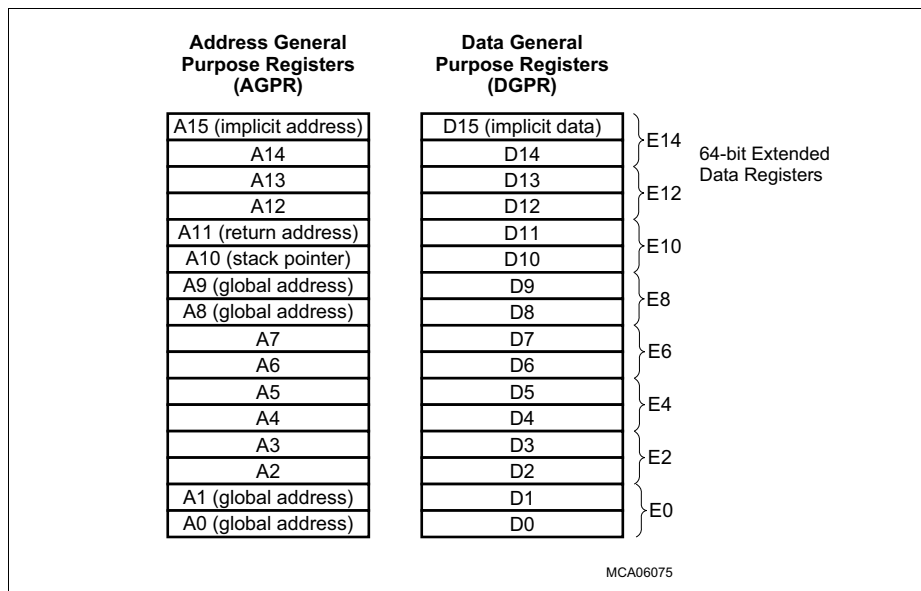


Figure 7 GPR Registers

Table 3 GPR Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
D0	Data Register 0	FF00 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D1	Data Register 1	FF04 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D2	Data Register 2	FF08 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D3	Data Register 3	FF0C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D4	Data Register 4	FF10 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H

Table 3 GPR Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
D5	Data Register 5	FF14 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D6	Data Register 6	FF18 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D7	Data Register 7	FF1C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D8	Data Register 8	FF20 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D9	Data Register 9	FF24 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D10	Data Register 10	FF28 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D11	Data Register 11	FF2C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D12	Data Register 12	FF30 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D13	Data Register 13	FF34 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D14	Data Register 14	FF38 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
D15	Data Register 15	FF3C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A0	Address Register 0 (Global Address Register)	FF80 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A1	Address Register 1 (Global Address Register)	FF84 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A2	Address Register 2	FF88 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A3	Address Register 3	FF8C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A4	Address Register 4	FF90 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H

Table 3 GPR Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
A5	Address Register 5	FF94 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A6	Address Register 6	FF98 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A7	Address Register 7	FF9C _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A8	Address Register 8 (Global Address Register)	FFA0 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A9	Address Register 9 (Global Address Register)	FFA4 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A10	Address Register 10 (Stack Pointer)	FFA8 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A11	Address Register 11 (Return Address)	FFAC _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A12	Address Register 12	FFB0 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A13	Address Register 13	FFB4 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A14	Address Register 14	FFB8 _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H
A15	Address Register 15	FFBC _H	U, SV, 32	SV, 32	Class 3 Reset XXXX XXXX _H

2.7 CPU Memory Protection Registers

As shown in **Figure 8**, there are four Memory Protection Register Sets in the TC1728. The sets specify memory protection ranges and permissions for code and data. The PSW.PRS bit field determines which of these sets is currently in use by the CPU. The Memory Protection Registers are Core Special Function Registers, they are described in detail in the TriCore Architecture Manual.

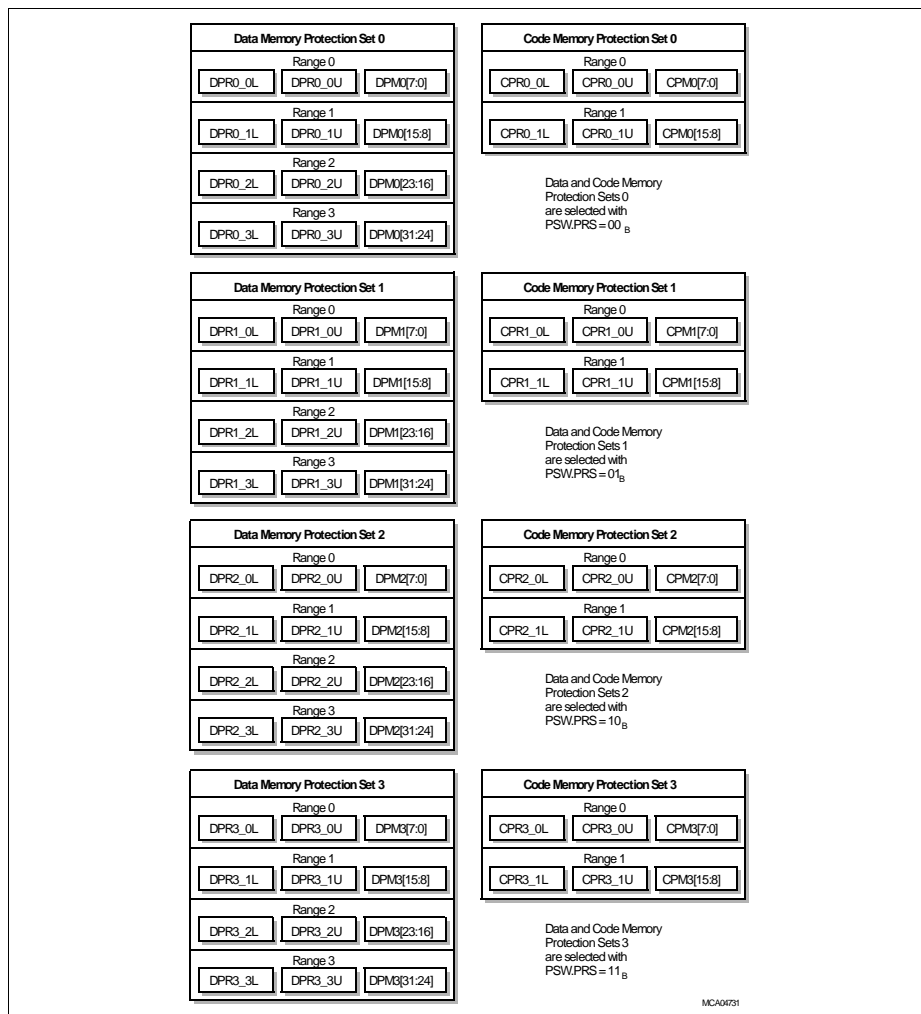


Figure 8 Memory Protection Register Sets of the TC1728

Table 4 Memory Protection Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
DPR0_0L	Data Segment Protection Register Set 0, Range 0, Lower Boundary	C000 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_0U	Data Segment Protection Register Set 0, Range 0, Upper Boundary	C004 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_1L	Data Segment Protection Register Set 0, Range 1, Lower Boundary	C008 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_1U	Data Segment Protection Register Set 0, Range 1, Upper Boundary	C00C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_2L	Data Segment Protection Register Set 0, Range 2, Lower Boundary	C010 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_2U	Data Segment Protection Register Set 0, Range 2, Upper Boundary	C014 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_3L	Data Segment Protection Register Set 0, Range 3, Lower Boundary	C018 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR0_3U	Data Segment Protection Register Set 0, Range 3, Upper Boundary	C01C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_0L	Data Segment Protection Register Set 1, Range 0, Lower Boundary	C400 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_0U	Data Segment Protection Register Set 1, Range 0, Upper Boundary	C404 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_1L	Data Segment Protection Register Set 1, Range 1, Lower Boundary	C408 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Table 4 Memory Protection Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
DPR1_1U	Data Segment Protection Register Set 1, Range 1, Upper Boundary	C40C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_2L	Data Segment Protection Register Set 1, Range 2, Lower Boundary	C410 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_2U	Data Segment Protection Register Set 1, Range 2, Upper Boundary	C414 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_3L	Data Segment Protection Register Set 1, Range 3, Lower Boundary	C418 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR1_3U	Data Segment Protection Register Set 1, Range 3, Upper Boundary	C41C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_0L	Data Segment Protection Register Set 2, Range 0, Lower Boundary	C800 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_0U	Data Segment Protection Register Set 2, Range 0, Upper Boundary	C804 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_1L	Data Segment Protection Register Set 2, Range 1, Lower Boundary	C808 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_1U	Data Segment Protection Register Set 2, Range 1, Upper Boundary	C80C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_2L	Data Segment Protection Register Set 2, Range 2, Lower Boundary	C810 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_2U	Data Segment Protection Register Set 2, Range 2, Upper Boundary	C814 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Table 4 Memory Protection Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
DPR2_3L	Data Segment Protection Register Set 2, Range 3, Lower Boundary	C818 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR2_3U	Data Segment Protection Register Set 2, Range 3, Upper Boundary	C81C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_0L	Data Segment Protection Register Set 3, Range 0, Lower Boundary	CC00 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_0U	Data Segment Protection Register Set 3, Range 0, Upper Boundary	CC04 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_1L	Data Segment Protection Register Set 3, Range 1, Lower Boundary	CC08 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_1U	Data Segment Protection Register Set 3, Range 1, Upper Boundary	CC0C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_2L	Data Segment Protection Register Set 3, Range 2, Lower Boundary	CC10 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_2U	Data Segment Protection Register Set 3, Range 2, Upper Boundary	CC14 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_3L	Data Segment Protection Register Set 3, Range 3, Lower Boundary	CC18 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPR3_3U	Data Segment Protection Register Set 3, Range 3, Upper Boundary	CC1C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR0_0L	Code Segment Protection Register Set 0, Range 0, Lower Boundary	D000 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Table 4 Memory Protection Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
CPR0_0U	Code Segment Protection Register Set 0, Range 0, Upper Boundary	D004 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR0_1L	Code Segment Protection Register Set 0, Range 1, Lower Boundary	D008 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR0_1U	Code Segment Protection Register Set 0, Range 1, Upper Boundary	D00C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR1_0L	Code Segment Protection Register Set 1, Range 0, Lower Boundary	D400 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR1_0U	Code Segment Protection Register Set 1, Range 0, Upper Boundary	D404 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR1_1L	Code Segment Protection Register Set 1, Range 1, Lower Boundary	D408 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR1_1U	Code Segment Protection Register Set 1, Range 1, Upper Boundary	D40C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR2_0L	Code Segment Protection Register Set 2, Range 0, Lower Boundary	D800 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR2_0U	Code Segment Protection Register Set 2, Range 0, Upper Boundary	D804 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR2_1L	Code Segment Protection Register Set 2, Range 1, Lower Boundary	D808 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR2_1U	Code Segment Protection Register Set 2, Range 1, Upper Boundary	D80C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Table 4 Memory Protection Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
CPR3_0L	Code Segment Protection Register Set 3, Range 0, Lower Boundary	DC00 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR3_0U	Code Segment Protection Register Set 3, Range 0, Upper Boundary	DC04 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR3_1L	Code Segment Protection Register Set 3, Range 1, Lower Boundary	DC08 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPR3_1U	Code Segment Protection Register Set 3, Range 1, Upper Boundary	DC0C _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPM0	Data Protection Mode Register Set 0	E000 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPM1	Data Protection Mode Register Set 1	E080 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPM2	Data Protection Mode Register Set 2	E100 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DPM3	Data Protection Mode Register Set 3	E180 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPM0	Code Protection Mode Register Set 0	E200 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPM1	Code Protection Mode Register Set 1	E280 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPM2	Code Protection Mode Register Set 2	E300 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPM3	Code Protection Mode Register Set 3	E380 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

2.8 FPU Registers

A number of FPU Special Function Registers (CSFRs) have been introduced to the TriCore 1.3.1 architecture in order to fully support functional enhancements.

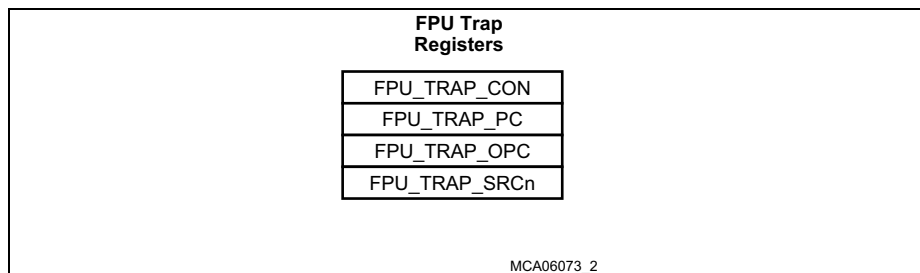


Figure 9 TriCore 1.3.1 CSFR Registers

Table 5 Floating Point Special Function Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
FPU_TRAP_CON	Trap Control Register	A000 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_TRAP_PC	Trapping Instruction Program Counter Register	A004 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_TRAP_OPC	Trapping Instruction Opcode Register	A008 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_TRAP_SRC1	Trapping Instruction Operand Register	A010 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_TRAP_SRC2	Trapping Instruction Operand Register	A014 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_TRAP_SRC3	Trapping Instruction Operand Register	A018 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
FPU_ID	Trapping Identification Register	A020 _H	U, SV, 32	SV, 32	Class 3 Reset 0054 C003 _H

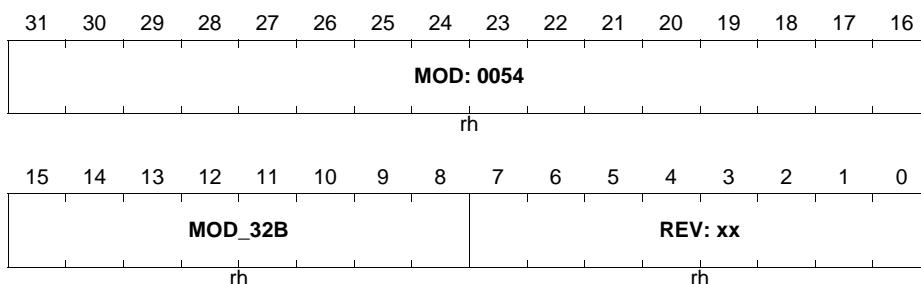
2.8.1 Registers

FPU Identification Register

FPU_ID

Trapping Identification Register

(F7E1 A020_H)

Reset Value: 0054 C003_H


Field	Bits	Type	Description
MOD_REV	[7:0]	rh	Revision Number 01 _H For version numbering. The value of the revision starts with 01 _H (first revision) up to FF _H FF _H Last revision
MOD_32B	[15:8]	rh	32-Bit Module Enable C0 _H A value of C0 _H in this field indicates a 32-bit module with a 32-bit module ID register.
MOD	[31:16]	rh	Module Identification Number 54 _H For module identification.

2.9 Memory Integrity Registers

Memory Integrity Registers (CSFRs).

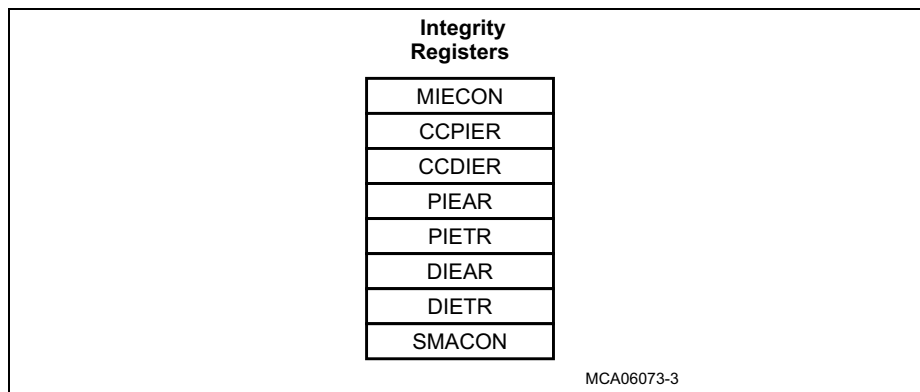


Figure 2-1 TriCore 1.3.1 CSFR Registers

Table 2-1 Memory Integrity Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
MIECON	Memory Integrity Error Control Register	9044 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
MIECON2	Memory Integrity Error Control Register 2	9048 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
CCPIER	Count of Corrected Program Integrity Errors Register	9218 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CCDIER	Count of Corrected Data Integrity Errors Register	9028 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
PIEAR	Program Integrity Error Address Register	9210 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
PIETR	Program Integrity Error Trap Register	9214 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
DIEAR	Data Integrity Error Address Register	9020 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Table 2-1 Memory (cont'd) Integrity Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
DIETR	Data Integrity Error Trap Register	9024 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
SMACON	SIST Mode Access Control Register	900C _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H

2.9.1 Register Descriptions

Memory Integrity Error Control Register

The Memory Integrity Error Control Register (MIECON) allows software to control the handling of uncorrectable memory integrity errors.

MIECON

Memory Integrity Error Control Register

(F7E1 9044_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
						0							PTIE E	0	DTIE E
						r							rw	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			0				PMIE E				0				DMI EE
			r				rw				r				rw

Field	Bits	Type	Description
DMIEE	0	rwh	Data Memory Integrity Error Enable Enables handling of uncorrectable integrity errors for the Data Memories. 0 _B Uncorrectable integrity error handling disabled - all memory accesses interpreted as error free. 1 _B Uncorrectable integrity error handling enabled.
PMIEE	8	rwh	Program Memory Integrity Error Enable Enables handling of uncorrectable integrity errors for the Program Memories. 0 _B Uncorrectable integrity error handling disabled - all memory accesses interpreted as error free. 1 _B Uncorrectable integrity error handling enabled.

CPU Subsystem

Field	Bits	Type	Description
DTIEE	16	rw	Data Tag Integrity Error Enable Enables handling of uncorrectable integrity errors for the Data Tag. 0_B Uncorrectable integrity error handling disabled - all memory accesses interpreted as error free. 1_B Uncorrectable integrity error handling enabled.
PTIEE	18	rw	Program Tag Integrity Error Enable Enables handling of uncorrectable integrity errors for the Program Tag. 0_B Uncorrectable integrity error handling disabled - all memory accesses interpreted as error free. 1_B Uncorrectable integrity error handling enabled.
0	[7:1] [15:9], 17, [31:19]	r	Reserved Read as 0; should be written with 0.

Memory Integrity Error Control Register 2

The Memory Integrity Error Control Register 2 (MIECON2) allows software to control the handling of correctable memory integrity errors.

The behaviour of MIECON2 is configured according to the tc_cfg_sec_con_en_i input to the TriCore1.3.1 core. When tc_cfg_sec_con_en_i is asserted, MIECON2 may only be written in supervisor mode and is endinit protected. MIECON2 reads return the register contents. When tc_cfg_sec_con_en_i is negated writes to MIECON2 have no effect and MIECON2 reads return all zeroes.

MIECON2

Memory Integrity Error Control Register 2

(F7E1 9048_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													PTS ECE	0	DTS ECE
r													rw	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						PMS ECE	0						DMS ECE		
r						rw	r						rw		

Field	Bits	Type	Description
DMSECE	0	rwh	Data Memory Single Error Correction Enable Enables single bit error correction for the Data Memories.
PMSECE	8	rwh	Program Memory Single Error Correction Enable Enables single bit error correction for the Program Memories.
DTSECE	16	rwh	Data Tag Single Error Correction Enable Enables single bit error correction for the Data Tag
PTSECE	18	rwh	Program Tag Single Error Correnction Enable Enables single bit error correction for the Program Tag.
0	[7:1] [15:9], 17, [31:19]	r	Reserved Read as 0; should be written with 0.

Function

Although the xxIEE and xxSECE bits for a given memory type exist in different registers (MIECON and MIECON2 respectively) due to different protection requirements for these CSFR bits, the bits interact to perform the following general functions.

Table 6 Functions

xxSECE	xxIEE	Description
0	0	No Memory Integrity Handling All single and double-bit memory integrity errors ignored.
0	1	Error Detection Mode Single and double-bit errors treated as uncorrectable errors.
1	0	SEC Only Mode Single-bit errors corrected by ECC, double-bit errors ignored
1	1	SECEDED Mode Single-bit errors corrected by ECC, double-bit errors treated as uncorrectable errors.

Program Integrity Error Information Registers

Two architecturally visible registers (PIETR, PIEAR) allow software to localise the source of the last detected uncorrectable program memory integrity error. These registers are updated when an uncorrectable program integrity error condition is detected and the PIETR.IED bit is zero. On update the PIETR.IED bit is set to one and remains set until cleared by software. Whilst PIETR.IED is set further hardware updates of PIETR and PIEAR are inhibited.

PIETR and PIEAR are updated on any uncorrectable program memory integrity error condition detected, either during a bus access or a CPU instruction pre-fetch. Since instruction pre-fetches are speculative, the PIETR and PIEAR registers may be updated without a corresponding PIE trap.

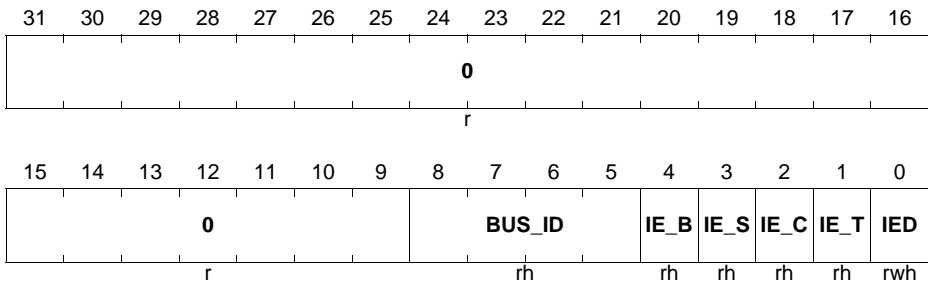
The Program Integrity Error Trap Register (PIETR) contains flags to support software in localising the source of the last detected uncorrectable program memory integrity error. Where an uncorrectable integrity error condition is detected during an instruction pre-fetch, the IE_S, IE_C and IE_T bits are updated to denote in which memory structure the error was detected, whilst BUS_ID and IE_B are cleared. Where the error is detected during a bus access, IE_B is set and BUS_ID updated to denote the master tag ID of the initiating bus master, whilst IE_S, IE_C and IE_T are cleared.

Program Integrity Error Trap Register (PIETR)

PIETR

Program Integrity Error Trap Register

(F7E1 9214_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
IED	0	rwh	Integrity Error Detected Read Operation: 0 _B No program integrity error condition occurred. 1 _B Program integrity error condition detected. PIETR and PIEAR contents valid, further PIETR and PIEAR updates disabled. Write Operation: 0 _B Clear IED bit, re-enable PIETR and PIEAR updates. 1 _B No effect.
IE_T	1	rh	Integrity Error - Tag Memory
IE_C	2	rh	Integrity Error - Cache Memory
IE_S	3	rh	Integrity Error - Scratchpad Memory
IE_B	[4]	rh	Integrity Error - Bus Access
BUS_ID	[8:5]	rh	Bus Master ID Bus Master Tag ID, where program integrity error is detected during bus access.
0	[31:9]	r	Reserved Read as 0; should be written with 0.

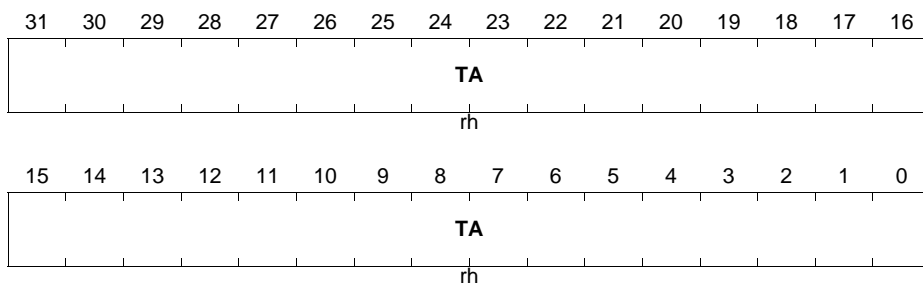
Program Integrity Error Address Register

This register contains the physical address accessed by the operation that encountered a uncorrectable program memory integrity error. This register is only updated if PIETR.IED is zero.

PIEAR

Program Integrity Error Address Register

(F7E1 9210_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
TA	[31:0]	rh	Transaction Address Physical address being accessed by operation that encountered program integrity error.

Data Integrity Error Information Registers

Two architecturally visible registers (DIETR, DIEAR) allow software to localise the source of the last detected uncorrectable data memory integrity error. These registers are updated when an uncorrectable data integrity error condition is detected and the DIETR.IED bit is zero. On update the DIETR.IED bit is set to one and remains set until cleared by software. Whilst DIETR.IED is set further hardware updates of DIETR and DIEAR are inhibited.

The Data Integrity Error Trap Register (DIETR) contains flags to support software in localising the source of the last detected uncorrectable data memory integrity error. Where an uncorrectable data memory integrity error condition is detected during a CPU Load/Store access, the IE_S, IE_C, IE_T and TRTYP bits are updated to denote in which memory structure the error was detected and the nature of the DIE trap, whilst BUS_ID and IE_B are cleared. Where the error is detected during a bus access, IE_B is set and BUS_ID updated to denote the master tag ID of the initiating bus master, whilst IE_S, IE_C, IE_T and TRTYP are cleared.

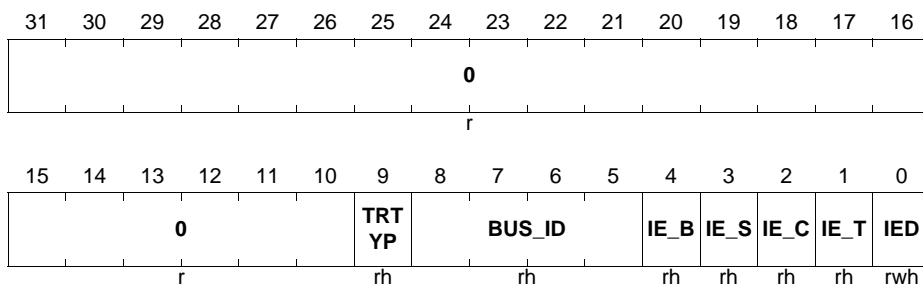
In TriCore 1.3.1 DIE traps are always asynchronous, independent of the type of transaction which encountered the data integrity error. The type of DIE trap is denoted by the DIETR.TYTYP bit. When a data integrity error is detected which causes an update of the DIE information registers and results in an asynchronous DIE trap, DIETR.IED = 1 and DIETR.TRTYP = 1, further asynchronous DIE traps are disabled until DIETR.IED is cleared by software.

Data Integrity Error Trap Register (DIETR)

DIETR

Data Integrity Error Trap Register

(F7E1 9024_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
IED	0	rwh	Integrity Error Detected Read Operation: 0 _B No data integrity error condition occurred. 1 _B Data integrity error condition detected. PIETR and DIEAR contents valid, further DIETR and DIEAR updates disabled. Write Operation: 0 _B Clear IED bit, re-enable DIETR and DIEAR update. 1 _B No effect.
IE_T	1	rh	Integrity Error - Tag Memory
IE_C	2	rh	Integrity Error - Cache Memory
IE_S	3	rh	Integrity Error - Scratchpad Memory
IE_B	4	rh	Integrity Error - Bus Access
BUS_ID	[8:5]	rh	Bus Master ID Bus Master Tag ID, where data integrity error is detected during bus access.
TRTYP	9	rh	Trap Type Type of trap generated, where data integrity error is detected during CPU Load/Store access. 0 _B Synchronous Trap

CPU Subsystem

Field	Bits	Type	Description
0	[31:10]	r	Reserved Read as 0; should be written with 0.

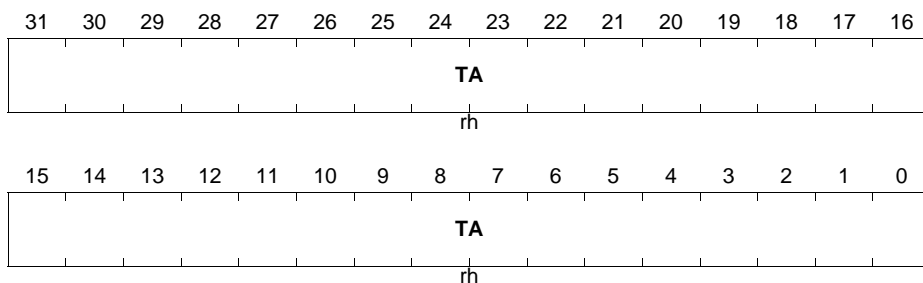
Data Integrity Error Address Register

This register contains the physical address accessed by the operation that encountered a uncorrectable data memory integrity error. This register is only updated if DIETR.IED is zero.

DIEAR

Data Integrity Error Address Register

(F7E1 9020_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
TA	[31:0]	rh	Transaction Address Physical address being accessed by operation that encountered data integrity error.

SIST (Software In-System) Test Support

The TriCore 1.3.1 core protects against memory integrity errors by ECC protection of the on-core memories. This has the side-effect of requiring memory blocks wider than the normal data access path to the memory. The additional ECC storage bits are not easily accessible via the existing data paths, causing problems where SIST based testing of the memories is required. The TriCore 1.3.1 core also includes embedded memory arrays, such as the tag memories, which are not ordinarily accessible by the usual CPU datapaths. In order to address this problem, the TriCore 1.3.1 core includes improved SIST support, allowing all on-core memory arrays to be accessed.

The mapping of embedded memory arrays into the TriCore address space and the enabling of other SIST related features is controlled by the setting of bits within the SIST Mode Access Control Register (SMACON). The fields of the SMACON register are implementation specific.

The embedded memory arrays are mapped into the program and data scratch areas (Segments C_H and D_H) of the address map by setting bits in the SMACON register. Program side embedded memories are mapped into the SPRAM area and located in the address range C01C0000_H - C01FFFFF_H (and mirrored at D41C0000_H - D41FFFFF_H). All other embedded memories are mapped into the LDRAM area and located in the address range D01C0000_H - D01FFFFF_H. A memory that has been mapped into the scratch memory area using the SMACON register may not be accessed in its normal operational mode.

SIST Mode Access Control Register

SMACON

SIST Mode Access Control Register

(F7E1 900C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							IODT	0							
r							rw	r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		DS		DT		DC		0		PS		PT		PC	
r		rw		rw		rw		r		rw		rw		rw	

Field	Bits	Type	Description
PC	[1:0]	rw	Instruction Cache Memory SIST Mode Access control¹⁾ 00 _B Normal Operation, No Mapping. 01 _B 1x _B Instruction cache memory configured as program SPR.
PT	[3:2]	rw	Program Tag Memory SIST Mode Access Control 00 _B Normal Operation, No Mapping. 01 _B Data Array Mapping, no error detection/correction. 10 _B Check Array Mapping, no error detection/correction. 11 _B Data Array Mapping, error detection/correction enabled.
PS	[5:4]	rw	Program Scratch Memory SIST Mode Access Control 00 _B Normal Operation, No Mapping. 01 _B Data Array Mapping, no error detection/correction. 10 _B Check Array Mapping, no error detection/correction. 11 _B Data Array Mapping, error detection/correction enabled.
DC	[9:8]	rw	Data Cache Memory SIST Mode Access Control 00 _B Normal Operation, No Mapping. 01 _B 1x _B Data cache memory configured as Data SPR.
DT	[11:10]	rw	Data Tag Memory SIST Mode Access Control 00 _B Normal Operation, No Mapping. 01 _B Data Array Mapping, no error detection/correction. 10 _B Check Array Mapping, no error detection/correction. 11 _B Data Array Mapping, error detection/correction enabled.

CPU Subsystem

Field	Bits	Type	Description
DS	[13:12]	rw	Data Scratch Memory SIST Mode Access Control 00 _B Normal Operation, No Mapping, Performance Optimised. 01 _B Data Array Mapping, no error detection/correction. 10 _B Check Array Mapping, no error detection/correction. 11 _B Data Array Mapping, error detection/correction enabled.
IODT	24	rw	In-Order Data Transactions 0 _B Normal operation, Non-dependent loads bypass stores. 1 _B In-order operation, Loads always flush preceding stores, processor store buffer disabled.
0	[7:6] [23:14] [31:25]	r	Reserved Read as 0; should be written with 0.

- 1) When the Flash Read Protection mechanism is active, the value of SMACON.PC is overridden and treated as 00_B 'normal operating mode'; however the field can still be read and written normally.

Control Fields

The control fields within the SMACON register allow individual control of the local memories. Each memory may be mapped to operate in a number of different modes.

Normal operation, No Mapping

No mapping of the memories is performed and normal operation is possible. Embedded memories not usually directly addressable are not accessible in the system address map. Performance optimisations are enabled such that loads may read from the physical memory or associated write buffers.

Data Array Mapping, no error detection/correction

The data array (only) of the memory is made visible in the address map. Writes to the memory will not affect the check bits. Error correction/detection for the memory is disabled. Performance optimisations are disabled such that memory accesses are guaranteed to be performed to the actual memory.

Check Array Mapping, no error detection/correction

The check bit array (only) of the memory is made visible in the address map. Writes to the memory will not affect the data bits. Error correction/detection for the memory is disabled. Performance optimisations are disabled such that memory accesses are guaranteed to be performed to the actual memory.

Data Array Mapping, error detection/correction enabled

The data array of the memory is made visible in the address map. Writes to the memory will update the check bits as per normal operation. Error correction/detection for the memory is enabled. Performance optimisations are disabled such that memory accesses are guaranteed to be performed to the actual memory.

2.10 CPU Slave Interface (CPS) Registers

The CPU Slave Interface (CPS) of the TriCore CPU directly accesses the interrupt service request registers in the CPU from the System Peripheral Bus. The CPS registers are described in detail in the TriCore Architecture Manual.

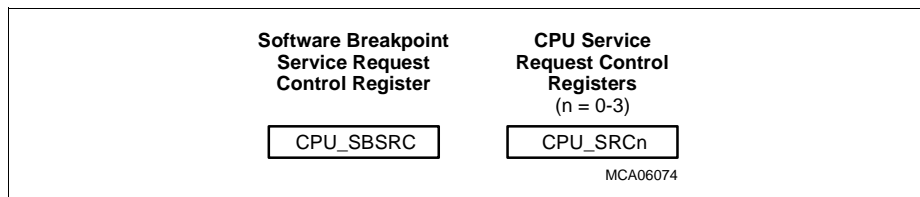


Figure 10 CPS Registers

Table 7 CPS Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
CPU_SBSRC	CPU Software Breakpoint Service Request Control Register	FFBC _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPU_SRC3	CPU Service Request Control 3 Register	FFF0 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPU_SRC2	CPU Service Request Control 2 Register	FFF4 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPU_SRC1	CPU Service Request Control 1 Register	FFF8 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
CPU_SRC0	CPU Service Request Control 0 Register	FFFC _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

Note: The registers CPU_SBSRC and CPU_SRC[3:0] are not bit-addressable.

2.10.1 Register Descriptions

This registers have a specific implementation detail, the Type of Service Control (TOS) bit/bit field.

CPU Service Request Control Register

CPU_SRCn (n = 0-3)

CPU Service Request Control Register n

(F7E0 FFFC_H-n*4)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0		SRPN							
w	w	rh	rw	r	rw	r		rw							

Field	Bits	Type	Description
TOS	10	rw	Type of Service Control 0 _B Service Provider = CPU 1 _B Service Provider = PCP2
0	11	r	Reserved Read as 0; should be written with 0.

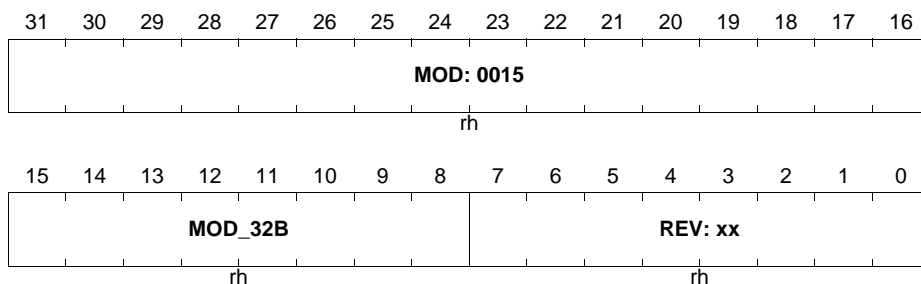
Note: The non-shaded areas in the register description define the implementation-specific bits/bit fields. The shaded areas are defined in the TriCore Architecture Manual.

CPS Module Identification Register

CPS_ID

CPS Module Identification Register

(F7E0 FF08_H)

Reset Value: 0015 C0XX_H


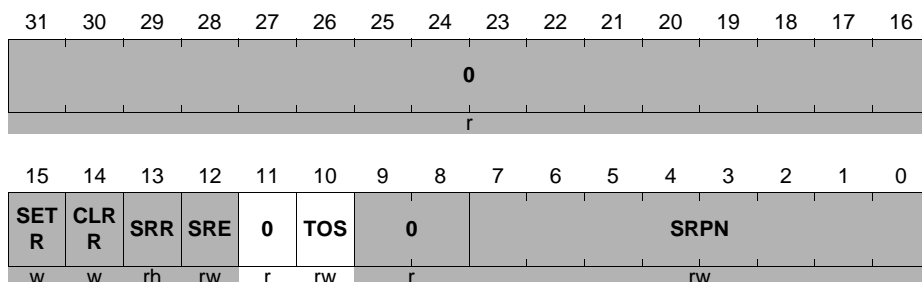
Field	Bits	Type	Description
MOD_REV	[7:0]	rh	Revision Number 01 _H For version numbering. The value of the revision starts with 01 _H (first revision) up to FF _H FF _H Last revision
MOD_32B	[15:8]	rh	32-Bit Module Enable C0 _H A value of C0 _H in this field indicates a 32-bit module with a 32-bit module ID register.
MOD	[31:16]	rh	Module Identification Number 15 _H For module identification.

CPU Software Breakpoint Service Request Control Register

CPU_SBSRC

CPU Software Breakpoint Service Request Control Register

(F7E0 FFBC_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
TOS	10	rw	Type of Service Control 0 _B Service Provider = CPU 1 _B Reserved
0	11	r	Reserved Read as 0; should be written with 0.

Note: The non-shaded areas in the register description define the implementation-specific bits/bit fields. The shaded areas are defined in the TriCore Architecture Manual.

2.11 Core Debug Registers

The Core Debug registers are available for debug purposes. For a complete description of all registers, refer to the TriCore Architecture Manual.

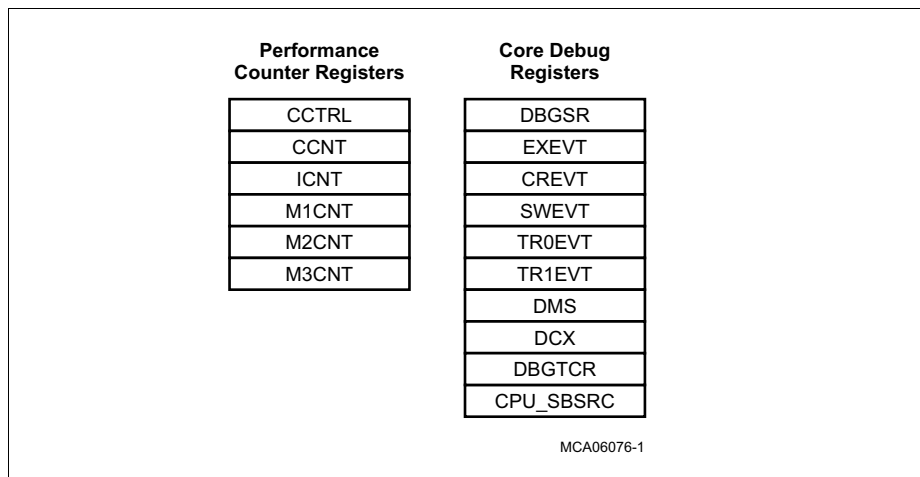


Figure 11 Core Debug Registers

Table 8 Core Debug Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
CCTRL	Counter Control Register	FC00 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
CCNT	CPU Clock Count Register	FC04 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
ICNT	Instruction Count Register	FC08 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
M1CNT	Multi-Count Register 1	FC0C _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
M2CNT	Multi-Count Register 2	FC10 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
M3CNT	Multi-Count Register 3	FC14 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
DBGSR	Debug Status Register	FD00 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H

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Table 8 Core Debug Registers (cont'd)

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
EXEVT	External Break Input Event Register	FD08 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
CREVT	Core SFR Access Break Event Register	FD0C _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
SWEVT	Software Break Event Register	FD10 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
TR0EVT	Trigger Event 0 Register	FD20 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
TR1EVT	Trigger Event 1 Register	FD24 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
DMS	Debug Monitor Start Address Register	FD40 _H	U, SV, 32	U, SV, 32, NC	Class 1 Reset DE00 0000 _H
DCX	Debug Context Save Area Pointer	FD44 _H	U, SV, 32	SV, 32	Class 1 Reset DE80 0000 _H
DBGTCR	Debug Trap Control Register	FD48 _H	U, SV, 32	SV, 32	Class 1 Reset 0000 0000 _H
CPU_SBSR C	CPU Software Breakpoint Service Request Control Register	FFBC _H ¹⁾	U, SV	SV, 32	Class 3 Reset 0000 0000 _H

1) Located in the CPU slave (CPS) interface register area.

2.12 Implementation Specific Reset Values

This section summarizes the implementation specific reset values of the CPU registers not defined in this chapter.

Table 9 Implementation Specific Reset Values

Register	Address	Reset Value
PCXI	F7E1 FE00 _H	0000 0000 _H
PCX	F7E1 FE00 _H	0000 0000 _H
CPU_ID	F7E1 FE18 _H	000A C0XX _H
FCX	F7E1 FE38 _H	0000 0000 _H
LCX	F7E1 FE3C _H	0000 0000 _H
COMPAT	F7E1 9400 _H	FFFF FFFF _H
ISP	F7E1 FE28 _H	0000 0100 _H
BIV	F7E1 FE20 _H	0000 0000 _H
BTV	F7E1 FE24 _H	A000 0100 _H
FPU_ID	F7E1 A020 _H	0054 C003 _H

2.13 CPU Instruction Timing

This section gives information on CPU instruction timing by execution unit. The Integer Pipeline and Load/Store Pipeline are always present, and the Floating Point Unit (FPU) is optional. The Load/Store unit implements the optional TLB instructions.

Definition of Terms:

- **Repeat Rate**

Assuming the same instruction is being issued sequentially, repeat is the minimum number of clock cycles between two consecutive issues. There may be additional delays described elsewhere due to internal pipeline effects when issuing a different subsequent instruction.

- **Result Latency**

The number of clock cycles from the cycle when the instruction is issued to the cycle when the result value is available to be used as an operand to a subsequent instruction or written into a GPR. Result latency is not meaningful for instructions that do not write a value into a GPR.

- **Address Latency**

The number of clock cycles from the cycle when the instruction is issued to the cycle when the addressing mode updated value is available as an operand to a subsequent instruction or written into an Address Register.

- **Flow Latency**

The number of clock cycles from the cycle when the instruction is issued to the cycle when the next instruction (located at the target location or the next sequential instruction if the control change is conditional) is issued.

2.13.1 Integer-Pipeline Instructions

These are the Integer-Pipeline instruction timings for each instruction.

2.13.1.1 Simple Arithmetic Instruction Timings

Each instruction is single issued.

Table 10 Simple Arithmetic Instruction Timing

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
Integer Pipeline Arithmetic Instructions					
ABS	1	1	MAX.H	1	1
ABS.B	1	1	MAX.HU	1	1
ABS.H	1	1	MAX.U	1	1
ABSDIF	1	1	MIN	1	1
ABSDIF.B	1	1	MIN.B	1	1
ABSDIF.H	1	1	MIN.BU	1	1
ABSDIFS	1	1	MIN.H	1	1
ABSDIFS.H	1	1	MIN.HU	1	1
ABSS	1	1	MIN.U	1	1
ABSS.H	1	1	RSUB	1	1
ADD	1	1	RSUBS	1	1
ADD.B	1	1	RSUBS.U	1	1
ADD.H	1	1	SAT.B	1	1
ADDC	1	1	SAT.BU	1	1
ADDI	1	1	SAT.H	1	1
ADDIH	1	1	SAT.HU	1	1
ADDS	1	1	SEL	1	1
ADDS.H	1	1	SELN	1	1
ADDS.HU	1	1	SUB	1	1
ADDS.U	1	1	SUB.B	1	1
ADDX	1	1	SUB.H	1	1
CADD	1	1	SUBC	1	1
CADDN	1	1	SUBS	1	1

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Table 10 Simple Arithmetic Instruction Timing (cont'd)

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
CSUB	1	1	SUBS.H	1	1
CSUBN	1	1	SUBS.HU	1	1
MAX	1	1	SUBS.U	1	1
MAX.B	1	1	SUBX	1	1
MAX.BU	1	1			
Compare Instructions					
EQ	1	1	LT.B	1	1
EQ.B	1	1	LT.BU	1	1
EQ.H	1	1	LT.H	1	1
EQ.W	1	1	LT.HU	1	1
EQANY.B	1	1	LT.U	1	1
EQANY.H	1	1	LT.W	1	1
GE	1	1	LT.WU	1	1
GE.U	1	1	NE	1	1
LT	1	1			
Count Instructions					
CLO	1	1	CLS.H	1	1
CLO.H	1	1	CLZ	1	1
CLS	1	1	CLZ.H	1	1
Extract Instructions					
DEXTR	1	1	INS.T	1	1
EXTR	1	1	INSN.T	1	1
EXTR.U	1	1	INSERT	1	1
IMASK	1	1			
Logical Instructions					
AND	1	1	OR.EQ	1	1
AND.AND.T	1	1	OR.GE	1	1
AND.ANDN.T	1	1	OR.GE.U	1	1
AND.EQ	1	1	OR.LT	1	1
AND.GE	1	1	OR.LT.U	1	1

CPU Subsystem

Table 10 Simple Arithmetic Instruction Timing (cont'd)

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
AND.GE.U	1	1	OR.NE	1	1
AND.LT	1	1	OR.NOR.T	1	1
AND.LT.U	1	1	OR.OR.T	1	1
AND.NE	1	1	OR.T	1	1
AND.NOR.T	1	1	ORN	1	1
AND.OR.T	1	1	ORN.T	1	1
AND.T	1	1	XNOR	1	1
ANDN	1	1	XNOR.T	1	1
ANDN.T	1	1	XOR	1	1
NAND	1	1	XOR.EQ	1	1
NAND.T	1	1	XOR.GE	1	1
NOR	1	1	XOR.GE.U	1	1
NOR.T	1	1	XOR.LT	1	1
OR	1	1	XOR.LT.U	1	1
OR.AND.T	1	1	XOR.NE	1	1
OR.ANDN.T	1	1	XOR.T	1	1
Move Instructions					
CMOV	1	1	MOV.U	1	1
CMOVN	1	1	MOVH	1	1
MOV	1	1			
Shift Instructions					
SH	1	1	SH.NE	1	1
SH.AND.T	1	1	SH.NOR.T	1	1
SH.ANDN.T	1	1	SH.OR.T	1	1
SH.EQ	1	1	SH.ORN.T	1	1
SH.GE	1	1	SH.XNOR.T	1	1
SH.GE.U	1	1	SH.XOR.T	1	1
SH.H	1	1	SHA	1	1
SH.LT	1	1	SHA.H	1	1
SH.LT.U	1	1	SHAS	1	1

Table 10 Simple Arithmetic Instruction Timing (cont'd)

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
SH.NAND.T	1	1			
Coprocessor 0 Instructions					
BMERGE	1	1	DVSTEP	4	4
BSPLIT	1	1	DVSTEP.U	4	4
DVADJ	1	1	IXMAX	1	1
DVINIT	1	1	IXMAX.U	1	1
DVINIT.U	1	1	IXMIN	1	1
DVINIT.B	1	1	IXMIN.U	1	1
DVINIT.H	1	1	PACK	1	1
DVINIT.BU	1	1	PARITY	1	1
DVINIT.HU	1	1	UNPACK	1	1

2.13.1.2 Multiply Instruction Timings

Each instruction is single issued.

Table 11 Multiply Instruction Timing

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
MUL	2	1	MUL.Q	2	1
MUL.U	2	1	MULM.H	2	1
MULS	2	1	MULR.H	2	1
MULS.U	2	1	MULR.Q	2	1
MUL.H	2	1			

2.13.1.3 Multiply Accumulate (MAC) Instruction Timing

Each instruction is single issued.

Table 12 Multiply Accumulate Instruction Timing

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
MADD	2	1	MSUB	2	1
MADD.U	2	1	MSUB.U	2	1
MADDS	2	1	MSUBS	2	1
MADDS.U	2	1	MSUBS.U	2	1
MADD.H	2	1	MSUB.H	2	1
MADD.Q	2	1	MSUB.Q	2	1
MADDM.H	2	1	MSUBM.H	2	1
MADDMS.H	2	1	MSUBMS.H	2	1
MADDR.H	2	1	MSUBR.H	2	1
MADDR.Q	2	1	MSUBR.Q	2	1
MADDRS.H	2	1	MSUBRS.H	2	1
MADDRS.Q	2	1	MSUBRS.Q	2	1
MADDS.H	2	1	MSUBS.H	2	1
MADDS.Q	2	1	MSUBS.Q	2	1
MADDSU.H	2	1	MSUBAD.H	2	1
MADDSUM.H	2	1	MSUBADM.H	2	1
MADDSUMS.H	2	1	MSUBADMS.H	2	1
MADDSUR.H	2	1	MSUBADR.H	2	1
MADDSURS.H	2	1	MSUBADRS.H	2	1
MADDSUS.H	2	1	MSUBADS.H	2	1

For MADD.Q, MADDS.Q, MSUB.Q, MSUBS.Q Instructions:

	Result Latency	Repeat Rate
16 × 16	2	1
16 × 32	2	1
32 × 32	2	1

2.13.1.4 Control Flow Instruction Timing

Note all Integer Pipeline Control flow instructions are conditional.

- Each instruction is single issued.
- All target locations yield a full instruction in one access (i.e. not 16-bits of a 32-bit instruction).
- All code fetches take a single cycle.
- Timing is best case; no cache misses for context operations, no pending stores.

Table 13 Integer Pipeline Control Flow Instruction Timing

Instruction	Flow Latency	Repeat Rate	Instruction	Flow Latency	Repeat Rate
Branch Instructions					
JEQ	1/2/3	1/2/3	JLTZ	1/2/3	1/2/3
JGE	1/2/3	1/2/3	JNE	1/2/3	1/2/3
JGE.U	1/2/3	1/2/3	JNED	1/2/3	1/2/3
JGEZ	1/2/3	1/2/3	JNEI	1/2/3	1/2/3
JGTZ	1/2/3	1/2/3	JNZ	1/2/3	1/2/3
JLEZ	1/2/3	1/2/3	JNZ.T	1/2/3	1/2/3
JLT	1/2/3	1/2/3	JZ	1/2/3	1/2/3
JLT.U	1/2/3	1/2/3	JZ.T	1/2/3	1/2/3

For All Control Flow Instructions:

	Flow Latency	Repeat Rate
Correctly predicted, not taken	1	1
Correctly predicted, taken	2	2
Wrongly predicted	3	3

2.13.2 Load-Store Pipeline Instructions

This section summarizes the Load-Store Pipeline instructions.

2.13.2.1 Address Arithmetic Timing

Each instruction is single issued.

Table 14 Address Arithmetic Instruction Timing

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
Load Store Arithmetic Instructions					
ADD.A	1	1	GE.A	1	1
ADDIH.A	1	1	LT.A	1	1
ADDSC.A	1	1	NE.A	1	1
ADDSC.AT	1	1	NEZ.A	1	1
EQ.A	1	1	SUB.A	1	1
EQZ.A	1	1	NOP	1	1
Trap and Interrupt Instructions					
DEBUG	—	1	TRAPSV¹⁾	—	1
DISABLE	—	1	TRAPV¹⁾	—	1
ENABLE	—	1	RSTV	—	1
Move Instructions					
MFCR	1	1	MOV.A	1	1
MTCR	—	1	MOV.AA	1	1
MOVH.A	1	1	MOV.D	1	1
Sync Instructions					
DSYNC²⁾	—	1	ISYNC³⁾	—	1

1) Execution cycles when no TRAP is taken. The execution timing in the case of raising these TRAPs is the same as other TRAPs such as SYSCALL.

2) Repeat rate assumes that no shadow register writeback is pending, otherwise the repeat rate will depend upon the time for all delayed memory operation to occur.

3) Repeat rate assumes that code refetch takes a single cycle.

2.13.2.2 Control Flow Instruction Timing

This section summarizes the timing of Control Flow instructions.

Each instruction is single issued.

- All targets yield a full instruction in one access (not 16-bits of a 32-bit instruction).
- All code fetches take a single cycle. Timing is best case; no cache misses for context operations, no pending stores.
- Latency of CSA related instructions varies according to preceding instruction and status of the shadow register file.

Table 15 Load Store Control Flow Instruction Timing

Instruction	Flow Latency	Repeat Rate	Instruction	Flow Latency	Repeat Rate
Branch Instructions					
J	2	2	JLI	2	2
JA	2	2	JEQ.A	1/2/3	1/2/3
JI	2	2	JNE.A	1/2/3	1/2/3
JL	2	2	JNZ.A	1/2/3	1/2/3
JLA	2	2	JZ.A	1/2/3	1/2/3
CSA Instructions					
CALL¹⁾	2-9	2-9	SYSCALL¹⁾	2-9	2-9
CALLA¹⁾	2-9	2-9	SVLCX⁴⁾	4-16	4-16
CALLI¹⁾	2-9	2-9	RSLCX²⁾	4, 8	4, 8
RET³⁾	2-9	2-9	RFE³⁾	2-9	2-9
BISR⁴⁾	4-16	4-16	RFM⁵⁾	2-5	2-5
Loop Instructions					
LOOP⁶⁾	2/1/3	2/1/3	LOOPU⁶⁾	2/1/3	2/1/3

1) The range is 2-5 for LDRAM. The average latency is ~2.7 cycles for LDRAM.

2) The range is 4 for LDRAM.

3) The range is 2-5 for LDRAM.

4) The range is 4-9 for LDRAM.

5) Not strictly a CSA operation, but retrieves from memory a subset of context information and changes control flow in a similar manner. The range is 2-3 for LDRAM.

6) First time encountered executed in LS pipeline: Flow latency = 2, Repeat rate = 2.

Successive time executed in Loop pipeline: Flow latency = 1: Repeat rate = 1 (nested up to 2 deep).

Last time encountered: Flow latency = 3: Repeat rate = 3.

For JLI, JEQ.A, JNE.A JNZ.A, JZ.A Instructions:

	Flow Latency	Repeat Rate
Correctly predicted, not taken	1	1
Correctly predicted, taken	2	2
Wrongly predicted	3	2

2.13.2.3 Load Instruction Timing

Load instructions can produce two results if they use the pre-increment, post-increment, circular or bit-reverse addressing modes. Hence, in those cases there are two latencies that must be specified, the result latency for the value loaded from memory and the address latency for using the updated address register result.

- Each instruction is single issued.
- The memory references is naturally aligned.
- The memory accessed takes a single cycle to return a data item.
- Timing is best case; no cache misses, no pending stores.

Table 16 Load Instruction Timing

Instruction	Address Latency	Result Latency	Repeat Rate	Instruction	Address Latency	Result Latency	Repeat Rate
Load Instructions							
LD.A	1	2	1	LD.Q	1	1	1
LD.B	1	1	1	LD.W	1	1	1
LD.BU	1	1	1	LDLCX	4	4	4
LD.D	1	1	1	LDUCX	4	4	4
LD.DA	1	2	1	SWAP.W	2	2	2
LD.H	1	1	1	LEA¹⁾	—	1	1
LD.HU	1	1	1				

1) The addressing mode returning an updated address is not relevant for this instruction.

2.13.2.4 Store Instruction Timing

Cache and Store instructions similar to Load instructions will have a result for the pre-increment, post-increment, circular or bit-reverse addressing modes, but do not produce a 'memory' result.

- Each instruction is single issued.
- The memory references is naturally aligned.
- The memory accessed takes a single cycle to accept a data item.
- Timing is best case; no cache misses, no pending stores.

Table 17 Cache and Store Instruction Timing

Instruction	Address Latency	Repeat Rate	Instruction	Address Latency	Repeat Rate
Cache Instructions					
CACHEA.I	1	1	CACHEA.WI¹⁾	1	1
CACHEA.W¹⁾	1	1	CACHEI.W	1	1
CACHEI.WI	1	1			
Store Instructions					
ST.A	1	1	ST.T	2	2
ST.B	1	1	ST.W	1	1
ST.D	1	1	STLCX	4	4
ST.DA	1	1	STUCX	4	4
ST.H	1	1	LDMST	2	2
ST.Q	1	1			

1) Repeat rate assumes that no memory writeback operation occurs. Otherwise the repeat rate will depend upon the time for the castout buffers to clear.

2.13.3 Floating Point Pipeline Timing

These instructions are only valid if the optional Floating Point Unit is implemented.

Each instruction is single issued.

Table 18 Floating Point Instruction Timing

Instruction	Result Latency	Repeat Rate	Instruction	Result Latency	Repeat Rate
Floating Point Instructions					
ADDF	2	2	ITOF	2	2
CMP.F	1	1	MADD.F	3	3
DIV.F	15	15	MSUB.F	3	3
FTOI	2	2	MUL.F	2	2
FTOIZ	2	2	Q31TOF	2	2
FTOQ31	2	2	QSEED.F	1	1
FTOQ31Z	2	2	SUB.F	2	2
FTOU	2	2	UPDFL	–	1
FTOUZ	2	2	UTOF	2	2

2.14 Program Memory Interface (PMI)

Figure 12 shows the block diagram of the Program Memory Interface (PMI) of the TC1728.

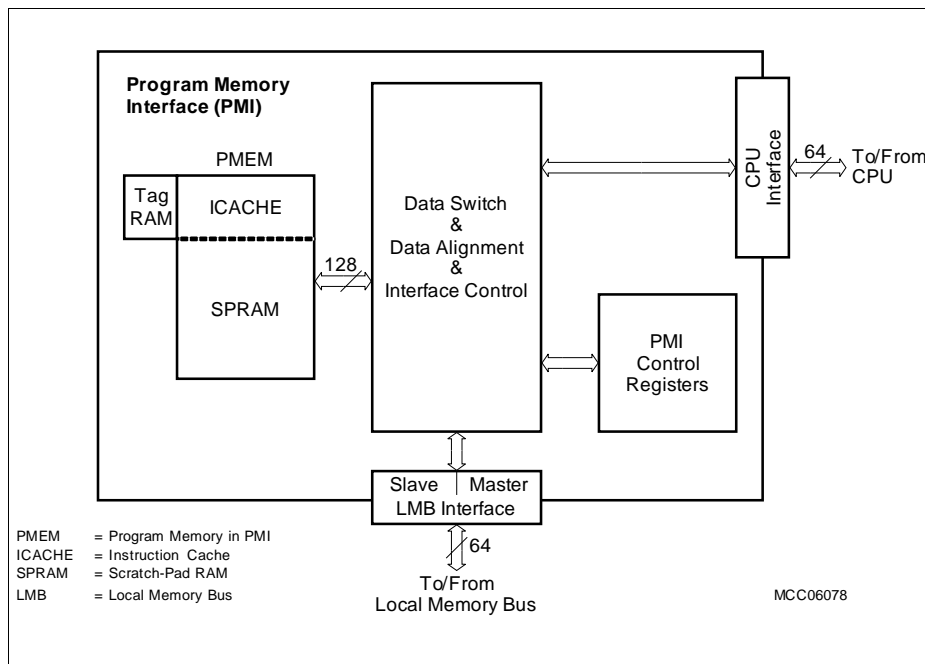


Figure 12 PMI Block Diagram

2.14.1 PMI Features

The Program Memory Interface (PMI) has the following features:

- 24 Kbyte total Program Memory (PMEM), with software configurable split between SPRAM and ICACHE. The following configurations are supported:

SPRAM	ICACHE
16	8
20	4
22	2
24	0

- ICACHE operation features:
 - Two-way set associative cache
 - LRU (Least-Recently Used) replacement algorithm
 - Cache line size: 256 bits (4 double-words)
 - Validity granularity: One valid bit per cache line
 - ICACHE can be globally invalidated to provide support for software cache coherency (to be handled by the programmer)
 - ICACHE can be bypassed to provide a direct fetch from the CPU to on-chip and off-chip resources
 - ICACHE refill mechanism:
 - critical double-word first, line wrap around, streaming to CPU
- CPU interface
 - Supporting unaligned accesses (16-bit aligned)
- Local Memory Bus (LMB) Master Interface
- Local Memory Bus (LMB) Slave Interface to scratchpad RAM
- PMI SRAMs (SPRAM, ICACHE, and cache tag SRAM) are ECC protected

2.14.2 LMB Access Priorities

The TC1728 contains a common local memory bus, shared between the Program Memory Interface (PMI), Data Memory Interface (DMI), DMA controller and LMB-FPI Interface (FPI) bus masters. In such systems, the DMI is the default bus master whilst LMB arbitration priorities are as follows:

1. DMA High
2. LFI
3. DMA Medium
4. DMI
5. PMI
6. DMA Low

2.14.3 Scratchpad RAM

The TC1728 contains up to 24 Kbyte of scratchpad RAM. Scratchpad RAM provides a fast, deterministic program fetch access from the CPU for use by performance critical code sequences.

- CPU program fetch accesses to scratchpad RAM are never cached in the instruction cache and are always directly targeted to the scratchpad RAM.
- The scratchpad RAM has the concept of a scratchpad RAM “line” (similar to the instruction cache). Scratchpad RAM lines are 256-bits long (4 double-words).

The CPU fetch interface will generate unaligned accesses (16-bit aligned), which will normally result in 64-bits of instruction being returned to the CPU.

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- If the fetch request is made within a scratchpad RAM line, the 64-bit instruction packet is returned to the CPU in a single cycle.
- If the fetch request is made to the end of a scratchpad RAM line, such that 64-bits would span two scratchpad RAM lines, then only the instruction half-words up to the end of the scratchpad RAM line are returned to the CPU.

Note that the CPU Fetch Unit can only read from the scratchpad RAM and can never write to it.

The scratchpad RAM may also be accessed from the LMB Slave interface by another bus master, such as the Data Memory Interface (DMI). The scratchpad RAM may be both read and written from the LMB. In the TC1728, the PMI LMB Slave interface supports all LMB transaction types.

2.14.4 Instruction Cache

The TC1728 contains up to 8 Kbyte of Instruction Cache (ICACHE). The ICACHE is a two-way set-associative cache with a Least-Recently-Used (LRU) replacement algorithm, and is organized as 256 cache lines, with 256-bits per line. Each ICACHE line has a single associated valid bit.

CPU program fetch accesses which target a cacheable memory segment (and where the ICACHE is not bypassed) target the ICACHE. If the requested address and its associated instruction are found in the cache (Cache Hit), the instruction is passed to the CPU Fetch Unit without incurring any wait states. If the address is not found in the cache (Cache Miss), the PMI cache controller issues a cache refill sequence and wait states are incurred whilst the cache line is refilled. The CPU fetch interface will generate unaligned accesses (16-bit aligned), which will normally result in 64-bits of instruction being returned to the CPU. If the fetch request is made within a ICACHE line, no matter the alignment, and a cache hit occurs, then the 64-bit instruction packet is returned to the CPU. If the fetch request is made to the end of a ICACHE line, such that 64-bits would span two ICACHE lines, then only the instruction half-words up to the end of the ICACHE line are returned to the CPU.

Instruction Cache Refill Sequence

Instruction Cache refills are performed using a critical double-word first strategy with cache line wrapping such that the refill size is always 4 double-words. ICACHE refills are always performed in 64-bit quantities. A refill sequence will always affect only one cache line. There is no prefetching of the next cache line.

ICACHE refills are therefore implemented using an LMB Burst Transfer 4 (BTR4) transfers. The Instruction Cache supports instruction streaming, meaning that it can deliver available instruction half-words to the CPU Fetch Unit whilst the refill operation is ongoing.

Instruction Cache Bypass

The Instruction Cache may be bypassed, under control of `PMI_CON0.PCBYP`, to provide a direct instruction fetch path for the CPU Fetch Unit. The default value of `PMI_CON0.PCBYP` is such that the ICACHE is bypassed after reset. ICACHE bypass should be disabled during initialization to enable the ICACHE.

Whilst ICACHE bypass is enabled, a fetch request by the CPU to a cacheable address will result in a forced cache miss, such that the cache controller issues a standard refill sequence and supplies instruction half-words to the CPU using instruction streaming, without updating the cache contents. Any valid cache lines within the ICACHE will remain valid and unchanged whilst the ICACHE is bypassed. As such, instruction fetch requests to cacheable addresses with ICACHE bypass enabled behave identically to instruction fetch requests to non-cacheable addresses.

Instruction Cache Invalidation

The PMI does not have automatic cache coherency support. Changes to the contents of memory areas external to the PMI that may have already been cached in the ICACHE are not detected. Software must provide the cache coherency in such a case. The PMI supports this via the cache invalidation function. The ICACHE contents may be globally invalidated by writing a '1' to `PMI_CON1.PCINV`. The ICACHE invalidation is performed over multiple cycles by a hardware state machine which cycles through the ICACHE entries marking each as invalid. The status of the ICACHE invalidation sequence may be determined by reading the `PMI_CON1.PCINV` bit.

2.14.5 Program Line Buffer

The PMI module contains a 256-bit Program Line Buffer (PLB). For accesses to cacheable addresses the PLB acts as a streaming buffer for the main instruction cache. Instruction cache refill sequences transfer data to the PLB and the immediately to the TriCore CPU without updating the main instruction cache. The PLB contents are then transferred to the main instruction cache on the next instruction cache miss.

Program fetch requests to non-cacheable addresses utilize the PLB as a single line cache. A single valid bit is associated with the PLB, denoting that the PLB contents are valid. As such all fetch requests resulting in an update of the PLB, whether to a cacheable address or not, are implemented as LMB Burst Transfer 4 (BTR4) transactions, with the critical double-word of the PLB line being fetched first size.

2.14.6 PMI Registers

Three control registers are implemented in the Program Memory Interface. These registers and their bits are described in this section.

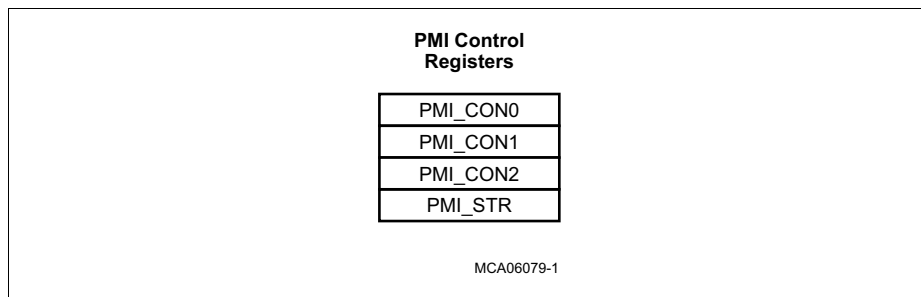


Figure 13 PMI Registers

Table 19 PMI Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
PMI_CON0	PMI Control Register 0	FD10 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0002 _H
PMI_CON1	PMI Control Register 1	FD14 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H
PMI_CON2	PMI Control Register 2	FD18 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0180 0183 _H
PMI_STR	PMI Synchronous Trap Register	FD20 _H	U, SV, 32	SV, 32	Class 3 Reset 0000 0000 _H

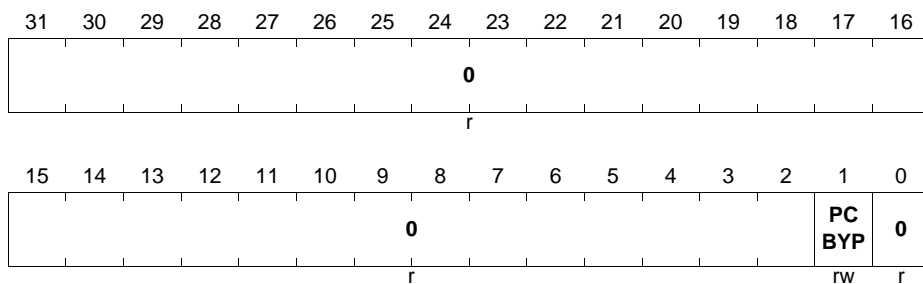
2.14.6.1 PMI Register Descriptions

PMI Control Register 0

PMI_CON0

PMI Control Register 0

(F87F FD10_H)

Reset Value: 0000 0002_H


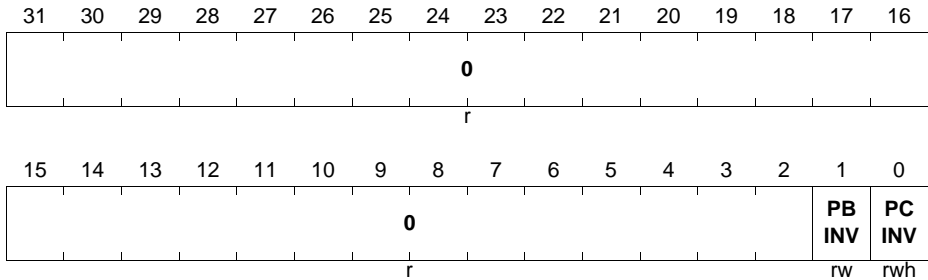
Field	Bits	Type	Description
PCBYP	1	rw	Instruction Cache Bypass 0 _B Cache enabled 1 _B Cache bypassed (disabled)
0	[31:2], 0	r	Reserved Read as 0; should be written with 0.

PMI Control Register 1

PMI_CON1

PMI Control Register 1

(F87F FD14_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
PCINV	0	rwh	Instruction Cache Invalidate Write Operation: 0 _B No effect. Normal instruction cache operation. 1 _B Initiate invalidation of entire instruction cache. Read Operation: 0 _B Normal operation. Instruction cache available. 1 _B Instruction cache invalidation in progress. Instruction cache unavailable.
PBINV	1	rw	Program Buffer Invalidate Write Operation: 0 _B No effect. Normal program line buffer operation. 1 _B Invalidate the program line buffer. This field returns 0 when read.
0	[31:2]	r	Reserved Read as 0; should be written with 0.

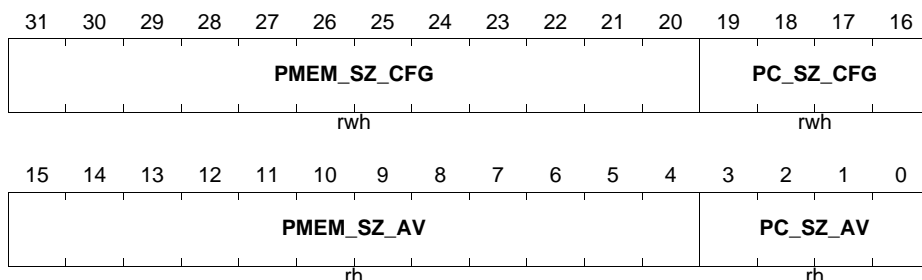
PMI Control Register 2

The PMI_CON2 register may only be written in supervisor mode and is endinit protected. In addition write accesses to PMI_CON2 are also dependent on the status of Flash read protection. Whenever Flash read protection is inactive PMI_CON2 may be written as often as required (bearing in mind operational constraints for changing SRAM and cache sizes). When Flash read protection becomes active after reset, PMI_CON2 may be written only the one time. Any further writes to PMI_CON2 with Flash read protection active are ignored. Setting Flash read protection inactive then active again does not allow further Flash read protection enabled PMI_CON2 writes; only a reset will re-enable the single Flash read protection enabled write.

PMI_CON2

PMI Control Register 2

(F87F FD18_H)

Reset Value: 0180 0183_H


Field	Bits	Type	Description
PC_SZ_AV	[3:0]	rh	Maximum Instruction Cache Size Available Size of the maximum available Instruction Cache. Encoding is as per PC_SZ_CFG.
PMEM_SZ_AV	[15:4]	rh	Maximum Program Memory Size Available Size of the maximum available Program Memory ¹⁾ , where size of PMEM = size of SPRAM + size of ICACHE. Encoding is as per PMEM_SZ_CFG.

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Field	Bits	Type	Description
PC_SZ_CFG	[19:16]	rwh	Instruction Cache Size Configuration Configuration of the Instruction Cache Size. Any program memory not utilised as instruction cache is configured as SPRAM. After reset this field is set to zero. This field may subsequently be written to select an alternative split of PMEM between ICACHE and SPRAM ²⁾ . The encoding of PC_SZ_CFG is as follows: 0000 _B No Instruction cache 0001 _B 2KByte Instruction cache 0010 _B 4Kbyte Instruction cache 0011 _B 8Kbyte Instruction cache Others : Reserved
PMEM_SZ_CFG	[31:20]	rwh	Program Memory Size Configuration Configuration of the Program Memory (PMEM) size. After reset this field is set to equal the maximum PMEM size available, PMEM_SZ_AV. This field may subsequently be written to force a smaller PMEM size to be visible to software ³⁾ . PMEM_SZ_CFG specifies the configured PMEM size in Kbytes: 000 _H Reserved. 004 _H 4Kbyte Program Memory. 008 _H 8Kbyte Program Memory. 00C _H 12Kbyte Program Memory. ... 100 _H 256Kbyte Program Memory.

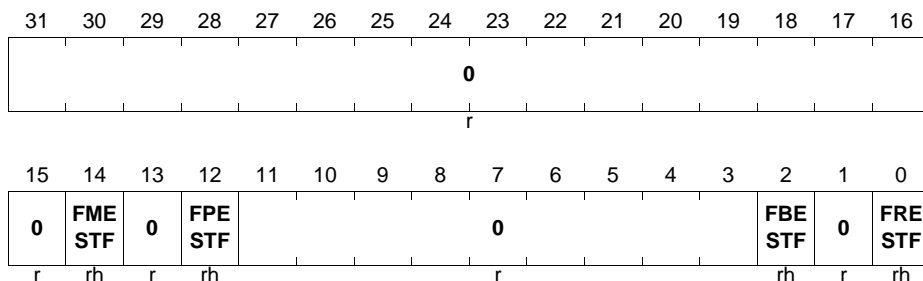
- 1) Configuration of program memory and instruction cache size is not intended to be performed on-the-fly by application code. The configuration should be selected once during the initialisation sequence, before PMI_CON0.PCBYP is cleared. Instruction fetches from SPRAM or cacheable program regions during switching of the PC_SZ_CFG field will give undefined behaviour.
- 2) Writing this field with a value larger than the maximum available ICACHE size (PC_SZ_AV) resets this field to PC_SZ_AV.
- 3) Writing this field with a value larger than the maximum available PMEM size (PMEM_SZ_AV) resets this field to PMEM_SZ_AV.

Program Memory Interface Synchronous Trap Register (PMI_STR)

PMI_STR

PMI Synchronous Trap Register (F87F FD20_H)

Reset Value: 0000 0000_H



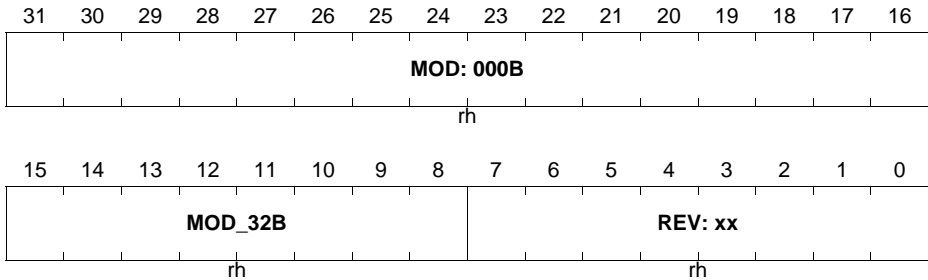
Field	Bits	Type	Description
FRESTF	0	rh	Fetch Range Error Synchronous Trap Flag
FBESTF	2	rh	Fetch Bus Error Synchronous Trap Flag
FPESTF	12	rh	Fetch Peripheral Error Synchronous Trap Flag
FMESTF	14	rh	Fetch MSIST Error Synchronous Trap Flag
0	1, [11:3], 15, [31:16]	r	Reserved Read as 0; should be written with 0.

PMI Identification Register

PMI_ID

PMI Identification Register

(F87F FD08_H)

Reset Value: 000B C0XX_H


Field	Bits	Type	Description
MOD_REV	[7:0]	rh	Revision Number 01 _H For version numbering. The value of the revision starts with 01 _H (first revision) up to FF _H FF _H Last revision
MOD_32B	[15:8]	rh	32-Bit Module Enable C0 _H A value of C0 _H in this field indicates a 32-bit module with a 32-bit module ID register.
MOD	[31:16]	rh	Module Identification Number 0B _H For module identification.

2.15 Data Memory Interface (DMI)

This figure shows the block diagram of the Data Memory Interface (DMI) of the TC1728.

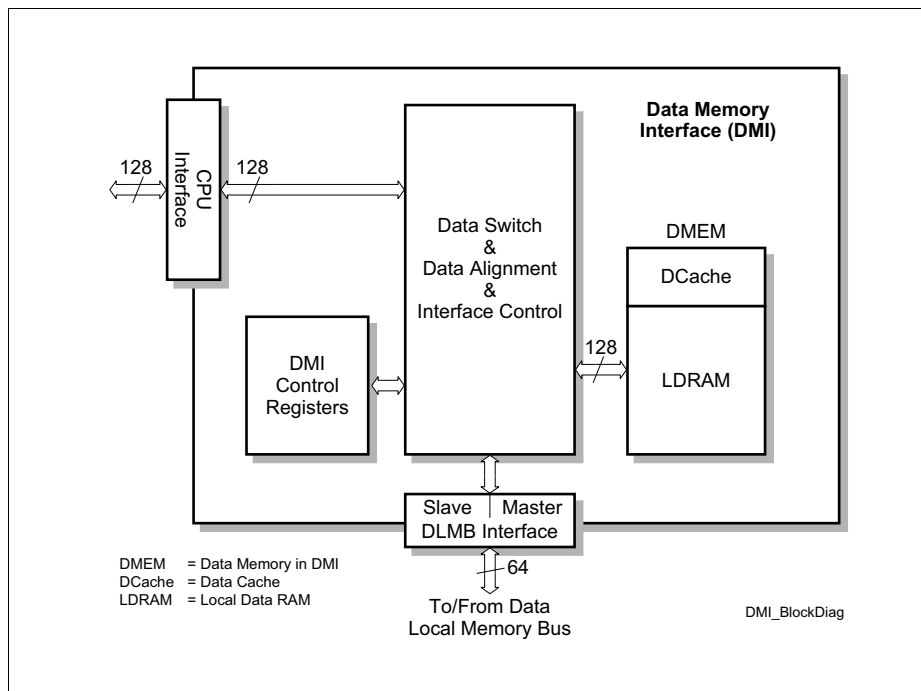


Figure 14 DMI Block Diagram

2.15.1 DMI Features

The Data Memory Interface (DMI) has the following features:

- 120 Kbyte total Data Memory (DMEM), with software configurable split between LDRAM and DCache. The following configurations are supported:

LDRAM	DCache
116	4
118	2
120	0

- Data Cache features:

- Two-way associative cache, LRU (least recently used) replacement algorithm
- Cache line size: 128 bits
- Validity granularity: One valid bit per cache line
- Write-back Cache: Writeback granularity: 128 bits
- Refill mechanism: full cache line refill
- CPU interface
 - supporting unaligned accesses (16-bit aligned) with a minimum penalty of one cycle for unaligned accesses crossing 2 lines LDRAM or DCache)
- Local Memory Bus (LMB) Master interface
- Local Memory Bus (LMB) Slave interface to LDRAM

2.15.2 LMB Access Priorities

See [“LMB Access Priorities” on Page 2-72](#).

2.15.3 Local Data RAM (LDRAM)

The TC1728 contains up to 120 Kbyte of LDRAM. LDRAM provides fast, deterministic data access to the CPU for use by performance critical code sequences.

The LDRAM has the concept of an LDRAM “line”. LDRAM lines are 128-bits long (2 double-words). The CPU load-store interface will generate unaligned accesses (16-bit aligned), which will result in up to 64-bits of data being transferred to or from the CPU (for non-context operations). If the data access is made within an LDRAM line, no matter the alignment, then the requested data is returned to the CPU in a single cycle. If the data access is made to the end of an LDRAM line, such that the requested data would span two LDRAM lines, a single wait cycle is incurred.

The LDRAM may also be accessed from the LMB Slave interface by another bus master, with both read and write transactions supported. The LDRAM may be accessed by the LMB Slave interface using any LMB transaction type, including burst transfers. In accordance with the LMB protocol, accesses to the LMB Slave interface must be naturally aligned.

2.15.4 Data Cache

The TC1728 contains up to 4 KByte of Data Cache (DCache). The DCache is a two-way set-associative cache with a Least-Recently-Used (LRU) replacement algorithm, and is organised as 256 cache lines, with 128-bits per line. Associated with each DCache line is a single valid bit which pertains to the entire line.

CPU data accesses to a cacheable memory segment target the DCache. If the requested address and its associated data are found in the cache (Cache Hit), the data is passed to/from the CPU Load-Store Unit without incurring any wait states. If the address is not found in the cache (Cache Miss), the DMI cache controller issues a cache refill sequence and wait states are incurred whilst the cache line is refilled. The CPU

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load-store interface will generate unaligned accesses (16-bit aligned), which will result in up to 64-bits of data being transferred to or from the CPU (for non-context operations). If the data access is made within a DCache line, no matter the alignment, and a cache hit is detected then the requested data is returned to the CPU in a single cycle. If the data access is made to the end of a DCache line, such that the requested data would span two DCache lines, a single wait cycle is incurred (if both cache lines are present in the cache, otherwise a refill sequence is required for the missing cache line(s)).

The TC1728 data cache is of the writeback type. When the CPU writes to a cacheable location the data is merged with the corresponding cache line and not written to main memory immediately. Associated with each cache line is a single 'dirty' bit, to denote that the data in the cache line has been modified. Whenever a CPU load-store access results in a cache miss, and each of the potential cache ways that could hold the requested cache line are valid, one of the cache lines is chosen for eviction based upon the LRU replacement algorithm. The line selected for eviction is then checked to determine if it has been modified using its dirty bit. If the line has not been modified the line is discarded and the refill sequence started immediately. If the line has been modified then the dirty data is first written back to main memory before the refill is initiated. Due to the single dirty bit per cache line, 128 bits of data will always be written back, resulting in LMB Burst Transfer 2 (BTR2) transactions.

Data Cache refills always result in the full cache line being refilled, with the critical double-word of the DCache line being fetched first. A refill sequence will always affect only one cache line. There is no prefetching of the next cache line. Due to the uniform size of DCache refill sequences, such refills are always implemented using LMB Burst Transfer 2 (BTR2) transactions.

2.15.5 Data Line Buffer

The DMI module contains a 128-bit Data Line Buffer (DLB).

When the TC1728 device is configured to contain a data cache, the DLB acts as a streaming buffer for the main data cache. Data cache refill sequences transfer data to the DLB and then immediately to the TriCore CPU without updating the main data cache. The DLB contents are then transferred to the main data cache on the next data cache miss. The presence of the DLB is transparent to software but ensures that accesses to cacheable addresses typically¹⁾ incur no more wait cycles than accesses to non-cacheable addresses.

When the TC1728 device is configured without a data cache, the DLB acts as a single line data cache for accesses to cacheable addresses.

1) No additional wait states are incurred as long as the data cache line to be replaced does not contain dirty information which requires a cache line writeback.

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A single valid bit is associated with the DLB, denoting that the DLB contents are valid. As such all accesses updating the DLB, whether data cache is configured or not, are implemented as LMB Burst Transfer 2 (BTR2) transactions, with the critical double-word of the DLB line being fetched first size.

Unlike the PMI modules PLB, data accesses to non-cacheable addresses always bypass the DLB.

2.15.6 DMI Trap Generation

CPU data accesses to the DMI may encounter one of a number of potential error conditions, which result in one of two trap conditions being reported by the DMI back to the CPU. Data Access Synchronous Bus Error (DSE) traps are generated as a result of load accesses, whilst Data Access Asynchronous Error (DAE) traps are generated as a result of store accesses. Since a number of potential error conditions exist, the DMI contains two read-only status registers that hold information about the type of the error. The DMI Synchronous Trap Flag Register (DMI_STR) contains the flags indicating the cause of a DSE trap, whilst the DMI Asynchronous Trap Flag Register (DMI_ATR) holds the flags indicating the cause of a DAE trap.

The possible error conditions and their corresponding trap flag register bits are as follows:

Range Error

Range errors are caused by accesses to LDRAM space (D000 0000_H - D3FF FFFF_H) outside the range of the LDRAM. Load accesses which generate a range error will result in the DMI_STR.LRESTF flag being set, store accesses will result in DMI_ATR.SREATF flag being set.

LMB Bus Error

LMB Bus errors are detected when CPU load-store accesses directly target the LMB and where an error condition is encountered on the LMB. Load accesses which generate an LMB Bus error will result in the DMI_STR.LBESTF flag being set, store accesses will result in the DMI_ATR.SBEATF flag being set. Note that accesses to DMI special function registers will also result in this error type, since such accesses are always directed to the LMB (even if performed by the CPU) and handled by the DMI LMB Slave interface.

Cache Refill Error

Cache refill errors are detected when a data cache or DLB refill sequence encounters a bus error on the LMB. Load accesses which generate a cache refill error will result in the DMI_STR.CRLESTF flag being set, whilst store accesses will result in the DMI_ATR.CRSEATF flag being set.

Cache Writeback Error

Cache writeback errors are detected when a data cache or DLB writeback sequence, initiated by a CPU load-store access generating a cache miss, encounters a bus error on the LMB. Note that unlike other error types, the address causing a cache writeback error is not related to the address of the CPU load-store access which caused the writeback.

Load accesses which encounter a cache writeback error will result in the DMI_STR.CWLESTF flag being set, whilst store accesses will result in the DMI_ATR.CWSEATF flag being set.

Cache Flush Error

Cache flush errors are detected when a data cache or DLB writeback sequence, initiated by a cache management instruction (cacha.w, cachea.wi, cachei.w, cachei.wi), encounters a bus error on the LMB. Cache management instructions which encounter such errors will result in the DMI_ATR.CFEATF flag being set.

Cache management Error

Cache management errors are detected when a cache management instruction (cacha.w, cachea.i, cachea.wi, cachei.w, cachei.wi) targets a non-cacheable address, either a noncacheable physical memory address. Cache management errors will result in the DMI_ATR.CMEATF flag being set.

2.15.7 DMI Registers

Two Control Registers, two Trap Flag registers, and four Error Detection registers are implemented in the DMI. These registers and their bits are described in this section.

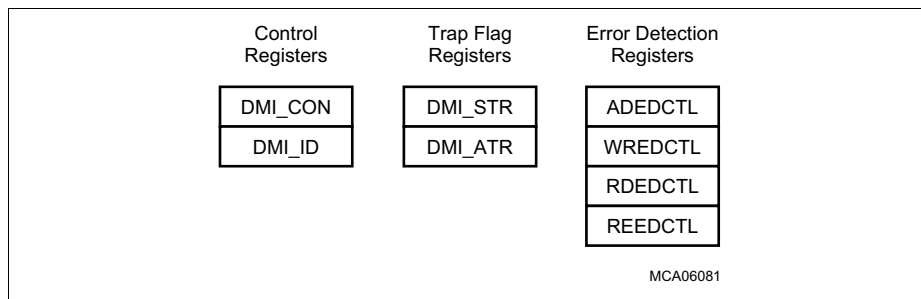


Figure 15 DMI Registers

Table 20 DMI Registers

Short Name	Description	Offset Address	Access Mode		Reset
			Read	Write	
DMI_CON	DMI Control Register	FC10 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0780 0782 _H
DMI_STR	DMI Synchronous Trap Flag Register	FC18 _H	U, SV, 32 ¹⁾	SV, 32	Class 3 Reset 0000 0000 _H
DMI_ATR	DMI Asynchronous Trap Flag Register	FC20 _H	U, SV, 32 ¹⁾	SV, 32	Class 3 Reset 0000 0000 _H
ADEDCTL	Address Error Detection Control	FC30 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
WREDCTL	Data Write Error Detection Control	FC38 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
RDEDCTL	Data Read Error Detection Control	FC40 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H
REEDCTL	Responded Control	FC48 _H	U, SV, 32	SV, E, 32	Class 3 Reset 0000 0000 _H

1) Reading these registers in supervisor mode returns the contents and then clears the register. Reading it in user mode only returns the contents of the register; it is not cleared. No error will be reported in this case.

Access to DMI control registers must only be made with double-word aligned word accesses. An access not conforming to this rule, or an access that does not follow the specified privilege mode (Supervisor mode, Endinit-protection), or a write access to a

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read-only register, will lead to a bus error if the access was from the LMB Bus, or to a trap, flagged in DMI_STR/DMI_ATR register in case of a CPU load/store access.

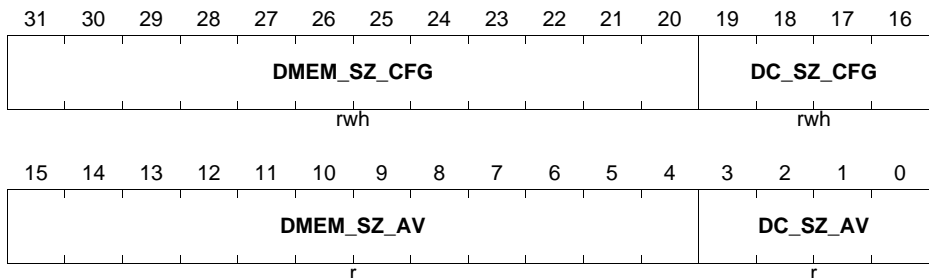
2.15.7.1 DMI Register Descriptions

DMI Control Register

The DMI control register indicates the DMI data memory size and data cache availability.

DMI_CON

DMI Control Register (F87F FC10_H) Reset Value: 0780 0782_H



Field	Bits	Type	Description
DC_SZ_AV	[3:0]	r	Maximum Data Cache Size Available Size of the maximum available Data Cache. Encoding is as per DC_SZ_CFG.
DMEM_SZ_AV	[15:4]	r	Maximum Data Memory Size Available Size of the maximum available Data Memory, where size of DMEM = size of LDRAM + size of DCache. Encoding is as per DMEM_SZ_CFG.
DC_SZ_CFG	[19:16]	rwh	Data Cache Size Configuration Configuration of the Data Cache Size. Any data memory not utilised as data cache is configured as a LDRAM. After reset this field is set to zero. This field may subsequently be written to select an alternative split of DMEM between DCache and LDRAM ¹⁾ . The encoding of DC_SZ_CFG is as follows: 0000 _B No Data cache. 0001 _B 2Kbyte Data cache. 0010 _B 4Kbyte Data cache Others : Reserved

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Field	Bits	Type	Description
DMEM_SZ_CFG G	[31:20]	rwh	Data Memory Size Configuration Configuration of the Data Memory (DMEM) size. After reset this field is set to equal the maximum DMEM size available, DMEM_SZ_AV. This field may subsequently be written to force a smaller DMEM size to be visible to software ²⁾ . DMEM_SZ_CFG specifies the configured DMEM size in Kbytes: 000 _H Reserved. 004 _H 4Kbyte Data Memory. 008 _H 8Kbyte Data Memory. 00C _H 12Kbyte Data Memory. ... 100 _H 256Kbyte Data Memory.

1) Writing this field with a value larger than the maximum available DCache size (DC_SZ_AV) resets this field to DC_SZ_AV.

2) Writing this field with a value larger than the maximum available DMEM size (DMEM_SZ_AV) resets this field to DMEM_SZ_AV.

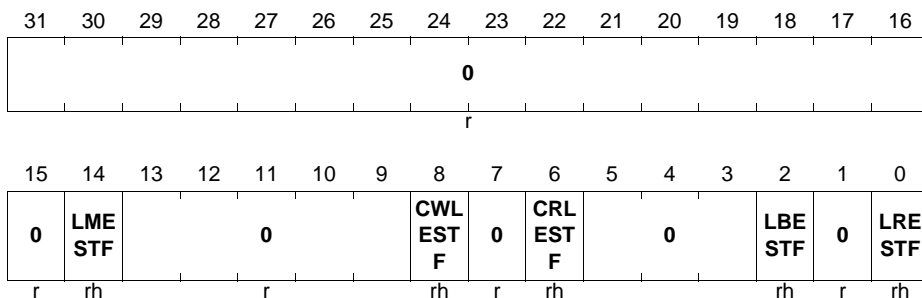
DMI Synchronous Trap Flag Register

The DMI Synchronous Trap Flag Register, DMI_STR, holds the flags that identify the root cause of a Data-access Synchronous Bus Error (DSE). Reading DMI_STR in supervisor mode returns the register contents and then clears its contents. Reading DMI_STR in user mode returns the contents of the register but does not clear its contents.

DMI_STR

DMI Synchronous Trap Flag Register

(F87F FC18_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
LRESTF	0	rh	Load Range Synchronous Error Trap Flag
LBESTF	2	rh	Bus Load Synchronous Error Trap Flag
CRLESTF	6	rh	Cache Refill Synchronous Error Trap Flag
CWLESTF	8	rh	Cache Writeback Synchronous Error Trap Flag
LMESTF	14	rh	Load MSIST Synchronous Error Trap Flag
0	1, [5:3], 7, [13:9], 15, [31:16]	r	Reserved Read as 0; should be written with 0.

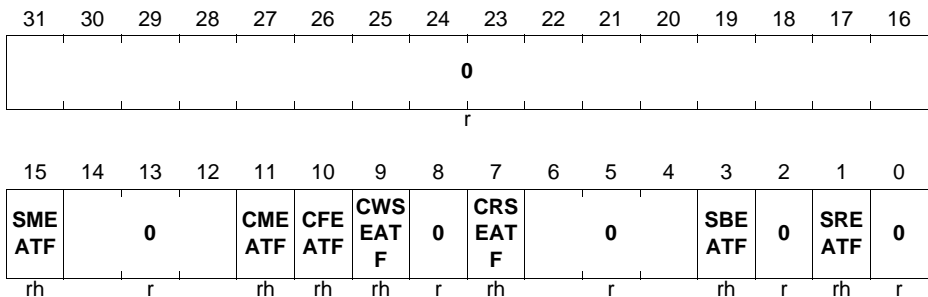
DMI Asynchronous Trap Flag Register

The DMI Asynchronous Trap Flag Register, DMI_ATR, holds the flags that inform about the root cause of a Data Access Asynchronous Bus Error (ASE). Reading DMI_ATR in supervisor mode returns the register contents and then clears its contents. Reading DMI_ATR in user mode returns the contents of the register but does not clear its contents.

DMI_ATR

DMI Asynchronous Trap Flag Register

(F87F FC20_H)

Reset Value: 0000 0000_H


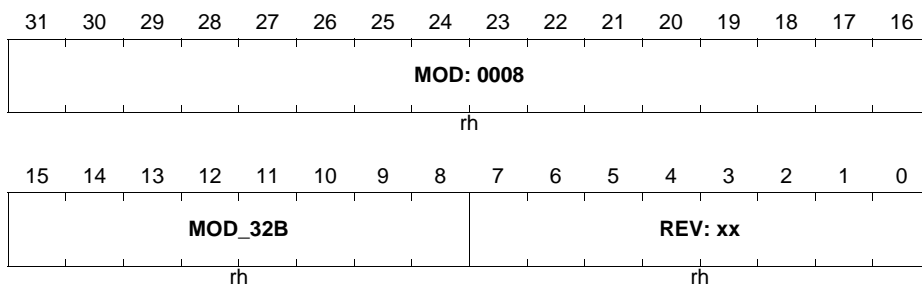
Field	Bits	Type	Description
SREATF	1	rh	Store Range Asynchronous Error Trap Flag
SBEATF	3	rh	LMB Bus Store Asynchronous Error Trap Flag
CRSEATF	7	rh	Cache Refill Store Asynchronous Error Trap Flag
CWSEATF	9	rh	Cache Writeback Store Asynchronous Error Trap Flag
CFEATF	10	rh	Cache Flush Store Asynchronous Error Trap Flag
CMEATF	11	rh	Cache Management Store Asynchronous Error Trap Flag
SMEATF	15	rh	Store MSIST Store Asynchronous Error Trap Flag
0	0, 2, [6:4], 8, [14:12] [31:16]	r	Reserved Read as 0; should be written with 0.

DMI Identification Register

DMI_ID

DMI Identification Register

(F87F FC08_H)

Reset Value: 0008 C0XX_H


Field	Bits	Type	Description
MOD_REV	[7:0]	rh	Revision Number 01 _H For version numbering. The value of the revision starts with 01 _H (first revision) up to FF _H FF _H Last revision
MOD_32B	[15:8]	rh	32-Bit Module Enable C0 _H A value of C0 _H in this field indicates a 32-bit module with a 32-bit module ID register.
MOD	[31:16]	rh	Module Identification Number 08 _H For module identification.

LMB Error Injection Control Registers

The LMB bus system of the TC1728 processor is protected against transmission errors caused by transient events. All signal groups - address group signals (address, bus opcode, etc.), data signals and response group signals are ECC protected, allowing the detection and signalling of single- or double-bit errors in the transmission protocol. In addition the LMB abort signal, which has unique cycle timing, is protected by the transmission of both the LMB abort signal and its complement.

In order to facilitate the testing of the LMB error detection mechanisms, the DMI contains four special function registers which enable the generation of corrupted LMB transmissions. To constrain the range of side-effects these registers provide only for the generation of corrupted redundancy information.

In order to simplify test sequences and allow multiple transmission error types to be generated for a single transaction, accesses to the four DMI error injection control registers themselves will not trigger the LMB error injection mechanisms, even if otherwise enabled. Specifically, any access to the address range $F87FFC30_H$ - $F87FFC4F_H$ will not trigger an error injection, whether the access is generated by the DMI or any other LMB master agent.

Where the TriCore CPU is utilised to program the error injection control registers via the DMI LMB master interface it is necessary to use a data barrier (DSYNC instruction) after modification of the required registers to ensure that the next transaction generated by the DMI module will be commenced with the desired error injection (or not). In addition, software should use a data barrier prior to modification of one of these four error injection registers to ensure no other buffered transaction receives an unintended error.

The injection of an LMB transmission error only occurs for one transaction (or cycle in the special case of a corrupted idle cycle) - and after the required transaction errors have been generated, the enable bit(s) used by the transaction are reset by hardware. Thus it is possible to determine if the requested error injections have occurred by reading the respective error injection control registers.

Address Error Detection Control Register

The ADECTL register enables the injection of errors on the ECC bits associated with the LMB address signal group and / or the complemented LMB abort signal, for transactions generated by the DMI LMB master interface. It may be used to check the LMB address and abort error detection functionality of any LMB slave interface¹⁾.

ADECTL

Address Error Detection Control Register

(F87F FC30_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AENABLE	IENABLE	0													
rwh	rwh	r													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							ABTFLIP	ADFLIP							
r							rw	rw							

Field	Bits	Type	Description
AENABLE	31	rwh	Address Enable Enables corruption of address signal group ECC bits and / or complemented LMB abort signal for the next non-idle transaction generated by the DMI LMB master: 0 _B Not enabled 1 _B Enabled Cleared by hardware after a non-excluded, non-idle transaction by the DMI has completed.

1) Load-Store transactions initiated by the TriCore CPU targeting LDRAM addresses are routed internally within the DMI module. In order to use the DMI LMB master to check the LMB address / abort error detection functionality of the DMI LMB slave interface, one of the DMI registers (other than one of the four error injection registers themselves) must be targetted. All accesses to DMI registers, whether from the TriCore CPU or any other LMB master, are routed via the LMB.

CPU Subsystem

Field	Bits	Type	Description
IENABLE	30	rwh	Idle Enable Enables corruption of address signal group ECC bits for the next non-excluded idle cycle ¹⁾ generated by the DMI LMB master when acting as LMB default master. 0 _B Not enabled 1 _B Enabled Cleared by hardware after a non-excluded idle cycle driven by the DMI has completed.
0	[29:9]	r	Reserved
ABTFLIP	8	rw	Abort Flip For a non-excluded, non-idle transaction if AENABLE is set and this bit is set, the complemented LMB abort signal transmitted by the DMI is flipped with respect to the true value.
ADFLIP	[7:0]	rw	Address Flip For a non-excluded transaction if AENABLE or IENABLE is set, for each bit in ADFLIP set, the corresponding LMB address group ECC signal transmitted by the DMI is flipped with respect to the true value.

- 1) After completion of programming of one of the four LMB error injection control registers by the DMI LMB master interface the address driven on the LMB by the DMI for an idle cycle will remain that of the previous transaction and as such will be flagged as an excluded address. The idle cycle corrupted by the DMI LMB master when IENABLE is set will be the first idle cycle after the next DMI transaction to a non-excluded address.

This register is ENDINIT protected.

This register is ENDINIT protected.

This register is ENDINIT protected

This register is ENDINIT protected.

3 System Control Unit (SCU)

The System Control Unit (SCU) of the TC1728 handles all system control tasks beside the debug related tasks which are controlled by the OCDS/Cerberus.

The SCU contains the following functional sub-blocks:

- Clock Control (see [Section 3.1](#))
- Reset Operation (see [Section 3.2](#))
- External Interface (see [Section 3.3](#))
- Power Supply and Control (see [Section 3.4](#))
- Power Management (see [Section 3.5](#))
- Software Boot Support (see [Section 3.6](#))
- SRAM ECC Control (see [Section 3.7](#))
- Watchdog Timer (see [Section 3.8](#))
- Emergency Stop Control (see [Section 3.9](#))
- Interrupt Generation (see [Section 3.10](#))
- NMI Trap Generation (see [Section 3.11](#))
- SCU registers and Address map (see [Section 3.12](#))
- SCU register overview table (see [Table 3-22](#))

3.1 Clock System Overview

This section describes the TC1728 clock system. Topics covered include clock generation and the operation of clock circuitry.

The TC1728 clock system provides the following functions:

- Acquires and buffers incoming clock signals to create a master clock frequency
- Distributes in-phase synchronized clock signals throughout the TC1728's entire clock tree
- Divides the master clock frequency into lower frequencies required by the different modules for operation
- Reduces electromagnetic interference (EMI) by switching off unused modules

Figure 3-1 shows the structure of the TC1728 clock system. The master clock f_{PLL} is generated by the oscillator circuit and the PLL (phase-locked loop) unit (see **Section 3-2**).

The functionality of the control blocks shown in **Figure 3-1** varies depending on the functional unit being controlled. Some functional units such as the watchdog timer, are directly driven by the system clock. The implemented clock control register options are described for each module in the module chapter itself.

All clock control registers CLC and the fractional divider registers FDR are Endinit-protected.

Features of the TC1728 Clock System

- PLL operation for multiplying clock source by different factors
- Direct drive capability for direct clocking
- Comfortable state machine for secure switching between Freerunning Mode / Normal Mode and Prescaler Mode

System Control Unit (SCU)

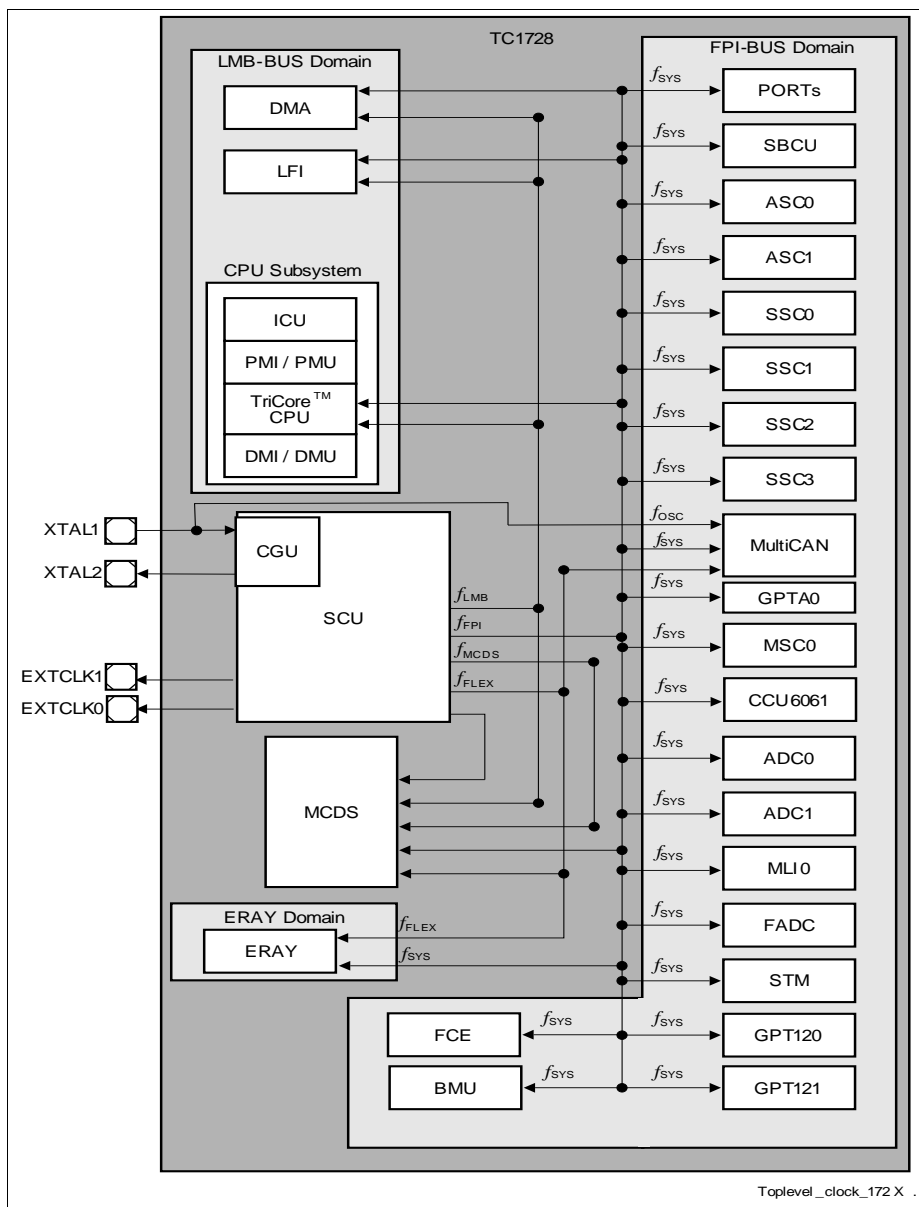


Figure 3-1 TC1728 Clocking System

System Control Unit (SCU)

3.1.1 Clock Generation Unit

The Clock Generation Unit (CGU) allows a very flexible clock generation for the TC1728. During user program execution the frequency can be programmed for an optimal ratio between performance and power consumption.

3.1.1.1 Overview

The CGU in the TC1728 consists of one oscillator circuit (OSC), Phase-Locked Loop module (PLL) and a Clock Control Unit (CCU). The CGU can convert a low-frequency external clock signal to a high-speed internal clock.

The CGU provides clock signals for the different parts of the device that can be configured depending on the application needs within certain limits.

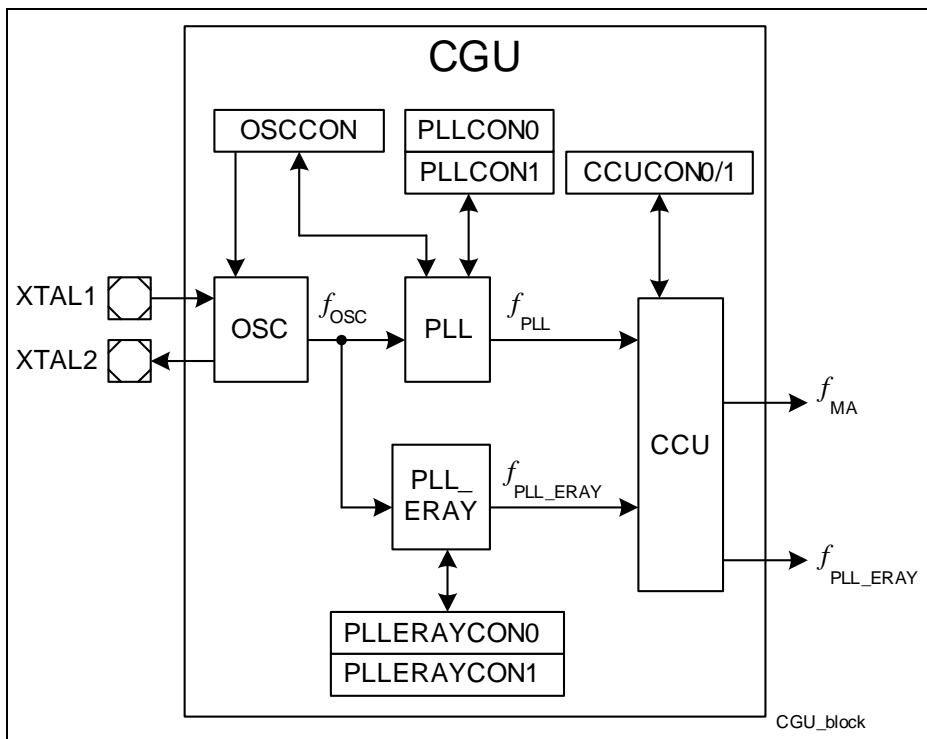


Figure 3-2 Clock Generation Unit Block Diagram

The following sections describe the different parts of the CGU.

System Control Unit (SCU)

3.1.1.2 Oscillator Circuit (OSC)

The oscillator circuit, a Pierce oscillator, is designed to work with both an external crystal / resonator or an external stable clock source, consists of an inverting amplifier with XTAL1 as input, and XTAL2 as output with an integrated feedback resistor.

External Input Clock Mode

When supplying the clock signal directly, not using an external crystal / ceramic resonator and bypassing the oscillator, the input frequency needs to be equal or greater than PLL VCO input frequency (the value is listed in the Data Sheet).

When using an external clock signal it must be connected to XTAL1. XTAL2 is left open (unconnected).

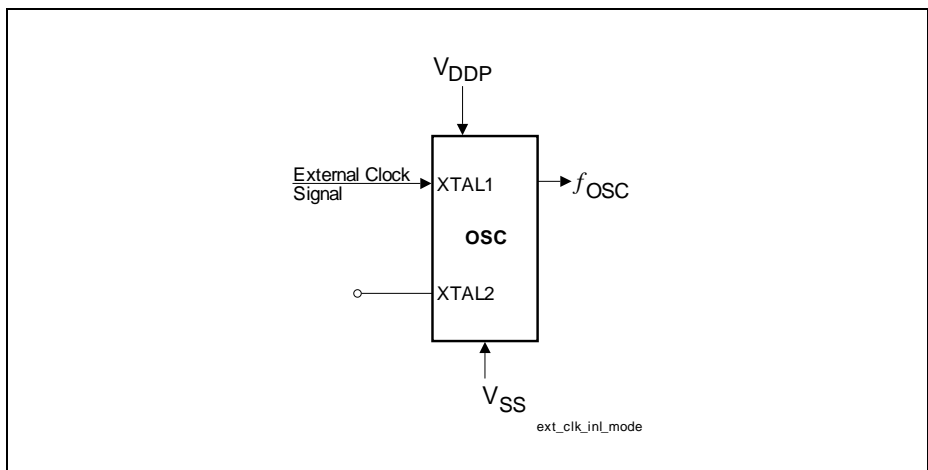


Figure 3-3 TC1728 Direct Clock Input

External Crystal / Ceramic Resonator Mode

Figure 3-4 shows the recommended external circuitries for both operating modes, External Crystal / Ceramic Resonator Mode with and without external components.

System Control Unit (SCU)

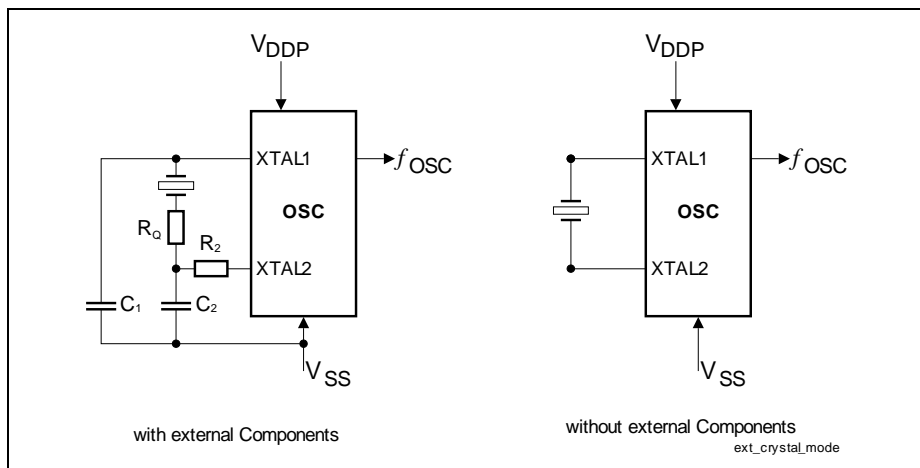


Figure 3-4 External Circuitry for Crystal / Ceramic Resonator operation

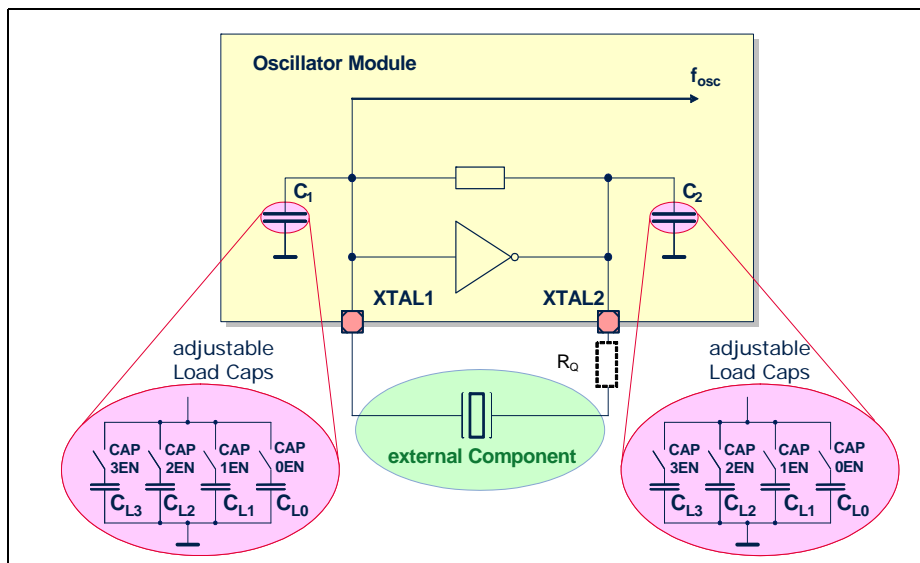


Figure 3-5 Circuitry for Crystal / Ceramic Resonator operation with internal CAPS

When using an external crystal / ceramic resonator, its frequency can be within the allowed range (the values are listed in the Data Sheet). An external oscillator load

System Control Unit (SCU)

circuitry must be used, connected to both pins, XTAL1 and XTAL2. Additionally are necessary, two load capacitances C_1 and C_2 , and depending on the crystal / ceramic resonator type, a series resistor R_2 to limit the current. A test resistor R_Q may be temporarily inserted to measure the oscillation allowance (negative resistance) of the oscillator circuitry. R_Q values are typically specified by the crystal / ceramic resonator vendor. The C_1 and C_2 values shown in the Data Sheet can be used as starting points for the negative resistance evaluation and for non-productive systems. The exact values and related operating range are dependent on the crystal / ceramic resonator frequency and have to be determined and optimized together with the crystal / ceramic resonator vendor using the negative resistance method. Oscillation measurement with the final target system is strongly recommended to verify the input amplitude at XTAL1 and to determine the actual oscillation allowance (margin negative resistance) for the oscillator-crystal / ceramic resonator system.

The oscillator can also be used in combination with a ceramic resonator. The final circuitry must be also verified by the resonator vendor.

3.1.1.3 Phase-Locked Loop (PLL) Module

The PLL can convert a low-frequency external clock signal to a high-speed internal clock for maximum performance. The PLL also has fail-safe logic that detects degenerate external clock behavior such as abnormal frequency deviations or a total loss of the external clock. It can execute emergency actions if it loses its lock on the external clock.

This module is a phase locked loop for integer frequency synthesis. It allows the use of input and output frequencies of a wide range by varying the different divider factors.

Features

- VCO lock detection
- 4-bit input divider **P**: (divide by PDIV+1)
- 7-bit feedback divider **N**: (multiply by NDIV+1)
- 7-bit output divider **K1 or K2**: (divide by either by K1DIV+1 or K2DIV+1)
- Oscillator Watchdog
 - Detecting too low input frequencies
 - Detecting too high input frequencies
 - Spike detection for the OSC input frequency
- Different operating modes
 - Prescaler Mode
 - Freerunning Mode
 - Normal Mode
- VCO Power Down
- Glitchless switching between both K-Dividers
- Glitchless switching between Normal Mode and Prescaler Mode

PLL Functional Description

The PLL consists of a Voltage Controlled Oscillator (VCO) with a feedback path. A divider in the feedback path (N-Divider) divides the VCO frequency down. The resulting frequency is then compared with the externally provided and divided frequency (P-Divider). The phase detection logic determines the difference between the two clocks and accordingly controls the frequency of the VCO (f_{VCO}). A PLL lock detection unit monitors and signals this condition. The phase detection logic continues to monitor the two clocks and adjusts the VCO clock if required. The PLL output clock f_{PLL} is derived from the VCO clock by the K2-Divider or from the oscillator clock and the K1-Divider.

The following figure shows the PLL block structure.

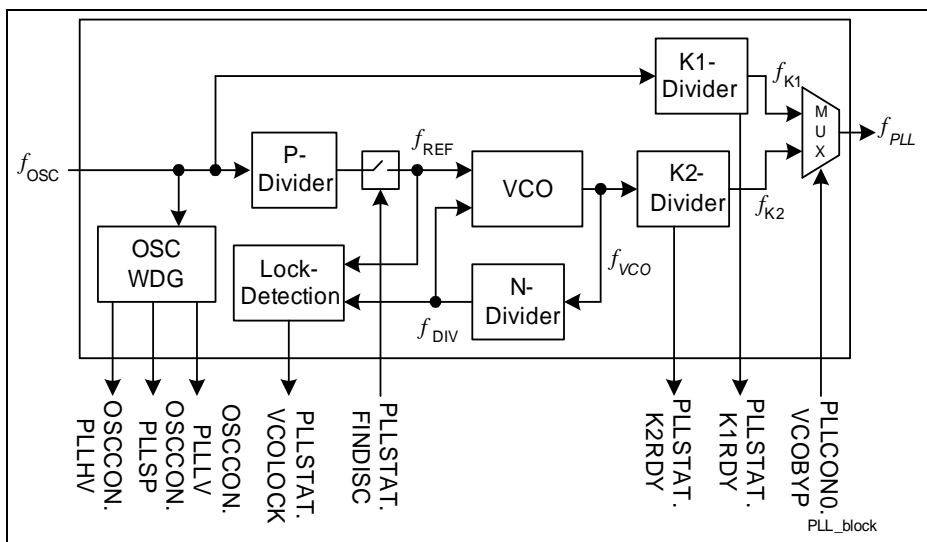


Figure 3-6 PLL Block Diagram

Clock Source Control

The PLL clock f_{PLL} is generated from f_{OSC} in one of three software selectable modes:

- Normal Mode
- Prescaler Mode
- Freerunning Mode

Normal Mode

In Normal Mode the input frequency f_{OSC} is divided down by a factor P, multiplied by a factor N and then divided down by a factor K2.

System Control Unit (SCU)

The output frequency is given by

(3.1)

$$f_{PLL} = \frac{N}{P \cdot K2} \cdot f_{OSC}$$

Prescaler Mode

In Prescaler Mode the reference frequency f_{OSC} is only divided down by a factor K1.

The output frequency is given by

(3.2)

$$f_{PLL} = \frac{f_{OSC}}{K1}$$

Freerunning Mode

In Freerunning Mode the base frequency output of the Voltage Controlled Oscillator (VCO) $f_{VCObase}$ is only divided down by a factor K2.

The output frequency is given by

(3.3)

$$f_{PLL} = \frac{f_{VCObase}}{K2}$$

Oscillator Watchdog (OSC_WDT)

The oscillator watchdog monitors the incoming clock frequency f_{OSC} from OSC. A stable and defined input frequency is a mandatory requirement for operation in both Prescaler Mode and Normal Mode. For operation in Freerunning Mode no f_{OSC} input frequency is required. Therefore this mode is selected automatically after each System Reset. In addition for the Normal Mode it is required that the input frequency f_{OSC} is in a certain frequency range to obtain a stabile master clock from the VCO part.

The expected input frequency is selected via the bit field OSCCON.OSCVAL. The OSC_WDT checks for too low frequencies and for too high frequencies.

The frequency that is monitored is f_{OSCREF} which is derived for f_{OSC} .

(3.4)

$$f_{OSCREF} = \frac{f_{OSC}}{OSCVAL + 1}$$

The divider value OSCCON.OSCVAL has to be selected in a way that f_{OSCREF} is 2.5 MHz.

System Control Unit (SCU)

Note: f_{OSCREF} has to be within the range of 2 MHz to 3 MHz and should be as close as possible to 2.5 MHz.

Before configuring the OSC_WDT function all the trap options should be disabled in order to avoid unintended traps. Thereafter the value of OSCCON.OSCVAL can be changed. Then the OSC_WDT should be reset by setting OSCCON.OSCRES. This requests the start of OSC_WDT monitoring with the new configuration. When the expected positive monitoring results of OSCCON.PLLLV and / or OSCCON.PLLHV are set the input frequency is within the expected range. As setting OSCCON.OSCRES clears all three bits OSCCON.PLLSP, OSCCON.PLLLV, and OSCCON.PLLHV all three trap status flags will be set. Therefore all three flags should be cleared before the trap generation is enabled again. The trap disabling-clearing-enabling sequence should also be used if only bit OSCCON.OSCRES is set without any modification of OSCCON.OSCVAL.

Configuration and Operation of the Freerunning Mode

In Freerunning Mode, the PLL is running at its VCO base frequency and f_{PLL} is derived from f_{VCO} only by the K2-Divider.

The Freerunning Mode is entered after each System Reset.

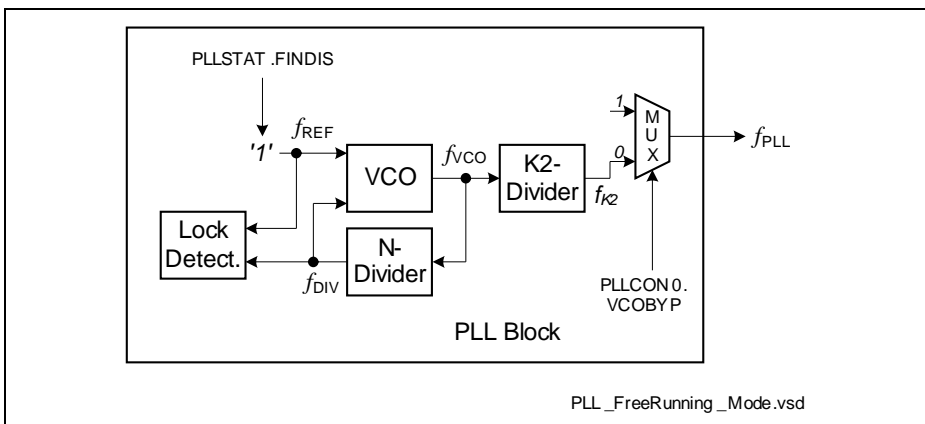


Figure 3-7 PLL Free-Running Mode Diagram

The output frequency is given by

$$f_{\text{PLL}} = \frac{f_{\text{VCObase}}}{K2} \quad (3.5)$$

The Freerunning Mode is selected by the following settings

System Control Unit (SCU)

- PLLCON0.VCOBYP = 0
- PLLCON0.SETFINDIS = 1

The Freerunning Mode is entered when

- PLLSTAT.FINDIS = 1
- AND
- PLLSTAT.VCOBYST = 0

Operation on the Freerunning Mode does not require an input clock frequency of f_{OSC} . The Freerunning Mode is automatically entered on a PLL VCO Loss-of-Lock event if bit PLLCON0.OSCDISCDIS is cleared. This mechanism allows a fail-safe operation of the PLL as in emergency cases still a clock is available.

The frequency of the Freerunning Mode $f_{VCObase}$ is listed in the Data Sheet.

Note: Changing the system operation frequency by changing the value of the K2-Divider has a direct coupling to the power consumption of the device. Therefore this has to be done carefully.

Depending on the selected divider value of the K2-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K2-divider values are defined in the Data Sheet.

Configuration and Operation of the Prescaler Mode

In Prescaler Mode, the PLL is running at the external frequency f_{OSC} and f_{PLL} is derived from f_{OSC} only by the K1-Divider.

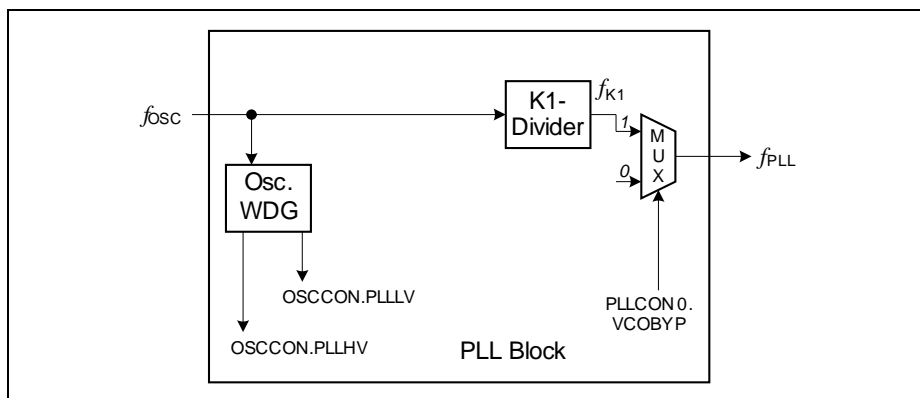


Figure 3-8 PLL Prescaler Mode Diagram

System Control Unit (SCU)

The output frequency is given by:

$$f_{\text{PLL}} = \frac{f_{\text{OSC}}}{K1} \quad (3.6)$$

The Prescaler Mode is selected by the following settings

- PLLCON0.VCOBYP = 1

The Prescaler Mode is entered when the following requirements are all together valid:

- PLLSTAT.VCOBYST = 1
- OSCCON.PLLLV = 1

Operation on the Prescaler Mode does require an input clock frequency of f_{OSC} . Therefore it is recommended to check and monitor if an input frequency f_{OSC} is available at all by checking OSCCON.PLLLV. For a better monitoring also the upper frequency can be monitored via OSCCON.PLLHV.

For the Prescaler Mode there are no requirements regarding the frequency of f_{OSC} .

The system operation frequency is controlled in the Prescaler Mode by the value of the K1-Divider. When the value of PLLCON1.K1DIV was changed the next update of this value should not be done before bit PLLSTAT.K1RDY is set.

Note: Changing the system operation frequency by changing the value of the K1-Divider has a direct coupling to the power consumption of the device. Therefore this has to be done carefully.

Depending on the selected divider value of the K1-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K1-divider values are defined in the Data Sheet.

The Prescaler Mode is requested from the Freerunning or Normal Mode by setting bit PLLCON.VCOBYP. The Prescaler Mode is entered when the status bit PLLSTAT.VCOBYST is set. Before the Prescaler Mode is requested the K1-Divider should be configured with a value generating a PLL output frequency f_{PLL} that matches the one generated by the Freerunning or Normal Mode as much as possible. In this way the frequency change resulting out of the mode change is reduced to a minimum.

The Prescaler Mode is requested to be left by clearing bit PLLCON.VCOBYP. The Prescaler Mode is left when the status bit PLLSTAT.VCOBYST is cleared.

Configuration and Operation of the Normal Mode

In Normal Mode, the PLL is running at the external frequency f_{OSC} and f_{PLL} is divided down by a factor P, multiplied by a factor N and then divided down by a factor K2.

System Control Unit (SCU)

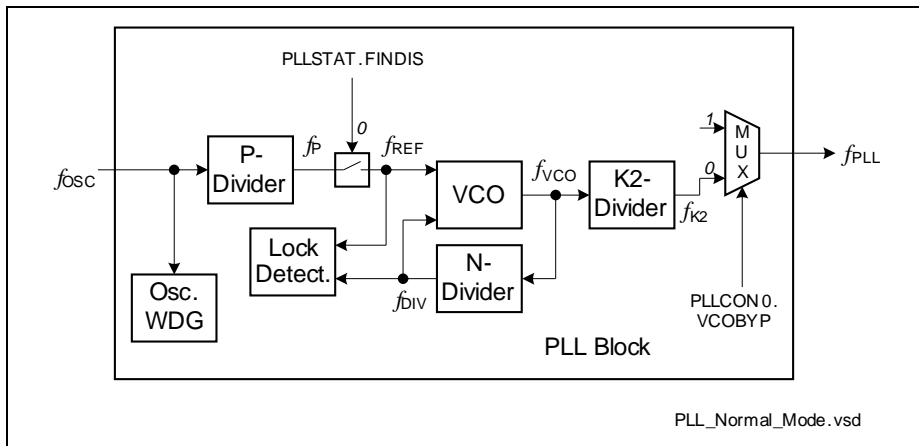


Figure 3-9 PLL Normal Mode Diagram

The output frequency is given by:

(3.7)

$$f_{PLL} = \frac{N}{P \cdot K2} \cdot f_{OSC}$$

The Normal Mode is selected by the following settings

- PLLCON0.VCOBYP = 0
- PLLCON0.CLRFINDIS = 1

The Normal Mode is entered when the following requirements are all together valid:

- PLLSTAT.FINDIS = 0
- PLLSTAT.VCOBYST = 0
- PLLSTAT.VCOLOCK = 1
- OSCCON.PLLLV = 1
- OSCCON.PLLHV = 1

For the Normal Mode operation it is recommended to clear bit PLLCON0.OSCDISCDIS.

Operation on the Normal Mode does require an input clock frequency of f_{OSC} . Therefore it is recommended to check and monitor if an input frequency f_{OSC} is available at all by checking OSCCON.PLLLV. For a better monitoring also the upper frequency can be monitored via OSCCON.PLLHV.

The system operation frequency is controlled in the Normal Mode by the values of the three dividers: P, N, and K2. A modification of the two dividers P and N has a direct influence to the VCO frequency and lead to a loss of the VCO Lock status. A modification

System Control Unit (SCU)

of the K2-divider has no impact on the VCO Lock status but still changes the PLL output frequency.

Note: When configuring the PLL for the first time after a system reset it is recommended to disconnect the input clock fOSC before configuring P, N, and K2 and connect fOSC before checking for the lock status.

Note: Changing the system operation frequency by changing the value of the K2-Divider has a direct coupling to the power consumption of the device. Therefore this has to be done carefully.

When the frequency of the Normal Mode should be modified or entered the following sequence should be followed:

First the Prescaler Mode should be configured and entered. For more details see the Prescaler Mode.

The NMI trap generation for the VCO Lock should be disabled.

While the Prescaler Mode is used the Normal Mode can be configured and checked for a positive VCO Lock status. The first target frequency of the Normal Mode should be selected in a way that it matches or is only slightly higher as the one used in the Prescaler Mode. This avoids big changes in the system operation frequency and therefore power consumption when switching later from Prescaler Mode to Normal Mode. The P and N divider should be selected in the following way:

- Selecting P and N in a way that f_{VCO} is in the lower area of its allowed values leads to a slightly reduced power consumption but to a slightly increased jitter
- Selecting P and N in a way that f_{VCO} is in the upper area of its allowed values leads to a slightly increased power consumption but to a slightly reduced jitter

After the P, N, and K2 dividers are updated for the first configuration the indication of the VCO Lock status should be await (PLLSTAT.VCOLOCK = 1).

Note: It is recommended to reset the VCO Lock detection (PLLCON0.RESLD = 1) after the new values of the dividers are configured to get a defined VCO lock check time.

When this happens the switch from Prescaler Mode to Normal Mode can be done. Normal Mode is requested by clearing PLLCON.VCOBYP. The Normal Mode is entered when the status bit PLLSTAT.VCOBYST is cleared.

Now the Normal Mode is entered. The NMI status flag for the VCO Lock trap should be cleared and then enabled again. The intended PLL output target frequency can now be configured by changing only the K2-Divider.

Depending on the selected divider value of the K2-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K2-divider values are defined in the Data Sheet. This can result in multiple changes of the K2-Divider to avoid to big

System Control Unit (SCU)

frequency changes. Between the update of two K2-Divider values 6 cycles of f_{PLL} should be waited.

PLL VCO Lock Detection

The PLL has a lock detection that supervises the VCO part of the PLL in order to differentiate between stable and instable VCO circuit behavior. The lock detector marks the VCO circuit and therefore the output f_{VCO} of the VCO as instable if the two inputs f_{REF} and f_{DIV} differ too much. Changes in one or both input frequencies below a level are not marked by a loss of lock because the VCO can handle such small changes without any problem for the system.

PLL VCO Loss-of-Lock Event

The PLL may become unlocked, caused by a break of the crystal or the external clock line. In such a case, an NMI trap is generated if the according NMI trap is enabled. Additionally, the OSC clock input f_{OSC} is disconnected from the PLL VCO to avoid unstable operation due to noise or sporadic clock pulses coming from the oscillator circuit. Without a clock input f_{OSC} , the PLL gradually slows down to its VCO base frequency and remains there. This automatic feature can be disabled by setting bit PLLCON0.OSCDISDIS. If this bit is set the OSC clock remains connected to the VCO.

VCO Power Down Mode

The PLL offers a VCO Power Down Mode. This mode can be entered to save power within the PLL. The VCO Power Down Mode is entered by setting bit PLLCON0.VCOPWD. While the PLL is in VCO Power Down Mode only the Prescaler Mode is operable. Please note that selecting the VCO Power Down Mode does not automatically switch to the Prescaler Mode. So before the VCO Power Down Mode is entered the Prescaler Mode must be active.

PLL Power Down Mode

The PLL offers a Power Down Mode. This mode can be entered to save power if the PLL is not needed at all. The Power Down Mode is entered by setting bit PLLCON0.PLLPWD. While the PLL is in Power Down Mode no PLL output frequency is generated.

3.1.1.4 ERAY Phase-Locked Loop (PLL_ERAY) Module

The PLL_ERAY can convert a low-frequency external clock signal to a high-speed internal clock for maximum performance. The PLL_ERAY also has fail-safe logic that detects degenerate external clock behavior such as abnormal frequency deviations or a total loss of the external clock. It can execute emergency actions if it loses its lock on the external clock.

This module is a phase locked loop for integer frequency synthesis. It allows the use of input and output frequencies of a wide range by varying the different divider factors.

Features

- VCO lock detection
- 6-bit feedback divider **N**: (multiply by $N \cdot DIV + 1$)
- 5-bit output divider **K1 or K2**: (divide by either by $K1 \cdot DIV + 1$ or $K2 \cdot DIV + 1$)
- Different operating modes
 - Prescaler Mode
 - Freerunning Mode
 - Normal Mode
- VCO Power Down (Sleep Mode)
- Glitchless switching between both K-Dividers
- Glitchless switching between Normal Mode and Prescaler Mode

PLL_ERAY Functional Description

The PLL_ERAY consists of a Voltage Controlled Oscillator (VCO) with a feedback path. A divider in the feedback path (N-Divider) divides the VCO frequency down. The resulting frequency is then compared with the externally provided frequency. The phase detection logic determines the difference between the two clocks and accordingly controls the frequency of the VCO (f_{VCO}). A PLL_ERAY lock detection unit monitors and signals this condition. The phase detection logic continues to monitor the two clocks and adjusts the VCO clock if required. The PLL_ERAY output clock f_{PLL_ERAY} is derived from the VCO clock by the K2-Divider or from the oscillator clock and the K1-Divider.

The following figure shows the PLL_ERAY block structure.

System Control Unit (SCU)

In Prescaler Mode the reference frequency f_{OSC} is only divided down by a factor $K1$.
The output frequency is given by

$$f_{PLL} = \frac{f_{OSC}}{K1} \quad (3.9)$$

Freerunning Mode

In Freerunning Mode the base frequency output of the Voltage Controlled Oscillator (VCO) $f_{VCObase}$ is only divided down by a factor $K2$.

The output frequency is given by

$$f_{PLL} = \frac{f_{VCObase}}{K2} \quad (3.10)$$

Configuration and Operation of the Freerunning Mode

In Freerunning Mode, the PLL_ERAY is running at its VCO base frequency and f_{PLL_ERAY} is derived from f_{VCO} only by the $K2$ -Divider.

The Freerunning Mode is entered after each System Reset.

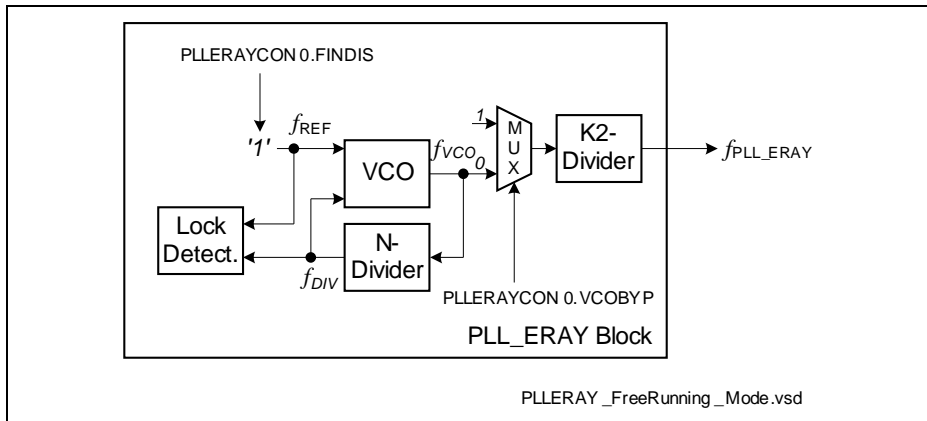


Figure 3-11 PLL_ERAY Free-Running Mode Diagram

System Control Unit (SCU)

The output frequency is given by

$$f_{\text{PLL}} = \frac{f_{\text{VCObase}}}{K2} \quad (3.11)$$

The Freerunning Mode is selected by the following settings

- PLLERAYCON0.VCOBYP = 0
- PLLERAYCON0.SETFINDIS = 1

The Freerunning Mode is entered when

- PLLERAYSTAT.FINDIS = 1
- AND
- PLLERAYSTAT.VCOBYST = 0

Operation on the Freerunning Mode does not require an input clock frequency of f_{OSC} . The Freerunning Mode is automatically entered on a PLL_ERAY VCO Loss-of-Lock event if bit PLLERAYCON0.OSCDISCDIS is cleared. This mechanism allows a fail-safe operation of the PLL_ERAY as in emergency cases still a clock is available.

The frequency of the Freerunning Mode f_{VCObase} is listed in the Data Sheet.

Depending on the selected divider value of the K2-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K2-divider values are defined in the Data Sheet.

Configuration and Operation of the Prescaler Mode

In Prescaler Mode, the PLL_ERAY is running at the external frequency f_{OSC} and $f_{\text{PLL_ERAY}}$ is derived from f_{OSC} only by the K1-Divider.

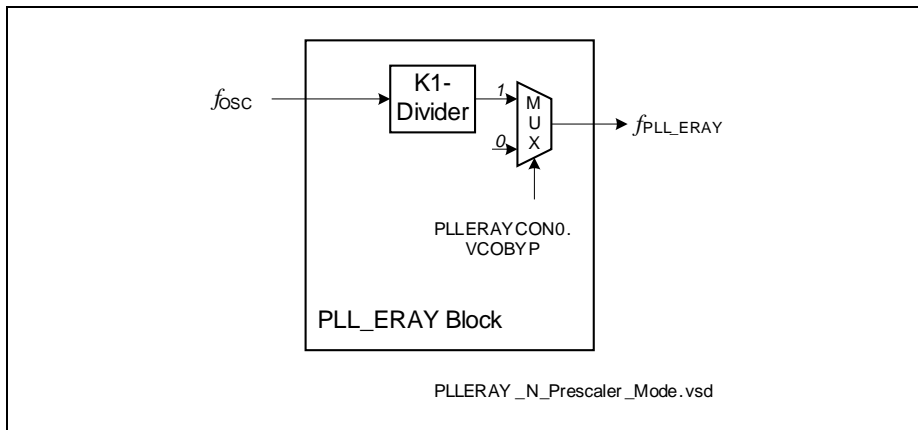


Figure 3-12 PLL_ERAY Prescaler Mode Diagram

The output frequency is given by:

$$f_{PLL} = \frac{f_{OSC}}{K1} \quad (3.12)$$

The Prescaler Mode is selected by the following settings

- PLLERAYCON0.VCOBYP = 1

The Prescaler Mode is entered when the following requirements are all together valid:

- PLLERAYSTAT.VCOBYST = 1
- OSCCON.PLLLV = 1

Operation on the Prescaler Mode does require an input clock frequency of f_{OSC} . Therefore it is recommended to check and monitor if an input frequency f_{OSC} is available at all by checking OSCCON.PLLLV. For a better monitoring also the upper frequency can be monitored via OSCCON.PLLHV.

For the Prescaler Mode there are no requirements regarding the frequency of f_{OSC} .

The system operation frequency is controlled in the Prescaler Mode by the value of the K1-Divider. When the value of PLLERAYCON1.K1DIV was changed the next update of this value should not be done before bit PLLERAYSTAT.K1RDY is set.

Depending on the selected divider value of the K1-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K1-divider values are defined in the Data Sheet.

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The Prescaler Mode is requested from the Freerunning or Normal Mode by setting bit PLLERAYCON.VCOBYP. The Prescaler Mode is entered when the status bit PLLERAYSTAT.VCOBYST is set. Before the Prescaler Mode is requested the K1-Divider should be configured with a value generating a PLL_ERAY output frequency $f_{\text{PLL_ERAY}}$ that matches the one generated by the Freerunning or Normal Mode as much as possible. In this way the frequency change resulting out of the mode change is reduced to a minimum.

The Prescaler Mode is requested to be left by clearing bit PLLERAYCON.VCOBYP. The Prescaler Mode is left when the status bit PLLERAYSTAT.VCOBYST is cleared.

Configuration and Operation of the Normal Mode

In Normal Mode, the PLL_ERAY is running at the external frequency f_{OSC} and $f_{\text{PLL_ERAY}}$ is multiplied by a factor N and then divided down by a factor K2.

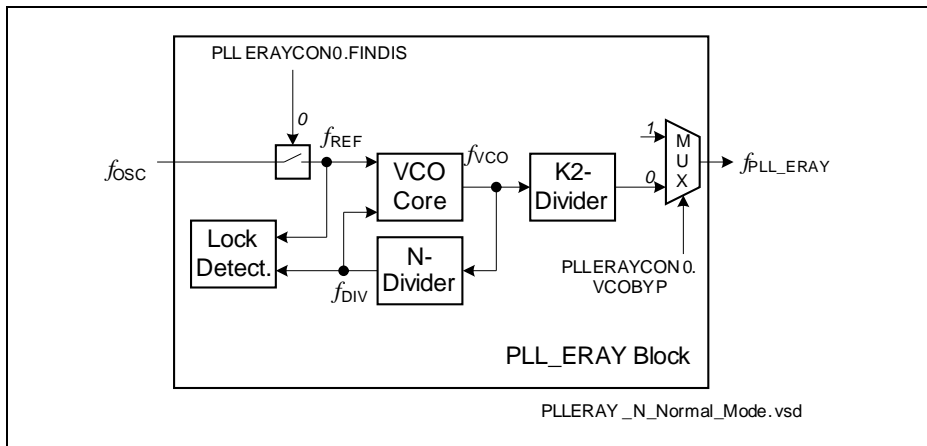


Figure 3-13 PLL_ERAY Normal Mode Diagram

The output frequency is given by:

(3.13)

$$f_{\text{PLL}} = \frac{N}{K2} \cdot f_{\text{OSC}}$$

The Normal Mode is selected by the following settings

- PLLERAYCON0.VCOBYP = 0
- PLLERAYCON0.CLRFINDIS = 1

The Normal Mode is entered when the following two requirements are all together valid:

- PLLERAYSTAT.FINDIS = 0

System Control Unit (SCU)

- PLLERAYSTAT.VCOBYST = 0
- PLLERAYSTAT.VCOLOCK = 1
- OSCCON.PLLLV = 1
- OSCCON.PLLHV = 1

Operation on the Normal Mode does require an input clock frequency of f_{OSC} . Therefore it is recommended to check and monitor if an input frequency f_{OSC} is available at all by checking OSCCON.PLLLV. For a better monitoring also the upper frequency can be monitored via OSCCON.PLLHV.

The system operation frequency is controlled in the Normal Mode by the values of the two dividers: N and K2. A modification of the divider N has a direct influence to the VCO frequency and lead to a loss of the VCO Lock status. A modification of the K2-divider has no impact on the VCO Lock status but still changes the PLL_ERAY output frequency.

When the frequency of the Normal Mode should be modified or entered the following sequence should be followed:

First the Prescaler Mode should be configured and entered. For more details see the Prescaler Mode.

The NMI trap generation for the VCO Lock should be disabled.

While the Prescaler Mode is used the Normal Mode can be configured and checked for a positive VCO Lock status. The first target frequency of the Normal Mode should be selected in a way that it matches or is only slightly higher as the one used in the Prescaler Mode. This avoids big changes in the system operation frequency and therefore power consumption when switching later from Prescaler Mode to Normal Mode. The N divider should be selected in the following way:

- Selecting N in a way that f_{VCO} is in the lower area of its allowed values leads to a slightly reduced power consumption but to a slightly increased jitter
- Selecting N in a way that f_{VCO} is in the upper area of its allowed values leads to a slightly increased power consumption but to a slightly reduced jitter

After the N and K2 dividers are updated for the first configuration the indication of the VCO Lock status should be await (PLLERAYSTAT.VCOLOCK = 1).

Note: It is recommended to reset the VCO Lock detection (PLLERAYCON0.RESLD = 1) after the new values of the dividers are configured to get a defined VCO lock check time.

When this happens the switch from Prescaler Mode to Normal Mode can be done. Normal Mode is requested by clearing PLLERAYCON.VCOBYP. The Normal Mode is entered when the status bit PLLERAYSTAT.VCOBYST is cleared.

Now the Normal Mode is entered. The NMI status flag for the VCO Lock trap should be cleared and then enabled again. The intended PLL_ERAY output target frequency can not be configured by changing only the K2-Divider.

System Control Unit (SCU)

Depending on the selected divider value of the K2-Divider the duty cycle of the clock is selected. This can have an impact for the operation with an external communication interface. The duty cycles values for the different K2-divider values are defined in the Data Sheet. This can result in multiple changes of the K2-Divider to avoid to big frequency changes. Between the update of two K2-Divider values 6 cycles of f_{PLL_ERAY} should be waited.

PLL_ERAY VCO Lock Detection

The PLL_ERAY has a lock detection that supervises the VCO part of the PLL_ERAY in order to differentiate between stable and instable VCO circuit behavior. The lock detector marks the VCO circuit and therefore the output f_{VCO} of the VCO as instable if the two inputs f_{REF} and f_{DIV} differ too much. Changes in one or both input frequencies below a level are not marked by a loss of lock because the VCO can handle such small changes without any problem for the system.

PLL_ERAY VCO Loss-of-Lock Event

The PLL_ERAY may become unlocked, caused by a break of the crystal or the external clock line. In such a case, an NMI trap is generated if the according NMI trap is enabled. Additionally, the OSC clock input f_{OSC} is disconnected from the PLL_ERAY VCO to avoid unstable operation due to noise or sporadic clock pulses coming from the oscillator circuit. Without a clock input f_{OSC} , the PLL_ERAY gradually slows down to its VCO base frequency and remains there. This automatic feature can be disabled by setting bit PLLERAYCON0.OSCDISCDIS. If this bit is cleared the OSC clock remains connected to the VCO.

VCO Power Down Mode

The PLL_ERAY offers a VCO Power Down Mode. This mode can be entered to save power within the PLL_ERAY. The VCO Power Down Mode is entered by setting bit PLLCON0.VCOPWD. While the PLL_ERAY is in VCO Power Down Mode only the Prescaler Mode is operable. Please note that selecting the VCO Power Down Mode does not automatically switch to the Prescaler Mode. So before the VCO Power Down Mode is enter the Prescaler Mode must be active.

PLL_ERAY Power Down Mode

The PLL_ERAY offers a Power Down Mode. This mode can be entered to save power if the PLL_ERAY is not needed at all. The Power Down Mode is entered by setting bit PLLCON0.PLLPWD. While the PLL_ERAY is in Power Down Mode no PLL_ERAY output frequency is generated.

3.1.1.5 Clock Control Unit

The Clock Control Unit (CCU) receives the clock that is created by the PLL f_{PLL} .

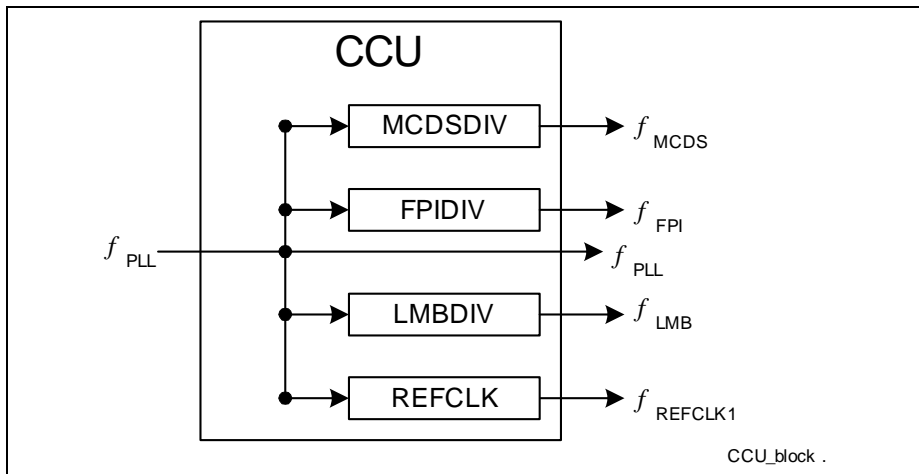


Figure 3-14 Clock Control Unit

The clocking system of the TC1728 consists of the Clock Control Unit (CCU) and the Clock Generation Unit.

There is also a fix reference clock REFCLK1 for the MCDS block which divides the master clock f_{PLL} by 24. This allows the MCDS to generate time stamps independent of the selected LMB-Bus and FPI-Bus clock speeds.

Clock Divider Limitations

There are several limitation and relations between the different clocks that could be configured via the CCUCON0 and CCUCON1 registers:

- $f_{LMB} = f_{FPI}$ or $f_{LMB} = 2 \times f_{FPI}$
- $f_{LMB} = (f_{MCDS})$ or $f_{LMB} = 2 \times (f_{MCDS})$
- $f_{PLL} = 24 \times f_{REFCLK1}$
- $f_{MCDS} \geq f_{FPI}$

3.1.1.6 External Clock Output

Two external clock outputs are provided via pins EXTCLK0 and EXTCLK1. These external clocks can be enabled/disabled via bits EXTCON.EN0 for EXTCLK0 and EXTCON.EN1 for EXTCLK1. Each of the clocks that defines a clock domain can individually be selected to be seen at pins EXTCLK0 or EXTCLK1, this is configured via bit field EXTCON.SEL0/1. Changing the content of bit field EXTCON.SEL0/1 can lead to spikes at pins EXTCLK0/1.

System Control Unit (SCU)

Additionally a connection to the GPTA module is implemented to support the start-up control of an external crystal for the device clock generation. The first time before the master clock is generated based on a external crystal 1000 cycles of the crystal clock f_{OSC} should be waited before the clock control system is changed to External Crystal Mode. The 1000 cycles can be counted with the GPTA using f_{OSC} as count input for the counter.

Programmable Frequency Output for EXTCLK0

This section describes the external clock generation using the Fractional Divider.

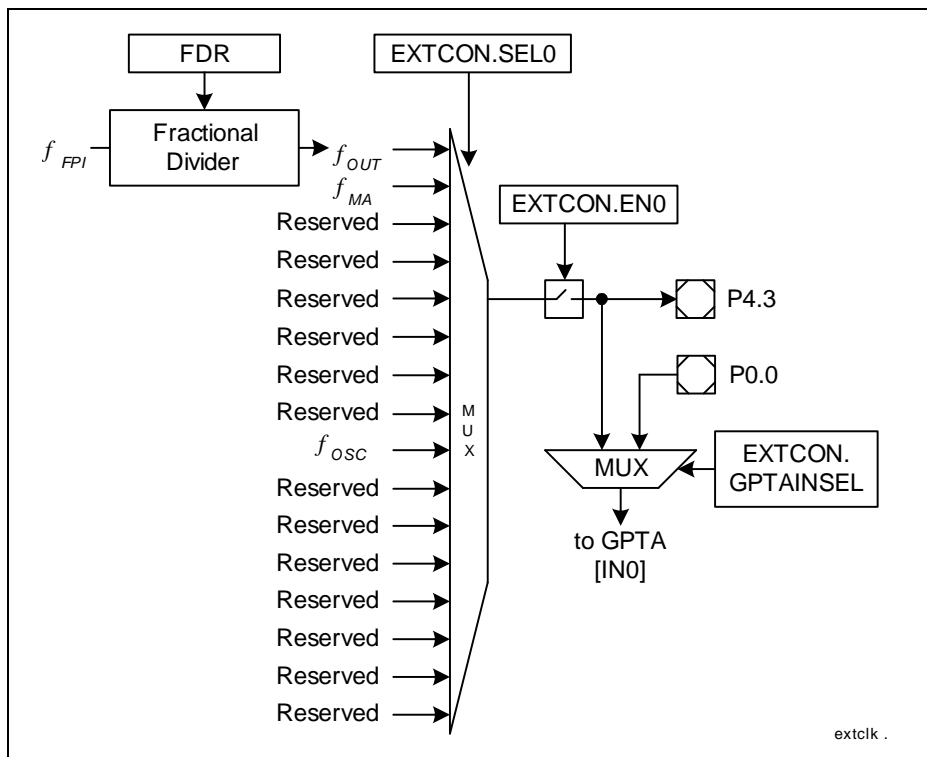


Figure 3-15 EXTCLK0 Generation

Overview

The fractional divider makes it possible to generate a external clock from the FPI-Bus clock using a programmable divider. The fractional divider divides the input clock f_{FPI} either by the factor $1/n$ or by a fraction of $n/1024$ for any value of n from 0 to 1023. This

System Control Unit (SCU)

clock is thereafter divider additionally by a factor of two to guarantee a 50% duty cycle and outputs the clock, f_{OUT} . The fractional divider is controlled by the FDR register.

Figure 3-16 shows the fractional divider block diagram.

The adder logic of the fractional divider can be configured for two operating modes:

- Reload counter (addition of +1), generating an output clock pulse on counter overflow
- Adder that adds a STEP value to the RESULT value and generates an output clock pulse on counter overflow

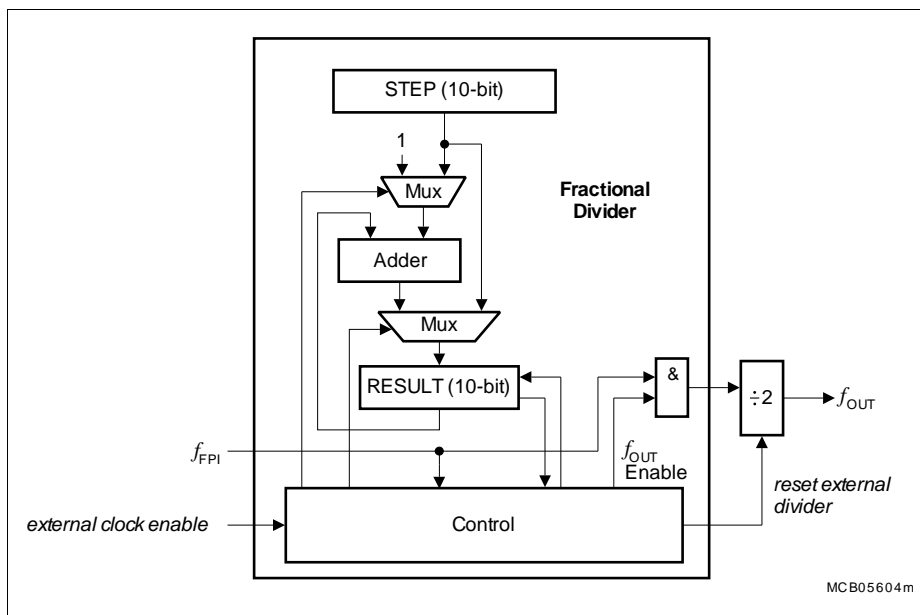


Figure 3-16 Fractional Divider Block Diagram

The adder logic of the fractional divider can be configured for two operating modes:

- **Normal Mode:** Reload counter ($RESULT = RESULT + 1$), generating an output clock pulse on counter overflow.
- **Fractional Divider Mode:** Adder that adds a STEP value to the RESULT value and generates an output clock pulse on counter overflow.

Fractional Divider Operating Modes

The fractional divider has two operating modes:

- Normal Divider Mode
- Fractional Divider Mode

System Control Unit (SCU)

Normal Divider Mode

In Normal Divider Mode ($FDR.DM = 01_B$), the fractional divider behaves as a reload counter (addition of +1) that generates an output clock pulse on the transition from $3FF_H$ to 000_H . $FDR.RESULT$ represents the counter value and $FDR.STEP$ determines the reload value.

The output frequencies in Normal Divider Mode are defined according to the following formulas:

$$f_{OUT} = \frac{f_{FPI} \times \frac{1}{n}}{2}, \text{ with } n = 1024 - STEP \quad (3.14)$$

In order to get $f_{OUT} = f_{FPI}/2$ STEP must be programmed with $3FF_H$.

Fractional Divider Mode

When the Fractional Divider Mode is selected ($FDR.DM = 10_B$), the output is derived from the input clock f_{FPI} by division of a fraction of $n/1024$ for any value of n from 0 to 1023 followed by the division of two. In general, the Fractional Divider Mode makes it possible to program the average output clock frequency with a higher accuracy than in Normal Divider Mode.

In Fractional Divider Mode, a pulse is generated depending on the result of the addition $FDR.RESULT + FDR.STEP$. If the addition leads to an overflow over $3FF_H$, a pulse is generated for the divider by two. Note that in Fractional Divider Mode the clock f_{OUT} can have a maximum period jitter of one f_{FPI} clock period.

The output frequencies in Fractional Divider Mode are defined according to the following formulas:

$$f_{OUT} = \frac{f_{FPI} \times \frac{n}{1024}}{2}, \text{ with } n = 0-1023 \quad (3.15)$$

External Clock Enable

When the external clock generation with the fractional divider has been disabled by software (setting $FDR.DISCLK = 1$), the disable state can be exited (hardware controlled) when the External Clock Enable input = 1.

Programmable Frequency Output for EXTCLK1

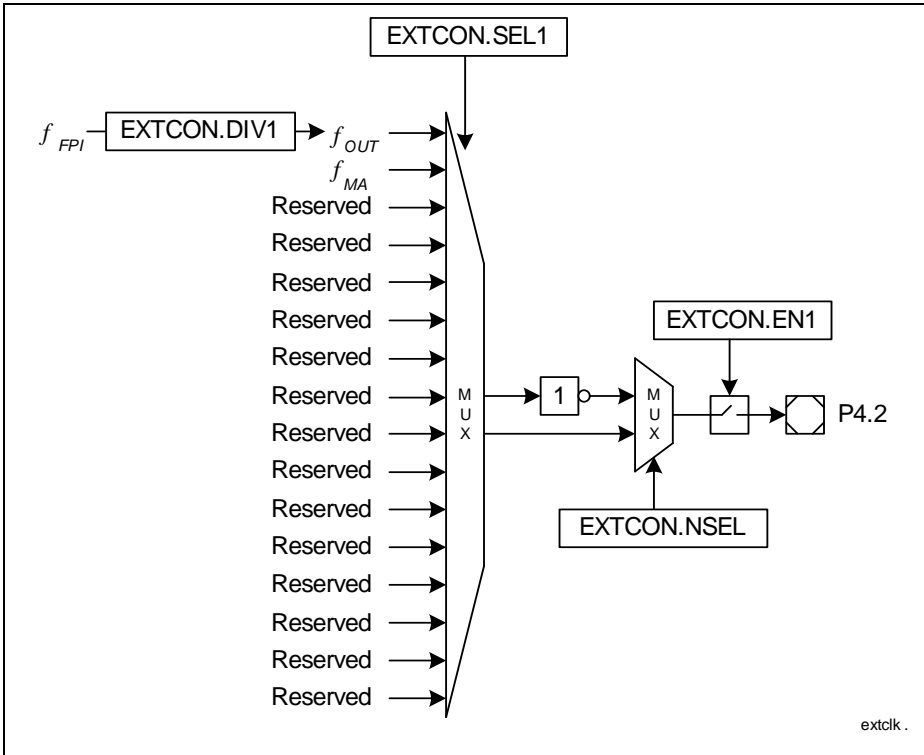


Figure 3-17 EXTCLK1 Generation

Clock f_{OUT} is generated via a counter, so the output frequency can be selected in small steps.

f_{OUT} always provides complete output periods.

Register EXTCON provides control over the output generation (frequency, activation).

System Control Unit (SCU)

3.1.1.7 CGU Registers

System Oscillator Register

This register controls the settings of OSC.

OSCCON

OSC Control Register

(010_H)

Reset Value: 0000 001C_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				0				0				OSCVAL			
r				rw				r				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				X1D EN	X1D	PLL SP	PLL HV	0	MODE		GAINSEL		OSC RES	PLL LV	0
r				rw	rh	rh	rh	rw	rw		rh		w	rh	

Field	Bits	Type	Description
PLLLV	1	rh	Oscillator for PLL Valid Low Status Bit This bit indicates if the frequency output of OSC is usable for the VCO part of the PLL. This is checked by the Oscillator Watchdog of the PLL. 0 _B The OSC frequency is not usable. Frequency f_{REF} is too low. 1 _B The OSC frequency is usable
OSCREG	2	w	Oscillator Watchdog Reset 0 _B The Oscillator Watchdog of the PLL is not cleared and remains active 1 _B The Oscillator Watchdog of the PLL is cleared and restarted
GAINSEL	[4:3]	rw	Oscillator Gain Selection 00 _B Reserved, do not use this combination 01 _B The gain control is configured for frequencies from 8 MHz to 16 MHz 10 _B The gain control is configured for frequencies from 8 MHz to 20 MHz 11 _B The gain control is configured for frequencies from 8 MHz to 25 MHz

System Control Unit (SCU)

Field	Bits	Type	Description
MODE	[6:5]	rw	Oscillator Mode This bit field defines which mode can be used and if the oscillator entered the Power-Saving Mode or not. 00 _B External Crystal Mode and External Input Clock Mode. The oscillator Power-Saving Mode is not entered. 01 _B OSC is disabled. The oscillator Power-Saving Mode is not entered. 10 _B External Input Clock Mode and the oscillator Power-Saving Mode is entered 11 _B OSC is disabled. The oscillator Power-Saving Mode is entered.
PLLHV	8	rh	Oscillator for PLL Valid High Status Bit This bit indicates if the frequency output of OSC is usable for the VCO part of the PLL. This is checked by the Oscillator Watchdog of the PLL. 0 _B The OSC frequency is not usable. Frequency f_{OSC} is too high. 1 _B The OSC frequency is usable
PLLSP	9	rh	Oscillator for PLL Valid Spike Status Bit This bit indicates if the frequency output of OSC is usable for the VCO part of the PLL. This is checked by the Oscillator Watchdog of the PLL. 0 _B The OSC frequency is not usable. Spikes are detected that disturb a locked operation 1 _B The OSC frequency is usable
X1D	10	rh	XTAL1 Data Value This bit monitors the value (level) of pin XTAL1. If XTAL1 is not used as clock input it can be used as GPI pin. This bit is only updated if X1DEN is set.
X1DEN	11	rw	XTAL1 Data Enable 0 _B Bit X1D is not updated 1 _B Bit X1D can be updated

System Control Unit (SCU)

Field	Bits	Type	Description
OSCV	[20:16]	rw	OSC Frequency Value This bit field defines the divider value that generates the reference clock that is supervised by the oscillator watchdog. f_{OSC} is divided by OSCVAL + 1 in order to generate f_{OSCREF} .
0	7, [27:23]	rw	Reserved Should be written with 0.
0	0, [15:12], [22:21], [31:28]	r	Reserved Read as 0; should be written with 0.

PLL Registers

These registers control the setting of the PLL.

PLLSTAT

PLL Status Register (014_H) **Reset Value: 0000 0009_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										K2R DY	K1R DY	FIN DIS	VCO LOC K	PWD STA T	VCO BY ST
r										rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
VCOBYST	0	rh	VCO Bypass Status 0 _B Freerunning / Normal Mode is entered 1 _B Prescaler Mode is entered
PWDSTAT	1	rh	PLL Power-saving Mode Status 0 _B PLL Power-saving Mode was not entered 1 _B PLL Power-saving Mode was entered

System Control Unit (SCU)

Field	Bits	Type	Description
VCOLOCK	2	rh	PLL VCO Lock Status 0_B The frequency difference of f_{REF} and f_{DIV} is greater than allowed. The VCO part of the PLL can not lock on a target frequency. 1_B The frequency difference of f_{REF} and f_{DIV} is small enough to enable a stable VCO operation. <i>Note: In case of a loss of VCO lock the f_{VCO} goes to the upper boundary of the VCO frequency if the reference clock input is greater than expected.</i> <i>Note: In case of a loss of VCO lock the f_{VCO} goes to the lower boundary of the VCO frequency if the reference clock input is lower than expected.</i>
FINDIS	3	rh	Input Clock Disconnect Select Status 0_B The input clock from the oscillator is connected to the VCO part 1_B The input clock from the oscillator is disconnected from the VCO part <i>Note: This bit can be set by setting bit PLLCON0.SETFINDIS.</i> <i>Note: This bit can be cleared by setting bit PLLCON0.CLRFINDIS.</i>
K1RDY	4	rh	K1 Divider Ready Status This bit indicates if the K1-divider operates on the configured value or not. this is of interest if the values is changed. 0_B K1-Divider is not ready to operate with the new value 1_B K1-Divider is ready to operate with the new value

System Control Unit (SCU)

Field	Bits	Type	Description
K2RDY	5	rh	K2 Divider Ready Status This bit indicates if the K2-divider operates on the configured value or not. this is of interest if the values is changed. 0_B K2-Divider is not ready to operate with the new value 1_B K2-Divider is ready to operate with the new value
0	[31:6]	r	Reserved Read as 0; should be written with 0.

PLLCON0

PLL Configuration 0 Register

(018_H)

Reset Value: 0001 C600_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				PDIV				0				RES LD	0	PLL PWD	
rw				rw				r				w	r	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDIV							0	0	OSC DISC DIS	CLR FIN DIS	SET FIN DIS	0	VCO PWD	VCO BYP	
rw							rw	r	rw	w	w	rw	rw	rw	

Field	Bits	Type	Description
VCOBYP	0	rw	VCO Bypass 0_B Normal operation, VCO is not bypassed 1_B Prescaler Mode; VCO is bypassed
VCOPWD	1	rw	VCO Power Saving Mode 0_B Normal behavior 1_B The VCO is put into a Power Saving Mode and can no longer be used. Only Prescaler Mode are active if previously selected.

System Control Unit (SCU)

Field	Bits	Type	Description
SETFINDIS	4	w	Set Status Bit PLLSTAT.FINDIS 0_B Bit PLLSTAT.FINDIS is left unchanged 1_B Bit PLLSTAT.FINDIS is set. The input clock from the oscillator is disconnected from the VCO part.
CLRFINDIS	5	w	Clear Status Bit PLLSTAT.FINDIS 0_B Bit PLLSTAT.FINDIS is left unchanged 1_B Bit PLLSTAT.FINDIS is cleared. The input clock from the oscillator is connected to the VCO part.
OSCDISCDIS	6	rw	Oscillator Disconnect Disable This bit is used to disable the control PLLSTAT.FINDIS in a PLL loss-of-lock case. 0_B In case of a PLL loss-of-lock bit PLLSTAT.FINDIS is set 1_B In case of a PLL loss-of-lock bit PLLSTAT.FINDIS is cleared
NDIV	[15:9]	rw	N-Divider Value The value the N-Divider operates is NDIV+1.
PLLPWD	16	rw	PLL Power Saving Mode 0_B The complete PLL block is put into a Power Saving Mode and can no longer be used. Only the Bypass Mode is active if previously selected. 1_B Normal behavior
RESLD	18	w	Restart VCO Lock Detection Setting this bit will clear bit PLLSTAT.VCOLOCK and restart the VCO lock detection. Reading this bit returns always a zero.
PDIV	[27:24]	rw	P-Divider Value The value the P-Divider operates is PDIV+1.
0	[3:2], 8, [31:28]	rw	Reserved Have to be written with 0.
0	7, 17, [23:19]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

PLLCON1

PLL Configuration 1 Register

(01C_H)

Reset Value: 0002 000F_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0										K1DIV					
r										rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										K2DIV					
r										rw					

Field	Bits	Type	Description
K2DIV	[6:0]	rw	K2-Divider Value The value the K2-Divider operates is K2DIV+1.
K1DIV	[22:16]	rw	K1-Divider Value The value the K1-Divider operates is K1DIV+1.
0	[15:7], [31:23]	r	Reserved Read as 0; should be written with 0.

PLL_ERAY Registers

These registers controls the setting of the PLL_ERAY.

PLLERAYSTAT

PLL_ERAY Status Register

(024_H)

Reset Value: 0000 0038_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										K2R DY	K1R DY	FIN DIS	VCO LOC K	PWD STA T	VCO BY ST
r										rh	rh	rh	rh	rh	rh

System Control Unit (SCU)

Field	Bits	Type	Description
VCOPYST	0	rh	VCO Bypass Status 0_B Freerunning / Normal Mode is entered 1_B Prescaler Mode is entered
PWDSTAT	1	rh	PLL_ERAY Power-saving Mode Status 0_B PLL_ERAY Power-saving Mode was not entered 1_B PLL_ERAY Power-saving Mode was entered
VCOLCK	2	rh	PLL VCO Lock Status 0_B The frequency difference of f_{REF} and f_{DIV} is greater than allowed. The VCO part of the PLL_ERAY can not lock on a target frequency. 1_B The frequency difference of f_{REF} and f_{DIV} is small enough to enable a stable VCO operation. <i>Note: In case of a loss of VCO lock the f_{VCO} goes to the upper boundary of the VCO frequency if the reference clock input is greater than expected.</i> <i>Note: In case of a loss of VCO lock the f_{VCO} goes to the lower boundary of the VCO frequency if the reference clock input is lower than expected.</i>
FINDIS	3	rh	Input Clock Disconnect Select Status 0_B The input clock from the oscillator is connected to the VCO part 1_B The input clock from the oscillator is disconnected from the VCO part <i>Note: This bit can be set by setting bit PLLERAYCON0.SETFINDIS.</i> <i>Note: This bit can be cleared by setting bit PLLERAYCON0.CLRFINDIS.</i>

System Control Unit (SCU)

Field	Bits	Type	Description
K1RDY	4	rh	K1 Divider Ready Status This bit indicates if the K1-divider operates on the configured value or not. this is of interest if the values is changed. 0_B K1-Divider is not ready to operate with the new value 1_B K1-Divider is ready to operate with the new value
K2RDY	5	rh	K2 Divider Ready Status This bit indicates if the K2-divider operates on the configured value or not. this is of interest if the values is changed. 0_B K2-Divider is not ready to operate with the new value 1_B K2-Divider is ready to operate with the new value
0	[31:6]	r	Reserved Read as 0; should be written with 0.

PLLERAYCON0
PLL_ERAY Configuration 0 Register (028_H)

Reset Value: 0001 2E00_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													RES LD	0	1
r													w	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	NDIV				0		OSC DISC DIS	CLR FIN DIS	SET FIN DIS	0		VCO PWD	VCO BYP	
r	rw	rw				r		rw	w	w	r		rw	rw	

Field	Bits	Type	Description
VCOBYP	0	rw	VCO Bypass 0_B Normal operation, VCO is not bypassed 1_B Prescaler Mode; VCO is bypassed

System Control Unit (SCU)

Field	Bits	Type	Description
VCOPWD	1	rw	VCO Power Saving Mode 0_B Normal behavior 1_B The VCO is put into a Power Saving Mode and can no longer be used.
SETFINDIS	4	w	Set Status Bit PLLERAYSTAT.FINDIS 0_B Bit PLLERAYSTAT.FINDIS is left unchanged 1_B Bit PLLERAYSTAT.FINDIS is set. The input clock from the oscillator is disconnected from the VCO part.
CLRFINDIS	5	w	Clear Status Bit PLLERAYSTAT.FINDIS 0_B Bit PLLERAYSTAT.FINDIS is left unchanged 1_B Bit PLLERAYSTAT.FINDIS is cleared. The input clock from the oscillator is connected to the VCO part.
OSCDISCDIS	6	rw	Oscillator Disconnect Disable This bit is used to disable the control PLLERAYSTAT.FINDIS in a PLL_ERAY loss-of-lock case. 0_B In case of a PLL loss-of-lock bit PLLERAYSTAT.FINDIS is set 1_B In case of a PLL loss-of-lock bit PLLERAYSTAT.FINDIS is cleared
NDIV	[13:9]	rw	N-Divider Value The value the N-Divider operates is (NDIV+1).
RESLD	18	w	Restart VCO Lock Detection Setting this bit will clear bit PLLERAYSTAT.VCOLOCK and restart the VCO lock detection. Reading this bit returns always a zero.
0	14	rw	Reserved Should be written with 0.
1	16	rw	Reserved Should be written with 1.
0	[3:2], [8:7], 15, 17, [31:19]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

PLLERAYCON1

PLL_ERAY Configuration 1 Register (02C_H)

Reset Value: 000F 000F_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0									K1DIV						
r									rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0									K2DIV						
r									rw						

Field	Bits	Type	Description
K2DIV	[6:0]	rw	K2-Divider Value The value the K2-Divider operates is K2DIV+1.
K1DIV	[22:16]	rw	K1-Divider Value The value the K1-Divider operates is K1DIV+1.
0	[15:7], [31:23]	r	Reserved Read as 0; should be written with 0.

CCU Control Registers

CCUCON0

CCU Clock Control Register 0 (030_H)

Reset Value: 8000 0001_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LCK	0			0			0			0					
rh	r			rw			r			rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				LMBDIV				0				FPIDIV			
r				rw				r				rw			

System Control Unit (SCU)

Field	Bits	Type	Function
FPIDIV	[3:0]	rw	FPI-Bus Divider Reload Value 0000 _B $f_{FPI} = f_{PLL}$ 0001 _B $f_{FPI} = f_{PLL}/2$ 0010 _B $f_{FPI} = f_{PLL}/3$ 0011 _B $f_{FPI} = f_{PLL}/4$ 0100 _B $f_{FPI} = f_{PLL}/5$ 0101 _B $f_{FPI} = f_{PLL}/6$ 0110 _B $f_{FPI} = f_{PLL}/7$ 0111 _B $f_{FPI} = f_{PLL}/8$ 1000 _B $f_{FPI} = f_{PLL}/9$ 1001 _B $f_{FPI} = f_{PLL}/10$ 1010 _B $f_{FPI} = f_{PLL}/11$ 1011 _B $f_{FPI} = f_{PLL}/12$ 1100 _B $f_{FPI} = f_{PLL}/13$ 1101 _B $f_{FPI} = f_{PLL}/14$ 1110 _B $f_{FPI} = f_{PLL}/15$ 1111 _B $f_{FPI} = f_{PLL}/16$
LMBDIV	[11:8]	rw	LMB-Bus Divider Reload Value 0000 _B $f_{LMB} = f_{PLL}$ 0001 _B $f_{LMB} = f_{PLL}/2$ 0010 _B $f_{LMB} = f_{PLL}/3$ 0011 _B $f_{LMB} = f_{PLL}/4$ 0100 _B $f_{LMB} = f_{PLL}/5$ 0101 _B $f_{LMB} = f_{PLL}/6$ 0110 _B $f_{LMB} = f_{PLL}/7$ 0111 _B $f_{LMB} = f_{PLL}/8$ 1000 _B $f_{LMB} = f_{PLL}/9$ 1001 _B $f_{LMB} = f_{PLL}/10$ 1010 _B $f_{LMB} = f_{PLL}/11$ 1011 _B $f_{LMB} = f_{PLL}/12$ 1100 _B $f_{LMB} = f_{PLL}/13$ 1101 _B $f_{LMB} = f_{PLL}/14$ 1110 _B $f_{LMB} = f_{PLL}/15$ 1111 _B $f_{LMB} = f_{PLL}/16$

System Control Unit (SCU)

Field	Bits	Type	Function
MCDSDIV	[3:0]	rw	MCDS Divider Reload Value 0000 _B $f_{MCDS} = f_{PLL}$ 0001 _B $f_{MCDS} = f_{PLL}/2$ 0010 _B $f_{MCDS} = f_{PLL}/3$ 0011 _B $f_{MCDS} = f_{PLL}/4$ 0100 _B $f_{MCDS} = f_{PLL}/5$ 0101 _B $f_{MCDS} = f_{PLL}/6$ 0110 _B $f_{MCDS} = f_{PLL}/7$ 0111 _B $f_{MCDS} = f_{PLL}/8$ 1000 _B $f_{MCDS} = f_{PLL}/9$ 1001 _B $f_{MCDS} = f_{PLL}/10$ 1010 _B $f_{MCDS} = f_{PLL}/11$ 1011 _B $f_{MCDS} = f_{PLL}/12$ 1100 _B $f_{MCDS} = f_{PLL}/13$ 1101 _B $f_{MCDS} = f_{PLL}/14$ 1110 _B $f_{MCDS} = f_{PLL}/15$ 1111 _B $f_{MCDS} = f_{PLL}/16$
REFCLKDIV	[11:8]	r	Reference Clock for MCDS Divider Reload Value 0000 _B $f_{REFCLK1} = f_{PLL}/2$ 0001 _B $f_{REFCLK1} = f_{PLL}/4$ 0010 _B $f_{REFCLK1} = f_{PLL}/6$ 0011 _B $f_{REFCLK1} = f_{PLL}/8$ 0100 _B $f_{REFCLK1} = f_{PLL}/10$ 0101 _B $f_{REFCLK1} = f_{PLL}/12$ 0110 _B $f_{REFCLK1} = f_{PLL}/14$ 0111 _B $f_{REFCLK1} = f_{PLL}/16$ 1000 _B $f_{REFCLK1} = f_{PLL}/18$ 1001 _B $f_{REFCLK1} = f_{PLL}/20$ 1010 _B $f_{REFCLK1} = f_{PLL}/22$ 1011 _B $f_{REFCLK1} = f_{PLL}/24$ 1100 _B $f_{REFCLK1} = f_{PLL}/26$ 1101 _B $f_{REFCLK1} = f_{PLL}/28$ 1110 _B $f_{REFCLK1} = f_{PLL}/30$ 1111 _B $f_{REFCLK1} = f_{PLL}/32$

System Control Unit (SCU)

Field	Bits	Type	Function
LCK	31	rh	Lock Status This bit indicates if the register can be updated with a new value or if the register is locked and a write action from the bus side has no effect. 0 _B The register is unlocked and can be updated 1 _B The register is locked and can not be updated
0	[7:4], [30:12]	r	Reserved Read as 0; should be written with 0.

CCUCON2

CCU Clock Control Register 2

(044_H)

Reset Value: 0000 0001_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LCK								0							
rh								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	0				0				0				ERAYDIV		
	r				rw				r				rw		

System Control Unit (SCU)

Field	Bits	Type	Function
ERAYDIV	[3:0]	rw	ERAY-Bus Divider Reload Value 0000 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}$ 0001 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/2$ 0010 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/3$ 0011 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/4$ 0100 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/5$ 0101 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/6$ 0110 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/7$ 0111 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/8$ 1000 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/9$ 1001 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/10$ 1010 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/11$ 1011 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/12$ 1100 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/13$ 1101 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/14$ 1110 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/15$ 1111 _B $f_{\text{ERAY}} = f_{\text{PLL_ERAY}}/16$
LCK	31	rh	Lock Status This bit indicates if the register can be updated with a new value or if the register is locked and a write action from the bus side has no effect. 0 _B The register is unlocked and can be updated 1 _B The register is locked and can not be updated
0	[11:8]	rw	Reserved Should be written with 0.
0	[7:4], [30:12]	r	Reserved Read as 0; should be written with 0.

Clock Output Control Register

This register controls the setting of external clock for pin 4.2 and 4.3 (EXTCLK0 and EXTCLK1).

System Control Unit (SCU)

EXTCON

External Clock Control Register

(03C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIV1								0	SEL1				N SEL	EN1	
rw								r	rw				rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								GPT AINS EL	SEL0				0	EN0	
r								rw	rw				r	rw	

Field	Bits	Type	Description
EN0	0	rw	External Clock Enable for EXTCLK0 0 _B No external clock is provided 1 _B The configured external clock is provided
SEL0	[5:2]	rw	External Clock Select for EXTCLK0 This bit field defines the clock source that is selected as output for pin EXTCLK0. 0000 _B f_{OUT} is selected for the external clock 0001 _B f_{PLL} is selected for the external clock 0010 _B Reserved, do not use this combination ... 1111 _B Reserved, do not use this combination
GPTAINSEL	6	rw	GPTA Input Select This value defines if either the input from P0.0 or the configured output frequency for EXTCLK0 is used as input for IN0 of the GPTA module. 0 _B P0.0 is selected as input for IN0 of the GPTA 1 _B EXTCLK0 output is selected as input for IN0 of the GPTA
EN1	16	rw	External Clock Enable for EXTCLK1 0 _B No external clock is provided 1 _B The configured external clock is provided
NSEL	17	rw	Negation Selection 0 _B The external clock is inverted 1 _B The external clock is not inverted

System Control Unit (SCU)

Field	Bits	Type	Description
SEL1	[21:18]	rw	External Clock Select for EXTCLK1 This bit field defines the clock source that is selected as output for pin EXTCLK1. 0000 _B f_{OUT} is selected for the external clock 0001 _B f_{PLL} is selected for the external clock 0010 _B Reserved, do not use this combination ... 1111 _B Reserved, do not use this combination
DIV1	[31:24]	rw	External Clock Divider for EXTCLK1 This value defines the reload value of the divider that generates f_{OUT} out of f_{FPI} ($f_{OUT} = f_{FPI}/(DIV1+1)$). The divider itself is cleared each time bit EN1 is cleared.
0	1, [15:7], [23:22]	r	Reserved Read as 0; should be written with 0.

FDR

Fractional Divider Register

(038_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS CLK	0					RESULT									
rw	r					rh									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM	0					STEP									
rw	r					rw									

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value In Normal Divider Mode, STEP contains the reload value for RESULT. In Fractional Divider Mode, this bit field determines the 10-bit value that is added to RESULT with each input clock cycle.

System Control Unit (SCU)

Field	Bits	Type	Description
DM	[15:14]	rw	Divider Mode This bit fields determines the functionality of the fractional divider block. 00 _B Fractional divider is switched off; no output clock is generated. The Reset External Divider signal is 1. RESULT is not updated (default after System Reset). 01 _B Normal Divider Mode selected. 10 _B Fractional Divider Mode selected. 11 _B Fractional divider is switched off; no output clock is generated. RESULT is not updated.
RESULT	[25:16]	rh	Result Value In Normal Divider Mode, RESULT acts as reload counter (addition +1). In Fractional Divider Mode, this bit field contains the result of the addition RESULT + STEP. If DM is written with 01 _B or 10 _B , RESULT is loaded with 3FF _H .
DISCLK	31	rwh	Disable Clock 0 _B Clock generation of f_{OUT} is enabled according to the setting of bit field DM. 1 _B Fractional divider is stopped. No change except when writing bit field DM. This bit is cleared when external clock enable input is asserted. In case of a conflict between hardware clear and software set of DISCLK, the software set wins. Any write or read-modify-write action leads to the described behavior. As a result, read-modify-write operations should be avoided.
0	[13:10], [30:26]	r	Reserved Read as 0; should be written with 0.

3.1.2 Module Clock Generation

The TC1728 on-chip modules have two registers for clock control:

- Clock Control Register CLC
- Fractional Divider Register FDR

The following sections describes the general functionality of CLC and FDR. The module-specific implementation details are described in the corresponding module chapters.

3.1.2.1 Clock Control Register CLC

All CLC registers have basically the same bit and bit field layout. However, not all CLC register functions are implemented for each peripheral module. [Table 3-1](#) defines in detail which bits and bit fields of the CLC registers are implemented for each clock control register.

The CLC register controls the generation of the peripheral module clock which is derived from the system clock. The following functions for the module are associated with the CLC register:

- Peripheral clock static on/off control
- Module clock behavior in Sleep Mode
- Operation during Suspend Mode
- Fast Shut-off Mode control

Module Enable/Disable Control

If a module is not used at all by an application, it can be completely shut off by setting bit DISR in its CLC register. For peripheral modules with a run mode clock divider field RMC, a second option to completely switch off the module is to set bit field RMC to 00_H. This also disables the module's operation.

The status bit DISS always indicates whether a module is currently switched off (DISS = 1) or switched on (DISS = 0).

Write operations to the non CLC registers of disabled modules are not allowed. However, the CLC of a disabled module can be written. An attempt to write to any of the other writable registers of a disabled module except CLC will cause the corresponding Bus Control Unit (BCU) to generate a bus error.

A read operation of registers of a disabled module is allowed and does not generate a bus error.

When a disabled module is switched on by writing an appropriate value to its MOD_CLC register (DISR = 0 and RMC (if implemented) > 0), status bit DISS changes from 1 to 0. During the phase in which the module becomes active, any write access to corresponding module registers (when DISS is still set) will generate a bus error. Therefore, when enabling a disabled module, application software should check after activation of the module once (read back of the CLC register) to find out whether DISS is already cleared, before a module register (including the CLC register) will be written to.

Sleep Mode Control

The EDIS bit in the CLC register controls whether or not a module is stopped during Sleep Mode. If EDIS is 0, a Sleep Mode request can be recognized by the module and, when received, its clock is shut off.

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If EDIS is set to 1, a Sleep Mode request is disregarded by the module and the module continues its operation.

Suspend Mode Control

During emulation and debugging of TC1728 applications, the execution of an application program can be suspended. When an application is suspended, normal operation of the application's program is halted, and the TC1728 begins (or resumes) executing a special debug monitor program. If bit SPEN is set, the operation of the peripheral module is stopped when the Suspend Mode request is generated. If SPEN is cleared, the module does not react to the Suspend Mode request and continues its normal operation. This feature allows each peripheral module to be adapted to the unique requirements of the application being debugged. Setting SPEN bits is usually performed by a debugger.

This feature is necessary because application requirements typically determine whether on-chip modules should be stopped or left running when an application is suspended for debugging. For example, a peripheral unit that is controlling the motion of an external device through motors in most cases must not be stopped so as to prevent damage of the external device due to the loss of control through the peripheral. On the other hand, it makes sense to stop the system timer while the debugger is actively controlling the chip because it should only count the time when the user's application is running.

Note that it is never appropriate for application software to set the SPEN bit. The Suspend Mode should only be set by a debug software. To guard against application software accidentally setting SPEN, bit SPEN is specially protected by the mask bit SBWE. The SPEN bit can only be written if, during the same write operation, SBWE is set, too. Application software should never set SBWE. In this way, user software can not accidentally alter the value of the SPEN bit that has been set by a debugger.

Entering Disabled Mode

Software can request that a peripheral unit be put into Disabled Mode by setting DISR. A module will also be put into Disabled Mode if the Sleep Mode is requested and the module is configured to allow Sleep Mode.

In Secure Shut-off Mode, a module first finishes any operation in progress, then proceeds with an orderly shut down. When all sub-components of the module are ready to be shut down, the module signals its clock control unit, that turns off the clock to this peripheral unit, that it is now ready for shut down. The status bit DISS is updated by the peripheral unit accordingly.

During emulation and debugging, it may be necessary to monitor the instantaneous state of the machine – including all or most of its modules – at the moment a software breakpoint is reached. In such cases, it may not be desired that the kernel of a module finish whatever transaction is in progress before stopping, because that might cause important states in this module to be lost. Fast Shut-off Mode, controlled by bit FSOE, is available for this situation.

System Control Unit (SCU)

If FSOE = 0, modules are stopped as described above. This is called Secure Shut-off Mode. The module is allowed to finish whatever operation is in progress. If Fast Shut-off Mode is selected (FSOE = 1), clock generation to the unit is stopped as soon as any outstanding bus operation is finished. The clock control unit does not wait until the module has finished its transaction. This option stops the unit's clock as fast as possible, and the state of the unit will be the closest possible to the time of the occurrence of the software breakpoint.

Note: In all TC1728 modules except MultiCAN and DMA, the only shut down operating mode that is available is the Fast Shut-off Mode TC1728, regardless of the state of the FSOE bit.

Whether Secure Shut-off Mode or Fast Shut-off Mode is required depends on the application, the needs of the debugger, and the type of unit. For example, the analog-to-digital converter might allow the converter to finish a running analog conversion before it can be suspended. Otherwise the conversion might be corrupted and a wrong value could be produced when Suspend Mode is exited and the unit is enabled again. This would affect further emulation and debugging of the application's program.

On the other hand, if a problem is observed to relate to the operation of the external analog-to-digital converter itself, it might be necessary to stop the unit as fast as possible in order to monitor its current instantaneous state. To do this, the Fast Shut-off Mode option would be selected. Although proper continuation of the application's program might not be possible after such a step, this would most likely not matter in such a case.

Note that it is never appropriate for application software to set the FSOE bit. Fast Shut-off Mode should only be set by debug software. To guard against application software accidentally setting FSOE, bit FSOE is specially protected by the mask bit SBWE. The SPEN bit can only be written if, during the same write operation, SBWE is set, too. Application software should never set SBWE. In this way, user software can not accidentally alter the value of the FSOE bit. Note that this is the same guard mechanism used for the SPEN bit.

Module Clock Divider Control

Peripheral modules of the TC1728 can have a RMC control bit field in their CLC registers. This Run Mode Clock control bit field makes it possible to slow down the CLC clock via a programmable clock divider circuit.

A value of 00_H in RMC disables the clock signals to these modules (CLC clock is switched off). If RMC is not equal to 00_H, the clock for a module register (f_{CLC}) accesses is generated as

(3.16)

$$f_{CLC} = \frac{f_{FPI}}{RMC}$$

System Control Unit (SCU)

where RMC is the content of its CLC register RMC field with a range of 1 to 255. If RMC is not available in a CLC register, the CLC clock frequency f_{CLC} is always equal to the frequency of f_{FPI} .

Note: The number of module clock cycles (wait states) that are required for a “destructive read” access (means: flags/bits are set/cleared by a read access) to a module register of a peripheral unit depends on the selected CLC clock frequency.

Therefore, a slower CLC clock (selected via bit field RMC in the CLC register) may result in a longer read cycle access time on the FPI-Bus for peripheral units with “destructive read” access (e.g. the ASC).

Module Clock Register Implementations

Table 3-1 shows which of the CLC register bits/bit fields are implemented for each peripheral module in the TC1728 and which modules are equipped with a fractional divider.

Table 3-1 Clock Generation Implementation of the TC1728 Peripheral Modules

Module	DISR Bit 0	DISS Bit 1	SPEN Bit 2	EDIS Bit 3	SBWE Bit 4	FSOE Bit 5	RMC	Fract. Divider 1)
ADC0 ADC1	?	?	?	?	?	?	—	—
FADC	?	?	?	?	?	?	—	?
ASC0 and ASC1	?	?	?	?	?	?	8-bit	—
SSC0	?	?	?	?	?	?	—	?
SSC1	?	?	?	?	?	?	—	?
SSC2	?	?	?	?	?	?	—	?
SSC3	?	?	?	?	?	?	—	?
GPT120	?	?	?	?	?	?	—	—
GPT121	?	?	?	?	?	?	—	—
MultiCAN	?	?	?	?	?	?	—	?
DMA	?	?	?	?	?	?	—	—
GPTA0	?	?	?	?	?	?	—	?
MLI0	not implemented, MLI is connected to DMA_CLC							?
STM	?	?	?	?	?	?	3-bit	—
ERAY	?	?	?	?	?	?	3-bit	—

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Table 3-1 Clock Generation Implementation of the TC1728 Peripheral Modules

Module	DISR Bit 0	DISS Bit 1	SPEN Bit 2	EDIS Bit 3	SBWE Bit 4	FSOE Bit 5	RMC	Fract. Divider 1)
BMU	?	?	?	?	?	?	—	—
FCE	?	?	—	—	—	—	—	—

1) Further info on FDR implementations see [Table 3-3](#).

Fractional Divider Operation

The fractional divider divides the input clock f_{CLC} either by the factor $1/n$ or by a fraction of $n/1024$ for any value of n from 0 to 1023, and outputs the clock signal, f_{MOD} . The fractional divider is controlled by the MOD_FDR register.

The fractional divider can be configured for two operating modes:

- **Normal Divider Mode:** Reload counter ($RESULT = RESULT + 1$), generating an output clock pulse on counter overflow.
- **Fractional Divider Mode:** Add a STEP value to the RESULT value and generates an output clock pulse on counter overflow.

Normal Divider Mode

In Normal Divider Mode ($MOD_FDR.DM = 01_B$), the fractional divider behaves as a reload counter (addition of +1) that generates an output clock pulse at f_{MOD} on the transition from $3FF_H$ to 000_H . $MOD_FDR.RESULT$ represents the counter value and $MOD_FDR.STEP$ determines the reload value.

The output frequencies in Normal Divider Mode are defined according to the following formulas:

$$f_{MOD} = f_{CLC} \times \frac{1}{n}, \text{ with } n = 1024 - STEP \quad (3.17)$$

Note: Each write to register FDR with bit field DM = 01_B or 10_B sets bit field RESULT to $3FF_H$.

In order to get $f_{MOD} = f_{CLC}$ MOD_FDR.STEP must be programmed with $3FF_H$. [Figure 3-18](#) shows the operation of the Normal Divider Mode with a reload value of $MOD_FDR.STEP = 3FD_H$.

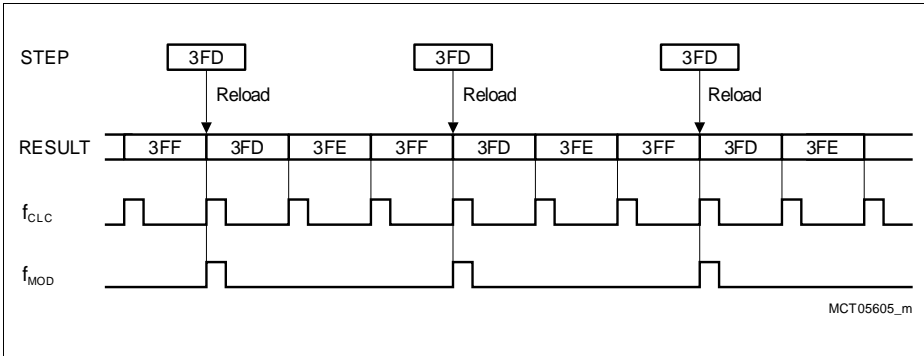


Figure 3-18 Normal Divider Mode

Fractional divider Mode

When the Fractional Divider Mode is selected ($\text{MOD_FDR.DM} = 10_B$), the module clock f_{MOD} is derived from the bus clock f_{CLC} by division of a fraction of $n/1024$ for any value of n from 0 to 1023. In general, the Fractional Divider Mode makes it possible to program the average module clock frequency with a higher accuracy than in Normal Divider Mode.

In Fractional Divider Mode, an clock pulse at f_{MOD} is generated depending on the result of the addition $\text{MOD_FDR.RESULT} + \text{MOD_FDR.STEP}$. If the addition leads to an overflow over $3FF_H$, a pulse is generated at f_{MOD} . Note that in Fractional Divider Mode the clock f_{MOD} can have a maximum period jitter of one f_{CLC} clock period.

The frequencies in Fractional Divider Mode are defined according to the following formula:

$$f_{\text{MOD}} = f_{\text{CLC}} \times \frac{n}{1024} \quad , \text{ with } n = 0-1023 \quad (3.18)$$

Note: Each write to register FDR with bit field DM = 01_B or 10_B sets bit field RESULT to 3FF_H.

Suspend Mode

The operation of the fractional divider can be controlled by the Suspend Mode Request input. This input is activated in Suspend Mode by the on-chip debug control logic. In Suspend Mode, module registers are accessible for read and write actions, but other module internal functions are frozen.

The state of the Suspend Mode Request and Suspend Mode Acknowledge is latched in two status flags of register MOD_FDR, SUSREQ and SUSACK. Suspend Mode Request

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and (Suspend Mode Acknowledge or bit SM) must remain set both to maintain the Suspend Mode.

The Kernel Disable Request becomes always active when the Module Disable Request signal is activated, independently of the Suspend Mode settings in the fractional divider.

External Clock Enable

When the module clock generation has been disabled by software (setting MOD_FDR.DISCLK = 1), the disable state can be exited when the External Clock Enable input = 1. This feature is enabled when MOD_FDR.ENHW = 1.

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Table 3-2 Fractional Divider Function Table

Mode	SC	DM	Result	f_{MOD}	Operation of Fractional Divider
Normal Mode	—	00 _B	unchanged	inactive	switched off
		01 _B	continuously updated	active	Normal Divider Mode
		10 _B			Fractional Divider Mode
		11 _B	unchanged	inactive	switched off
Suspend Mode	00 _B	00 _B	unchanged	inactive	switched off
		01 _B	continuously updated	active	Normal Divider Mode
		10 _B			Fractional Divider Mode
		11 _B	unchanged	inactive	switched off
	01 _B	00 _B	unchanged		switched off
		01 _B	loaded with 3FF _H		halted
		10 _B			
		11 _B	unchanged		switched off
	10 _B	00 _B	loaded with 3FF _H	inactive	switched off
		01 _B			halted
		10 _B			switched off
		11 _B			
	11 _B	—	loaded with 3FF _H	inactive	switched off

Fractional Divider Register Implementations

Table 3-3 shows the implementations specific differences of the fractional divider functionality.

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Table 3-3 FDR Register Implementations

FDR Register	Suspend Mode Acknowledge Operation¹⁾	ENHW²⁾
CAN_FDR	Acknowledge depends on module state	—
GPTA0_FDR	Always immediately acknowledged; independently from module states	from MultiCAN
MLI0_FDR	Acknowledge depends on module state	—
SSC0_FDR	Always immediately acknowledged; independently from module state	from MultiCAN
SSC1_FDR	Always immediately acknowledged; independently from module state	from MultiCAN

1) This column shows whether a suspend acknowledge from a FDR controlled module depends on the module's state or not. If a suspend acknowledge depends from the module state, typically module operations such as serial transmissions are terminated before a suspend request is acknowledged back to the fractional divider. Note that bit FDR.SM must be cleared (granted suspend mode selected) when using the suspend mode acknowledge/grant functionality. If immediate suspend mode is selected (FDR.SM = 1), Suspend Mode is entered at once (if FDR.SC not equal 00_B) independently from the suspend acknowledge answer from the module.

2) This column shows whether the External Clock Enable input of a fractional divider is controlled by on-chip hardware (source module see comment) or not ("—").

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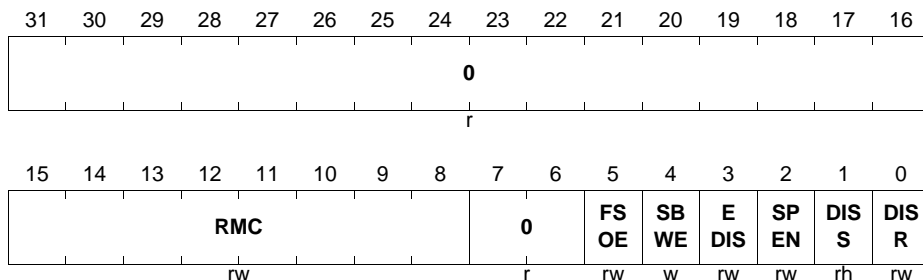
Module CLC Register

MOD_CLC

Clock Control Register

(00_H)

Reset Value: Module-specific



Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module. 0 _B Module disable is not requested 1 _B Module disable is requested
DISS	1	rh	Module Disable Status Bit Bit indicates the current status of the module 0 _B Module is enabled 1 _B Module is disabled If the RMC field is implemented and if it is 0, DISS is set automatically.
SPEN	2	rw	Module Suspend Enable Used for enabling the Suspend Mode. 0 _B Module cannot be suspended (suspend is disabled) 1 _B Module can be suspended (suspend is enabled) This bit can be written only if SBWE is set during the same write operation.
EDIS	3	rw	Sleep Mode Enable Control Used for module Sleep Mode control. 0 _B Sleep Mode request is regarded. Module is enabled to go into Sleep Mode. 1 _B Sleep Mode request is disregarded: Sleep Mode cannot be entered on a request.

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Field	Bits	Type	Description
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected. 0_B Bits SPEN and FSOE are write-protected 1_B Bits SPEN and FSOE are overwritten by respective value of SPEN or FSOE Reading this bit returns always 0.
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch-off in Suspend Mode. 0_B Clock switch-off in Suspend Mode via Disable Control Feature (Secure Clock Switch Off) selected 1_B Fast clock switch off in Suspend Mode selected This bit can be written only if SBWE is set during the same write operation.
RMC	[15:8]	rw	8-Bit Clock Divider Value in RUN Mode This is a maximum 8-bit divider value for clock f_{FPI} . If RMC is set to 0 the module is disabled.
0	7, 6, [31:16]	r	Reserved Read as 0; should be written with 0.

MOD_FDR

Fractional Divider Register

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS CLK	EN HW	SUS REQ	SUS ACK	0	RESULT										
rw	rw	rh	rh	r	rh										
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM	SC	SM	0	STEP											
rw	rw	rw	r	rw											

System Control Unit (SCU)

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value In Normal Divider Mode, STEP contains the reload value for RESULT. In Fractional Divider Mode, this bit field determines the 10-bit value that is added to RESULT with each input clock cycle.
SM	11	rw	Suspend Mode SM selects between granted or immediate Suspend Mode. 0 _B Granted Suspend Mode selected 1 _B Immediate Suspend Mode selected
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in Suspend Mode (bit SUSREQ and SUSACK set). 00 _B Clock generation continues. 01 _B Clock generation is stopped and the clock output signal is not generated. RESULT is not changed except when writing bit field DM with 01 _B or 10 _B . 10 _B Clock generation is stopped and the clock output signal is not generated. RESULT is loaded with 3FF _H . 11 _B Same as SC = 10 _B but signal Reset External Divider is 1 (independently of bit field DM).
DM	[15:14]	rw	Divider Mode This bit fields determines the functionality of the fractional divider block. 00 _B Fractional divider is switched off; no output clock is generated. The Reset External Divider signal is 1. RESULT is not updated. 01 _B Normal Divider Mode selected. 10 _B Fractional Divider Mode selected. 11 _B Fractional divider is switched off; no output clock is generated. RESULT is not updated.

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Field	Bits	Type	Description
RESULT	[25:16]	rh	Result Value In Normal Divider Mode, RESULT acts as reload counter (addition +1). In Fractional Divider Mode, this bit field contains the result of the addition RESULT + STEP. If DM is written with 01 _B or 10 _B , RESULT is loaded with 3FF _H .
SUSACK	28	rh	Suspend Mode Acknowledge 0 _B Suspend Mode is not acknowledged. 1 _B Suspend Mode is acknowledged. Suspend Mode is entered when SUSACK and SUSREQ are set.
SUSREQ	29	rh	Suspend Mode Request 0 _B Suspend Mode is not requested. 1 _B Suspend Mode is requested. Suspend Mode is entered when SUSREQ and SUSACK are set.
ENHW	30	rw	Enable Hardware Clock Control 0 _B Bit DISCLK cannot be cleared by a high level of the External Clock Enable input 1 _B Bit DISCLK is cleared while the External Clock Enable input is at high level.
DISCLK	31	rwh	Disable Clock 0 _B Clock generation of f_{MOD} is enabled according to the setting of bit field DM. 1 _B Fractional divider is stopped. Signal f_{MOD} becomes inactive. No change except when writing bit field DM.
0	10, [27:26]	r	Reserved Read as 0; should be written with 0.

3.2 Reset Operation

This section describes the conditions under which the TC1728 will be reset and the reset operation configuration and control.

3.2.1 Overview

The following reset request triggers are available:

- 1 External power-on hardware reset request trigger; $\overline{\text{PORST}}$, (cold reset)
- 2 External System Request reset triggers; $\overline{\text{ESR0}}$, and $\overline{\text{ESR1}}$, (warm reset)
- Watchdog Timer (WDT) reset request trigger, (warm reset)
- Software reset (SW), (warm reset)
- Debug (OCDS) reset request trigger, (warm reset)
- Resets via the JTAG interface
- Flash Tuning Protection (TP) (warm reset)
- JTAG reset (special reset)
- EVR13 reset triggering a power-on reset (cold reset)
- EVR33 reset triggering a power-on reset (cold reset)
- EVR5 reset triggering a power-on reset (cold reset)

Note: The JTAG and OCDS resets are described in the OCDS chapter.

There are two basic types of reset request triggers:

- Trigger sources that do not depend on a clock, such as the $\overline{\text{PORST}}$ or the EVR13 / 33 / 5. This trigger force the device into an asynchronous reset assertion independently of any clock. The activation of an asynchronous reset is asynchronous to the system clock, whereas its de-assertion is synchronized.
- Trigger sources that need a clock in order to be asserted, such as the input signals $\overline{\text{ESR0}}$, $\overline{\text{ESR1}}$, the WDT trigger, TP trigger, or the SW trigger.

Note: A $\overline{\text{PORST}}$ reset should only triggered for power related issue and not for pure functional purpose.

3.2.2 Reset Types

The following summary shows the different reset types.

- Power-on Reset:
This reset leads to a initialization into a defined state of the complete system. This reset should only be requested on a real power-on event and can not by any non power related event.
A Power-on Reset also generates a System Reset and an Application Reset.
- System Reset:
This reset leads to a initialization into a defined state of the complete system without the following parts: reset control, power control.
A System Reset also generates an Application Reset.

System Control Unit (SCU)

- **Debug Reset:**
This reset leads to a initialization into a defined state of the complete debug system.
- **Application Reset:**
This reset leads to a initialization into a defined state of the complete application system with the following parts: all peripherals, the CPU and partially the SCU and the flash memory.

3.2.3 Reset Sources Overview

The connection of the reset sources and the activated reset signals/domains are shown in [Table 3-4](#).

Table 3-4 Effects of Resets for Reset Signal Activation

Reset Request Trigger	Application Reset	Debug Reset	System Reset
PORST	Activated	Activated	Activated
EVR13	Activated	Activated	Activated
EVR33	Activated	Activated	Activated
EVR5	Activated	Activated	Activated
ESR0	Configurable	Not Activated	Configurable
ESR1	Configurable	Not Activated	Configurable
WDT	Configurable	Not Activated	Configurable
SW	Configurable	Not Activated	Configurable
OCDS Reset	Not Activated	Activated	Not Activated
CBS_OJCONF.RSTCL0	Activated	Not Activated	Activated
CBS_OJCONF.RSTCL1	Not Activated	Activated	Not Activated
CBS_OJCONF.RSTCL3	Activated	Not Activated	Not Activated

3.2.4 Module Reset Behavior

[Table 3-5](#) lists how the various functions of the TC1728 are affected through a reset depending on the reset type. A “X” means that this block has at least some register/bits that are affected by this reset.

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Table 3-5 Effect of Reset on Device Functions

Module / Function		Application Reset	Debug Reset	System Reset	Power-on Reset
CPU Core		X	X	X	X
Peripherals (except SCU)		X	X	X	X
SCU		X	Not affected	X	X
On-chip Static RAMs¹⁾	OVRAM	Not affected, reliable	Not affected, reliable	Affected, un-reliable	Affected, un-reliable
	LDRAM	Not affected, reliable	Not affected, reliable	Affected, un-reliable	Affected, un-reliable
	DCACHE	Not affected, reliable	Not affected, reliable	Affected, un-reliable	Affected, un-reliable
	SPRAM	Not affected, reliable	Not affected, reliable	Affected, un-reliable	Affected, un-reliable
	ICACHE	Not affected, reliable	Not affected, reliable	Affected, un-reliable	Affected, un-reliable
Flash Memory		X ₂₎	Not affected, reliable	X	X
JTAG Interface		Not affected	Not affected	Not affected	Affected
OCDS		Not affected	X	Not affected	X
MCDS		Not affected	X	Not affected	X
Oscillators, PLL		Not affected	Not affected	X	X
Port Pins		X	Not affected	X	X
Pins ESRx		Not affected	Not affected	X	X

1) Reliable here means that also the redundancy is not affected by the reset.

2) Parts of the flash memory block are only reset by a class 0 reset. For more detail see the flash chapter.

3.2.5 General Reset Operation

A reset is generated if an enabled reset request trigger is asserted. Most reset request trigger can be configured for the reset type that should initiated by it. No action (disabled) is one possible configuration and can be selected for a reset request trigger by setting the adequate bit field in a Reset Configuration Register to 00_B. The Debug Reset can only be requested by dedicated reset request triggers and can not be selected via a Reset Configuration Register. For more information see also register RSTCON.

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The duration of a reset is defined by two independent counters. One counter for the Power-on, System, and Application Reset types and one separate counter for the Debug Reset. A separate counter for the Debug Reset was implemented to allow a non-intrusive adaptation of the reset length to the debugger needs without modification of the application setting.

3.2.6 Reset State Machine

There is one central Reset State Machine (RSM) controlling the reset generation for the complete device beside the JTAG reset domain.

Note: The JTAG reset domain is controlled by the \overline{TRST} pin.

The RSM is composed of a control block responsible for the operation flow, two counters with a reload register, and a distribution logic that controls the generation of the three dedicated resets.

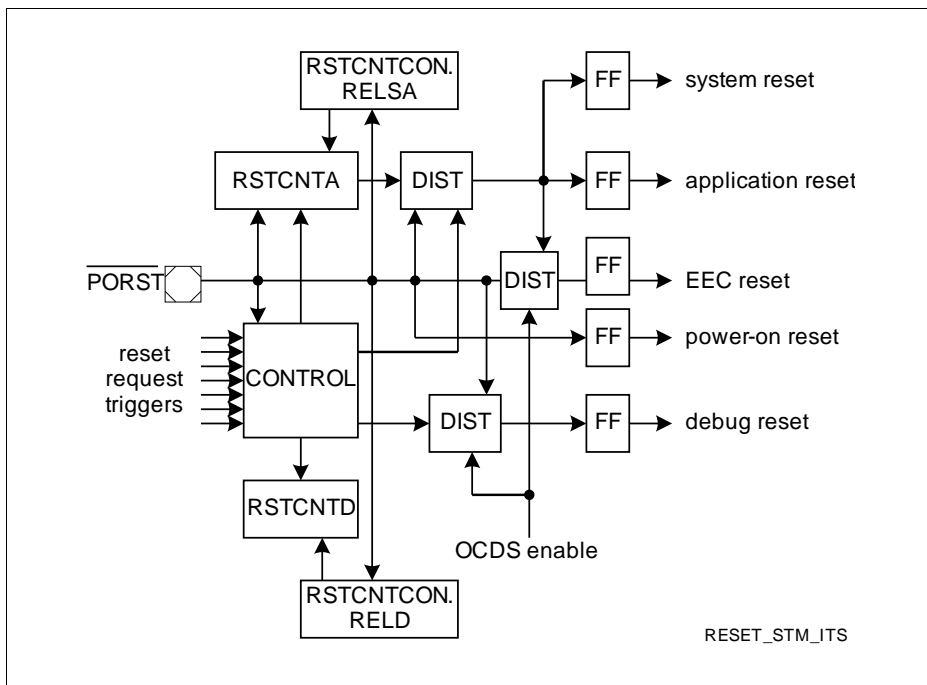


Figure 3-19 Reset State Machine Block Diagram

System Control Unit (SCU)

3.2.7 Reset Counters (RSTCNTA and RSTCNTD)

There are two reset counters implemented. RSTCNTA is the reset counter that controls the reset length for all non debug relevant resets (System Reset and Application Reset). RSTCNTD is the reset counter that controls the reset length for the Debug Reset.

The reset counters can be used for the following purposes:

- First to control the length of the internal resets.
- Second to configure the reset length in a way that the reset outputs via the ESRx pins match with the reset input requirements of external blocks connected with the reset outputs.

A reset counter RSTCNT is an 16-bit counter counting down from the reload value defined by RSTCNTCON.RELx (x = SA or D). The counter is started by the control block as soon as a reset request trigger condition becomes active (for more information see [Table 3-6](#) and [Table 3-7](#)). Whether the counter has to be started or not depends on the reset request trigger and whether the counter is already active or not. In case that the counter is inactive, not counting down, it is always started. While the counter is already active it depends on the reset of the new reset request trigger that was asserted anew if the counter is restarted or not. This behavior is summarized in [Table 3-6](#) and [Table 3-7](#).

Table 3-6 Restart of RSTCNTA

Reset Active	New Reset Request			
	Power-on	System	Debug	Application
Power-on Reset	Restart	No Restart	No Restart	No Restart
System	Restart	No Restart	No Restart	No Restart
Application	Restart	Restart	No Restart	No Restart

Table 3-7 Restart of RSTCNTD

Reset Active	New Reset / Reset Type Request			
	Power-on	System	Debug	Application
Debug	Restart	No Restart	No Restart	No Restart

RSTCNTx ensures that a reset request trigger generates a reset of a minimum length which is configurable. But if a reset request trigger is asserted continuously longer than the counter needs for the complete count-down process the reset cannot be deasserted before the reset request trigger is also deasserted. Anyway the counter is not started again, instead the control block informs the distribution logic (DIST) that the reset still has to be asserted until the reset request trigger is deasserted.

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The reset state of the control block is implemented such that the RSTCNTA is started and two reset types (System and Application) have to be asserted by the distribution logic.

The reset state of the control block is implemented such that the RSTCNTD is started and the Debug Reset has to be asserted by the distribution logic.

Note: The reset counter should not be configured with a value lower than $20H$ due to the implementation.

3.2.8 De-assertion of a Reset

The reset is de-asserted when all of the following conditions are fulfilled.

- The reset counter has expired (reached zero)
- No reset request trigger that is configured to generate the same reset is currently asserted

3.2.8.1 Example1:

Reset request trigger A is asserted and leads to an Application Reset. If the reset request trigger is de-asserted before RSTCNTA reached zero the Application Reset is de-asserted when RSTCNTA reaches zero. If the reset request trigger is de-asserted after RSTCNTA reached zero the Application Reset is de-asserted when the reset request trigger is de-asserted.

3.2.8.2 Example2:

Reset request trigger A is asserted and leads to an Application Reset. Reset request trigger A is de-asserted before RSTCNTA reached zero. Reset request trigger B is asserted after reset request trigger A but before RSTCNTA reaches zero. Reset request trigger B is also configured to result in an Application Reset. If the reset request trigger B is de-asserted before RSTCNTA reached zero the Application Reset is de-asserted when RSTCNTA reaches zero. If the reset request trigger B is de-asserted after RSTCNTA reached zero the Application Reset is de-asserted when the reset request trigger B is de-asserted.

3.2.8.3 Example3:

Reset request trigger A is asserted and leads to a System Reset. Reset request trigger A is de-asserted before RSTCNTA reached zero. Reset request trigger B is asserted after reset request trigger A but before RSTCNTA reaches zero. Reset request trigger B is configured to result in an Application Reset. If the reset request trigger B is de-asserted before RSTCNTA reached zero the System and Application Resets are de-asserted when RSTCNTA reaches zero. If the reset request trigger B is de-asserted after

System Control Unit (SCU)

RSTCNTA reached zero the Application Reset is de-asserted when the reset request trigger B is de-asserted.

3.2.9 Reset Triggers

There are two types of reset triggers for the reset control logic:

- Triggers that lead to a specific reset
- Triggers that lead to a configurable reset

3.2.9.1 Specific Reset Triggers

These triggers lead to a predefined reset if the trigger is asserted. Additionally these triggers can not be enabled / disabled. All specific reset are listed in [Table 3-8](#).

Table 3-8 Specific Reset Triggers

Reset Trigger	Reset Type Request
Debug (OCDS from Cerberus)	Debug Reset
Cerberus 0 (CB0)	System Reset
Cerberus 1 (CB1)	Debug Reset
Cerberus 3 (CB3)	Application Reset
EVR13	Power-on Reset
EVR33	Power-on Reset
EVR5	Power-on Reset

3.2.9.2 Configurable Reset Triggers

These triggers lead to a selectable reset if the trigger is asserted. Additionally these triggers can be enabled / disabled. The behavior of the reset triggers action is defined by the configuration of the dedicated bit field for this trigger in register RSTCON.

3.2.10 Debug Specific Behavior

For safety reasons it is required by the debugger that if the OCDS system is disabled a Debug Reset is also asserted every time an Application Reset is asserted.

3.2.11 EEC Reset Specific Behavior

The complete EEC part is reset with the Power-on Reset. For safety reasons it is required by the debugger that if the OCDS system is disabled a EEC reset is also asserted every time an Application Reset is asserted.

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3.2.12 Reset Controller Registers

3.2.12.1 Status Registers

After a reset has been executed, the Reset Status registers provide information on the source of the last reset(s). The reset status registers are updated upon each reset cycle. A reset cycle is finished when all resets are de-asserted. Within a reset cycle the status flags are used as sticky flags.

RSTSTAT

Reset Status Register

(050 _H)																Reset Value: 0001 0000 _H			
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16				
0						EVR 5	EVR 33	EVR 13	0	TP	CB3	CB1	CB0	OCD S	POR ST				
r						rh	rh	rh	r	rh	rh	rh	rh	rh	rh				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0											SW	WDT	0	ESR 1	ESR 0				
r											rh	rh	r	rh	rh				

Field	Bits	Type	Description
ESR0	0	rh	Reset Request Trigger Reset Status for ESR0 0 _B The last reset was not requested by this reset trigger 1 _B The last reset was requested by this reset trigger <i>Note: This bit is set if the ESR0 pin is configured as open drain for output characteristics (IOCR.PC0 = 1101_H or 1110_H) and ESR0 is configured to generate a Reset (RSTCON.ESR0 = 01_B or 10_B) AND a reset is signaled by the ESR0 pin to the outside. That this bit is set under this condition can be avoided by either setting IOCR.PC0 = 1001_H or 1010_H or RSTCON.ESR0 = 00_B.</i>

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Field	Bits	Type	Description
ESR1	1	rh	Reset Request Trigger Reset Status for ESR1 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger <i>Note: This bit is set if the ESR1 pin is configured as open drain for output characteristics (IOCR.PC1 = 1101_H or 1110_H) and ESR1 is configured to generate a Reset (RSTCON.ESR1 = 01_B or 10_B) AND a reset is signaled by the ESR1 pin to the outside. That this bit is set under this condition can be avoided by either setting IOCR.PC1 = 1001_H or 1010_H or RSTCON.ESR1 = 00_B.</i>
WDT	3	rh	Reset Request Trigger Reset Status for WDT 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
SW	4	rh	Reset Request Trigger Reset Status for SW 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
PORST	16	rh	Reset Request Trigger Reset Status for PORST 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger This bit is also set if the bits CB0, CB1, and CB3 are set in parallel.
OCDS	17	rh	Reset Request Trigger Reset Status for OCDS 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger

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Field	Bits	Type	Description
CB0	18	rh	Reset Request Trigger Reset Status for Cerberus System Reset 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
CB1	19	rh	Reset Request Trigger Reset Status for Cerberus Debug Reset 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
CB3	20	rh	Reset Request Trigger Reset Status for Cerberus Application Reset 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
TP	21	rh	Reset Request Trigger Reset Status for TP 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
EVR13	23	rh	Reset Request Trigger Reset Status for EVR13 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
EVR33	24	rh	Reset Request Trigger Reset Status for EVR33 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger
EVR5	25	rh	Reset Request Trigger Reset Status for EVR5 0_B The last reset was not requested by this reset trigger 1_B The last reset was requested by this reset trigger

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Field	Bits	Type	Description
0	2, [15:5], 22, [31:26]	r	Reserved Read as 0; should be written with 0.

3.2.12.2 Configuration Registers

Reset Counter Control Register

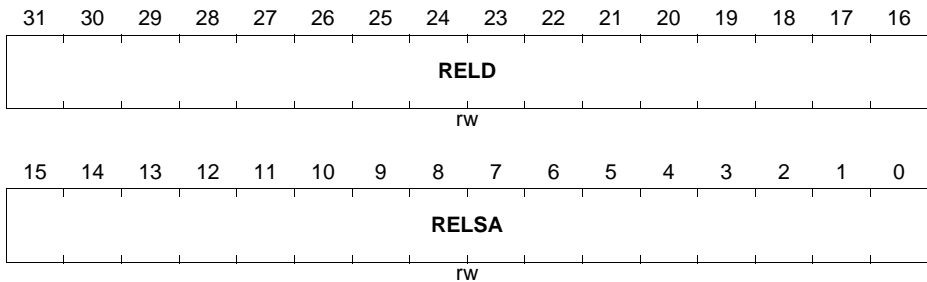
This register controls the reset length settings for the three resets.

RSTCNTCON

Reset Counter Control Register

(054_H)

Reset Value: 05BE 05BE_H



Field	Bits	Type	Description
RELSA	[15:0]	rw	System Application Reset Counter Reload Value This bit field defines the reload value of RSTCNTA. This value is always used when counter RSTCNTA is started.
RELD	[31:16]	rw	Debug 1 Reset Counter Reload Value This bit field defines the reload value of RSTCNTD. This value is always used when counter RSTCNTD is started.

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RSTCON

Reset Configuration Register

(058_H)

Reset Value: 0000 02A2_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						SW	WDT	1	0	ESR1	ESR0				
rw						rw	rw	rw	rw	rw	rw	rw			

Field	Bits	Type	Description
ESR0	[1:0]	rw	ESR0 Reset Request Trigger Reset Configuration This bit field defines which reset is generated by a reset request trigger from ESR0 reset. 00 _B No reset is generated for a trigger of ESR0 01 _B A System Reset is generated for a trigger of ESR0 reset 10 _B An Application Reset is generated for a trigger of ESR0 reset 11 _B Reserved, do not use this combination
ESR1	[3:2]	rw	ESR1 Reset Request Trigger Reset Configuration This bit field defines which reset is generated by a reset request trigger from ESR1 reset. 00 _B No reset is generated for a trigger of ESR1 01 _B A System Reset is generated for a trigger of ESR1 reset 10 _B An Application Reset is generated for a trigger of ESR1 reset 11 _B Reserved, do not use this combination

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Field	Bits	Type	Description
WDT	[7:6]	rw	WDT Reset Request Trigger Reset Configuration This bit field defines which reset is generated by a reset request trigger from WDT reset. 00 _B No reset is generated for a trigger of WDT 01 _B A System Reset is generated for a trigger of WDT reset 10 _B An Application Reset is generated for a trigger of WDT reset 11 _B Reserved, do not use this combination
SW	[9:8]	rw	SW Reset Request Trigger Reset Configuration This bit field defines which reset is generated by a reset request trigger from software reset. 00 _B No reset is generated for a trigger of software reset 01 _B A System Reset is generated for a trigger of Software reset 10 _B An Application Reset is generated for a trigger of Software reset 11 _B Reserved, do not use this combination
1	5	rw	Reserved Should be written with 1.
0	4, [31:10]	rw	Reserved Should be written with 0.

ARSTDIS

Application Reset Disable Register

(05C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								0							STM DIS
r								rw							rw

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Field	Bits	Type	Description
STMDIS	0	rw	STM Disable Reset This bit field defines if an Application Reset leads to an reset for the STM. 0_B An Application Reset resets the STM 1_B An Application Reset has no effect for the STM
0	[7:1]	rw	Reserved Should be written with 0.
0	[31:8]	r	Reserved Read as 0; should be written with 0.

SW Reset Configuration Register

This register controls the SW Reset operation.

SWRSTCON

Software Reset Configuration Register

(060_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWCFG								0				SW RST REQ		SW BOOT	
rw								r				w		rw	

Field	Bits	Type	Description
SWBOOT	0	rw	Software Boot Configuration Selection 0_B Bit field STSTAT.HWCFG is not updated with the content of SWCFG upon an Application Reset 1_B Bit field STSTAT.HWCFG is updated with the content of SWCFG upon an Application Reset

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Field	Bits	Type	Description
SWRSTREQ	1	w	Software Reset Request 0_B No SW Reset is requested 1_B A SW Reset request trigger is generated This bit is automatically cleared and read always as zero.
SWCFG	[15:8]	rw	Software Boot Configuration A software boot configuration different from the external applied hardware configuration can be specified with these bits. The configuration encoding is equal to the HWCFG encoding in register STSTAT.
0	[7:2], [31:16]	r	Reserved Read as 0; should be written with 0.

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3.3 External Interface

The SCU provides interface pads for system purpose. Various functions are covered by these pins. Due to the different tasks some of the pads can not be shared with other functions but most of them can. The following functions are covered by the SCU controlled pads:

- Reset request triggers
- Reset indication
- Trap request triggers
- Interrupt request triggers
- Non SCU module triggers

The first three points are covered by the ESR pads and the last two points by the ERU pads.

3.3.1 External Service Requests ($\overline{\text{ESRx}}$)

The ESR pins can be used to trigger either a reset, a trap (NMI), as reset output, or as data pin.

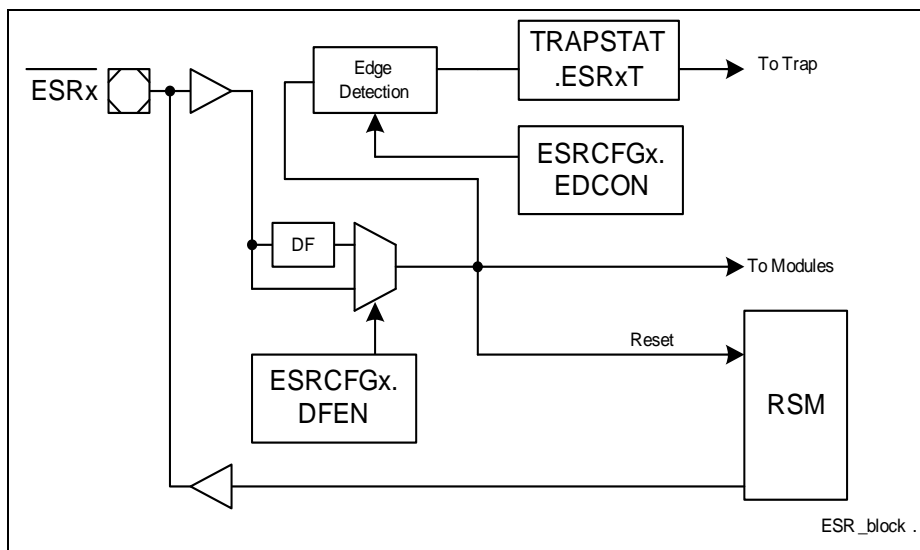


Figure 3-20 ESR Operation

3.3.1.1 $\overline{\text{ESRx}}$ as Reset Request Trigger

An $\overline{\text{ESR0/ESR1}}$ reset request trigger leads to a System or Application Reset. The type of the reset can be configured via RSTCON.ESRx.

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In order to be safely recognized $\overline{\text{ESR0}}/\overline{\text{ESR1}}$ has to be active for a minimum of $2 f_{\text{FPI}}$ clock cycles.

The input signal $\overline{\text{ESR0}}/\overline{\text{ESR1}}$ have digital filters (3-stage median filters), that can be disabled.

A 3-stage median filter samples with f_{FPI} three consecutive clock cycles and the output is defined by the majority of the three sampled values.

The behavior of all three $\overline{\text{ESR0}}/\overline{\text{ESR1}}$ pins can be configured by programming the registers ESRCFGn . The pad control functionality can be configured independently for each pin, comprising:

- A selection of the driver type (open-drain or push-pull)
- An enable function for the output driver (input and/or output capability)
- An enable function for the pull-up/down resistance

3.3.1.2 $\overline{\text{ESRx}}$ as Reset Output

The external pins $\overline{\text{ESR0}}/\overline{\text{ESR1}}$ can serve as an reset output (open drain) for the Application Reset.

Note: The reset output is only asserted for the duration the reset counter RSTCNTA is active. During a possible reset extension the reset output is not longer asserted.

If the pin $\overline{\text{ESR0}}/\overline{\text{ESR1}}$ is enabled as reset output and the input level is low while the output stage is disabled (indicating that it is still driven low externally), the reset circuitry holds the chip in reset until a high level is detected on $\overline{\text{ESR0}}/\overline{\text{ESR1}}$. The internal output stage drives a low level during reset only while RSTCNTA is active. It deactivates the output stage when the time defined by RSTCNTCON.RELSA has passed.

System Control Unit (SCU)

3.3.1.3 ESR Registers

ESRCFG0

ESR0 Configuration Register

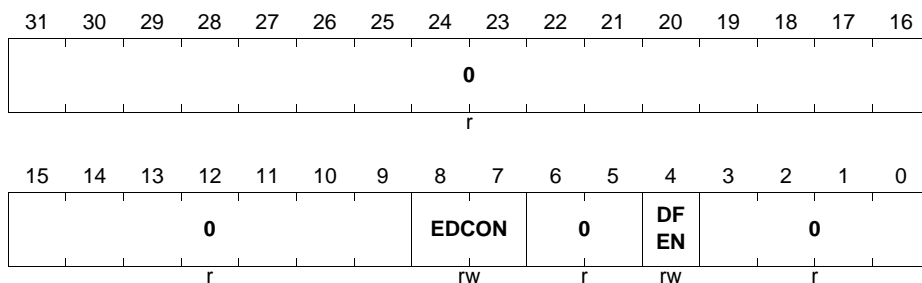
(070_H)

Reset Value: 0000 0110_H

ESRCFG1

ESR1 Configuration Register

(074_H)

Reset Value: 0000 0090_H


Field	Bits	Type	Description
DFEN	4	rw	Digital Filter Enable This bit defines if the 3-stage median filter of the ESR0 is used or bypassed. 0 _B The filter is bypassed 1 _B The filter is used
EDCON	[8:7]	rw	Edge Detection Control This bit field defines the edges that lead to an ESR0 trigger of the synchronous path. 00 _B No trigger is generated 01 _B A trigger is generated upon a rising edge 10 _B A trigger is generated upon a falling edge 11 _B A trigger is generated upon a rising OR falling edge
0	[3:0], [6:5], [31:9]	r	Reserved Read as 0; should be written with 0.

Input/Output Control Registers

The input/output control registers select the digital output and input driver functionality and characteristics of the pin. Direction (input or output), pull-up or pull-down devices for

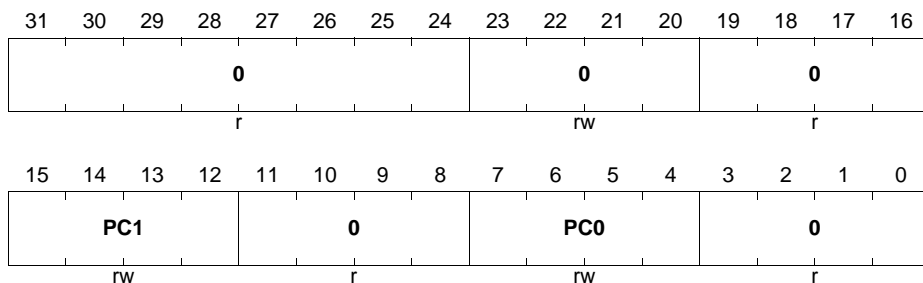
System Control Unit (SCU)

inputs, and push-pull or open-drain functionality for outputs can be selected by the corresponding bit fields PCx (x = 0-1).

IOCR

Input/Output Control Register

(0A0_H)

Reset Value: 0020 10E0_H


Field	Bits	Type	Description
PC0	[7:4]	rw	Control for ESR0 Pin This bit field defines the $\overline{\text{ESR0}}$ pin functionality according to the coding table (see Table 3-9).
PC1	[15:12]	rw	Control for ESR1 Pin This bit field defines the $\overline{\text{ESR1}}$ pin functionality according to the coding table (see Table 3-10).
0	[23:20]	rw	Reserved Have to be written with 0010 _B .
0	[3:0], [11:8], [19:16], [31:24]	r	Reserved Read as 0; should be written with 0.

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Pad Control Coding

Table 3-9 describes the coding of the PC0 bit field that determine the port line functionality.

Table 3-9 PC0 Coding

PC0[3:0]	I/O	Output Characteristics	Selected Pull-up/Pull-down/ Selected Output Function
0X00 _B	Input is active and not inverted; Output is inactive		No input pull device connected
0X01 _B			Input pull-down device connected
0X10 _B			Input pull-up device connected
0X11 _B			No input pull device connected
1000 _B	Input is active and not inverted; Output is active	Push-pull	General-purpose Output
1001 _B			Output drives a 0 for System Resets, a weak pull-up is active otherwise
1010 _B			Output drives a 0 for Application Resets, a weak pull-up is active otherwise
1011 _B			Reserved, do not use this combination
1100 _B	the input is active and not inverted; Output is active	Open-drain	General-purpose Output
1101 _B			Output drives a 0 for System Resets, a weak pull-up is active otherwise
1110 _B			Output drives a 0 for Application Resets, a weak pull-up is active otherwise
1111 _B			Reserved, do not use this combination

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Pad Control Coding

Table 3-10 describes the coding of the PC1 bit field that determine the port line functionality.

Table 3-10 PC1 Coding

PC1[3:0]	I/O	Output Characteristics	Selected Pull-up/Pull-down/ Selected Output Function
0X00 _B	Input is active and not inverted; Output is inactive		No input pull device connected
0X01 _B			Input pull-down device connected
0X10 _B			Input pull-up device connected
0X11 _B			No input pull device connected
1000 _B	Input is active and not inverted; Output is active	Push-pull	General-purpose Output
1001 _B			Output drives a 0 for System Resets, a 'Z' otherwise
1010 _B			Output drives a 0 for Application Resets, a 'Z' otherwise
1011 _B			Reserved, do not use this combination
1100 _B	the input is active and not inverted; Output is active	Open-drain	General-purpose Output
1101 _B			Output drives a 0 for System Resets, a 'Z' otherwise
1110 _B			Output drives a 0 for Application Resets, a 'Z' otherwise
1111 _B			Reserved, do not use this combination

Output Register

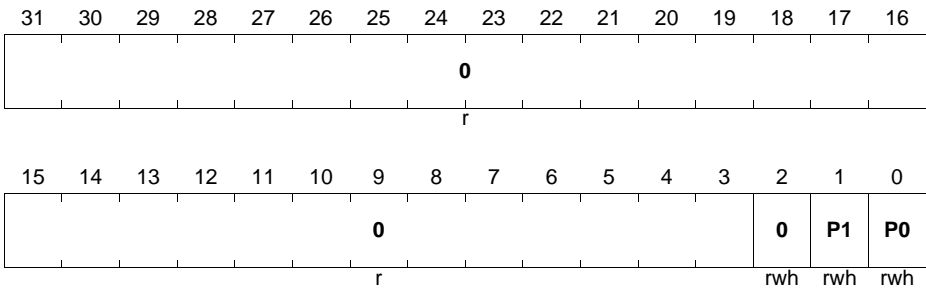
The output register determines the value of a GPIO pin when it is selected by IOCR as output. Writing a 0 to a OUT.Px (x = 0-1) bit position delivers a low level at the corresponding output pin. A high level is output when the corresponding bit is written with a 1. Note that each single bit or group of bits of OUT.Px can be set/cleared by writing appropriate values into the output modification register OMR.

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OUT

Output Register

(0A4_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
Px (x = 0-1)	x	rwh	Output Bit x This bit determines the level at the output pin $\overline{\text{ESRx}}$ if the output is selected as $\overline{\text{GPIO}}$ output. 0_{B} The output level of $\overline{\text{ESRx}}$ is 0 1_{B} The output level of $\overline{\text{ESRx}}$ is 1 Px can also be set/cleared by control bits of the OMR register.
0	2	rwh	Reserved Have to be written with 0.
0	[31:3]	r	Reserved Read as 0; should be written with 0.

Output Modification Register

The output modification register contains control bits that make it possible to individually set, clear, or toggle the logic state of a single pad by manipulating the output register.

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OMR

Output Modification Register

(0A8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													0	PR 1	PR 0
r													w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0													0	PS 1	PS 0
r													w	w	w

Field	Bits	Type	Description
PSx (x = 0-1)	x	w	Set Bit x Setting this bit will set or toggle the corresponding bit in the output register OUT. The function of this bit is shown in Table 3-11 .
PRx (x = 0-1)	x + 16	w	Clear Bit x Setting this bit will clear or toggle the corresponding bit in the port output register OUT. The function of this bit is shown in Table 3-11 .
0	2, 18	w	Reserved Read as 0; have to be written with 0.
0	[15:3], [31:19]	r	Reserved Read as 0; should be written with 0.

Table 3-11 Function of the Bits PRx and PSx

PRx	PSx	Function
0	0	Bit OUT.Px is not changed
0	1	Bit OUT.Px is set
1	0	Bit OUT.Px is cleared
1	1	Bit OUT.Px is toggled

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Input Register

The logic level of a GPIO pin can be read via the read-only port input register IN. Reading the IN register always returns the current logical value at the GPIO pin independently whether the pin is selected as input or output.

IN

Input Register

(0AC_H)

Reset Value: 0000 000X_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								0							
								r						P1 rh	P0 rh

Field	Bits	Type	Description
Px (x = 0-1)	x	rh	Input Bit x This bit indicates the level at the input pin $\overline{\text{ESR}}_x$. 0 _B The input level of $\overline{\text{ESR}}_x$ is 0 1 _B The input level of $\overline{\text{ESR}}_x$ is 1
0	[31:2]	r	Reserved Read as 0.

3.3.2 External Request Unit (ERU)

The External Request Unit (ERU) is a versatile event and pattern detection unit. Its major task is the **generation of interrupts based on selectable trigger events at different inputs**, e.g. to generate external interrupt requests if an edge occurs at an input pin. The detected events can also be used by other modules to trigger or to gate module-specific actions.

3.3.2.1 Introduction

The ERU of the TC1728 can be split in three main functional parts:

- 4 independent **Input Channels x** for input selection and conditioning of trigger or gating functions
- Event distribution: A **Connecting Matrix** defines the events of the Input Channel x that lead to a reaction of an Output Channel y.
- 4 independent **Output Channels y** for combination of events, definition of their effects and distribution to the system (interrupt generation, ...)

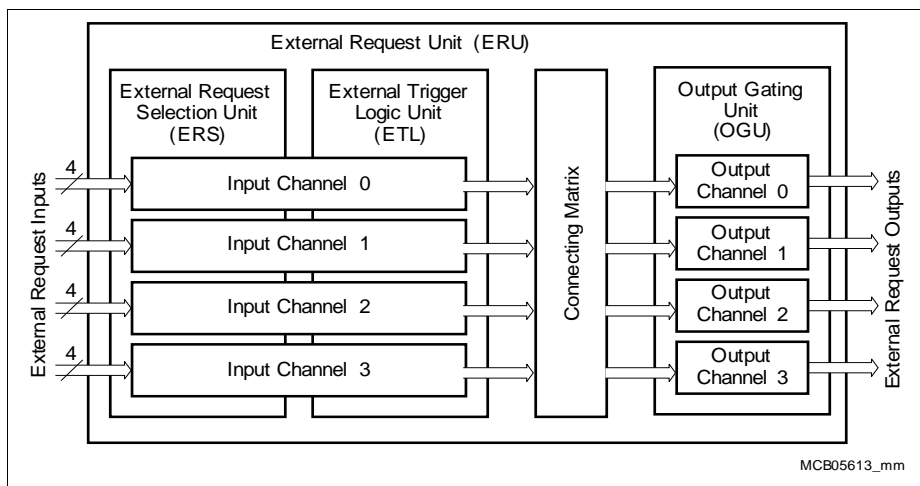


Figure 3-21 External Request Unit Overview

These tasks are handled by the following building blocks:

- An **External Request Select Unit (ERSx)** per Input Channel allows the selection of one input vector out of the 4 possible inputs available.
- An **Event Trigger Logic (ETLx)** per Input Channel allows the definition of the transition (edge selection, or by software) that lead to a trigger event and can also store this status. Here, the input levels of the selected signals are translated into

System Control Unit (SCU)

events (event detected = event flag becomes set, independent of the polarity of the original input signals).

- The **Connecting Matrix** distributes the events and status flags generated by the Input Channels to the Output Channels.
- An **Output Gating Unit (OGUy)** per Output Channel that combines the available trigger events and status information from the Input Channels. An event of one Input Channel can lead to reactions of several Output Channels, or also events of several Input Channels can be combined to a reaction of one Output Channel (pattern detection).

Different types of reactions are possible, e.g. interrupt generation (based on signals ERU_IOUTy).

3.3.2.2 ERU Pin Connections

Figure 3-22 shows the ERU input connections.

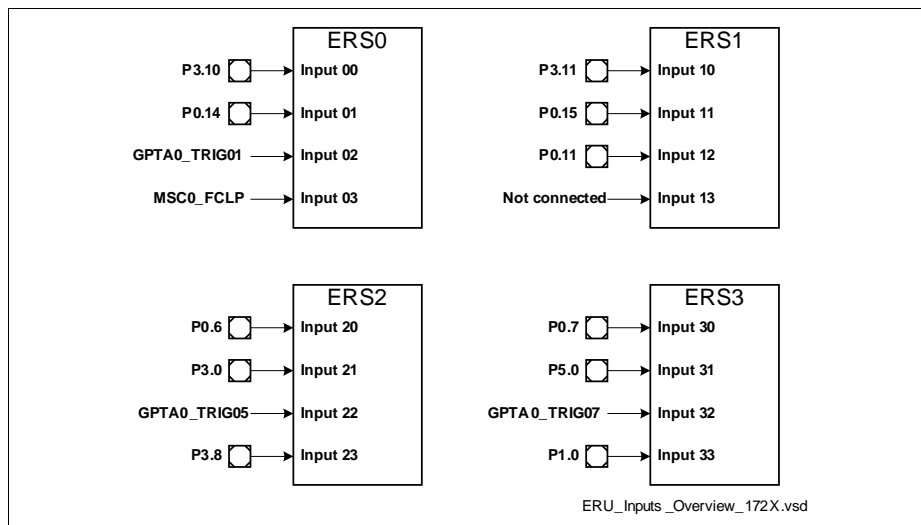


Figure 3-22 ERU Inputs Overview

The inputs to the ERU can be selected from a large number of input signals. While some of the inputs come directly from a pin, other inputs use signals from various peripheral modules.

Usually, such signals would be selected for an ERU function when the input function to the other module is not used otherwise, or the module is not used at all. However, it is also possible to select a input which is actually needed in the other module, and to use it also in the ERU to provide for certain trigger functions, eventually combined with other signals (e.g. to generate an interrupt trigger in case a start of frame is detected at a selected communication).

3.3.2.3 External Request Select Unit (ERS)

Each ERS combines four inputs to the one input signal of the respective input channel.

Figure 3-23 shows the structure of this block.

In addition to the direct choice of either input Ax or Bx or their inverted values, the possible logical combinations for two selected inputs are a logical AND or a logical OR.

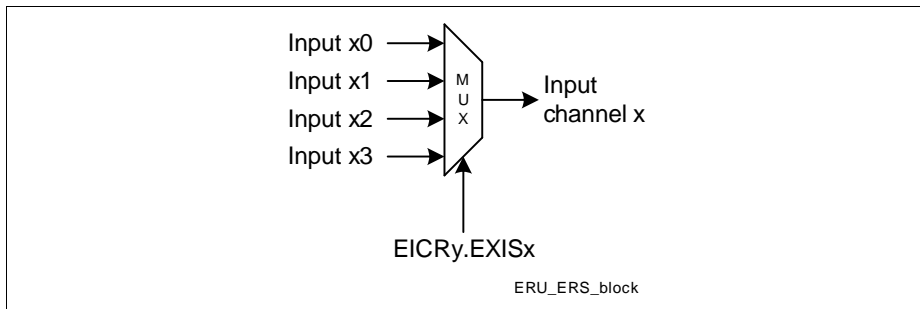


Figure 3-23 External Request Select Unit Overview

The ERS unit for channel x is controlled via bit field ERICly.EXISx.

3.3.2.4 Event Trigger Logic (ETL)

For each Input Channel x, an event trigger logic ETLx derives a trigger event and a status from the input channel x delivered by the associated ERSx unit. Each ETLx is based on an edge detection block, where the detection of a rising or a falling edge can be individually enabled. Both edges lead to a trigger event if both enable bits are set (e.g. to handle a toggling input).

Each pair of the four ETL units has an associated EICRy register, that controls all options of an ETL (the register also holds control bits for the associated ERS unit pair, e.g. EICR0 to control ESR0 and ESR1 plus and ETL0 and ETL1).

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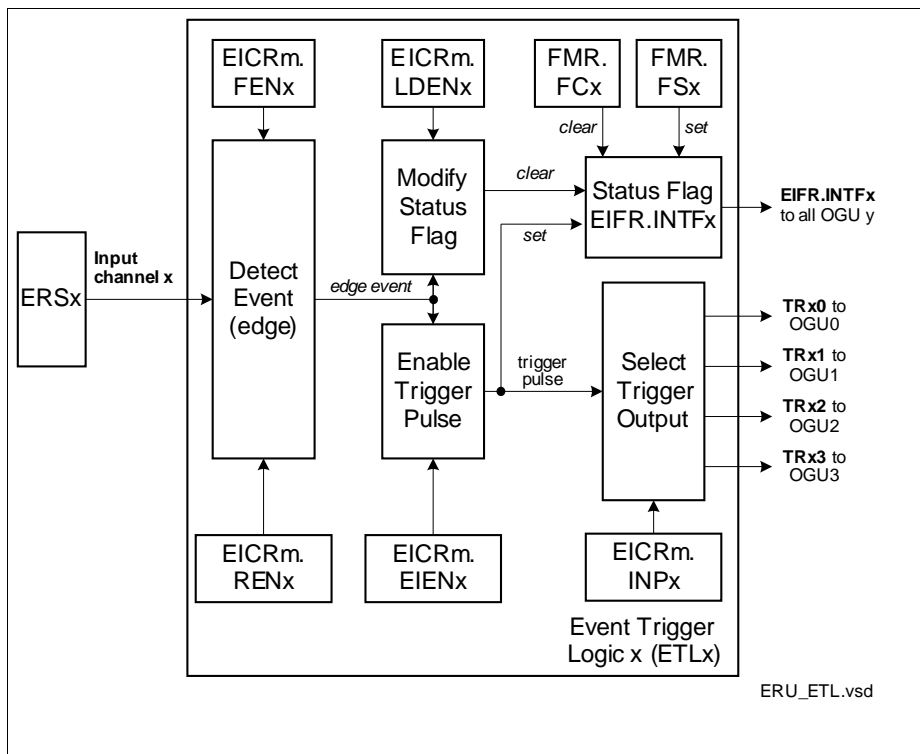


Figure 3-24 Event Trigger Logic Overview

When the selected event (edge) is detected, the status flag EIFR.INTFx becomes set. the status flag is cleared automatically if the “opposite” event is detected if enabled so via bit EICRy.LDENx = 1. For example, if only the falling edge detection is enabled to set the status flag, it is cleared when the rising edge is detected. In this mode, it can be used for pattern detection where the actual status of the input is important (enabling both edge detections is not useful in this mode).

The output of the status flag is connected to all following Output Gating Units (OGUz) in parallel (see [Figure 3-25](#)) to provide **pattern detection capability of all OGUz** units based on different or the same status flags.

In addition to the modification of the status flag, a trigger pulse output TRxz of ETLx can be enabled (by bit EICRy.EIENx) and selected to **trigger actions in one of the OGUz** units. The target OGUz for the trigger is selected by bit field EICRy.INPx.

The trigger becomes active when the selected edge event is detected, independently from the status flag EIFR.INTFx.

3.3.2.5 Connecting Matrix

The connecting matrix distributes the trigger signals (TRxy) and status signals (EIFR.INPFx) from the different ETLx units between the OGUy units. **Figure 3-25** provides a complete overview of the connections between the ETLx and the OGUz units.

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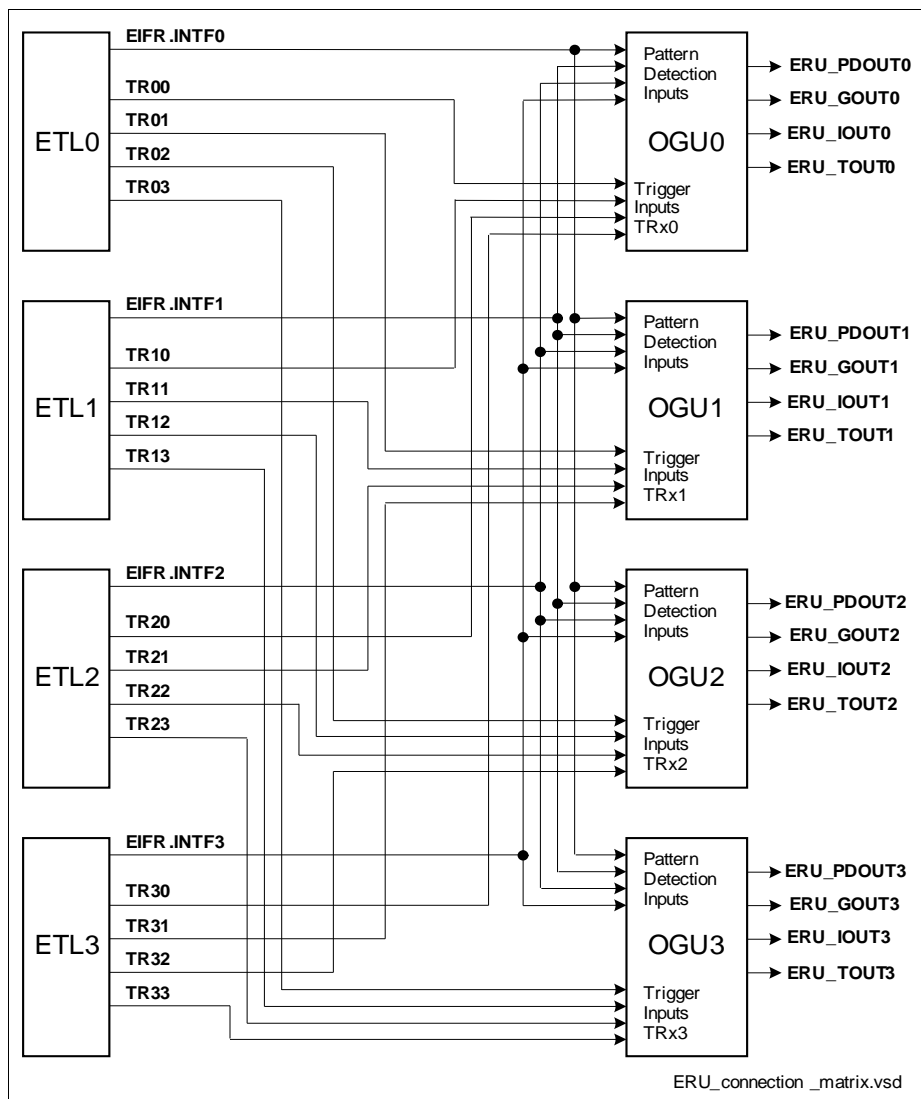


Figure 3-25 Connecting Matrix between ETLx and OGUy

3.3.2.6 Output Gating Unit (OGU)

Each OGUy unit combines the available trigger events and status flags from the Input Channels and distributes the results to the system. illustrates the logic blocks within an OGUy unit. All functions of an OGUy unit are controlled by the associated IGCRm registers, one for each pair of output channels e.g. IGCR1 for OGU2 and OGU3. The function of an OGUy unit can be split into two parts:

- **Trigger combination:**
All trigger signals TRxy from the Input Channels that are enabled and directed to OGUy and a pattern change event (if enabled) are logically OR-combined.
- **Pattern detection:**
The status flags EIFR.INTF_x of the Input Channels can be enabled to take part in the pattern detection. A pattern match is detected while all enabled status flags are set.

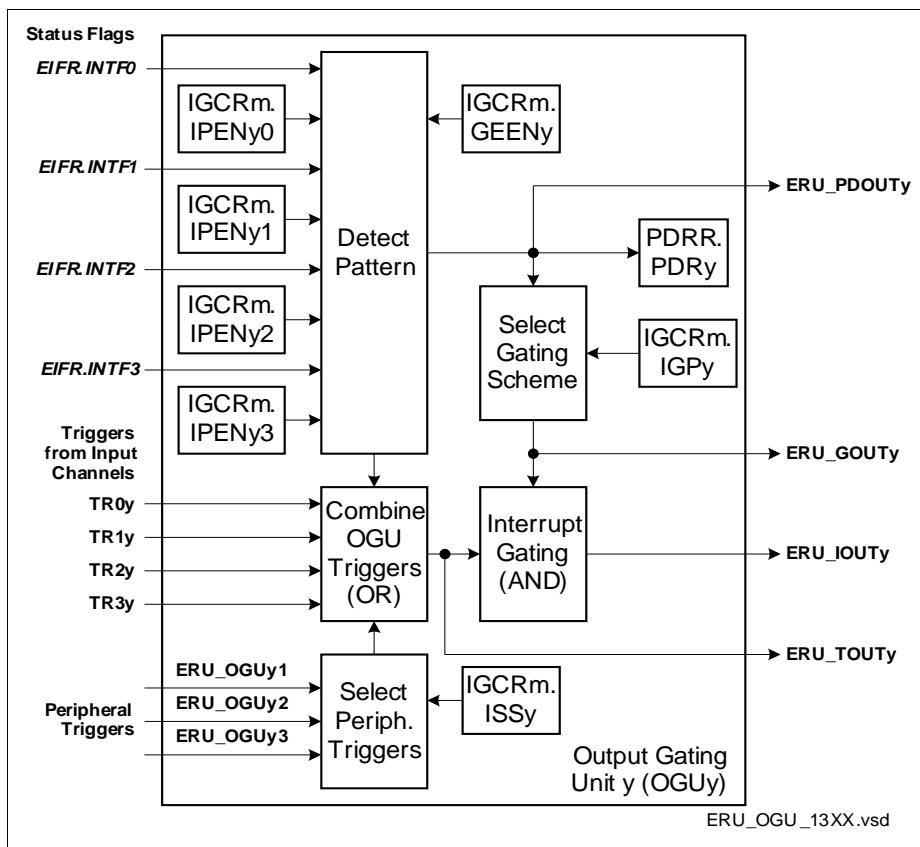


Figure 3-26 Output Gating Unit for Output Channel y

Each OGUy units generates 4 output signals that are distributed to the system.

- **ERU_PDOUTy** to directly output the pattern match information for gating purposes in other modules (pattern match = 1).
- **ERU_GOUTy** to output the pattern match or pattern miss information (inverted pattern match), or a permanent 0 or 1 under software control for gating purposes in other modules.
- **ERU_TOUTy** as combination of a peripheral trigger, a pattern detection result change event, or the ETLx trigger outputs $TRxy$ to trigger actions in other modules.
- **ERU_IOUTy** as gated trigger output (ERU_GOUTy logical AND-combined with ERU_TOUTy) to trigger interrupts (e.g. the interrupt generation can be gated to allow interrupt activation during a certain time window).

System Control Unit (SCU)

Trigger Combination

The trigger combination logically OR-combines different trigger inputs to form a common trigger ERU_TOUTy. Possible trigger inputs are:

- In each ETLx unit of the **Input Channels**, the trigger output TRxy can be enabled and the trigger event can be directed to one of the OGUy units.
- One out of three **peripheral trigger** signals per OGUy can be selected as additional trigger source. These peripheral triggers are generated by on-chip peripheral modules, such as capture/compare or timer units. The selection is done by bit field EXOCONy.ISS.
- In the case that at least one **pattern detection** input is enabled (IGCRm.IPENxy) and a change of the pattern detection result from pattern match to pattern miss (or vice-versa) is detected, a trigger event is generated to indicate a pattern detection result event (if enabled by IGCRm.GEENy).

The trigger combination offers the possibility to program different trigger criteria for several input signals (independently for each Input Channel) or peripheral signals, and to combine their effects to a single output, e.g. to generate an interrupt or to start e.g. an ADC conversion. This combination capability allows the generation of an interrupt per OGU that can be triggered by several inputs (multitude of request sources -> one reaction).

The following table describes the peripheral trigger connections for the OGUy stages. The selection is defined by the bit fields ISS in registers **IGCR0** (for OGU0 and OGU1) and **IGCR1** (for OGU2 and OGU3).

Table 3-12 OGUy Peripheral Trigger Connections in TC1728

Input	from/to Module	I/O to OGUy	Can be used to/as
-------	----------------	-------------	-------------------

OGU0 Inputs

ERU_OGU01	CCU60_SR1	I	peripheral triggers for OGU0
ERU_OGU02	Reserved	I	
ERU_OGU03	Reserved	I	

OGU1 Inputs

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Table 3-12 OGUy Peripheral Trigger Connections in TC1728 (cont'd)

Input	from/to Module	I/O to OGUy	Can be used to/as
ERU_OGU11	CCU61_SR1	I	peripheral triggers for OGU1
ERU_OGU12	Reserved	I	
ERU_OGU13	Reserved	I	

OGU2 Inputs

ERU_OGU21	Reserved	I	peripheral triggers for OGU2
ERU_OGU22	Reserved	I	
ERU_OGU23	Reserved	I	

OGU3 Inputs

ERU_OGU31	Reserved	I	peripheral triggers for OGU3
ERU_OGU32	Reserved	I	
ERU_OGU33	Reserved	I	

Pattern Detection

The pattern detection logic allows the combination of the status flags of all ETLx units. Each status flag can be individually included or excluded from the pattern detection for each OGUy, via control bits IGCRm.IPENxy. The pattern detection block outputs the following pattern detection results:

- **Pattern match** (PDRR.PDRy = 1 and ERU_PDOUTy = 1):
A pattern match is indicated while all status flags that are included in the pattern detection are 1.
- **Pattern miss** (PDRR.PDRy = 0 and ERU_PDOUTy = 0):
A pattern miss is indicated while at least one of the status flags that are included in the pattern detection is 0.

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In addition, the pattern detection can deliver a trigger event if the pattern detection result changes from match to miss or vice-versa (if enabled by IGCRm.GEENy = 1). The pattern result change event is logically OR-combined with the other enabled trigger events to support interrupt generation or to trigger other module functions (e.g. in an ADC). The event is indicated when the pattern detection result changes and PDRR.PDRy becomes updated.

The interrupt generation in the OGUy is based on the trigger ERU_TOUTy that can be gated (masked) with the pattern detection result ERU_PDOUTy. This allows an automatic and reproducible generation of interrupts during a certain time window, where the request event is elaborated by the trigger combination block and the time window information (gating) is given by the pattern detection. For example, interrupts can be issued on a regular time base while a combination of input signals occurs (pattern detection based on ETLx status bits).

A programmable gating scheme introduces flexibility to adapt to application requirements and allows the generation of interrupt requests ERU_IOUTy under different conditions:

- **Pattern match** (IGCRm.IGPy = 10_B):
An interrupt request is issued when a trigger event occurs while the pattern detection shows a pattern match.
- **Pattern miss** (IGCRm.IGPy = 11_B):
An interrupt request is issued when the trigger event occurs while the pattern detection shows a pattern miss.
- **Independent** of pattern detection (IGCRm.IGPy = 01_B):
In this mode, each occurring trigger event leads to an interrupt request. The pattern detection output can be used independently from the trigger combination for gating purposes of other peripherals (independent use of ERU_TOUTy and ERU_PDOUTy with interrupt requests on trigger events).
- **No interrupts** (IGCRm.IGPy = 00_B, default setting)
In this mode, an occurring trigger event does not lead to an interrupt request. The pattern detection output can be used independently from the trigger combination for gating purposes of other peripherals (independent use of ERU_TOUTy and ERU_PDOUTy without interrupt requests on trigger events).

3.3.2.7 ERU Output Connections

This section describes the connections of the ERU output signals for gating or triggering other module functions, as well as the connections to the interrupt control registers.

Table 3-13 ERU Output Connections in TC1728

Output	from/to Module	I/O to OGUy	Can be used to/as
--------	-------------------	----------------	-------------------

OGU0 Outputs

ERU_ PDOUT0	not connected	O	pattern detection output
ERU_ GOUT0	not connected	O	gated pattern detection output
ERU_ TOUT0	not connected	O	trigger output
ERU_ IOUT0	Interrupt Generation DMA channel 00 DMA channel 04	O	interrupt output

OGU1 Outputs

ERU_ PDOUT1	not connected	O	pattern detection output
ERU_ GOUT1	not connected	O	gated pattern detection output
ERU_ TOUT1	not connected	O	trigger output
ERU_ IOUT1	Interrupt Generation DMA channel 01 DMA channel 05 GPTA0 input INT1	O	interrupt output

OGU2 Outputs

ERU_ PDOUT2	ADC gating input FADC input FADC_GSC	O	pattern detection output
ERU_ GOUT2	not connected	O	gated pattern detection output
ERU_ TOUT2	not connected	O	trigger output

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Table 3-13 ERU Output Connections in TC1728 (cont'd)

Output	from/to Module	I/O to OGUy	Can be used to/as
ERU_IOUT2	Interrupt Generation DMA channel 02 DMA channel 06 ADC trigger input FADC input FADC_TSC GPTA0 input INT2	O	interrupt output

OGU3 Outputs

ERU_PDOUT3	ADC gating input FADC input FADC_GSD	O	pattern detection output
ERU_GOUT3	not connected	O	gated pattern detection output
ERU_TOUT3	not connected	O	trigger output
ERU_IOUT3	Interrupt Generation DMA channel 03 DMA channel 07 ADC trigger input FADC input FADC_TSD GPTA0 input INT3	O	interrupt output

3.3.2.8 External Request Unit Registers

The External Input Channel Register EICR0 and EICR1 for the external input channels 0 to 3 contain bits to configure the external request selection ERS and the event trigger logic ETL.

System Control Unit (SCU)

EICR0

External Input Channel Register 0 (080_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		INP1			EI EN1	LD EN1	R EN1	F EN1	0		EXIS1		0		
r		rw			rw	rw	rw	rw	r		rw		r		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		INP0			EI EN0	LD EN0	R EN0	F EN0	0		EXIS0		0		
r		rw			rw	rw	rw	rw	r		rw		r		

Field	Bits	Type	Description
EXIS0	[5:4]	rw	External Input Selection 0 This bit field determines which input line is selected for Input Channel 0. 00 _B Input 00 is selected 01 _B Input 01 is selected 10 _B Input 02 is selected 11 _B Input 03 is selected
FEN0	8	rw	Falling Edge Enable 0 This bit determines if the falling edge of Input Channel 0 is used to set bit INTF0. 0 _B The falling edge is not used 1 _B The detection of a falling edge of Input Channel 0 generates a trigger event (INTF0 becomes set)
REN0	9	rw	Rising Edge Enable 0 This bit determines if the rising edge of Input Channel 0 is used to set bit INTF0. 0 _B The rising edge is not used 1 _B The detection of a rising edge of Input Channel 0 generates a trigger event (INTF0 becomes set)

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Field	Bits	Type	Description
LDEN0	10	rw	Level Detection Enable 0 This bit determines if bit INTF0 is cleared automatically if an edge of the input Input Channel 0 is detected, which has not been selected (rising edge with REN0 = 0 or falling edge with FEN0 = 0). 0 _B Bit INTF0 will not be cleared 1 _B Bit INTF0 will be cleared
EIEN0	11	rw	External Input Enable 0 This bit enables the generation of a trigger event for request channel 0 (e.g. for interrupt generation) when a selected edge is detected. 0 _B The trigger event is disabled 1 _B The trigger event is enabled
INP0	[14:12]	rw	Input Node Pointer This bit field determines the destination (output channel) for trigger event 0 (if enabled by EIEN0). 000 _B The event of input channel 0 triggers output channel 0 (signal INT00) 001 _B The event of input channel 0 triggers output channel 1 (signal INT01) 010 _B The event of input channel 0 triggers output channel 2 (signal INT02) 011 _B The event of input channel 0 triggers output channel 3 (signal INT03) 100 _B Reserved, do not use this combination 101 _B Reserved, do not use this combination 110 _B Reserved, do not use this combination 111 _B Reserved, do not use this combination
EXIS1	[21:20]	rw	External Input Selection 1 This bit field determines which input line is selected for Input Channel 1. 00 _B Input 10 is selected 01 _B Input 11 is selected 10 _B Input 12 is selected 11 _B Input 13 is selected

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Field	Bits	Type	Description
FEN1	24	rw	Falling Edge Enable 1 This bit determines if the falling edge of Input Channel 1 is used to set bit INTF1. 0 _B The falling edge is not used 1 _B The detection of a falling edge of Input Channel 1 generates a trigger event (INTF1 becomes set)
REN1	25	rw	Rising Edge Enable 1 This bit determines if the rising edge of Input Channel 1 is used to set bit INTF1. 0 _B The rising edge is not used 1 _B The detection of a rising edge of Input Channel 1 generates a trigger event (INTF1 becomes set)
LDEN1	26	rw	Level Detection Enable 1 This bit determines if bit INTF1 is cleared automatically if an edge of the input Input Channel 1 is detected, which has not been selected (rising edge with REN1 = 0 or falling edge with FEN1 = 0). 0 _B Bit INTF1 will not be cleared 1 _B Bit INTF1 will be cleared
EIEN1	27	rw	External Input Enable 1 This bit enables the generation of a trigger event for request channel 1 (e.g. for interrupt generation) when a selected edge is detected. 0 _B The trigger event is disabled 1 _B The trigger event is enabled

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Field	Bits	Type	Description
INP1	[30:28]	rw	Input Node Pointer This bit field determines the destination (output channel) for trigger event 1 (if enabled by EIEN1). 000 _B The event of input channel 1 triggers output channel 0 (signal INT10) 001 _B The event of input channel 1 triggers output channel 1 (signal INT11) 010 _B The event of input channel 1 triggers output channel 2 (signal INT12) 011 _B The event of input channel 1 triggers output channel 3 (signal INT13) 100 _B Reserved, do not use this combination 101 _B Reserved, do not use this combination 110 _B Reserved, do not use this combination 111 _B Reserved, do not use this combination
0	[3:0], [7:6], [19:15], [23:22], 31	r	Reserved Read as 0; should be written with 0.

EICR1

External Input Channel Register 1 (084_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	INP3		EI EN3	LD EN3	R EN3	F EN3	0		EXIS3		0				
r	rw		rw	rw	rw	rw	r		rw		r				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	INP2		EI EN2	LD EN2	R EN2	F EN2	0		EXIS2		0				
r	rw		rw	rw	rw	rw	r		rw		r				

System Control Unit (SCU)

Field	Bits	Type	Description
EXIS2	[5:4]	rw	External Input Selection 2 This bit field determines which input line is selected for Input Channel 2. 00 _B Input 20 is selected 01 _B Input 21 is selected 10 _B Input 22 is selected 11 _B Input 23 is selected
FEN2	8	rw	Falling Edge Enable 2 This bit determines if the falling edge of Input Channel 2 is used to set bit INTF2. 0 _B The falling edge is not used 1 _B The detection of a falling edge of Input Channel 2 generates a trigger event (INTF3 becomes set)
REN2	9	rw	Rising Edge Enable 2 This bit determines if the rising edge of signal Input Channel 2 is used to set bit INTF2. 0 _B The rising edge is not used 1 _B The detection of a rising edge of Input Channel 2 generates a trigger event (INTF2 becomes set)
LDEN2	10	rw	Level Detection Enable 2 This bit determines if bit INTF2 is cleared automatically if an edge of the input Input Channel 2 is detected, which has not been selected (rising edge with REN2 = 0 or falling edge with FEN2 = 0). 0 _B Bit INTF2 will not be cleared 1 _B Bit INTF2 will be cleared
EIEN2	11	rw	External Input Enable 2 This bit enables the generation of a trigger event for request channel 2 (e.g. for interrupt generation) when a selected edge is detected. 0 _B The trigger event is disabled 1 _B The trigger event is enabled

System Control Unit (SCU)

Field	Bits	Type	Description
INP2	[14:12]	rw	Input Node Pointer This bit field determines the destination (output channel) for trigger event 2 (if enabled by EIEN2). 000 _B The event of input channel 2 triggers output channel 0 (signal INT20) 001 _B The event of input channel 2 triggers output channel 1 (signal INT21) 010 _B The event of input channel 2 triggers output channel 2 (signal INT22) 011 _B The event of input channel 2 triggers output channel 3 (signal INT23) 100 _B Reserved, do not use this combination 101 _B Reserved, do not use this combination 110 _B Reserved, do not use this combination 111 _B Reserved, do not use this combination
EXIS3	[21:20]	rw	External Input Selection 3 This bit field determines which input line is selected for Input Channel 3. 00 _B Input 30 is selected 01 _B Input 31 is selected 10 _B Input 32 is selected 11 _B Input 33 is selected
FEN3	24	rw	Falling Edge Enable 3 This bit determines if the falling edge of Input Channel 3 is used to set bit INTF3. 0 _B The falling edge is not used 1 _B The detection of a falling edge of Input Channel 3 generates a trigger event (INTF3 becomes set)
REN3	25	rw	Rising Edge Enable 3 This bit determines if the rising edge of signal Input Channel 3 is used to set bit INTF3. 0 _B The rising edge is not used 1 _B The detection of a rising edge of Input Channel 3 generates a trigger event (INTF3 becomes set)

System Control Unit (SCU)

Field	Bits	Type	Description
LDEN3	26	rw	Level Detection Enable 3 This bit determines if bit INTF3 is cleared automatically if an edge of the input Input Channel 3 is detected, which has not been selected (rising edge with REN3 = 0 or falling edge with FEN3 = 0). 0 _B Bit INTF3 will not be cleared 1 _B Bit INTF3 will be cleared
EIEN3	27	rw	External Interrupt Enable 3 This bit enables the generation of a trigger event for request channel 3 (e.g. for interrupt generation) when a selected edge is detected. 0 _B The trigger event is disabled 1 _B The trigger event is enabled
INP3	[30:28]	rw	Interrupt Node Pointer This bit field determines the destination (output channel) for trigger event 3 (if enabled by EIEN3). 000 _B The event of input channel 3 triggers output channel 0 (signal INT30) 001 _B The event of input channel 3 triggers output channel 1 (signal INT31) 010 _B The event of input channel 3 triggers output channel 2 (signal INT32) 011 _B The event of input channel 3 triggers output channel 3 (signal INT33) 100 _B Reserved, do not use this combination 101 _B Reserved, do not use this combination 110 _B Reserved, do not use this combination 111 _B Reserved, do not use this combination
0	[3:0], [7:6], [19:15], [23:22], 31	r	Reserved Read as 0; should be written with 0.

The External Input Flag Register EIFR contains all status flags for the external input channels. The bits in this register can be cleared by software by setting FMR.FCx, and set by setting FMR.FSx.

System Control Unit (SCU)

EIFR

External Input Flag Register

(088_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												INT F3	INT F2	INT F1	INT F0
r												rh	rh	rh	rh

Field	Bits	Type	Description
INTFx (x = 0-3)	x	rh	External Interrupt Flag of Channel x This bit monitors the status flag of the event trigger condition for the input channel x. This bit is automatically cleared when the selected condition (see RENx, FENx) is no longer met (if LDENx = 1) or remains set until it is cleared by software (if LDENx = 0).
0	[31:4]	r	Reserved Read as 0; should be written with 0.

FMR

Flag Modification Register

(08C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												FC 3	FC 2	FC 1	FC 0
r												w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												FS 3	FS 2	FS 1	FS 0
r												w	w	w	w

System Control Unit (SCU)

Field	Bits	Type	Description
FSx (x = 0-3)	x	w	Set Flag INTFx for Channel x Setting this bit will set the corresponding bit INTFx in register EIFR. Reading this bit always delivers a 0. 0 _B The bit x in register EIFR is not modified 1 _B The bit x in register EIFR is set
FCx (x = 0-3)	16 + x	w	Clear Flag INTFx for Channel x Setting this bit will clear the corresponding bit INTFx in register EIFR. Reading this bit always delivers a 0. 0 _B The bit x in register EIFR is not modified 1 _B The bit x in register EIFR is cleared
0	[15:4], [31:20]	r	Reserved Read as 0; should be written with 0.

The Pattern Detection Result Register monitors the combinatorial output status of the pattern detection units.

PDRR

Pattern Detection Result Register (090_H) **Reset Value: 0000 000F_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												PDR	PDR	PDR	PDR
r												3	2	1	0
												rh	rh	rh	rh

Field	Bits	Type	Description
PDRy (y = 0-3)	y	rh	Pattern Detection Result of Channel y This bit monitors the output status of the pattern detection for the output channel y.
0	[31:4]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

The Interrupt Gating Control Registers IGCR0 and IGCR1 contain bits to enable the pattern detection and to control the gating for output channel 0 to 3.

IGCR0

Interrupt Gating Register 0

(094_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IGP1		GE EN1	0			ISS1		0			IPEN 13	IPEN 12	IPEN 11	IPEN 10	
rw		rw	r			rw		r			rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IGP0		GE EN0	0			ISS0		0			IPEN 03	IPEN 02	IPEN 01	IPEN 00	
rw		rw	r			rw		r			rw	rw	rw	rw	

Field	Bits	Type	Description
IPEN0x (x = 0-3)	x	rw	Interrupt Pattern Enable for Channel 0 Bit IPEN0x determines if the flag INTFx of channel x takes part in the pattern detection for the gating of the requests for the output signals GOUTy and IOUTy. 0 _B The bit INTFx does not take part in the pattern detection 1 _B The bit INTFx is taken into consideration for the pattern detection
ISS0	[9:8]	rw	Internal Trigger Source Selection This bit field defines which input is selected as peripheral trigger input for OGU0. The possible input signals are given in Table 3-13 . 00 _B The peripheral trigger function is disabled 01 _B Input ERU_OGU01 is selected 10 _B Input ERU_OGU02 is selected 11 _B Input ERU_OGU03 is selected

System Control Unit (SCU)

Field	Bits	Type	Description
GEEN0	13	rw	<p>Generate Event Enable 0</p> <p>Bit GEEN0 enables the generation of a trigger event for output channel 0 when the result of the pattern detection changes. When using this feature, a trigger (e.g. for an interrupt) is generated during the first clock cycle when a pattern is detected or when it is no longer detected.</p> <p>0_B The trigger generation at a change of the pattern detection result is disabled</p> <p>1_B The trigger generation at a change of the pattern detection result is enabled</p>
ISS1	[25:24]	rw	<p>Internal Trigger Source Selection</p> <p>This bit field defines which input is selected as peripheral trigger input for OGU1. The possible input signals are given in Table 3-13.</p> <p>00_B The peripheral trigger function is disabled</p> <p>01_B Input ERU_OGU11 is selected</p> <p>10_B Input ERU_OGU12 is selected</p> <p>11_B Input ERU_OGU13 is selected</p>
IGP0	[15:14]	rw	<p>Interrupt Gating Pattern 0</p> <p>Bit field IGP0 determines how the pattern detection influences the output lines GOUT0 and IOUT0.</p> <p>00_B The detected pattern is not taken into account. An activation of IOUT0 is always possible due to a trigger event.</p> <p>01_B The detected pattern is not taken into account. An activation of IOUT0 is not possible.</p> <p>10_B The detected pattern is taken into account. An activation of IOUT0 is only possible due to a trigger event while the pattern is detected.</p> <p>11_B The detected pattern is taken into account. An activation of IOUT0 is only possible due to a trigger event while the pattern is not detected.</p>

System Control Unit (SCU)

Field	Bits	Type	Description
IPEN1x (x = 0-3)	16+x	rw	Interrupt Pattern Enable for Channel 1 Bit IPEN1x determines if the flag INTFx of channel x takes part in the pattern detection for the gating of the requests for the output signals GOUTy and IOUTy. 0 _B The bit INTFx does not take part in the pattern detection 1 _B The bit INTFx is taken into consideration for the pattern detection
GEEN1	29	rw	Generate Event Enable 1 Bit GEEN1 enables the generation of a trigger event for output channel 1 when the result of the pattern detection changes. When using this feature, a trigger (e.g. for an interrupt) is generated during the first clock cycle when a pattern is detected, or when it is no longer detected. 0 _B The trigger generation at a change of the pattern detection result is disabled 1 _B The trigger generation at a change of the pattern detection result is enabled
IGP1	[31:30]	rw	Interrupt Gating Pattern 1 Bit field IGP1 determines how the pattern detection influences the output lines GOUT1 and IOUT1. 00 _B The detected pattern is not taken into account. An activation of IOUT1 is always possible due to a trigger event. 01 _B The detected pattern is not taken into account. An activation of IOUT1 is not possible. 10 _B The detected pattern is taken into account. An activation of IOUT1 is only possible due to a trigger event while the pattern is detected. 11 _B The detected pattern is taken into account. An activation of IOUT1 is only possible due to a trigger event while the pattern is not detected.
0	[7:4], [12:10], [23:20],[28:26]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

IGCR1

Interrupt Gating Register 1

(098_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IGP3		GE EN3	0			ISS3		0			IPEN 33	IPEN 32	IPEN 31	IPEN 30	
rw		rw	r			rw		r			rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IGP2		GE EN2	0			ISS2		0			IPEN 23	IPEN 22	IPEN 21	IPEN 20	
rw		rw	r			rw		r			rw	rw	rw	rw	

Field	Bits	Type	Description
IPEN2x (x = 0-3)	x	rw	Interrupt Pattern Enable for Channel 2 Bit IPEN2x determines if the flag INTFx of channel x takes part in the pattern detection for the gating of the requests for the output signals GOUTy and IOUTy. 0 _B The bit INTFx does not take part in the pattern detection 1 _B The bit INTFx is taken into consideration for the pattern detection
ISS2	[9:8]	rw	Internal Trigger Source Selection This bit field defines which input is selected as peripheral trigger input for OGU2. The possible input signals are given in Table 3-13 . 00 _B The peripheral trigger function is disabled 01 _B Input ERU_OGU21 is selected 10 _B Input ERU_OGU22 is selected 11 _B Input ERU_OGU23 is selected

System Control Unit (SCU)

Field	Bits	Type	Description
GEEN2	13	rw	<p>Generate Event Enable 2</p> <p>Bit GEEN2 enables the generation of a trigger event for output channel 2 when the result of the pattern detection changes. When using this feature, a trigger (e.g. for an interrupt) is generated during the first clock cycle when a pattern is detected, or when it is no longer detected.</p> <p>0_B The trigger generation at a change of the pattern detection result is disabled</p> <p>1_B The trigger generation at a change of the pattern detection result is enabled</p>
IGP2	[15:14]	rw	<p>Interrupt Gating Pattern 2</p> <p>Bit field IGP2 determines how the pattern detection influences the output lines GOUT2 and IOUT2.</p> <p>00_B The detected pattern is not taken into account. An activation of IOUT2 is always possible due to a trigger event.</p> <p>01_B The detected pattern is not taken into account. An activation of IOUT2 is not possible.</p> <p>10_B The detected pattern is taken into account. An activation of IOUT2 is only possible due to a trigger event while the pattern is detected.</p> <p>11_B The detected pattern is taken into account. An activation of IOUT2 is only possible due to a trigger event while the pattern is not detected.</p>
IPEN3x (x = 0-3)	16+x	rw	<p>Interrupt Pattern Enable for Channel 3</p> <p>Bit IPEN3x determines if the flag INTFx of channel x takes part in the pattern detection for the gating of the requests for the output signals GOUTy and IOUTy.</p> <p>0_B The bit INTFx does not take part in the pattern detection</p> <p>1_B The bit INTFx is taken into consideration for the pattern detection</p>

System Control Unit (SCU)

Field	Bits	Type	Description
ISS3	[25:24]	rw	Internal Trigger Source Selection This bit field defines which input is selected as peripheral trigger input for OGU13. The possible input signals are given in Table 3-13 . 00 _B The peripheral trigger function is disabled 01 _B Input ERU_OGU31 is selected 10 _B Input ERU_OGU32 is selected 11 _B Input ERU_OGU33 is selected
GEEN3	29	rw	Generate Event Enable 3 Bit GEEN3 enables the generation of a trigger event for output channel 3 when the result of the pattern detection changes. When using this feature, a trigger (e.g. for an interrupt) is generated during the first clock cycle when a pattern is detected, or when it is no longer detected. 0 _B The trigger generation at a change of the pattern detection result is disabled 1 _B The trigger generation at a change of the pattern detection result is enabled
IGP3	[31:30]	rw	Interrupt Gating Pattern 3 Bit field IGP3 determines how the pattern detection influences the output lines GOUT3 and IOUT3. 00 _B The detected pattern is not taken into account. An activation of IOUT3 is always possible due to a trigger event. 01 _B The detected pattern is not taken into account. An activation of IOUT3 is not possible. 10 _B The detected pattern is taken into account. An activation of IOUT3 is only possible due to a trigger event while the pattern is detected. 11 _B The detected pattern is taken into account. An activation of IOUT3 is only possible due to a trigger event while the pattern is not detected.
0	[7:4], [12:10], [23:20], [28:26]	r	Reserved Read as 0; should be written with 0.

3.4 Power Supply and Control

3.4.1 Basic Operation

The TC1728 can run from a single external power supply. The pad and core supply voltages can be generated by on-chip Embedded Voltage Regulators (EVRs) or can be provided externally.

The following figures show the different supply options beside that all voltages are provided externally.

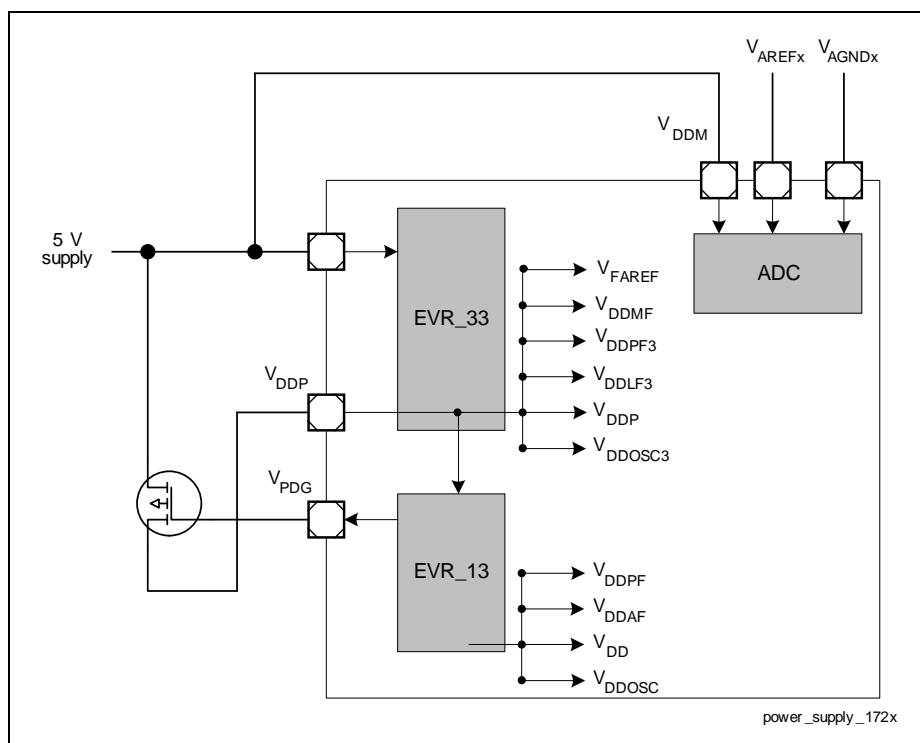


Figure 3-27 Basic EVR concept for 5V supply with Pass Device

System Control Unit (SCU)

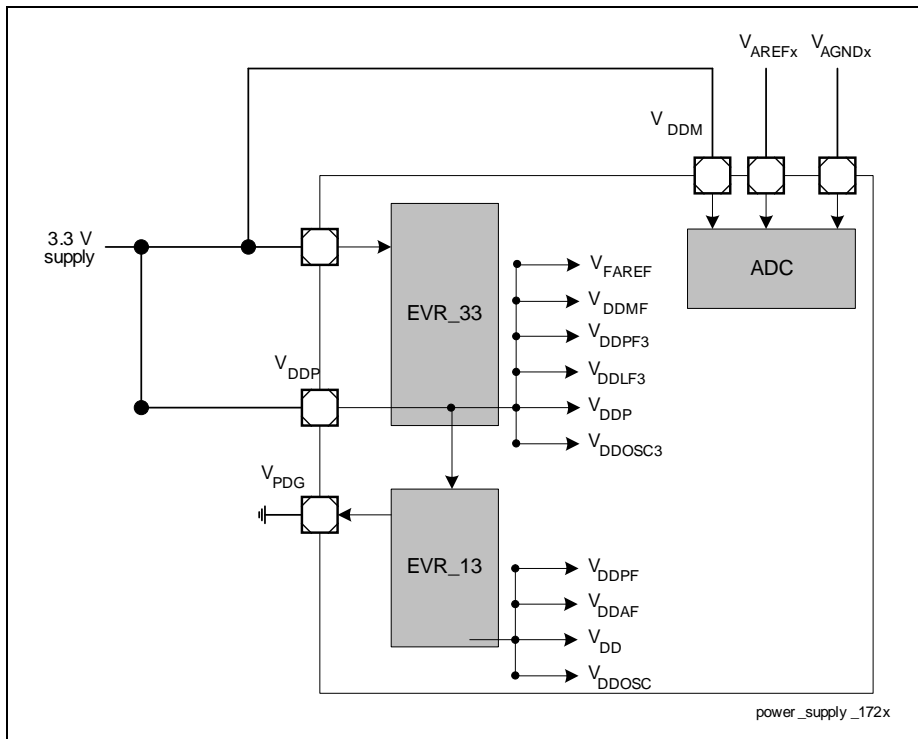


Figure 3-29 Basic EVR concept for 3.3V supply with Pass Device

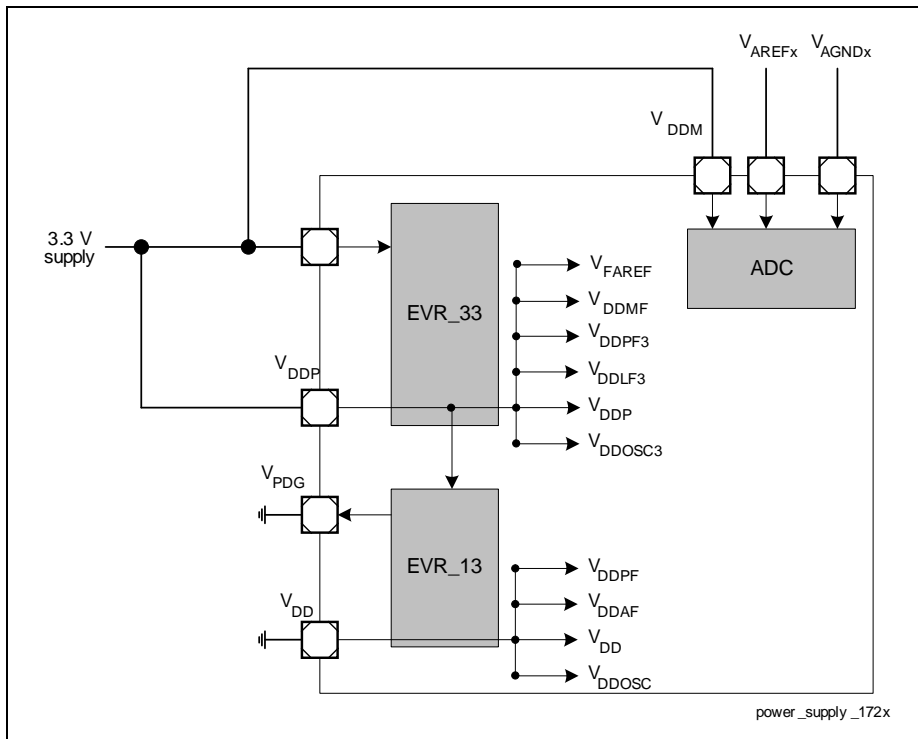


Figure 3-30 Basic EVR concept for 3.3V supply without Pass Device

The basic power supply concept of the TC1728 implies of a single external 5 V power supply source and two cascaded EVRs. All required supply voltages beside the ADC analogue supply voltage V_{DDM} and V_{AREF_x} are generated internally.

In order to distribute the heat the core supplies are generated out of the 3.3 V EVR and not by the 5 V external supply in order to avoid the large voltage drop here.

The basic operating mode is the external single supply mode. Optional there is also the option to supply all voltages from external for backward compatible usage. Nevertheless the default reset setting here is also single external 5 V supply and later the EVRs are disabled and the external supply for 3.3 V and 1.3 V is used. Please note that these two supply levels must be available and stable with the release of the Power-On reset. For more information see the reset part of this document.

3.4.2 Enhanced Reset System

The existing reset system is only enhanced and not changed. Adaptation is only done where the EVR introduction itself generates new requirements.

The PORST pin needs to be a bidirectional reset in/output for power related resets. This is not replacement for the ESR pins transporting the functional reset information.

In the EVR block there are four blocks contributing to the reset system:

- PORST pad
- 5 V EVR voltage monitoring
- 3.3 V EVR voltage monitoring
- 1.3 V EVR voltage monitoring

The four possible reset sources define the Power-on reset of the system.

These four reset triggers needs to be combined logically by an OR to the Power-on reset known today. If a EVR is disabled no reset is generated by this EVR at all.

The three reset requests of the two EVRs (5 V monitoring, EVR33 and EVR13) are combined by a logical OR in the EVR implementation block and connected with the open drain output of the PORST pad.

3.4.3 Power-up Flow

The EVR compose mainly of 2 sub-blocks:

- EVR33
- EVR13

5 V External Supply Only

Beginning with a minimum level of the external supplied 5 V detected by the 5 V monitoring the EVR33 for the 3.3 V pad domain is started.

The EVR33 has to be configured as enabled by input HWCFG[5] (P0.5) = 0 during power-up. The EVR13 has to be configured as enabled by input HWCFG[4] (P0.4) = 0 during power-up. HWCFG[5] and HWCFG[4] are configured to weak pull down while PORST is active which ensure that if left unconnected, the device starts in the 5 V single supply mode after a Power-on Reset.

An external pass device would be required if the actual power consumption exceeds a threshold which would be provided in the Data Sheet. The external pass device is connected to the EVR33 only and not to the EVR13. The external pass need to provide at least 3.0 V when the external 5 V supply reaches 3.6 V.

The control pad for the external pass device is checked. In case an external pass device is used, then this pin should be held via a pull up. Otherwise if internal pass device is sufficient to meet the power requirements, the control pin should be connected to ground. For this case only the internal pass devices are used.

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When the EVR33 reaches its active level the EVR13 is started. When this EVR also reaches the active level the system is ready for operation and the normal start-up is started.

3.3 V External Supply Only

Here the EVR33 is not required for the supply concept. The EVR33 has to be configured as disabled by input HWCFG[5] (P0.5) = 1 during power-up. If external 3.3 V supply is configured no external pass device is required at all.

The EVR13 is started. When this EVR also reaches the active level the system is ready for operation and the normal start-up is started. The EVR13 has to be configured as enabled by input HWCFG[4] (P0.4) = 0 during power-up.

5 V, 3.3 V, and 1.3 V External Supply

When all supply levels are provided from external no internal EVR is required. The EVR33 as to be configured as disabled by input HWCFG[5] (P0.5) = 1 during power-up. The EVR13 has to be configured as disabled by input HWCFG[4] (P0.4) = 1 during power-up.

Table 3-14 EVR Configuration

HWCFG[5]	HWCFG[4]	EVR Status
0	0	EVR33 and EVR13 active
0	1	This combination is not supported
1	0	EVR33 inactive and EVR13 active
1	1	EVR33 and EVR13 inactive

Voltage Monitoring

Additional undervoltage monitoring against programmable thresholds is provided for all supplied and generated voltages. This includes the external supply voltage and the internally generated EVR13 and EVR33 output voltages. In case of a threshold violation, a reset is triggered. Also the occurrence of the trigger event may be dependent on the direction of voltage transition. The appropriate configuration for voltage monitoring can be made in register EVRRSTCON.

In order to perform voltage monitoring the EVRs shall be enabled. It is possible to supply all supply voltages externally and keep the EVRs active for voltage monitoring.

If the undervoltage monitoring detects for an enabled monitor a threshold violation the link reset (RSTSTAT.EVRx) is requested.

System Control Unit (SCU)

3.4.4 EVR Control Registers

EVRRSTCON

EVR Reset Control Register

(06C_H)

Reset Value: 10C9 86C7_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LCK	0	BPR ST5 OFF	RST 5OF F	BPR ST33 OFF	RST 33O FF	BPR ST13 OFF	RST 13O FF	RST50TRIM							
rh	rw	w	rw	w	rw	w	rw	rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RST33TRIM								RST13TRIM							
rw								rw							

Field	Bits	Type	Description
RST13TRIM	[7:0]	rw	1.3 V Regulator Reset Trim Value This bit field selects the reset generation level of the EVR13.
RST33TRIM	[15:8]	rw	3.3 V Regulator Reset Trim Value This bit field selects the reset generation level of the EVR33.
RST50TRIM	[23:16]	rw	5.0 V Pre-Regulator Reset Trim Value This bit field selects the reset generation level of the pre-regulator 5.0 detection.
RST13OFF	24	rw	Reset EVR13 Off 0 _B A reset trigger signal is generated and forward to the SCU by the EVR13 block depending on the selected reset trim value 1 _B No reset trigger signal is generated and forward to the SCU by the EVR13 block depending on the selected reset trim value This bit can only be changed if bit BPRST13OFF is set in parallel.
BPRST13OFF	25	w	Bit Protection RST13 Off Setting this bit enables that bit RST13OFF can be changed in this write operation. This bit read also as zero.

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Field	Bits	Type	Description
RST33OFF	26	rw	Reset EVR33 Off 0_B A reset trigger signal is generated and forward to the SCU by the EVR33 block depending on the selected reset trim value 1_B No reset trigger signal is generated and forward to the SCU by the EVR33 block depending on the selected reset trim value This bit can only be changed if bit BPRST33OFF is set in parallel.
BPRST33OFF	27	w	Bit Protection RST33 Off Setting this bit enables that bit RST33OFF can be changed in this write operation. This bit read also as zero.
RST5OFF	28	rw	Reset EVR5 Off 0_B A reset trigger signal is generated and forward to the SCU by the EVR5 block depending on the selected reset trim value 1_B No reset trigger signal is generated and forward to the SCU by the EVR5 block depending on the selected reset trim value This bit can only be changed if bit BPRST5OFF is set in parallel.
BPRST5OFF	29	w	Bit Protection RST5 Off Setting this bit enables that bit RST5OFF can be changed in this write operation. This bit read also as zero.
LCK	31	rh	Lock Status This bit indicates if the register can be updated with a new value or if the register is locked and a write action from the bus side has no effect. 0_B The register is unlocked and can be updated 1_B The register is locked and can not be updated
0	30	rw	Reserved Read as 0; should be written with 0.

3.5 Power Management

This section describes the power management system of the TC1728. Topics covered here include the internal system interfaces, external interfaces, and the operations of the CPU and peripherals.

3.5.1 Power Management Overview

The TC1728 power-management system allows software to configure the various processing units so that they automatically adjust to draw the minimum necessary power for the application.

As shown in [Table 3-15](#), there are three power management modes available:

- Run Mode
- Idle Mode
- Sleep Mode

Table 3-15 Power Management Mode Summary

Mode	Description
Run Mode	The system is fully operational. CPU and peripherals are enabled, as determined by software.
Idle Mode	The CPU is disabled, waiting for a condition to return it to Run Mode. Idle Mode can be entered by software when the processor has no active tasks to perform. Processor memory is accessible to peripherals. An Application Reset, Watchdog Timer event, an NMI trap, or any interrupt for the CPU will return the system to Run Mode.
Sleep Mode	Only those peripherals programmed to operate in Sleep Mode are active. The other peripheral module will be shut down. Interrupts for the CPU, a Watchdog Timer event, an NMI trap, or an Application Reset will return the system to Run Mode. Entering this state requires an orderly shut-down controlled by the Power Management State Machine.

The power-management modes provide flexible reduction of power consumption through a combination of techniques, including:

- Stopping the CPU
- Stopping other system components individually
- Clock-speed reduction of some peripheral components individually

The Power Management controls the power mode of all system components during Run Mode, Idle Mode, and Sleep Mode. This flexibility in power management provides minimum power consumption for any application.

In typical operation, Idle Mode and Sleep Mode may be entered and exited frequently during the run time of an application. For example, system software will typically cause

System Control Unit (SCU)

the CPU to enter Idle Mode each time it has to wait for an interrupt before continuing its tasks. In Sleep Mode and Idle Mode, wake-up is performed automatically when any interrupt is detected or if an NMI trap is activated.

3.5.2 Power Management Modes

This section describes in more detail the power management modes, their operations, and how power management modes are entered and exited. It also describes the behavior of TC1728 system components in all power management modes.

3.5.2.1 Idle Mode

The Idle Mode is requested by software when writing to register PMCSR.REQSLP = 01_B. The CPU finishes its current operation, sends an acknowledge to the Power Management, and then enters an inactive state in which the CPU and the DMI and PMI memory units are shut off.

Other system components that are able to write to register PMCSR can also request the Idle Mode. For example, the DMA controller can request Idle Mode by writing to the PMCSR register.

During Idle Mode, memory accesses to the DMI and PMI cause these units to awaken automatically to handle the transactions. When memory transactions are complete, the DMI and PMI return to Idle Mode again.

The system will return to Run Mode through the occurrence of any of the following conditions:

- An interrupt is received from an interrupt source of the CPU
- An NMI trap request is received
- An Application Reset is generated

If any of these conditions arise, the TC1728 immediately awakens and returns to Run Mode. If it is awakened by a reset, the TC1728 system begins its reset sequence. If it is awakened by a Watchdog Timer overflow event, it executes the instruction following the one that was last executed before Idle Mode was entered. If it is awakened by an NMI or interrupt, the CPU will immediately vector to the appropriate handler.

3.5.2.2 Sleep Mode

The Sleep Mode is requested by software when writing to register `PMCSR.REQSLP = 10B`.

Entering Sleep Mode

Sleep Mode is entered in two steps:

1. The CPU is put into Idle Mode as described in the previous section. When the Power Management receives the Idle acknowledge back from the CPU, it proceeds with the second step.
2. Each FPI Bus unit is requested to enter the Sleep Mode. The response of each FPI Bus unit to the sleep request is determined by its clock control register. These clock control registers must have been previously configured by software.

TC1728 State During Sleep Mode

Sleep Mode is disabled for a unit if `MOD_CLC.EDIS` is set. The sleep request is ignored in this case and the corresponding unit continues normal operation. If `MOD_CLC.EDIS` is cleared, Sleep Mode is enabled for this unit and the unit enters Sleep Mode. Two actions then occur:

- The unit finishes whatever bus transaction was in progress when the signal was received
- The unit functions are suspended

Depending on bit `MOD_CLC.FSOE`, the module is either immediately stopped (`MOD_CLC.FSOE = 1`), or the unit is allowed to finish ongoing operations (`MOD_CLC.FSOE = 0`) before the Sleep Mode is entered. For example, setting `MOD_CLC.FSOE` to 1 for a serial port will stop all actions in the serial port immediately when the sleep request is received. Ongoing transmissions or receptions will be aborted. If `MOD_CLC.FSOE` is cleared, ongoing transmissions or receptions will be completed, before Sleep Mode is entered. The purpose of setting `MOD_CLC.FSOE = 1` is to allow a debugger to observe the internal state of a peripheral unit immediately.

Exiting Sleep Mode

The system will be returned to Run Mode by the same events that exit Idle Mode. The response of the CPU to being awakened is also the same as for Idle Mode. Peripheral units that have entered Sleep Mode will switch back to their selected Run Mode operation.

3.5.3 Power Management Control and Status Register, PMCSR

The set of registers used for power management is divided between central TC1728 components and peripheral components. The PMCSR register provides software control

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and status information for the central part. There are individual clock control registers for peripheral components because the Sleep Mode behavior of each peripheral component is programmable. When entering Idle Mode and Sleep Mode, the Power Management directly controls TC1728 components such as the CPU, but indirectly controls peripheral components through their clock control registers.

PMCSR

Power Management Control and Status Register

(0B0_H)

Reset Value: 0000 0100_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				PMST				0				REQSLP			
r				rh				r				rwh			

Field	Bits	Type	Function
REQSLP	[1:0]	rwh	Idle Mode and Sleep Mode Request 00 _B Normal Run Mode 01 _B Request Idle Mode 10 _B Request Sleep Mode 11 _B Reserved; do not use this combination In Idle Mode or Sleep Mode, these bits are cleared in response to an interrupt for the CPU, or when bit 15 of the Watchdog Timer count register (the WDT_SR.TIM[15] bit) changes from 0 to 1.
PMST	[10:8]	rh	Power Management Status 000 _B Waiting for PLL lock condition 001 _B Normal Run Mode 010 _B Idle Mode requested 011 _B Idle Mode acknowledged 100 _B Sleep Mode 101 _B Reserved, do not use this combination 110 _B Reserved, do not use this combination 111 _B Reserved, do not use this combination

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Field	Bits	Type	Function
0	[7:2], [31:11]	r	Reserved Read as 0; should be written with 0.

3.6 Software Boot Support

In order to determine the correct starting point of operation for the software a minimum of hardware support is required. As much as possible is done via software. Some decisions have to be done in hardware because they must be known before any software is operational.

For a startup operation there are two general cases that have to be handled:

- Differentiation between Test Mode and Normal Mode for each Power-on Reset event (see [Section 3.6.1](#))
- Configuration of the boot option for each Application Reset event (see [Section 3.6.2](#))

3.6.1 Configuration done with Start-up

With the device power-on some basic operating mode selection has to be made. The first decision that has to be made is if the device should operate in Test Mode or in Normal (Customer) Mode. The Test Mode is only for Infineon internal usage not for any customer and has nothing to do with debugging.

If the Normal Mode was selected the next decision is which debug interface type issued for debugging for this session (until the next power-on event).

Table 3-16 Normal Mode / Test Mode Input Selection

Field	Description
TESTL	Latched TEST Signal 0 A Test Mode can be selected 1 Normal Mode is selected
TRSTL	Latched TRST Signal 0 The JTAG interface is active 1 The DAP interface is active

After these two decisions were made the detailed decision has to be made to define the real startup configuration. Most is made via the software and can be supported by some hardware selections depending on the startup configuration that should be selected.

3.6.2 Start-up Configuration Options

For the support of the start-up pins P0.0 to P0.7 are latched with the rising edge of the Application Reset and stored in register STSTAT.HWCFG. The update of bit field STSTAT.HWCFG with the latched value is only done if bit STSTAT.LUDIS is cleared. If bit STSTAT.LUDIS is set the value of STSTAT.HWCFG is not updated.

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3.6.3 Start-up Registers

3.6.3.1 Start-up Status Register

Register STSTAT contains the information required by the boot software to identify the different start-up settings that can be selected.

STSTAT

Start-up Status Register

(0C0_H)

Reset Value: 0000 8000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
					0						SPD EN	TRS TL	0	LU DIS	FCB AE
					r						rh	rh	r	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOD E				0											
rh				r								rh			

Field	Bits	Type	Description
HWCFG	[7:0]	rh	Hardware Configuration Setting This bit field contains the value that is used by the boot software. This bit field is updated in case of an Application Reset with the content by register SWRSTCON.SWCFG if bit SWRSTCON.SWBOOT AND RSTSTAT.SW are set. This bit field is updated in case of an Application Reset with the content of the latches of P0.0 to P0.7 if bit SWRSTCON.SWBOOT OR RSTSTAT.SW are cleared and bit STSTAT.LUDIS is cleared. This bit field is left unchanged in case of an Application Reset and is not updated with the content of the latches of P0.0 to P0.7 if bit SWRSTCON.SWBOOT OR RSTSTAT.SW are cleared and bit STSTAT.LUDIS is set. This bit field is updated with the value written to bit field STCON.HWCFG on a software write action.

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Field	Bits	Type	Description
Mode	15	rh	Mode This bit indicates if the Test Mode is entered or not. 0 _B A Test Mode can be selected 1 _B Normal Mode is selected
FCBAE	16	rh	Flash Config. Sector Access Enable 0 _B Flash config sector is not accessible. Instead the flash memory area is accessed. 1 _B Flash config sector is accessible. The flash memory area can not be accessed. This bit can be cleared by setting bit STCON.CFCBAE. This bit can be set by setting bit STCON.SFCBAE.
LUDIS	17	rh	Latch Update Disable 0 _B Bit field STSTAT.HWCFG is automatically updated with the latched value of pins P0.0 to P0.7 1 _B Bit field STSTAT.HWCFG is not updated with the latched value of pins P0.0 to P0.7 This bit can be set by setting bit SYSCON.SETLUDIS.
TRSTL	19	rh	TRSTL Status This bit simply displays the value of TRSTL.
SPDEN	20	rh	Single Pin DAP Mode Enable 0 _B Single Pin DAP Mode is disabled 1 _B Single Pin DAP Mode is enabled
0	[14:8], 18, [31:21]	r	Reserved Read as 0; should be written with 0.

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STCON

Start-up Configuration Register

(0C4_H)

Reset Value: 0000 8000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STP	CFC BAE	SFC BAE			0										
rw	w	w			r								w		

Field	Bits	Type	Description
HWCFG	[7:0]	w	Hardware Configuration Setting Writing to this bit field updates bit field STSTAT.HWCFG. Reading this bit field returns zero.
SFCBAE	13	w	Set Flash Config. Sector Access Enable Setting this bit sets bit STSTAT.FCBAE. Reading this bit returns always a zero. <i>Note: This bit may not be set in parallel with bit CFCBAE.</i>
CFCBAE	14	w	Clear Flash Config. Sector Access Enable Setting this bit clears bit STCON.FCBAE. Reading this bit returns always a zero. <i>Note: This bit may not be set in parallel with bit SFCBAE.</i>
STP	15	rw	Start-up Protection Setting 0 _B Start-up code is executed. Start-up protection is disabled. 1 _B Start-up code protection is active This bit is also cleared by an Application Reset.
0	[12:8], [31:16]	r	Reserved Read as 0; should be written with 0.

3.7 ECC Error Handling

The on-chip RAM and flash modules check ECC information during read accesses and in case of an error a signal is generated. These signals are combined and trigger a trap.

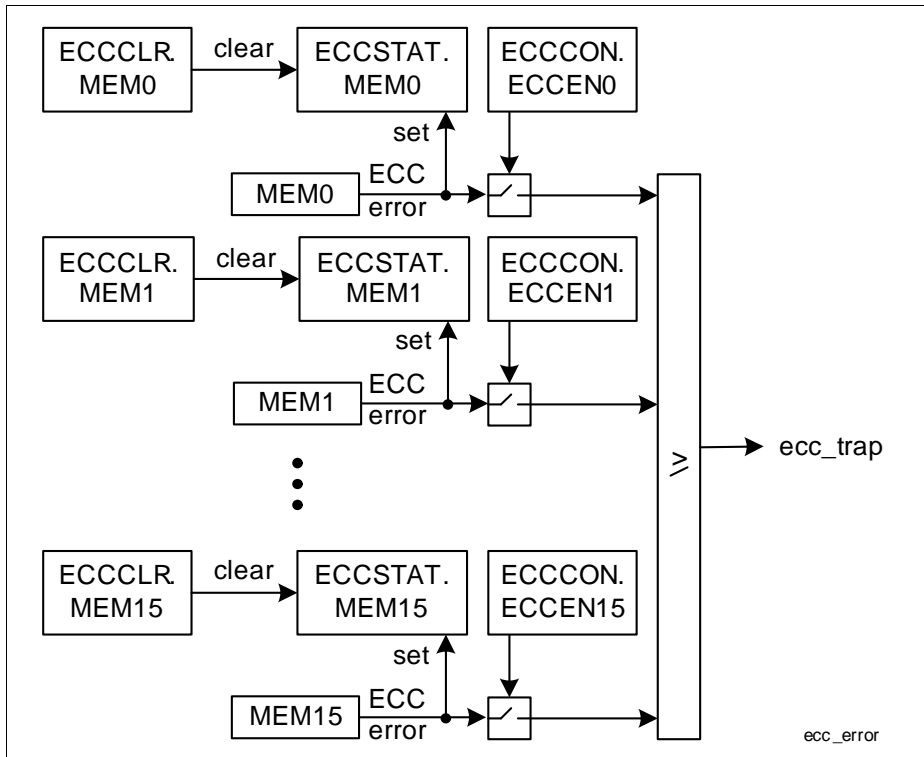


Figure 3-31 ECC Error Control Logic

3.7.1 ECC Software Testing Support

This can be done for each module individually by simply disabling the ECC protection in the module change the content of a memory address enable ECC again and read the memory address again. For more information see the different module chapters.

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Field	Bits	Type	Description
ECCENPTAG	3	rw	ECC Error Trap Enable for Program Cache TAG RAM Memory This bit determine whether a trap is requested if an uncorrected ECC error is detected in the program cache TAG RAM memory. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested
ECCENPMU	4	rw	ECC Error Trap Enable for PMU Memory This bit determine whether a trap is requested if an uncorrected ECC error is detected in the PMU memory. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested
ECCENPRAM	5	rw	ECC Error Trap Enable for PCP Parameter RAM This bit determine whether a trap is requested if an uncorrected ECC error is detected in the PCP Parameter RAM. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested
ECCENCMEM	6	rw	ECC Error Trap Enable for PCP Code Memory This bit determine whether a trap is requested if an uncorrected ECC error is detected in the PCP Code memory. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested
ECCENCAN	7	rw	ECC Error Trap Enable for CAN Memory This bit determine whether a trap is requested if an uncorrected ECC error is detected in the CAN memory. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested
ECCENERAY	8	rw	ECC Error Trap Enable for ERAY Memory This bit determine whether a trap is requested if an uncorrected ECC error is detected in the ERAY memories. 0 _B No ECC error trap trigger is requested 1 _B A ECC error trap trigger is requested

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Field	Bits	Type	Description
ECCENLMB	9	rw	ECC Error Trap Enable for LMB This bit determine whether a trap is requested if an uncorrected ECC error is detected by the LMB. 0_B No ECC error trap trigger is requested 1_B A ECC error trap trigger is requested
ECCENBMU	11	rw	ECC Error Trap Enable for BMU This bit determine whether a trap is requested if an uncorrected ECC error is detected by the BMU. 0_B No ECC error trap trigger is requested 1_B A ECC error trap trigger is requested
0	10, [15:12]	rw	Reserved Should be written with 0.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: Register ECCCON is Endinit-protected for write operations.

ECCSTAT

ECC Status Register

(0D4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				BMU	0	LMB	ERA Y	CAN	C MEM	P RAM	PMU	P TAG	SP RAM	D TAG	LD RAM
r				rh		r	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
LDRAM	0	rh	ECC Error Flag for LDRAM and DCACHE Memory This bit indicate whether an ECC error has been detected in the LDRAM / DCACHE memory. 0_B No ECC error detected 1_B ECC error is detected

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Field	Bits	Type	Description
DTAG	1	rh	ECC Error Flag for Data Cache TAG RAM Memory This bit indicate whether an ECC error has been detected in the data TAG RAM memory. 0_B No ECC error detected 1_B ECC error is detected
SPRAM	2	rh	ECC Error Flag for SPRAM and ICACHE Memory This bit indicate whether an ECC error has been detected in the SPRAM / ICACHE memory. 0_B No ECC error detected 1_B ECC error is detected
PTAG	3	rh	ECC Error Flag for Program Cache TAG RAM Memory This bit indicate whether an ECC error has been detected in the program TAG RAM memory. 0_B No ECC error detected 1_B ECC error is detected
PMU	4	rh	ECC Error Flag for PMU Memory This bit indicate whether an ECC error has been detected in the PMU memory. 0_B No ECC error detected 1_B ECC error is detected
PRAM	5	rh	ECC Error Flag for Parameter RAM Memory This bit indicate whether an ECC error has been detected in the Parameter RAM memory. 0_B No ECC error detected 1_B ECC error is detected
CMEM	6	rh	ECC Error Flag for Code Memory This bit indicate whether an ECC error has been detected in the code memory. 0_B No ECC error detected 1_B ECC error is detected
CAN	7	rh	ECC Error Flag for CAN Memory This bit indicate whether an ECC error has been detected in the CAN memory. 0_B No ECC error detected 1_B ECC error is detected

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Field	Bits	Type	Description
ERAY	8	rh	ECC Error Flag for ERAY Memory This bit indicate whether an ECC error has been detected in the ERAY memory. 0_B No ECC error detected 1_B ECC error is detected
LMB	9	rh	ECC Error Flag for LMB-Bus This bit indicate whether an ECC error has been detected in the LMB-Bus. 0_B No ECC error detected 1_B ECC error is detected
BMU	11	rh	ECC Error Flag for BMU Memory This bit indicate whether an ECC error has been detected in the BMU memory. 0_B No ECC error detected 1_B ECC error is detected
0	10, [31:12]	r	Reserved Read as 0; should be written with 0.

ECCCLR

ECC Clear Register

(0D8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				BMU	0	LMB	ERAY	CAN	C MEM	P RAM	PMU	P TAG	SP RAM	D TAG	LD RAM
r				w	r	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
LDRAM	0	w	Clear LDRAM and DCACHE ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.LDRAM This bit always read as 0.

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Field	Bits	Type	Description
DTAG	1	w	Clear Data Cache TAG RAM ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.DTAG This bit always read as 0.
SPRAM	2	w	Clear SPRAM and ICACHE ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.SPRAM This bit always read as 0.
PTAG	3	w	Clear Program Cache TAG RAM ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.PTAG This bit always read as 0.
PMU	4	w	Clear PMU Memory ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.PMU This bit always read as 0.
PRAM	5	w	Clear Parameter RAM Memory ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.PRAM This bit always read as 0.
CMEM	6	w	Clear Parameter Code Memory ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.CMEM This bit always read as 0.
CAN	7	w	Clear CAN Memory ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.CAN This bit always read as 0.
ERAY	8	w	Clear ERAY Memory ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.ERAY This bit always read as 0.
LMB	9	w	Clear LMB-Bus ECC Error Status 0_B No action 1_B Setting this bit clears bit ECCSTAT.LMB This bit always read as 0.

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Field	Bits	Type	Description
BMU	11	w	Clear BMU Memory ECC Error Status 0 _B No action 1 _B Setting this bit clears bit ECCSTAT.BMU This bit always read as 0.
0	10, [31:12]	r	Reserved Read as 0; should be written with 0.

3.8 Watchdog Timer

This section describes the TC1728 Watchdog Timer (WDT). Topics include an overview of the WDT function and descriptions of the registers, the password-protection scheme, accessing registers, modes, and initialization.

3.8.1 Watchdog Timer Overview

The WDT provides a highly reliable and secure way to detect and recover from software or hardware failure. The WDT helps to abort an accidental malfunction of the TC1728 in a user-specified time period. When enabled, the WDT can cause the TC1728 system to be reset if the WDT is not serviced within a user-programmable time period. The CPU must service the WDT within this time interval to prevent the WDT from causing a TC1728 System or Application Reset. Hence, routine service of the WDT confirms that the system is functioning properly.

In addition to this standard "Watchdog" function, the WDT incorporates the End-of-Initialization (Endinit) feature and monitors its modifications.

Because servicing the Watchdog and modifications of the ENDINIT bit are critical functions that must not be allowed in case of a system malfunction, a sophisticated scheme is implemented that requires a password and guard bits during accesses to the WDT control register. Any write access that does not deliver the correct password or the correct value for the guard bits is regarded as a malfunction of the system, and a Watchdog reset is requested. In addition, even after a valid access has been performed and the ENDINIT bit has been cleared to provide access to the critical registers, the Watchdog imposes a time limit for this access window. If bit ENDINIT has not been properly set again before this limit expires, the system is assumed to have malfunctioned, and a Watchdog reset is requested. These stringent requirements, although not guaranteed, nonetheless provide a high degree of assurance of the robustness of system operation.

A further enhancement in the TC1728's WDT is its reset prewarning operation. Instead of immediately resetting the device on the detection of an error (the way that standard Watchdogs do), the WDT first issues a Non-Maskable Interrupt (NMI) to the CPU before finally resetting the device at a specified time period later.

3.8.2 Features of the Watchdog Timer

The main features of the WDT are summarized here.

- 16-bit Watchdog counter
- Selectable input frequency: $f_{FPI}/256$ or $f_{FPI}/16384$
- 16-bit user-definable reload value for normal Watchdog operation, fixed reload value for Time-Out and Prewarning Modes
- Incorporation of the ENDINIT bit and monitoring of its modifications

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- Sophisticated Password Access mechanism with fixed and user-definable password fields
- Access Error Detection: Invalid password (during first access) or invalid guard bits (during second access) trigger the Watchdog reset generation
- Overflow Error Detection: An overflow of the counter triggers the Watchdog reset generation
- Watchdog function can be disabled; access protection and ENDINIT bit monitor function remain enabled
- Double Reset Detection

3.8.3 The Endinit Function

It is a prerequisite to understand the ENDINIT bit and its function for better understanding of the descriptions in the following sections. Hence, its function is explained first.

There are a number of registers in the TC1728 that are usually programmed only once during the initialization sequence of the application. Modification of such registers during normal application run can have a severe impact on the overall operation of modules or the entire system.

While the Supervisor Mode, that allows writes to registers only when it is active, provides a certain level of protection against unintentional modifications, it may not provide enough security for system-critical registers.

The TC1728 provides one more level of protection for such registers via the Endinit feature. This is a highly secure write-protection scheme that makes unintentional modifications of registers protected by this feature nearly impossible.

The Endinit feature consists of an ENDINIT bit incorporated in the WDT control register, WDT_CON0. Registers protected via Endinit determine whether or not writes are enabled. Writes are only enabled if bit ENDINIT = 0 AND Supervisor Mode is active. Write attempts if this condition is not true will be discarded and the register contents will not be modified in this case. The BCU controls the further operation following a discarded write access.

To get the highest level of security, this bit is incorporated in the highly secure access protection scheme implemented in the WDT. This is a complex procedure, that makes it nearly impossible for the ENDINIT bit to be modified unintentionally. In addition, the WDT monitors ENDINIT bit modifications by starting a time-out sequence each time software opens access to the critical registers through clearing bit ENDINIT. If the time out period ends before bit ENDINIT is set again, a malfunction of the software is assumed and a reset request is generated.

The access-protection scheme and the Endinit time-out operation of the WDT is described in the following sections. [Table 3-17](#) lists the registers that are protected via the Endinit feature in the TC1728.

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Note: The clearing of the ENDINIT bit takes some time. Accesses to Endinit-protected registers after the clearing of the ENDINIT bit must only be done when bit ENDINIT is really cleared. As a solution, WDT_CON0 (the register with the ENDINIT bit) should be read back once before Endinit-protected registers are accessed the first time after bit ENDINIT has been cleared.

Table 3-17 TC1728 Registers Protected via the Endinit Feature

Register Name	Description
mod_CLC	All clock control registers of the individual peripheral modules are Endinit-protected
mod_FDR	All clock fractional divider registers of the individual peripheral modules are Endinit-protected
BTV, BIV, ISP	Trap and interrupt vector table pointer as well as the interrupt stack pointer are Endinit-protected
MIECON SMACON COMPAT	CPU Control Registers
FLASH0_FCON FLASH0_MARP	Flash configuration registers
WDT_CON1	The Watchdog Timer Control Register 1, which controls the disabling and the input frequency of the Watchdog Timer, is Endinit-protected. In addition, its bits will only have an effect on the WDT when ENDINIT is properly set to 1 again.
SCU_OSCCON SCU_PLLCON0 SCU_PLLCON1 SCU_CCUCON0 FDR SCU_CCUCON1	All clock control registers are protected
SCU_RSTCNTCON SCU_RSTCON SCU_ARSTDIS SCU_SWRSTCON	All reset control registers are protected
SCU_ESRCFG0 SCU_ESRCFG1	All ESR control registers are protected
SCU_EMSR	The emergency stop register

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Table 3-17 TC1728 Registers Protected via the Endinit Feature (cont'd)

Register Name	Description
SCU_TRAPSET SCU_TRAPDIS	The trap set and disable register
Px_ESR Px_PDR	Port Control Registers
DMA_MExARR DMA_MExAENR DMA_OCDSR DMA_SUSPMR	DMA Control Registers
PCP_CS	PCP Control Registers
DMI_CON	DMI Control Registers

3.8.3.1 Password Access to WDT_CON0

A correct password must be written to register WDT_CON0 in order to unlock it for modifications. Software must either know the correct password in advance or compute it at runtime. The password required to unlock the register is formed by a combination of bits in registers WDT_CON0 and WDT_CON1, plus a number of guard bits. [Table 3-18](#) summarizes the requirements for the password.

Table 3-18 Password Access Bit Pattern Requirements

Bit Position	Required Value
0	Current state of bit WDT_CON0.ENDINIT
1	Fixed; must be written with 0
2	Current state of bit WDT_CON1.IR
3	Current state of bit WDT_CON1.DR
[7:4]	Fixed; must be written to 1111 _B
[15:8]	Current value of user-definable password field WDT_CON0.PW
[31:16]	Current value of user-definable reload value, WDT_CON0REL

The password is designed such that it is not possible to just read the contents of a register and use this as the password. The password is never identical to the contents of WDT_CON0 or WDT_CON1, it is always required to modify the read value (at least bits 1 and [7:4]) to get the correct password. This prevents a malfunction from accidentally reading a WDT register's contents and writing it to WDT_CON0 as an unlocking password.

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If the password matches the requirements, WDT_CON0 will be unlocked as soon as the Password Access is completed. The unlocked condition will be indicated by WDT_CON0.LCK = 0.

If an improper password value is written to WDT_CON0 during the Password Access, a Watchdog Access Error condition exists. Bit WDT_SR.AE is set and the Prewarning Mode is entered.

The user-definable password, WDT_CON0.PW, provides additional options for adjusting the password requirements to the application's needs. It can be used, for instance, to detect unexpected software loops, or to monitor the execution sequence of routines.

3.8.3.2 Modify Access to WDT_CON0

If WDT_CON0 is successfully unlocked, the following write access to WDT_CON0 can modify it. However, this access must also meet certain requirements in order to be accepted and regarded as valid. [Table 3-19](#) lists the required bit patterns. If the access does not follow these rules, a Watchdog Access Error condition is detected, bit WDT_SR.AE is set, and the Prewarning Mode is entered.

Table 3-19 Modify Access Bit Pattern Requirements

Bit Position	Value
0	User-definable; desired value for bit WDT_CON0.ENDINIT.
1	Fixed; must be written with 1.
2	Fixed; must be written with 0.
3	Fixed; must be written with 0.
[7:4]	Fixed; must be written with 1111 _B .
[15:8]	User-definable; desired value of user-definable password field, WDT_CON0.PW.
[31:16]	User-definable; desired value of user-definable reload value, WDT_CON0.REL.

After the Modify Access has completed, WDT_CON0.LCK is set again, automatically re-locking WDT_CON0. Before the register can be modified again, a valid Password Access must be executed again.

3.8.3.3 Access to Endinit-Protected Registers

If some or all of the system's Endinit-protected registers must be changed during run time of an application, access can be re-opened. To do this, WDT_CON0 must first be unlocked with a Valid Password Access. In the subsequent Valid Modify Access,

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ENDINIT can be cleared. Access to Endinit-protected registers is now open again. However, when WDT_CON0 is unlocked, the WDT is automatically switched to Time-Out Mode. Thus, the access window is time-limited. Time-Out Mode is only terminated after ENDINIT has been set again, requiring another Valid Password and Valid Modify Access to WDT_CON0.

If the WDT is not used in an application and is therefore disabled ($WDT_SR.DS = 1$), the above described case is the only occasion when WDT_CON0 must be accessed again after the system is initialized. If there are no further changes to critical system registers needed, no further accesses to WDT_CON0, WDT_CON1, or WDT_SR are necessary. However, it is recommended that the WDT be used in an application for safety reasons.

For debugging support the Cerberus module can override the ENDINIT control to ease the debug flow. If bit CBS_OSTATE.ENIDIS is set the ENDINIT protection is disabled independent of the current status configured by the WDT. If CBS_OSTATE.ENIDIS is cleared the complete control is within the WDT.

3.8.4 Timer Operation

The timer is automatically active after an Application Reset. The 16-bit counter implementing the timer functionality is either triggered with $f_{FPI} / 256$ or $f_{FPI} / 16384$. The two possible counting rates are controlled via bit WDT_CON1.IR.

Determining WDT Periods

The WDT uses the FPI-Bus clock f_{FPI} . A clock divider in front of the WDT provides two output frequencies, $f_{FPI} / 256$ and $f_{FPI} / 16384$.

The general formula to calculate a Watchdog period is:

$$\text{period} = \frac{(2^{16} - \text{startvalue}) \cdot 256 \cdot 2^{(1-IR) \cdot 6}}{f_{FPI}} \quad (3.19)$$

The parameter start value represents the fixed value $FFFC_H$ for the calculation of the Time-Out Period, and the user-programmable reload value WDT_CON0.REL for the calculation of the Normal Period.

3.8.4.1 Timer Modes

The Watchdog Timer can operate in one of four different operating modes:

- Time-Out Mode
- Normal Mode
- Disable Mode
- Prewarning Mode

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The following overview describes these modes and how the WDT changes from one mode to the other.

Time-Out Mode

The Time-Out Mode is entered after an Application Reset or when a valid Password Access to register WDT_CON0 is performed (see [Section 3.8.3.1](#)). The Time-Out Mode is indicated by bit WDT_SR.TO = 1. The timer is set to $FFFC_H$ and starts counting upwards. Time-Out Mode can only be exited properly by setting ENDINIT = 1 with a correct access sequence. If an improper access to the WDT is performed, or if the timer overflows before ENDINIT is set, a WDT_NMI is requested, and Prewarning Mode is entered.

A proper exit from Time-Out Mode can either be to the Normal or the Disable Mode, depending on the state of the disable request bit WDT_CON1.DR.

Normal Mode

In Normal Mode (DR = 0), the WDT operates in a standard Watchdog fashion. The timer is set to WDT_CON0.REL, and begins counting up. It has to be serviced before the counter overflows. Servicing is performed through a proper access sequence to the control register WDT_CON0. This enters the Time-Out Mode.

If the WDT is not serviced before the timer overflows, a system malfunction is assumed. Normal Mode is terminated, a WDT_NMI is requested, and Prewarning Mode is entered.

Disable Mode

Disable Mode is provided for applications which truly do not require the WDT function. It can be requested from Time-Out Mode when the disable request bit WDT_CON1.DR is set. The Disable Mode is entered when was requested AND bit WDT_CON0.ENDINIT is set. The timer is stopped in this mode. However, disabling the WDT only stops it from performing the standard Watchdog function, eliminating the need for timely service of the WDT. It does not disable Time-Out and Prewarning Mode. If an access to register WDT_CON0 is performed in Disable Mode, Time-Out Mode is entered if the access was valid, and Prewarning Mode is entered if the access was invalid. Thus, the ENDINIT monitor function as well as (a part of) the system malfunction detection will still be active.

Prewarning Mode

Prewarning Mode is entered always when a Watchdog error is detected. This can be due to an overflow of the timer in Normal or Time-Out Mode, or an invalid access to register WDT_CON0. Instead of immediately requesting a reset of the device, the WDT enables the system to enter a secure state by a prewarning before the reset occurs.

In Prewarning Mode, after having generated the NMI request, the WDT counts up from $FFFC_H$, and then generates a Watchdog reset request on the overflow. This reset

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request cannot be avoided in this mode; the WDT does not react anymore to accesses to its registers, nor will it change its state unless reset by an Application Reset. This is to prevent a malfunction from falsely terminating this mode, disabling the reset, and letting the device to continue to function improperly. Register WDT_CON0 can still be accessed by a valid Password Access.

Note: In Prewarning Mode, it is not required for the part to wait for the end of this mode and the reset. After having saved required state in the NMI routine, software can execute an Application Reset to shorten the time.

Note: The Prewarning Mode is only left by an application Reset and not only on the reset request. Therefore if bit field RSTCON.WDT is set to 00_B the Prewarning Mode is not left.

3.8.4.2 WDT Reset Behavior

WDT reset requests are generated for three cases:

- Invalid password access to register WDT_CON0
- Not finishing a password access before a timer overflow occurs in the Time-Out Mode
- Not serving the WDT before a timer overflow occurs in the Normal Mode

If a reset is generated on a WDT reset request and the kind of the reset can be configured via bit field RSTCON.WDT.

Note: The WDT itself is reset by any Application Reset.

Before a reset is requested the Prewarning Mode is entered, for more details see [Section 3.8.4.1](#).

Double WDT Reset

If the Watchdog induced reset occurs twice, a severe system malfunction is assumed and the TC1728 is held in reset until a System Reset occurs. This prevents the device from being periodically reset if, for instance, connection to the external memory has been lost such that even system initialization could not be performed.

If the WDT is configured to request an Application Reset the second reset request will be permanently asserted resulting (without any change in the reset configuration) resulting in a permanent Application Reset. The information about the first WDT reset request is stored in an internal flag which is reset with the System Reset. This flag is set when the Prewarning Mode is finished and the reset request is generated. If a new reset is requested and the internal flag is already set a double reset event has occurred and a permanent request is generated. This internal flag is cleared by any System Reset or when bit WDT_CON1.CLRIRF is set AND bit WDT_CON0.ENDINIT is set too. Please note that a correct service of the WDT does not clear this internal flag. Bit WDT_CON1.CLRIRF can only be set when bit WDT_CON0.ENDINIT is cleared.

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Note: It does not matter whether a reset was generated on a WDT reset request or if the reset configuration was changed between the two reset requests.

Note: If for any reason random code is executed bit field RSTCON.WDT can be updated unintentional. This can result that a WDT error does not lead to an reset. To avoid this after the SSW is finished this bit field should be checked and the ENDINIT protection enabled.

Servicing the Watchdog Timer

If the WDT is used in an application and is enabled ($\text{WDT_SR.DS} = 0$), it must be regularly serviced to prevent it from overflowing.

Service is performed in two steps. a Valid Password Access followed by a Valid Modify Access. The Valid Password Access to WDT_CON0 automatically switches the WDT to Time-Out Mode. Thus, the Modify Access must be performed before the Time-out expires or a System Reset will result.

During the next Modify Access, the strict requirement is that WDT_CON0.ENDINIT as well as bit 1 and bits [7:4] are written with 1, while bits [3:2] are written with 0.

Note: ENDINIT must be written with 1 to perform a proper service, even if it is already set to 1.

Changes to the reload value WDT_CON0.REL , or the user-definable password WDT_CON0.PW , are not required. However, changing WDT_CON0.PW is recommended so that software can monitor WDT service operations throughout the duration of an application program (see next section).

When WDT service is properly executed, Time-Out Mode is terminated, and the WDT switches back to its former mode of operation, and WDT service is complete.

3.8.4.3 WDT Operation During Power-Saving Modes

If the CPU is in Idle Mode or Sleep Mode, it cannot service the WDT because no software is running. Excluding the case where the system is running normally, a strategy for managing the WDT is needed while the CPU is in Idle or Sleep Mode. There are two ways to manage the WDT in these cases. First, the Watchdog can be disabled before idling the CPU. The disadvantage of this is that the system will no longer be monitored during the idle period.

A better approach to this problem relies upon a wake-up feature of the WDT. Whenever the CPU is put in Idle or Sleep Mode and the WDT is not disabled, it causes the CPU to be awakened at regular intervals. When the WDT changes its count value (WDT_SR.TIM) from $7FFF_H$ to 8000_H , the CPU is awakened and continues to execute the instruction following the instruction that was last executed before entering the Idle or Sleep Mode.

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Note: Before switching into a non-running power-management mode, software should perform a Watchdog service sequence. At the Modify Access, the Watchdog reload value, WDT_CON0.REL, should be programmed such that the wake-up occurs after a period which best meets application requirements. The maximum period between two CPU wake-ups is one-half of the maximum WDT period.

3.8.4.4 Suspend Mode Support

In an enabled and active debug session the Watchdog functionality can lead to unintended resets. Therefore to avoid these resets the OCDS can control if the WDT is enabled or disabled (default after Application Reset) via bit CBS_OSTATE.WDTSUS if it is not already stopped.

Table 3-20 OCDS Behavior of WDT

STCON. STP	WDT_ SR.DS	CBS_OSTATE. OEN	CBS_OSTATE. SUS	CBS_MCDSSG. SOS	WDT Action
0	X	X	X	X	Stopped
1	1	X	X	X	Stopped
1	0	0	X	X	Running
1	0	1	0	X	Stopped
1	0	1	1	0	Running
1	0	1	1	1	Stopped

3.8.5 Watchdog Timer Registers

3.8.5.1 Watchdog Timer Control Register 0

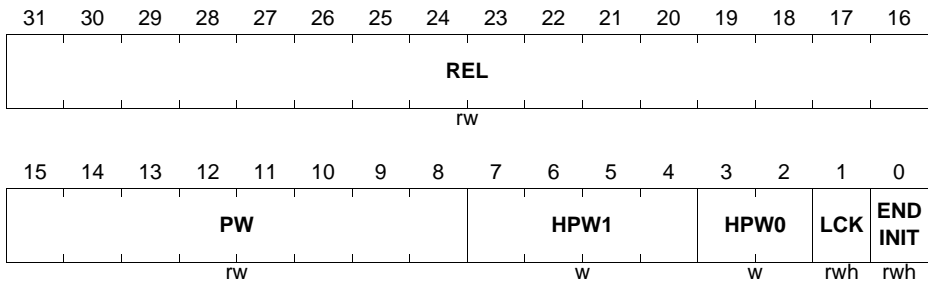
Register WDT_CON0 manages Password Access to the Watchdog Timer. It also stores the timer reload value, a user-definable password field, a lock bit, and the End-of-Initialization (ENDINIT) control bit.

System Control Unit (SCU)

WDT_CON0

WDT Control Register 0

(F000 05F0_H)

Reset Value: FFFC 0002_H


Field	Bits	Type	Description
ENDINIT	0	rwh	End-of-Initialization Control Bit 0 _B Access to Endinit-protected registers is permitted (default after Application Reset) 1 _B Access to Endinit-protected registers is not permitted
LCK	1	rwh	Lock Bit to Control Access to WDT_CON0 0 _B Register WDT_CON0 is unlocked 1 _B Register WDT_CON0 is locked (default after Application Reset) The actual value of LCK is controlled by hardware. It is cleared after a valid Password Access to WDT_CON0, and automatically set again after a valid Modify Access to WDT_CON0. During a write to WDT_CON0, the value written to this bit is only used for the password-protection mechanism and is not stored. This bit must be cleared during a Password Access to WDT_CON0, and set during a Modify Access to WDT_CON0. That is, the inverted value read from LCK always must be written to itself.

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Field	Bits	Type	Description
HPW0	[3:2]	w	Hardware Password 0 This bit field must be written with the value of the bits WDT_CON1.DR and WDT_CON1.IR during a Password Access. This bit field must be written with 0s during a Modify Access to WDT_CON0. When read, these bits always return 0.
HPW1	[7:4]	w	Hardware Password 1 This bit field must be written with 1111 _B during both Password Access and Modify Access to WDT_CON0. When read, these bits always return 0.
PW	[15:8]	rw	User-Definable Password Field for Access to WDT_CON0 This bit field must be written with its current contents during a Password Access. It can be changed during a Modify Access to WDT_CON0.
REL	[31:16]	rw	Reload Value for the WDT If the Watchdog Timer is enabled and in Normal Timer Mode, it will start counting from this value after a correct Watchdog service. This bit field must be written with its current contents during a Password Access. It can be changed during a Modify Access to WDT_CON0 (FFFC _H = default after Application Reset).

3.8.5.2 Watchdog Timer Control Register 1

WDT_CON1 manages operation of the WDT. It includes the disable request and frequency selection bits. It is ENDINIT-protected.

System Control Unit (SCU)

WDT_CON1

WDT Control Register 1

(F000 05F4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												DR	IR	0	CLR IRF
r												rw	rw	r	rwh

Field	Bits	Type	Description
CLRIRF	0	rwh	Clear Internal Reset Flag This bit is used to request a clear of the internal flag storing the information about the first WDT reset request. 0_B No action 1_B Request to clear the internal flag This bit can only be modified if WDT_CON0.ENDINIT is cleared. The internal flag is cleared when ENDINIT is set again. As long as ENDINIT is cleared, the internal flag is unchanged and controls the current past error status of the WDT. When ENDINIT is set again with a Valid Modify Access, the internal flag is cleared together with this bit.
IR	2	rw	Input Frequency Request Control Bit 0_B Request to set input frequency to $f_{FPI}/16384$. 1_B Request to set input frequency to $f_{FPI}/256$. This bit can only be modified if WDT_CON0.ENDINIT is cleared. WDT_SR.IS is updated by this bit only when ENDINIT is set again. As long as ENDINIT is cleared, WDT_SR.IS controls the current input frequency of the Watchdog Timer. When ENDINIT is set again, WDT_SR.IS is updated with the state of IR.

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Field	Bits	Type	Description
DR	3	rw	Disable Request Control Bit 0_B Request to enable the WDT 1_B Request to disable the WDT This bit can only be modified if WDT_CON0.ENDINIT is cleared. WDT_SR.DS is updated when ENDINIT is set again. As long as ENDINIT is cleared, bit WDT_SR.DS controls the current enable/disable status of the WDT. When ENDINIT is set again with a Valid Modify Access, WDT_SR.DS is updated with the state of DR.
0	1, [31:4]	r	Reserved Read as 0; should be written with 0.

3.8.5.3 Watchdog Timer Status Register

Register WDT_SR shows the current state of the WDT. Status include bits indicating reset prewarning, Time-Out, enable/disable status, input clock status, and access error status.

WDT_SR

WDT Status Register

(F000 05F8_H)

Reset Value: FFFC 0010_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TIM															
rh															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										PR	TO	DS	IS	OE	AE
r										rh	rh	rh	rh	rh	rh

System Control Unit (SCU)

Field	Bits	Type	Description
AE	0	rh	Watchdog Access Error Status Flag 0_B No Watchdog access error 1_B A Watchdog access error has occurred This bit is set when an illegal Password Access or Modify Access to register WDT_CON0 was attempted. This bit is only cleared when WDT_CON0.ENDINIT is set during a Valid Modify Access However, it is not possible to clear this bit if the WDT is in Prewarning Mode.
OE	1	rh	Watchdog Overflow Error Status Flag 0_B No Watchdog overflow error 1_B A Watchdog overflow error has occurred This bit is set when the WDT overflows from $FFFF_H$ to 0000_H . This bit is only cleared when WDT_CON0.ENDINIT is set to 1 during a Valid Modify Access. However, it is not possible to clear this bit if the WDT is in Prewarning Mode.
IS	2	rh	Watchdog Input Clock Status Flag 0_B The timer operation clock is $f_{FPI}/16384$ (default after Application Reset) 1_B The timer operation clock is $f_{FPI}/256$ This bit is updated with the state of bit WDT_CON1.IR after WDT_CON0.ENDINIT is written with 1 during a Valid Modify Access to register WDT_CON0.
DS	3	rh	Watchdog Enable/Disable Status Flag 0_B WDT is enabled (default after Application Reset) 1_B WDT is disabled This bit is updated with the state of bit WDT_CON1.DR after WDT_CON0.ENDINIT is set during a Valid Modify Access to register WDT_CON0.

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Field	Bits	Type	Description
TO	4	rh	Watchdog Time-Out Mode Flag 0 _B The Watchdog is not operating in Time-Out Mode 1 _B The Watchdog is operating in Time-Out Mode (default after Application Reset) This bit is set when Time-Out Mode is entered. It is automatically cleared when Time-Out Mode is left.
PR	5	rh	Watchdog Prewarning Mode Flag 0 _B The Watchdog is not operating in Prewarning Mode 1 _B The Watchdog is operating in Prewarning Mode This bit is set when a Watchdog error is detected. The WDT has issued a trap trigger and is in Prewarning Mode. A reset of the chip occurs after the prewarning period has expired if it is enabled in bit field RSTCON.WDT.
TIM	[31:16]	rh	Timer Value Reflects the current content of the WDT.
0	[15:6]	r	Reserved Read as 0.

3.9 Emergency Stop Output Control

The emergency stop feature of the TC1728 allows for a fast emergency reaction on an external event without the intervention of software. In an emergency case, the outputs can be selectively put immediately to a well-defined logic state (for more information see the port chapter).

The emergency case is indicated by an emergency input signal with selectable polarity that has to be connected to input P..

shows a diagram of the emergency stop input logic. This logic is controlled by the SCU Emergency Stop Register EMSR.

The emergency stop control logic for the ports can basically operate in two modes:

- Synchronous Mode (default after reset):
Emergency case is activated by hardware and released by software.
- Asynchronous Mode:
Emergency case is activated and released by hardware.

In Synchronous Mode (selected by `EMSR.MODE = 0`), the port signal is sampled for a inactive-to-active level transition, and an emergency stop flag `EMSR.EMSF` is set if the transition is detected. The setting of `EMSR.EMSF` activates the emergency stop signal. An emergency case can only be terminated by clearing `EMSR.EMSF` via software. The synchronous control logic is clocked by the system bus clock f_{FPI} . This results in a small delay between the port signal and emergency stop signal generation.

In Asynchronous Mode (selected by `EMSR.MODE = 1`), the occurrence of an active level at the port input immediately activates the emergency stop signal. Of course, a valid-to-invalid transition of the port input (emergency case is released) also immediately deactivates the emergency stop signal.

The `EMSR.POL` bit determines the active level of the input signal. The `EMSR.MODE` bit selects Synchronous or Asynchronous Mode for emergency stop signal generation.

System Control Unit (SCU)

3.9.1 Emergency Stop Register

The Emergency Stop Register EMSR contains control and status bits/flags of the emergency stop input logic.

EMSR

Emergency Stop Register

(100_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						EMSM		0						EMSF	
r						w		r						rh	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												ENON		MODE	POL
r												rw		rw	rw

Field	Bits	Type	Description
POL	0	rw	Input Polarity This bit determines the polarity of the input line. 0 _B Input is high active 1 _B Input is low active
MODE	1	rw	Mode Selection This bit determines the operating mode of the emergency stop signal. 0 _B Synchronous Mode selected; emergency stop is derived from the state of flag EMSF 1 _B Asynchronous Mode selected; emergency stop is directly derived from the state of the input signal
ENON	2	rw	Enable ON This bit enables the setting of flag EMSF by an inactive-to-active level transition of input signal. 0 _B Setting of EMSF is disabled 1 _B Setting of EMSF is enabled

System Control Unit (SCU)

Field	Bits	Type	Description
EMSF	16	rh	Emergency Stop Flag This bit indicates if an emergency stop condition has occurred. 0 _B An emergency stop has not occurred 1 _B An emergency stop has occurred and signal emergency stop becomes active (if MODE = 0)
EMSFM	[25:24]	w	Emergency Stop Flag Modification This bit field set or clear flag EMSF via software. 00 _B EMSF remains unchanged 01 _B EMSF becomes set 10 _B EMSF becomes cleared 11 _B EMSF remains unchanged EMSFM is always read as 00 _B .
0	[15:3], [23:17], [31:26]	r	Reserved Read as 0; should be written with 0.

3.10 Interrupt Generation

The interrupt structure is shown in [Figure 3-32](#). The interrupt request or the corresponding interrupt set bit (in register INTSET) can trigger the interrupt generation at the selected interrupt node x. The service request pulse is generated independently from the interrupt flag in register INTSTAT. The interrupt flag can be cleared by software by writing to the corresponding bit in register INTCLR.

If more than one interrupt source is connected to the same interrupt node pointer (in register INTNP), the requests are combined to one common line.

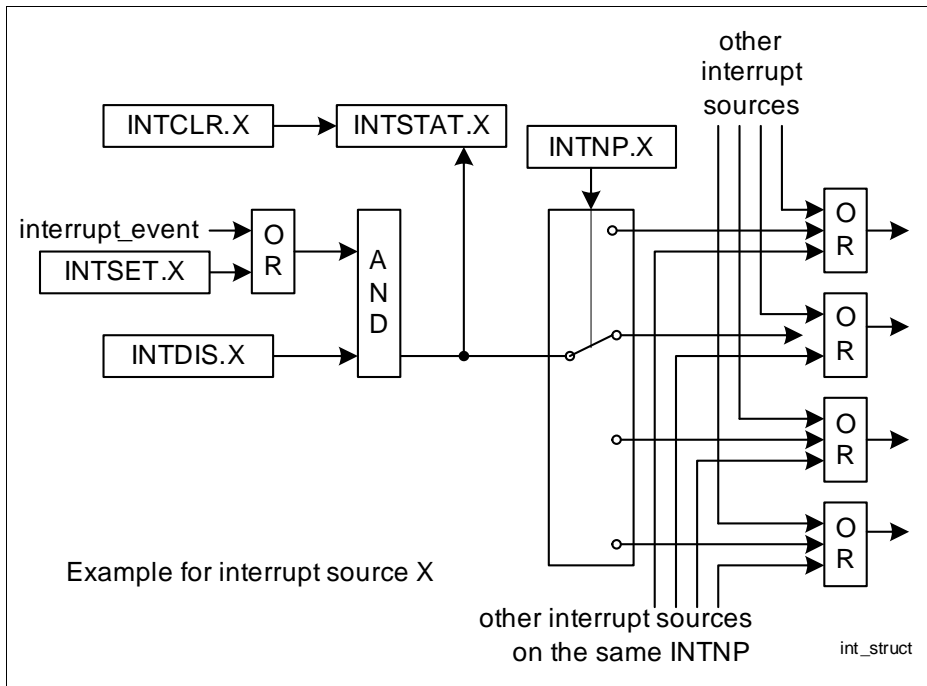


Figure 3-32 Interrupt Generation

System Control Unit (SCU)

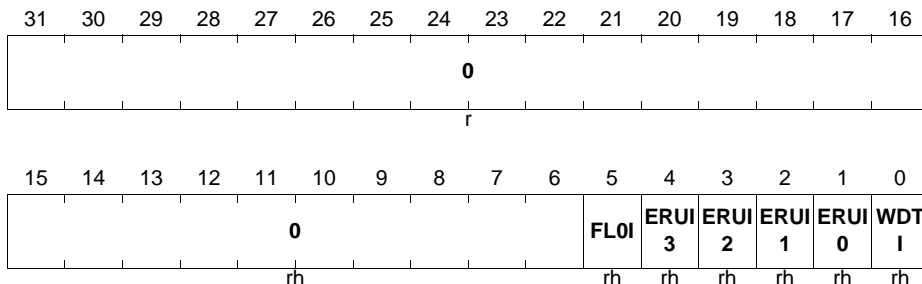
3.10.1 Interrupt Control Registers

INTSTAT

Interrupt Status Register

(110_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
WDTI	0	rh	Watchdog Timer Interrupt Request Flag This bit is set if the WDT Prewarning Mode is entered and bit is INTDIS.WDTI = 0. 0 _B No interrupt was requested since this bit was cleared the last time 1 _B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.WDTI. This bit can be set by bit INTSET.WDTI.
ERUI0	1	rh	ERU Channel 0 Interrupt Request Flag This bit is set if the ERU channel 0 is active and bit is INTDIS.ERUI0 = 0. 0 _B No interrupt was requested since this bit was cleared the last time 1 _B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.ERUI0. This bit can be set by bit INTSET.ERUI0.

System Control Unit (SCU)

Field	Bits	Type	Description
ERUI1	2	rh	ERU Channel 1 Interrupt Request Flag This bit is set if the ERU channel 1 is active and bit is INTDIS.ERUI1 = 0. 0_B No interrupt was requested since this bit was cleared the last time 1_B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.ERUI1. This bit can be set by bit INTSET.ERUI1.
ERUI2	3	rh	ERU Channel 2 Interrupt Request Flag This bit is set if the ERU channel 2 is active and bit is INTDIS.ERUI2 = 0. 0_B No interrupt was requested since this bit was cleared the last time 1_B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.ERUI2. This bit can be set by bit INTSET.ERUI2.
ERUI3	4	rh	ERU Channel 3 Interrupt Request Flag This bit is set if the ERU channel 3 is active and bit is INTDIS.ERUI3 = 0. 0_B No interrupt was requested since this bit was cleared the last time 1_B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.ERUI3. This bit can be set by bit INTSET.ERUI3.
FL0I	5	rh	Flash 0 Interrupt Request Flag This bit is set if the Flash interrupt trigger is active and bit is INTDIS.FL0I = 0. 0_B No interrupt was requested since this bit was cleared the last time 1_B An interrupt was requested since this bit was cleared the last time This bit can be cleared by bit INTCLR.FL0I. This bit can be set by bit INTSET.FL0I.

System Control Unit (SCU)

Field	Bits	Type	Description
0	[15:6]	rh	Reserved Read as 0. This bit can be cleared by bit INTCLR.[x]. This bit can be set by bit INTSET.[x]. <i>Note: x = 6, [13:8], 15.</i>
0	[31:16]	r	Reserved Read as 0; should be written with 0.

INTSET

Interrupt Set Register

(114_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FL0I	ERUI3	ERUI2	ERUI1	ERUI0	WDTI
w										w	w	w	w	w	w

Field	Bits	Type	Description
WDTI	0	w	Set Interrupt Request Flag WDTI Setting this bit set bit INTSTAT.WDTI. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI0	1	w	Set Interrupt Request Flag ERUI0 Setting this bit set bit INTSTAT.ERUI0. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI1	2	w	Set Interrupt Request Flag ERUI1 Setting this bit set bit INTSTAT.ERUI1. Clearing this bit has no effect. Reading this bit returns always zero.

System Control Unit (SCU)

Field	Bits	Type	Description
ERUI2	3	w	Set Interrupt Request Flag ERUI2 Setting this bit set bit INTSTAT.ERUI2. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI3	4	w	Set Interrupt Request Flag ERUI3 Setting this bit set bit INTSTAT.ERUI3. Clearing this bit has no effect. Reading this bit returns always zero.
FL0I	5	w	Set Interrupt Request Flag FL0I Setting this bit set bit INTSTAT.FL0I. Clearing this bit has no effect. Reading this bit returns always zero.
0	[15:6]	w	Reserved Read as 0; have to be written with 0.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

INTCLR

Interrupt Clear Register

(118_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FL0I	ERUI3	ERUI2	ERUI1	ERUI0	WDTI
w										w	w	w	w	w	w

Field	Bits	Type	Description
WDTI	0	w	Clear Interrupt Request Flag WDTI Setting this bit clears bit INTSTAT.WDTI. Clearing this bit has no effect. Reading this bit returns always zero.

System Control Unit (SCU)

Field	Bits	Type	Description
ERUI0	1	w	Clear Interrupt Request Flag ERUI0 Setting this bit clears bit INTSTAT.ERUI0. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI1	2	w	Clear Interrupt Request Flag ERUI1 Setting this bit clears bit INTSTAT.ERUI1. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI2	3	w	Clear Interrupt Request Flag ERUI2 Setting this bit clears bit INTSTAT.ERUI2. Clearing this bit has no effect. Reading this bit returns always zero.
ERUI3	4	w	Clear Interrupt Request Flag ERUI3 Setting this bit clears bit INTSTAT.ERUI3. Clearing this bit has no effect. Reading this bit returns always zero.
FL0I	5	w	Clear Interrupt Request Flag FL0I Setting this bit clears bit INTSTAT.FL0I. Clearing this bit has no effect. Reading this bit returns always zero.
0	[15:6]	w	Reserved Read as 0; have to be written with 1.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

INTDIS

Interrupt Disable Register

(11C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FL0I	ERUI 3	ERU T12	ERUI 1	ERUI 0	WDT I
rw										rw	rw	rw	rw	rw	rw

System Control Unit (SCU)

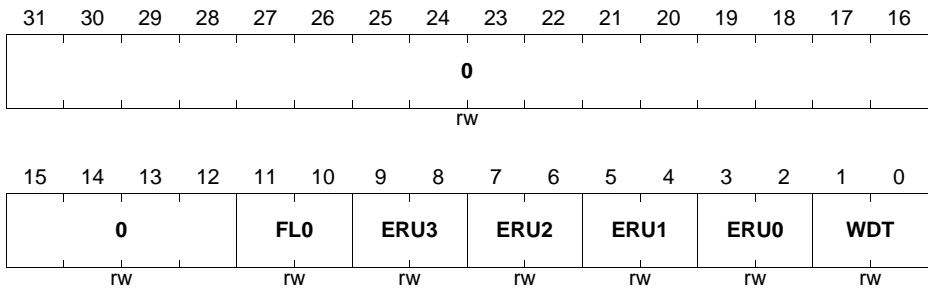
Field	Bits	Type	Description
WDTI	0	rw	Disable Interrupt Request WDT 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
ERUI0	1	rw	Disable Interrupt Request ERU0 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
ERUI1	2	rw	Disable Interrupt Request ERU1 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
ERUI2	3	rw	Disable Interrupt Request ERU2 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
ERUI3	4	rw	Disable Interrupt Request ERU3 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
FL0I	5	rw	Disable Interrupt Request Flash 0 0_B An interrupt request can be generated for this source 1_B No interrupt request can be generated for this source
0	[15:6]	rw	Reserved Have to be written with 1.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

INTNP

Interrupt Node Pointer Register

(120_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
WDT	[1:0]	rw	Interrupt Node Pointer for Interrupt WDT This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.WDTI (if enabled by bit INTDIS.WDTI). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected
ERU0	[3:2]	rw	Interrupt Node Pointer for Interrupt ERU0 This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.ERUI0 (if enabled by bit INTDIS.ERUI0). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected
ERU1	[5:4]	rw	Interrupt Node Pointer for Interrupt ERU1 This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.ERUI1 (if enabled by bit INTDIS.ERUI1). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected

System Control Unit (SCU)

Field	Bits	Type	Description
ERU2	[7:6]	rw	Interrupt Node Pointer for Interrupt ERU2 This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.ERUI2 (if enabled by bit INTDIS.ERUI2). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected
ERU3	[9:8]	rw	Interrupt Node Pointer for Interrupt ERU3 This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.ERUI3 (if enabled by bit INTDIS.ERUI3). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected
FL0	[11:10]	rw	Interrupt Node Pointer for Interrupt FL0 This bit field defines the interrupt node, that is requested due to the set condition for bit INTSTAT.FLOI (if enabled by bit INTDIS.FLOI). 00 _B Interrupt node 0 is selected 01 _B Interrupt node 1 is selected 10 _B Interrupt node 2 is selected 11 _B Interrupt node 3 is selected
0	[31:12]	rw	Reserved Should be written with 0.

System Control Unit (SCU)

SRC0

Service Request Control 0 Register (1FC_H)

Reset Value: 0000 0000_H

SRC1

Service Request Control 1 Register (1F8_H)

Reset Value: 0000 0000_H

SRC2

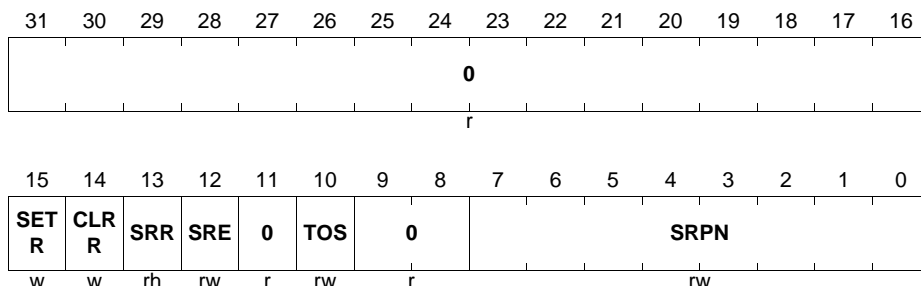
Service Request Control 2 Register (1F4_H)

Reset Value: 0000 0000_H

SRC3

Service Request Control 3 Register (1F0_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority ... FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP request is initiated
SRE	12	rw	Service Request Enable 0 _B Service request is disabled 1 _B Service request is enabled
SRR	13	rh	Service Request Flag 0 _B No service request is pending 1 _B A service request is pending
CLRR	14	w	Request Clear Bit CLRR is required to clear SRR. 0 _B No action 1 _B Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.

System Control Unit (SCU)

Field	Bits	Type	Description
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 _B No action 1 _B Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

3.11 NMI Trap Generation

The NMI trap structure is shown in [Figure 3-33](#). The trap request trigger or the corresponding trap set bit (in register TRAPSET) can trigger the NMI trap generation. The trap flag can be cleared by software by writing to the corresponding bit in register TRAPCLR. A NMI request is only generated if the trap source was not disabled. Otherwise only the trap status flag is set but no NMI request is generated.

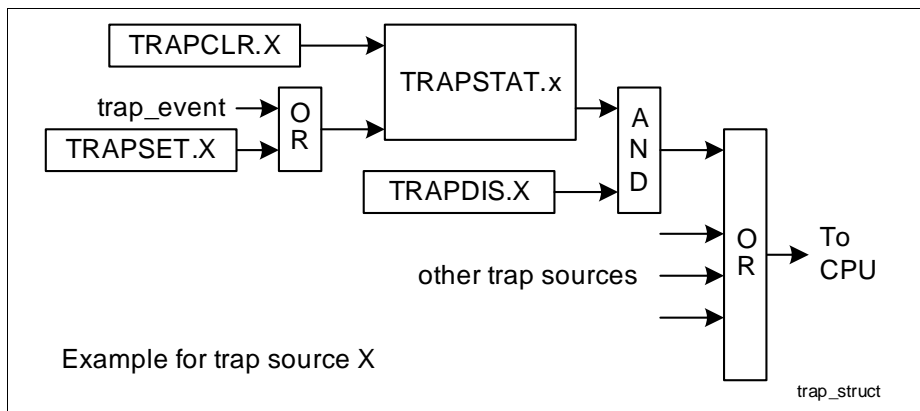


Figure 3-33 NMI Trap Generation

Handling NMI Traps

As an NMI trap is generated while the trap source is enable AND the trap status flag is set it is recommended to clear the trap status flag before the trap source is enabled. The trap status flag can be set before the trap source is enabled and simply enabling the trap source can result in unintended NMI traps. At the end of a NMI trap handling routine the trap status flag should be cleared.

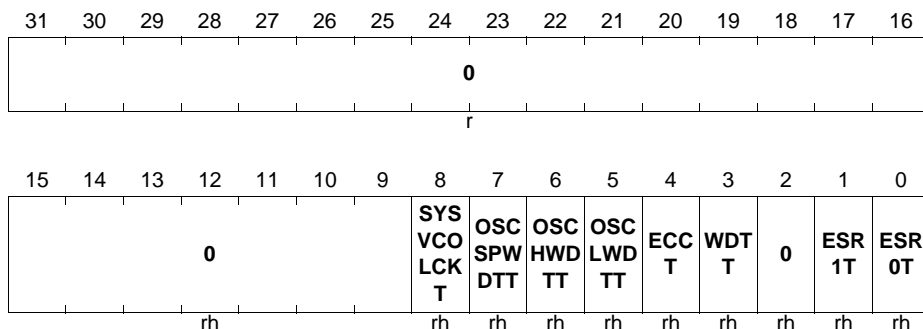
System Control Unit (SCU)

3.11.1 Trap Control Registers

TRAPSTAT

Trap Status Register

(124_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ESR0T	0	rh	ESR0 Trap Request Flag This bit is set if an <u>ESR0</u> event is triggered and bit is TRAPDIS.ESR0T is cleared. 0 _B No trap was requested since this bit was cleared the last time 1 _B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.ESR0T. This bit can be set by setting bit TRAPSET.ESR0T.
ESR1T	1	rh	ESR1 Trap Request Flag This bit is set if an <u>ESR1</u> event is triggered and bit is TRAPDIS.ESR1T is cleared. 0 _B No trap was requested since this bit was cleared the last time 1 _B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.ESR1T. This bit can be set by setting bit TRAPSET.ESR1T.

System Control Unit (SCU)

Field	Bits	Type	Description
WDTT	3	rh	WDT Trap Request Flag This bit is set if a WDT trap is indicated and bit is TRAPDIS.WDTT is cleared. 0 _B No trap was requested since this bit was cleared the last time 1 _B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.WDTT. This bit can be set by setting bit TRAPSET.WDTT.
ECCT	4	rh	ECC Error Trap Request Flag This bit is set if a memory ECC error is indicated and bit is TRAPDIS.ECCT is cleared. 0 _B No trap was requested since this bit was cleared the last time 1 _B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.ECCT. This bit can be set by setting bit TRAPSET.ECCT.
OSCLWDTT	5	rh	OSCWDT Low Trap Request Flag This bit is set if a oscillator WDT of the PLL detects a low event and bit is TRAPDIS.OSCLWDTT cleared. 0 _B No trap was requested since this bit was cleared the last time 1 _B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.OSCLWDTT. This bit can be set by setting bit TRAPSET.OSCLWDTT.

System Control Unit (SCU)

Field	Bits	Type	Description
OSCHWDTT	6	rh	OSCWDT High Trap Request Flag This bit is set if a oscillator WDT of the PLL detects a high event and bit is TRAPDIS.OSCHWDTT cleared. 0_B No trap was requested since this bit was cleared the last time 1_B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.OSCHWDTT. This bit can be set by setting bit TRAPSET.OSCHWDTT.
OSCPWDTT	7	rh	OSCWDT Spike Trap Request Flag This bit is set if a oscillator WDT of the PLL detects a spike event and bit is TRAPDIS.OSCPWDTT cleared. 0_B No trap was requested since this bit was cleared the last time 1_B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.OSCPWDTT. This bit can be set by setting bit TRAPSET.OSCPWDTT.
SYSVCOLCKT	8	rh	SYSVCOWDT Trap Request Flag This bit is set if a PLL VCO Loss-of-Lock event is triggered and bit is TRAPDIS.SYSVCOLCKT cleared. 0_B No trap was requested since this bit was cleared the last time 1_B A trap was requested since this bit was cleared the last time This bit can be cleared by setting bit TRAPCLR.SYSVCOLCKT. This bit can be set by setting bit TRAPSET.SYSVCOLCKT.
0	2, [15:9]	rh	Reserved Read as 0. This bit can be cleared by bit TRAPCLR.[x]. This bit can be set by bit TRAPSET.[x]. <i>Note: $x = 2, [15:9]$.</i>

System Control Unit (SCU)

Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0; should be written with 0.

TRAPSET

Trap Set Register

(128_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							SYS VCO LCK T	OSC SPW DTT	OSC HWD TT	OSC LWD TT	ECC T	WDT T	0	ESR 1T	ESR 0T
w							w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
ESR0T	0	w	Set Trap Request Flag ESR0T Setting this bit set bit TRAPSTAT.ESR0T. Clearing this bit has no effect. Reading this bit returns always zero.
ESR1T	1	w	Set Trap Request Flag ESR1T Setting this bit set bit TRAPSTAT.ESR1T. Clearing this bit has no effect. Reading this bit returns always zero.
WDTT	3	w	Set Trap Request Flag WDTT Setting this bit set bit TRAPSTAT.WDTT. Clearing this bit has no effect. Reading this bit returns always zero.
ECCT	4	w	Set Trap Request Flag ECCT Setting this bit set bit TRAPSTAT.ECCT. Clearing this bit has no effect. Reading this bit returns always zero.

System Control Unit (SCU)

Field	Bits	Type	Description
OSCLWDTT	5	w	Set Trap Request Flag OSCLWDTT Setting this bit set bit TRAPSTAT.OSCLWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
OSCHWDTT	6	w	Set Trap Request Flag OSCHWDTT Setting this bit set bit TRAPSTAT.OSCHWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
OSCSPWDTT	7	w	Set Trap Request Flag OSCSPWDTT Setting this bit set bit TRAPSTAT.OSCSPWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
SYSVCOLCKT	8	w	Set Trap Request Flag SYSVCOLCKT Setting this bit set bit TRAPSTAT.SYSVCOLCKT. Clearing this bit has no effect. Reading this bit returns always zero.
0	2, [15:9]	w	Reserved Read as 0; have to be written with 0.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

TRAPCLR

Trap Clear Register

(12C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							SYS VCO LCK T	OSC SPW DTT	OSC HWD TT	OSC LWD TT	ECC T	WDT T	0	ESR 1T	ESR 0T
w							w	w	w	w	w	w	w	w	w

System Control Unit (SCU)

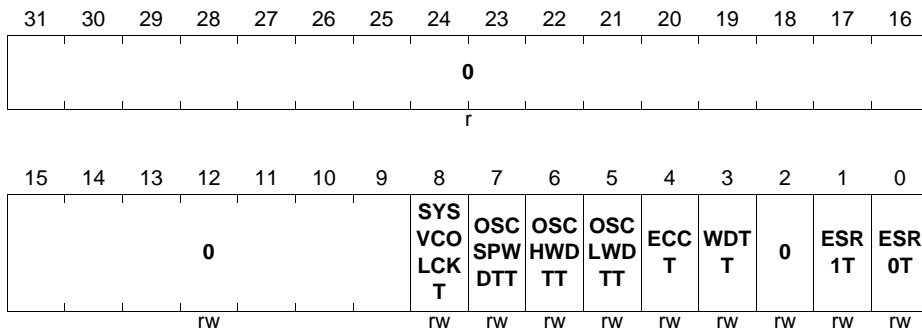
Field	Bits	Type	Description
ESR0T	0	w	Clear Trap Request Flag ESR0T Setting this bit clears bit TRAPSTAT.ESR0T. Clearing this bit has no effect. Reading this bit returns always zero.
ESR1T	1	w	Clear Trap Request Flag ESR1T Setting this bit clears bit TRAPSTAT.ESR1T. Clearing this bit has no effect. Reading this bit returns always zero.
WDTT	3	w	Clear Trap Request Flag WDTT Setting this bit clears bit TRAPSTAT.WDTT. Clearing this bit has no effect. Reading this bit returns always zero.
ECCT	4	w	Clear Trap Request Flag ECCT Setting this bit clears bit TRAPSTAT.ECCT. Clearing this bit has no effect. Reading this bit returns always zero.
OSCLWDTT	5	w	Clear Trap Request Flag OSCLWDTT Setting this bit clears bit TRAPSTAT.OSCLWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
OSCHWDTT	6	w	Clear Trap Request Flag OSCHWDTT Setting this bit clears bit TRAPSTAT.OSCHWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
OSCSPWDTT	7	w	Clear Trap Request Flag OSCSPWDTT Setting this bit clears bit TRAPSTAT.OSCSPWDTT. Clearing this bit has no effect. Reading this bit returns always zero.
SYSVCOLCK T	8	w	Clear Trap Request Flag SYSVCOLCKT Setting this bit clears bit TRAPSTAT.SYSVCOLCKT. Clearing this bit has no effect. Reading this bit returns always zero.
0	2, [15:9]	w	Reserved Read as 0; should be written with 0.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

TRAPDIS

Trap Disable Register

(130_H)

Reset Value: 0000 FFFF_H


Field	Bits	Type	Description
ESR0T	0	rw	Disable Trap Request ESR0T 0 _B A trap request can be generated for this source 1 _B No trap request can be generated for this source
ESR1T	1	rw	Disable Trap Request ESR1T 0 _B A trap request can be generated for this source 1 _B No trap request can be generated for this source
WDTT	3	rw	Disable Trap Request WDTT 0 _B A trap request can be generated for this source 1 _B No trap request can be generated for this source
ECCT	4	rw	Disable Trap Request ECCT 0 _B A trap request can be generated for this source 1 _B No trap request can be generated for this source
OSCLWDTT	5	rw	Disable Trap Request OSCLWDTT 0 _B A trap request can be generated for this source 1 _B No trap request can be generated for this source

System Control Unit (SCU)

Field	Bits	Type	Description
OSCHWDTT	6	rw	Disable Trap Request OSCHWDTT 0_B A trap request can be generated for this source 1_B No trap request can be generated for this source
OSCSPWDTT	7	rw	Disable Trap Request OSCSPWDTT 0_B A trap request can be generated for this source 1_B No trap request can be generated for this source
SYSVCOLCKT	8	rw	Disable Trap Request SYSVCOLCKT 0_B A trap request can be generated for this source 1_B No trap request can be generated for this source
0	2, [15:9]	rw	Reserved Have to be written with 1.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

3.12 Miscellaneous System Control Register

This section collects different register that serve various system aspects.

3.12.1 GPTA Input IN1 Control

In the TC1728, the input line IN1 of the GPTA module can be used to measure the baud rate of an ASC0 or ASC1 receiver input signal with GPTA. This feature is controlled by SYSCON.GPTAIS.

Table 3-21 GPTA0/LTCA2 Input Line IN1 Connections

SYSCON.GPTAIS	GPTA0/LTCA2 Input IN1 Connected to
00 _B	P0.1 / IN1 (default after Application Reset)
01 _B	P3.0 / RXD0A
10 _B	P3.12 / RXD0B
11 _B	P3.14 / RXD1B

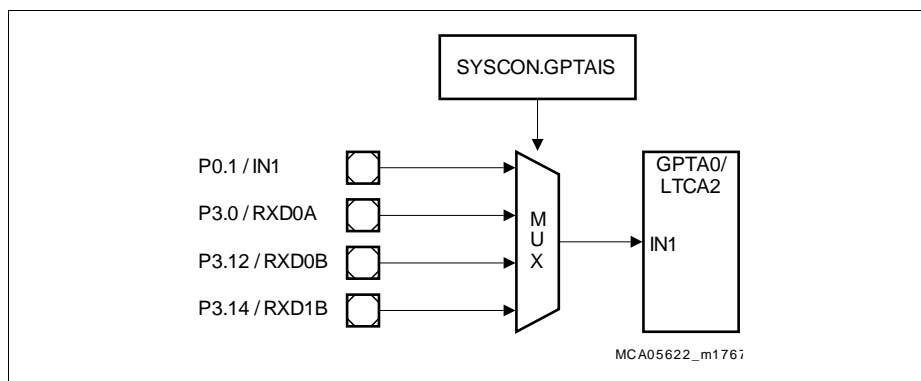
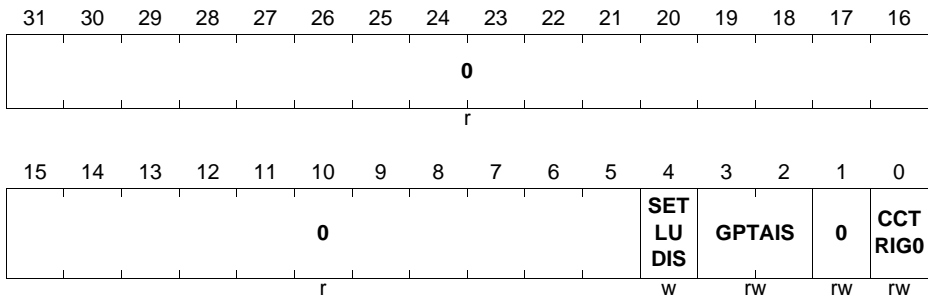


Figure 3-34 GPTA0/LTCA2 Input IN1 Control

3.12.2 System Control Register

This register controls various functionality used by the SCU but that are located outside of the module. Additionally some functions for other modules are included.

System Control Unit (SCU)

SYSCON
System Control Register
(040_H)
Reset Value: 0000 0000_H


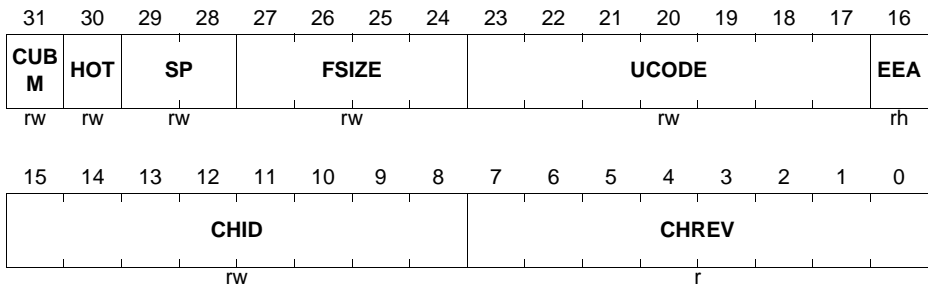
Field	Bits	Type	Description
CCTRIG0	0	rw	Capture Compare Trigger 0 This bit is used to trigger the Synchronous Start feature of the CAPCOMs in the system.
GPTAIS	[3:2]	rw	GPTA Input Select This bit field selects the input that is used for IN1 of the GPTA module. For more information see either Section 3.12.1 or the GPTA chapter. 00 _B IN0 is selected 01 _B IN1 is selected 10 _B IN2 is selected 11 _B IN3 is selected
SETLUDIS	4	w	Set Latch Update Disable Setting this bit sets bit STSTAT.LUDIS. Clearing this bit has no effect. This bit reads always as zero.
0	1	rw	Reserved Should be written with 0.
0	[31:5]	r	Reserved Read as 0; should be written with 0.

3.12.3 Identification Registers

CHIPID

Chip Identification Register

(140_H)

Reset Value: XXXX 9CXX_H


Field	Bits	Type	Description
CHREV	[7:0]	r	Chip Revision Number This bit field indicates the revision number of the TC1728 device. The value of this bit field is defined in the TC1728 Data Sheet.
CHID	[15:8]	rw	Chip Identification Number This bit field defines the product by a unique number. 9C _H = 1728
EEA	16	rh	Emulation Extension Available Indicates if the emulation extension is available or not. 0 _B EEC is not available 1 _B EEC is available
UCODE	[23:17]	rw	µCode Version This bit field displays the Version x.y of the flash µCode.
FSIZE	[27:24]	rw	Program Flash Size this bit field indicates available program flash size for this device. Detailed information is shown in the Data Sheet.
SP	[29:28]	rw	Speed This bit field indicates the maximum allowed speed for the CPU of this device. Detailed information is shown in the Data Sheet.

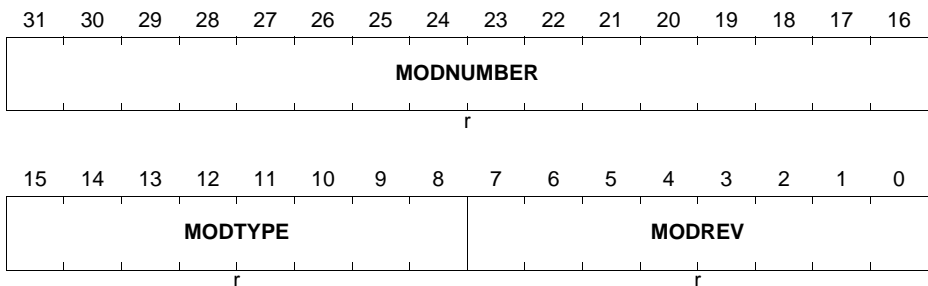
System Control Unit (SCU)

Field	Bits	Type	Description
HOT	30	rw	Hot Package Variante This bit indicates if the package is designed for a hot temperature variante. 0 _B Normal temperature package used 1 _B Hot temperature package used
CUBM	31	rw	Copper Bond Material This bit indicates if copper was used for the bond wires. 0 _B No copper was used 1 _B Copper was used

ID

Identification Register

(008_H)

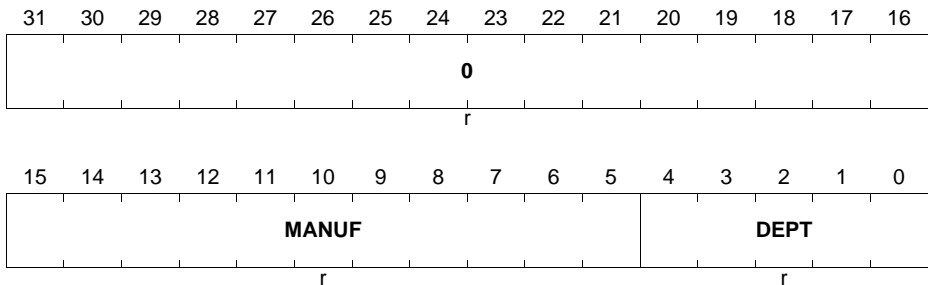
Reset Value: 0052 C0XX_H


Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number This bit field indicates the revision number of the TC1728 module (01 _H = first revision).
MODTYPE	[15:8]	r	Module Type This bit field is C0 _H . It defines a 32-bit module
MODNUMBER	[31:16]	r	Module Number This bit field defines the module identification number.

System Control Unit (SCU)

MANID

Manufacturer Identification Register (144_H)

Reset Value: 0000 1820_H


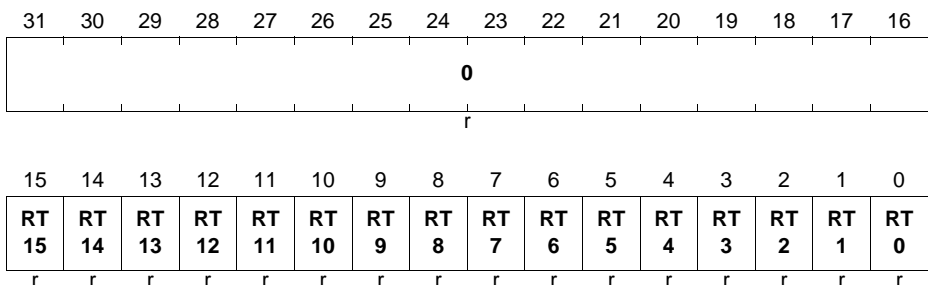
Field	Bits	Type	Description
DEPT	[4:0]	r	Department Identification Number = 00 _H ; indicates the Automotive & Industrial microcontroller department within Infineon Technologies.
MANUF	[15:5]	r	Manufacturer Identification Number This is a JEDEC normalized manufacturer code. MANUF = C1 _H stands for Infineon Technologies.
0	[31:16]	r	Reserved Read as 0.

The Redesign Tracing Register RTID provides a means of signalling minor redesigns that are not reflected in the CHIPID.CHREV bit field.

RTID

Redesign Tracing Identification Register

(148_H)

Reset Value: 0000 XXXX_H


System Control Unit (SCU)

Field	Bits	Type	Description
RTx (x = 0-15)	x	r	Redesign Trace Bit x 0 _B No change indicated 1 _B A change has been made (without changing bit field CHIPID.CHREV). RTx can be used, e.g., for minor redesign stepping identification purposes.
0	[31:16]	r	Reserved Read as 0

Note: The RTID reset value for a major design step (without modifications) is 0000_H.

3.12.4 SCU Kernel Registers

This section describes the kernel registers of the 32-bit Platform SCU module. Most of 32-bit Platform SCU kernel register names described in this section will be referenced in other parts of the TC1728 User's Manual by the module name prefix "SCU_".

SCU Kernel Register Overview

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
–	Reserved	000 _H - 004 _H	BE	BE	–	–
ID	Identification Register	008 _H	U, SV	BE	System Reset	Page 3-182
–	Reserved	00C _H	BE	BE	–	–
OSCCON	OSC Control Register	010 _H	U, SV	SV, E	System Reset	Page 3-29
PLLCON0	PLL Configuration 0 Register	018 _H	U, SV	SV, E	System Reset	Page 3-33
PLLCON1	PLL Configuration 1 Register	01C _H	U, SV	SV, E	System Reset	Page 3-35
–	Reserved	020 _H	BE	BE	–	–
PLLERY STAT	PLL_ERAY Status Register	024 _H	U, SV	BE	System Reset	Page 3-35

System Control Unit (SCU)

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
PLLERYAY CON0	PLL_ERAY Configuration 0 Register	028 _H	U, SV	SV, E	System Reset	Page 3-37
PLLERYAY CON1	PLL_ERAY Configuration 1 Register	02C _H	U, SV	SV, E	System Reset	Page 3-39
CCUCON0	CCU Control Register 0	030 _H	U, SV	SV, E	System Reset	Page 3-39
CCUCON1	CCU Control Register 1	034 _H	U, SV	SV, E	System Reset	Page 3-41
FDR	Fractional Divider Register	038 _H	U, SV	SV, E	System Reset	Page 3-46
EXTCON	External Clock Control Register	03C _H	U, SV	U, SV	System Reset	Page 3-45
SYSCON	System Control Register	040 _H	U, SV	U, SV	System Reset	Page 3-180
CCUCON2	CCU Control Register 2	044 _H	U, SV	SV, E	System Reset	Page 3-43
RSTSTAT	Reset Status Register	050 _H	U, SV	BE	Power-on Reset	Page 3-69
RSTCNTCON	Reset Counter Control Register	054 _H	U, SV	SV, E	Power-on Reset	Page 3-72
RSTCON	Reset CON Register	058 _H	U, SV	SV, E	Power-on Reset	Page 3-73
ARSTDIS	Application Reset Disable Register	05C _H	U, SV	SV, E	Power-on Reset	Page 3-74
SWRSTCON	Software Reset Configuration Register	060 _H	U, SV	SV, E	Power-on Reset	Page 3-75
EVRSTCON	EVR Reset Control Register	06C _H	U, SV	SV, E	Power-on Reset	Page 3-121
–	Reserved	064 _H - 068 _H	BE	BE	–	–

System Control Unit (SCU)

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
ESRCFG0	ESR0 Configuration Register	070 _H	U, SV	SV, E	System Reset	Page 3-79
ESRCFG1	ESR1 Configuration Register	074 _H	U, SV	SV, E	System Reset	Page 3-79
–	Reserved	078 _H - 07C _H	BE	BE	–	–
EICR0	External Input Channel Register 0	080 _H	U, SV	U, SV	Application Reset	Page 3-100
EICR1	External Input Channel Register 1	084 _H	U, SV	U, SV	Application Reset	Page 3-103
EIFR	External Input Flag Register	088 _H	U, SV	U, SV	Application Reset	Page 3-107
FMR	Flag Modification Register	08C _H	U, SV	U, SV	Application Reset	Page 3-107
PDRR	Pattern Detection Result Register	090 _H	U, SV	U, SV	Application Reset	Page 3-108
IGCR0	Interrupt Gating Register 0	094 _H	U, SV	U, SV	Application Reset	Page 3-109
IGCR1	Interrupt Gating Register 1	098 _H	U, SV	U, SV	Application Reset	Page 3-112
–	Reserved	09C _H	BE	BE	–	–
IOCR	Input/Output Control Register	0A0 _H	U, SV	U, SV	System Reset	Page 3-80
OUT	Output Register	0A4 _H	U, SV	U, SV	System Reset	Page 3-83
OMR	Output Modification Register	0A8 _H	U, SV	U, SV	System Reset	Page 3-84
IN	Input Register	0AC _H	U, SV	BE	System Reset	Page 3-85

System Control Unit (SCU)

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
PMCSR	Power Management Control and Status Register	0B0 _H	U, SV	U, SV	Application Reset	Page 3-126
–	Reserved	0B4 _H - 0BC _H	BE	BE	–	–
STSTAT	Start-up Status Register	0C0 _H	U, SV	BE	Power-on Reset	Page 3-129
STCON	Start-up Configuration Register	0C4 _H	U, SV	ST	Power-on Reset	Page 3-131
–	Reserved	0C8 _H - 0CC _H	BE	BE	–	–
ECCCON	ECC Control Register	0D0 _H	U, SV	SV, E	Application Reset	Page 3-133
ECCSTAT	ECC Status Register	0D4 _H	U, SV	BE	Application Reset	Page 3-135
ECCCLR	ECC Clear Register	0D8 _H	U, SV	U, SV	Application Reset	Page 3-137
–	Reserved	0E8 _H - 0EC _H	BE	BE	–	–
WDT_CON0	WDT Control Register 0	0F0 _H	U, SV	U, SV	Application Reset	Page 3-150
WDT_CON1	WDT Control Register 1	0F4 _H	U, SV	SV, E	Application Reset	Page 3-152
WDT_SR	WDT Status Register	0F8 _H	U, SV	BE	Application Reset	Page 3-153
–	Reserved	0FC _H	BE	BE	–	–
EMSR	Emergency Stop Register	100 _H	U, SV	SV, E	Application Reset	Page 3-157
–	Reserved	104 _H - 10F _H	BE	BE	–	–
INTSTAT	Interrupt Status Register	110 _H	U, SV	BE	Application Reset	Page 3-160

System Control Unit (SCU)

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
INTSET	Interrupt Set Register	114 _H	U, SV	U, SV	Application Reset	Page 3-162
INTCLR	Interrupt Clear Register	118 _H	U, SV	U, SV	Application Reset	Page 3-163
INTDIS	Interrupt Disable Register	11C _H	U, SV	U, SV	Application Reset	Page 3-164
INTNP	Interrupt Node Pointer Register	120 _H	U, SV	U, SV	Application Reset	Page 3-166
TRAPSTAT	Trap Status Register	124 _H	U, SV	BE	System Reset	Page 3-171
TRAPSET	Trap Set Register	128 _H	U, SV	SV, E	System Reset	Page 3-174
TRAPCLR	Trap Clear Register	12C _H	U, SV	U, SV	System Reset	Page 3-175
TRAPDIS	Trap Disable Register	130 _H	U, SV	SV, E	Application Reset	Page 3-177
–	Reserved	134 _H - 13F _H	BE	BE	–	–
CHIPID	Chip Identification Register	140 _H	U, SV	ST	System Reset	Page 3-181
MANID	Manufacture Identification Register	144 _H	U, SV	BE	System Reset	Page 3-183
RTID	Redesign Trace Identification Register	148 _H	U, SV	BE	System Reset	Page 3-183
–	Reserved	14C _H - 1EF _H	BE	BE	–	–
–	Reserved	198 _H - 1EF _H	BE	BE	–	–
SRC3	Service Request Control Register 3	1F0 _H	U, SV	SV	Application Reset	Page 3-168
SRC2	Service Request Control Register 2	1F4 _H	U, SV	SV	Application Reset	Page 3-168

System Control Unit (SCU)

Table 3-22 Register Overview of SCU

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
SRC1	Service Request Control Register 1	1F8 _H	U, SV	SV	Application Reset	Page 3-168
SRC0	Service Request Control Register 0	1FC _H	U, SV	SV	Application Reset	Page 3-168

- 1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

3.12.5 SCU Address Area

Table 3-23 Registers Address Space - SCU Kernel Registers

Module	Base Address	End Address	Note
SCU	F000 0500 _H	F000 06FF _H	-

4 On-Chip System Buses and Bus Bridges

The TC1728 has two independent on-chip buses:

- Local Memory Bus (LMB)
- System Peripheral Bus (SPB)

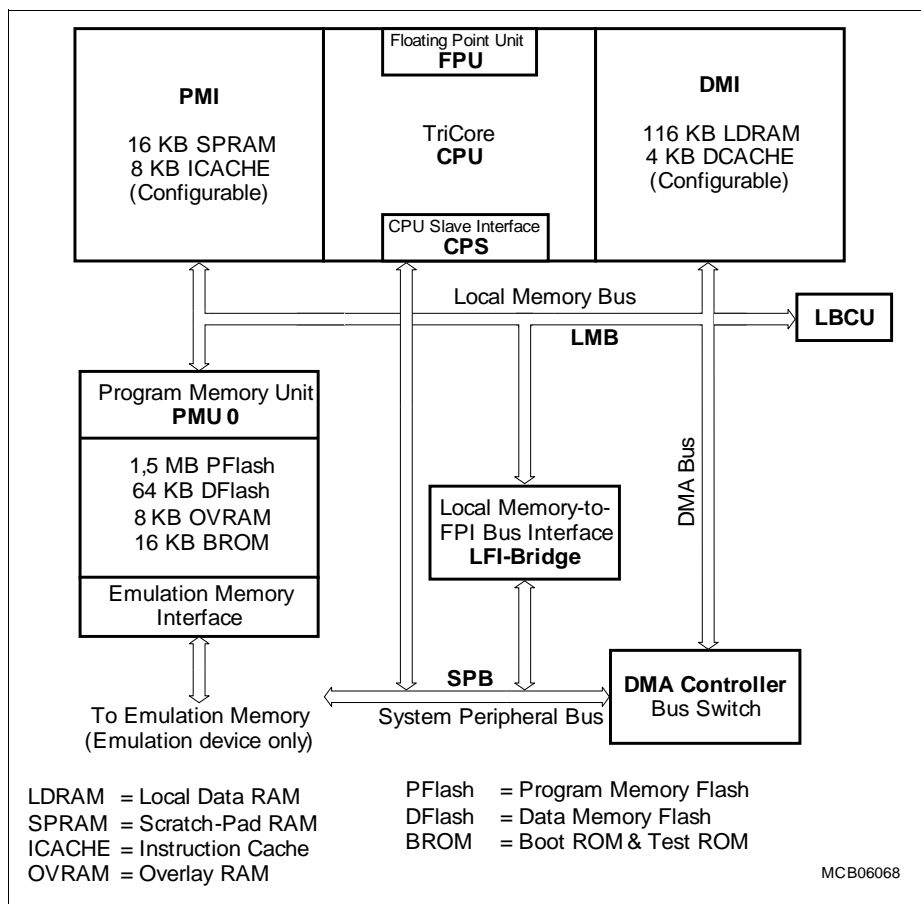


Figure 4-1 On Chip Buses in TC1728 Processor Subsystem

The LMB connects the TriCore CPU to its local resources for instruction fetches and data accesses.

The SPB is accessible by the CPU via the LFI Bridge.

On-Chip System Buses and Bus Bridges

4.1 What is new

Major differences of the AudoFuture On Chip Bus System architecture compared to AudoNG:

- The TC1728 is based on two on chip busses (LMB, SPB). The remote peripheral bus (RPB) was removed.
- The DMA is additionally connected to the LMB bus with a master interface.
- The E-Ray module is additionally connected to the SPB with a slave interface.
- The OCDS module is connected to the DMA. The OCDS module has direct access to the LMB/SPB bus via the DMA-LMB and DMA-SPB master interface.
- DMA decides to forward transactions from DMA internal sources (Move Engine 0/1, MLI0 and Cerberus) to LMB/SPB by internal address decoding (see address map chapter).
- The DMA controller can generate single data read and write transactions on the LMB bus. The DMA does not forward directly transactions from the FPI bus to the LMB bus or vice versa (no LMB<->FPI bridge functionality). Further DMA details and/or DMA changes compared to AudoNG can be found in the DMA chapter.
- The DMA module is now able to access the LMB / SPB bus with three priorities (see [Page 4-6](#) and [Page 4-34](#)). Priority of DMA access is controlled by the OCDS (for DMA-OCDS accesses) and by the Move Engine Channels for DMA-Move Engine accesses. A detailed description of the DMA internal control of the priorities can be found in the DMA chapter.
- The LMB-to-FPI bridge (LFI) address translation table was adapted to the AudoFuture address space ([Page 4-24](#)).
- Some clarifications were added (example: Figure of the BCU Breakpoint Trigger Combination Logic, [Page 4-42](#)).
- The SBCU_DBDAT register was introduced. (see [Page 4-65](#)).
- The table On Chip Bus Master TAG Assignments was adapted ([Page 4-67](#)).

Major differences of the AudoMax On Chip Bus System architecture compared to AudoFuture:

-

On-Chip System Buses and Bus Bridges

4.2 Local Memory Bus

The following terminology is used for the bus:

Table 4-1 LMB Bus Terms

Term	Description
Agent	An LMB agent is any master or slave device which is connected to the LMB Bus.
Master	An LMB master device is an LMB agent which is able to initiate transactions on the LMB. It is also able to react as an LMB slave.
Slave	An LMB slave device is an LMB agent which is not able to initiate transactions on the LMB. It is only able to handle operations that are dedicated to it by an LMB master device.

4.2.1 Overview

The LMB is a synchronous and pipelined bus with variable block size transfer support. The protocol supports 8-, 16-, 32-, and 64-bit single transactions and 2/4 wide 64-bit block transfers.

The LMB has the following features:

- Optimized for high speed and high performance data transfers
- 32-bit address bus, 64-bit data bus
- Simple central arbitration per cycle
- Slave-controlled wait state insertion
- Address pipelining (max. depth - 2)
- Support of atomic operations LDMST, ST.T and SWAP.W
- Block transfers with variable block length (two or four 64-bit data transactions)
- LMB transfers are ECC protected (error detection)

4.2.2 Transaction Types

There are three transaction types of the LMB.

4.2.2.1 Single Transfers

Single transfers are all transactions that are initiated by any instruction (code or data) of the TriCore 1 CPU and that require a system resource which is not part of the TriCore 1 PMI or DMI. The only exceptions are the following instructions:

- LDMST, ST.T and SWAP.W generate atomic transfers
- Cache miss instructions generate block transfers

On-Chip System Buses and Bus Bridges

4.2.2.2 Block Transfers

Block transfers are only issued in the following ways:

1. By the PMI and DMI in case of a cache miss.
2. By the PCP if it uses a BCOPY instruction.

Block transfers work in the same way as single transfers, except that only one address phase with consecutive two or four data phases is generated.

4.2.2.3 Atomic Transfers

Atomic transfers are initiated by instructions that require two single transfers (e.g. read-modify-write instructions such as LDMST, ST.T and SWAP.W). During an atomic transfer any other LMB master is blocked for gaining bus ownership.

4.2.3 Address Alignment Rules

Depending on the data size, there are rules that determine the address alignment of an LMB transfer.

1. Byte accesses must always be located on byte address boundaries.
2. Half-word accesses must be aligned to addresses with address line $A_0 = 0$.
3. Word accesses must be aligned to addresses with address lines $A[1:0] = 00_B$.
4. Double-word accesses must be aligned to addresses with address lines $A[2:0] = 000_B$.
5. Block transfers must be aligned identical as double-word addresses.

4.2.4 Reaction of a Busy Slave

If an LMB slave is busy at an incoming LMB transaction request, it can delay the execution of the LMB transaction. The requesting LMB master releases the LMB for one cycle after the LMB transaction request in order to allow the LMB slave to indicate if it is ready to handle the requested LMB transaction.

Note: For the LMB default master, the one cycle gap does not result in a performance loss because it is granted the LMB in this cycle as default master if no other master request the LMB for some other reasons.

On-Chip System Buses and Bus Bridges

4.2.5 LMB Basic Operation

Figure 4-2 describes some basic bus operations of the LMB.

Bus Cycle	1	2	3	4	5
Transfer 1	Request/ Grant	Address Cycle	Data Cycle		
Transfer 2		Request/ Grant	Address Cycle	Data Cycle	
Transfer 3		Request/Grant		Address Cycle	Data Cycle

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Figure 4-2 Basic LMB Transactions

Transfer 1 displays the three cycles of any LMB transaction:

1. **Request/Grant Cycle:** The LMB master wants to perform a read or write transfer and requests for the LMB. If the LMB is available, it is granted in the same cycle by the LMB controller.
2. **Address Cycle:** After the request/grant cycle the master puts the address on the LMB and all LMB slave devices check whether they are addressed for the following data cycle.
3. **Data Cycle:** In the data cycle either the LMB master puts write data on the LMB which is read by the LMB slave (write cycle) or vice versa (read cycle).

Transfers 2 and 3 show the conflict when two masters try to use the LMB, and how the conflict is resolved. In the example, the LMB master of transfer 2 has a higher priority than the LMB master of transfer 3.

During a block transfer, the address cycle of a second transfer is extended until the data cycles of the block transfer are finished. In the example shown in **Figure 4-3**, transfer 1 is a block transfer while transfer 2 is a single transfer.

Bus Cycle	1	2	3	4	5	6	7
Transfer 1	Request/ Grant	Address Cycle	Data Cycle	Data Cycle	Data Cycle	Data Cycle	
Transfer 2		Request/ Grant	Address Cycle				Data Cycle

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Figure 4-3 LMB Block Transactions

On-Chip System Buses and Bus Bridges

4.3 Local Memory Bus Controller Unit

The LMB in the TC1728 has an LMB Bus Control Unit (LBCU).

4.3.1 Basic Operation

The LBCU handles the cycle sequences of the transfers which have been requested by the LMB master devices. The LBCU is also able to detect bus protocol violations and addressing of un-implemented addresses. In case of a bus error, the LBCU captures all relevant data like bus address, bus data and bus status information in register where the information can be analyzed by software.

4.3.2 LMB Bus Arbitration

All LMB master devices requesting the LMB will participate in an arbitration round. Arbitration rounds are performed in each cycle that precedes a possible address cycle. Each LMB master device has a fixed priority as shown in [Table 4-2](#).

Table 4-2 Priority of Master LMB Agents

Priority	LMB Master	Comment
Highest	DMA, high priority	DMA Requests from modules: - Cerberus high priority ¹⁾ - DMA channels with high priority ²⁾
	LFI Bridge	–
	DMA, medium priority	DMA Requests from modules: - DMA Channel medium priority ²⁾
	Data Memory Interface (DMI)	Default Master
	Program Memory Interface (PMI)	–
Lowest	DMA, low priority	DMA requests from modules: - Cerberus low priority ¹⁾ - DMA channels low priority ²⁾ - MLI

1) Priority of Cerberus transaction at the On Chip Busses is defined by the register bit IOCONF.FPI_PPIO. The register is defined in the OCDS chapter.

2) Priority of a DMA channel is defined by the corresponding CHCRmn.DMAPRIO bits. The registers are defined in the DMA chapter.

For all the masters requesting the LMB during any one cycle, the granted master is the one with the highest priority.

4.3.2.1 LMB Bus Default Master

When no LMB master is requesting the LMB, it is granted to the LMB default master. This means, if the default master needs the LMB in the next cycle, it can enter the address cycle without running through a request/grant cycle.

4.3.3 LMB Bus Error Handling

When an error occurs on LMB, the LMB controller captures and stores data about the erroneous condition and generates a service request if enabled to do so. The error conditions that force an error capture event are:

- Un-implemented Address: No LMB slave responds to an address target
- Error Acknowledge: An LMB slave responds with an error to a transaction

When a transaction causes an error, the address and data phase signals of the transaction causing the error are captured and stored in the following registers:

- The LMB Error Address Register (LEADDR) stores the LMB address that has been captured during the last erroneous LMB transaction.
- The LMB Error Data Registers (LEDATL/LEDATH) stores the LMB data bus information that has been captured during the last erroneous LMB transaction.
- The LMB Error Attribute Register (LEATT) stores status information of the bus error event.

If more than one LMB transaction generates a bus error, only the first bus error is captured. After a bus error was captured, the capture mechanism must be released again by software.

If a write transaction from the PCP or DMA on the SPB that is forwarded by the LFI module to the LMB causes a bus error on the LMB Bus, the originating masters are not informed about this bus error because these write transactions are finished on SPB when the error happens on LMB. With each bus error-capture event, a service request is generated and interrupt can be generated if enabled and configured in the corresponding service request register.

On-Chip System Buses and Bus Bridges

4.3.4 LMB Bus Control Unit Registers

Figure 4-4 and **Table 4-4** are showing the address maps with all registers of LMB Bus Control Unit (LBCU) module.

LBCU Unit Register Overview

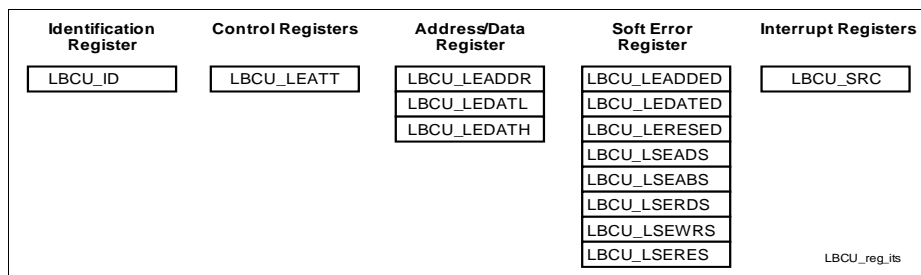


Figure 4-4 LMB Bus Control Unit Registers

Note: Addresses listed in column “Offset Address” of **Table 4-4** are word (32-bit) addresses.

Table 4-3 Registers Address Space - LBCU Register Address Space

Module	Base Address	End Address	Note
LBCU	F87F FE00 _H	F87F FEFF _H	

Table 4-4 Registers Overview - LBCU Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
-	Reserved	000 _H - 004 _H	BE	BE	-	-
LBCU_ID	LBCU Module Identification Register	008 _H	U, SV	BE	-	Page 4-11
-	Reserved	00C _H - 01C _H	BE	BE	-	-
LBCU_LE ATT	LBCU LMB Error Attribute Register	020 _H	U, SV, 32	SV, 32	3	Page 4-12
LBCU_LE ADDR	LBCU LMB Error Address Register	024 _H	U, SV	BE	3	Page 4-15

On-Chip System Buses and Bus Bridges

Table 4-4 Registers Overview - LBCU Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
LBCU_LE DATL	LBCU LMB Error Data Low Register	028 _H	U, SV, 64	BE	3	Page 4-15
LBCU_LE DATH	LBCU LMB Error Data High Register	02C _H	U, SV	BE	3	Page 4-16
-	Reserved	030 _H	BE	BE	-	-
LBCU_LE ADDED	LBCU LMB Error Address Error Detection Register	034 _H	U, SV	BE	-	Page 4-16
LBCU_LE DATED	LBCU LMB Error Data Error Detection Register	038 _H	U, SV, 32	BE	-	Page 4-17
LBCU_LE RESED	LBCU LMB Error Response Error Detection Register	03C _H	U, SV, 32	BE	-	Page 4-17
LBCU_LS EADS	LBCU LMB Soft Error Address Source	040 _H	U, SV, 32	BE	-	Page 4-18
LBCU_LS EABS	LBCU LMB Soft Error Abort Source	044 _H	U, SV, 32	BE	-	Page 4-19
LBCU_LS ERDS	LBCU LMB Soft Error Read Source	048 _H	U, SV, 32	BE	-	Page 4-20
LBCU_LS EWRS	LBCU LMB Soft Error Write Source	04C _H	U, SV, 32	BE	-	Page 4-21
LBCU_LS ERES	LBCU LMB Soft Error Response Source	050 _H	U, SV, 32	BE	-	Page 4-22
-	Reserved, read as 0.	054 _H	U, SV, 32	BE	-	-

On-Chip System Buses and Bus Bridges

Table 4-4 Registers Overview - LBCU Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
-	Reserved	058 _H - 0F8 _H	BE	BE	-	-
LBCU_SRC	LBCU Service Request Control Register	0FC _H	U, SV, 32	SV, 32	3	Page 4-23

- 1) The absolute register address is calculated as follows:
Module Base Address ([Table 4-3](#)) + Offset Address (shown in this column)

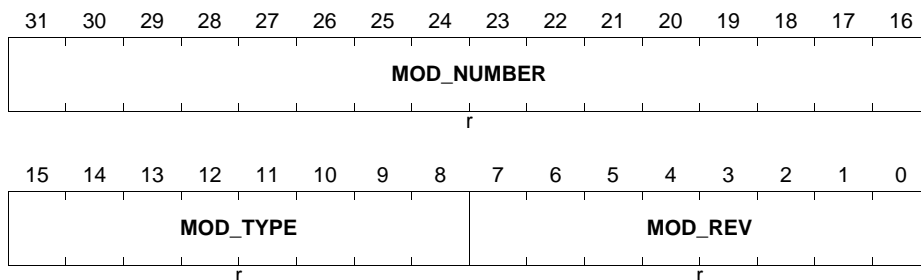
On-Chip System Buses and Bus Bridges

4.3.4.1 LMB Bus Control Unit Control Registers

The identification register allows the programmer version-tracking of the module. The table below shows the identification register which is implemented in the LBCU module.

LBCU_ID

Module Identification Register (008_H) **Reset Value: 000F C0XX_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the LBCU module is 000F _H .

On-Chip System Buses and Bus Bridges

LBCU_LEATT

LBCU LMB Error Attribute Register (020_H)

Reset Value: XXXX XXX0_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OPC				0	TAG				RD	WR	SVM	0	UIS	ACK	
rh				r	rh				rh	rh	rh	r	rh	rh	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LOC	NOS	ABT	ABT _ED	0				FPITAG				0	TIP	DVL D	LEC
rh	rh	rh	rh	r				rh				r	rh	rh	rwh

Field	Bits	Type	Description
LEC	0	rwh	Lock Error Capture This bit indicates and controls whether the error-capture mechanism is unlocked or locked. 0 _B The error-capture mechanism is unlocked. The next LMB Bus error will be captured. 1 _B The error-capture mechanism is locked. The registers LEADDR and bits [31:4] of LEATT contain valid data. The registers LEADTL and LEDATH contain valid data if LEATT.UIS = '0'. LEC is automatically set when an LMB bus error has been captured. Any further LMB bus error is not captured if LEC = 1. When writing a 1 to LEC, the error-capture mechanism becomes unlocked and is ready for the next LMB bus error-capture event.
DVLD	1	rh	LMB DVALID This bit indicates the state of the lmb_dvalid_n signal in case of an LMB bus error.
TIP	2	rh	LMB TIP This bit indicates the state of the lmb_tip_n signal in case of an LMB bus error.

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
FPITAG	[7:4]	rh	FPI Bus Master TAG This bit field indicates the FPI Bus master tag in case of an LMB bus error. Note that the FPI Bus master tag is only of interest if the erroneous LMB transfer was initiated by the DMA or the PCP..
ABT-ED	2	rh	LMB Abort ED This bit indicates the state of the lmb_abort_ed signal in case of an LMB bus error.
ABT	2	rh	LMB Abort This bit indicates the state of the lmb_abort_d signal in case of an LMB bus error.
NOS	14	rh	LMB No Split This bit indicates the state of the lmb_no_split_n signal in case of an LMB bus error.
LOC	15	rh	LMB Bus Lock State This bit indicates the bus lock state in case of an LMB bus error. 0 _B LMB bus error occurred at an atomic transfer. 1 _B LMB bus error occurred at a single or block transfer.
ACK	[18:16]	rh	LMB Bus Slave Response State This bit indicates status information of the LMB slave device in case of an LMB bus error. 000 _B Slave is in normal operation. 010 _B Slave is busy. 011 _B Slave has an error encountered. Other bit combinations are reserved.
UIS	19	rh	Un-implemented Address This bit indicates whether the LMB bus error occurred by an un-implemented address. 0 _B LMB slave address is valid. 1 _B Invalid LMB slave address occurred.
SVM	21	rh	LMB Bus Supervisor Mode This bit indicates whether the LMB bus error occurred in Supervisor Mode or in User Mode. 0 _B Transfer was initiated in Supervisor Mode. 1 _B Transfer was initiated in User Mode.

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
WR	22	rh	LMB Bus Write Error Indication This bit indicates whether the LMB bus error occurred at a write cycle (see Table 4-5).
RD	23	rh	LMB Bus Read Error Indication This bit indicates whether the LMB bus error occurred at a read cycle (see Table 4-5).
TAG	[26:24]	rh	LMB Master TAG¹⁾ This bit field indicates the LMB master device in case of an LMB bus error (see Table 4-15). 000 _B LFI 010 _B PMI 100 _B DMI 101 _B DMA Other bit combinations are reserved.
OPC	[31:28]	rh	LMB Bus Error Transaction Type This bit field indicates the type of transfer at which the LMB bus error occurred. 0000 _B 8-bit data single transfer 0001 _B 16-bit data single transfer 0010 _B 32-bit data single transfer 0011 _B 64-bit data single transfer 1000 _B 2 * 64-bit data block transfer 1001 _B 4 * 64-bit data block transfer Other bit combinations are reserved.
0	27, 20, [11:9], 3	r	Reserved Read as 0; should be written with 0.

1) Pls. note that this bit field represents bit 0-2 of the master TAG as shown in [Table 4-15](#)). This as bit 3 of the On Chip Bus master TAGs is always 0 for master interfaces connected to the LMB Bus.

Note: LEATT[31:4] contains valid read data only if its bit LEC is set.

Table 4-5 LMB Bus Read/Write Error Indication

RD	WR	LMB Bus Cycle
0	0	LMB bus error occurred at the read cycle of an atomic transfer.
0	1	LMB bus error occurred at a read cycle of a single transfer.

On-Chip System Buses and Bus Bridges

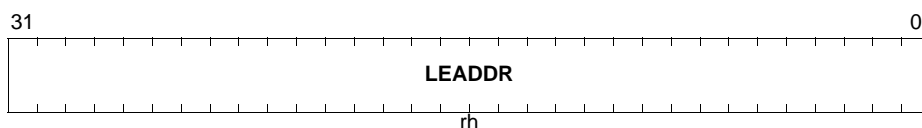
Table 4-5 LMB Bus Read/Write Error Indication (cont'd)

RD	WR	LMB Bus Cycle
1	0	LMB bus error occurred at a write cycle of a single transfer or at the write cycle of an atomic transfer.
1	1	Does not occur.

LBCU_LEADDR

LBCU LMB Error Address Register (024_H)

Reset Value: XXXX XXXX_H

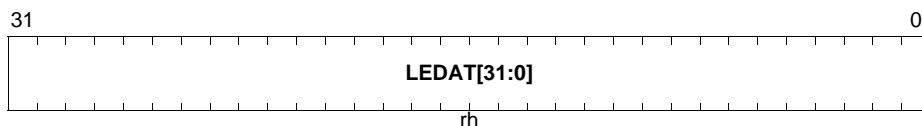


Field	Bits	Type	Description
LEADDR	[31:0]	rh	LMB Bus Address This bit field holds the LMB address that has been captured at an LMB error. LEADDR only contains valid read data when bit LEC in the corresponding register LEATT is set.

LBCU_LEDATL

LBCU LMB Error Data Low Register (028_H)

Reset Value: XXXX XXXX_H



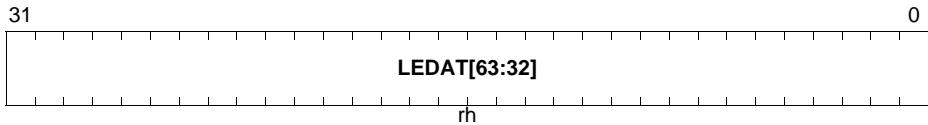
Field	Bits	Type	Description
LEDAT[31:0]	[31:0]	rh	LMB Bus Address Bits [31:0] This bit field holds the lower 32-bit part of the 64-bit LMB data that has been captured at an LMB bus error. LEDAT[31:0] only contains valid read data when bit LEC in the corresponding register LEATT is set.

On-Chip System Buses and Bus Bridges

LBCU_LEDATH

LBCU LMB Error Data High Register (02C_H)

Reset Value: XXXX XXXX_H

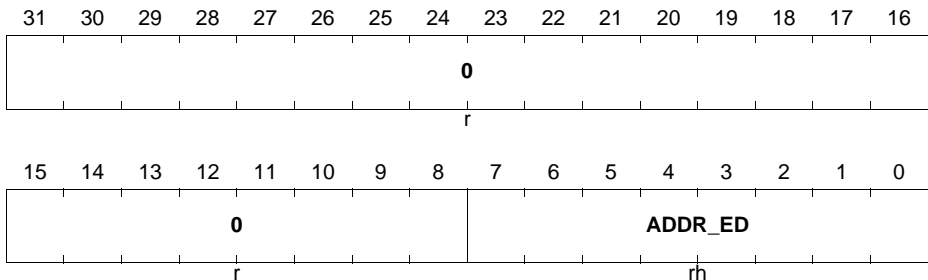


Field	Bits	Type	Description
LEDAT[63:32]	[31:0]	rh	LMB Bus Address Bits [31:0] This bit field holds the upper 32-bit part of the 64-bit LMB data that has been captured at an LMB bus error. LEDAT[63:32] only contains valid read data when bit LEC in the corresponding register LEATT is set.

LBCU_LEADED

LMB Error Address Error Detection Register (034_H)

Reset Value: XXXX XXXX_H

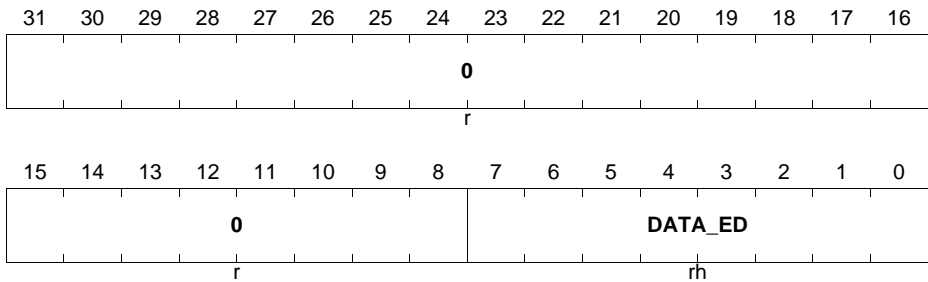


Field	Bits	Type	Description
ADDR_ED	[7:0]	rh	LMB Error Address Error Detection LMB address Error Detection information captured during erroring transaction.
0	[31:8]	r	Reserved Read as 0.

On-Chip System Buses and Bus Bridges

LBCU_LEDATED

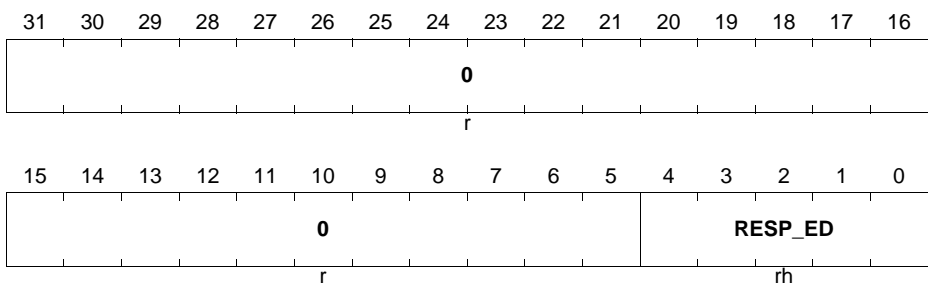
LMB Error Data Error Detection Register (038_H)

Reset Value: 0000 00XX_H


Field	Bits	Type	Description
DATA_ED	[7:0]	rh	LMB Error Data Error Detection LMB data Error Detection information captured during erroring transaction.
0	[31:8]	r	Reserved Read as 0.

LBCU_LERESED

LMB Error Response Error Detection Register (03C_H)

Reset Value: 0000 000X_H


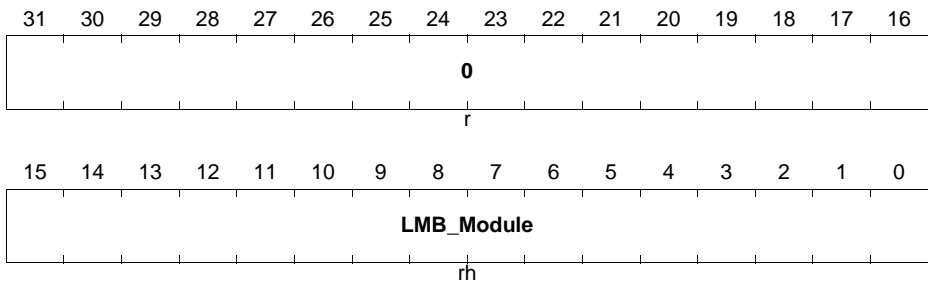
Field	Bits	Type	Description
RESP_ED	[4:0]	rh	LMB Error Response Error Detection LMB error response information captured during erroring transaction.

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
0	[31:5]	r	Reserved Read as 0.

LBCU_LSEADS

LMB Soft Error Address Source Register (040_H)

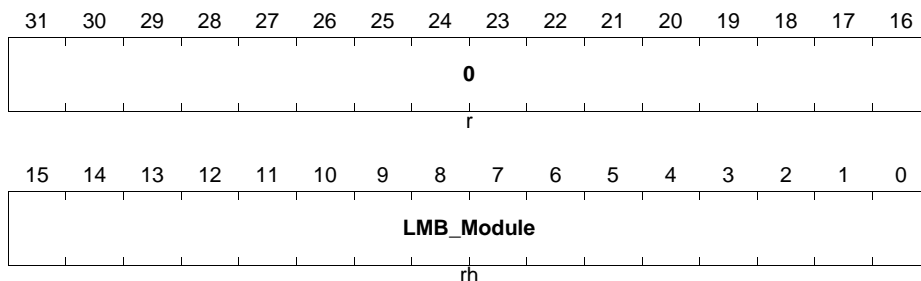
Reset Value: 0000 XXXX_H


Field	Bits	Type	Description
LMB_Module	[15:0]	rh	LMB Soft Error Address Source LMB modules that indicated an error in the address phase of the current transaction. Mapping of the LMB modules to the bit field: <ul style="list-style-type: none"> • 8: LMB BCU • 4: PMU • 3: LFI • 2: DMA • 1: DMI • 0: PMI • Reserved: [15:9], [7:5]
0	[31:16]	r	Reserved Read as 0.

On-Chip System Buses and Bus Bridges

LBCU_LSEABS

LMB Soft Error Abort Source Register (044_H)

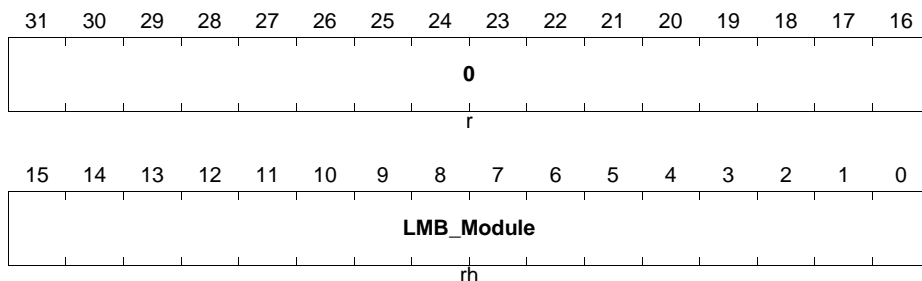
Reset Value: 0000 XXXX_H


Field	Bits	Type	Description
LMB_Module	[15:0]	rh	LMB Soft Error Abort Source LMB modules that indicated an error in the abort phase of the current transaction. Mapping of the LMB modules to the bit field: <ul style="list-style-type: none"> 8: LMB BCU 4: PMU 3: LFI 2: DMA 1: DMI 0: PMI Reserved: [15:9], [7:5]
0	[31:16]	r	Reserved Read as 0.

On-Chip System Buses and Bus Bridges

LBCU_LSERDS

LMB Soft Error Read Source Register (048_H)

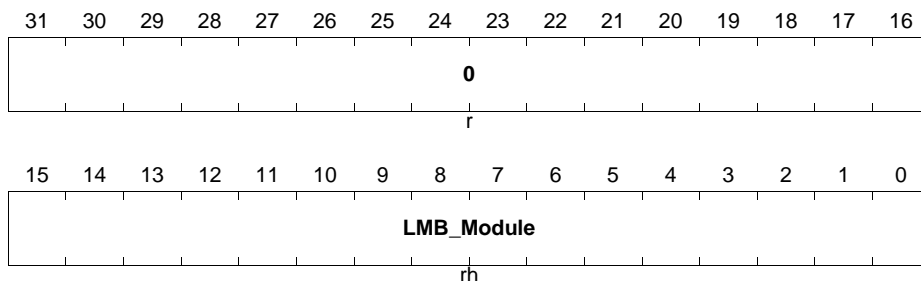
Reset Value: 0000 XXXX_H


Field	Bits	Type	Description
LMB_Module	[15:0]	rh	LMB Soft Error Read Source LMB modules that indicated an error in the read data phase of the current transaction. Mapping of the LMB modules to the bit field: <ul style="list-style-type: none"> 8: LMB BCU 4: PMU 3: LFI 2: DMA 1: DMI 0: PMI Reserved: [15:9], [7:5]
0	[31:16]	r	Reserved Read as 0.

On-Chip System Buses and Bus Bridges

LBCU_LSEWRS

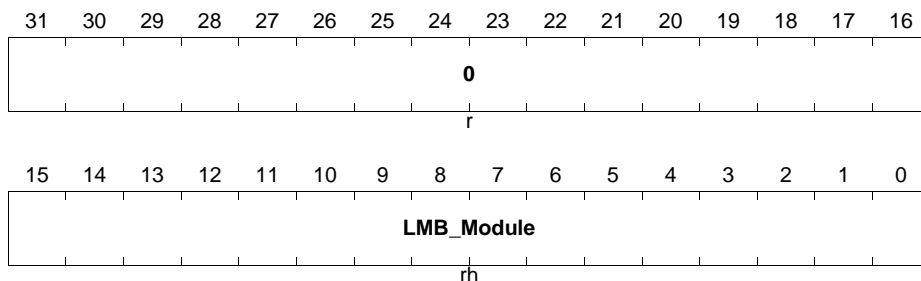
LMB Soft Error Write Source Register (04C_H)

Reset Value: 0000 XXXX_H


Field	Bits	Type	Description
LMB_Module	[15:0]	rh	LMB Soft Error Write Source LMB modules that indicated an error in the write data phase of the current transaction. Mapping of the LMB modules to the bit field: <ul style="list-style-type: none"> 8: LMB BCU 4: PMU 3: LFI 2: DMA 1: DMI 0: PMI Reserved: [15:9], [7:5]
0	[31:16]	r	Reserved Read as 0.

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LBCU_LSERES

LMB Soft Error Response Register (050_H)
Reset Value: 0000 XXXX_H


Field	Bits	Type	Description
LMB_Module	[15:0]	rh	LMB Soft Error Abort Source LMB modules that indicated an error in the acknowledge phase of the current transaction. Mapping of the LMB modules to the bit field: <ul style="list-style-type: none"> • 8: LMB BCU • 4: PMU • 3: LFI • 2: DMA • 1: DMI • 0: PMI • Reserved: [15:9], [7:5]
0	[31:16]	r	Reserved Read as 0.

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LBCU_SRC

LBCU Service Request Control Register

(0FC_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	TOS	0		SRPN								
w	w	rh	rw	r	r		rw								

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	[11:10]	r	Type-of-Service State Always read as 00 _B . This means type-of-service is associated with interrupt bus 0 (CPU interrupt arbitration bus).
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Flag Clear Bit
SETR	15	w	Request Flag Set Bit
0	[9:8], [31:16]	r	Reserved Read as 0; should be written with 0.

On-Chip System Buses and Bus Bridges

4.4 Local Memory Bus to FPI Bus Interface (LFI Bridge)

This section describes the basic functionality of the LFI Bridge.

4.4.1 Functional Overview

The LFI Bridge is a bi-directional bus bridge between the LMB and the System Peripheral FPI Bus (SPB). The bridge supports all transactions types of both the LMB Bus and FPI Bus.

The bridge is not direction-transparent, this means that the master TAG of a bus master is not forwarded to the other side of the bridge and is replaced instead by the master TAG of the LFI Bridge itself.

In order to avoid deadlocks, priority is given to transactions initiated by the DMA or the PCP.

The bridge supports the pipelining of both connected buses. Therefore, no additional delay is created except for bus protocol conversions.

Address Translation

Addresses of SPB transfers (initiated by the DMA or the PCP) via the LFI Bridge that address an LMB slave device, are translated into an LMB address according to [Table 4-6](#).

Table 4-6 SPB to LMB Bus Address Translation

Transaction Destination	SPB Access Range	Translated LMB Address
Reserved	E800 0000 _H - E83F FFFF _H	C800 0000 _H - C83F FFFF _H
DMI LDRAM	E840 0000 _H - E841 EFFF _H	D000 0000 _H - D001 EFFF _H
Reserved	E841 F000 _H - E84F EFFF _H	D001 F000 _H - D00F FFFF _H
PMI SPRAM	E850 0000 _H - E850 5FFF _H	C000 0000 _H - C000 5FFF _H
Reserved	E850 6000 _H - E85F FFFF _H	C000 6000 _H - C000 FFFF _H

Bus Errors at Writes via the LFI Bridge

When a write operation has been initiated and directed to the LFI Bridge by an SPB bus master, the LFI Bridge handles the write transaction at the LMB autonomously. If the write operation at the LMB results in a bus error, the LBCU detects the bus error and generates an LMB bus error interrupt. There is no bus error generated at the SPB side in this case because of the posted nature of a write operation.

The equivalent behavior occurs when an LMB master initiates a write to an SPB slave device. In this case, SPB bus errors are detected by the SBCU but not at the LMB side.

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Note that this behavior occurs only at write operations via the LFI Bridge. It can also be triggered by an erroneous write cycle of a read-modify-write bus transaction.

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4.4.2 LMB to FPI Bridge Control Registers

Table 4-7 and **Table 4-8** are showing the address maps with all registers of the LMB to FPI Bridge (LFI) module.

LFI Register

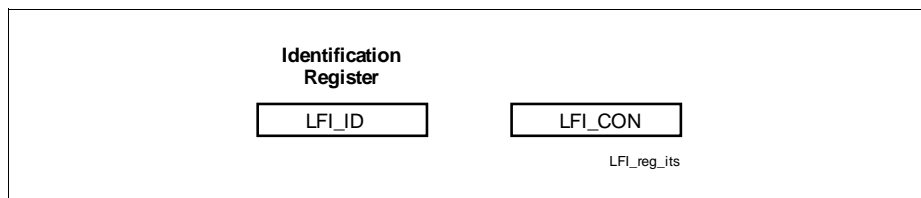


Figure 4-5 LFI Register

*Note: Addresses listed in column “Address” of **Table 4-8** are word (32-bit) addresses.*

Table 4-7 Registers Address Space - LFI Bridge

Module	Base Address	End Address	Note
LFI	F87F FF00 _H	F87F FFFF _H	

Table 4-8 Registers Overview - LFI Bridge Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
–	Reserved	000 _H - 004 _H	BE	BE	-	-
LFI_ID	LFI Module Identification Register	008 _H	U, SV	BE	-	Page 4-27
–	Reserved	00C _H	BE	BE	-	-
LFI_CON	LFI Configuration Register	010 _H	U, SV	SV	3	Page 4-28
–	Reserved	014 _H - 0F4 _H	BE	BE	-	-
–	Reserved	0F8 _H	nBE ²⁾	nBE ²⁾	-	-
–	Reserved	0FC _H - 0FF _H	BE	BE	-	-

1) The absolute register address is calculated as follows:

Module Base Address ([Table 4-7](#)) + Offset Address (shown in this column)

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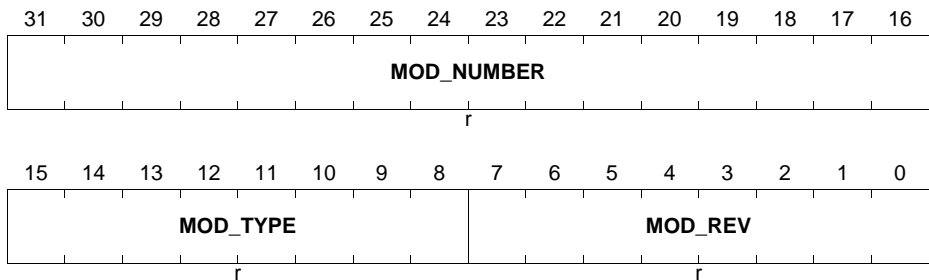
2) Read as 0. Should not be written. If it is written, it must be written with 0.

4.4.2.1 LFI Register Description

The identification register allows the programmer version-tracking of the module. The table below shows the identification register which is implemented in the LFI module.

LFI_ID

Module Identification Register (008_H) **Reset Value: 000C C0XX_H**



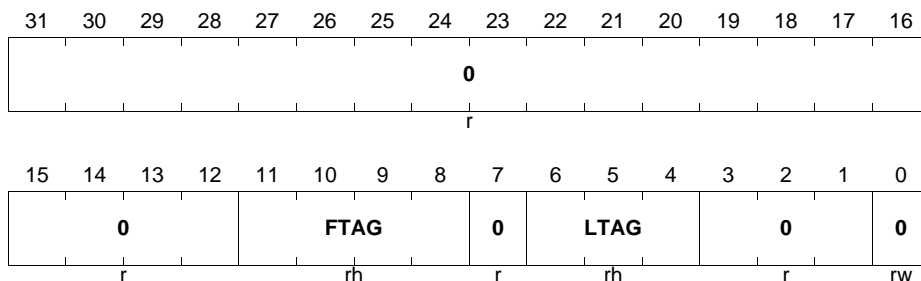
Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the LFI module is 000C _H .

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LFI_CON

LFI Configuration Register

(010_H)

Reset Value: 0000 0B00_H


Field	Bits	Type	Description
0	0	rw	Reserved Returns 0 if read; must be written with 0.
LTAG	[6:4]	rh	LMB Bus Tag ID In the TC1728, the bit field LTAG = 000 _B .
FTAG	[11:8]	rh	FPI Bus (SPB) Tag ID In the TC1728, the bit field FTAG = 1011 _B , which reflects the tag number of the LFI Bridge on the SPB.
0	[3:1], 7, [31:12]	r	Reserved Returns 0 if read; must be written with 0.

4.5 System Peripheral Bus

The TC1728 has one on-chip FPI Bus:

- System Peripheral Bus (SPB)
 - System bus for on-chip peripherals

This section gives an overview of the on-chip FPI Bus. It describes its bus control units, the bus characteristics, bus arbitration, scheduling, prioritizing, error conditions, and debugging support.

4.5.1 Overview

The FPI Bus interconnects the on-chip peripheral functional units with the TC1728 processor subsystem.

The FPI Bus is designed to be quick to be acquired by on-chip functional units, and quick to transfer data. The low setup overhead of the FPI Bus access protocol guarantees fast FPI Bus acquisition, which is required for time-critical applications.

The FPI Bus is designed to sustain high transfer rates. For example, a peak transfer rate of up to 320 Mbyte/s can be achieved with the 32-bit data bus at 80 MHz bus clock. Multiple data transfers per bus arbitration cycle allow the FPI Bus to operate close to its peak bandwidth.

Additional features of the FPI Bus include:

- Optimized for high speed and high performance
- Support of multiple bus masters and pipelined transactions
- 32-bit wide address and data buses
- 8-, 16-, and 32-bit data transfers
- 64-, 128-, and 256-bit block transfers
- Central simple per-cycle arbitration
- Slave-controlled wait state insertion
- Support of atomic operations LDMST, ST.T and SWAP.W

The functional units of the TC1728 are connected to the FPI Bus via FPI Bus interfaces. An FPI Bus interfaces acts as bus agents, requesting bus transactions on behalf of their functional unit, or responding to bus transaction requests.

There are two types of bus agents:

- FPI Bus master agents can initiate FPI Bus transactions and can also act as slaves.
- Slave agents can only react and respond to FPI Bus transaction requests in order to read or write internal registers of slave modules as for example memories.

When an FPI Bus master attempts to initiate a transfer on the FPI Bus, it first signals a request for bus ownership to the bus control unit (SBCU). When bus ownership is granted by the SBCU, an FPI Bus read or write transaction is initiated. The unit targeted by the transaction becomes the FPI Bus slave, and responds with the requested action.

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Some functional units operate only as slaves, while others can operate as either masters or slaves on the FPI Bus. In the TC1728, DMI and PMI (via the LFI Bridge), PCP and DMA (including Cerberus and MLI's) operate as FPI Bus masters. On-chip peripheral units are typically FPI Bus slaves.

FPI Bus arbitration is performed by the Bus Control Unit (SBCU) of the FPI Bus. In case of bus errors, the SBCU generates an interrupt request to the CPU and provides debugging information about the actual bus error to the CPU.

4.5.2 Bus Transaction Types

This section describes the SPB transaction types.

Single Transfers

Single transfers are byte, half-word, and word transactions that target any slave connected to SPB. Note that the LFI Bridge operates as an SPB master.

Block Transfers

Block transfers operate in principle in the same way as single transfers do, but one address phase is followed by multiple data phases. Block transfers can be composed of 2 word, 4 word, or 8 word transfers.

Note: In general, block transfers (2 word, 4 word, or 8 word) cannot be executed in the TC1728 with peripheral units that operate as FPI Bus slaves during an FPI Bus transaction.

Block transfers are initiated by the following CPU instructions: LD.D, LD.DA, MOV.D, ST.D and ST.DA. The BCOPY instruction of the PCP also initiates a block transfer transaction on the FPI Bus.

Atomic Transfers

Atomic transfers are generated by LDMST, ST.T and SWAP.W instructions that require two single transfers. The read and write transfer of an atomic transfer are always locked and cannot be interrupted by another bus masters. Atomic transfers are also referenced as read-modify-write transfers.

Note: See also [Table 4-11](#) for available FPI Bus transfer types.

4.5.3 Reaction of a Busy Slave

If an FPI Bus slave is busy at an incoming FPI Bus transaction request, it can delay the execution of the FPI Bus transaction. The requesting FPI Bus master releases the FPI Bus for one cycle after the FPI Bus transaction request, in order to allow the FPI Bus slave to indicate if it is ready to handle the requested FPI Bus transaction. This sequence is repeated as long as the slave indicates that it is busy.

Note: For the FPI Bus default master, the one cycle gap does not result in a performance loss because it is granted the FPI Bus in this cycle as default master if no other master requests the FPI Bus for some other reasons.

On-Chip System Buses and Bus Bridges

4.5.4 Address Alignment Rules

FPI Bus address generation is compliant with the following rules:

- Half-word transactions must have a half-word aligned address ($A_0 = 0$). Half-word accesses on byte lanes 1 and 2 addresses are illegal.
- Word transactions must always have word-aligned addresses ($A[1:0] = 00_B$).
- Block transactions must always have block-type aligned addresses.

4.5.5 FPI Bus Basic Operations

This section describes some basic transactions on the FPI Bus.

The example in [Figure 4-6](#) shows the three cycles of an FPI Bus operation:

1. **Request/Grant Cycle:** The FPI Bus master attempts to perform a read or write transfer and requests for the FPI Bus. If the FPI Bus is available, it is granted in the same cycle by the FPI Bus controller.
2. **Address Cycle:** After the request/grant cycle, the master puts the address on the FPI Bus, and all FPI Bus slave devices check whether they are addressed for the following data cycle.
3. **Data Cycle:** In the data cycle, either the master puts write data on the FPI Bus which is read by the FPI Bus slave (write cycle) or vice versa (read cycle).

Transfers 2 and 3 show the conflict when two master try to use the FPI Bus and how the conflict is resolved. In the example, the FPI Bus master of transfer 2 has a higher priority than the FPI Bus master of transfer 3.

Bus Cycle	1	2	3	4	5
Transfer 1	Request/ Grant	Address Cycle	Data Cycle		
Transfer 2		Request/ Grant	Address Cycle	Data Cycle	
Transfer 3		Request/ Grant		Address Cycle	Data Cycle

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Figure 4-6 Basic FPI Bus Transactions

At a block transfer, the address cycle of a second transfer is extended until the data cycles of the block transfer are finished. In the example of [Figure 4-7](#), transfer 1 is a block transfer, while transfer 2 is a single transfer.

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Bus Cycle	1	2	3	4	5	6	7
Transfer 1	Request/ Grant	Address Cycle	Data Cycle	Data Cycle	Data Cycle	Data Cycle	
Transfer 2		Request/ Grant	Address Cycle				Data Cycle

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Figure 4-7 FPI Bus Block Transactions

On-Chip System Buses and Bus Bridges

4.6 FPI Bus Control Unit (SBCU)

The TC1728 incorporates one BCU for the SPB, called SBCU.

4.6.1 FPI Bus Arbitration

The arbitration unit of the BCU determines whether it is necessary to arbitrate for FPI Bus ownership, and, if so, which available bus requestor gets the FPI Bus for the next data transfer. During arbitration, the bus is granted to the requesting agent with the highest priority. If no request is pending, the bus is granted to a default master. If no bus master takes the bus, the BCU itself will drive the FPI Bus to prevent it from floating electrically.

4.6.1.1 Arbitration on the System Peripheral Bus

The TC1728 SPB has three bus agents that can become a SPB bus master (DMA, LFI, PCP). Each agent is supplied an arbitration priority as shown in [Table 4-9](#). DMA controller agent can be assigned to low, medium or high priority by software (via DMA Channel and OCDS control registers).

Table 4-9 Priority of TC1728 SPB Bus Agents

Priority	Agent	Comment
highest	Any bus requestor meeting the starvation protection criteria is assigned this priority	Highest priority, used only for starvation protection
	DMA, high priority	DMA requests from module: - OCDS high priority ¹⁾ - DMA channel with high priority ²⁾
	Peripheral Control Processor (PCP)	Default master 0
	DMA, medium priority	DMA requests from module: - DMA channels with med. priority
	LFI Bridge	Default master 1
	DMA, low priority	DMA requests from modules: - Cerberus low priority ¹⁾ - DMA channels low priority ²⁾
lowest		- MLI

1) Priority of Cerberus transaction at the On Chip Busses is defined by the register bit IOCONF.FPI_PRI0. The register is defined in the OCDS chapter.

2) Priority of a DMA channel is defined by the corresponding CHCRmn.DMAPRIO bits. The registers are defined in the DMA chapter.

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If there is no request from an SPB bus master, the SPB is granted to a default master (LFI Bridge or PCP) which has been at last the active master.

4.6.1.2 Starvation Prevention

Starvation prevention is a feature of the SBCU that can take care that even requesting low priority master agents will be granted after a period, where the period length can be controlled by SBCU control registers. Because the priority assignment of the SPB agents is fixed, it is possible that a lower-priority bus requestor may never be granted the bus if a higher-priority bus requestor continuously asks for, and receives, bus ownership. To protect against bus starvation of lower-priority masters, the starvation prevention mechanism of the SBCU will detect such cases and momentarily raise the priority of the lower-priority requestor to the highest priority (above all other priorities), thereby guaranteeing it access.

Starvation protection employs a counter that is decremented each time an arbitration is performed on the connected FPI bus. The counter is re-loaded with the starvation period value in the SBCU_CON.SPC bit field as long it is enabled SBCU_CON.SPE. When this counter is counted down to zero, for each active bus request a request flag is stored in the BCU. This flag is cleared automatically when a master is granted the bus.

When the next period is finished, an active request of a master from which the request flag was set, a starvation event happened. This master will now be set to the highest priority and will be granted service. If there are several masters to which this starvation condition applies, they are served in the order of their hard-wired priority ranking.

If a master that is processing its transaction under starvation condition is retried, its corresponding request flag is automatically again.

Starvation protection can be enabled and disabled through bit SBCU_CON.SPE. The sample period of the counter is programmed through bit field SBCU_CON.SPC. SPC should be set to a value at least greater than or equal to the number of masters. Its reset value is 40_H.

4.6.2 FPI Bus Error Handling

When an error occurs on an FPI Bus, its BCU captures and stores data about the erroneous condition and generates a service request if enabled to do so. The error conditions that force an error-capture are:

- Error Acknowledge: An FPI Bus slave responds with an error to a transaction.
- Un-implemented Address: No FPI Bus slave responds to a transaction request.
- Time-out: A slave does not respond to a transaction request within a certain time window. The number of bus clock cycles that can elapse until a bus time-out is generated is defined by bit field SBCU_CON.TOUT.

When a transaction causes an error, the address and data phase signals of the transaction causing the error are captured and stored in registers.

- The Error Address Capture Register (SBCU_EADD) stores the 32-bit FPI Bus address that has been captured during the erroneous FPI Bus transaction.

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- The Error Data Capture Registers (SBCU_EDAT) stores the 32-bit FPI Bus data bus information that has been captured during the erroneous FPI Bus transaction.
- The Error Control Capture Register (SBCU_ECON) stores status information of the bus error event.

If more than one FPI Bus transaction generates a bus error, only the first bus error is captured. After a bus error has been captured, the capture mechanism must be released again by software.

If a write transaction from TriCore causes an error on the SPB, the originating master is not informed about this error as it is not an SPB master agent. With each bus error-capture event, a service request is generated, and an interrupt can be generated if enabled and configured in the corresponding service request register.

Interpreting the BCU Control Register Error Information

Although the address and data values captured in registers SBCU_EADD and SBCU_EDAT, respectively, are self-explanatory, the captured FPI Bus control information needs some more explanation.

Register SBCU_ECON captures the state of the read (RDN), write (WRN), Supervisor Mode (SVM), acknowledge (ACK), ready (RDY), abort (ABT), time-out (TOUT), bus master identification lines (TAG) and transaction operation code (OPC) lines of the FPI Bus.

The SVM signal is set to 1 for an access in Supervisor Mode and set to 0 for an access in User Mode. The time-out signal indicates if there was no response on the bus to an access, and the programmed time (via SBCU_TOUT) has elapsed. TOUT is set to 1 in this case. An acknowledge code has to be driven by the selected slave during each data cycle of an access. These codes are listed in [Table 4-10](#).

Table 4-10 FPI Bus Acknowledge Codes

Code (ACK)	Description
00 _B	NSC: No Special Condition.
01 _B	SPT: Split Transaction (not used in the TC1728).
10 _B	RTY: Retry. Slave can currently not respond to the access. Master needs to repeat the access later.
11 _B	ERR: Bus Error, last data cycle is aborted.

Transactions on the FPI Bus are classified via a 4-bit operation code (see [Table 4-11](#)). Note that split transactions (OPC = 1000_B to 1110_B) are not used in the TC1728.

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Table 4-11 FPI Bus Operation Codes (OPC)

OPC	Description
0000_B	Single Byte Transfer (8-bit)
0001_B	Single Half-Word Transfer (16-bit)
0010_B	Single Word Transfer (32-bit)
0100_B	2-Word Block Transfer
0101_B	4-Word Block Transfer
0110_B	8-Word Block Transfer
1111	No operation
0011_B, 0111_B, 1000_B - 1110_B	Reserved

4.6.3 BCU Debug Support

For debugging purposes, the BCU has the capability for breakpoint generation support. This OCDS debug capability is controlled by the Cerberus module and must be enabled by it (indicated by bit SBCU_DBCNTL.EO).

When BCU debug support has been enabled ($EO = 1$), any breakpoint request generated by the BCU to the Cerberus disarms the BCU breakpoint logic for further breakpoint requests. In order to rearm the BCU breakpoint logic again for the next breakpoint request generation, bit SBCU_DBCNTL.RA must be set. The status of the BCU breakpoint logic (armed or disarmed) is indicated by bit SBCU_DBCNTL.OA.

There are three types of trigger events:

- Address triggers
- Signal triggers
- Grant triggers

4.6.3.1 Address Triggers

The address debug trigger event conditions are defined by the contents of the SBCU_DBADR1, SBCU_DBADR2, and SBCU_DBCNTL registers. A wide range of possibilities arise for the creation of debug trigger events based on addresses. The following debug trigger events can be selected:

- Match on one signal address
- Match on one of two signal addresses
- Match on one address area
- Mismatch on one address area

Each pair of DBADR x registers and DBCNTL.ONA x bits determine one possible debug trigger event. The combination of these two possible debug trigger events defined by DBCNTL.CONCOM1 determine the address debug trigger event condition.

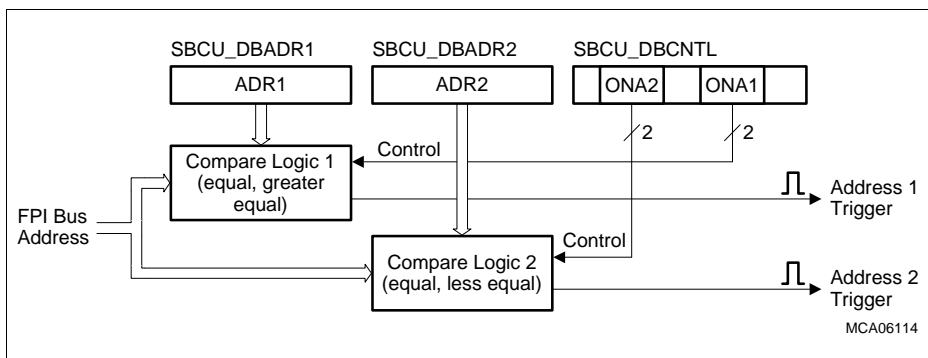


Figure 4-8 Address Trigger Generation

4.6.3.2 Signal Status Triggers

The signal status debug trigger event conditions are defined by the contents of the SBCU_DBBOS and SBCU_DBCNTL registers. Depending on the selected configuration a wide range of possibilities arise for the creation of a debug trigger event based on FPI Bus status signals. Possible combinations are:

- Match on a single signal status
- Match on a multiple signal status

With the multiple signal match conditions, all single signal match conditions are combined with a logical **AND** to the signal status debug trigger event signal. The selection whether or not a single match condition is selected can be enabled/disabled selectively for each condition via the SBCU_DBCNTL.ONBOSx bits.

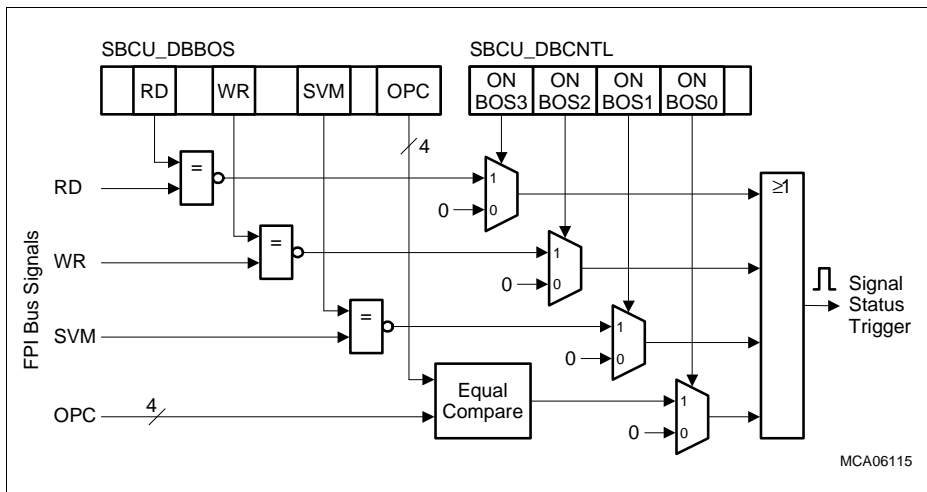


Figure 4-9 Signal Status Trigger Generation

4.6.3.3 Grant Triggers

The signal status debug trigger event conditions are defined via the registers SBCU_DBGRNT and SBCU_DBCNTL. Depending on the configuration of these registers, any combination of FPI Bus master trigger events can be configured. Only the enabled masters in the SBCU_DBGRNT register are of interest for the grant debug trigger event condition. The grant debug trigger event condition can be enabled/disabled via bit SBCU_DBCNTL.ONG (see [Figure 4-10](#)).

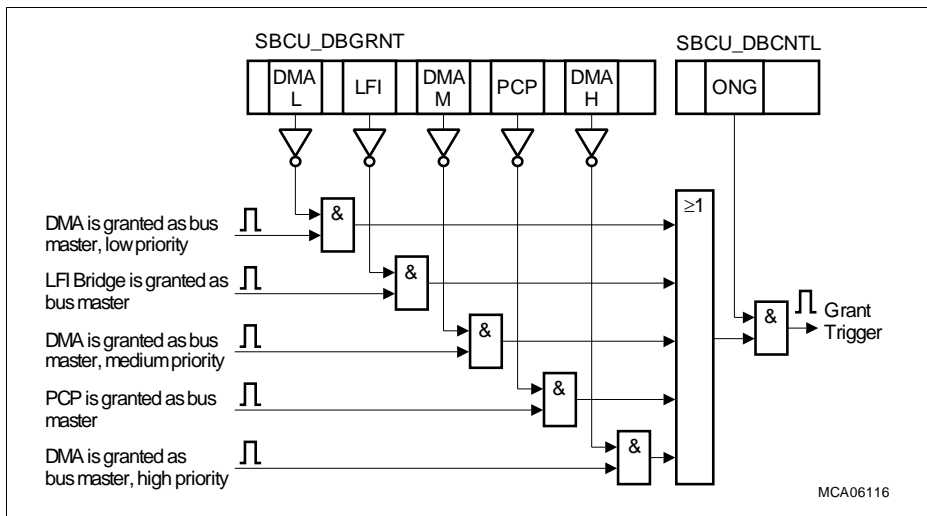


Figure 4-10 Grant Trigger Generation

4.6.3.4 Combination of Triggers

The combination of the four debug trigger signals to the single BCU breakpoint trigger event is defined via the bits CONCOM[2:0] of register SBCU_DBCNTL (see [Figure 4-11](#)). The two address triggers are combined to one address trigger that is further combined with signal status and grant trigger signals. A logical AND or OR combination can be selected for the BCU breakpoint trigger generation.

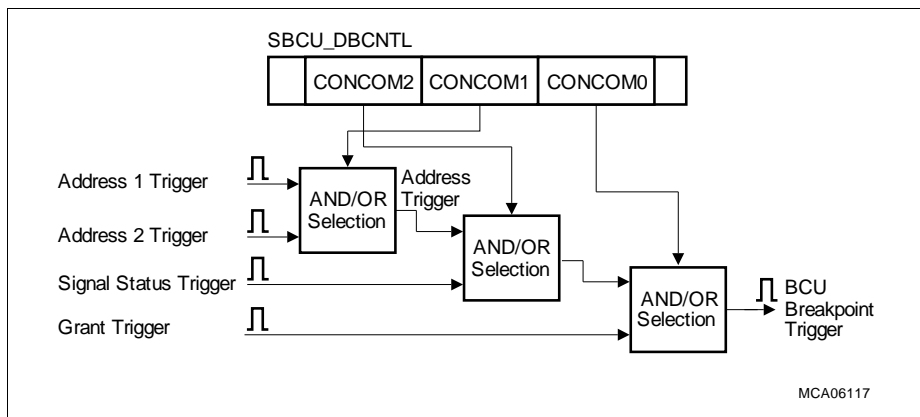


Figure 4-11 BCU Breakpoint Trigger Combination Logic

4.6.3.5 BCU Breakpoint Generation Examples

This section gives three examples of how BCU debug trigger events are programmed.

OCDS Debug Example 1

- Task: Generation of a BCU debug trigger event on any SPB write access to address 00002004_H or 000020A0_H by SPB master of the LFI Bridge or the PCP.

For this task, the following programming settings for the BCU breakpoint logic must be executed:

- Writing SBCU_DBADR1 = 0000 2004_H
- Writing SBCU_DBADR2 = 0000 20A0_H
- Writing SBCU_DBCNTL = C1115010_H:
 - ONBOS[3:0] = 1100_B means that no signal status trigger is generated (disabled) for a read signal match AND write signal match condition according to the settings of bits RD and WR in register SBCU_DBBOS. Debug trigger event generation for Supervisor Mode signal match and opcode signal match condition is disabled.
 - ONA2 = 01_B means that the equal match condition for debug address 2 register is selected.

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- c) $\text{ONA1} = 01_{\text{B}}$ means that the equal match condition for debug address 1 register is selected.
- d) $\text{ONG} = 1$ means that the grant debug trigger is enabled.
- e) $\text{CONCOM}[2:0] = 101_{\text{B}}$ means that the address trigger is created by address trigger 1 OR address trigger 2 ($\text{CONCOM1} = 0$), and that the grant trigger is ANDed with the address trigger ($\text{CONCOM0} = 1$), and that the signal status trigger is ANDed with the address trigger ($\text{CONCOM2} = 1$).
- f) $\text{RA} = 1$ means that the BCU breakpoint logic is rearmed.
- 4. Writing $\text{SBCU_DBGRNT} = \text{FFFFFFD7}_{\text{H}}$:
means that the grant trigger for the SPB master of the PCP and LFI Bridge is enabled.
- 5. Writing $\text{SBCU_DBBOS} = 00001000_{\text{H}}$:
means that the signal status trigger is generated on a write transfer and not on a read transfer.

OCDS Debug Example 2

- Task: generation of a BCU debug trigger event on any half-word access in User Mode to address area $01\text{FFFFFF}_{\text{H}}$ to $02\text{FFFFFF}_{\text{H}}$ by any master.

For this task, the following programming settings for the BCU breakpoint logic must be executed:

1. Writing $\text{SBCU_DBADR1} = 01\text{FFFFFF}_{\text{H}}$
2. Writing $\text{SBCU_DBADR2} = 02\text{FFFFFF}_{\text{H}}$
3. Writing $\text{SBCU_DBCNTL} = 32206010_{\text{H}}$:
 - a) $\text{ONBOS}[3:0] = 0011_{\text{B}}$ means that the signal status trigger is disabled for a read or for write signal status match but enabled for Supervisor Mode match AND opcode match conditions according to the settings of bit SVM and bit field OPC in register SBCU_DBBOS .
 - b) $\text{ONA2} = 10_{\text{B}}$ means that the address 2 trigger is generated if the FPI Bus address is greater or equal to SBCU_DBADR2 .
 - c) $\text{ONA1} = 10_{\text{B}}$ means that the address 1 trigger is generated if the FPI Bus address is greater or equal to SBCU_DBADR1 .
 - d) $\text{ONG} = 0$ means that the grant debug trigger is disabled.
 - e) $\text{CONCOM}[2:0] = 110_{\text{B}}$ means that the address trigger is created by address trigger 1 AND address trigger 2 ($\text{CONCOM1} = 1$), and that the grant trigger is OR-ed with the address trigger ($\text{CONCOM0} = 0$), and that the signal status trigger is AND-ed with the address trigger ($\text{CONCOM2} = 1$).
 - f) $\text{RA} = 1$ means that the BCU breakpoint logic is rearmed.
4. Writing $\text{SBCU_DBGRNT} = \text{FFFFFFF}_{\text{H}}$:
means that no grant trigger for SPB masters is selected ("don't care" because also disabled by $\text{ONG} = 0$).
5. Writing $\text{SBCU_DBBOS} = 00000001_{\text{H}}$:
means that the signal status trigger is generated for read ($\text{RD} = 0$) and write ($\text{WR} = 0$) half-word transfers ($\text{OPC} = 0001_{\text{B}}$) in User Mode ($\text{SVM} = 0$).

OCDS Debug Example 3

- Task: Generation of a BCU debug trigger event on any access into address area $01FFFFFF_H$ to $FFFFFFFF_H$ by the PCP.

For this task the following programming settings for the BCU breakpoint logic must be executed:

1. Writing $SBCU_DBADR1 = 01FFFFFF_H$
2. Writing $SBCU_DBADR2 = \text{don't care}$
3. Writing $SBCU_DBCNTL = 00215010_H$:
 - a) $ONBOS[3:0] = 0000_B$ means that a signal status trigger is generated for all FPI Bus opcodes not equal to a “no operation” opcode.
 - b) $ONA2 = 00_B$ means that no address 2 trigger is generated.
 - c) $ONA1 = 10_B$ means that the address 1 trigger is generated if the FPI Bus address is greater or equal to $SBCU_DBADR1$.
 - d) $ONG = 1$ means that the grant debug trigger is enabled.
 - e) $CONCOM[2:0] = 101_B$ means that the address trigger is created by address trigger 1 OR address trigger 2 ($CONCOM1 = 0$), and that the grant trigger is AND-ed with the address trigger ($CONCOM0 = 1$), and that the signal status trigger is ANDed with the address trigger ($CONCOM2 = 1$).
 - f) $RA = 1$ means that the BCU breakpoint logic is rearmed.
4. Writing $SBCU_DBGRNT = FFFFFFFF7_H$:

means that the grant trigger for the SPB bus master of the PCP is enabled.
5. Writing $SBCU_DBBOS$ is “don't care”. No signal trigger for SVM, WR, or RD is generated.

On-Chip System Buses and Bus Bridges

4.6.4 System Bus Control Unit Registers

Figure 4-12 and **Table 4-13** are showing the address maps with all registers of the System Bus Control Unit (SBCU) module.

SBCU Control Registers Overview

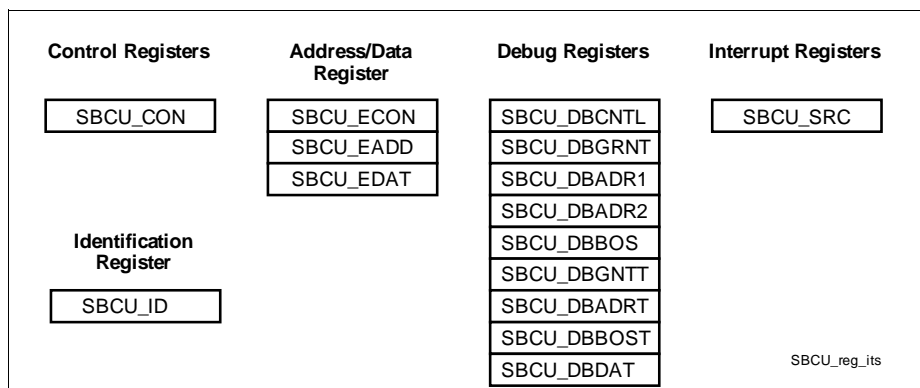


Figure 4-12 SBCU Registers

Table 4-12 Registers Address Space - SBCU Address Space

Module	Base Address	End Address	Note
SBCU	F000 0100 _H	F000 01FF _H	

Table 4-13 Registers Overview - SBCU Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
–	Reserved	000 _H - 004 _H	BE	BE	-	-
SBCU_ID	SBCU Module Identification Register	008 _H	U, SV	BE	-	Page 4-47
–	Reserved	00C _H	BE	BE	-	-
SBCU_CON	SBCU Control Register	010 _H	U, SV	SV	3	Page 4-48
–	Reserved	014 _H - 01C _H	BE	BE	3	-

On-Chip System Buses and Bus Bridges

Table 4-13 Registers Overview - SBCU Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
SBCU_ECON	SBCU Error Control Capture Register	020 _H	U, SV	SV	3	Page 4-49
SBCU_EADD	SBCU Error Address Capture Register	024 _H	U, SV	SV	3	Page 4-51
SBCU_EDAT	SBCU Error Data Capture Register	028 _H	U, SV	SV	3	Page 4-52
–	Reserved	02C _H	BE	BE	-	-
SBCU_DBCNTL	SBCU Debug Control Register	030 _H	U, SV	SV	1	Page 4-53
SBCU_DBGRNT	SBCU Debug Grant Mask Register	034 _H	U, SV	SV	1	Page 4-56
SBCU_DBADR1	SBCU Debug Address Register 1	038 _H	U, SV	SV	1	Page 4-57
SBCU_DBADR2	SBCU Debug Address Register 2	03C _H	U, SV	SV	1	Page 4-58
SBCU_DBBOS	SBCU Debug Bus Operation Signals Register	040 _H	U, SV	SV	1	Page 4-58
SBCU_DBGNTT	SBCU Debug Trapped Master Register	044 _H	U, SV	BE	1	Page 4-60
SBCU_DBADRT	SBCU Debug Trapped Address Register	048 _H	U, SV	BE	1	Page 4-62
SBCU_DBBOST	SBCU Debug Trapped Bus Operation Signals Register	04C _H	U, SV	BE	1	Page 4-62
SBCU_DBDAT	SBCU Debug Data Status Register	050 _H	U, SV	BE	1	Page 4-65
–	Reserved	054 _H - 0F8 _H	BE	BE	-	-
SBCU_SRC	SBCU Service Request Control Register	0FC _H	U, SV	SV	3	Page 4-66

1) The absolute register address is calculated as follows:

Module Base Address ([Table 4-12](#)) + Offset Address (shown in this column)

On-Chip System Buses and Bus Bridges

4.6.4.1 SBCU ID Register Description

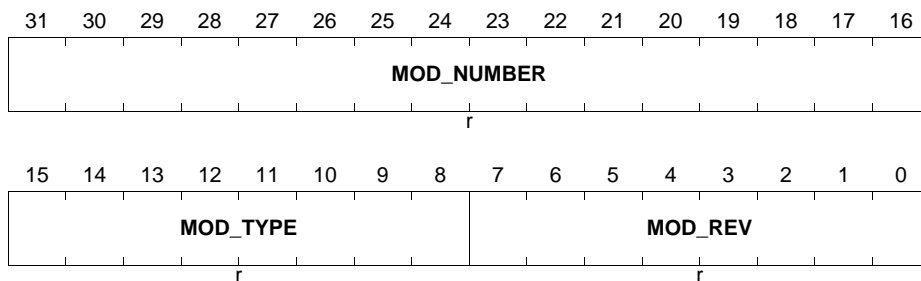
The identification register allows the programmer version-tracking of the module. The table below shows the identification register which is implemented in the SBCU module.

SBCU_ID

Module Identification Register

(008_H)

Reset Value: 0000 6AXX_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_NUMBER	[15:8]	r	Module Number Value This bit field defines a module identification number. The value for the LBCU module is 006AH.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

On-Chip System Buses and Bus Bridges

4.6.4.2 SBCU Control Registers Descriptions

The SBCU Control Register controls the overall operation of the SBCU, including setting the starvation sample period, the bus time-out period, enabling starvation-protection mode, and error handling.

SBCU_CON

SBCU Control Register

(010_H)

Reset Value: 4009 FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SPC								0				SPE	0		DBG
rw								r				rw	rw		rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TOUT															
rw															

Field	Bits	Type	Description
TOUT	[15:0]	rw	SBCU Bus Time-Out Value The bit field determines the number of System Peripheral Bus time-out cycles. Default after reset is FFFF _H (= 65536 bus cycles). Pls. Note: TOUT value must be >= 5.
DBG	16	rw	SBCU Debug Trace Enable 0 _B SBCU debug trace disabled 1 _B SBCU debug trace enabled (default after reset)
SPE	19	rw	SBCU Starvation Protection Enable 0 _B SBCU starvation protection disabled 1 _B SBCU starvation protection enabled (default after reset)
SPC	[31:24]	rw	Starvation Period Control Determines the sample period for the starvation counter. Must be larger than the number of masters. The reset value is 40 _H .
0	[18:17], [23:20]	r	Reserved Read as 0; should be written with 0.

On-Chip System Buses and Bus Bridges

4.6.4.3 SBCU Error Registers Descriptions

The capture of bus error conditions is enabled by setting SBCU_CON.DBG to 1. In case of a bus error, information about the condition will then be stored in the SBCU error capture registers. The SBCU error capture registers can then be examined by software to determine the cause of the FPI Bus error.

If enabled and an FPI Bus error occurs, the SBCU_ECON register holds the captured FPI Bus control information and an error count of the number of bus errors. The SBCU_EADD register stores the captured FPI Bus address. The SBCU_EDAT register stores the captured FPI Bus data.

If the capture of FPI Bus error conditions is disabled (SBCU_CON.DBG = 0), the SBCU error capture registers remain untouched.

Note: The SBCU error capture registers store only the parameters of the first error. In case of multiple bus errors, an error counter SBCU_ECON.ERRCNT shows the number of bus errors since the first error occurred. An application reset clears this bit field to zero, but the counter can be set to any value through software. This counter is prevented from overflowing, so a value of $2^{16} - 1$ indicates that at least this many errors have occurred, but there may have been more. After SBCU_ECON has been read, the SBCU_ECON, SBCU_EADD and SBCU_EDAT registers are re-enabled to trace FPI Bus error conditions.

SBCU_ECON

SBCU Error Control Capture Register(020_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OPC				TAG				RDN	WRN	SVM	ACK	ABT	RDY	T OUT	
rwh				rwh				rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERRCNT															
rwh															

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
ERRCNT	[15:0]	rwh	FPI Bus Error Counter ERRCNT is incremented on every occurrence of an FPI Bus error. ERRCNT is reset to 0000 _H after the SBCU_ECON register is read. ¹⁾
TOUT	16	rwh	State of FPI Bus Time-Out Signal This bit indicates the state of the time-out signal at an FBI Bus error. 0 _B No time-out occurred 1 _B Time-out has occurred
RDY	17	rwh	State of FPI Bus Ready Signal This bit indicates the state of the ready signal at an FBI Bus error. 0 _B Wait state(s) have been inserted. Ready signal was active 1 _B Ready signal was inactive
ABT	18	rwh	State of FPI Bus Abort Signal This bit indicates the state of the abort signal at an FBI Bus error. 0 _B Master has aborted an FPI Bus transfer. Abort signal was active 1 _B Abort signal was inactive
ACK	[20:19]	rwh	State of FPI Bus Acknowledge Signals This bit field indicates the acknowledge code that has been output by the selected slave at an FPI Bus error. Coding see Table 4-10 .
SVM	21	rwh	State of FPI Bus Supervisor Mode Signal This bit indicates whether the FPI Bus error occurred in Supervisor Mode or in User Mode. 0 _B Transfer was initiated in User Mode 1 _B Transfer was initiated in Supervisor Mode
WRN	22	rwh	State of FPI Bus Write Signal This bit indicates whether the FPI Bus error occurred at a write cycle (see Table 4-14).
RDN	23	rwh	State of FPI Bus Read Signal This bit indicates whether the FPI Bus error occurred at a read cycle (see Table 4-14).

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
TAG	[27:24]	rwh	FPI Bus Master Tag Number Signals This bit field indicates the FPI Bus master TAG number (definitions see Table 4-15).
OPC	[31:28]	rwh	FPI Bus Operation Code Signals The FPI Bus operation codes are defined in Table 4-11 .

- 1) In the TC1728, aborted accesses to a 0 wait state SPB slave may also increment ERRCNT when the slave generates an error acknowledge.

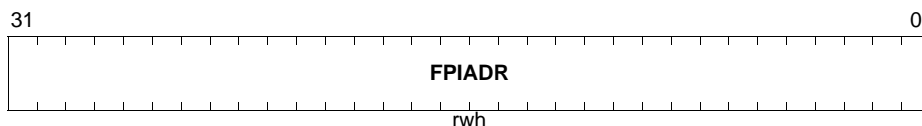
Table 4-14 FPI Bus Read/Write Error Indication

RD	WR	FPI Bus Cycle
0	0	FPI Bus error occurred at the read transfer of a read-modify-write transfer.
0	1	FPI Bus error occurred at a read cycle of a single transfer.
1	0	FPI Bus error occurred at a write cycle of a single transfer or at the write cycle of a read-modify-write transfer.
1	1	Does not occur.

SBCU_EADD

SBCU Error Address Capture Register (024_H)

Reset Value: 0000 0000_H



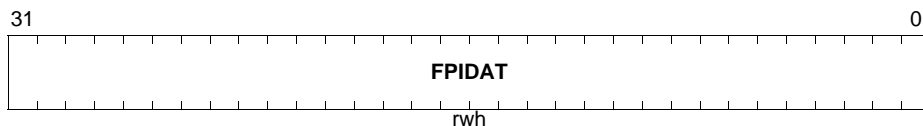
Field	Bits	Type	Description
FPIADR	[31:0]	rwh	Captured FPI Bus Address This bit field holds the 32-bit FPI Bus address that has been captured at an FPI Bus error. Note that if multiple bus errors occurred, only the address of the first bus error is captured.

On-Chip System Buses and Bus Bridges

SBCU_EDAT

SBCU Error Data Capture Register (028_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
FPIDAT	[31:0]	rwh	Captured FPI Bus Address This bit field holds the 32-bit FPI Bus data that has been captured at an FPI Bus error. Note that if multiple bus errors occurred, only the data of the first bus error is captured.

On-Chip System Buses and Bus Bridges

4.6.4.4 SBCU OCDS Registers Descriptions

SBCU_DBCNTL

SBCU Debug Control Register

(030_H)

Reset Value: 0000 7003_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ON BOS 3	ON BOS 2	ON BOS 1	ON BOS 0	0		ONA2		0		ONA1		0		ONG	
rw	rw	rw	rw	r		rw		r		rw		r		rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CON COM 2	CON COM 1	CON COM 0	0							RA	0		OA	EO
r	rw	rw	rw	r							w	r		r	r

Field	Bits	Type	Description
EO	0	r	Status of SBCU Debug Support Enable This bit is controlled by the Cerberus and enables the SBCU debug support. 0 _B SBCU debug support is disabled 1 _B SBCU debug support is enabled (default after reset)
OA	1	r	Status of SBCU Breakpoint Logic 0 _B The SBCU breakpoint logic is disarmed. Any further breakpoint activation is discarded 1 _B The SBCU breakpoint logic is armed The OA bit is set by writing a 1 to bit RA. When OA is set, registers SBCU_DBGNTT, SBCU_DBADRT, and SBCU_DBBOST are reset.
RA	4	w	Rearm SBCU Breakpoint Logic Writing a 1 to this bit rearms SBCU breakpoint logic and sets bit OA = 1. RA is always reads as 0.

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
CONCOM0	12	rw	Grant and Address Trigger Relation 0_B The grant phase trigger condition and the address trigger condition (see CONCOM1) are combined with a logical OR for further control 1_B The grant phase trigger condition and the address trigger condition (see CONCOM1) are combined with a logical AND for further control (see Figure 4-11)
CONCOM1	13	rw	Address 1 and Address 2 Trigger Relation 0_B Address 1 trigger condition and address 2 trigger condition are combined with a logical OR to the address trigger condition for further control 1_B Address 1 trigger condition and address 2 trigger condition are combined with a logical AND to the address trigger condition for further control (see Figure 4-11)
CONCOM2	14	rw	Address and Signal Trigger Relation 0_B Address trigger condition (see CONCOM1) and signal status trigger conditions are combined with a logical OR for further control 1_B Address phase trigger condition (see CONCOM1) and the signal status trigger conditions are combined with a logical AND for further control (see Figure 4-11)
ONG	16	rw	Grant Trigger Enable 0_B No grant debug event trigger is generated 1_B The grant debug event trigger is enabled and generated according the settings of register SBCU_DBGRNT (see Figure 4-10)
ONA1	[21:20]	rw	Address 1 Trigger Control 00_B No address 1 trigger is generated 01_B An address 1 trigger event is generated if the FPI Bus address is equal to SBCU_DBADR1 10_B An address 1 trigger event is generated if FPI Bus address is greater or equal to SBCU_DBADR1 11_B same as 00_B See also Figure 4-8 .

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
ONAA2	[25:24]	rw	Address 2 Trigger Control 00 _B No address 2 trigger is generated 01 _B An address 2 trigger event is generated if the FPI Bus address is equal to SBCU_DBADR2 10 _B An address 2 trigger event is generated if FPI Bus address is greater or equal to SBCU_DBADR2 11 _B same as 00 _B See also Figure 4-8 .
ONBOS0	28	rw	Opcode Signal Status Trigger Condition 0 _B A signal status trigger is generated for all FPI Bus opcodes except a “no operation” opcode 1 _B A signal status trigger is generated if the FPI Bus opcode matches the opcode as defined in DBBOS.OPC (see Figure 4-9)
ONBOS1	29	rw	Supervisor Mode Signal Trigger Condition 0 _B The signal status trigger generation for the FPI Bus Supervisor Mode signal is disabled 1 _B A signal status trigger is generated if the FPI Bus Supervisor Mode signal state is equal to the value of DBBOS.SVM (see Figure 4-9)
ONBOS2	30	rw	Write Signal Trigger Condition 0 _B The signal status trigger generation for the FPI Bus write signal is disabled 1 _B A signal status trigger is generated if the FPI Bus write signal state is equal to the value of DBBOS.WR (see Figure 4-9)
ONBOS3	31	rw	Read Signal Trigger Condition 0 _B The signal status trigger generation for the FPI Bus read signal is disabled 1 _B A signal status trigger is generated if the FPI Bus read signal state is equal to the value of DBBOS.RD (see Figure 4-9)

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
0	[3:2], [11:5], 15, [19:17], [23:22], [27:26]	r	Reserved Read as 0; should be written with 0.

SBCU_DBGRT

SBCU Debug Grant Mask Register (034_H) **Reset Value: 0000 FFFF_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ONES									DMA L	LFI	DMA M	PCP	ONE	DMA H	
rw									rw	rw	rw	rw	rw	rw	

Field	Bits	Type	Description
DMAH	0	rw	Cerberus Grant Trigger Enable, High Priority¹⁾ 0 _B FPI Bus transactions with high-priority DMA as bus master are enabled for grant trigger event generation 1 _B FPI Bus transactions with high-priority DMA as bus master are disabled for grant trigger event generation
ONE, ONES	[2:1], [15:7]	rw	Reserved Read as 1 after reset; reading these bits will return the value last written.
PCP	3	rw	PCP Grant Trigger Enable 0 _B FPI Bus transactions with PCP as bus master are enabled for grant trigger event generation 1 _B FPI Bus transactions with PCP as bus master are disabled for grant trigger event generation

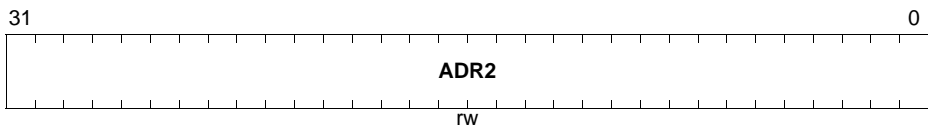
On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
ADR1	[31:0]	rw	Debug Trigger Address 1 This register contains the address for the address 1 trigger event generation.

SBCU_DBADR2

SBCU Debug Address 2 Register (03C_H)

Reset Value: 0000 0000_H



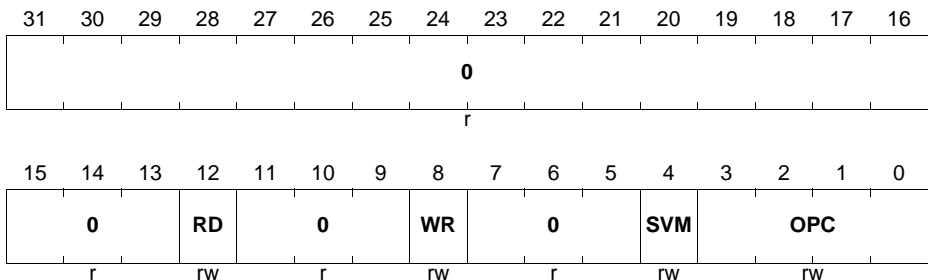
Field	Bits	Type	Description
ADR2	[31:0]	rw	Debug Trigger Address 2 This register contains the address for the address 2 trigger event generation.

SBCU_DBBOS

SBCU Debug Bus Operation Signals Register

(040_H)

Reset Value: 0000 0000_H



On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
OPC	[3:0]	rw	<p>Opcode for Signal Status Debug Trigger This bit field determines the type (opcode) of an FPI Bus transaction for which a signal status debug trigger event is generated (if enabled by DBCNTL.ONBOS0 = 1).</p> <p>0000_B Trigger on single byte transfer selected 0001_B Trigger on single half-word transfer selected 0010_B Trigger on single word transfer selected 0100_B Trigger on 2-word block transfer selected 0101_B Trigger on 4-word block transfer selected 0110_B Trigger on 8-word block transfer selected 1111_B Trigger on no operation selected Other bit combinations are reserved.</p>
SVM	4	rw	<p>SVM Signal for Status Debug Trigger This bit determines the mode of an FPI Bus transaction for which a signal status debug trigger event is generated (if enabled by DBCNTL.ONBOS1 = 1).</p> <p>0_B Trigger on User Mode selected 1_B Trigger on Supervisor Mode selected</p>
WR	8	rw	<p>Write Signal for Status Debug Trigger This bit determines the state of the WR signal of an FPI Bus transaction for which a signal status debug trigger event is generated (if enabled by DBCNTL.ONBOS2 = 1).</p> <p>0_B Trigger on a single write transfer or write cycle of an atomic transfer selected 1_B No operation or read transaction selected</p>
RD	12	rw	<p>Write Signal for Status Debug Trigger This bit determines the state of the RD signal of an FPI Bus transaction for which a signal status debug trigger event is generated (if enabled by DBCNTL.ONBOS3 = 1).</p> <p>0_B Trigger on a single read transfer or read cycle of an atomic transfer selected 1_B No operation or write transfer selected</p>

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
0	[7:5], [11:9], [31:13]	r	Reserved Read as 0; should be written with 0.

SBCU_DBGNTT

SBCU Debug Trapped Master Register

(044_H)

Reset Value: 0000 FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								CH NR 07	CH NR 06	CH NR 05	CH NR 04	CH NR 03	CH NR 02	CH NR 01	CH NR 00
r								rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ONES								DMA L	LFI	DMA M	PCP	ONE		DMA H	
r								rh	rh	rh	rh	r		rh	

Field	Bits	Type	Description
DMAH	0	rh	High-Priority DMA FPI Bus Master Status¹⁾ This bit indicates whether the DMA with a high priority request was FPI Bus master when the break trigger event occurred. 0 _B The high-priority DMA was not the FPI bus master. 1 _B The high-priority DMA was the FPI Bus master.
PCP	3	rh	PCP FPI Bus Master Status This bit indicates whether the PCP was FPI Bus master when the break trigger event occurred. 0 _B The PCP was not an FPI bus master. 1 _B The PCP was FPI bus master at the break trigger event.

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
DMAM	4	rh	High-Priority DMA FPI Bus Master Status²⁾ This bit indicates whether the DMA with a medium priority request was FPI Bus master when the break trigger event occurred. 0 _B The medium-priority DMA was not the FPI bus master. 1 _B The medium-priority DMA was the FPI Bus master.
LFI	5	rh	LFI Bridge FPI Bus Master Status This bit indicates whether the LFI Bridge was FPI Bus master when the break trigger event occurred. 0 _B The LFI Bridge was not an FPI Bus master. 1 _B The LFI Bridge was FPI Bus master.
DMAL	6	rh	Low-Priority DMA FPI Bus Master Status³⁾ This bit indicates whether the DMA with a low-priority request was the FPI Bus master when the break trigger event occurred. 0 _B The low-priority DMA was not the FPI Bus master. 1 _B The low-priority DMA was the FPI Bus master.
CHNR0y (y = 0-7)	16+y	rh	DMA Channel Number Status These bits indicate which DMA channel with number 0y was active when a DMA break trigger event occurred. 0 _B DMA channel 0y was not active at a DMA break trigger event. 1 _B DMA channel 0y was active at a DMA break trigger event.
ONE, ONES	[15:7], [2:1]	r	Reserved Read as 1; should be written with 0.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

1) Including DMA transactions from DMA channels with high priority and from Cerberus with high priority.

2) Including DMA transactions from DMA channels with medium priority.

3) Including DMA transactions from DMA channels with low priority, MLI and from Cerberus with low priority.

On-Chip System Buses and Bus Bridges

SBCU_DBADRT

SBCU Debug Trapped Address Register

(048_H)

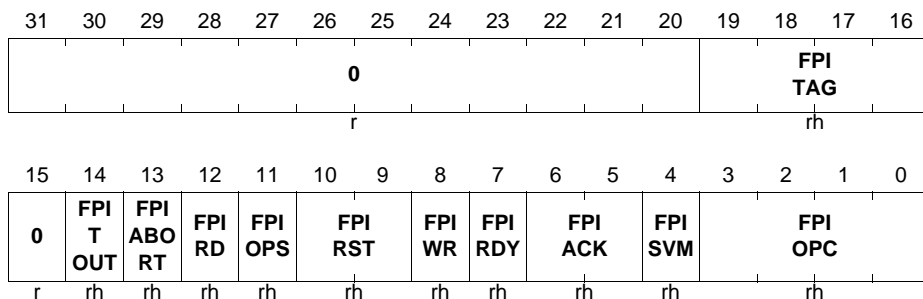
Reset Value: 0000 0000_H


Field	Bits	Type	Description
FPIADR	[31:0]	rh	FPI Bus Address Status This register contains the FPI Bus address that was captured when the OCDS break trigger event occurred.

SBCU_DBBOST

SBCU Debug Trapped Bus Operation Signals Register

(04C_H)

Reset Value: 0000 3180_H


On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
FPIOPC	[3:0]	rh	FPI Bus Opcode Status This bit field indicates the type (opcode) of the FPI Bus transaction captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0000 _B Single byte transfer 0001 _B Single half-word transfer 0010 _B Single word transfer 0100 _B 2-word block transfer 0101 _B 4-word block transfer 0110 _B 8-word block transfer 1111 _B No operation Other bit combinations are reserved.
FPI SVM	4	rh	FPI Bus Supervisor Mode Status This bit indicates the state of the Supervisor Mode signal captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B User mode 1 _B Supervisor mode
FPI ACK	[6:5]	rh	FPI Bus Acknowledge Status This bit field indicates the acknowledge signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 00 _B No special case 01 _B Error 10 _B Reserved 11 _B Retry, slave did not respond
FPI RDY	7	rh	FPI Bus Ready Status This bit indicates the ready signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B Last cycle of transfer 1 _B Not last cycle of transfer

On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
FPIWR	8	rh	FPI Bus Write Indication Status This bit indicates the write signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B Single write transfer or write cycle of an atomic transfer 1 _B No operation or read transfer
FPIRST	[10:9]	rh	FPI Bus Reset Status This bit field indicates the reset signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 00 _B Reset of all FPI Bus components 11 _B No reset Other bit combinations are reserved.
FPIOPS	11	rh	FPI Bus OCDS Suspend Status This bit indicates the OCDS suspend signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B No OCDS suspend request is pending 1 _B An OCDS suspend request is pending
FPIRD	12	rh	FPI Bus Read Indication Status This bit indicates the read signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B Single read transfer or read cycle of an atomic transfer 1 _B No operation or write transfer
FPIABORT	13	rh	FPI Bus Abort Status This bit indicates the abort signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B A transfer that has already started was aborted 1 _B Normal operation
FPIROUT	14	rh	FPI Bus Time-out Status This bit indicates the time-out signal status captured from the FPI Bus signal lines when the BCU break trigger event occurred. 0 _B Normal operation 1 _B A time-out event was generated

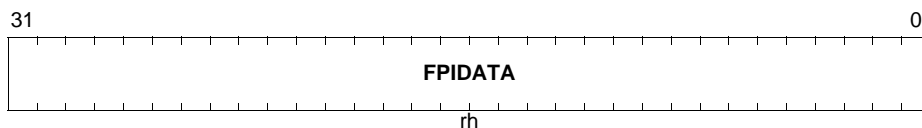
On-Chip System Buses and Bus Bridges

Field	Bits	Type	Description
FPITAG	[19:16]	rh	FPI Bus Master TAG Status This bit field indicates the master TAG captured from the FPI Bus signal lines when the BCU break trigger event occurred (see Table 4-15). The master TAG identifies the master of the transfer which generated BCU break trigger event.
0	15, [31:20]	rh	Reserved Read as 0; should be written with 0.

SBCU_DBDAT

SBCU Debug Data Status Register

(050_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
FPIDATA	[31:0]	rh	FPI Bus Data Status This register contains the FPI Bus data that was captured when the OCDS break trigger event occurred.

On-Chip System Buses and Bus Bridges

4.7 On Chip Bus Master TAG Assignments

Each master interface on the FPI Bus and on the LMB Bus is assigned to a 4-bit (FPI Bus) or 3-bit (LMB Bus) identification number, the master TAG number (see [Table 4-15](#)). This makes it possible for software debug and MCDS purposes to distinguish which master has performed the current transaction (see [“LBCU_LEATT” on Page 4-12](#)¹⁾ and [“SBCU_DBADRT” on Page 4-62](#)).

Table 4-15 On Chip Bus Master TAG Assignments

TAG-Number	Module	Location	Description
0000 _B	LFI	LMB	LFI Master Interface to LMB
0001 _B	-	-	Reserved
0010 _B	PMI	LMB	Program Memory Interface
0011 _B	-	-	Reserved
0100 _B	DMI	LMB	Data Memory Interface
0101 _B	-	-	Reserved
0110 _B	-	-	Reserved
0111 _B	DMA	LMB	DMA Controller Master Interface on LMB
1000 _B	-	-	Reserved
1001 _B	PCP	SPB	Peripheral Control Processor
1010 _B	DMA	SPB	DMA Controller Master Interface on SPB
1011 _B	LFI	SPB	LFI Master Interface to SPB
1100 _B	-	-	Reserved
1101 _B	-	-	Reserved
1110 _B	-	-	Reserved
1111 _B	-	-	Reserved

1) Pls. note that the TAG bit field in the register [“LBCU_LEATT” on Page 4-12](#) represents only bit 0-2 of the TAG-Number as the TAG number of all On Chip Bus master interfaces connected to LMB is 0.

5 Program Memory Unit (PMU)

The devices of this family have at least one Program Memory Unit. This is named "PMU0". The high-end devices can have additional PMUs which are named "PMU1", ...

The TC1728 has only the PMU0.

The PMU0 contains the following submodules:

- The Flash command and fetch control interface for Program Flash and Data Flash.
- The Overlay RAM interface with Online Data Acquisition (OLDA) support.
- The Boot ROM interface.
- The Emulation Memory interface.
- The Local Memory Bus LMB slave interface.

Following memories are controlled by and belong to the PMU0:

- 1.5 Mbyte of Program Flash memory (PFLASH).
- 64 Kbyte of Data Flash memory (DFLASH). It can represent up to 16 Kbyte EEPROM.
- 16 Kbyte of Boot ROM (BROM).
- 8 Kbyte Overlay RAM (OVRAM).

The [Figure 5-1](#) shows the block diagram of the PMU0:

Program Memory Unit (PMU)

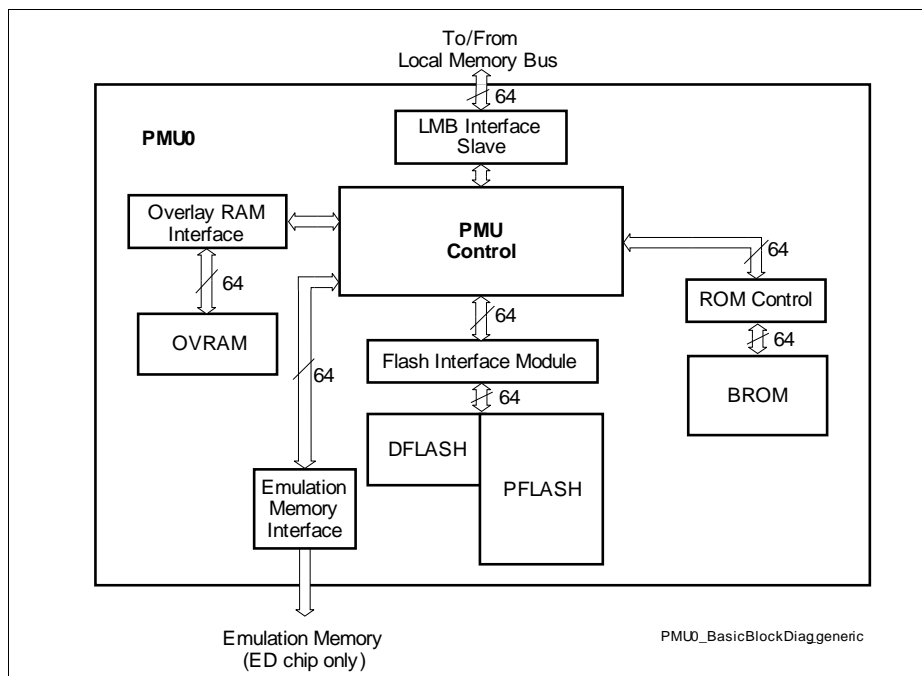


Figure 5-1 PMU0 Basic Block Diagram

Program Memory Unit (PMU)**5.1 BootROM**

The BootROM in PMU0 has a capacity of 16 KB, organized with double-words of 64 bits. The BootROM consists basically of two parts, used for:

- startup and boot SW (also called firmware), and
- factory test routines.

5.1.1 Addressing

The BootROM is visible at two locations, as can be seen in the memory map:

- In segment 8_H (cached space) starting at location $8FFF\ C000_H$
- In segment A_H (non-cached space) starting at location $AFFF\ C000_H$

After any reset, the hardware-controlled start address is $AFFF\ C000_H$. At this location, the first instruction of the startup procedure is stored and started. Another start location after reset is not supported, guaranteeing, that always the only one startup firmware within the BootROM is executed after reset.

5.1.2 Firmware Program Structure

The different sections of the firmware in BootROM provide startup and boot operations after reset, such as:

- The startup SW, which is the main control firmware in the BootROM executed after reset.
- The bootstrap loaders, which load a program code via a serial interface into the Scratchpad RAM (SPRAM) of the PMI and start its execution.
- The alternate boot modes, which provide a CRC checksum test of Flash regions before starting the user program
- The emulation support, if the chip is an emulation device.

The BootROM also includes special routines, which are used for testing, stressing and qualification of the component.

5.2 Overlay RAM and Data Acquisition

The overlay memory OVRAM is provided in the PMU0 especially for redirection of program memory accesses to the OVRAM by using the data overlay function. The data overlay functionality itself is controlled in the DMI module to avoid any performance penalty during the execution of redirection, and to support also external memories.

For online data acquisition (OLDA) of application or calibration data a virtual 32 KB memory range is provided which can be accessed without error reporting. Accesses to this OLDA range can also be redirected to the overlay memory.

5.2.1 Internal Overlay Memory

The capacity of the OVRAM is 8 KB. The base address of the OVRAM is A/8FE8 0000_H. The internal Overlay Memory OVRAM is available in both, the production device and the Emulation Device. Write accesses to the Overlay Memory OVRAM are possible in byte, half-word, word and double-word widths. Read accesses are performed in 64-bit width. Read-Modify-Write accesses are not supported.

As all other SRAMs in the device, also the OVRAM is ECC protected. The ECC generation and detection is enabled in the OVRCON register. After enabling, the OVRAM should be initialized by the user before any read access is performed. Also byte or half-word write accesses to the OVRAM may result in ECC error detection (due to read-modify-write) if the memory has not been initialized before the access¹⁾. An ECC error is reported to the SCU for control of error indication and of NMI trap (disabled after reset).

5.2.2 Online Data Acquisition (OLDA)

Calibration is additionally supported by an OLDA memory range of up to 32 Kbyte, which is a virtual memory and physically only available, if it is redirected (by user-controlled overlay function) to the internal OVRAM, or in an Emulation Device to the Emulation Memory EMEM or to the overlay region in external memory. Thus, if not redirected, write accesses to the OLDA range are not really executed, and they do not generate a bus error trap²⁾. Read accesses to the OLDA range in production devices generate a bus error trap, if not redirected to a physically available overlay block. After redirection into the OVRAM ECC errors may be reported also for byte/half-word/word write accesses (see above).

1) Please note: the write of this read-modify-write sequence is always performed even if the read incurs a double-bit error. So despite the reported error the written data and its ECC is correct after the sequence.

2) Attention: write accesses to the cached memory range will be executed by the TriCore by first reading this address to fill the cache line before merging the new data in. The read will trigger the bus error trap in this situation.

Program Memory Unit (PMU)

The base address of the virtual OLDA memory range is A/8FE7 0000_H (non-cached/cached space), the end address is A/8FE7 7FFF_H.

5.2.3 Access Performance

Write accesses to the PMU Overlay Memory OVRAM are performed with two cycles (because of the read-modify-write for ECC generation) for bytes, half-words and words but in one cycle for double-words. Read accesses to the OVRAM take one cycle. Additionally, one address select cycle is required in the PMU for read and write accesses. Bursts (BTR2) need one (for read) or two (for write) additional cycles.

5.2.4 Overlay Memory Control Register

The OLDA function and the ECC protection of OVRAM are controlled via the Overlay RAM Control register OVRCON. Bit protection allows independent control of OLDA and ECC function. Write accesses to this register are permitted only in Supervisor Mode SV, read accesses in User Mode or SV. The OVRCON register is cleared with the application (= class 3) reset.

The SCU controls if detected ECC errors trigger an NMI trap.

The register is defined as follows:

PMU0_OVRCON

Overlay RAM Control Register (F800 0520_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								ECCW							
r								rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ECC DBE R	0	DBE RINT DIS	0	0	0	ECC GEN DIS	PEC CCT R	0	0	0	0	0	0	POL DAE N	OLD AEN
rw	r	rw	r	r	r	rw	w	r	r	r	r	r	r	w	rw

Field	Bits	Type	Description
OLDAEN	0	rw	Online Data Acquisition Enabled 0 _B Trap generation on write access to virtual OLDA memory is enabled 1 _B The write trap is disabled although the OLDA memory is virtual and not available in both, the production device and the Emulation Device.

Program Memory Unit (PMU)

Field	Bits	Type	Description
POLDAEN	1	w	Protection Bit for OLDAEN 0_B Bit protection: Bit OLDAEN remains unchanged with register OVRCON write 1_B OLDAEN can be changed with current write access to register OVRCON This bit enables OLDAEN write during OVRCON write. Return 0 if read.
PECCCTR	8	w	Protection Bit for ECC Control Bits 0_B Bit protection: The writable ECC control bits (ECCGENDIS, DBERINTDIS) remain unchanged with register OVRCON write. 1_B The ECC control bits can be changed with current write access to register OVRCON. Return 0 if read.
ECCGENDIS	9	rw	ECC Generation Disable 0_B Write accesses to the OVRAM use an ECC calculated from the data. 1_B Write accesses to the OVRAM use the content of OVRCON.ECCW instead of generating an ECC from the data.
DBERINTDIS	13	rw	ECC Double-Bit Error Interrupt Disable 0_B Double-bit errors are reported to the SCU for NMI triggering and to the redundancy wrapper. 1_B Double-bit errors are not reported to the SCU and to the redundancy wrapper.
ECCDBER	15	rwh	ECC Double-Bit Error Sticky Flag This bit is set when a read or read-modify-write access had a double-bit error. It can be cleared by writing a 0.
ECCW	[23:16]	rw	ECC Write Data When the ECC encoding of the OVRAM is disabled with OVRCON.ECCGENDIS=1 the write accesses write this data field into the SRAM instead of the generated ECC code.
0	[31:24], 14, 13, 12, 10, 11, [7:2]	r	Reserved Reserved for future use. Write 0, read 0.

5.3 Emulation Memory Interface

In the Emulation Device, an Emulation Memory (EMEM) is provided, which can be used for calibration via program memory or OLDA overlay. Its base address is A/8FF0 0000_H. As for Flash and OVRAM accesses, cached (segment 8_H) and non-cached (segment A_H) accesses can be used for EMEM accesses via PMU.

The Emulation Memory interface shown in [Figure 5-1](#) is a 64-bit wide memory interface that controls the CPU-accesses to the Emulation Memory in the Emulation Device. All widths of write accesses are supported (byte, half-word, word, double-word). CPU-controlled Load-Modify-Store accesses (with LDMST instruction) are not supported.

In the TC1728 production device, the EMEM interface is always disabled. A CPU read access from the Emulation Memory region causes a DSE trap and an LMB bus error. If the Emulation Memory region read access is initiated by a SPB master (e.g. PCP), additionally a SPB error interrupt is generated. Per default, write accesses to the Emulation Memory by any master cause an LMB bus error trap in production device.

In the Emulation Device, a LMB bus error trap is reported by the PMU, if the CPU access can't be handled by the EMEM, for example, when the CPU accesses a trace memory tile in EMEM. In this case, the EMEM access is aborted by the PMU.

Similar to the internal 8 KB OVRAM, the EMEM can also be used for overlay blocks dedicated to blocks in the internal Program Flash or to the virtual OLDA memory, redirecting (in DMI) Flash/OLDA addresses to the Emulation Memory. Also the external memory is supported for redirection of blocks into the EMEM.

Program Memory Unit (PMU)

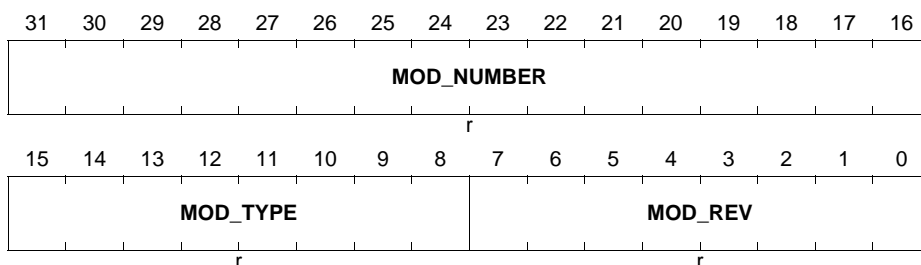
5.4 PMU ID Register

The PMU_ID register is a read-only register, thus write accesses lead to a bus error trap. Read accesses are permitted in Supervisor Mode SV and in User Mode. The PMU_ID register is defined as follows:

PMU0_ID

PMU0 Identification Register

(F800 0508_H)

Reset Value: 0096 C0XX_H


Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the module revision number. The value of a module revision starts with 01 _H (first rev.).
MOD_TYPE	[15:8]	r	Module Type This bit field is C0 _H . It defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines the module identification number for PMU0.

5.5 Tuning Protection

The special tuning protection support represents a security function provided additionally to Flash read/write/OTP protection (see [Page 5-21](#) and [Chapter 5.6.5](#)) and additionally to the Alternate Boot Mode (see BootROM spec).

For details on the tuning protection please contact your Infineon representative.

5.6 Program and Data Flash

This chapter describes the embedded Flash module of the TC1728.

5.6.1 Introduction

The embedded Flash module of TC1728 includes 1.5 MB of Flash memory for code or constant data (called Program Flash) and 64 Kbyte of additional Flash memory used for emulation of EEPROM data (called Data Flash).

The Program Flash is realized as one independent Flash bank, whereas the Data Flash is built of two Flash banks, allowing the following combinations of concurrent Flash operations:

- Read code or data from Program Flash, while one bank of Data Flash is busy with a program or erase operation.
- Read data from one bank of Data Flash, while the other bank of Data Flash is busy with a program or erase operation.
- Program one bank of Data Flash while erasing the other bank of Data Flash, read from Program Flash.

Both, the Program Flash and the Data Flash, provide error correction of single-bit errors within a 64-bit read double-word, resulting in an extremely low failure rate. Read accesses to Program Flash are executed in 256-bit width, to Data Flash in 64-bit width (both plus ECC). Read accesses are very efficiently controlled, supporting a read line buffer for Program Flash with buffer hit control and a separate read buffer for Data Flash. Single-cycle burst transfers of up to 4 double-words and sequential prefetching with control of prefetch hit are additionally supported for Program Flash. Accesses to Data Flash do not disturb buffered data and prefetched data in Program Flash for hit control.

The minimum programming width is one page, consisting of 256 bytes in Program Flash and 128 bytes in Data Flash. Concurrent programming and erasing in Data Flash is performed using an automatic erase suspend and resume function.

The whole Flash module is divided into the following two sub-modules:

- The Flash array module (FAM) with one Flash bank PFLASH and with two Flash banks DFLASH, with separate read buffers for PFLASH and DFLASH, with Flash standard interface FSI, including the Flash array controller, with page write buffers (assembly buffers) and voltage generators.
- The Flash interface and control module (FIM), which controls the execution of Flash commands and which is responsible for the error correction and ECC generation. It is interfaced via LMB bus to the PMI module for instruction accesses and to the DMI and DMA modules for data accesses.

The Flash interface module is main part of the Program Memory Unit PMU. An overview of system integration and system architecture is presented in the TC1728 block diagram.

A basic block diagram of the Flash Module is shown in the following [Figure 5-2](#).

Program Memory Unit (PMU)

- User controlled configuration blocks (UCB) in configuration sector for keywords and for sector-specific lock bits (one block for every user; up to three users).
- Pad supply voltage also used for program and erase (no VPP pin).
- Efficient 256 byte page program operation.
- Programming time: typ. 5 msec per page.
- All Flash operations controlled by CPU per command sequences (unlock sequences) for protection against unintended operation.
- Write state machine for automatic program and erase, including verification of operation quality.
- End-of-busy as well as error reporting with interrupt and bus error trap.
- Support of margin check.
- Erase time per sector: max. 5 sec.
- Delivery in erased state (read all zeros).
- Global and sector specific status information.
- Overlay support for calibration applications.
- Configurable wait state selection for different CPU frequencies
- Endurance = 1000; allowed number of program/erase cycles per physical sector; reduced endurance of 100 per 16 KB sector.
- Operating lifetime (incl. Retention): 20 years with endurance = 1000.
- For further operating conditions see data sheet.

Summary of Data Flash Features and Functions

- 64 Kbyte on-chip Flash, configured in two independent Flash banks of equal size.
- Sector architecture: one sector per bank.
- 64 bit read interface.
- Erase/program one bank while data read access from the other bank.
- Programming one bank while erasing the other bank using an automatic suspend/resume function.
- Dynamic correction of single-bit errors during read access.
- Read access time: 50 ns.
- 128 byte pages to be written in one step.
- Selectable read/write protection in combination with PFlash read protection.
- Programming time: typ. 5 msec per page¹⁾.
- Operational control per command sequences (unlock sequences, same as those of Program Flash) for protection against unintended operation.
- End-of-busy as well as error reporting with interrupt and bus error trap.
- Write state machine for automatic program and erase.
- Margin check for detection of problematic Flash bits.

1) The maximum programming time (see data sheet) depends on the number of programming repetitions. A special "emergency programming mode" (see [Chapter 5.6.8](#)) can enforce that no repetitions are executed. Data programmed in this mode has a reduced retention time of 1 year.

Program Memory Unit (PMU)

- Erase time per sector: max. 1.5 sec. (increased for low frequencies).
- Endurance = 60000; i.e. 60000 program/erase cycles per sector are allowed, with a retention of min. 5 years¹⁾
- Dedicated DFlash status information.
- Other characteristics: Same as Program Flash.

¹⁾ This number of cycles requires a specific robust EEPROM emulation algorithm as described in [Section 5.6.6.3](#).

Program Memory Unit (PMU)

5.6.2 Architectural and Operational Overview

In the following, an overview of the internal structure and of operations is presented.

5.6.2.1 Sector and Page Architecture

The Program Flash as well as the Data Flash memory are characterized by their sector architecture and by their page structure. Sectors are Flash memory partitions of different sizes. Some Flash operations are dedicated to and are only performed on complete sectors, such as sector erase operations and installation of sector write protection. Programming operations are generally dedicated to pages (byte, word or double-word program is not supported).

Page and Wordline Structure

The whole Flash memory is divided into pages of defined and always identical size, which depends on Flash type. Program Flash and Data Flash have different page sizes:

- Program Flash: Page size is 256 Byte (32 double-words).
- Data Flash: Page size is 128 Byte (16 double-words).

The page size is defined by the wordline length of the array: a wordline always consists of two sequential pages with according even and odd page addresses.

Sector Partitioning in Program Flash

The Program Flash memory is divided into the following sectors:

- Eight 16 Kbyte logical sectors, together building two 64 Kbyte physical sectors,
- one 128 Kbyte (physical) sector,
- and five 256 Kbyte (physical) sectors.

Additionally a configuration sector is implemented, which is not user-accessible.

Physical and Logical Sectors

The maximum number of program/erase cycles is always related to physical sectors. Thus the specified endurance of 1000 belongs to the sectors with 64 Kbyte and more capacity, but not to the small 16K sectors.

The 16K sectors are called logical sectors, because they are not physically separated from their neighboring sectors. They are “logically” separated simply by definition of 16K address ranges within a 64K physical sector, to avoid the area overhead necessary for physical sector separation. Because all logical sectors within a physical sector use the same bit lines, the maximum number of erase cycles without refreshing must be limited to 100 for every logical sector. This means, that after 100 erase operations to a 16K sector the whole 64K sector (which includes the 16K sector) has to be refreshed (erased and re-programmed), before the next 100 erase cycles can be performed on the **same** 16K sector. Thus, all four 16K sectors of a physical 64K sector can be erased 100

Program Memory Unit (PMU)

times before refreshing the 64K sector. In total, also for each logical sector the max. number of erase cycles is 1000. Erase of the 64K physical sector can be performed with one 64K erase operation or with four 16K erase operations.

Data Flash Sectors

The 64 Kbyte Data Flash is divided into two erasable (physical) sectors of equal size. The two sectors are identical to the two Flash banks, which are defined to support concurrent operations. Only in case of read protection, full write protection of DFlash is supported (can be disabled), but it is not possible to select sector write protection only for DFlash sectors.

5.6.2.2 Data Flash and EEPROM Emulation

The Data Flash consists of two independent Flash banks (contrary to the Program Flash). A Data Flash bank also represents a sector, which can be erased only completely as a unit, and can be programmed page by page. The structure with two independent Data Flash banks is used to allow simultaneous read or program operations on one bank while erasing the other bank in the background.

The general structure of the Data Flash is selected to support the emulation of an EEPROM. In this context, the main difference between a Flash memory and an EEPROM is the endurance, combined with a shorter retention. For EEPROM, an endurance of e.g. 120 000 write/erase cycles is required, what is not supported with the standard Flash memory.

For EEPROM emulation and thus for increasing the endurance, the Data Flash is used like a circular buffer-memory: The newest data updates are programmed always above the last programmed page. When the top of sector is reached, all actual data (representing the actual EEPROM region) are copied to the bottom area of the next sector and the last sector is then erased. This round robin procedure, using multi-fold replications of the emulated EEPROM size (called EEPROM regions), significantly increases the endurance. Thus, the endurance can be selected by changing the size of emulated EEPROM.

Example 1

The DFLASH is logically divided into four regions (i.e. two per bank) that operate as a circular buffer memory. At a time, one of the four regions is always regarded as active EEPROM region. The active EEPROM region is simply identified by the used region with the highest address within the active DFLASH bank.

The active EEPROM region is held as a EEPROM mirror in an on-chip RAM area. After a reset operation, the active EEPROM region is copied into the RAM. When the EEPROM data must be updated, the next consecutive region within the DFLASH circular

Program Memory Unit (PMU)

buffer becomes the active EEPROM region. The “old” DFLASH bank can be erased, when the active EEPROM region has been switched to the “new” DFLASH bank.

As a result of the continuously changing assignment of the active EEPROM region in a circular buffer, the DFLASH memory cells of one EEPROM region can be erased/programmed 4-times as often as one physical region, resulting in an 4-fold endurance for one EEPROM region. Additionally, a reduced retention is assumed for EEPROM data supporting a higher endurance (e.g. 30000 for Data Flash with retention of 5 years). Thus, for the above described example with four regions and with a retention of 5 years, the endurance for an emulated EEPROM region is increased to 120000 write/erase cycles.

Example 2

For emulation of more complex EEPROM structures, several EEPROM region types can be defined in parallel, with different endurance or update requirements. Each region type is identified by an identification label. The active region of each type is identified by the highest address of all regions with the same label. If a “new” Flash bank is entered, all active regions are copied into the new bank, so that the “old” DFLASH bank can be erased. It is recommended to delay the copy (and erase) operation so that more active regions in the “old” bank are renewed (updated) in the “new” bank anyway.

Depending on the number of pages used for dynamic programming of EEPROM data, the endurance of an EEPROM region can additionally be optimized. If only that part of EEPROM region, which has been changed, is re-programmed during update-operation, the endurance is further increased, because not always a full EEPROM region is wasted when only one wordline (two pages) has to be updated. It is thus necessary to indicate old (invalid) wordlines. Therefore, a wordline can be marked as invalid wordline by re-programming one (or both) pages of the wordline with all-ones (only this kind of twofold programming of a page is allowed in Data Flash and in Program Flash). For this “invalidation stamp”, a correct ECC code is ensured because the ECC algorithm is selected in that way that either for the erased state (all zeros) or for the invalidated state (all ones) the according ECC code (also all zeros or all ones) is correct.

Note: Only two page writes for one wordline are allowed. Therefore, if a third page write is executed for the invalidation stamp, not only this page, but the whole wordline including this page is in an invalid state.

5.6.2.3 Operational Overview

In general, the operations of Program Flash and Data Flash are controlled identically. Therefore, in the following, the operational overview is mainly presented only for the Program Flash. When necessary, additional explanations are made for the Data Flash.

Standard Read

In standard read mode (the normal operating mode) the Flash memory appears like an on-chip ROM. The Flash array module offers an asynchronous read access of 256-bit read data (Data Flash: 64-bit read data) with an access time of 26 ns (Data Flash: 50 ns). Depending on the clock frequency of the PMU it has to wait a defined number of wait cycles (see [Table 5-1](#)). Instruction read accesses are 64-bit accesses. Because the read data width of Program Flash is 256 bit, always a full burst transfer of four 64-bit double-words is executed. Data operand reads are 64-bit accesses out of PFLASH or DFLASH. In case of data access in cached address space, two double-words are transferred. In case of non-cached data accesses only the addressed DW is accessed and directly transferred to the CPU.

Note: The Flash module delivers always 64-bit read data. The addressed data (word, half-word, byte depending on data type) within the double-word read data is selected by the CPU.

The Flash addresses are mapped into the total address space of the controller with different base addresses (see [“Address Mapping” on Page 5-26](#)).

The physical address range of the 24 Kbyte configuration sector starts also with address zero, and it is mapped to the same base address as the Program Flash, but read and direct write accesses to the config-sector are not possible for the user.

To eliminate any possibility of read data corruption, the Flash module provides ECC with SEC-DED (Single Error Correction, Double Error Detection) capability over a 64-bit double-word. For verify operations, the normal read can be combined with a margin check (more critical control of sense amps). Single and double-bit errors are indicated in the Flash status register and, if enabled, reported to the CPU by means of error interrupts; the double-bit error causes a hardware trap (if not disabled for margin checks).

Operation Control with Command Sequences

All operations besides normal read operations are initiated and controlled by command sequences written to the flash interface&command state machine. During normal read operations, a first write cycle to the Flash address space is automatically interpreted as a command cycle, initiating a command sequence. The different write cycles of command sequences are not only used for operation definitions such as program commands or sector erase commands, but also as fail-safe and unlock cycles in order

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to protect against inadvertent writes. Some commands which do not directly control Flash array operations are implemented as single cycle commands.

All command cycles are write (store) cycles to the Flash. During command cycles, the low order 16 bits of the address bus (A15–A0) define the Flash command address, and only command cycles with addresses to sectors, pages and wordlines also use the Flash address bits A20–A16. Additionally, the command addresses are mapped into the total address space of the controller by using base addresses dedicated to the Flash bank to be operated on (see **“Address Mapping” on Page 5-26**).

The write data of a command cycle define the 8-bit operation code or security pattern in case of unlock cycles, the 32-bit password for protection disable cycles, or it represents the 64 or 32-bit data to be programmed. Improper command cycles or interrupted command sequences are indicated by the sequence error flag in the Flash status register.

Note: User code, that writes command sequences to the Program Flash, should not be executed from the internal Flash; it shall be located in other internal or external program memory, e.g. in the scratchpad SPRAM. But user code, that writes command sequences to the Data Flash, can be located in and executed from the Program Flash.

Note: The write cycles, belonging to a command sequence, may be buffered on its way to the Flash in store/write buffers. To maintain data coherency (strictly in-order sequence of command cycles is mandatory) and to guarantee immediate transfer of the command cycles to the PMU, all write cycles to the Flash must access the Flash in its non-cached address space. Additionally, it is recommended to include a dummy read (ld.w) instruction to a PMU register (e.g. PMU_ID) after the last write cycle of a command sequence to flush the write buffers.

Additional hints are available in chapter **“Application Hints and Guidelines” on Page 5-84**, possible error conditions and their reporting in FSR are summarized in **Chapter 5.6.6.3**.

Programming Control

Programmed Flash bits deliver a ‘1’ value. The Flash module provides a page assembly mechanism for all program (data write) operations in Program Flash and Data Flash. This assembly mechanism requires to assemble 256 bytes (Data Flash: 128 bytes) in a page assembly buffer before this assembly buffer is being written to Flash in one program cycle.

Page write operations are executed by load/store command sequences, comprising the following three steps:

1. Start with the ‘Enter Page Mode’ command. This command’s address determines in its high order address bits also the bank of Flash (Program Flash or Data Flash bank) to be programmed.

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2. Execute 32 (Data Flash: 16) 'Load Page' commands to transfer double-words or execute 64(32) commands to transfer words to the respective page assembly buffer. Mixed transfers of words and double-words are not allowed (error indication). The first double-word is loaded into the page assembly buffer to the location with address zero (starting address of page register). The address of following double-words within page register is internally controlled by incrementing the start address; thus the write cycles have always the same address, pointing to the Flash bank to be programmed. For every double-word (or 2 words), the ECC code is internally generated and also stored in the assembly buffer.
3. 'Write Page' command sequence (4 cycles) to program the whole 64 (DFlash: 32) words within the page assembly buffer in one step into the flash memory. The page address is defined by the last command cycle. The write data of the last command cycle is a confirm pattern. All base addresses of command cycles have to point to the Flash bank to be programmed.

A write command for a not completely filled buffer is executed (not loaded words of page use 'old' contents of assembly buffer and are therefore undefined) but reported to the user by error indication in the status register. If a memory region shall be programmed with always the same pattern, it is possible to use the 'old' contents of the assembly buffer for several page write operations, if always the Enter Page Mode command is directly followed by the Write Page command.

Command cycles addressing a busy Flash bank cause a stall of the bus system and the sending master until the busy clears.

After receiving the Write Page command the module executes the program operation. The page of 256 (Data Flash: 128) bytes is programmed within typ. 5 msec (Data Flash: 5 msec). The programming algorithm is followed by a quality check to guarantee the specified retention for each programmed bit. Thereby, the quality check is performed with tightened read conditions on all programmed ('1') bits as defined by the assembly buffer contents. Weak bits are re-programmed. If re-programming is no more possible, an error flag (VER) is set in the Flash Status Register FSR (see [Chapter 5.6.6.3](#)).

Termination of operation is indicated in the Flash Status Register and can also be configured to generate an end-of-busy interrupt. During a program operation, the minimum system clock is limited to 1 MHz. Any reset condition stops a program operation within max. 250 µsec. Such an error state can be recognized by proper handling and checking of the PROG status flag in Flash Status Register FSR (except for power-on reset).

Erase Control

This Flash module features a sector erase architecture. Erase is accomplished by executing the six-cycle erase command sequence including the sector address in its last cycle (for sector addressing see [Chapter 5.6.3.5](#)). All command cycles of the command sequence have to use base addresses which point to the Flash bank to be operated on.

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If the Flash bank, which is addressed, is still busy, the command cycle stalls the bus system and the sending master. After the last cycle of the command sequence, the device automatically starts and controls the erase procedure. Start of operation is delayed, if another bank is busy with a write operation at that time. Termination of operation is indicated in the Flash status register and can also be enabled to generate an end-of-busy interrupt. After erase operation, the Flash memory delivers '0' data with correct ECC code on read access.

For the physical sectors in Program Flash (64K, 128K and 256K) a maximum number (endurance) of 1000 erase and program operations is supported. For the (logical) 16K sectors in PFlash max. 100 erase cycles are allowed to the same sector without refresh (see [Chapter 5.6.2.1](#)). For the Data Flash sectors a maximum number of 60000 erase cycles are defined (can depend on the device).

Besides sector erase, also a special six-cycle block erase operation is available dedicated only to the User Configuration Blocks (UCB). This operation supports the change of user-specific Flash configuration regarding protection functions, i.e. the lock bits or keywords. Since a UC block comprises four pages, a 1 Kbyte block is erased with this operation. The maximum number of UCB changes is limited to 4. The UCB erase time is shorter than the sector erase time (max. 500 ms).

As the program operation, also the sector erase operation includes an erase quality check that identifies incorrectly erased bits in the Flash sector, and that indicates a verification error if weak bits can no more be corrected (see [Chapter 5.6.6.3](#)).

An erase operation is executed within max. 5 s (Data Flash: 1.5 s) (but depending on sector size and on CPU frequency). In Data Flash an automatic erase suspend function is implemented for immediate execution of program operations to the other DFlash bank. During an erase operation, the minimum system clock is limited to 1 MHz. A system reset condition stops an erase operation within max. 250 µsec. Such an error state can be recognized by proper handling and checking of the ERASE status flag in Flash Status Register FSR (except for power-on reset).

In-System Programming

In-system programming is fully supported. No special program voltage VPP is required. Because of the automatic execution of erase and program algorithms, write operations are reduced to transferring commands and data to the Flash and reading the status (see [Chapter 5.6.6.5](#) for hints). Because of the page assembly function, write data may be written to the Flash very comfortably and fast. User code that writes data to the page assembly buffer can be executed also from the same internal Program Flash (in non-cached operating mode). User code that writes command sequences to the Program Flash must be executed from memory outside the addressed on-chip Flash memory (on-chip RAM or if available other Flash module or external memory).

Note: Simultaneous read accesses to Program Flash while erasing or programming the Data Flash are supported. Thus, command sequences for the Data Flash can be

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written by user code accessed from Program Flash. In Data Flash, also parallel write operations (programming one bank while erasing the other bank) are possible.

Register Access Control

Register accesses for polling the status register are allowed in any state, also during erase and program operations (but then executed out of other internal or external memory).

Read/Write/OTP Protection

The Flash module provides sophisticated security functions that protect against unauthorized readout or modification by any third party. For this, the Flash supports read protection for the whole Flash array (including Data Flash, if not separately disabled). The read protection automatically includes a global Flash write protection (Data Flash included, if not separately disabled) for protection against Trojan Horse programs. Additionally, sector-specific write and OTP protection for all sectors in Program Flash is provided. Write protected sectors are re-programmable (with passwords), OTP (One Time Programmable) protected sectors are locked for ever and have ROM functionality.

If read protection is installed and active, any Flash read access is disabled if the instruction execution is started after reset from another memory but from Program Flash itself, e.g. in case of bootstrap loader start after reset. The debug interface is enabled in this case, because the Flash module itself disables code and data accesses. In case of start after reset from internal Flash, Flash accesses are enabled, but the debug interface is locked by the firmware in BootROM, and the user himself has to control the debug interface. In any case the Flash-user can control by himself the access rights for instructions and data and for different masters (e.g. DMA controller). The Flash read protection can be temporarily disabled (with passwords), e.g. to change the access rights to the Flash memory or to perform a programming operation.

Write and OTP protection of Program Flash sectors is provided to protect code and constant data against any manipulation (e.g. against tuning). This feature will disable both, program and erase operations, for any combination of selected sectors. Sector protection is accomplished by sector specific lock bits which are programmed by the user directly into its 'User Configuration Block' (UC block) in the configuration sector. The installation of read and/or write protection will become active after the next reset.

Three different user-classes (also called levels) and thus three different UC blocks (UCB0, UCB1 and UCB2) are supported, two with separate keywords, one (UCB2) for selection of OTP protected sectors, which can never be erased and re-programmed again. The user-classes are organized hierarchically: After disabling the protection with his password user 0 can program or erase all those sectors that are protected by him (even if they are protected also by user 1) but not sectors that are protected by user 2

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and sectors that are protected only by user 1. User 1 can change sectors that are protected only by him but not sectors that are protected by user 0 or user 2.

As for read protection, also for short-term disablement of sector write protection a password checking feature is provided. Only if the passwords match the keywords in the UCB of the user, a temporarily unprotected state of his sectors is taken and erase or program commands are enabled for these unlocked sectors. If not finished by the single cycle command 'Re-Enable Read/Write Protection', the unprotected state is terminated with the next reset. User 2 protection (OTP sectors with ROM functionality) cannot temporarily be disabled and therefore does not need passwords.

Password checking is based on two keywords (together 64 bit) which are programmed by the user directly into his 'User Configuration Block' in the configuration sector (same procedure as used for lock bits). To avoid forever-lock conditions in case of disturbed keywords (e.g. because of power problem during programming of keywords), the keyword-correctness (users 0 and 1) has first to be checked by the user before a special confirmation code has to be written to a second wordline within the user's configuration block. User 2 confirms with the confirmation code the protection configuration (OTP sectors get ROM functionality) in UCB2.

If any protection is configured and confirmed (thus installed correctly), this state is indicated in the Flash Status Register FSR. Additionally, protection summary bits are provided in FSR for every user indicating the installation of read protection (only user 0) or/and write protection and for indication of a temporarily disabled state (user 0 and 1). The locked state of every sector is indicated by sector specific flags in the Protection Configuration registers PROCON0, PROCON1 and PROCON2.

Note: If any sector of user 2 is locked for ever (OTP protected via PROCON2), investigation of FARs by Infineon is very limited because accesses to the Flash array registers (SFRs) are no more possible.

Note: The physical sector, including a 16 KB OTP sector, can never be erased; thus the endurance of its 16K logical sectors is limited to 100.

Note: If any protection is enabled also the related user block(s) in configuration sector is especially protected.

With the three possibilities for write protection — whole memory or sector specific with or without re-program capability and with all combinations of these possibilities — a flexible installation of write protection is supported to protect the Flash memory or parts of it from unauthorized programming and to provide virus-proof security for all system code sectors.

Power Reduction

The Flash module supports a SCU-controlled sleep mode, globally requested by the Power Management System, and it supports an individual sleep mode, selected by the user as power down feature, if the Flash is not needed for certain processor states. If the

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sleep state is requested, all active or pending Flash array operations are at first correctly terminated, and only then the power down state is taken.

The wakeup from sleep ramps up the voltage generators, before the Flash read mode is activated again. Its duration is documented in the data sheet.

Additionally, the PMU/Flash module supports a dynamic power reduction mode, where idle states are used to disable the wordline drivers. If this mode is enabled, the prefetch functionality is simplified.

5.6.2.4 Flash Access Control and Performance

The required number of wait states for an initial access to PFlash or DFlash is related to the maximum operating frequency (including PLL jitter). Because the default after reset is a worst case setting sufficient for all frequencies, the access times have to be configured by the user according to the application's frequency for optimum performance. This configuration of wait states must be performed via the 4-bit-fields "WSPFLASH" and "WSDFLASH" in register FCON (Flash Configuration Register, see [Page 5-53](#)) according to the following table.

Note: If the initial access (either instruction or data access) addresses a double-word in PFlash which is already available in the 256-bit Flash read buffer (either because of earlier initial access or because of automatic prefetching), the defined number of wait states (in FCON register) is disabled and the access is performed without wait state, thus with 0 ns access time ("buffer hit"). In case of prefetch line hit the number of access cycles is reduced to 1 wait state, if the prefetched read-data line is already pending before the read buffer.

Table 5-1 Selection of Wait States in Relation to Operating Frequency for Flash modules with Ta=26 ns

Operating Frequency ¹⁾	WS for Initial Access	WS for Read Buffer Hit Access	WS for Prefetch Line Hit
150 MHz < f _{LMB} ≤ 180 MHz	5	0	min. 1
112 MHz < f _{LMB} ≤ 150 MHz	4	0	min. 1
75 MHz < f _{LMB} ≤ 112 MHz	3	0	min. 1
37.5 MHz < f _{LMB} ≤ 75 MHz	2	0	min. 1
f _{LMB} ≤ 37.5 MHz	1	0	min. 1

1) The maximum operating frequency of a device is documented in its data sheet.

Table 5-2 Selection of Wait States in Relation to Operating Frequency for Flash modules with Ta=50 ns

Operating Frequency ¹⁾	WS for Initial Access	WS for Read Buffer Hit Access	WS for Prefetch Line Hit
178 MHz < f _{LMB} ≤ 180 MHz	10	0	min. 1
158 MHz < f _{LMB} ≤ 178 MHz	9	0	min. 1
138 MHz < f _{LMB} ≤ 158 MHz	8	0	min. 1
118 MHz < f _{LMB} ≤ 138 MHz	7	0	min. 1

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Table 5-2 Selection of Wait States in Relation to Operating Frequency for Flash modules with Ta=50 ns (cont'd)

Operating Frequency ¹⁾	WS for Initial Access	WS for Read Buffer Hit Access	WS for Prefetch Line Hit
99 MHz < f _{LMB} ≤ 118 MHz	6	0	min. 1
79 MHz < f _{LMB} ≤ 99 MHz	5	0	min. 1
59 MHz < f _{LMB} ≤ 79 MHz	4	0	min. 1
39.5 MHz < f _{LMB} ≤ 59 MHz	3	0	min. 1
19.5 MHz < f _{LMB} ≤ 39.5 MHz	2	0	min. 1
f _{LMB} ≤ 19.5 MHz	1	0	min. 1

1) The maximum operating frequency of a device is documented in its data sheet.

In the table above, also the number of wait states for accesses with read buffer hit and with prefetch line hit (both only in PFlash available) are shown, which are both identical for all frequencies.

The wait state control bit in FCON for additional wait state for the ECC cycle during PFlash and DFlash accesses need not be changed by the user.

Note: The number of wait states may be changed in register FCON at any time, as long as the new number considers the maximum frequency as described in table above; this change can also be performed with code executed from Program Flash.

Mixed Accesses to PFlash and DFlash

Parallel read accesses to the Program Flash and to the Data Flash are not supported. The accesses are serialized on LMB bus and thus also on the Flash array interface. Therefore, a burst transfer from PFlash cannot be interrupted by a DFlash cycle. If a DFlash request is received during prefetching the PFlash, the prefetch access is aborted and the DFlash access is immediately started. Prefetched data or code is only inhibited and prefetching PFlash is aborted in case of a new request (data or code) to PFlash.

5.6.3 Functional Description

In the following chapters, the detailed Flash functions and the related user interface are described.

5.6.3.1 Address Mapping

The total address range of 4 Gbyte (addresses A31–A0) is divided into 16 segments of each 256 Mbyte, which are addressed by A31–A28. The Program Flash as well as the Data Flash are located in segment A_H for non-cached accesses, and in segment 8_H for cached accesses. Thus the segment address bits are:

- A31–A28 = 8_H for all cached Flash accesses, and
- A31–A28 = A_H for all non-cached Flash accesses.

Note: Data accesses to Overlay Memory shall only be performed in the non-cached address space to bypass the cache/line buffer in the DMI module (necessary for data consistency after write).

Note: Command sequence cycles to the Flash shall be mapped always to the non-cached address space of the Flash which shall be operated on.

The following table **Table 5-3** presents a summary of address mappings for the Program Flash and Data Flash, and of related Flash register address mappings in PMU0.

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Table 5-3 Flash Memory Map and Access Control in PMU0

Range Description	Size	Segment	Start Address	Access Control	Transaction Control
Program Flash cached space	1.5 Mbyte	8_H	8000 0000 _H	Instr. Access via LMB	4x64-bit into PMI cache, with prefetch
				Data Access via LMB	2x64-bit into DMI cache, with prefetch
Data Flash cached space	64 Kbyte		8FE0 0000 _H	Data Access via LMB	2x64-bit into DMI cache, no burst, no prefetch
DFlash bank 0	32 KB				
DFlash bank 1	32 KB				
Program Flash non-cached	1.5 Mbyte	A_H	A000 0000 _H	Instr. Access via LMB	4x64-bit into PMI Line Buffer, with prefetch
				Data Access via LMB	1x64-bit; DMI line buffer bypassed, with prefetch
Data Flash non-cached	64 Kbyte		AFE0 0000 _H	Data Access via LMB	1x64-bit; DMI line buffer bypassed, no prefetch
DFlash bank 0	32 KB				
DFlash bank 1	32 KB				
Flash Registers	1 Kbyte	F_H	F800 2000 _H	Data Access via LMB	1x64-bit, buffer bypass

5.6.3.2 Basic Operating Modes

Generally, the Flash module distinguishes two basic operating modes, the standard read mode and the command mode. Additionally to the read mode, the page mode can be activated. Since the Flash array is represented by three autonomous Flash banks, one bank of Program Flash and two banks of Data Flash, the operating modes belong to every Flash bank and can partly be active concurrently. Parallel write command execution (program one bank while erasing the other bank) is supported for the two Data Flash banks, but not for the Program Flash and one Data Flash bank.

Note: Register accesses are independent from the operating mode and allowed in any state.

The initial state after power-on and after reset is in all three Flash banks the standard read mode.

Every write access cycle into the memory address space of Program Flash or Data Flash is automatically interpreted as a command cycle, belonging to a command sequence. Thereby a command sequence consists of up to six command cycles with defined address and data values. After the last command of a command sequence, the device enters the command mode. Rules and guidelines for command sequences are provided in the chapter "Operation Control with Command Sequences" on [Page 5-17](#) and in the chapter "Operation Hints and Guidelines" on [Page 5-84](#).

In general, the command mode remains active during the whole command execution, also indicated by the "busy" bits in the status register. Those command sequences which do not affect the Flash array, e.g. the Enter Page Mode command or the Clear Status command, are immediately executed and are therefore not visible through the busy status bit. The command mode is terminated by the correct execution of the command or by an error condition as indicated in the status register. An end-of-busy and/or error interrupt can be enabled to inform the CPU about the new state.

5.6.3.3 Command Sequence Definitions

Flash operations are selected and started by writing specific address and data bus cycles to the Flash module, thus performing the command sequences. All command cycles of command sequences which define Flash bank operations have to use base addresses which point to the Flash bank to be operated on. All command addresses are aligned to word addresses ($A1/A0=0$). All command cycles belonging to one command sequence have to be mapped into the same non-cached Flash bank space. All command data (exception write and password data) are right-bounded 8-bit data. The command sequences are described in following table, whereby the shortcuts used in this table have following meanings.

- WD: 64-bit (or 32-bit) write data to be loaded into page assembly buffer.
- y: Flash Type $y=0_H$ selects the Program Flash, $y=D_H$ selects the Data Flash.
- PA: Page address; base address of PFlash/DFlash page to be programmed.

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- UCPA: User configuration page address.
- SA: Sector address; base address of sector to be erased.
- UCBA: User configuration block address; base address of the 1 Kbyte UC block.
- UL: User protection level; the command user level is zero (master user) or one.
- PW: 32-bit password.

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Table 5-4 Command Sequences for Flash Control

Command Sequence ¹⁾²⁾		1. Cycle	2. Cycle	3. Cycle	4. Cycle	5. Cycle	6. Cycle
Reset to Read	Address Data	.5554 ..xxF0					
Enter Page Mode^{*)}	Address Data	.5554 ..xx5y					
Load Page^{*)3)}	Address Data	.55F0 WD					
Write Page^{*)4)5)}	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.5554 ..xxA0	PA ..xxAA		
Write UC Page^{*)5)}	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.5554 ..xxC0	UCPA ..xxAA		
Erase Sector^{*)5)}	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.5554 ..xx80	.5554 ..xxAA	.AAA8 ..xx55	SA ..xx30
Erase Phys Sector^{*)6)}	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.5554 ..xx80	.5554 ..xxAA	.AAA8 ..xx55	SA ..xx40
Erase UC Block^{*)5)}	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.5554 ..xx80	.5554 ..xxAA	.AAA8 ..xx55	UCBA ..xxC0
Disable Write Protection⁷⁾	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.553C UL	.AAA8 PW 0	.AAA8 PW 1	.5558 ..xx05
Disable Read Protection⁷⁾	Address Data	.5554 ..xxAA	.AAA8 ..xx55	.553C ..xx00	.AAA8 PW 0	.AAA8 PW 1	.5558 ..xx08
Resume Protection	Address Data	.5554 ..xx5E					
Clear Status	Address Data	.5554 ..xxF5					

1) Addresses are byte addresses but are aligned to word addresses (A1/A0=0).

Address bits A20–A16 are not used for most command addresses; however, all command and data addresses to the Flash have to be mapped to the non-cached Flash memory space by using proper base addresses according to mapping of Program Flash or Data Flash memory bank. (DFlash banks are selected with A16). Within a command sequence all base addresses have to be identical.

*) These command sequences have to use non-cached base addresses pointing to the Flash bank to be operated on.

2) Addresses and data within the table are written in Hex format. Data are shown as right-bounded bytes in 32-bit words; however, their position on the 64-bit data bus is defined by address bit A2.

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- 3) The address "55F0_H" is used for load DW (64-bit) operations and for load word (32-bit) operations with word transfer on even half of 64-bit bus. In case of word transfers, for every second word the address has to be "55F4_H" because the word is transferred on the high half of the 64-bit data bus (A2=1).
In case of completely filled assembly buffer, overrun data are lost and an error flag and interrupt is generated.
- 4) The assembly buffer should be filled with Load Page commands before this command is executed. The page address is used from the 4. cycle.
- 5) This command sequence is only accepted, if read protection and/or write protection for the addressed sector is disabled or not installed (user specific).
- 6) Phys Sector = Physical Sector. Used to erase a physical 64K Program Flash Sector, if none of its 16K logical sectors is protected. Also used to erase DFlash sectors. This command sequence is only accepted, if read protection or write protection for the addressed sector (user specific) is disabled or not installed
- 7) Two password cycles are included for unlock operations (PW0 = low order 32-bit of password).

5.6.3.4 Functional Command Description

In the following, the commands are described in their standard functionality and with all the particularities, which have to be considered for application.

Reset to Read

The internal command state machine is reset to initial state and returns to read mode. An already started program or erase operation is not affected and will be continued.

The Reset to Read command is a single cycle command. It can be used at any point during the command sequence to reset the internal state machines and to return the device to the initial state, the read mode. With the Reset to Read command, also all error flags in the Flash Status Register FSR are cleared and an active page mode is aborted. A busy state of array (write operation or voltage ramp-up) is not aborted and the busy flags in FSR are not affected¹⁾.

Enter Page Mode

The page mode is entered and the pointer for the first write data into the page assembly buffer is cleared to point to the first word location. This command is a single cycle command. Its base address (A31–A16) has to point to the addressed Flash bank. The addressed Flash type (Program Flash or Data Flash) is selected with the parameter "y". Simultaneous page modes in Program Flash and Data Flash are not supported. In a DFLASH bank the page mode can be entered simultaneously to an erase operation within another DFLASH bank, but not simultaneously to a program operation²⁾.

- 1) The exact behavior of Reset to Read in case of busy Flash banks is: when a busy Flash bank is addressed the writing master is stalled (as for all commands). When Reset to Read addresses a different Flash bank it is executed as described (clearing the documented flags) but in order to note that a command sequence was executed while a Flash bank was busy the SQER flag is set.
- 2) Attention: trying to program a DFLASH bank while a program operation is still ongoing in the other DFLASH bank is not prevented by hardware and it does not trigger a SQER or other error indication. However both program operations can be disturbed and program erroneous data!

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With this command, the 'page mode' is entered, indicating that the page assembly buffer is enabled to be filled up with Load Page commands, and that a program operation is in preparation. Selection between assembly buffers of Program Flash and Data Flash is performed with the nibble "y" in the low byte of data word: $y=0_H$ selects the assembly buffer (256 byte) of Program Flash, $y=D_H$ selects the assembly buffer (128 byte) of Data Flash. The page mode is indicated in the status register FSR with the PAGE bit, separately for PFlash and DFlash. The page mode and the read mode are allowed in parallel at the same time and in the same Flash memory. The page mode can be aborted and the related PAGE bit in FSR be cleared with the Reset to Read command. A new Enter Page Mode command during page mode aborts the actual page mode, which is indicated with error flag 'Sequence Error', and enters the new page mode as described above. The assembly buffer remains unchanged (not cleared) with a new Enter Page Mode command.

Load Page

Load page assembly buffer with 64-bit double-word or with 32-bit word. The first or a sequential or the last double-word (or word) is loaded into the page assembly buffer with each Load Page command.

Note: For loading one page, the transfer width must always be identical. Mixed transfers of 64-bit and 32-bit write data are not supported by the PMU, because the ECC generation would be disabled in case of single 32-bit transfers (SQER error reporting in case of mixed transfers).

This (sequential) data write access to the assembly buffer belongs to and is only accepted in Page Mode. The data width (64-bit or 32-bit) is selected by the data-source (normally the DMI-unit) and it is indicated to the Flash by a qualifier to the data address. For 64-bit transfers, the address (A15–A0) of this single cycle command is always the same (55F0_H), in case of 32-bit transfers, the address must alternate between even or odd (55F0_H or 55F4_H) word addresses. The low order address bits also identify the Load Page command and the sequential write data to be loaded into the assembly buffer. The page assembly buffer to be accessed, either the 256-byte assembly buffer of the Program Flash or the 128-byte assembly buffer of the Data Flash, is defined by the base address of the command cycle. The location within the page assembly buffer is defined by the internal address pointer (see command Enter Page Mode), which is incremented after every load operation.

The page assembly buffer is a two-stage buffer, with the first stage (in Flash Interface Module) representing a 2-word data latch for ECC generation, and a second stage, representing the page assembly buffer, being filled with the double-words. After every received double-word, an 8-bit error correction code ECC is automatically generated and the double-word plus ECC code is loaded into the page assembly buffer. Not loaded double-words in the assembly buffer are undefined (not cleared). Load Page operations shall not be started before a preceding Write Page operation is terminated.

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In case of a completely filled page assembly buffer, an overrun condition is sampled during Load Page operations. In this case, the write data causing the overflow condition are lost. The overflow condition is indicated by the sequence error flag and by an error interrupt (if enabled), but the execution of a following Write Page command is not suppressed (the page mode is not aborted). When a Load Page command is received and the Flash is **not** in page mode, a sequence error is reported in FSR with SQER flag. A sequence error is also indicated if during page mode a new Enter Page command is received. In case of a Reset to Read command during page mode, or in case of a system reset, the page mode is aborted (but the write data in the page assembly buffer are not cleared).

Note: A sequence error generates an error interrupt if enabled in the configuration register FCON.

Write Page

The contents of the selected page assembly buffer (the whole page) is written (programmed) into the Flash array at page address PA. The addressed Flash type has to be the same as in the Enter Page Mode command (otherwise, a sequence error is reported instead of execution).

The complete

- 256-byte Program Flash assembly buffer and the 32 ECC-bytes, or the
- 128-byte Data Flash assembly buffer and the 16 ECC-bytes,

are programmed to Flash in one program operation, autonomously controlled by the Flash array module.

The bits

- A20 to A8 of PA (address of 4. cycle) define the page address which is the location of the page within the Program Flash
- A14 to A7 of PA (address of 4. cycle) define the page address and thus the location of the page within that Data Flash bank, which is addressed with A16.

The page address has to be aligned, therefore the bits A7–A0 (Data Flash: A6 to A0) of PA have to be zero. The data pattern of the 4. cycle is fixed (AA_H) and only used for confirmation of the page address.

If the page assembly buffer is not completely filled when receiving the command, a sequence error is reported, however the command is executed. If the 2-word data latch for ECC generation (in FIM) is not completely filled, the word is lost and again a sequence error is reported.

With the Write Page command, the page mode is terminated, indicated by resetting the related PAGE flag and — if the command is accepted — the command mode is entered and the PROG flag in the status register FSR is activated. The Write Page command is only executed (PROG is only set), if the addressed Flash bank is not busy; otherwise,

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the first command cycle is acknowledged with a retry request. After start of program operation also the BUSY flag for the addressed bank is set in FSR.

The start of program operation can be delayed:

- If initiated for one DFlash bank while the other DFlash bank is in erase operation (which will be automatically suspended and resumed). The delay depends on the state of the erase operation and the erase timing. Typically the delay is less or equal to 15 ms.
- Until an active Data Flash erase operation is terminated, if the program operation is initiated for the Program Flash.

Read accesses to Data Flash banks during busy state of Program Flash are not allowed. Read accesses to one Data Flash bank while the other DFlash bank is busy with a program operation is especially supported. A read access to a busy Flash bank is serviced with a retry acknowledge until the addressed Flash bank is not busy anymore. A new Write Page command is only accepted after a new Enter Page Mode command.

Note: Multiple writes to the same page location before erase are not allowed; in this case stored data in adjacent cells (in the second page of the same wordline) may be disturbed. However, there is one exception for a second write to the same page in Data Flash and in Program Flash: A page can once be overwritten with all-ones data (and correct all-ones ECC) for example to create an invalidation stamp for indication of an invalid wordline.

During the program operation, the quality of the programmed bits is autonomously verified by the Flash FSI. Weak bits are re-programmed. A verification error (re-programming is not possible anymore) is indicated with the VER bit in FSR (see also [Page 5-19](#)).

If write protection is installed for the sector to be programmed or in case of active read protection (including global write protection, if not separately disabled for the Data Flash), the Write Page command is only executed when read/write protection has been disabled before, using a 'Disable Protection' command sequence with two 32-bit passwords. If the sector-specific and/or global write protection is not disabled when the Write Page command is received or if an OTP protected sector is addressed, only the page mode is terminated, but command mode and thus the program operation is not started, and the protection error flag PROER is set in the FSR.

Write User Configuration (UC) Page

This command is identical to the Write Page command for the Program Flash with the following exceptions: The addressed page (UCPA) belongs to one User Configuration Block (UCB) in the configuration sector and not to the user Flash array. This command can only be executed on the user's four pages in his UCB. Only if protection is not installed (e.g. for the very first installation of protection), it is not necessary to disable the user's protection before execution of this command. After writing the correct protection

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confirmation code in the respective UC page, the new protection configuration is valid and active after the next reset.

If the protection configuration in an UC block has to be re-programmed (not possible for UCB2), at first the user's protection must be disabled and then its UC block must be erased. Thus also the UCB's protection confirmation code is erased and the protection is uninstalled. Only in this unprotected state an UC page can be (re-)programmed. A Write UC Page command to a User Configuration Block with active (not disabled) write protection disables the command and generates a protection error (PROER in FSR). In case of installed and active read protection, all three UC Blocks are locked and not accessible (PROER is indicated in FSR).

The structure of the User Configuration Block (comprising four User Configuration Pages UCP0–UCP3 per block) is described in [Chapter 5.6.5.4](#).

Note: If the program operation is aborted (e.g. by a reset), written UCB-data may be disturbed and the protection can possibly no more be disabled.

Erase Sector

The addressed sector in the Program Flash is erased. This command cannot be used for Data Flash sectors. It is a six-cycle command sequence.

The sector to be erased is addressed by SA (sector address) in the last command cycle. Sectors can be erased (and re-programmed) as often as defined by the endurance value (max. 1000, for special handling of logical 16K sectors see [Chapter 5.6.2.1](#)). The timing of erase execution is autonomously controlled by the Flash array module. The max. erase time is five sec., but its exact timing depends on the sector size and the CPU frequency.

The address bits A20 to A14 of SA (address of 6. cycle) define the sector address and thus the sector to be erased. The sector address has to be aligned, therefore the bits A13 to A0 of SA have to be zero. The addresses of command sequence cycles including the sector address have to be mapped to the base address of the non-cached Program Flash (sequence error, if mapped to DFlash).

With the last cycle of the Erase Sector command, the command mode is entered, indicated by activation of the ERASE and by the PBUSY flag in the status register FSR. The start of an erase operation can be delayed until an active erase and/or program operation(s) is terminated. Allowed is only to issue an erase of a DFLASH bank while the other DFLASH bank is busy.

Read accesses to Data Flash banks during busy state of Program Flash are not allowed. Read accesses to one Data Flash bank while the other DFlash bank is busy with erase operation is especially supported. A read access to the busy Flash bank is serviced with a retry acknowledge until the addressed Flash bank is no more busy. A new command sequence to the busy Flash bank is also serviced with a retry acknowledge.

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The sector erase algorithm includes an erase quality check that identifies incorrect erased bits in the Flash sector. If re-erasing of weak bits or soft re-programming of over-erased bits is unsuccessful, the verify error flag FSR.VER is set (see [Chapter 5.6.6.3](#)).

If write protection is installed for the sector to be erased or in case of active read protection (including global write protection, if not separately disabled for Data Flash), the command is only executed when read/write protection has been disabled before, using a 'Disable Protection' command sequence with two 32-bit passwords. If write protection is not disabled when the Sector Erase command is received or if an OTP protected sector is addressed, the command mode and thus the erase operation is not started and the protection error flag PROER is set in the FSR.

Erase Physical Sector

The addressed physical sector in the Data Flash or in Program Flash is erased. Cannot be used for 16K sectors in Program Flash. It is a six-cycle command sequence.

The sectors, which can be erased with this command, are the two Data Flash sectors (banks) DS0 and DS1 and the two 64K physical sectors PS0 and PS4 in Program Flash which comprise the logical 16K sectors (see [Table 5-6](#)). This command shall not be used for the large sectors above S7. Besides the different sector address definitions, the command execution is analogous to the Erase Sector command (including erase quality check).

The sector addresses (see [Page 5-40](#)) have to be aligned, therefore all low order address bits of SA are zero. All command cycle addresses, including the sector address SA, have to be mapped into that space (PFlash or DFlash range) where the sector to be erased is located.

The start of sector erase operation can be delayed by up to 5 msec if initiated while another bank (DFlash or PFlash) is active with program operation.

Read accesses to Data Flash banks during busy state of Program Flash are not allowed. Read accesses to one Data Flash bank while the other DFlash bank is busy with erase operation is especially supported. A read access to the busy Flash bank is serviced with a retry acknowledge until the addressed Flash bank is no more busy. A new command sequence to the busy Flash bank is also serviced with a retry acknowledge. The busy state of Flash bank is indicated in the FSR separately for PFlash and for bank 0 and bank 1 of DFlash.

If read protection (includes global write protection with or without Data Flash) is installed, the command is only executed when read protection has before been disabled using the unlock command sequence 'Disable Read Protection' with two passwords, belonging to user 0. If read protection is not disabled when the Erase Phys Sector command is received, the command mode and thus the erase operation is not started, and the protection error flag PROER is set in the FSR.

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If the Erase Phys Sector operation is used to erase a physical 64K sector of Program Flash (including the 16K sectors), this operation is only executed, if none of its 16K sectors is write protected or if protection is disabled (user 0 and/or user 1). If write protection is not disabled, or if one or more of the included 16K sectors are OTP protected, the erase operation is not started, and the protection error flag PROER is set.

The Erase Phys Sector operation in one DFlash bank can be executed simultaneously to program operation in the other Data Flash bank or/and to read accesses to Program Flash.

Erase User Configuration Block

The addressed user configuration block (UCB 0–2) is erased. A UC block has the capacity of four pages (1 Kbyte).

Note: If sector write protection is configured and confirmed (thus installed) in UCB 2, this block can never be erased again. As its write protected sectors, UCB 2 is only one time programmable (OTP). UCB 2 can only be erased before installation of OTP write protection.

The addressed UC block belongs to the configuration sector and not to the universal Flash array. This command can only be executed after disabling of sector write protection of the addressed UCB (representing the user's protection level), and/or after disabling of read protection. If protection is not disabled when the Erase UC Block command is received, the command mode and thus the erase operation is not started, and the protection error flag PROER is set in the FSR.

The UC block to be erased is addressed by UCBA (UCB address) in the last command cycle to the Program Flash. The bits A20 to A10 of UCBA (address of 6. cycle) define the UC block address and thus the two wordlines (four pages) of array to be erased. The UCB address has to be aligned, therefore the bits A9 to A0 of UCBA have to be zero. The addresses of all cycles of the command sequence including the UC block address have to be mapped to the base address of Program Flash.

The command execution is analogous to an Erase Sector operation in Program Flash. With the last cycle of the Erase UC Block command, the command mode is entered, indicated by activation of the ERASE and the PBUSY flag in the status register FSR. Read accesses to Data Flash banks during busy state of Program Flash are not allowed. A read access to the busy Flash is serviced with a retry acknowledge until the addressed Flash bank is no more busy.

Note: If the erase operation is aborted (e.g. by a reset), UCB-data and the whole config sector may be disturbed and the protection can possibly no more be disabled. In this case, also the init code may be affected, resulting in a fatal startup error.

After the erase operation, the new protection configuration (including keywords and protection confirmation code) can be written to the UC pages (see description in [Chapter 5.6.5](#)).

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Disable Sector Write Protection

Sector write protection of all protected sectors belonging to the user's protection level (only in Program Flash) is temporarily disabled.

This is a protected command sequence, using two user defined passwords to release this command. For every password one command cycle is required (see command sequence definitions). The 32-bit passwords are internally compared with the keywords out of the User Configuration Block, which is assigned to the user's protection level. If one or both passwords are not identical to their related keywords, the protected sectors remain in the locked state and a protection error (PROER) is indicated in the Flash Status Register. In this case, a new Disable Sector Write Protection command or a Disable Read Protection command is only accepted after the next application reset.

Note: The Disable Sector Write Protection command is not accepted for user 2 sectors, which are OTP protected and handled as ROM sectors.

After correct execution of this command, all protected sectors (which belong to the user) are unlocked, which is indicated in the Flash Status Register (FSR) with the user's WPRODIS bit. Erase and write operations on the unlocked sectors are now possible, if not coincidentally the read protection (including global write protection) is enabled. The protection is resumed, when:

- The command Resume Read/Write Protection is executed
- The next application reset (including HW and SW reset) is received.

Note: This command sequence is also used to check the correctness of keywords before the protection is locked with the confirmation code in the User Configuration Block. A wrong keyword is indicated by the FSR flag PROER.

Disable Read Protection

Flash read protection and global write protection of the whole Flash array including the Data Flash (if also protected) are temporarily disabled.

This is a protected command sequence, using two user defined passwords to release this command. For every password one command cycle is required (see command sequence definitions). The both 32-bit passwords are internally compared with the keywords out of the User Configuration Wordline, which is assigned to the user protection level zero. If one or both passwords are not identical to their related keywords, the protected array remains in the locked state and a protection error (PROER) is indicated in the Flash status register. In this case, a new Disable Read Protection command or a Disable Sector Write Protection command is only accepted after the next application reset.

After correct execution of this command, the whole Flash is unlocked and the read protection disable bit RPRODIS is set in the Flash Status Register (FSR). Erase and write operations on all sectors are now possible, if they are not separately write protected or OTP protected. Additionally, Flash read accesses from any master are

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now supported in the PMU. The read protection control flags DCF and DDF in FCON register can now be cleared via FCON register access. The read protection (including global write protection) remains disabled until the command Resume Read/Write Protection is executed, or until the next application reset (including HW and SW reset).

Note: This command sequence is also used to check the correctness of keywords before the protection is locked with the confirmation code in the User Configuration Block zero. A wrong keyword is indicated by the FSR flag PROER.

Resume Protection

Write protection of temporarily unlocked protected sectors and/or read protection is resumed.

This single-cycle command resumes all kinds of temporarily disabled protection installations, as defined in the User Configuration Pages belonging to the UC-blocks. This command is released immediately after execution.

Clear Status

The error flags in Flash status register are cleared. Additionally, the write status bits (PROG, ERASE) are cleared, if Flash is not busy.

The single-cycle command 'Clear Status' is accepted only in Read Mode (otherwise 'Sequence Error')¹⁾. Note: Read Mode is also taken after every error detection and indication in FSR.

1) The exact behavior of Clear Status in case of busy Flash banks is: as all commands it stalls the issuing master when addressing a busy Flash bank. When addressing a not busy Flash bank Clear Status is not executed and SQER is set additionally.

5.6.3.5 Sector, Page and Block Addressing

As all command cycles of command sequences, sector, page and block addressing as required in the command sequences shall be performed in the non-cached address space of Program Flash and Data Flash (for definition of address mapping see [Table 5-3](#)). In the following, the base addresses of Program Flash and Data Flash banks, which depend on this mapping are not considered. Only the physical addresses within the Flash array, which always start with address zero, are defined.

Sector addresses are required for the commands 'Erase Sector' for the Program Flash and 'Erase Phys Sector' for the Data and Program Flash.

Block addressing is required for the command 'Erase User Configuration Block'.

Page addressing is necessary for the commands 'Write Page' and 'Write User Configuration Page'.

Sector Addresses

Sector addresses SA are identical to the sector start addresses (represented by lowest address within the sector) which are defined by the address bits A20–A14 in the appropriate command cycles. Depending on the sector size at least the address bits A13–A0 must be zero for sector addresses which have to be aligned. The high order address bits A31–A21 are defined by the base address of the Program Flash memory and the base address of the Data Flash in case of DFlash sectors, as described in [Chapter 5.6.3.1](#).

The following two tables define the sectors with their sector numbers, the sector sizes, the sector (start) addresses and the ranges of the sectors for the (standard) sectors in Program Flash and for the physical sectors in Program Flash and Data Flash. The address bits written with bold characters are fixed within the respective range.

All sectors in Program Flash can separately be locked by up to three users for write or OTP protection.

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Table 5-5 Addresses and Sizes of Sectors in Program Flash

Sector	Phys. Sector	Sector Size	Sector Addresses SA									Sector Range Physical Addr. (hex)	
			A21 – A19			A18– A17		A16 – A14			A13– A00		
S0	PS0	16 KB	0	0	0	0	0	0	0	0	0	- 0 -	00'0000 – 00'3FFF
S1		16 KB	0	0	0	0	0	0	0	1	0	- 0 -	00'4000 – 00'7FFF
S2		16 KB	0	0	0	0	0	0	1	0	0	- 0 -	00'8000 – 00'BFFF
S3		16 KB	0	0	0	0	0	0	1	1	0	- 0 -	00'C000 – 00'FFFF
S4	PS4	16 KB	0	0	0	0	0	1	0	0	0	- 0 -	01'0000 – 01'3FFF
S5		16 KB	0	0	0	0	0	1	0	1	0	- 0 -	01'4000 – 01'7FFF
S6		16 KB	0	0	0	0	0	1	1	0	0	- 0 -	01'8000 – 01'BFFF
S7		16 KB	0	0	0	0	0	1	1	1	0	- 0 -	01'C000 – 01'FFFF
S8	–	128 KB	0	0	0	0	1	0	0	0	0	- 0 -	02'0000 – 03'FFFF
S9	–	256 KB	0	0	0	1	0	0	0	0	0	- 0 -	04'0000 – 07'FFFF
S10	–	256 KB	0	0	1	0	0	0	0	0	0	- 0 -	08'0000 – 0B'FFFF
S11	–	256 KB	0	0	1	1	0	0	0	0	0	- 0 -	0C'0000 – 0F'FFFF
S12	–	256 KB	0	1	0	0	0	0	0	0	0	- 0 -	10'0000 – 13'FFFF
S13	–	256 KB	0	1	0	1	0	0	0	0	0	- 0 -	14'0000 – 17'FFFF

For compatibility between devices with different amount of PFLASH all sectors maintain their address and number throughout the family. PMUs with less PFLASH have fewer of the 256 Kbyte sectors:

- 0.5 Mbyte PFLASH: sectors S0 – S9 are implemented.
- 1 Mbyte PFLASH: sectors S0 – S11 are implemented.
- 1.5 Mbyte PFLASH: sectors S0 – S13 are implemented.
- 2 Mbyte PFLASH: sectors S0 – S15 are implemented.
- 2.5 Mbyte PFLASH: sectors S0 – S17 are implemented.

*Note: All addresses defined in the sector table above are internal addresses of and within the Program Flash memory. However, all sector addresses to the Flash have to be assigned to the respective Flash memory base address by using proper **A31–A21** address bits according to the mapping of Program Flash memory.*

Both Data Flash sectors (DS0 and DS1) and the two PFlash sectors (PS0 and PS4), as used in the command sequence 'Erase Phys Sector' (see [Table 5-4](#)) are addressed according to the standard sector addressing, with their start addresses (see table

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Table 5-6). The high order address bits A31 – A22 are again defined by the address mapping of Data Flash or Program Flash.

Table 5-6 Addresses of Phys Sectors in DFlash and in PFlash

Sector Number	Sector Size	Sector Addresses SA			Sector Range Physical Addr. (hex)
		A21 – A17	A16	A15 – A00	
DS0	32 KB	- 0 -	0	-0-	0'0000 – 0'7FFF
DS1	32 KB	- 0 -	1	-0-	1'0000 – 1'7FFF
PS0	64 KB	- 0 -	0	-0-	00'0000 – 00'FFFF
PS4	64 KB	- 0 -	1	-0-	01'0000 – 01'FFFF

As noted before in all DFLASH implementation throughout the family the start addresses of both DFLASH banks/sectors remains constant.

Page Addresses

Pages in Program Flash (256 byte pages) are addressed via the address bits A20–A8, pages of Data Flash bank (128 byte pages) are addressed with the address bits A14 to A7 during the last command cycle of a 'Write Page' command sequence. The low order address bits A7–A0 (Data Flash A6–A0) have to be zero, thus the page address PA must be aligned. As for sector addresses, the high order address bits A31–**A21** for Program Flash and A31–A16 for Data Flash are defined by the base address of the accessed Flash bank and depend on the Flash mapping (see [Table 5-3](#) for PMU0). The addresses of User Configuration Pages (UCP) are handled as the PFlash page addresses PA11 – PA0.

Table 5-7 Addresses and Sizes of Pages

Page Number	Page Size	Page Addresses PA							Page Range Physical Addr. (hex)
		A21– A17	A 16	A15– A12	A11– A9	A 8	A 7	A6– A0	
Program Flash									
Pneven	256 Byte	-X-	X	-X-	-X-	0	- 0 -	xx'xx00 – xx'xxFF	
Pnodd	256 Byte	-X-	X	-X-	-X-	1	- 0 -	xx'xx00 – xx'xxFF	
Data Flash									
DPneven	128 Byte	Base=0	b ¹⁾	XXXX	-X-	X	0	- 0 -	x'xx00 – x'xx7F
DPnodd	128 Byte	Base=0	b ¹⁾	XXXX	-X-	X	1	- 0 -	x'xx80 – x'xxFF

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Table 5-7 Addresses and Sizes of Pages (cont'd)

Page Number	Page Size	Page Addresses PA							Page Range Physical Addr. (hex)
		A21– A17	A 16	A15– A12	A11– A9	A 8	A 7	A6– A0	
User Configuration Block									
UCPneven	256 Byte	- 0-	0	- 0-	-X-	0	- 0 -		00'0x00 – 00'0xFF
UCPnodd	256 Byte	- 0-	0	- 0-	-X-	1	- 0 -		00'0x00 – 00'0xFF

1) "b" selects the Data Flash bank. b=0: DFlash bank 0, b=1: DFlash bank 1

In table above, 'X' indicate relevant address bits or relevant hex-numbers of physical (Flash-internal) addresses. The useful range of addresses depends obviously on the amount of implemented flash memory, i.e. the size of the banks.

User Configuration Block Addresses

Three User Configuration Blocks (UCB) are available in the configuration sector in Program Flash. Each UC block has the capacity of 1 KB (four pages).

Table 5-8 Addresses and Sizes of User Configuration Blocks

UCB Number	UCB Size	UCB Addresses				UCB Range Physical Addr. (hex)
		A21– A15	A14– A12	A11/ A10	A9–A0	
UCB0	1 Kbyte	- 0-	- 0-	00	- 0 -	00'0000 – 00'03FF
UCB1	1 Kbyte	- 0-	- 0-	01	- 0 -	00'0400 – 00'07FF
UCB2	1 Kbyte	- 0-	- 0-	10	- 0 -	00'0800 – 00'0BFF

5.6.3.6 Register Addresses and Access Restrictions

Register accesses are supported for CPU controlled accesses via the DMI unit and for accesses via the debug interface. All register addresses are word aligned, independently of the register width. Besides word-read/write accesses, also byte or half-word read/write accesses are supported.

All Flash register read and write accesses are single cycle operations.

For Flash registers separate address spaces are reserved for each PMU (see [Table 5-9](#)). The detailed register list of PMU0 is contained in [Table 5-3](#).

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Table 5-9 Registers Address Spaces of Flash Registers

Module	Base Address	End Address	Note
FLASH0	F800 1000 _H	F800 23FF _H	See Table 5-11

Within the register address table below, the Access Modes “Read” and “Write” indicate access rights and restrictions as well as values, using symbols as follows:

Table 5-10 Address Map Symbols

Symbol	Description
U	Access permitted in User Mode 0 or 1.
SV	Access permitted in Supervisor Mode.
E	ENDINIT protected register/address.
BE	Indicates that an access to this address range generates a Bus Error.
X	Undefined value or bit.

Note: In the table above, the declaration of access protection with ENDINIT indicates the standard “ENDINIT” protection feature (including watchdog password access control) which is used for write accesses to protected system registers. Using this mechanism, it is possible to change the protected register only before End of Initialization or after ENDINIT with valid password access to WDT_CON0. Read accesses are always possible.

The following table shows the addresses, the access modes and reset types for the Flash registers in PMU0:

Table 5-11 Addresses of Flash0 Registers

Short Name	Description	Address	Access Mode		Reset	See
			Read	Write		
FLASH0_COMM0	FSI Communication	F800 1000 _H	U, SV	SV	Class3 Reset	Page 5-93
FLASH0_COMM1	FSI Communication	F800 1004 _H	U, SV	SV	Class3 Reset	Page 5-93
FLASH0_COMM2	FSI Communication	F800 1008 _H	U, SV	SV	Class3 Reset	Page 5-93
–	Reserved	F800 2000 _H – F800 2004 _H	BE	BE	–	–

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Table 5-11 **Addresses of Flash0 Registers** (cont'd)

Short Name	Description	Address	Access Mode		Reset	See
			Read	Write		
FLASH0_ID	Flash Module Identification Register	F800 2008 _H	U, SV	BE	Class3 Reset	Page 5-59
–	Reserved	F800 200C _H	BE	BE	–	–
FLASH0_FSR	Flash Status Register	F800 2010 _H	U, SV	BE	Class3+ PORST Reset	Page 5-46
FLASH0_FCON	Flash Configuration Register	F800 2014 _H	U, SV	SV, E	Class3 Reset	Page 5-53
FLASH0_MARP	Flash Margin Control Register PFlash	F800 2018 _H	U, SV	SV, E	Class3 Reset	Page 5-62
FLASH0_MARD	Flash Margin Control Register DFlash	F800 201C _H	U, SV	U, SV	Class3 Reset	Page 5-63
FLASH0_PROCON0	Flash Protection Configuration User 0	F800 2020 _H	U, SV	BE	Class3 Reset	Page 5-69
FLASH0_PROCON1	Flash Protection Configuration User 1	F800 2024 _H	U, SV	BE	Class3 Reset	Page 5-71
FLASH0_PROCON2	Flash Protection Configuration User 2	F800 2028 _H	U, SV	BE	Class3 Reset	Page 5-72
–	Reserved	F800 202C _H – F800 23FC _H	BE	BE	–	

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5.6.3.7 Flash Status Definition

The Flash Status Register FSR reflects the overall status of the Flash module after Reset and after reception of the different commands. Sector specific protection states are not indicated in the FSR, but in the registers PROCON0, PROCON1 and PROCON2. The status register is a read-only register. Only the error flags and the two status flags (PROG, ERASE) are affected with the “Clear Status” command. The error flags are also cleared with the “Reset to Read” command.

The FSR is defined as follows:

FSR

Flash Status Register

(1010_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
VER	X	0	SLM	0	W PRO DIS1	W PRO DIS0	0	W PRO IN2	W PRO IN1	W PRO IN0	0	R PRO DIS	R PRO IN	0	PRO IN
rh	rh	r	rh	r	rh	rh	r	rh	rh	rh	r	rh	rh	r	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DF DB ER	PF DB ER	DF SB ER	PF SB ER	PRO ER	SQ ER	DF OP ER	PF OP ER	DF PAG E	PF PAG E	ERA SE	PRO G	D1 BUS Y	D0 BUS Y	FA BUS Y	P BUS Y
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
PBUSY ¹⁾	0	rh	Program Flash Busy HW-controlled status flag. 0 _B PFlash ready, not busy; PFlash in read mode. 1 _B PFlash busy; PFlash not in read mode. Indication of busy state of PFlash because of active execution of program or erase operation; PFlash busy state is also indicated during Flash recovery (after reset) and in power ramp-up state or in sleep mode; while in busy state, the PFlash is not in read mode.
FABUSY ¹⁾	1	rh	Flash Array Busy Internal busy flag for testing purposes. Must be ignored by application software. This may only use PBUSY, D0BUSY and D1BUSY.

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Field	Bits	Type	Description
D0BUSY⁽¹⁾	2	rh	Data Flash Bank 0 Busy HW-controlled status flag. 0 _B DFlash0 ready, not busy; DFlash0 in read mode. 1 _B DFlash0 busy; DFlash0 not in read mode. Indication of busy state of DFlash bank 0 because of active execution of program or erase operation; DFlash0 busy state is also indicated during Flash recovery (after reset) and in power ramp-up state or in sleep mode; while in busy state the DFlash0 is not in read mode.
D1BUSY⁽¹⁾	3	rh	Data Flash Bank 1 Busy HW-controlled status flag. 0 _B DFlash1 ready, not busy; DFlash1 in read mode. 1 _B DFlash1 busy; DFlash1 not in read mode. Indication of busy state of DFlash bank 1 because of active execution of program or erase operation; DFlash1 busy state is also indicated during Flash recovery (after reset) and in power ramp-up state or in sleep mode; while in busy state the DFlash0 is not in read mode.
PROG⁽³⁾⁽⁴⁾	4	rh	Programming State HW-controlled status flag. 0 _B There is no program operation requested or in progress or just finished. 1 _B Programming operation (write page) requested (from FIM) or in action or finished. Set with last cycle of Write Page command sequence, cleared with Clear Status command (if not busy) or with power-on reset. If one BUSY flag is coincidentally set, PROG indicates the type of busy state. If xOPER is coincidentally set, PROG indicates the type of erroneous operation. Otherwise, PROG indicates, that operation is still requested or finished.

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Field	Bits	Type	Description
ERASE³⁾⁴⁾	5	rh	Erase State HW-controlled status flag. 0 _B There is no erase operation requested or in progress or just finished 1 _B Erase operation requested (from FIM) or in action or finished. Set with last cycle of Erase command sequence, cleared with Clear Status command (if not busy) or with power-on reset. Indications are analogous to PROG flag.
PFPAGE¹⁾²⁾	6	rh	Program Flash in Page Mode HW-controlled status flag. 0 _B Program Flash not in page mode 1 _B Program Flash in page mode; assembly buffer of PFlash (256 byte) is in use (being filled up) Set with Enter Page Mode for PFlash, cleared with Write Page command <i>Note: Concurrent page and read modes are allowed</i>
DFPAGE¹⁾²⁾	7	rh	Data Flash in Page Mode HW-controlled status flag. 0 _B Data Flash not in page mode 1 _B Data Flash in page mode; assembly buffer of DFlash (128 byte) is in use (being filled up) Set with Enter Page Mode for DFlash, cleared with Write Page command. <i>Note: Concurrent page and read modes are allowed</i>
PFOPER²⁾³⁾⁴⁾	8	rh	Program Flash Operation Error 0 _B No operation error reported by Program Flash 1 _B Flash array operation aborted, because of a Flash array failure, e.g. an ECC error in microcode. This bit is not cleared with application reset, but with power-on reset. Registered status bit; must be cleared per command
DFOPER²⁾³⁾⁴⁾	9	rh	Data Flash Operation Error Function analogous to Program Flash OPER

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Field	Bits	Type	Description
SQER¹⁾²⁾³⁾	10	rh	Command Sequence Error 0_B No sequence error 1_B Command state machine operation unsuccessful because of improper address or command sequence. A sequence error is not indicated if the Reset to Read command aborts a command sequence. Registered status bit; must be cleared per command
PROER¹⁾²⁾³⁾	11	rh	Protection Error 0_B No protection error 1_B Protection error. A Protection Error is reported e.g. because of a not allowed command, for example an Erase or Write Page command addressing a locked sector, or because of wrong password(s) in a protected command sequence such as "Disable Read Protection" Registered status bit; must be cleared per command
PFSBER¹⁾²⁾³⁾	12	rh	PFlash Single-Bit Error and Correction 0_B No Single-Bit Error detected during read access to PFlash 1_B Single-Bit Error detected and corrected Registered status bit; must be cleared per command
DFSBER¹⁾²⁾³⁾	13	rh	DFlash Single-Bit Error and Correction Function analogous to PFlash PFSBER
PFDBER¹⁾²⁾³⁾	14	rh	PFlash Double-Bit Error 0_B No Double-Bit Error detected during read access to PFlash 1_B Double-Bit Error detected in PFlash Registered status bit; must be cleared per command
DFDBER¹⁾²⁾³⁾	15	rh	DFlash Double-Bit Error Function analogous to PFlash PFDBER
PROIN	16	rh	Protection Installed 0_B No protection is installed 1_B Read or/and write protection for one or more users is configured and correctly confirmed in the User Configuration Block(s). HW-controlled status flag

Program Memory Unit (PMU)

Field	Bits	Type	Description
RPROIN	18	rh	Read Protection Installed 0_B No read protection installed 1_B Read protection and global write protection (with or without Data Flash) is configured and correctly confirmed in the User Configuration Block 0. Supported only for the master user (user zero). HW-controlled status flag
RPRODIS¹⁾⁵⁾	19	rh	Read Protection Disable State 0_B Read protection (if installed) is not disabled 1_B Read and global write protection is temporarily disabled. Flash read with instructions from other memory, as well as program or erase on not separately write protected sectors is possible. HW-controlled status flag
WPROIN0	21	rh	Sector Write Protection Installed for User 0 0_B No write protection installed for user 0 1_B Sector write protection for user 0 is configured and correctly confirmed in the User Configuration Block 0. HW-controlled status flag
WPROIN1	22	rh	Sector Write Protection Installed for User 1 0_B No write protection installed for user 1 1_B Sector write protection for user 1 is configured and correctly confirmed in the User Configuration Block 1. HW-controlled status flag
WPROIN2	23	rh	Sector OTP Protection Installed for User 2 0_B No OTP write protection installed for user 2 1_B Sector OTP write protection with ROM functionality is configured and correctly confirmed in the UCB2. The protection is locked for ever. HW-controlled status flag

Program Memory Unit (PMU)

Field	Bits	Type	Description
WPRODIS0¹⁾⁵⁾	25	rh	Sector Write Protection Disabled for User 0 0 _B All protected sectors of user 0 are locked if write protection is installed 1 _B All write-protected sectors of user 0 are temporarily unlocked, if not coincidentally locked by user 2 or via read protection. Hierarchical protection control: User-0 sectors are also unlocked, if coincidentally protected by user 1. But not vice versa. HW-controlled status flag
WPRODIS1¹⁾⁵⁾	26	rh	Sector Write Protection Disabled for User 1 0 _B All protected sectors of user 1 are locked if write protection is installed 1 _B All write-protected sectors of user 1 are temporarily unlocked, if not coincidentally locked by user 0 or user 2 or via read protection. HW-controlled status flag
SLM¹⁾	28	rh	Flash Sleep Mode HW-controlled status flag. Indication of Flash sleep mode taken because of global or individual sleep request; additionally indicates when the Flash is in shut down mode. 0 _B Flash not in sleep mode 1 _B Flash is in sleep or shut down mode
X	30	rh	Reserved Value undefined
VER¹⁾³⁾	31	rh	Verify Error 0 _B The page is correctly programmed or the sector correctly erased. All programmed or erased bits have full expected quality. 1 _B A program verify error or an erase verify error has been detected. Full quality (retention time) of all programmed ("1") or erased ("0") bits cannot be guaranteed. See Chapter 5.6.6.3 and Chapter 5.6.6.4 for proper reaction. Registered status bit; must be cleared per command

Program Memory Unit (PMU)

Field	Bits	Type	Description
0	17,20, 24, 27, 29	r	Reserved Read zero, no write

Note: The footnote numbers of FSR bits describe the specific reset conditions:

- 1)Cleared with application reset (class 3 reset)
- 2)Cleared with command "Reset to Read"
- 3)Cleared with command "Clear Status"
- 4)Cleared with power-on reset (PORST)
- 5)Cleared with command "Resume Protection"

Note: The xBUSY flags as well as the protection flags cannot be cleared with the "Clear Status" command or with the "Reset to Read" command. These flags are controlled by HW.

Note: The reset value above is indicated after correct execution of Flash rampup. Additionally, errors are possible after rampup (see [Chapter 5.6.6.4](#)).

Program Memory Unit (PMU)

5.6.3.8 Flash Configuration Control

The Flash Configuration Register FCON reflects and controls the following general Flash configuration functions:

- Number of wait states for Flash accesses (see also [Table 5-1](#) for selection).
- Indication of installed and active read protection.
- Instruction and data access control for read protection.
- Interrupt mask bits.
- Power reduction and shut down control.

FCON is a “ENDINIT” protected register. It is defined as follows:

FCON

Flash Configuration Register

(1014_H)

Reset value: 0007 0A06_H¹⁾

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EOB M	DF DB ERM	PF DB ERM	DF SB ERM	PF SB ERM	PRO ERM	SQ ERM	VOP ERM	0	0	DDF PCP	DDF DMA	0	DDF	DCF	RPA
rw	rw	rw	rw	rw	rw	rw	rw	r	r	rw	rw	r	rwh	rwh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SL EEP	ESL DIS	IDLE	WS EC DF	WS DFLASH				0	0	0	WS EC PF	WS PFLASH			
rw	rw	rw	rw	rw				r	r	r	rw	rw			

1) After Flash rampup and execution of the startup SW in BootROM (after firmware exit), the initial value is 000X 0A06_H.

Program Memory Unit (PMU)

Field	Bits	Type	Description
WSPFLASH	[3:0]	rw	Wait States for read access to PFlash This bitfield defines the number of wait states, which are used for an initial read access to the Program Flash memory area (see Table 5-1 for selection). 0000 _B PFlash access in one clock cycle 0001 _B PFlash access in one clock cycle 0010 _B PFlash access in two clock cycles 0011 _B PFlash access in three clock cycles 0100 _B PFlash access in four clock cycles 0101 _B PFlash access in five clock cycles 0110 _B PFlash access in six clock cycles 0111 _B PFlash access in seven clock cycles. PFlash access in eight up to fourteen clock cycles. 1111 _B PFlash access in fifteen clock cycles.
WSECPF	4	rw	Wait State for Error Correction of PFlash 0 _B No additional wait state for error correction 1 _B One additional wait state for error correction during read access to Program Flash. If enabled, this wait state is only used for the first transfer of a burst transfer. Set this bit only when requested by Infineon.
WSDFLASH	[11:8]	rw	Wait States for read access to DFlash This bitfield defines the number of wait states, which are used for a read access to the Data Flash memory area (see Table 5-1 for selection). 0000 _B DFlash access in one clock cycle 0001 _B DFlash access in one clock cycle 0010 _B DFlash access in two clock cycles 0011 _B DFlash access in three clock cycles 0100 _B DFlash access in four clock cycles 0101 _B DFlash access in five clock cycles 0110 _B DFlash access in six clock cycles 0111 _B DFlash access in seven clock cycles. 1000 _B DFlash access in eight clock cycles. DFlash access in nine up to fourteen clock cycles. 1111 _B DFlash access in fifteen clock cycles.

Program Memory Unit (PMU)

Field	Bits	Type	Description
WSECDF	12	rw	Wait State for Error Correction of DFlash 0_B No additional wait state for error correction 1_B One additional wait state for error correction during read access to Data Flash
IDLE	13	rw	Dynamic Flash Idle 0_B Normal/standard Flash read operation 1_B Dynamic idle of Program Flash enabled for power saving; static prefetching disabled <i>Note: In Data Flash, dynamic idle is always enabled (prefetching not supported).</i>
ESLDIS	14	rw	External Sleep Request Disable 0_B External sleep request signal input is enabled 1_B Externally requested Flash sleep is disabled The 'external' signal input is connected with a global power-down/sleep request signal from SCU.
SLEEP	15	rw	Flash SLEEP 0_B Normal state or wake-up 1_B Flash sleep mode is requested, Wake-up from sleep is started with clearing of the SLEEP-bit.
RPA	16	rh	Read Protection Activated This bit monitors the status of the Flash-internal read protection. This bit can only be '0' when read protection is not installed or while the read protection is temporarily disabled with password sequence. 0_B The Flash-internal read protection is not activated. Bits DCF, DDF are not taken into account. Bits DCF, DDFx can be cleared 1_B The Flash-internal read protection is activated. Bits DCF, DDF are enabled and evaluated.

Program Memory Unit (PMU)

Field	Bits	Type	Description
DCF	17	rwh	<p>Disable Code Fetch from Flash Memory</p> <p>This bit enables/disables the code fetch from the internal Flash memory area. Once set, this bit can only be cleared when RPA='0'.</p> <p>This bit is automatically set with reset and is cleared during rampup, if no RP installed, and during startup (BootROM SW) in case of internal start out of Flash.</p> <p>0_B Code fetching from the Flash memory area is allowed.</p> <p>1_B Code fetching from the Flash memory area is not allowed. This bit is not taken into account while RPA='0'.</p>
DDF	18	rwh	<p>Disable Any Data Fetch from Flash</p> <p>This bit enables/disables the data read access to the Flash memory area (Program Flash and Data Flash). Once set, this bit can only be cleared when RPA='0'.</p> <p>This bit is automatically set with reset and is cleared during rampup, if no RP installed, and during startup (BootROM SW) in case of internal start out of Flash.</p> <p>0_B Data read access to the Flash memory area is allowed.</p> <p>1_B Data read access to the Flash memory area is not allowed. This bit is not taken into account while RPA='0'.</p>
DDFDMA	20	rw	<p>Disable Data Fetch from DMA Controller</p> <p>This bit enables/disables the data read access to PFlash&DFlash memory from the DMA controller and other bus masters that access the LMB bus via the DMA peripheral interfaces — these are, dependent on the device: Cerberus, MLI and Memcheck.</p> <p>Once set, this bit can only be cleared when RPA='0'.</p> <p>0_B The data read access by the DMA controller and its peripheral interfaces to the Flash memory area is allowed.</p> <p>1_B The data read access to the Flash memory area is not allowed for the DMA controller and its peripheral interfaces.</p>

Program Memory Unit (PMU)

Field	Bits	Type	Description
DDFPCP	21	rw	Disable Data Fetch from PCP Controller This bit enables/disables the data read access to PFlash&DFlash memory via the LFI bridge (used from PCP controller). Once set, this bit can only be cleared when RPA='0'. 0 _B The data read access by the PCP controller to the Flash memory area is allowed. 1 _B The data read access to the Flash memory area is not allowed for the PCP controller.
VOPERM	24	rw	Verify and Operation Error Interrupt Mask 0 _B Interrupt not enabled 1 _B Flash interrupt because of Verify Error or Operation Error in Flash array (FSI) is enabled
SQERM	25	rw	Command Sequence Error Interrupt Mask 0 _B Interrupt not enabled 1 _B Flash interrupt because of Sequence Error is enabled
PROERM	26	rw	Protection Error Interrupt Mask 0 _B Interrupt not enabled 1 _B Flash interrupt because of Protection Error is enabled
PFSBERM	27	rw	PFlash Single-Bit Error Interrupt Mask 0 _B No Single-Bit Error interrupt enabled 1 _B Single-Bit Error interrupt enabled for PFlash
DFSBERM	28	rw	DFlash Single-Bit Error Interrupt Mask 0 _B No Single-Bit Error interrupt enabled 1 _B Single-Bit Error interrupt enabled for DFlash
PFDBERM	29	rw	PFlash Double-Bit Error Interrupt Mask 0 _B Double-Bit Error interrupt for PFlash not enabled 1 _B Double-Bit Error interrupt for PFlash enabled. Especially intended for margin check
DFDBERM	30	rw	DFlash Double-Bit Error Interrupt Mask 0 _B Double-Bit Error interrupt for DFlash not enabled 1 _B Double-Bit Error interrupt for DFlash enabled. Especially intended for margin check

Program Memory Unit (PMU)

Field	Bits	Type	Description
EOBM	31	rw	End of Busy Interrupt Mask 0 _B Interrupt not enabled 1 _B EOB interrupt is enabled
0	[7:5], 19, [23:22]	r	Reserved Read/write zero

Note: The default numbers of wait states represent the slow cases. This is a general proceeding and additionally opens the possibility to execute higher frequencies without changing the configuration.

Note: After reset and execution of BootROM startup SW, the read protection control bits are coded as follows:

DDF, DCF, RPA = "110": No read protection installed

DDF, DCF, RPA = "001": Read protection installed; start in internal Flash

DDF, DCF, RPA = "111": Read protection installed; start not in internal Flash.

Program Memory Unit (PMU)

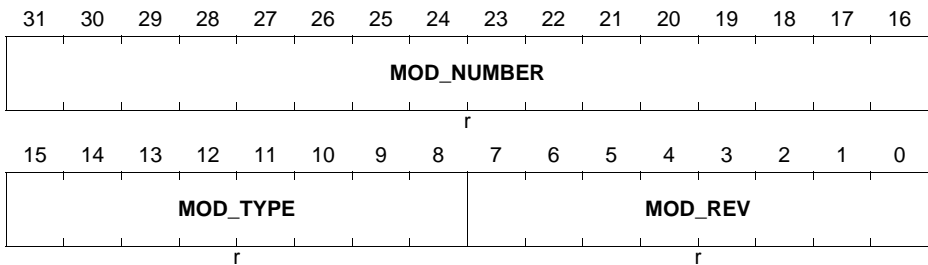
5.6.3.9 Flash Identification Register

The module identification register of Flash module is directly accessible by the CPU via PMU access. This register is mapped into the space of the Flash Interface Module's registers (see [Table 5-11](#)).

FLASH0_ID

Flash Module Identification Register (1008_H)

Reset Value: 0097 C0XX_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type This bit field is C0 _H . It defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. For the TC1728 Flash0 this number is 0097 _H .

5.6.4 Error Correction and Margin Control

Error detection and correction is provided for all read accesses to Program Flash and Data Flash. The combination of error detection with the also available margin check provides an excellent verify function for Flash data safety.

5.6.4.1 Dynamic Error Correction

The Flash module supports the following error detection and correction functions for read accesses to both, the Program Flash as well as the Data Flash:

- Detection of single-bit errors within 64-bit read data and correction on the fly
- Detection of double-bit errors
- Two read error flags in the Flash Status Register FSR, indicating a single-bit error:
 - Flag PFSBER indicates, that one (or more) single-bit error was detected and corrected in the Program Flash
 - Flag DFSBER indicates, that one (or more) single-bit error was detected and corrected in the Data Flash
- Two read error flags in the Flash Status Register FSR, indicating a double-bit error:
 - Flag PFDBER indicates, that one (or more) double-bit error was detected in the Program Flash
 - Flag DFDBER indicates, that one (or more) double-bit error was detected in the Data Flash.
- An error interrupt is generated in case of any single-bit error, if enabled in the FCON register.
- An error interrupt is generated in case of any double-bit error, if enabled in the FCON register. This interrupt shall only be used for margin check, when trap is disabled
- A bus error trap is reported in case of a double-bit error during access to Program Flash or Data Flash, as soon as the disturbed instruction or data is transferred to the PMI or DMI unit via the LMB bus. This trap can be disabled for margin checks.

Note: A single-bit or a double-bit error may also be caused by a disturbed EC-code with correct 64-bit data, or by a wrong selection of access time with wait states.

Error detection and correction is controlled using a SEC-DED algorithm that results in an 8-bit error correction code (ECC) for every 64-bit data in PFlash and in DFlash. This 8-bit ECC is dynamically generated during write operations to the assembly buffer and then programmed to the Flash array with the Write Page command. For every read access to the Flash the 64-bit read data is fetched together with its associated 8-bit ECC.

The ECC algorithm is selected in such a way, that all zero data have an all zero ECC and all one data have an all one ECC. It is thus supported, that erased locations (all zero) have a correct EC-code, and it is also supported to re-program a Data Flash page to all ones to indicate a special page, e.g. with an invalidation stamp. This over-program operation also results in a correct EC-code (all ones).

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After an erase operation, a correct ECC code (all zero) is provided for the erased sector in the Program Flash as well as in the Data Flash.

For details about handling ECC errors and other flags see [Chapter 5.6.6.3](#).

5.6.4.2 Margin Check Control

Margin control is supported for the sense amplifiers separately of the Program Flash and the Data Flash. With the two margin control registers MARP (for Program Flash) and MARD (for Data Flash) the sensing of array bit lines can be controlled more critical for '0' or '1' values during read operations. The Margin Control Registers MARP and MARD are used to change the margin levels for read operations to find problematic array bits. Since problematic bits always change their value from '1' to '0', it is quite simple to find those bits: The array area to be checked is read with changed margins which are more critical for sensing '1' values (verify operation). A single or double-bit error will be reported to the CPU by an error interrupt or a bus error trap. The double-bit error trap can be disabled for margin checks and also redirected to an error interrupt.

The different margin levels are enabled and selected with the Margin Control Registers MARP and MARD. The high margin levels which can be selected, are one low level margin (coded with '0') and one high level margin (coded with '1').

Note: Only one margin change (high or low level, PFlash or DFlash) is allowed at a time.

*Note: To increase the security and to inhibit unintended write accesses, the standard "ENDINIT" protection feature (including watchdog password access control) is used for write accesses to the margin control register MARP (for Program Flash). The MARD register for Data Flash is **not** especially protected.*

Note: After change of margin level, a wait time of >10μsec. for sense amp adjustment is necessary before read operations with the modified margins shall be executed.

Note: During erase or program operation only the standard (default) margins are allowed (no margin change for parallel read accesses).

Note: Although double-bit error traps are disabled with reset, the traps are enabled by the startup SW (firmware) in Boot ROM before Boot ROM exit.

The Margin Control Registers for Program Flash (MARP) and for Data Flash (MARD) are defined as follows:

Program Memory Unit (PMU)

MARP

Margin Control Register PFLASH (1018_H)
Reset Value: 0000 8000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TRAPDIS	0											MARGIN1	MARGIN0		
rw	r											rw	rw	rw	rw

Field	Bits	Type	Description
MARGIN0	[1:0]	rw	PFLASH Margin Selection for Low Level 00 _B Standard (default) margin 01 _B High margin for 0 (low) level 10 _B Reserved 11 _B Reserved
MARGIN1	[3:2]	rw	PFLASH Margin Selection for High Level 00 _B Standard (default) margin 01 _B High margin for 1 (high) level 10 _B Reserved 11 _B Reserved
TRAPDIS	15	rw	PFLASH Double-Bit Error Trap Disable 0 _B If a double-bit error occurs in PFLASH, a bus error trap is generated ¹⁾ . 1 _B The double-bit error trap is disabled. Shall be used only during margin check
0	[14:4], [31:16]	r	Reserved; always read as 0; should be written with 0.

1) After Boot ROM exit, double-bit error traps are enabled (TRAPDIS = 0).

Program Memory Unit (PMU)

MARD

Margin Control Register DFLASH (101C_H)
Reset Value: 0000 8000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TR AP DIS							0					BNK SEL	MARGIN 1	MARGIN 0	
rw							r					rw	rw	rw	rw

Field	Bits	Type	Description
MARGIN0	[1:0]	rw	DFLASH Margin Selection for Low Level 00 _B Standard (default) margin 01 _B High margin for 0 (low) level 10 _B Reserved 11 _B Reserved
MARGIN1	[3:2]	rw	DFLASH Margin Selection for High Level 00 _B Standard (default) margin 01 _B High margin for 1 (high) level 10 _B Reserved 11 _B Reserved
BNKSEL	4	rw	Enable DFLASH Margin Control 0 _B The active read margin for both DFLASH banks is determined by MARGIN0 and MARGIN1. 1 _B Both DFLASH banks are read with standard (default) margin independent of MARGIN0 and MARGIN1.
TRAPDIS	15	rw	DFLASH Double-Bit Error Trap Disable 0 _B If a double-bit error occurs in DFLASH, a bus error trap is generated ¹⁾ . 1 _B The double-bit error trap is disabled. Shall be used only during margin check
0	[14:5], [31:16]	r	Reserved; always read as 0; should be written with 0.

1) After Boot ROM exit, double-bit error traps are enabled (TRAPDIS = 0).

5.6.5 Read and Write Protection

For an overview please refer to [Chapter 5.6.2.3](#)

In general, three user levels are supported for installation of protection configuration, and three different types of protection can be assigned to the user levels as follows:

1. User 0: This is the master user. He is able to install read protection for the whole Flash (with or without DFlash). Additionally or alternatively, he can install sector specific write protection. User 0 controls the User Configuration Block UCB0 in the configuration sector and defines his keywords in UCB0.
2. User 1 is able to install sector specific write protection, with lower priority than user 0. User 1 controls the UCB1 in config sector and defines his keywords in UCB1.
3. User 2 is able to install sector specific OTP protection with ROM functionality. Sectors with ROM functionality are locked for ever and are never re-programmable. Keywords for temporary disabling the protection are therefore not necessary. User 2 (who might be identical to user 0 or user 1) controls the UCB2.

Any installation of protection will become active only after next reset.

5.6.5.1 Read Protection

When read protection is installed and active, read accesses to the Flash memory are disabled and suppressed, if the program execution does not start in internal Flash after reset. Thus Flash read accesses by instructions fetched from other memory but internal Flash are initially blocked. The read protection is characterized by the following definitions:

- The read protection is installed, if the read protection configuration is programmed (thus the read protection is configured) and confirmed in the User Configuration Block of user 0 (UCB0); the installed read protection is indicated in the FSR register by RPROIN-bit and in PROCON0 by RPRO-bit. If read protection is configured but not confirmed, only RPRO is set after next reset.
- The Data Flash is only excluded from read protection, if the bit DFEXPRO is set additionally to the RPRO-bit in register PROCON0.
- The read protection is active, when it is installed and not temporarily disabled with password protected command sequence 'Disable Read Protection'; this state is shown with RPA-bit in configuration register FCON.
- If read protection is active (RPA=1), also a global write protection for the whole Flash array is activated. The Data Flash is only excluded from the global write protection, if the bit DFEXPRO is set additionally to the RPRO-bit in register PROCON0. Flash erase/program commands are generally disabled and not executed. But accesses to registers and command cycles (write cycles) to the state machine are enabled (necessary for the disable command sequence).
- If read protection is active, the Flash read accesses are controlled with the disable bits DCF (disable code fetch) and DDF (disable data fetch) in FCON register. After reset, these bits are set if the user program start is not executed from internal Flash

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(e.g. start from external memory or from internal scratchpad memory after bootstrap execution).

- If read protection is active and a bootstrap loader is selected by reset configuration, the execution of bootstrap loader is not suppressed because the Flash is fully protected with DCF and DDF (see above).
- If read protection is active and user program is started in internal Flash, the debug interfaces are totally disabled after reset (controlled by BootROM startup).
- If read protection is active, only one re-configuration of the instruction cache in PMI unit is possible after reset. The user shall install his SPR/cache configuration quickly after reset to lock the configuration and thus the protection; then, data read accesses to the instruction cache are disabled (because this requires a change of configuration). Subsequent changes of SPR/cache configuration are only possible, if the read protection is temporarily disabled with correct passwords.
- If read protection is active, Flash read accesses are generally **not** disabled in case of internal start after reset out of the Program Flash (DCF and DDF are cleared before start of program execution, controlled by BootROM startup). In this case the user SW in Flash has to handle access restrictions to the Flash by controlling the Disable Flash Fetch bits in the FCON register.

Examples:

- Before jumping to external memory or internal RAM, bit DDF is set by user SW in Flash. In this case, all Flash data accesses are disabled but return to Program Flash instruction execution is possible (because DCF is not set).
- Before jumping to external memory or internal RAM, bit DDF is set by the user. DCF is also set by the user directly after jumping to internal or external RAM. Now, Flash data accesses and return to code fetch from Program Flash are disabled; return is only possible if the read protection is temporarily disabled (not active) using the password protected disable command sequence. In this case, bits DCF and DDF must be cleared by the user before the read protection is resumed, because otherwise accesses are blocked after resumption.
- If read protection is active or not, Flash data accesses from dedicated bus masters others than the CPU/DMI can be separately disabled with the FCON bits DDFDMA and DDFPCP (bus cycle sources are indicated by tags). These bits cannot be cleared while read protection is active.
- A disabled but installed read protection is indicated by RPRODIS=1 in FSR register.

Note: If read protection is active and DCF and DDF are set, not allowed data or instruction read accesses to Flash result in a LMB bus error (trap) indication. This has also to be considered for jump predictions. The user has to make sure that the prediction does not point into the protected Flash.

Installation of read protection is performed with the "Write User Configuration Page" operation, controlled by the user 0. With this command, user 0 writes the protection configuration bits RPRO and eventually DFEXPRO, and the two 32-bit keywords into the UCB0-page 0. Additionally, with a second "Write User Configuration Page" command, a

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special 32-bit confirmation (lock-) code is written into the UCB0-page2. Only this confirmation code enables the protection and thus the keywords. The confirmation write operation to the second wordline of the User Configuration Block shall be executed only after check of keyword-correctness (with command “Disable Read Protection” after next reset). The confirmed state and thus the installation of protection is indicated with the FSR-bit PROIN in Flash Status Register FSR and for read protection with bit RPROIN in FSR. If read protection is not correctly confirmed and thus not enabled, the bits PROIN and RPROIN in the FSR are not set. The configured read protection as fetched from UCB0 is indicated in the protection configuration register PROCON0¹⁾.

For safety of the information stored in the UCB pages, all keywords, lock bits and the confirmation code are stored two-times in the two wordlines. In case of a disturbed original data detected during rampup, its copy is used. Layout of the four UC pages belonging to the user's UC block is shown in [Chapter 5.6.5.4](#) below, the command “Write User Configuration Page” is described in [Chapter 5.6.3.4](#).

With the command sequence “Disable Read Protection” a short-term disablement of read protection is provided. With this command, it is possible to disable the Flash protection (latest until next reset) for user controlled erase and re-program operations as well as for clearing of DCF and DDF control bits after external program execution. The “Disable Read Protection” command sequence is a protected command, which is only processed by the command state machine, if the included two passwords are identical to the two keywords of user 0. The disabled state of read protection is controlled with the FCON-bit RPA=‘0’ and indicated in the Flash Status Register FSR with the RPRODIS bit (see [Chapter 5.6.3.7](#)). As long as read protection is disabled (and thus not active), the FCON-bits DDF and DCF can be cleared.

Resumption of read protection after disablement is performed with the “Resume Read/Write Protection” command. After execution of this single cycle command, read protection (if installed) is again active, indicated by the FCON bit RPA=‘1’.

Generally, Flash read protection will remain installed as long as it is confirmed (locked) in the User Configuration Block 0. Erase of UC block and re-program of UC pages can be performed up to 4 times. But note, after execution of the Erase UC block command (which is protected and therefore requires the preceding disable command with the user's specific passwords), all keywords and all protection installations of user 0 are erased; thus, the Flash is no more read protected (beginning with next reset) until re-programming the UC pages. But the division and separation of the protection configuration data and of the confirmation data into two different UCB-wordlines guarantees, that a disturb of keywords can be discovered and corrected before the protection is confirmed. For this reason, the command sequence “Disable Read Protection” can also be used when protection is programmed (configured) but not confirmed; wrong keywords are then indicated by the error flag PROER.

1) PROCON0.DFEXPRO is only set when in UCB0 the bits for RPRO and DFEXPRO are set to 1.

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Read protection can be combined with sector specific write protection. In this case, after execution of the command 'Disable Read Protection' only those sectors are unlocked for write accesses, which are not separately write protected.

5.6.5.2 Write and OTP Protection

If sector write protection is installed and active, erasing and programming of write protected sectors is not possible. An installed write protection is indicated per user by the three (because three users are supported) WPROIN bits in FSR register, and sector-specific by the configuration status bits in the Protection Configuration registers PROCON0 (for user 0), PROCON1 (for user 1) and PROCON2 (sectors of user 2 with OTP protection, representing ROM functionality).

*Note: Sectors in **Data Flash** cannot be separately write protected (only generally via Read Protection).*

Note: Beginning with sector S10, only sector-pairs of two 256 KB sectors can be defined for installation of sector-specific write or OTP protection (see PROCON registers).

Note: An installation of OTP protection (for ROM functionality) can be performed only once, because the UCB2 block is locked for ever after the installation.

Note: Full FAR test of protected Flash is only possible, if the customer has de-installed the protection before, or if the passwords are known by the test person. In case of OTP/ROM protection, the Flash test capability of FAR is very limited, because FSI-SFRs and FSI-SRAM are no more accessible.

As read protection, installation of write protection is performed with the "Write User Configuration Page" operation, controlled by the user. With this command, the user defines and writes into the UCBx page 0 the write protection configuration bits for all sectors, which shall be locked by the specific user, and the user-specific two keywords (not necessary for user 2). The position of sector lock bits is identical as defined for the PROCON registers. The correctness of keywords shall then (after next reset) be checked with the command 'Disable Sector Write Protection', which delivers a protection error PROER in case of wrong passwords. Only if the keywords are correct, the special 32-bit confirmation code must be written into the page 2 of UCBx with a second "Write User Configuration Page" command. Only this confirmation code enables the write protection of the User Control Block UCBx, and only in this case the installation bit(s) in FSR is (are) set during rampup.

Note: If the write protection is configured in the user's UCB page 0 but not confirmed via page 2 (necessary for check of keywords), the state after next reset is as follows:

- The selected sector(s) are protected (good for testing of protection, also of OTP)
- The UCBx is not protected, thus it can be erased without passwords
- The related WPROINx bit in FSR is not set
- The Disable Write Protection command sets the WPRODISx bit
- The Resume command does not clear the WPRODISx bit.

Program Memory Unit (PMU)

The structure and layout of the three UC blocks is shown in [Chapter 5.6.5.4](#) below, the command “Write User Configuration Page” is described in [Chapter 5.6.3.4](#).

With the command sequence “Disable Sector Write Protection” a short-term disablement of write protection for user 0 or user 1 is provided. This command unlocks temporarily all locked sectors belonging to the user. The “Disable Sector Write Protection” command sequence is a protected command, which is only processed by the command state machine, if the included two passwords are correct. The disabled state of sector protection is indicated in the Flash Status Register FSR with the WPRODIS bit of the user 0 or/and user 1 (see [Chapter 5.6.3.7](#)). For user 2 who owns the sectors with ROM functionality, a disablement of write protection and thus re-programming is not possible.

Resumption of write protection after disablement is performed with the “Resume Read/Write Protection” command, which is identical for user 0 and user 1.

Generally, sector write protection will remain installed as long as it is configured and confirmed in the User Configuration Block belonging to the user. Erase of UC block and re-program of UC pages can be performed up to 4 times, for user 0 and user 1 only. But note, after execution of the Erase UC block command (which is still protected and therefore requires the preceding disablement of write protection with the user's passwords), the complete protection configuration including the keywords of the specific user (not user 2) is erased; thus, the sectors belonging to the user are totally unprotected until the user's UC pages are re-programmed. Only exception: sectors protected by user 2 are locked for ever because the UCB2 can no more be erased after installation of write protection in UCB2.

Sector specific write protection may be combined with read protection. In this case, after execution of the command ‘Disable Sector Write Protection’ the protected sectors are only unlocked if read protection is also disabled.

The write protection is hierarchically controlled, thus the user 0 has the highest level of access rights with write access to all ‘his’ sectors (if they are not protected by user 2): When user 0 disables the write protection for ‘his’ sectors, the write protection is also disabled for those sectors, which are coincidentally protected by user 1. But user 1 can only disable his own protected sectors, if they are not coincidentally protected by user 0 (and user 2). If one sector is coincidentally protected by user 0 and 1, user 1 can only write-access this sector if unlocked also with the passwords of user 0.

5.6.5.3 Protection Configuration Indication

The configuration of read/write/OTP protection is indicated with registers PROCON0, PROCON1 and PROCON2, thus separately for every user, and it is generally indicated in the status register FSR.

If write protection is installed for user 0 or 1 or OTP protection for user 2, for each sector of the Program Flash it is indicated in the user-specific Protection Configuration register PROCONx, if it is locked or unlocked for program or erase operations.

Program Memory Unit (PMU)

The Flash Protection Configuration registers PROCONx are loaded by the FIM state machine out of the user's configuration block directly after reset during rampup. The three PROCONx registers are read-only registers. They are defined as follows:

PROCON0

Flash Protection Configuration Register User 0

(1020_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R PRO	DF EX PRO	0	0	S12/ S13L	S10/ S11L	S9L	S8L	S7L	S6L	S5L	S4L	S3L	S2L	S1L	S0L
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
SnL (n=0-9)	n	rh	Sector n Locked for Write Protection by User 0 These bits indicate whether PFLASH sector n is write-protected by user 0 or not. 0 _B No write protection is configured for sector n. 1 _B Write protection is configured for sector n.
S10/S11L	10	rh	Sectors 10 and 11 Locked for Write Protection by User 0 This bit is only used if PFLASH has more than 0.5 Mbyte. It indicates whether PFLASH sectors 10+11 (together 512 KB) are write-protected by user 0 or not. 0 _B No write protection is configured for sectors 10+11. 1 _B Write protection is configured for sectors 10+11.

Program Memory Unit (PMU)

Field	Bits	Type	Description
S12/S13L	11	rh	Sectors 12 and 13 Locked for Write Protection by User 0 This bit is only used if PFLASH has more than 1 Mbyte. It indicates whether PFLASH sectors 12+13 (together 512 KB) are write-protected by user 0 or not. 0 _B No write protection is configured for sectors 12+13. 1 _B Write protection is configured for sectors 12+13.
DFEXPRO	14	rh	Data Flash Excluded from Read Protection When read protection is configured this bit indicates whether the DFLASH shall be excluded from read protection and global write protection or not. Attention: Even when the corresponding bit in UCB0 is programmed to 1 _B this bit is only set to 1 _B when RPRO is also programmed to 1 _B . 0 _B DFLASH not excluded from read protection and global write protection. 1 _B DFLASH is excluded from read/write protection; read protection and global write protection is configured by user 0 only for the PFLASH
RPRO	15	rh	Read Protection Configuration This bit indicates whether read protection is configured for PFLASH and DFLASH by user 0. 0 _B No read protection configured 1 _B Read protection and global write protection is configured by user 0 (master user)
0	13, 12	rh	Reserved; deliver the corresponding UCB0 entry. Shall be configured to 0.
0	[31:16]	r	Reserved; always read as 0.

Program Memory Unit (PMU)

PROCON1

Flash Protection Configuration Register User 1

(1024_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0															SPR	
r															EC	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0	0	0	S12/ S13L	S10/ S11L	S9L	S8L	S7L	S6L	S5L	S4L	S3L	S2L	S1L	S0L		
r	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	

Field	Bits	Type	Description
SnL (n=0-9)	n	rh	Sector n Locked for Write Protection by User 1 These bits indicate whether PFLASH sector n is write-protected by user 1 or not. 0 _B No write protection is configured for sector n. 1 _B Write protection is configured for sector n.
S10/S11L	10	rh	Sectors 10 and 11 Locked for Write Protection by User 1 This bit is only used if PFLASH has more than 0.5 Mbyte. It indicates whether PFLASH sectors 10+11 (together 512 KB) are write-protected by user 1 or not. 0 _B No write protection is configured for sectors 10+11. 1 _B Write protection is configured for sectors 10+11.
S12/S13L	11	rh	Sectors 12 and 13 Locked for Write Protection by User 1 This bit is only used if PFLASH has more than 1 Mbyte. It indicates whether PFLASH sectors 12+13 (together 512 KB) are write-protected by user 1 or not. 0 _B No write protection is configured for sectors 12+13. 1 _B Write protection is configured for sectors 12+13.

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Field	Bits	Type	Description
SPREC	16	rh	SPREC Soft-Programming Recover. 0 _B Program 1-data. 1 _B Soft Recover. See Page 5-91 .
0	13, 12	rh	Reserved ; deliver the corresponding UCB1 entry. Shall be configured to 0.
0	[31:17], 15, 14	r	Reserved ; always read as 0.

PROCON2

Flash Protection Configuration Register User 2

(1028_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	DAT M								0						
r	rh								r						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	S12/ S13 ROM	S10/ S11 ROM	S9 ROM	S8 ROM	S7 ROM	S6 ROM	S5 ROM	S4 ROM	S3 ROM	S2 ROM	S1 ROM	S0 ROM
r	r	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
SnROM (n=0-9)	n	rh	Sector n Locked Forever by User 2 These bits indicate whether PFLASH sector n is an OTP protected sector with read-only functionality, thus if it is locked for ever. 0 _B No ROM functionality configured for sector n. 1 _B ROM functionality is configured for sector n. Re-programming of this sector is no longer possible.

Program Memory Unit (PMU)

Field	Bits	Type	Description
S10/S11ROM	10	rh	Sectors 10 and 11 Locked Forever by User 2 This bit is only used if PFLASH has more than 0.5 Mbyte. It indicates whether PFLASH sectors 10+11 (together 512 KB) are read-only sectors or not. 0 _B No ROM functionality is configured for sectors 10+11. 1 _B ROM functionality is configured for sectors 10+11.
S12/S13ROM	11	rh	Sectors 12 and 13 Locked Forever by User 2 This bit is only used if PFLASH has more than 1 MByte. It indicates whether PFLASH sectors 12+13 (together 512 KB) are read-only sectors or not. 0 _B No ROM functionality is configured for sectors 12+13. 1 _B ROM functionality is configured for sectors 12+13.
0	13, 12	r	Reserved; deliver the corresponding UCB2 entry. Shall be configured to 0.
DATM	30	rh	Disable ATM This bit indicates if the ATM "Application Test Mode" is disabled or not. 0 _B ATM is enabled. 1 _B ATM is disabled. This bit is only used in PMU0.
0	31, [29:16], 15, 14	r	Reserved; always read as 0.

5.6.5.4 User Configuration Blocks and Pages

In the User Configuration Pages, the installation of read and write protection is configured and confirmed by the user. Three UC blocks of each 1 Kbyte are provided for three different users. With the dedicated commands (see command definitions), the UC blocks can be initially programmed. The UC blocks UCB0 and UCB1 can be modified up to 4 times.

Each of the three User Configuration Blocks UCB0, UCB1 and UCB2 contains four User Configuration Pages UCP0–3; for UCP addresses see [Table 5-8](#). The User Configuration Pages are ECC-protected as all other information in the Flash sectors. The User Configuration Blocks and their UC pages are organized and programmed as follows.

User Configuration Block UCB0

- The **UC Page 0** (bytes 255–0) of UCB0 includes the following information
 - Bytes 1–0: Protection configuration bits, for configuration of array read protection and for each sector to be write protected; structure of this configuration info is identical to the structure of the PROCON0 register (see [Chapter 5.6.5.3](#)).
 - Bytes 9–8: Copy of protection configuration bits
 - Bytes 19–16: First 32-bit keyword of user 0
 - Bytes 23–20: Second 32-bit keyword of user 0
 - Bytes 27–24: Copy of first 32-bit keyword
 - Bytes 31–28: Copy of second 32-bit keyword
 - All other page bytes: zero
- The User Configuration **Page 1** is not used (reserved for future, all zero).
- The User Configuration **Page 2** (bytes 255–0) includes the following information
 - Bytes 3–0: 32-bit confirmation code. The confirmation code (also called lock code) indicates that a protection is correctly installed and enabled. The 32-bit confirmation code is defined as follows: “8AFE15C3_H”.
 - Bytes 11–8: Copy of confirmation code
 - All other page bytes: zero
- The User Configuration **Page 3** is not used (reserved for future, all zero).

User Configuration Block UCB1

The structure of this UC block is identical to UCB0 with following exceptions

- Read protection cannot be installed (configuration is identical to PROCON1).
- The bit 0 of byte 2 (position of PROCON1.16) is called SPREC (Soft-Programming Recover). It configures the behavior of the Flash startup, see [“Recovery From Aborted Logical Sector Erase \(“ALSE”\)” on Page 5-91](#).
- The byte 3 (position corresponds to bits 24 to 31 of PROCON1) is called ALSEDIS. It is also used to configure the behavior of the Flash startup, see [“Recovery From](#)

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Aborted Logical Sector Erase (“ALSE”) on Page 5-91. These bits are not reflected in the PROCON1 register, therefore their correct content can't be verified.

- The keywords are the keywords from user 1

User Configuration Block UCB2

- The UC **Page 0** (bytes 255–0) of UCB2 includes the following information
 - Bytes 1–0: OTP protection configuration bits, one for each sector with ROM functionality; structure of this configuration info is identical to the structure of the PROCON2 register (see [Chapter 5.6.5.3](#)).
 - Bytes 9–8: Copy of protection configuration bits
 - All other page bytes: zero
- The User Configuration **Page 1** is not used (reserved for future, all zero)
- The User Configuration **Page 2** (bytes 255–0) includes the following information
 - Bytes 3–0: 32-bit confirmation code. The confirmation code (also called lock code) indicates that a protection is correctly installed and enabled. The 32-bit confirmation code is defined as follows: “8AFE15C3_H”.
 - Bytes 11–8: Copy of confirmation code
 - All other page bytes: zero
- The User Configuration **Page 3** is not used (reserved for future, all zero).

Note: The configuration of sectors with ROM functionality can no more be changed after confirmation of its configuration, because the UCB2 block can never be erased.

The confirmation code for user 0 and user 1 shall be programmed only after check of correct programming of keywords, e.g. with the command ‘Disable Read Protection’. The confirmation code is programmed in the 2. wordline to exclude any possibility of disturbing the keywords or the protection configuration while writing the confirmation code. The confirmation code is identical for all users. If a wrong confirmation code with correct ECC is detected after reset, protection is not enabled and the respective installation bits in status register FSR are not set. However, if a double-bit error is detected during fetching the confirmation code, protection is installed and activated.

During rampup after reset, always the original value is fetched at first. Only in case of double-bit error within the original, its copy is fetched. If this is also disturbed and cannot be corrected, the double-bit error is indicated in FSR and additionally the protection error bit PROER.

Note: Accesses to the User Configuration Blocks are only possible, if the protection at first has been disabled with correct passwords.

Note: Besides accesses to the User Configuration Blocks, CPU-controlled accesses to the configuration sector are only supported during Flash Test Mode and during startup procedure out of BootROM.

5.6.6 Interrupt, Error and Operation Control

Access and/or operational errors (e.g. wrong command sequences) may be reported to the user by interrupts, and they are indicated by flags in the Flash Status Register FSR. Additionally, bus errors may be generated resulting in CPU traps (also shortly called bus error traps, although this is not correct).

5.6.6.1 Interrupt Control

The Flash module supports immediate error and status information to the user by interrupt generation. One CPU interrupt request is provided by the Flash module to be controlled in the SCU. The source Flash (in devices with more than one PMU) of Flash interrupts is defined by the related service request input in the SCU. In the SCU, the Flash interrupts are controlled and indicated via bit 5 (FLO) and bit 6 (FL1 for PMU1) in the SCU-registers for interrupt control (registers INTSET, INTCLR, INTDIS, INTNP and INTSTAT).

The Flash interrupt can be issued because of following events:

- End of busy state: program or erase operation finished
- Operational error: program or erase operation aborted
- Verify error: program or erase operation not correctly finished
- Protection error
- Sequence error
- Single-bit error: corrected read data from PFlash or DFlash delivered
- Double-bit error in Program Flash or Data Flash.

Note: In case of an OPER or VER error, the error interrupt is issued not before the busy state of the Flash is deactivated.

The source of interrupt is indicated in the Flash Status Register FSR by the error flags or by the PROG or ERASE flag in case of end of busy interrupt. An interrupt is also generated for a new error event, if the related error flag is still set from a previous error interrupt.

Every interrupt source is masked (disabled) after reset and can be enabled via dedicated mask bits in the Flash Configuration Register FCON.

5.6.6.2 Trap Control

CPU traps are executed because of LMB bus errors, generated by the PMU in case of erroneous Flash accesses from the PMI (Program Fetch Synchronous Error: PSE trap) or DMI (Data Access Synchronous Error: DSE trap). LMB bus errors are generated synchronously to the bus cycle requesting the not allowed Flash access or the disturbed Flash read data. The error attributes are captured in the LMB Bus Control Unit in synchronous capture registers. Bus errors are issued because of following events:

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- Not correctable double-bit error of 64-bit read data from PFlash or DFlash (if not disabled for margin check)
- Not allowed write access to read only register (see [Table 5-11](#))
- Not allowed write access to ENDINIT protected register (see [Table 5-11](#))
- Not allowed test register access (see [Table 5-11](#))
- Not allowed data or instruction read access in case of active read protection
- Access to not implemented addresses within the register or array space.
- Read-modify-write access to the Flash array.

Write accesses to the Flash array address space are interpreted as command cycles and initiate not a bus error but a sequence error if the address or data pattern is not correct. However, command sequence cycles, which address a busy Flash bank, are serviced with a retry-acknowledge¹⁾, not with a sequence error.

If the trap event is a double-bit error in PFlash or DFlash, it is indicated in the FSR. With exception of this error trap event, all other trap sources cannot be disabled within the PMU.

Note: A double-bit error trap during margin check can be disabled (via MARP or MARD register) and redirected to an interrupt request.

5.6.6.3 Handling Errors During Operation

The previous sections described shortly the functionality of “error indicating” bits in the flash status register [FSR](#). This section elaborates on this with more in-depth explanation of the error conditions and recommendations how these should be handled by customer software. This first part handles error conditions occurring during operation (i.e. after issuing command sequences) and the second part ([Section 5.6.6.4](#)) error conditions detected during startup.

SQER “Sequence Error”

Fault conditions:

- Improper command cycle address or data, i.e. incorrect command sequence.
- New “Enter Page” in Page Mode.
- “Load Page” and not in Page Mode.
- “Load Page” results in buffer overflow.
- “Load Page” with mixed 32/64 transfers.
- First “Load Page” addresses 2. word.
- “Write Page” with buffer underflow.
- “Write Page” and not in Page Mode.
- “Write Page” to wrong Flash type.

1) Please note that the CPU (i.e. the initiator of the last command cycle) stalls as long it receives a retry-acknowledge.

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- Byte transfer to password or data.
- “Clear Status” or “Reset to Read” while busy¹⁾.
- “Erase Sector” command to DFlash.
- Erase UCB with wrong UCBA.

New state:

Read mode is entered with following exceptions:

- “Enter Page” in Page Mode re-enters Page Mode.
- “Write Page” with buffer underflow is executed.
- After “Load Page” causing a buffer overflow the Page Mode is not left, a following “Write Page” is executed.

Proposed handling by software:

Usually this bit is only set due to a bug in the software. Therefore in development code the responsible error tracer should be notified. In production code this error will not occur. It is however possible to clear this flag with “Clear Status” or “Reset to Read” and simply issue the corrected command sequence again.

PFOPER/DFOPER “Operation Error”

Fault conditions:

ECC double-bit error detected in Flash microcode SRAM during a program or erase operation in PFlash or DFlash. This can be a transient event due to alpha-particles or illegal operating conditions or it is a permanent error due to a hardware defect. This situation will practically not occur.

Attention: these bits can also be set during startup (see [Chapter 5.6.6.4](#)).

New state:

The Flash operation is aborted, the BUSY flag is cleared and read mode is entered.

Proposed handling by software:

The flag should be cleared with “Clear Status”. The last operation can be determined from the PROG and ERASE flags²⁾. In case of an erase operation the affected physical sector must be assumed to be in an invalid state, in case of a program operation only the affected page. Other physical sectors can still be read. New program or erase commands must not be issued before the next reset.

Consequently a reset must be performed. This performs a new Flash rampup with initialization of the microcode SRAM. The application must determine from the context which operation failed and react accordingly. Mostly erasing the addressed sector and re-programming its data is most appropriate. If a “Program Page” command was affected

1) When the command addresses the busy Flash bank, the access is serviced with retry acknowledge.

2) Only when both DFlash banks were busy, one with program and the other with erase the affected bank and operation can not be determined.

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and the sector can not be erased (e.g. in Flash EEPROM emulation) the wordline could be invalidated if needed by marking it with all-one data and the data could be programmed to another empty wordline.

Only in case of a defective microcode SRAM the next program or erase operation will incur again this error.

Note: Although this error indicates a failed operation it is possible to ignore it and rely on a data verification step to determine if the Flash memory has correct data. Before re-programming the Flash the flow must ensure that a new reset is applied.

Note: Even when the flag is ignored it is recommended to clear it. Otherwise all following operations — including “sleep” — could trigger an interrupt even when they are successful (see [Chapter 5.6.6.1](#), interrupt because of operational error).

PROER “Protection Error”

Fault conditions:

- Password failure.
- Erase/Write to protected sector.
- Erase UCB and protection active.
- Write UC-Page to protected UCB.

Attention: a protection violation can even occur when a protection was not explicitly installed by the user. This is the case when the Flash startup detects an error and starts the user software with read-only Flash (see [Chapter 5.6.6.4](#)). Trying to change the Flash memory will then cause a PROER.

New state:

Read mode is entered. The protection violating command is not executed.

Proposed handling by software:

Usually this bit is only set during runtime due to a bug in the software. In case of a password failure a reset must be performed in the other cases the flag can be cleared with “Clear Status” or “Reset to Read”. After that the corrected sequence can be executed.

VER “Verification Error”

Fault conditions:

This flag is a warning indication and not an error. It is set when a program or erase operation was completed but with a suboptimal result. This bit is already set when only a single bit is left over-erased or weakly programmed which would be corrected by the ECC anyhow.

However excessive VER occurrence can be caused by operating the Flash out of the specified limits, e.g. incorrect voltage or temperature. A VER after programming can also

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be caused by programming a page whose sector was not erased correctly (e.g. aborted erase due to power failure).

Under correct operating conditions a VER after programming will practically not occur. A VER after erasing is not unusual.

Attention: this bit can also be set during startup (see [Chapter 5.6.6.4](#)).

New state:

No state change. Just the bit is set.

Proposed handling by software:

This bit can be ignored. It should be cleared with “Clear Status” or “Reset to Read”. In-spec operation of the Flash memory must be ensured.

If the application allows (timing and data logistics), a more elaborate procedure can be used to get rid of the VER situation:

- VER after program: erase the sector and program the data again. This is only recommended when there are more than 3 program VERs in the same sector. When programming the DFlash in field (EEPROM emulation) ignoring program VER is normally the best solution because its most likely cause are violated operating conditions. Take care that never a sector is programmed in which the erase was aborted. In the EEPROM emulation the algorithm must ensure this e.g. by programming a marker after finishing successfully the erase.
- VER after erase: the erase operation can be repeated until VER disappears. Repeating the erase more than 3 times consecutively for the same sector is not recommended. After that it is better to ignore the VER, program the data and check its readability. Again for EEPROM emulation its most likely cause are violated operating conditions. Therefore it is recommended to repeat the erase at most once or ignore it altogether.

For optimizing the quality of Flash programming see the following section about handling single-bit ECC errors.

Note: Even when this flag is ignored it is recommended to clear it. Otherwise all following operations — including “sleep” — could trigger an interrupt even when they are successful (see [Chapter 5.6.6.1](#), interrupt because of verify error).

PFSBER/DFSBER “Single-Bit Error”

Fault conditions:

When reading data or fetching code from PFlash or DFlash the ECC evaluation detected a single-bit error (“SBE”) which was corrected.

This flag is a warning indication and not an error. A certain amount of single-bit errors must be expected because of known physical effects.

New state:

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No state change. Just the bit is set.

Proposed handling by software:

This flag can be used to analyze the state of the Flash memory. During normal operation it should be ignored. In order to count single-bit errors it must be cleared by "Clear Status" or "Reset to Read" after each occurrence¹⁾.

Usually it is sufficient after programming data to compare the programmed data with its reference values ignoring the SBE bits. When there is a comparison error the sector is erased and programmed again.

When programming the PFlash (end-of-line programming or SW updates) customers can further reduce the probability of future read errors by performing the following check after programming:

- Change the read margin to "high margin 0".
- Verify the data and count the number of SBEs.
- When the number of SBEs exceeds a certain limit (e.g. 10 in 2 MByte) the affected sectors could be erased and programmed again.
- Repeat the check for "high margin 1".
- Each sector should be reprogrammed at most once, afterwards SBEs can be ignored.

In case of EEPROM emulation using DFlash the verification of programmed data should be done with the normal read level and SBEs should be ignored. When a comparison error is found the sector can usually not be erased because it contains active data in other pages. The emulation algorithm can mark the affected page as invalid and program the data to a following page. As always the number of consecutive repetitions should be limited (e.g. to 3) as protection against violated operating conditions.

To keep the EEPROM emulation alive even when wordline oriented fails occur (e.g. due to over-cycling) the algorithm can implement the following scheme for highest possible robustness:

- Before programming a page save the content of the other page on the same wordline in SRAM.
- Program the new page and compare the content of this page and of the saved page with their reference data. This can be done with normal read margins. Ignore SBEs.
- If the data comparison fails program this page and the saved content of the other page to a different wordline.
- This procedure can be repeated if the data comparison fails again. The number of repetitions should be limited (e.g. to 3) in case the programming fails because of out-of-spec operating conditions.

1) Further advice: remember that the ECC is evaluated when the data is read from the PMU. When counting single-bit errors use always the non-cached address range otherwise the error count can depend on cache hit or miss and it refers to the complete cache line. As the ECC covers a block of 64 data bits take care to evaluate the FSR only once per 64-bit block.

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- Wordline oriented fails can also have the effect that the affected wordlines can not be erased anymore (other wordlines stay fully functional). A robust EEPROM emulation is immune against such wordlines (e.g. by identifying old data by version counters).

For the TC1728 this robust EEPROM algorithm is required for the usage of the DFlash.

Due to the specificity of each application the appropriate usage and implementation of these measures (together with the more elaborate VER handling) must be chosen according to the context of the application.

5.6.6.4 Handling Errors During Startup

The FSR flags are not only used to inform about the success of Flash command sequences but they are also used to inform (1) the startup software and (2) the user software about special situations incurred during startup. In order to react on this information these flags must be evaluated after reset before performing any flag clearing sequence as "Clear Status" or "Reset to Read".

The following two levels of situations are separated:

- Fatal level: the user software is not started. A WDT reset is performed.
- Error level: the user software is started but the Flash memory must not be programmed or erased.
- Warning level: the user software is started but a warning is issued.

Fatal Level (WDT Reset)

These error conditions are evaluated by the startup software which decides that the Flash is not operable and thus waits for a WDT reset. The application sees only a longer startup time followed by a WDT reset.

The reason for a failed Flash startup can be a hardware error or damaged configuration data.

Error Level (Flash Read-Only)

In this condition the user software is started but the Flash memory must not be programmed or erased. If writability of the Flash is mandatory the user software itself has to perform a reset.

Flash microcode error:

FSR bits set: PFOPER and DFOPER.

The user software is started normally but the Flash must not be programmed or erased. Please note that programming or erasing is not blocked by hardware. Issuing program or erase sequences despite this condition is forbidden.

Program Memory Unit (PMU)**Warning Level**

These conditions inform the user software about an internally corrected or past error condition.

Logical sector corrected:

FSR bits set: VER.

The Flash detected that a logical sector erase was apparently aborted by reset or power failure. In order to maintain readability of the other logical sectors the Flash tried to repair this state. The aborted erase operation must be repeated. See also **[“Recovery From Aborted Logical Sector Erase \(“ALSE”\)” on Page 5-91](#)**.

Leftover OPER:

FSR bits set: PFOPER or/and DFOPER.

The OPER flags are only cleared by the command sequence “Clear Status” or with a power-on reset (Class 0). After any other reset a OPER flag can still be set when the user software is started.

Single-bit error in protection:

FSR bits set: PFSBER.

An corrected ECC single-bit error was detected during installation of the protection.

5.6.6.5 Application Hints and Guidelines

Every command execution is started with the last command cycle of the command sequence, and it is indicated by the busy bit of Program Flash or Data Flash in the status register FSR. Depending on the specific operation additionally one of the following status bits may be set:

- PROG indicating a requested, running or just finished program operation (page, User Configuration Page),
- ERASE indicating a requested, running or just finished erase execution (sector, User Configuration Block)

The status bits have to be cleared by SW. It is thus possible to qualify the BUSY bits and the OPER bits with the two status bits PROG and ERASE (see FSR description in [Chapter 5.6.3.7](#)). Polling the BUSY bits show directly the termination of the specific operation. The termination is additionally reported to the CPU by an end-of-busy interrupt (if enabled in the FCON register). Because the termination could have been also caused by a fault condition, the error flags shall be sampled after each command sequence and after the termination of its execution. All error conditions are additionally indicated to the CPU by an error interrupt, if enabled in the FCON register.

In summary a flash operation shall be controlled by the following process:

- Write command sequence to Flash
- Check for correct command sequence by sampling the SQER and PROER bits in status register FSR, or install a proper error interrupt reaction.
- In case of an indicated fault condition: clear the error flag with a Clear Status or a Reset to Read command and start a specific SW reaction, for example a retry operation. If no error:
- In case of a Flash array operation: check, if the command has been correctly requested by polling the PROG or ERASE bit in status register
- Check, if the command is in operation by sampling the BUSY bit
- When the execution of the command is finished (reported per interrupt or noticed per polling the busy flag) check the VER and OPER flags; if one flag is set: see [Chapter 5.6.6.3](#) for proper reaction; else: clear PROG or ERASE flag and continue user program execution.

The status flags PROG and ERASE are cleared only with a power-on reset. It is therefore possible to detect, if a program or erase operation has been interrupted by a warm reset. Assumption: These flags are normally cleared by SW (with the Clear Status command) immediately after termination of the operation.

In the following, some additional application hints and guidelines are presented, to be considered by the user (some of them are already noted in other sections of the chapter):

- User code, that writes command sequences to the Program Flash, should not be executed from the same internal Flash module (because the Flash takes the busy state with last command cycle); it shall be located in other internal or external

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program memory, e.g. in the scratchpad SPRAM, or in the other Flash module. But user code, that writes command sequences to the Data Flash, can be located in and executed from the Program Flash in the same Flash module.

- The write cycles, belonging to a command sequence, must access the Flash in its non-cached address space (otherwise they will remain in the data cache). Additionally, it is recommended to include a dummy read (ld.w) instruction to a PMU register (e.g. PMU_ID) after the last write cycle of a command sequence to flush the write buffers.
- The caches (data cache in DMI "DCache" and instruction cache in PMI "ICACHE") as well as the data line buffer in the DMI "DLB" are not automatically invalidated nor updated after changing Flash content by erasing or programming. It is therefore recommended to either invalidate them actively or read the Flash content via the non-cached address range. Otherwise old data might be delivered from these buffers.
 - The ICACHE is invalidated by writing PMI_CON1.PCINV to '1'.
 - When the DCache is enabled it is invalidated (i.e. all clean lines) by writing OVC_OCON.DCINVAL to '1'. This invalidates also the DLB.
 - When the DCache is disabled the DLB works as one-line data cache. When it is clean it is invalidated by writing OVC_OCON.DCINVAL to '1'. It can be also invalidated by reading a different memory address or using the instruction "cachei.wi".
 - Generally all buffers are invalidated by a reset.
- After change of margin level, a wait time of min. 10 µsec. is necessary for sense amp adjustment before read operations are executed with the modified margins.
- After installation of OTP write protection for sectors with ROM functionality or after installation of tuning protection, accesses to Flash SFRs are no more possible; this greatly reduces the FAR analysis possibility.
- If write protection is configured in the user's UCB page 0 but not confirmed via page 2, the protection is only partially enabled after next reset (see [Chapter 5.6.5.2](#)).
- The selection of wait states for PFlash and DFlash accesses must be controlled via the FCON register by the user in relation to his application frequency (see [Table 5-1](#)).
- The performance of data read accesses to the Program Flash can be influenced by support of buffer hit or cache hit mechanisms in PMU and DMI; therefore data locations in Flash shall be located sequentially, so that the read buffer in PMU (32 bytes) and the cache/buffer line in DMI (16 bytes) are optimally used. This has especially to be considered in devices with more than one PMU, where data accesses can be isolated from instruction accesses by proper assignments to different PMUs.

For customer Flash tests it may be wanted to perform checkerboard tests of Program Flash or Data Flash. Programming checkerboard patterns into the Flash can simply be done, because a Flash wordline always consists of two sequential and bitwise-interleaved pages with according even and odd page addresses (see [Table 5-7](#)). Thus, it is only necessary to program complete pages either with ones or zeros to get a

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checkerboard pattern. Always four sequential pages must then be programmed as follows: Page 0 with all ones, page 1 remains erased (all zeros), page 2 remains erased (all zeros), page 3 is programmed with all ones. Identically the next four pages are treated, and so on.

5.6.7 Power Supply and Reset

The following chapters describe the required power supplies, the power consumption and its possible reduction, the control of Flash Sleep Mode and the basic control of Reset.

5.6.7.1 Power Supply

The flash module uses the standard V_{DDP} I/O power supply to generate the voltages for both read and write functions. A VPP pin is not used for write operations. Internally generated and regulated voltages are provided for the program and erase operations as well as for read operations. The standard V_{DD} is used for all digital control functions.

5.6.7.2 Flash Power Consumption

For dynamic reduction of power consumption, the PMU controls the activity of the word line drivers of the Flash array, if enabled in the FCON register. If this dynamic power reduction is enabled, the read performance is slightly reduced because the control of prefetching is limited in this case. In DFlash, dynamic power reduction is provided per default, because DFlash prefetching is not supported.

5.6.7.3 Flash Sleep Mode

As power reduction feature, the Flash module provides a Flash sleep mode which can be selected by the user individually for the Flash, if the FCON-bit 15 (SLEEP) is set. Additionally, the sleep mode can be requested by a global SLEEP signal from a Power Management System. This 'external' sleep request signal is only accepted by Flash state machines, when it is not disabled with the FCON-bit ESLDIS.

The requested sleep mode is only taken if the Flash is in idle state and when all pending or active requests are processed and terminated. Only then, the Flash array performs the ramp down into the sleep mode: the sense amplifiers are switched off, the voltages are ramped down and the array-oscillator is switched off.

As long as the Flash is in sleep mode, this state is indicated by the SLM bit in the Flash Status Register FSR.

Wake-up from sleep is controlled with clearing of bit FCON.15, if selected via this bit, or wake-up is initialized by trailing edge of the broadcasted ('external') sleep signal from SCU. After wake-up, the Flash oscillator is switched on, the voltages are ramped up and the Flash takes the read mode. Note: A wake-up is only accepted by the Flash in its sleep mode; it is not accepted while it is ramped down.

Note: During ramp-down, sleep and wake-up, the Flash is reported to be busy. Thus, read and write accesses to the Flash in sleep mode are acknowledged with 'retry' and should therefore be avoided; those accesses make sense only during wake-up, when waiting for the Flash read mode.

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Note: The wake-up time is documented in the data sheet. This time may fully delay the interrupt response time in sleep mode.

5.6.7.4 Reset Control

The PMU-part of Flash module (FIM) uses

- the application reset ("class 3 reset"), which may include all reset sources (power-on, HW, SW and watchdog reset, if configured), and
- the power-on reset.

If not otherwise stated, always the application/class 3 reset is used.

The flash will be automatically reset to the read mode after every reset.

Resets During Flash Operation

A reset or power failure during an ongoing Flash operation (i.e. program or erase) must be considered as violation of stable operating conditions. However the Flash was designed to prevent damage to non-addressed Flash ranges when the reset is applied as defined in the data sheet. The exceptions are erasing logical sectors and UCBs. Aborting an erase process of a logical sector can leave the complete physical sector unreadable. An automatic recovery mechanism is implemented (see next section). When an UCB erase is aborted the complete Flash can become unusable. There is no recovery implemented because UCBs are usually only erased in a controlled environment. The addressed Flash range is left in an undefined state.

When an erase operation is aborted the addressed logical or physical sector can contain any data. It can even be in a state that doesn't allow this range to be programmed.

When a page programming operation is aborted the page can still appear as erased (but contain slightly programmed bits), it can appear as being correctly programmed (but the data has a lowered retention) or the page contains garbage data. It is also possible that the read data is instable so that depending on the operating conditions different data is read.

For the detection of an aborted Flash process the flags FSR.PROG and FSR.ERASE could be used as indicator but only when the reset was an application reset. Power-on resets can not be determined from any flags. It is not possible to detect an aborted operation simply by reading the Flash range. Even the margin reads don't offer a reliable indication.

When erasing or programming the PFlash usually an external instance can notice the reset and simply restart the operation by erasing the Flash range and programming it again.

However for the case of EEPROM emulation in the DFlash this external instance is not existing. A common solution is detecting an abort by performing two operations in sequence and determine after reset from the correctness of the second the completeness of the first operation.

E.g. after erasing a DFlash sector a page is programmed. After reset the existence of this page proves that the erase process was performed completely.

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The detection of aborted programming processes can be handled similarly. After programming a block of data an additional page is programmed as marker. When after reset the block of data is readable and the marker is existent it is ensured that the block of data was programmed without interruption.

Because often very small amounts of data need to be programmed in EEPROM emulation not always a complete page can be spent as marker. The following recipe allows to reduce the marker size to 8 bytes. This recipe violates the rule that a page may be programmed only once. This violation is only allowed for this purpose (EEPROM emulation with DFlash) and only when the algorithm is robust against disturbed pages (see also recommendations for handling single-bit errors) by repeating a programming step when it detects a failure.

Robust programming of a page of data with an 8 byte marker:

1. After reset program preferably always first to an even page ("Target Page").
2. If the Other Page on the same wordline contains active data save it to SRAM (the page can become disturbed because of the 4 programming operations per wordline).
3. Program the data to the Target Page.
4. Perform strict check of the Target Page (see below).
5. Program 8 byte marker to Target Page.
6. Perform strict check of the Target Page.
7. In case of any error of the strict check go to the next wordline and program the saved data and the target data again following the same steps.
8. Ensure that the algorithm doesn't repeat unlimited in case of a violation of operating conditions.

Strict checking of programmed data:

1. Ignore single-bit errors and the VER flag.
2. Switch to tight margin 0.
3. If the data (check the complete page) is not equal to the expected data report an error.
4. If a double-bit error is detected report an error.

When this algorithm is performed while the other DFlash bank is busy with erasing an additional rule is violated: margin reads are normally not allowed while any Flash operation is ongoing. In this case this is allowed.

After reset the algorithm has to check the last programmed page if it was programmed completely:

1. Read with normal read level. Ignore single-bit errors.
2. Read 8-byte marker and check for double-bit error.
3. Read data part and verify its consistency (e.g. by evaluating a CRC). Check for double-bit error.
4. If the data part is defective don't use it (e.g. by invalidating the page).
5. If the data part is ok:

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- a) If the marker is erased the data part could have been programmed incompletely. Therefore the data part should not be used or alternatively it could be programmed again to a following page.
- b) If the marker contains incorrect data the data part was most likely programmed correctly but the marker was programmed incompletely. The page could be used as is or alternatively the data could be programmed again to a following page.
- c) If the marker is ok the data part was programmed completely and has the full retention. However this is not ensured for the marker part itself. Therefore the algorithm must be robust against the case that the marker becomes unreadable later.

Recovery From Aborted Logical Sector Erase (“ALSE”)

When while erasing one of the logical sectors a power failure occurs or a reset is triggered the aborted erase process might leave the complete physical sector unreadable. As often the logical sectors contain important boot code the application might not start anymore. Thus the recommended step to repeat the aborted erase after startup can not be realized.

The FAM implements two recovery algorithms. The selection between the two is done with the SPREC bit (“Soft-Programming Recovery”), i.e. bit 0 of byte 2 in the UCB1 (see [“User Configuration Block UCB1” on Page 5-74](#)).

In both cases the algorithm checks first the sectors PS0 and PS4 for an over-erased state. When this is detected the bit FSR.VER is set to inform the application (see [Chapter 5.6.6.4](#)). After that the algorithm tries to repair this state:

- The default algorithm is selected with SPREC = 0. The over-erased logical sector is searched. When finding one this algorithm programs it shortly with all-one data. The other logical sectors become readable again.
At least theoretically (especially when operating the device outside of the allowed operating conditions) this algorithm could destroy valid data: when an over-erased logical sector is reported incorrectly during normal startup without a preceding sector erase the data of a logical sector would be overwritten with all-one.
- An alternative algorithm is selected when SPREC = 1. This algorithm searches also for the over-erased logical sector as before. For repair a smarter but more time consuming algorithm is performed. The affected logical sector is not overwritten with all-one but only the over-erased 0-bits are slightly programmed so that they become normal 0-bits again. Under all circumstances this algorithm can not destroy any data but when a lot of data has to be repaired the flash startup time can be increased to over 250 ms.

Note: The ALSE recovery algorithm is triggered by every reset. However in case of an application reset at high clock frequencies the algorithm “SPREC=1” might not finish before the watchdog is triggered. This can cause a device hang-up. A

Program Memory Unit (PMU)

power-on reset (which switches to a slower clock during startup) lets the repair algorithm finish and the device boot successfully again.

Attention: The ALSE repair algorithm was designed to recover the device after a reset during erase caused by an accidental loss of power. Any other possible cause of resets must be prevented by the customer.

When the ALSE repair algorithm is not needed (e.g. because an ABM boot mode is used) then it can be switched off with the ALSEDIS bits in UCB1 (see [User Configuration Block UCB1](#), on [Page 5-74](#)). Each bit 0 – 7 of ALSEDIS corresponds to one logical sector. If this bit is configured to 1 the logical sector is not repaired. If bits 0–3 of ALSEDIS are set to F_H then the physical sector PS0 is not checked for an over-erased state during startup. The same with bits 4-7 for physical sector PS4.

When the ALSE repair algorithm is not needed it is recommended to switch it off completely by configuring the ALSEDIS to FF_H .

5.6.8 Emergency Programming

This feature allows in the TC1728 to program data to a DFlash bank with minimum latency. This can be used for programming a “crash record” to a pre-erased DFlash area for Airbag applications.

A “Write Page” command sequence in DFlash bank 0 executes in the emergency mode when the COMM1.DATA register contains 57_H, and in bank 1 when the COMM2.DATA register contains 57_H. All other steps for programming are unchanged from a normal programming job, including the use of “Enter Page Mode” and “Load Page” command sequences.

The used registers COMM1 and COMM2 (additionally COMM0 is existing) enable direct communication of software with the FSI.

Write access to these registers is SV protected. Read and write accesses are possible while the PMU is busy with program/erase in one of the DFlash banks. Changing their value during an ongoing programming process can cause unpredictable results.

Note: The registers don't support byte selects for write accesses. If a byte write access is (incorrectly) performed to COMMx.STATUS the other byte COMMx.DATA would be written with an undefined value. However when (correctly) the COMMx.DATA is addressed no side effects happen because the other byte COMMx.STATUS is read-only.

Note: Writing or reading these registers when the Flash is in sleep mode is forbidden and has unpredictable results.

Note: The STATUS field of these registers can be changed by every FSI operation including startup, programming and erase. The content is therefore unpredictable.

Note: The DATA field of these registers can be changed during Flash startup.

Note: After startup the DATA field of these registers is not affected by FSI operations. Therefore in order to finish the emergency mode the value 57_H shall be explicitly cleared after finishing all programming steps.

For programming in the PFlash and for all other command sequences these registers are not evaluated.

Specific Features of Emergency Programming

Normal mode programming of a page in Flash consists of a programming pulse which can be repeated if some cells are not programmed good enough to fulfill the defined retention. The maximum number of repetitions depends on the Flash bank and on the technology. It is reflected by the maximum programming time documented in the data sheet.

In the emergency programming only one programming pulse is applied. The retention of the programmed data is not verified and no repetition pulses are applied. Therefore the

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page programming time is minimized. Skipping repetition pulses has as consequence a reduced minimum retention and higher PPM rate.

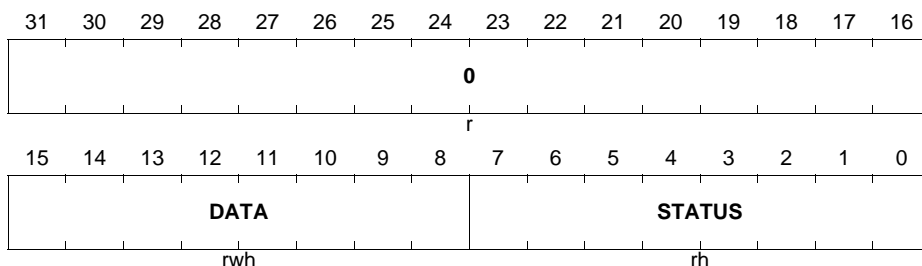
When one DFlash bank is busy with an erase process when a page programming in emergency mode is started the normal erase suspend delay is incurred. But in contrast to normal mode programming the erase jobs is silently aborted and not automatically resumed. This avoids spending the erase-suspend delay for the following programming jobs again. As side effect the erased bank can be left in an illegal state (as if a reset has happened during erase, see [Chapter 5.6.7.4](#)). Therefore the erase job must be repeated after finishing all programming jobs.

If the emergency programming was triggered by a false alarm and the application decides to resume normal operation it has to clean up Flash states that were caused by the emergency programming: the COMM1/2 registers should be cleared, an aborted erase has to be repeated and programmed data should be invalidated and programmed in normal mode again to different pages.

COMMO

FSI Communication 0

(0000_H)

Reset Value: 0000 0000_H


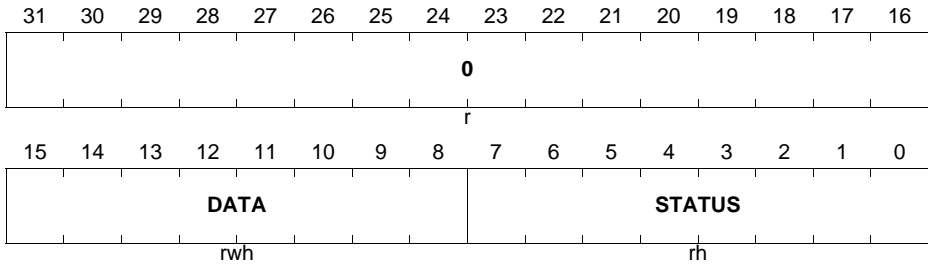
Field	Bits	Type	Description
STATUS	[7:0]	rh	Status This field can be only written by the FSI.
DATA	[15:8]	rwh	Data This field can be written by software and by the FSI.
0	[31:16]	r	Reserved ; always read as 0.

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COMM1

FSI Communication 1

(0004_H)

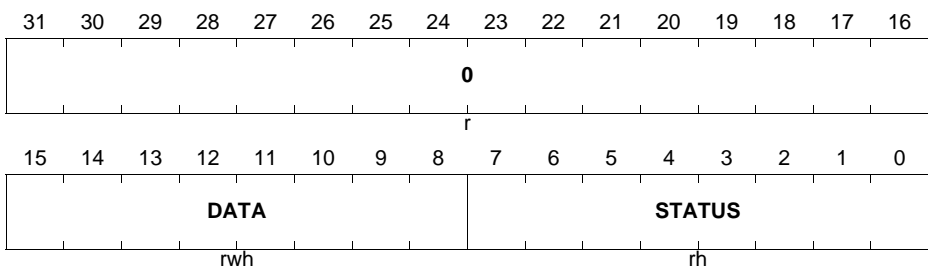
Reset Value: 0000 0000_H


Field	Bits	Type	Description
STATUS	[7:0]	rh	Status This field can be only written by the FSI.
DATA	[15:8]	rwh	Data This field can be written by software and by the FSI.
0	[31:16]	r	Reserved ; always read as 0.

COMM2

FSI Communication 2

(0008_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
STATUS	[7:0]	rh	Status This field can be only written by the FSI.
DATA	[15:8]	rwh	Data This field can be written by software and by the FSI.

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Field	Bits	Type	Description
0	[31:16]	r	Reserved; always read as 0.

6 Data Access Overlay (OVC)

The data overlay functionality provides the capability to redirect data accesses by the TriCore to program memory (segments 8_H and A_H) called “target memory” to a different memory called “overlay memory”.

Depending on the device the following overlay memories can be available:

- Overlay SRAM in the PMU.
- Emulation Memory¹⁾.
- External memory²⁾.

This functionality makes it possible, for example, to modify the application’s test and calibration parameters (which are typically stored in the program memory) during run time of a program.

As the address translation is implemented in the DMI, it affects only data accesses (reads and writes) of the TriCore. Instruction fetches by the TriCore or accesses by any other master (including the debug interface) are not redirected.

Summary of Features and Functions

- 16 overlay ranges (“blocks”) configurable.
- Support of 8 Kbyte embedded Overlay SRAM (OVRAM) in PMU.
- Support of up to 384 Kbyte overlay/calibration memory (EMEM)¹⁾.
- Support of up to 2 MB overlay memory in external memory (EBU space)²⁾.
- Support of Online Data Acquisition into range of up to 32 KB and of its overlay.
- Support of different overlay memory selections for every enabled overlay block.
- Sizes of overlay blocks selectable depending on the overlay memory:
 - OVRAM: from 16 byte to 2 Kbyte.
 - EMEM¹⁾ and external memory²⁾: 1 Kbyte to 128 Kbyte.
- All prepared overlay blocks can be enabled with only one register write access.
- Programmable flush (invalidate) control for data cache in DMI.

6.1 Basic Overlay Control

This chapter describes the complete overlay functionality irrespective of the overlay memory availability.

Per overlay block, there are three possibilities for redirection of the original data address, redirection to the Overlay SRAM in the PMU, redirection to the external memory and redirection to the Emulation Memory EMEM, if the chip includes the Emulation Extension Control EEC for an Emulation Device. In all cases, the same overlay mechanism is used.

The basic overlay scheme is shown in [Figure 6-1](#).

1) Only available in Emulation Device “ED”.

2) Only available in Emulation Device with EBU.

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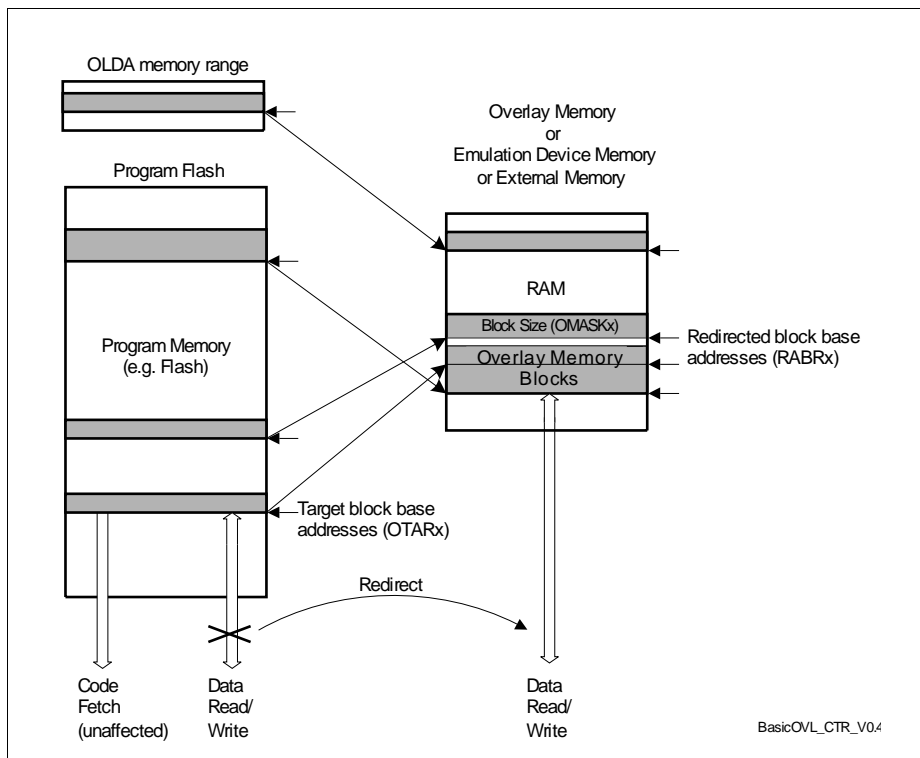


Figure 6-1 Redirection of Data Accesses to/from Code Memory to Internal OVRAM or to Emulation Memory (or to External Memory)

In the TC1728, the target memory (Program Flash, external memory or OLDA range, see [Chapter 6.4.1](#)) can be divided into a maximum of sixteen memory blocks for redirection into an overlay memory. The base address in target and overlay memory as well as the block size of each overlay block can be individually selected. The possible sizes of overlay blocks depend on the selected overlay memory: Blocks in the internal OVRAM are smaller than overlay blocks in EMEM or external memory. All enabled overlay blocks can be overlaid (redirected) together with only one register access. Concurrently, the data cache in the DMI may be flushed.

The operation of the address translation process is described in [Figure 6-2](#), shown for redirection into the internal Overlay RAM OVRAM.

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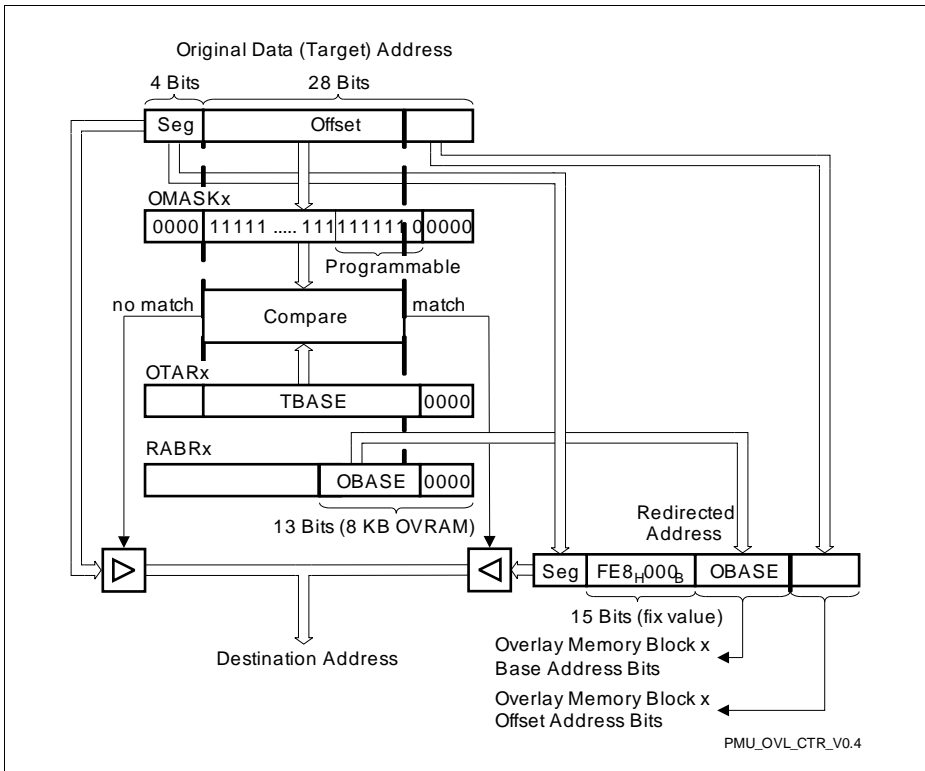


Figure 6-2 Address Translation Process for Overlay into OVRAM

In each enabled overlay block control logic, three registers hold the information to control the overlay functionality:

- The overlay target address in the Overlay Target Address Register OTARx, which determines the base address of the program or OLDA memory data block x to be redirected.
- The base address of the overlay memory block in the OVRAM, external memory or EMEM (if emulation Device) in the Redirected Address Base Register RABRx, and the related enable and control bits.
- A mask in the Overlay Mask Register OMASKx, defining the size of the block, the address bits to be checked for an address match, and which bits are used from the redirected address base and which from the original data address.

The size of the overlay memory blocks can be 2^n times the minimal block size (16 byte for internal memory overlay or 1 Kbyte for Emulation Memory overlay, respectively) with

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$n=0-7$. The start address of the block can be an integer multiple of the programmed block size (natural page boundary).

If the data segment address is A_H or 8_H , the segment offset of the original data address is compared with the target base addresses of all overlay blocks which are enabled in RABRx. This bit-wise comparison is qualified by the content of the mask, ignoring the address bits that form the offset into the overlaid block.

If there is no match, the original data address is taken to perform the access.

If there is a match (see **Figure 6-2**):

- The four segment address bits (A_H or 8_H) are taken directly from the data address.
- The most significant part of the segment offset, that addresses the base address of the overlay memory, is set to predefined values according to the address map (fixed bits in registers RABRx).
- The part of the target block address, that corresponds to the overlay block base address, is replaced by the respective overlay block base address bits (bits OBASE in RABRx, where the corresponding mask bits OMASK in registers OMASKx are set to "1").
- The address is completed by the original offset into the block; the number of bits used are determined by the bits set to "0" in the mask OMASK.

6.2 Online Data Acquisition (OLDA) and its Overlay

Calibration is additionally supported by an OLDA memory range of up to 32 Kbyte, which is a virtual memory and physically only available, if it is redirected (as described above) to the internal or external overlay memory or to the EMEM in Emulation Device. If OLDA is enabled in PMU, direct write accesses (without redirection) to the OLDA range are not really executed, and they do not generate a bus error trap. This trap suppression works only for accesses to the non-cached range. Read accesses to the OLDA range generate a bus error trap, if not redirected to a physically available overlay block.

The base address of the virtual OLDA memory range is $A/8FE7\ 0000_H$, the end address is $A/8FE7\ 7FFF_H$. Accesses to the OLDA range are also supported in cached address space but there the bus error trap for write accesses is not suppressed.

Note: In OTARx registers, any target address can be selected for redirection, thus also addresses in the OLDA range. However, the handling of direct accesses to the OLDA range is completely controlled in the PMU.

6.3 Enable Control of Overlay Blocks

For basic control of overlay execution, the OCON register is provided with following functionality:

- 16 enable bits (SHOVENx), one for every overlay block configuration, to support concurrent and parallel switching of up to 16 overlay ranges (blocks); shadow

Data Access Overlay (OVC)

functionality to the single enable bits in the 16 block control registers (RABRx) provide compatibility to enable-control in TC1766/96.

- One common overlay start bit (OVSTRT) to enable all prepared (enabled) overlay configurations by writing all shadow enable bits into the 16 block control registers in parallel (write-only bit); stop-function if all-zeros are written.
- One control flag (DCINVAL), to be set by the CPU or Cerberus, to flush (invalidate) the (clean) data cache lines in the DMI (write-only bit).
- One common overlay stop (OVSTP) bit to disable all overlay configurations in the 16 block control registers (write-only bit), without changing the configuration
- One overlay configured status bit (OVCONF), which may be set when overlay registers are configured by the Cerberus via JTAG interface, and which may be cleared by the CPU after common overlay start (re-direction of all enabled overlay blocks).

The control flag in the high byte of the Overlay Control Register OCON (see [Page 6-20](#)) is implemented with additional protection bit, supporting write access to OCON by different users without violation of such control bit which shall remain unchanged. Additionally, byte protection is possible by support of byte write accesses to OCON.

6.4 Target and Overlay Memories

In the following, the possible target and overlay memories are described, and for the overlay memories also their block-specific selection and the possible block sizes. The Internal Overlay Memory OVRAM and the interface to the Emulation Memory EMEM are located in the PMU. The EMEM can only be selected for overlay blocks, if the chip is an Emulation Device ED.

6.4.1 Target Memories

Any data read or write access to the segments 8_H and A_H is checked for a valid overlay target address, using all 16 OTARx registers concurrently for comparison (if they are enabled for overlay execution). Since the OTARx registers are writable, any data memory within the segments 8_H and A_H may be used for redirection to an overlay memory. Thus, the following memories can be selected as target memories:

- Program Flash
- Data Flash
- The (virtual) OLDA memory range
- The external memory.

6.4.2 Internal Overlay Memory

The capacity of the Internal Overlay Memory OVRAM is 8 KB. The base address of the OVRAM is $A/8FE8\ 0000_H$ (non-cached/cached space). The OVRAM is selected for overlay execution, if the bits IEMS and EXOMS in the block-related RABRx register are

Data Access Overlay (OVC)

zero. During address translation, the upper 19 address bits are set to $A/8FE8_H000_B$ using the same segment address as the original data (target) address. For internal overlay, the size of the overlay blocks can be $2^n \times 16\text{ B}$, with $n = 0$ to 7 (16 byte to 2 Kbyte). The internal overlay memory OVRAM is available in both the Production Device and the Emulation Device.

6.4.3 Emulation Overlay Memory

In the corresponding emulation device “ED” an Emulation Memory of 384 Kbyte is provided, which can fully be used for calibration via program memory or OLDA overlay. Its base address is $A/8FF0\ 0000_H$. The Emulation Memory EMEM is selected for overlay execution, if the block-related RABRx bits $IEMS=1$ and $EXOMS=0$. During address translation, the upper 13 address bits are set to AFF_H0_B (non-cached) or to $8FF_H0_B$ (cached space) using the same segment address as the original data address.

For Emulation Memory (EMEM) overlay, the size of the overlay blocks can be $2^n \times 1\text{ Kbyte}$, with $n = 0$ to 7 (1 Kbyte to 128 Kbyte).

6.4.4 External Overlay Memory

If an external memory is available in the Emulation Device system, it can also be used for calibration via program memory or OLDA overlay. The External Memory is selected for overlay execution, if the block-related RABRx bits $IEMS=1$ and $EXOMS=1$. During address translation, the upper 9 address bits are set to $A0_H1_B$ (non-cached) or to 80_H1_B (cached space) using the same segment address as the original data target address.

For redirection into the external EBU memory, the same sizes of the overlay blocks are provided as for Emulation Memory overlay: $2^n \times 1\text{ Kbyte}$, with $n = 0$ to 7 (1 Kbyte to 128 Kbyte). Thus, the maximum space supported for the overlay region is 2 MB.

6.5 Change of Overlay Parameters and Overlay Start

When changing the overlay parameters of a block or when switching a block from one overlay memory to another overlay memory, it must be ensured that the respective OVEN bit in register RABRx is reset, before the block parameters are set properly, and then the overlay block is enabled again. Otherwise, unintended access redirections may occur.

It is especially supported to enable (start) all prepared overlay blocks concurrently, when using the shadow mechanism for the OVEN bits in the one OCON register instead of the single OVEN bits in the different RABRx registers (see [Chapter 6.3](#)). With this function it is possible to switch directly from one set of overlay blocks to another set of overlay blocks, without any restriction concerning the block-specific use of (available) overlay memories.

Data Access Overlay (OVC)

Note: The Overlay Control does not prevent configuring the translation logic incorrectly so that memory accesses are translated to not implemented or forbidden memory ranges.

6.6 Block Priority and Access Performance

If concurrent matches in more than one enabled overlay block occur, the block with the lowest order number will win and perform the address translation.

The dynamic address translation for redirection to the overlay memory is executed without performance penalty.

6.7 Overlay Control Registers

Figure 6-3 shows all the overlay control registers associated with control of the overlay memory blocks.

Overlay Control Registers Overview

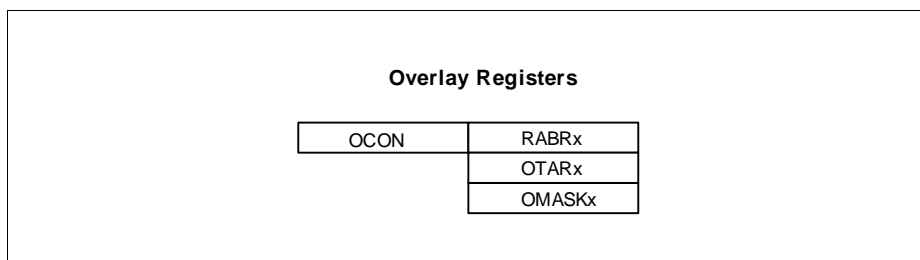


Figure 6-3 Overlay Control Registers

The address space for the overlay control registers is as follows:

Table 6-1 Registers Address Space of OVC Registers

Module	Base Address	End Address	Note
OVC	F87F FB00 _H	F87F FBFF _H	

Data Access Overlay (OVC)

Table 6-2 Registers Overview

Register ¹⁾ Short Name	Register Long Name	Offset Address	Access Mode ²⁾		Description see
			Read	Write	
OTARx	Overlay Target Address Register x (x = 0-15)	0024 _H + x * C _H	U, SV	SV	Page 6-9
RABRx	Redirected Address Base Register x (x = 0-15)	0020 _H + x * C _H	U, SV	SV	Page 6-11
OMASKx	Overlay Mask Register x (x = 0-15)	0028 _H + x * C _H	U, SV	SV	Page 6-16
OCON	Overlay Control Register	00E0 _H	U, SV	SV	Page 6-20

1) The OVC register short names are extended with the module name prefix "OVC_".

2) Symbol U: Access permitted in User Mode 0 or 1
Symbol SV: Access permitted in Supervisor Mode

Note: Accesses to free/not used register addresses within the OVC address space are not executed and not serviced with a bus error trap.

Register Descriptions

For each of the 16 overlay memory blocks (indicated by index x), three registers control the overlay operation and the memory selection:

- The Overlay Target Address Register OTARx, which holds the base address of the memory block in internal Flash, in external memory or in the OLDA memory being overlaid (and being compared with original data address).
- The Redirected Address Base Register RABRx, which holds the base address of the overlay memory to be used (with fixed address bits) and of the overlay memory block within the overlay memory, and some control bits.
- The Overlay Mask Register OMASKx, which determines which bits (from RABRx) are used for the base address (of overlay memory and block) and which bits (of original data address) are directly used as offset within the block (remaining unchanged).

Additionally, for general overlay control the register OCON is provided.

All overlay block and control registers are reset to their default values with the application reset. A special debug reset is not considered.

Note: All overlay block control registers have different definitions for overlay blocks in internal OVRAM (RABRx.IEMS=0), and overlay blocks in EMEM or external memory (RABRx.IEMS=1 or RABRx.EXOMS=1). Therefore, in the following, two (RABRx: three) different definitions are provided for the same register.

Data Access Overlay (OVC)

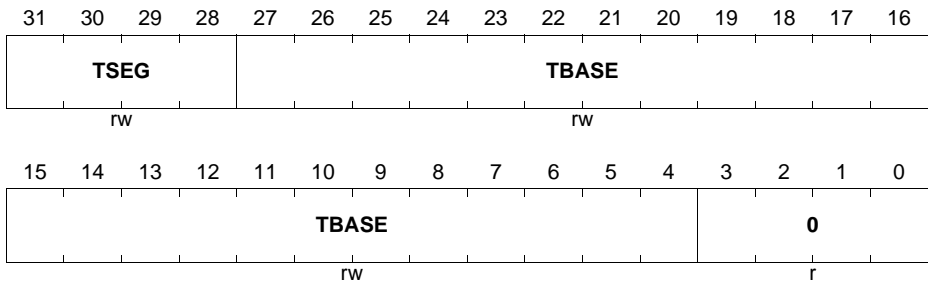
If RABRx.IEMS=0, the OTARx register is defined as follows.

OTARx (x=0-15)

Overlay Target Address Register x

$$(24_H + x \cdot C_H)$$

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TBASE	[27:4]	rw	Target Base This field holds the base address of the overlay memory block in the target memory (Program Flash or OLDA memory or external memory).
TSEG	[31:28]	rw	Target Segment (reserved) This bit field is reserved for future use, to select a segment. In TC1728 implementation, any access to segments 8 _H , or A _H will be checked for a valid base address; return 0 if read; should be written with 0.
0	[3:0]	r	Reserved Read as 0; should be written with 0.

Data Access Overlay (OVC)

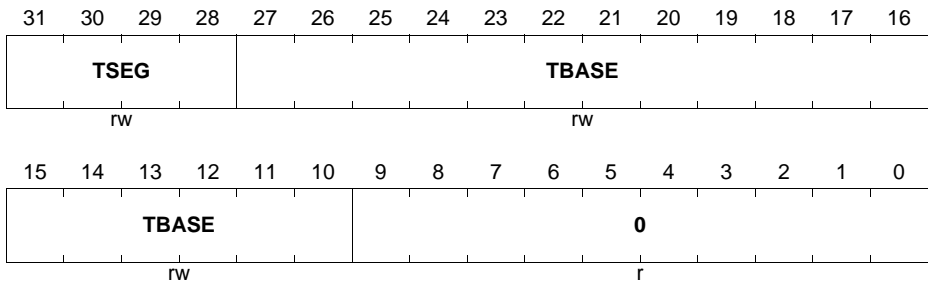
If RABRx.IEMS=1, the OTARx register is defined as follows.

OTARx (x=0-15)

Overlay Target Address Register x

$$(24_H + x \cdot C_H)$$

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TBASE	[27:10]	rw	Target Base This field holds the base address of the overlay memory block in the target memory (Program Flash or OLDA memory or external memory).
TSEG	[31:28]	rw	Target Segment (reserved) This bit field is reserved for future use, to select a segment. In TC1728 implementation, any access to segments 8 _H , or A _H will be checked for a valid base address; return 0 if read; should be written with 0.
0	[9:0]	r	Reserved Read as 0; should be written with 0.

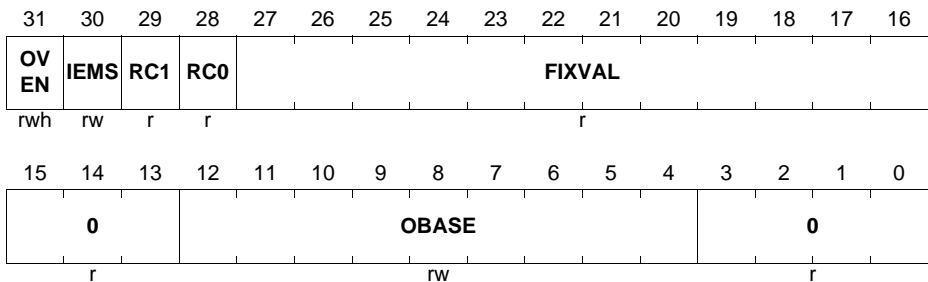
Data Access Overlay (OVC)

If RABRx.IEMS=0, the RABRx register is defined as follows.

RABRx (x=0-15)

Redirected Address Base Register x

 $(20_H + x \cdot C_H)$

Reset Value: 0FE8 0000_H


Field	Bits	Type	Description
OBASE	[12:4]	rw	Overlay Block Base Address This bit field holds the base address of the overlay memory block in the overlay memory OVRAM. The largest block base address that is allowed, is (OBASE _{max} - block size ¹⁾)
FIXVAL	[27:16]	r	Fixed Value Base address of OVRAM within segment. FE8 _H Base address. All other values are reserved. Returns FE8 _H if read; should be written with FE8 _H .
RC0, RC1	28, 29	r	Reserved Control Bits Reserved for future control expansions. Read returns 0. Must be written with 0.
IEMS	30	rw	Internal or Emulation/External Memory Select IEMS selects the type of the overlay memory and the size-range of overlay blocks. 0 _B Internal OVRAM is selected as overlay memory. Block sizes are 2 ⁿ Bytes, n = 4-11. 1 _B Emulation Memory EMEM is selected as overlay memory if not coincidentally EXOMS is set. Block sizes are 2 ⁿ x 1 KB, n = 0-7. IEMS must be written with zero in production device.

Data Access Overlay (OVC)

Field	Bits	Type	Description
OVEN	31	rwh	Overlay Enabled This bit controls whether or not the overlay function of overlay block x is enabled. 0 _B Overlay function of block x is disabled. 1 _B Overlay function of block x is enabled. This bit can also be changed via its shadow bit in the OCON register.
0	[3:0], [15:13]	r	Fixed Value Read as 0; should be written with 0.

1) The block size is determined by the mask register OMASK.

Data Access Overlay (OVC)

If RABRx.IEMS=1 and RABRx.EXOMS=0, the RABRx register is defined as follows. The reset value is meaningless in this case because after reset the register has always the layout defined on [Page 6-11](#).

RABRx (x=0-15)

Redirected Address Base Register x

 $(20_H + x \cdot C_H)$

Reset Value: XXXX XXXX_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OV EN	IEMS	EXO MS	RC0	FIXVAL								0	OBASE		
rwh	rw	rw	r	r								r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OBASE								0							
rw								r							

Field	Bits	Type	Description
OBASE	[18:10]	rw	Overlay Block Base Address This bit field holds the base address of the overlay memory block in the Emulation Memory EMEM. The largest block base address that is allowed, is (OBASE _{max} - block size ¹⁾)
FIXVAL	[27:20]	r	Fixed Value Base address of EMEM within segment. FF _H Base address. All other values are reserved. Returns FF _H if read; should be written with FF _H .
RC0	28	r	Reserved Control Bit Reserved for future control expansions. Read returns 0. Must be written with 0.
EXOMS	29	rw	External Overlay Memory Select If set, the external memory is used as overlay memory. 0 _B Overlay memory of block x is not the external memory. 1 _B Overlay memory of block x is the external memory. The block sizes are identical to EMEM blocks: 2 ⁿ x 1 KB, with n = 0-7.

Data Access Overlay (OVC)

Field	Bits	Type	Description
IEMS	30	rw	Internal or Emulation/External Memory Select IEMS selects the type of the overlay memory and the size-range of overlay blocks. 0 _B Internal OVRAM is selected as overlay memory. Block sizes are 2 ⁿ Bytes, n = 4-11. 1 _B Emulation Memory EMEM is selected as overlay memory if not coincidentally EXOMS is set. Block sizes are 2 ⁿ x 1 KB, n = 0-7.
OVEN	31	rwh	Overlay Enabled This bit controls whether or not the overlay function of overlay block x is enabled. 0 _B Overlay function of block x is disabled. 1 _B Overlay function of block x is enabled. This bit can also be changed via its shadow bit in the OCON register.
0	[9:0], 19	r	Fixed Value Read as 0; should be written with 0.

1) The block size is determined by the mask register OMASK.

Data Access Overlay (OVC)

If RABRx.IEMS=1 and RABRx.EXOMS=1, the RABRx register is defined as follows. The reset value is meaningless in this case because after reset the register has always the layout defined on [Page 6-11](#).

RABRx (x=0-15)

Redirected Address Base Register x

 $(20_H + x \cdot C_H)$

Reset Value: XXXX XXXX_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OV EN	IEMS	EXO MS	RC0	FIXVAL					OBASE						
rw	rw	rw	r	r					rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OBASE						0									
rw						r									

Field	Bits	Type	Description
OBASE	[22:10]	rw	Overlay Block Base Address This bit field holds the base address of the overlay memory block in the external memory. The largest block base address that is allowed, is (OBASE _{max} - block size ¹⁾)
FIXVAL	[27:23]	r	Fixed Value Base address of external memory within segment. 00001 _B Base address. All other values are reserved. Returns 00001 _B if read; should be written with 00001 _B .
RC0	28	r	Reserved Control Bit Reserved for future control expansions. Read returns 0. Must be written with 0.
EXOMS	29	rw	External Overlay Memory Select If set, the external memory is used as overlay memory. 0 _B Overlay memory of block x is not the external memory. 1 _B Overlay memory of block x is the external memory. The block sizes are identical to EMEM blocks: 2 ⁿ x 1 KB, with n = 0-7.

Data Access Overlay (OVC)

Field	Bits	Type	Description
IEMS	30	rw	Internal or Emulation/External Memory Select IEMS selects the type of the overlay memory and the size-range of overlay blocks. 0 _B Internal OVRAM is selected as overlay memory. Block sizes are 2 ⁿ Bytes, n = 4-11. 1 _B Emulation Memory EMEM is selected as overlay memory if not coincidentally EXOMS is set. Block sizes are 2 ⁿ x 1 KB, n = 0-7.
OVEN	31	rwh	Overlay Enabled This bit controls whether or not the overlay function of overlay block x is enabled. 0 _B Overlay function of block x is disabled. 1 _B Overlay function of block x is enabled. This bit can also be changed via its shadow bit in the OCON register.
0	[9:0]	r	Fixed Value Read as 0; should be written with 0.

1) The block size is determined by the mask register OMASK.

The Overlay Mask Register OMASK_x determines the size of the overlay memory block x (by the number of least significant zero's). It also determines which address bits will participate in the address compare for the block base address (all high-order one's), and in case of address match which bits are taken from RABRx (as many high order bits as defined in OMASK_x for address compare) and which bits are used from the original data address as offset within the block (all low order bits related to zero values in OMASK_x).

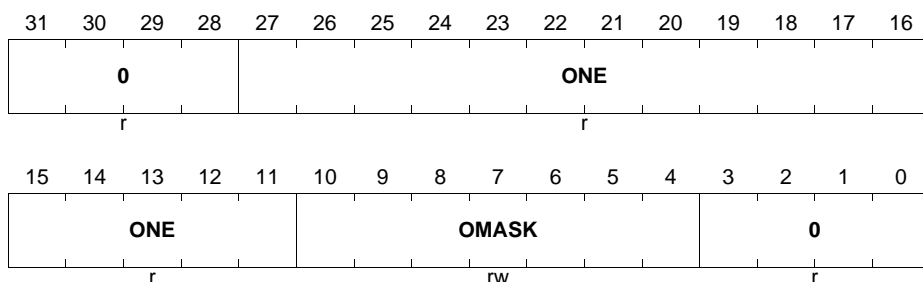
If RABRx.IEMS=0, the OMASK_x register is defined as follows.

OMASK_x (x=0-15)

Overlay Mask Register x

(28_H+x*C_H)

Reset Value: 0FFF FFE0_H



Data Access Overlay (OVC)

Field	Bits	Type	Description
OMASK	[10:4]	rw	Overlay Address Mask This bitfield determines the overlay block size in OVRAM and the bits used for address comparison and translation. Selectable overlay memory block sizes in OVRAM: 0000000 _B 2 Kbyte 1000000 _B 1 Kbyte 1100000 _B 512 byte 1110000 _B 256 byte 1111000 _B 128 byte 1111100 _B 64 byte 1111110 _B 32 byte 1111111 _B 16 byte “Zero” bits determine the corresponding address bits which are not used in the address comparison and thus determine the block size; corresponding final address bits are derived from the original data address. “One” bits determine the corresponding address bits which are used for the address comparison; corresponding final address bits are derived from RABRx register in case of address match. All OMASK bits located right of the most significant mask bit which is set to zero, are treated as zeros as well, independent from their actual value. They will be read back as 0.
ONE	[27:11]	r	Fixed “1” Values Corresponding address bits are participating in the address comparison. Corresponding final address bits are taken from RABRx.
0	[3:0], [31:28]	r	Fixed “0” Values Corresponding address bits are not used in the address comparison. Corresponding final address bits are taken from the original data address.

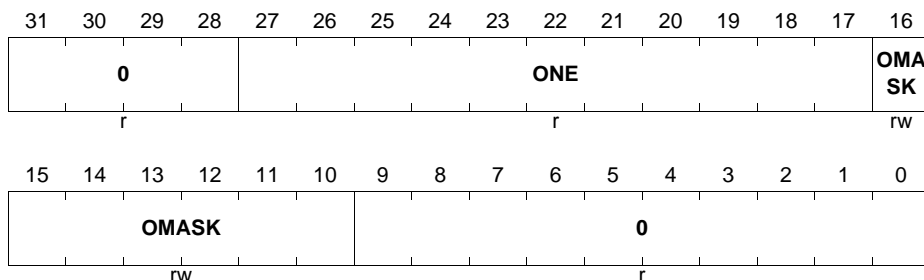
If RABRx.IEMS=1, the OMASKx register is defined as follows.

Data Access Overlay (OVC)

OMASKx (x=0-15)

Overlay Mask Register x

 $(28_H + x \cdot C_H)$

Reset Value: 0FFF FC00_H


Field	Bits	Type	Description
OMASK	[16:10]	rw	Overlay Address Mask This bitfield determines the overlay block size in EMEM or in external memory (if EXOMS=1) and the bits used for address comparison and translation. Selectable overlay memory block sizes in EMEM: 0000000 _B 128 Kbyte 1000000 _B 64 Kbyte 1100000 _B 32 Kbyte 1110000 _B 16 Kbyte 1111000 _B 8 Kbyte 1111100 _B 4 Kbyte 1111110 _B 2 Kbyte 1111111 _B 1 Kbyte “Zero” bits determine the corresponding address bits which are not used in the address comparison and thus determine the block size; corresponding final address bits are derived from the original data address. “One” bits determine the corresponding address bits which are used for the address comparison; corresponding final address bits are derived from RABRx register in case of address match. All OMASK bits located right of the most significant mask bit which is set to zero, are treated as zeros as well, independent from their actual value. They will be read back as 0.

Data Access Overlay (OVC)

Field	Bits	Type	Description
ONE	[27:17]	r	Fixed “1” Values Corresponding address bits are participating in the address comparison. Corresponding final address bits are taken from RABR.
0	[9:0], [31:28]	r	Fixed “0” Values Corresponding address bits are not used in the address comparison. Corresponding final address bits are taken from the original address.

Data Access Overlay (OVC)

The Overlay Control Register OCON is defined as follows:

OCON

Overlay Control Register

(00E0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	0	0	0	0	0	POV CON F	OV CON F	0	0	0	0	0	DC IN VAL	OV STP	OV ST RT
r	r	r	r	r	r	w	rw	r	r	r	r	r	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SHOVENx															
rw															

Field	Bits	Type	Description
SHOVENx (x=0-15)	x	rw	Shadow Overlay Enable x 0 _B Overlay block x is disabled with next OVSTRT 1 _B Overlay block x is enabled with next OVSTRT For each of the 16 overlay blocks (indicated by index x), one enable (disable) bit is provided.
OVSTRT	16	w	Overlay Start 0 _B No action 1 _B All 16 shadow overlay enable bits SHOVEN are loaded into the related OVEN bits in RABRx registers in parallel. Related to the SHOVEN bits state, the overlay blocks are concurrently enabled or disabled. Return 0 if read.
OVSTP	17	w	Overlay Stop 0 _B No action 1 _B All 16 OVEN bits in RABRx registers are cleared in parallel independently of the SHOVEN bits and without changing the SHOVEN bits. Return 0 if read.

Data Access Overlay (OVC)

Field	Bits	Type	Description
DCINVAL	18	w	Data Cache Invalidate No function in devices without data cache in Tricore. 0 _B No action 1 _B Data Cache Lines in DMI are invalidated (flushed). <i>Note: Per write modified cache lines are not invalidated.¹⁾</i> Return 0 if read.
OVCONF	24	rw	Overlay Configured Overlay configured status bit 0 _B Overlay is not configured or it has been already started by CPU 1 _B Overlay block control registers are configured and ready for overlay start This bit may be used as handshake bit between a debug device (via JTAG interface and Cerberus) and the CPU.
POVCONF	25	w	Protection Bit for OVCONF 0 _B Bit protection: Bit OVCONF remains unchanged with register OCON write 1 _B OVCONF can be changed with actual write access to register OCON This bit enables OVCONF-write during OCON write. Return 0 if read.
0	[23:19] , [31:26]	r	Reserved Read/write 0.

1) Because the data cache is a writeback cache (not a writethrough cache; therefore saving of modified data in cache has to be performed by the user) it is highly recommended to use only non-cached accesses for overlaid (redirected) accesses to the target memory (normally the Program Flash), if write accesses are involved.

7 BootROM Content

The BOOT_TC1728_TS consists basically of three parts:

- Startup Software (short name SSW);
- Software modules implementing additional functions (Bootstrap Loaders);
- Test Firmware.

7.1 Startup Software

The Startup Software is the first software executed after a chip reset. This means, the first value (determined by the System Control Unit, SCU) loaded into the Program Counter register PC points to address AFFF'C000_H inside the BootROM - the SSW entry-point.

The Startup Software contains procedures to initialize the device depending on one or more from the following:

- values applied to external (configuration-) pins;
- the type of event which has triggered the SSW-execution (the last reset event);
- information previously stored into the Flash Configuration Sector;
- the current state of special bits/fields in dedicated register/memory locations.

The SSW also calls - in case - other firmware modules.

7.1.1 Boot Options Summary

This chapter summarizes the TC1728 startup configurations in user (not test) mode.

Internal Start

In this basic startup mode, the first user instruction is fetched from the Internal Program Flash of the device.

Bootloader Modes

Different Bootstrap Loader routines are used in these modes to download code/data into the Instruction Scratchpad Memory SPRAM (PMI), as follows:

- ASC bootloader;
- CAN bootloader;
- Generic bootloader - the bootloading procedure itself here is in fact one of the two above possibilities - ASC/CAN. The selection either to use ASC- or CAN-communication protocol is done by the SSW upon the first byte received at the couple of pins, which are then respectively configured to ASC or to MultiCAN module.

Alternate Boot Modes

In these modes, program code is started from user-defined address but only if at least one of the two check-conditions is satisfied. If both the conditions are false - a Bootstrap Loader routine is started to download the code into the device, this code is afterwards started by the SSW.

Check-condition true means a correct program code is available at the defined location. The check condition itself is evaluated by calculating CRC sum over the content of a defined memory range. All the information needed for the SSW to handle ABM startup modes is collected into the so-called Headers. The checks are performed according to two Headers defined inside the Internal Flash memory of the device.

Several Alternate Boot Modes (ABM) are available in TC1728, the differences are in:

- which communication channel is used for code downloading upon an error in check-condition: ASC or CAN.

7.1.2 Conditions upon SSW entry

The SSW execution starts upon the following basic environment conditions within the TC1728 system:

- system clock
 - after class 0 reset: 16.66 MHz system frequency (nominal)
 - otherwise: as previously configured (no changes due to the reset)
- interrupts and traps
 - all maskable interrupts are disabled due to ICR.IE=0 after any reset
 - all NMI-traps are disabled after any reset
- Watchdog-Timer
 - stopped after any reset
- Program Cache
 - bypassed, due to the reset-value PMI_CON0.PCBYP=1
- Data Cache
 - configured to 0 KB after reset, therefore not effectively used

7.1.3 Startup Software Main Flow

In next Chapters, the SSW functionality is specified, during different execution-steps (refer to [Figure 7-1](#)) and upon various configuration settings.

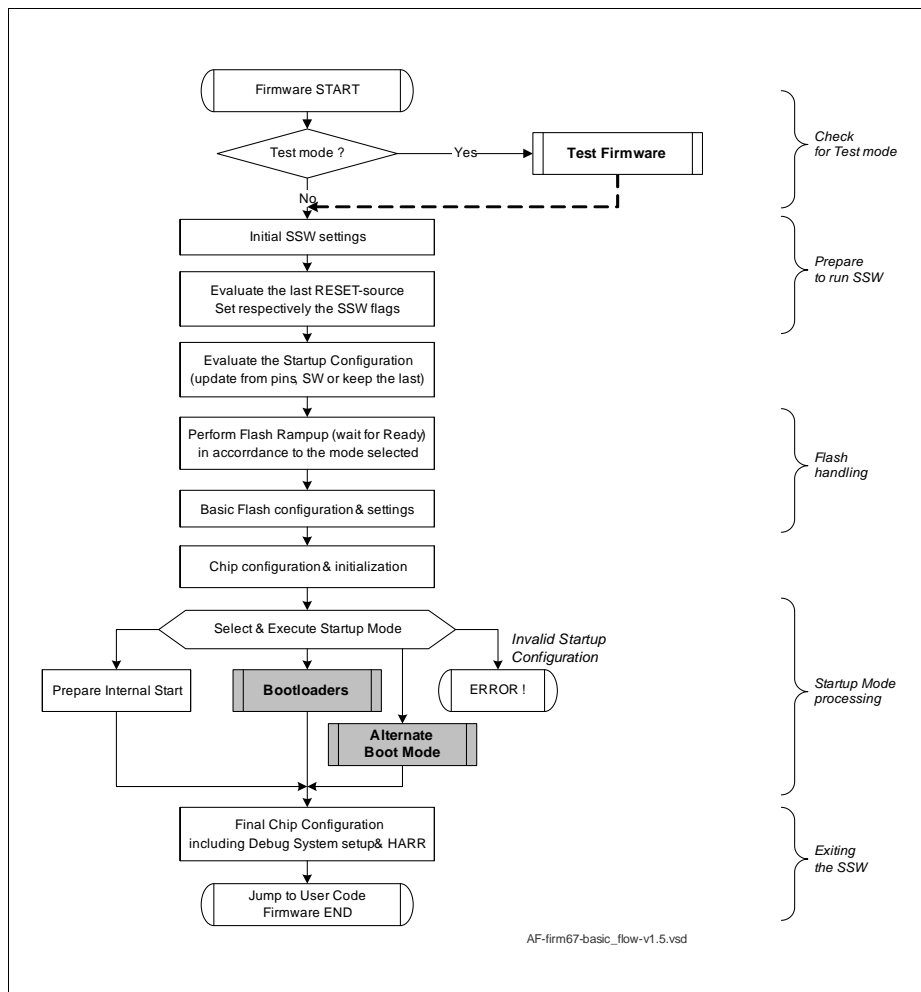


Figure 7-1 TC1728 Firmware: SSW main flow

7.1.3.1 Entering the Startup Software

The first SSW instruction is fetched after any reset from address AFFF'C000_H in BootROM Bytes - the SSW entry-point.

As first operation, the SSW checks SCU_STSTAT.MODE bit. This bit represents the value latched upon reset at the TEST pin, and when the value is 0 - a jump to the Test Firmware is performed.

Next, the SSW prepares some basic conditions for its further execution:

- All NMI-Traps are disabled in SCU_TRAPDIS register
Note: first the previous (user) value is saved and later - before the SSW end - restored.
- Trap Vector Table Pointer register BTV is written with AFFF'FFE0_H (SSW-specific value)
This way, in case of a Trap during the SSW-execution, jump to the above address in BootROM will be performed and the SSW Trap-servicing routine will be entered, which ends up in the error-processing module.
- SSW Exit-code is reset (corresponding to OK status)

7.1.3.2 Initial Handling of the Startup Configuration

The SSW determines which startup mode to execute based on the configuration coded in SCU_STSTAT.HWCFCG bit field.

The value in this bit field can be updated in different ways:

1. with values latched at the configuration pins P0[7:0] upon the rising reset-edge
This happens when SCU_STSTAT.LUDIS=0, therefore after any system (class 0) reset, and after other resets - depending on LUDIS bit.
2. with values from SCU_SWRSTCON.SWCFCG bit field
This happens upon Software reset - triggered by writing 1 to SCU_SWRSTCON.SWRSTREQ - if at the same time Software Boot Configuration is selected - SCU_SWRSTCON.SWBOOT=1.

Due to the way HWCFCG-bit field is handled by TC1728 hardware, at this point of its flow the SSW does not need to do some special processing regarding the startup configuration. besides of setting SSW-internal flag:

- “Reset Configuration Updated” flag
 - is set to 1 if
 - the last reset has been a software-reset with software-configuration
((SCU_RSTSTAT.SW=1) AND (SCU_SWRSTCON.SWBOOT=1))
 - if the last reset is of a type NOT stated in a)
 - the flag is set to the inverted value of SCU_STSTAT.LUDIS bit

7.1.3.3 Flash Rampup

The Flash Rampup is automatically started after every reset by hardware (refer to PMU Chapter, Program and Data Flash). Therefore the SSW does not initiate the Rampup but only observes the flags in Flash SFRs and reacts accordingly.

The Flash Rampup is further handled by the SSW. Basically the Flash “Busy” status is checked as the section below describes.

If after the time-out the Flash is still “Busy”, then:

- “Flash Rampup” error-code is created
- the Flash is put into sleep mode
- a jump to the SSW Error-processing routine is performed

Flash Rampup

Flash “Busy” status is continuously checked but no longer than for a defined time-out. Once all of the Flash Array Banks are “Ready” (PBUSY=0), the startup procedure continues immediately. As far as the Rampup duration varies from device to device and upon operational conditions, the overall startup time respectively will be slightly different.

7.1.3.4 Basic Device Settings

The target of this functional module is to initialize several TC1728-registers with the values, which will be first seen by the user - or generally available - after exiting the SSW.

Following device resources are initialized here:

- JTAG Device Identification register (JTAGID.JTAG_ID)
- Unique Chip ID - it is written by the SSW at the beginning of LDRAM - 4 Words starting at D000'0000_H.

7.1.3.5 RAMs Handling

No RAM initialization is performed by the Startup Software in TC1728.

Attention: In regard to TC1728 RAMs after startup the user must consider:

- if ECC will be enabled for a RAM module - correct initial content of this memory must be assured
- upon the application software start, the error detection is disabled in all memories

Note: MultiCAN memory is an exception from the above rule and error-detection is enabled for it, but due to the special access-mechanism implemented (no direct read/write by the user software) initialization is not needed there.

7.1.3.6 Select and Prepare Startup Modes

TC1728 User Startup Configurations and modes are summarized in [Table 10-1](#).

Table 7-1 Startup Modes supported in TC1728

HWCFG[7:0] 1)	Startup Mode	Pins used
11VWxxx _B	Internal Start from Flash	4
01VWxxx _B	Generic (CAN/ASC auto detected) Bootstrap Loader - P3[13:12]	4
10VWxxx _B	Alternate Boot Mode, Generic Bootloader on fail - P3[13:12]	4
00VW10xx _B	ASC Bootstrap Loader - P3[1:0]	6
00VW11xx _B	Alternate Boot Mode, ASC Bootloader on fail - P3[1:0]	6
else	Reserved	-

1) V bit - EVR 3.3V control: 0 - on; 1 - off
W bit - EVR 1.3V control: 0 - on; 1 - off

The SSW evaluates the configuration in SCU_STSTAT.HWCFG and device-start is prepared in accordance to the mode currently selected (refer to [Figure 10-2](#)).

Basically, the User Start Address is prepared in STADD, as well as additional functions are executed in case - like Bootstrap Loaders and Alternate Boot.

Internal Start

This is the basic TC1728 type of operation in which the user code is started out of the Internal Flash Memory.

The User Start Address STADD is set to the beginning of Internal Flash Memory Module at address A000'0000_H.

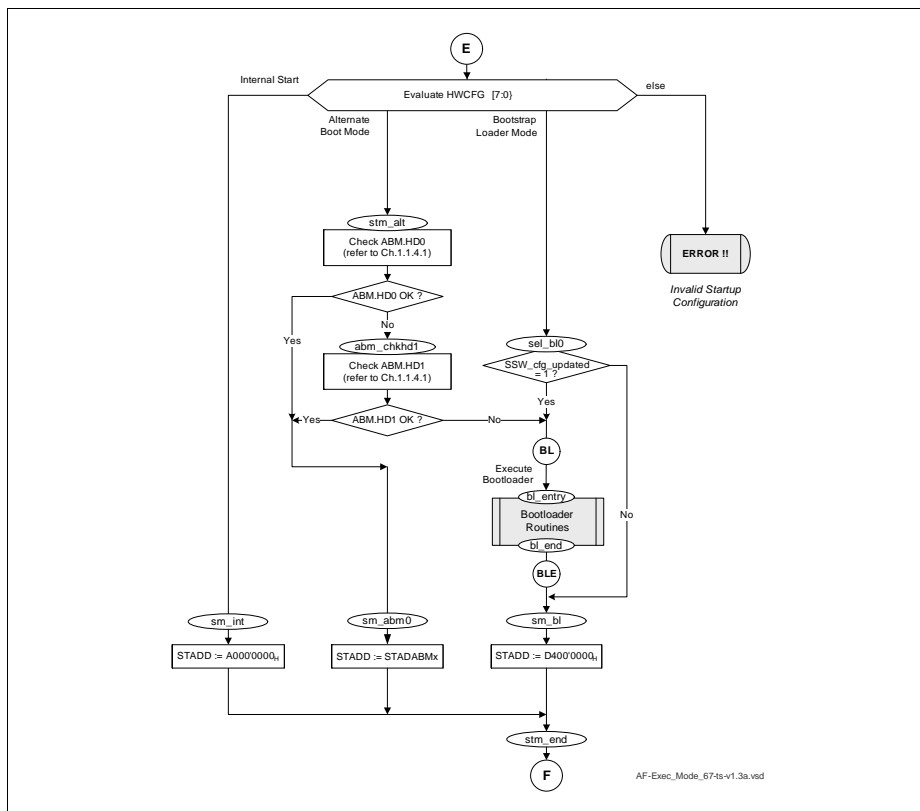


Figure 7-2 TC1728 Firmware: Select and Prepare Start Mode

Bootstrap Loader Modes

The selected Bootstrap Loader (these routines are described in [Chapter 10.2](#)) is executed only if the SSW-flag “Reset Configuration Updated” is set (refer to [Chapter 10.1.3.2](#)). This is to avoid multiple executions of the Bootstrap Loader and to start directly the code already downloaded after some - intended to be “application only” - reset events, for example after a Watchdog Timer reset which has been configured as class 3 reset.

The supported Bootloader selections are:

- ASC Bootloader - ASC communication protocol via ASC pins
- Generic Bootloader via CAN pins - the communication protocol is automatically selected by the SSW between ASC and CAN

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After downloading (in case) the code, the User Start Address STADD is set to the beginning of PMI Scratchpad RAM at D400'0000_H.

Alternate Boot Modes

There are variety of such modes in TC1728, whereas the differences are in:

1. which Bootloader to execute upon an error in ABM Header
 - a) ASC Bootloader
 - b) Generic Bootloader at CAN pins

The SSW flow in these modes is:

- check the Headers - refer to the description in [Chapter 10.1.4.1](#) - and react accordingly:
 - if the check is OK for one of the Headers - set the User Start Address STADD to the respective value from this correct header (STADABMx) and continue
 - if both the Header-checks fail - start a Bootloader (ASC/Generic) corresponding to the startup configuration. After downloading the code, the User Start Address STADD is set to the beginning of PMI Scratchpad RAM at D400'0000_H.

7.1.3.7 Final Chip Settings

The last device configuration steps performed by the SSW include:

Unique Chip ID Installation

The Unique Chip ID represents a 16-Byte value which is written by the SSW at the beginning of LDRAM - starting from address D000'0000_H.

Calibration Data Installation

The Calibration Data (for FADC, as well as placeholder for future extensions) represents a 128-Byte value which is written after power-on reset by the SSW into LDRAM starting from address D000'0018_H.

Flash Protection Control

The SSW processing on Flash protection differs upon the startup mode currently selected:

1. in modes where the user code is started from Internal Flash - Internal start, Internal ABM with CRC OK:
 - a) if Read Protection is NOT activated (FCON.RPA=0):
 - SSW enables all the specific (DMA, PCP, Debug) Data Fetches from Flash
 - no SSW action is needed regarding Code and Data Fetches from Flash - they are generally enabled by hardware.

- b) if Read Protection is Activated (FCON.RPA=1):
 - SSW enables Code Fetch from Flash;
 - SSW enables Data Fetch from Flash in general as well as in particular for DMA (FCON.DDFDMA=0) and PCP;
 - SSW disables Data Fetch from Flash for the Debug Controller.
- 2. in modes where the user code is not started from Internal Flash - all Bootstrap Loader modes, all ABM modes after the CRC fails:
 - a) if Read Protection is NOT activated (FCON.RPA=0) - the same functionality as upon a start from Internal Flash - refer to 1.a) above;
 - b) if Read Protection is activated (FCON.RPA=1):
 - SSW disables all Code and Data Fetches from Flash
 - SSW disables all the specific (DMA, PCP, Debug) Data Fetches from Flash.

At the end of this module, accesses to Configuration Sector Data are disabled.

Debug System handling

As first point of this processing, the SSW internal flag Unlock Debug Interface is set, with exception of the following case only:

- Internal start with active Flash protection

In any other case, debugging is no security risk as far as either the protection is not activated or reading from Flash is not possible.

Next, Halt after Reset is prepared if requested. Besides a Halt itself is no security risk - even the system is stopped but a channel (communication/debug) is still needed to access internal resources - this feature is configured and enabled only if the SSW-flag "Unlock Debug IF" is set.

The SSW processing here is as follows:

- check either external (debug) access to the device will be generally granted (SSW_Internal_flag=1)
 - if Not -> exit this procedure
- check either Halt After Reset is requested (OSTATE.HARR=1)
 - if Not -> exit this procedure
- configure a Break After Make breakpoint at the last SSW instruction
 - write the respective address into Code Segment Protection Lower Bound register MPR_CPR0_0L
 - configure signal assertion from Memory Protection System to Core Debug Controller upon instruction fetch access match with MPR_CPR0_0L (write MPR_CPM0.BLO=1)
 - configure debug action in Trigger Event 0 control register TR0EVT as follows:
 - Halt on break - EVTA := 010_B
 - Break After Make - BBM := 0
 - Suspend output active - SUSP := 1
- enable On-Chip Debug Support system.

Note: The final debug-related operation - unlocking (in case) the debug interface - is performed later - refer to [Chapter 10.1.3.9](#).

7.1.3.8 Ending the SSW and Starting the User Code

The last steps executed by the SSW are:

- activate the Startup Protection
 - as a result, the Watchdog Timer starts to run
- if the Debug Interface is to be unlocked (SSW_Unlock_DIF=1):
 - perform a write to OEC with IF_LCK=0 and IF_LCK_P=1 (protection bit). With this operation OSTATE.IF_LCK gets reset to 0 and the debug interface is unlocked - the IOClient (Cerberus) is allowed to enter RW Mode and therefore can access potentially all the system resources.
- restore default content of registers modified by SSW
- jump to the first User Instruction at address STADD.

7.1.4 Specific SSW Features

Below some specific procedures are described, which are used at several places during the SSW flow. The definition is given separately here for a more readable form of the complete document.

7.1.4.1 Header Check in Alternate Boot Modes

The Alternate Boot Modes (ABMs) are intended to start program code already available at arbitrary user-defined address if a check-condition is satisfied. If the check-condition fails - a Bootstrap Loader routine is invoked in accordance to the current startup mode.

The address of the code to be started together with all information needed to verify the check-condition are contained in dedicated memory areas named ABM Headers. In any Alternate Boot Mode of TC1728 two such Headers are defined - Header 0 and Header 1 (referred as ABM.HD0 and ABM.HD1), respectively user code can be started from up to two different start addresses.

In TC1728 only Internal starts are supported as Startup Configurations, respectively the ABM Headers can be only located in Internal Flash memory of the device, whereas the locations are defined:

- Header 0 - Base address A001'FFE0_H; End address A001'FFFF_H
- Header 1 - Base address A000'FFE0_H; End address A000'FFFF_H

Any of the Headers is 32 Bytes long, containing information in accordance to [Table 10-2](#).

Table 7-2 ABM Headers Structure

Offset Addr.	Size Byte	Field Name	Description
00 _H	4	STADABM	User Code Start Address
04 _H	4	ABMHDID	ABM Header ID = DEAD BEEF _H (Confirmation code)
08 _H	4	ChkStart	Memory Range to be checked - Start Address
0C _H	4	ChkEnd	Memory Range to be checked - End Address
10 _H	4	CRCrang	Check Result for the Memory Range
14 _H	4	CRCrang	Inverted Check Result for the Memory Range
18 _H	4	CRChad	Check Result for the ABM Header (offset 00 _H ..17 _H)
1C _H	4	CRChad	Inverted Check Result for the ABM Header

In any Alternate Boot Mode always the Header 0 is checked first, and if failed - Header 1 is checked next. Where the check gives OK, the full start address is taken from the respective Header field STADABM_x (index x=0,1 for Header 0,1).

If check fails for both the Headers, the further execution depends on the startup mode currently configured in HWCFG: a jump either to ASC- or to Generic- (CAN pins) Bootloader is performed by the SSW.

The validation procedure executes CRC calculation based on a 32-bit polynomial:

$$f(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1 \quad (7.1)$$

This calculation is performed by the SSW using the Memory Checker Module in TC1728.

The complete check-procedure for a Header consists of the following steps:

- check the ABM Header ID at offsets 04_H..07_H (the correct values are given in [Table 10-2](#)):
 - if OK - continue with 2.
 - if Not - exit the check-procedure for this Header with Error.
- calculate the CRC of the first 24 Bytes from the ABM Header - process the fields STADABM...CRCrang at offsets 00_H..17_H
 - compare the result with the CRChad value (offset 18_H)
 - if OK - continue with 2.b)
 - if Not - exit the check-procedure for this Header with Error.
 - inverse the result value and compare with CRChad (offset 1C_H)
 - if OK - continue with 3.
 - if Not - exit the check-procedure for this Header with Error.
- calculate the CRC over the memory address range ChkStart...ChkEnd (start- and end- addresses taken from offsets 08_H and 0C_H respectively)

- a) compare the result with the CRCrange value (offset 10_H)
 - if OK - continue with 3.b)
 - if Not - exit the check-procedure for this Header with Error.
- b) inverse the result value and compare with CRCrange (offset 14_H)
 - if Not - exit the check-procedure for this Header with Error.
 - if OK - the check-procedure PASSEd for this Header !

According to the result returned from this check procedure, the startup software continues either with user-code start from STADABMx address (on success), or with checking the second header (on error in the first one), or with a Bootstrap loader (on error in the second header).

7.1.5 Startup Errors Handling

There are a number of check-points during the Startup Software execution where Errors can be raised (refer to the SSW block-diagrams). The processing upon an Error is as follows:

- an Exit-code according to the error is stored into CBS_COMDATA register (refer to **Table 7-3**)
- the Watchdog Timer Reset is configured to class 3
- all code- and data- fetches from Flash are disabled (if protection is active)
- access to the Flash Config sector is disabled
- startup protection is activated, which activation starts the Watchdog Timer
- the debug interface is unlocked
- an endless loop is executed (jump to itself)

As far as the Watchdog Timer is already enabled, the endless loop is aborted by a WDT reset which triggers a new SSW-execution. If this new startup fails again, the following error-processing will lead to the same endless loop. Respectively, a second WDT reset will occur being already a locked reset, which can be aborted only by a next power-on sequence.

Table 7-3 Errors reported by the TC1728 SSW

Coding in d12/COMDATA	Description
00000001 _H	Bootcode wrongly called after exiting startup mode
00000002 _H	Flash error during rampup
00000003 _H	Error in Flash Configuration sector
00000004 _H	Invalid Startup mode selected
00000005 _H	Reserved
00000006 _H	Reserved

Table 7-3 Errors reported by the TC1728 SSW

Coding in d12/COMDATA	Description
00000008 _H	MultiCAN module not available but CAN Bootloader selected
00000009 _H	ASC module not available but ASC Bootloader selected
00000010 _H	ECC error in BootROM
00000018 _H	CAN0 node not available but CAN Bootloader selected
0000004x _H	Trap of Class x (0..7) raised during SSW

7.2 Bootstrap Loaders

These routines provide mechanisms to load an user program via selected interface by moving code into PMI Scratchpad RAM (an Internal Program memory). The loaded code is started after exiting the BootROM.

Two interfaces can be utilized for downloading in TC1728 - ASC and CAN. Besides two separate procedures are supporting any of these interfaces/protocols, they have a common first part. In other words, there is one entry-point **bl_entry** for all bootloader procedures.

7.2.1 Common Procedures for all Bootloaders

The first such a common procedure is to reconfigure the clock system in case the last reset is a Power-on. This reconfiguration switches from the initial PLL Freerunning mode (VCO base frequency) to Prescaler Mode with $F_{FPI}:F_{OSC}=1:2$.

Therefore the FPI-peripherals (including MultiCAN and ASC modules) run at half the frequency of an external crystal which must be connected between XTAL1/XTAL2 pins if a Bootloader mode will be selected upon Power-on. This 1:2 relation must be taken into account when selecting the host speed for downloading. For example, when using the MultiCAN bootstrap loader F_{OSC} should be greater or equal to 20 MHz for a baud rate of 1 Mbit/s.

Attention: This clock-switch to external oscillator upon Power-on is overwritten by a switch back to PLL freerunning mode at the end of SSW .

Therefore if it is desired after downloading to continue communication with the same baudrate, the user code must first reinstall:

- PLL prescaler mode ($SCU_PLLCON0.VCOBYP:=0$) and
- K1 divider 1:1 ($SCU_PLLCON1.KDIV:=00_{16}$).

Upon any other reset but not power-on, the clock configuration - respectively the system frequency - remains the same as previously selected.

Next, depending on the Bootloader-type currently configured in HWCFG a pin is selected as receive-data input (RxD) which will be evaluated on the following step. Note, that still

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no further pin-configuration is done here - e.g. no assignment to a specific (ASC/CAN) module functionality - but only the pin input-value is directly checked in this procedure.

The procedure waits to receive a low-level pulse at RxD and measures its duration - the time between the falling and rising edges - into the BL_meas work variable.

Then, the SSW checks the startup configuration in HWCFG:

- upon **ASC Bootloader** Mode - a jump to the respective routine (**Chapter 10.2.2**) is directly executed
- upon Generic Bootloader Mode - the type of interface (ASC/CAN) currently used must be detected by the SSW. For this the RxD pin is checked until:
 - low level is found there - then a jump to CAN Bootloader routine will be executed;
 - OR**
 - no edge is found for a time 6 time longer than the value in BL_meas - then ASC Bootloader routine will be executed.

This interface-detection procedure is based on the following principles:

- an ASC-Bootloader Host sends one only start Byte and then waits for a response from the target system
- a CAN-Bootloader Host sends a complete frame, whereas no more than 5 consecutive bits can be sent having equal logical levels - i.e. after two consecutive edges for a given time dT, in any case another edge must follow within the next time-frame of 6*dT.

7.2.2 ASC Bootstrap loader

The ASC Bootloading routine implements the following steps:

- RxD/TxD pins configuration is done in accordance to the TC1728 definitions, as well as depending either the routine is invoked upon "ASC Bootloader"-startup mode (ASC-only pins are used) or following an ASC-protocol detection upon "Generic Bootloader"-mode (CAN/ASC-shared pins are used but configured to ASC module)
- baudrate calculation is done based on the value already captured
- ASC0 is initialized (without enabling the receiver) to the baudrate as determined, 8 data and 1 stop bit
- acknowledge byte D5_H is sent to the host indicating the device is ready to accept a data transfer
- after the acknowledge byte is transmitted, the receiver is enabled
- the bootloader enters a loop waiting to receive exactly 128 bytes which are stored as 32 words in PMI Scratchpad RAM starting from address D400'0000_H

Once 128 bytes are received, the SSW starts the user code from address D400'0000_H.

7.2.3 CAN Bootstrap Loader

The CAN bootstrap loader transfers program code/data via node 0 of the MultiCAN module into the PMI Scratchpad RAM. Data is transferred from the external host to the

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TC1728 using eight-byte data frames. The number of data frames to be received is programmable and determined by the 16-bit data message count value DMSGC.

The communication between TC1728 and external host is based on the following three CAN standard frames:

- Initialization frame - sent by the external host to the TC1728
- Acknowledge frame - sent by the TC1728 to the external host
- Data frame(s) - sent by the external host to the TC1728

The initialization frame is used in the TC1728 for baud rate detection. After a successful baud rate detection is reported to the external host by sending the acknowledge frame, data is transmitted using data frames.

Initialization Phase

The first task is to determine the CAN baud rate at which the external host is communicating. This task requires the external host to send initialization frames continuously to the TC1728. The first two data bytes of the initialization frame include a 2-byte baud rate detection pattern (5555_H), an 11-bit (2-byte) identifier ACKID for the acknowledge frame, a 16-bit data message count value DMSGC, and an 11-bit (2-byte) identifier DMSGID to be used by the data frame(s).

The CAN baud rate is determined by analyzing the received baud rate detection pattern (5555_H) and the baud rate registers of the MultiCAN module are set accordingly. The TC1728 is now ready to receive CAN frames with the baud rate of the external host.

Acknowledge Phase

In the acknowledge phase, the bootstrap loader waits until it receives the next correctly recognized initialization frame from the external host, and acknowledges this frame by generating a dominant bit in its ACK slot. Afterwards, the bootstrap loader transmits an acknowledge frame back to the external host, indicating that it is now ready to receive data frames. The acknowledge frame uses the message identifier ACKID that has been received with the initialization frame.

Data Transmission Phase

In the data transmission phase, data frames are sent by the external host and received by the TC1728. The data frames use the 11-bit data message identifier DMSGID that has been sent with the initialization frame. Eight data bytes are transmitted with each data frame. The first data byte is stored in PMI Scratchpad RAM starting from address D400'0000_H. Consecutive data bytes are stored at incrementing addresses.

Both communication partners evaluate the data message count DMSGC until the requested number of CAN data frames has been transmitted.

After the reception of the last CAN data frame, the SSW starts the user code from address D400'0000_H.

7.3 Influencing the next SSW-execution

By writing 1 to SYSCON.SETLUDIS (no protection), the user software will prevent automatic update of SCU_STSTAT.HWCFG upon the next application (class 3) reset.

If such setting is active when a Bootstrap Loader mode is configured in STSTAT.HWCFG bitfield, after the next class 3 reset the Bootloader routine will not be executed but directly the application-code will be started from SPRAM.

The LUDIS=1 setting will have effect until a system (class 0) reset which will force the SYSCON register to its reset value with LUDIS=0. Therefore, upon class 0 reset the startup HW-configuration (SCU_STSTAT.HWCFG) is always updated from pins.

8 Memory Maps

This chapter gives an overview of the TC1728 memory map, and describes the address locations and access possibilities for the units, memories, and reserved areas as “seen” from the two different on-chip buses’ point of view.

The TC1728 has the following memories

- Program Memory Unit (PMU) with
 - 1.5 Mbyte of Program Flash Memory (PFLASH)
 - 64 Kbyte of Data Flash Memory (DFLASH)
 - 16 Kbyte of Boot ROM (BROM)
 - 8 KB Overlay Memory (OVRAM¹⁾)
- Program Memory Interface (PMI)
 - 24 Kbyte of Scratch-Pad RAM (SPRAM²⁾¹⁾)
 - 8 Kbyte of Instruction Cache (ICACHE²⁾¹⁾)
- Data Memory Interface (DMI)
 - 120 Kbyte of Local Data RAM (LDRAM³⁾¹⁾)
 - 4 Kbyte of Data Cache (DCACHE³⁾)
- PCP memory
 - 24 Kbyte of PCP Code Memory (CMEM¹⁾)
 - 8 Kbyte of PCP Data Memory (PRAM¹⁾)

Furthermore, the TC1728 has two on-chip buses:

- System Peripheral Bus (SPB)
- Local Memory Bus (LMB)

1) Before enabling error detection, the memory has to be initialized by customer SW

2) Up to 8 Kbyte out of the 24 Kbyte SPRAM can be configured as ICACHE. The supported SPRAM / ICACHE configurations are described in the CPU sub-chapter: ‘Program Memory Interface (PMI)’.

3) Up to 4 Kbyte out of the 120 Kbyte LDRAM can be configured as DCACHE. The supported LDRAM / DCACHE configurations are described in the CPU sub-chapter: ‘Data Memory Interface (DMI)’.

8.1 What is new

The target for the AudioFutureAudioMax devices memory map is to keep it compatible to AudioNG and AudioFuture wherever it is possible. This means to keep memory space/flash segment start addresses and peripheral control register address spaces where they were mapped to in AudioNG and AudioFuture.

Major differences of the TC1728 Memory Map compared to AudioNG:

- Address map is adapted to the peripheral set of the products (peripherals where added/removed, number of ports is adapted).
- Target was to keep the start address where possible of all common modules, SRAMs and Flash segments
- Added PMI Byte Read/Write access in [Table 8-5](#)
- Added Double-Word support for PCP-CRAM and PCP-PRAM accesses. Means that CPU has also 64 bit access to the PCP memories ([Table 8-5](#))
- Moved SCU address map inside Segment 15 as SCU requires now 2x256Byte
- Moved ADC and FADC address maps inside Segment 15 as these modules require more 256 byte slices now.
- Adapted memory and flash sizes (SPRAM, LDRAM, CRAM, PRAM, PFlash, DFlash)
- Notes for the Instruction / Data Cache configurations where added.
- OVRAM is moved from Segment 12 to Segment 8 and Segment 10.
- Emulation Device Memory was moved from xFF2-0000 -> xFF5FFFF to xFF0-0000 -> xFF3-FFFF
- An PMI memory mirror image was added (SPRAM + configurable ICACHE) to C000. Added map of the mirrored PMI memory image to segment E800.
- Removed Boot ROM Address Space in segment D as it is not necessary any more.
- Added Online Data Acquisition Address Space (OLDA) to segment 8 and A with a footnote that it is controlled via PMU_OVRCON.OLDAEN bit.
- MultiCAN module address space increased from 8KB -> 16KB
- Changed the SPB view of segment C and D in a way that it is now fully transparent (write accesses to reserved addresses result in LMBBE, read to SPBBE & LMBBE)
- Added Overlay Control Module (OVC) with 256 byte to segment 15 ([Table 8-3](#)) as this functionality is moved now to DMI.

Major differences of the TC1728 Memory Map compared to AudioFuture:

- Address map is adapted to the peripheral set of the products (peripherals where added/removed, number of ports is adapted).
- Address map is compatible for peripherals instantiated in AudioFuture and AudioMax
- Start address of common modules, SRAMs and Flash segments was kept compatible.

8.2 How to Read the Address Maps

The bus-specific address maps describe how the different bus master devices react on accesses to on-chip memories and modules, and which address ranges are valid or invalid for the corresponding buses.

The FPI Bus address map shows the system addresses from the point of view of the SPB master agents. SPB master agents are PCP2 and DMA¹⁾.

The LMB address map shows the system addresses from the point of view of the LMB master agents. LMB master agents are PMI, DMI and DMA¹⁾.

The LFI is a bi-directional bridge between LMB and SPB and therefore not mentioned here as LMB or SPB master in the Address Map. The LFI includes an SPB to LMB address translation mechanism. The SPB to LMB Bus Address Translation Table can be found in the chapter: 'On-Chip System Buses and Bus Bridges' / 'Local Memory to FPI Bus Interface (LFI Bridge)'.

1) DMA including: DMA Move Engines and module connected to the DMA Peripheral Interface like MLI module.

Memory Maps

Table 8-1 defines the acronyms and other terms that are used in the address maps (**Table 8-2** to **Table 8-4**).

Table 8-1 Definition of Acronyms and Terms

Term	Description
...BE	Means "Bus error" generation.
...BET	Means "Bus error & trap" generation.
SPBBE	A bus access is terminated with a bus error on the SPB.
SPBBET	A bus access is terminated with a bus error on the SPB and a DSE trap (read access) or DAE trap (write access).
LMBBE	A bus access is terminated with a bus error on the LMB.
LMBBET	A bus access is terminated with a bus error on the LMB and a DSE trap (read access) or DAE trap (write access).
access	A bus access is allowed and is executed.
ignore	A bus access is ignored and is not executed. No bus error is generated.
trap	A DSE trap (read access) or DAE trap (write access) is generated.
32	Only 32-bit word bus accesses are permitted to that register/address range.
nE	A bus access generates no bus error, although the bus access points to an undefined address or address range. This is valid e.g. for CPU accesses (MTCR/MFCR) to undefined addresses in the CSFR range.

8.3 Contents of the Segments

This section summarizes the contents of the segments.

Segments 0-7

These segments are reserved segments in the TC1728.

Segment 8

From the SPB point of view (PCP), this memory segment allows accesses to all PMU memories (PFLASH, DFLASH, BROM, TROM and OVRAM).

From the LMB point of view (CPU-PMI¹⁾²⁾, CPU-DMI¹⁾²⁾, DMA including Cerberus and MLI), this memory segment allows cached accesses to all PMU memories (PFLASH, DFLASH, BROM, TROM and OVRAM).

Segment 9

This memory segment is reserved in the TC1728.

Segment 10

From the SPB point of view (PCP), this memory segment allows non-cached accesses to all PMU memories (PFLASH, DFLASH, BROM, TROM and OVRAM).

From the LMB point of view (CPU-PMI, CPU-DMI, DMA including Cerberus and MLI), this memory segment allows non-cached accesses to all PMU memories (PFLASH, DFLASH, BROM, TROM and OVRAM).

From the DMA point of view, Move Engine, Cerberus and MLI accesses to this segment are processed by the DMA LMB master interface on the LMB Bus.

Segment 11

This memory segment is reserved in the TC1728.

Segment 12

From the SPB point of view (PCP), this memory segment allows non-cached accesses to the PMI scratch-pad RAM (SPRAM).

1) CPU access to OLDA address space via segment 8 (cached) results in LMB Bus Error Trap independent of the PMU_OVRCON.OLDAEN bit setting.

2) For CPU accesses to segment 8 the specific PMI and DMI features for segment 8 accesses have to be taken into account.

Memory Maps

From the LMB point of view (CPU-PMI, CPU-DMI, DMA including Cerberus and MLI), this memory segment allows non-cached accesses to the PMI scratch-pad RAM (SPRAM).

From the DMA point of view, Move Engine, Cerberus and MLI accesses to this segment are processed by the DMA LMB master interface on the LMB Bus.

Segment 13

From the SPB point of view (PCP), this memory segment allows non-cached accesses to the PMI scratch-pad RAM (SPRAM) and the DMI memory (LDRAM).

From the LMB point of view (CPU-PMI, CPU-DMI, DMA including Cerberus and MLI), this memory segment allows non-cached accesses to the PMI scratch-pad RAM (SPRAM) and the DMI memory (LDRAM) as well as read access to the boot ROM and test ROM (BROM and TROM).

From the DMA point of view, Move Engine, Cerberus and MLI accesses to this segment are processed by the DMA LMB master interface on the LMB Bus.

Segment 14

From the SPB point of view (PCP, DMA including Cerberus and MLI), this memory segment allows accesses the DMI Local Data RAM (LDRAM), and the PMI scratch-pad RAM (SPRAM). All accesses to this segment will be translated by the LFI into Segment 12 and Segment 13 accesses. The detailed SPB to LMB Bus Address Translation is described in the Chapter: Local Memory to FPI Bus Interface (LFI).

From the CPU point of view (PMI and DMI), this memory segment is reserved in the TC1728.

From the DMA point of view, Move Engine, Cerberus and MLI accesses to this segment are processed by the DMA FPI master interface on the SPB Bus.

Segment 15

From the SPB point of view (PCP, DMA, Cerberus and MLI), this memory segment allows accesses to all SFRs, CSFRs, the PCP memories and the MLI transfer windows.

From the CPU point of view (PMI and DMI), this memory segment allows accesses to all SFRs, CSFRs, the PCP memories, and the MLI transfer windows.

From the DMA point of view, Move Engine, Cerberus and MLI accesses to this segment are processed by the DMA FPI master interface on the SPB Bus.

8.4 Address Map of the FPI Bus System

This chapter describes the system address map from FPI Bus (SPB) point of view.

8.4.1 Segments 0 to 14

Table 8-2 shows the address map of segments 0 to 14 as it is seen from the SPB bus masters PCP, DMA and OCDS.

Table 8-2 SPB Address Map of Segment 0 to 14

Segment	Address Range	Size	Description	Access Type	
				Read	Write ¹⁾
0-7	0000 0000 _H - 0000 0007 _H	8 byte	Reserved (virtual address space)	MPN trap	MPN trap
	0000 0008 _H - 7FFF FFFF _H	8 × 256 Mbyte		SPBBE	SPBBE
8	8000 0000 _H - 8017 FFFF _H	1,5 Mbyte	Program Flash (PFLASH)	access	access ¹⁾
	8018 0000 _H - 803F FFFF _H	2,5 Mbyte	Reserved	LMBBE & SPBBE	access ²⁾
	8040 0000 _H - 807F FFFF _H	4 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
	8080 0000 _H - 8FDF FFFF _H	246 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
	8FE0 0000 _H - 8FE0 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 0	access	access ¹⁾
	8FE0 8000 _H - 8FE0 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE
	8FE1 0000 _H - 8FE1 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 1	access	access ¹⁾
	8FE1 8000 _H - 8FE1 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE
	8FE2 0000 _H - 8FE6 FFFF _H	–	Reserved	LMBBE & SPBBE	LMBBE
	8FE7 0000 _H - 8FE7 7FFF _H	32 Kbyte	Online Data Acquisition (OLDA)	LMBBE & SPBBE	access ³⁾ / LMBBE & SPBBE
	8FE7 8000 _H - 8FE7 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE

Memory Maps

Table 8-2 SPB Address Map of Segment 0 to 14 (cont'd)

Seg- ment	Address Range	Size	Description	Access Type	
				Read	Write ¹⁾
	8FE8 0000 _H - 8FE8 1FFF _H	8 Kbyte	Overlay memory (OVRAM)	access	access
	8FE8 2000 _H - 8FEF FFFF _H	–	Reserved	LMBBE & SPBBE	LMBBE
	8FF0 0000 _H - 8FF5 FFFF _H	384 Kbyte	Reserved for TC1728 emulation device memory	SPBBE	SPBBE
	8FF6 0000 _H - 8FFF BFFF _H	–	Reserved	SPBBE	SPBBE
	8FFF C000 _H - 8FFF FFFF _H	16 Kbyte	Boot ROM (BROM)	access	SPBBE
9	9000 0000 _H - 9FFF FFFF _H	256 Mbyte	Reserved	SPBBE	SPBBE
10	A000 0000 _H - A017 FFFF _H	1,5 Mbyte	Program Flash (PFLASH)	access	access ¹⁾
	A018 0000 _H - A03F FFFF _H	2,5 Mbyte	Reserved	LMBBE & SPBBE	access ²⁾
	A080 0000 _H - AFDF FFFF _H	246 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
	AFE0 0000 _H - AFE0 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 0	access	access ¹⁾
	AFE0 8000 _H - AFE0 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE
	AFE1 0000 _H - AFE1 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 1	access	access ¹⁾
	AFE1 8000 _H - AFE1 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE
	AFE2 0000 _H - AFE6 FFFF _H	–	Reserved	LMBBE & SPBBE	LMBBE
	AFE7 0000 _H - AFE7 7FFF _H	32 Kbyte	Online Data Acquisition (OLDA)	LMBBE & SPBBE	access ³⁾ / LMBBE & SPBBE
	AFE7 8000 _H - AFE7 FFFF _H	32 Kbyte	Reserved	LMBBE & SPBBE	LMBBE

Memory Maps

Table 8-2 SPB Address Map of Segment 0 to 14 (cont'd)

Seg- ment	Address Range	Size	Description	Access Type	
				Read	Write ¹⁾
	AFE8 0000 _H - AFE8 1FFF _H	8 Kbyte	Overlay memory (OVRAM)	access	access
	AFE8 2000 _H - AFE8 FFFF _H	–	Reserved	LMBBE & SPBBE	LMBBE
	AFF0 0000 _H - AFF5 FFFF _H	384 Kbyte	Reserved for TC1728 emulation device memory	LMBBE & SPBBE	LMBBE
	AFF6 0000 _H - AFFB BFFF _H	–	Reserved	LMBBE & SPBBE	LMBBE
	AFFF C000 _H - AFFF FFFF _H	16 Kbyte	Boot ROM (BROM)	access	LMBBE
11	B000 0000 _H - BFFF FFFF _H	256 Mbyte	Reserved	SPBBE	SPBBE
12	C000 0000 _H - C000 1FFF _H	8 Kbyte	PMI Scratch-Pad RAM (SPRAM)	access	access
	C000 2000 _H - C000 3FFF _H	8 Kbyte		access	access
	C000 4000 _H - C000 4FFF _H	4 Kbyte		access ⁴⁾	access ⁴⁾
	C000 5000 _H - C000 57FF _H	2 Kbyte		access ⁵⁾	access ⁵⁾
	C000 5800 _H - C000 5FFF _H	2 Kbyte		access ⁶⁾	access ⁶⁾
	C000 6000 _H - CFFF FFFF _H	≈ 256 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
13	D000 0000 _H - D001 CFFF _H	116 Kbyte	DMI Local Data RAM (LDRAM)	access	access
	D001 D000 _H - D001 D7FF _H	2 Kbyte		access ⁷⁾	access ⁷⁾
	D001 D800 _H - D001 DFFF _H	2 Kbyte		access ⁸⁾	access ⁸⁾
	D001 E000 _H - D3FF FFFF _H	≈ 64 Mbyte	Reserved	LMBBE & SPBBE	LMBBE

Memory Maps

Table 8-2 SPB Address Map of Segment 0 to 14 (cont'd)

Seg- ment	Address Range	Size	Description	Access Type	
				Read	Write ¹⁾
	D400 0000 _H - D400 1FFF _H	8 Kbyte	PMI Scratch-Pad RAM (SPRAM)	access	access
	D400 2000 _H - D400 3FFF _H	8 Kbyte		access	access
	D400 4000 _H - D400 4FFF _H	4 Kbyte		access ⁴⁾	access ⁴⁾
	D400 5000 _H - D400 57FF _H	2 Kbyte		access ⁵⁾	access ⁵⁾
	D400 5800 _H - D400 5FFF _H	2 Kbyte		access ⁶⁾	access ⁶⁾
	D400 6000 _H - D7FF FFFF _H	≈ 64 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
14	D800 0000 _H - DFFF FFFF _H	128 Mbyte	Reserved	LMBBE & SPBBE	LMBBE
	E000 0000 _H - E7FF FFFF _H	128 MB	Reserved	LMBBE	LMBBE
	E800 0000 _H - E83F FFFF _H	4 MB	Reserved	LMBBE	LMBBE
	E840 0000 _H - E841 CFFF _H	116 Kbyte	DMI Local Data RAM (LDRAM)	access	access
	E841 D000 _H - E841 D7FF _H	2 Kbyte		access ⁷⁾	access ⁷⁾
	E841 D800 _H - E841 DFFF _H	2 Kbyte		access ⁸⁾	access ⁸⁾
	E841 E000 _H - E85F FFFF _H	≈ 1 Mbyte	Reserved	LMBBE	LMBBE

Memory Maps

Table 8-2 SPB Address Map of Segment 0 to 14 (cont'd)

Segment	Address Range	Size	Description	Access Type	
				Read	Write ¹⁾
	E850 0000 _H - E850 1FFF _H	8 Kbyte	PMI Scratch-Pad RAM (SPRAM)	access	access
	E850 2000 _H - E850 3FFF _H	8 Kbyte		access	access
	E850 4000 _H - E850 4FFF _H	4 Kbyte		access ⁴⁾	access ⁴⁾
	E850 5000 _H - E850 57FF _H	2 Kbyte		access ⁵⁾	access ⁵⁾
	E850 5800 _H - E850 5FFF _H	2 Kbyte		access ⁶⁾	access ⁶⁾
	E850 6000 _H - E85F FFFF _H	≈ 1 Mbyte	Reserved	LMBBE	LMBBE
	E860 C000 _H - EFFF FFFF _H	≈ 122 Mbyte	Reserved	LMBBE	LMBBE
15	F000 0000 _H - FFFF FFFF _H	256 Mbyte	see Table 8-3		

1) Write access to PFlash / DFlash only applicable when writing Flash command sequences.

2) Write is handled by PMU (Flash command sequence, see PMU chapter for details)

3) Online Data Acquisition address space can be disabled/enabled via PMU control register bit PMU_OVRCON.OLDAEN. CPU access to OLDA address space via segment 8 (cached) results in LMBBET independent of the PMU_OVRCON.OLDAEN bit setting.

4) Not available when Instruction Cache is configured for 8 Kbyte

5) Not available when Instruction Cache is configured for 4 Kbyte or 8 Kbyte

6) Not available when Instruction Cache is configured for 2 Kbyte, 4 Kbyte or 8 Kbyte

7) Not available when Data Cache is configured for 2 Kbyte or 4 Kbyte

8) Not available when Data Cache is configured for 2 Kbyte

8.4.2 Segment 15

Table 8-3 shows the address map of segment 15 as seen from the SPB bus masters PCP, DMA and OCDS. Please note that access in **Table 8-3** means only that an access to an address within the defined address range is not automatically incorrect or ignored.

Table 8-3 SPB Address Map of Segment 15

Unit	Address Range	Size	Access Type	
			Read	Write
Reserved	F000 0000 _H - F000 00FF _H	–	SPBBE	SPBBE
System Peripheral Bus Control Unit (SBCU)	F000 0100 _H - F000 01FF _H	256 byte	access	access
System Timer (STM)	F000 0200 _H - F000 02FF _H	256 byte	access	access
Reserved	F000 0300 _H - F000 03FF _H	–	SPBBE	SPBBE
On-Chip Debug Support (Cerberus)	F000 0400 _H - F000 04FF _H	256 byte	access	access
System Control Unit (SCU) and Watchdog Timer (WDT)	F000 0500 _H - F000 06FF _H	2 × 256 byte	access	access
Reserved	F000 0700 _H - F000 07FF _H	–	SPBBE	SPBBE
MicroSecond Bus Controller 0 (MSC0)	F000 0800 _H - F000 08FF _H	256 byte	access	access
Reserved	F000 0900 _H - F000 09FF _H	–	SPBBE	SPBBE
Async./Sync. Serial Interface 0 (ASC0)	F000 0A00 _H - F000 0AFF _H	256 byte	access	access
Async./Sync. Serial Interface 1 (ASC1)	F000 0B00 _H - F000 0BFF _H	256 byte	access	access
Port 0	F000 0C00 _H - F000 0CFF _H	256 byte	access	access
Port 1	F000 0D00 _H - F000 0DFF _H	256 byte	access	access
Port 2	F000 0E00 _H - F000 0EFF _H	256 byte	access	access

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit	Address Range	Size	Access Type	
			Read	Write
Port 3	F000 0F00 _H - F000 0FFF _H	256 byte	access	access
Port 4	F000 1000 _H - F000 10FF _H	256 byte	access	access
Port 5	F000 1100 _H - F000 11FF _H	256 byte	access	access
Port 6	F000 1200 _H - F000 12FF _H	256 byte	access	access
Reserved	F000 1300 _H - F000 13FF _H	–	SPBBE	SPBBE
Port 8	F000 1400 _H - F000 14FF _H	256 byte	access	access
Port 9	F000 1500 _H - F000 15FF _H	256 byte	access	access
Port 10	F000 1600 _H - F000 16FF _H	256 byte	access	access
Port 11	F000 1700 _H - F000 17FF _H	256 byte	access	access
General Purpose Timer Array (GPTA0)	F000 1800 _H - F000 1FFF _H	8 × 256 byte	access	access
Reserved	F000 2000 _H - F000 27FF _H	–	SPBBE	SPBBE
Reserved	F000 2800 _H - F000 2FFF _H	–	SPBBE	SPBBE
Capture/Compare Unit 6 0 (CCU60)	F000 3000 _H - F000 30FF _H	256 byte	access	access
Capture/Compare Unit 6 1 (CCU61)	F000 3100 _H - F000 31FF _H	256 byte	access	access
Reserved	F000 3200 _H - F000 33FF _H	–	SPBBE	SPBBE
General Purpose Timer 12 0 (GPT120)	F000 3400 _H - F000 34FF _H	256 byte	access	access

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit		Address Range	Size	Access Type	
				Read	Write
General Purpose Timer 12 1 (GPT121)		F000 3500 _H - F000 35FF _H	256 byte	access	access
Reserved		F000 3600 _H - F000 37FF _H	–	SPBBE	SPBBE
Reserved		F000 3800 _H - F000 3BFF _H	–	SPBBE	SPBBE
Direct Memory Access Controller (DMA)		F000 3C00 _H - F000 3EFF _H	3 × 256 byte	access	access
Reserved		F000 3F00 _H - F000 3FFF _H	–	SPBBE	SPBBE
MultiCAN Controller (CAN)		F000 4000 _H - F000 7FFF _H	16 Kbyte	access	access
Reserved		F000 8000 _H - F000 FFFF _H	–	SPBBE	SPBBE
FlexRay™ Protocol Controller (E-Ray)		F001 0000 _H - F001 7FFF _H	32 Kbyte	access	access
Reserved		F001 8000 _H - F003 FFFF _H	–	SPBBE	SPBBE
PCP	Reserved	F004 0000 _H - F004 3EFF _H	–	SPBBE	SPBBE
	PCP Registers	F004 3F00 _H - F004 3FFF _H	256 byte	access	access
	Reserved	F004 4000 _H - F004 FFFF _H	–	SPBBE	SPBBE
	PCP Data Memory (PRAM)	F005 0000 _H - F005 1FFF _H	8 Kbyte	nE, 32	nE, 32
	Reserved	F005 2000 _H - F005 FFFF _H	–	SPBBE	SPBBE
	PCP Code Memory (CMEM)	F006 0000 _H - F006 5FFF _H	24 Kbyte	nE, 32	nE, 32
	Reserved	F006 6000 _H - F007 FFFF _H	–	SPBBE	SPBBE

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit	Address Range	Size	Access Type	
			Read	Write
Reserved	F008 0000 _H - F00F FFFF _H	–	SPBBE	SPBBE
Synchronous Serial Interface 3 (SSC3)	F010 0000 _H - F010 00FF _H	256 byte	access	access
Synchronous Serial Interface 0 (SSC0)	F010 0100 _H - F010 01FF _H	256 byte	access	access
Synchronous Serial Interface 1 (SSC1)	F010 0200 _H - F010 02FF _H	256 byte	access	access
Synchronous Serial Interface 2 (SSC2)	F010 0300 _H - F010 03FF _H	256 byte	access	access
Fast Analog-to-Digital Converter (FADC)	F010 0400 _H - F010 04FF _H	256 byte	access	access
Reserved	F010 0500 _H - F010 0FFF _H	–	SPBBE	SPBBE
Analog-to-Digital Converter 0 (ADC0)	F010 1000 _H - F010 13FF _H	4 × 256 byte	access	access
Analog-to-Digital Converter 1 (ADC1)	F010 1400 _H - F010 17FF _H	4 × 256 byte	access	access
Reserved	F010 1800 _H - F010 9FFF _H	–	SPBBE	SPBBE
Reserved	F010 A000 _H - F010 BFFF _H	–	SPBBE	SPBBE
Micro Link Interface 0 (MLI0)	F010 C000 _H - F010 C0FF _H	256 byte	access	access
Reserved	F010 C100 _H - F010 C1FF _H	–	SPBBE	SPBBE
Memory Checker (MCHK)	F010 C200 _H - F010 C2FF _H	256 byte	access	access
Reserved	F010 C300 _H - F01D FFFF _H	–	SPBBE	SPBBE
MLI0 Small Transfer Windows	F01E 0000 _H - F01E 7FFF _H	4 × 8 Kbyte	access	access

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit	Address Range	Size	Access Type	
			Read	Write
Reserved	F01E 8000 _H - F01F FFFF _H	–	SPBBE	SPBBE
MLIO Large Transfer Windows	F020 0000 _H - F023 FFFF _H	4 × 64 Kbyte	access	access
Reserved	F024 0000 _H - F02F FFFF _H	-	SPBBE	SPBBE
Port 12	F030 0000 _H - F030 00FF _H	256 byte	access	access
Reserved	F030 0100 _H - F031 0FFF _H	–	SPBBE	SPBBE
Reserved	F031 1000 _H - F031 FFFF _H	–	SPBBE	SPBBE
Flexible CRC Engine (FCE)	F032 0000 _H - F032 00FF _H	256 byte	access	access
Reserved	F032 0100 _H - F032 01FF _H	–	SPBBE	SPBBE
Reserved	F032 0200 _H - F032 02FF _H	-	SPBBE	SPBBE
Reserved	F032 0300 _H - F032 0FFF _H	–	SPBBE	SPBBE
Reserved	F032 1000 _H - F032 19FF _H	-	SPBBE	SPBBE
Reserved	F032 1A00 _H - F032 2FFF _H	–	SPBBE	SPBBE
Bus Monitor Unit Registers (BMU)	F032 3000 _H - F032 31FF _H	2x256 byte	access	access
Reserved	F032 3200 _H - F032 3FFF _H	–	SPBBE	SPBBE
Bus Monitor Unit Memory (BMURAM)	F032 4000 _H - F032 4FFF _H	4 Kbyte	access	access
Reserved	F032 5000 _H - F7E0 FFFF _H	–	SPBBE	SPBBE

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit		Address Range	Size	Access Type	
				Read	Write
CPU	CPU Slave Interface Registers (CPS)	F7E0 FF00 _H - F7E0 FFFF _H	256 byte	access	access
	CPU Core SFRs & GPRs	F7E1 0000 _H - F7E1 FFFF _H	64 Kbyte	access	access
Reserved		F7E2 0000 _H - F7FF FFFF _H	–	SPBBE	SPBBE
Reserved		F800 0000 _H - F800 03FF _H	–	SPBBE	SPBBE
Reserved		F800 0400 _H - F800 04FF _H	–	LMBBE & SPBBE	LMBBE
Program Memory Unit (PMU)		F800 0500 _H - F800 05FF _H	256 byte	access	access
Reserved		F800 0600 _H - F800 0FFF _H	–	LMBBE & SPBBE	LMBBE
Flash Register (PMU)		F800 1000 _H - F800 23FF _H	5 Kbyte	access	access
Reserved		F800 2400 _H - F801 00FF _H	–	LMBBE & SPBBE	LMBBE
Reserved		F801 0100 _H - F801 01FF _H	–	LMBBE & SPBBE	LMBBE
Reserved		F801 0200 _H - F87F F9FF _H	–	LMBBE & SPBBE	LMBBE
Reserved		F87F FA00 _H - F87F FAFF _H	–	LMBBE & SPBBE	LMBBE
Overlay Control Unit (OVC)		F87F FB00 _H - F87F FBFF _H	256 byte	access	access
CPU	DMI Registers	F87F FC00 _H - F87F FCFF _H	256 byte	access	access
	PMI Registers	F87F FD00 _H - F87F FDFE _H	256 byte	access	access
Local Memory Bus Control Unit (LBCU)		F87F FE00 _H - F87F FEFF _H	256 byte	access	access

Memory Maps

Table 8-3 SPB Address Map of Segment 15 (cont'd)

Unit	Address Range	Size	Access Type	
			Read	Write
LFI Bridge	F87F FF00 _H - F87F FFFF _H	256 byte	access	access
Reserved	F880 0000 _H - FFFF FFFF _H	—	LMBBE & SPBBE	LMBBE

Memory Maps

8.5 Address Map of the Local Memory Bus (LMB)

Table 8-4 shows the address map as seen from the LMB bus masters (PMI, DMI, DMA, MLI and Cerberus).

Table 8-4 LMB Address Map

Segment	Address Range	Size	Description	Action	
				Read	Write ¹⁾
0-7	0000 0000 _H - 0000 0007 _H	8 byte	Reserved (virtual address space)	MPN trap	MPN trap
	0000 0008 _H - 7FFF FFFF _H	8 × 256 Mbyte		SPBBET	SPBBE
8	8000 0000 _H - 8017 FFFF _H	1,5 Mbyte	Program Flash (PFLASH)	access	access ¹⁾
	8018 0000 _H - 803F FFFF _H	2,5 Mbyte	Reserved	LMBBE	access ²⁾
	8080 0000 _H - 8FDF FFFF _H	246 Mbyte	Reserved	LMBBET	LMBBET
	8FE0 0000 _H - 8FE0 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 0	access	access ¹⁾
	8FE0 8000 _H - 8FE0 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	8FE1 0000 _H - 8FE1 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 1	access	access ¹⁾
	8FE1 8000 _H - 8FE1 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	8FE2 0000 _H - 8FE6 FFFF _H	—	Reserved	LMBBET	LMBBET
	8FE7 0000 _H - 8FE7 7FFF _H	32 Kbyte	Online Data Acquisition (OLDA)	LMBBET	access ³⁾ / LMBBET
	8FE7 8000 _H - 8FE7 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	8FE8 0000 _H - 8FE8 1FFF _H	8 Kbyte	Overlay memory (OVRAM)	access	access
	8FE8 2000 _H - 8FEF FFFF _H	—	Reserved	LMBBET	LMBBET
	8FF0 0000 _H - 8FF5 FFFF _H	384 Kbyte	Reserved for TC1728 emulation device memory	LMBBET	LMBBET

Memory Maps

Table 8-4 LMB Address Map (cont'd)

Seg- ment	Address Range	Size	Description	Action	
				Read	Write ¹⁾
	8FF6 0000 _H - 8FFF BFFF _H	–	Reserved	LMBBET	LMBBET
	8FFF C000 _H - 8FFF FFFF _H	16 Kbyte	Boot ROM (BROM)	access	LMBBET
9	9000 0000 _H - 9FFF FFFF _H	256 Mbyte	Reserved	SPBBET	SPBBE
10	A000 0000 _H - A017 FFFF _H	1,5 Mbyte	Program Flash (PFLASH)	access	access ¹⁾
	A018 0000 _H - A03F FFFF _H	2,5 Mbyte	Reserved	LMBBE	access ²⁾
	A080 0000 _H - AFDF FFFF _H	246 Mbyte	Reserved	LMBBET	LMBBET
	AFE0 0000 _H - AFE0 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 0	access	access ¹⁾
	AFE0 8000 _H - AFE0 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	AFE1 0000 _H - AFE1 7FFF _H	32 Kbyte	Data Flash (DFLASH) Bank 1	access	access ¹⁾
	AFE1 8000 _H - AFE1 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	AFE2 0000 _H - AFE6 FFFF _H	–	Reserved	LMBBET	LMBBET
	AFE7 0000 _H - AFE7 7FFF _H	32 Kbyte	Online Data Acquisition (OLDA)	LMBBET	access ³⁾ / LMBBET
	AFE7 8000 _H - AFE7 FFFF _H	32 Kbyte	Reserved	LMBBET	LMBBET
	AFE8 0000 _H - AFE8 1FFF _H	8 Kbyte	Overlay memory (OVRAM)	access	access
	AFE8 2000 _H - AFEF FFFF _H	–	Reserved	LMBBET	LMBBET
	AFF0 0000 _H - AFF5 FFFF _H	384 Kbyte	Reserved for TC1728 emulation device memory	LMBBET	LMBBET

Memory Maps

Table 8-4 LMB Address Map (cont'd)

Seg- ment	Address Range	Size	Description	Action	
				Read	Write ¹⁾
	AFF6 0000 _H - AFFB BFFF _H	–	Reserved	LMBBET	LMBBET
	AFFF C000 _H - AFFF FFFF _H	16 Kbyte	Boot ROM (BROM)	access	LMBBET
11	B000 0000 _H - BFFF FFFF _H	256 Mbyte	Reserved	SPBBET	SPBBE
12	C000 0000 _H - C000 1FFF _H	8 Kbyte	PMI Scratch-Pad RAM (SPRAM)	access	access
	C000 2000 _H - C000 3FFF _H	8 Kbyte		access	access
	C000 4000 _H - C000 4FFF _H	4 Kbyte		access ⁴⁾	access ⁴⁾
	C000 5000 _H - C000 57FF _H	2 Kbyte		access ⁵⁾	access ⁵⁾
	C000 5800 _H - C000 5FFF _H	2 Kbyte		access ⁶⁾	access ⁶⁾
	C000 6000 _H - CFFF FFFF _H	≈ 256 Mbyte	Reserved	LMBBET	LMBBET
13	D000 0000 _H - D001 CFFF _H	116 Kbyte	DMI Local Data RAM (LDRAM)	access	access
	D001 D000 _H - D001 D7FF _H	2 Kbyte		access ⁷⁾	access ⁷⁾
	D001 D800 _H - D001 DFFF _H	2 Kbyte		access ⁸⁾	access ⁸⁾
	D001 E000 _H - D3FF FFFF _H	≈ 64 Mbyte	Reserved	LMBBET	LMBBET

Memory Maps

Table 8-4 LMB Address Map (cont'd)

Seg- ment	Address Range	Size	Description	Action	
				Read	Write ¹⁾
	D400 0000 _H - D400 1FFF _H	8 Kbyte	PMI Scratch-Pad RAM (SPRAM)	access	access
	D400 2000 _H - D400 3FFF _H	8 Kbyte		access	access
	D400 4000 _H - D400 4FFF _H	4 Kbyte		access ⁴⁾	access ⁴⁾
	D400 5000 _H - D400 57FF _H	2 Kbyte		access ⁵⁾	access ⁵⁾
	D400 5800 _H - D400 5FFF _H	2 Kbyte		access ⁶⁾	access ⁶⁾
	D400 6000 _H - D7FF FFFF _H	≈ 64 Mbyte	Reserved	SPBBE	LMBBET
	D800 0000 _H - DFFF FFFF _H	128 Mbyte	Reserved	LMBBET	LMBBET
14	E000 0000 _H - E7FF FFFF _H	128 Mbyte	Reserved	LMBBET	LMBBET
	E800 0000 _H - EFFF FFFF _H	128 Mbyte	Reserved	LMBBET	LMBBET
15	F000 0000 _H - F7FF FFFF _H	128 Mbyte	Address map is identical to FPI Bus segment 15 address map (see Table 8-3) Reserved areas give an bus error.	SPBBET	SPBBE
	F800 0000 _H - F800 04FF _H	1,25 Kbyte	Reserved	LMBBET	LMBBET
	F800 0500 _H - F800 05FF _H	256 byte	Program Memory Unit (PMU)	access	access
	F800 0600 _H - F800 0FFF _H	≈ 2 Kbyte	Reserved	LMBBET	LMBBET
	F800 1000 _H - F800 23FF _H	5 Kbyte	Flash Registers (PMU)	access	access
	F800 2400 _H - F87F FAFF _H	≈ 8 Mbyte	Reserved	LMBBET	LMBBET

Memory Maps

Table 8-4 LMB Address Map (cont'd)

Seg- ment	Address Range	Size	Description	Action	
				Read	Write ¹⁾
	F87F FB00 _H - F87F FBFF _H	256 byte	Overlay Control Unit (OVC)	access	access
	F87F FC00 _H - F87F FCFF _H	256 byte	Data Memory Interface Unit (DMI)	access	access
	F87F FD00 _H - F87F FDF _H	256 byte	Program Memory Interface Unit (PMI)	access	access
	F87F FE00 _H - F87F FEFF _H	256 byte	LBCU register space	access	access
	F87F FF00 _H - F87F FFFF _H	256 byte	LFI Bus Bridge	access	access
	F880 0000 _H - FFFF FFFF _H	≈ 119 Mbyte	Reserved	LMBBET	LMBBET

1) Write access to PFlash / DFlash only applicable when writing Flash command sequences.

2) Write is handled by PMU (Flash command sequence, see PMU chapter for details)

3) Online Data Acquisition address space can be disabled/enabled via PMU control register bit PMU_OVRCON.OLDAEN. CPU access to OLDA address space via segment 8 (cached) results in LMBBET independent of the PMU_OVRCON.OLDAEN bit setting.

4) Not available when Instruction Cache is configured for 8 Kbyte

5) Not available when Instruction Cache is configured for 4 Kbyte or 8 Kbyte

6) Not available when Instruction Cache is configured for 2 Kbyte, 4 Kbyte or 8 Kbyte

7) Not available when Data Cache is configured for 2 Kbyte or 4 Kbyte

8) Not available when Data Cache is configured for 2 Kbyte

8.6 Memory Module Access Restrictions

Table 8-5 describes which type of accesses are possible to the different memories in the TC1728.

Table 8-5 Possible Memory Accesses

Memory		Bit	Byte		Half-word		Word		Double-word	
		rmw	r	w	r	w	r	w	r	w
PMI ¹⁾	SPRAM	?	?	?	?	?	?	?	?	?
DMI ¹⁾	LDRAM	?	?	?	?	?	?	?	?	?
PMU	ROM	—	?	—	?	—	?	—	?	—
	PFLASH	—	?	—	?	—	?	?	?	?
	DFLASH	—	?	—	?	—	?	?	?	?
	OVRAM ¹⁾	—	?	?	?	?	?	?	?	?
PCP ²⁾	CMEM	?	—	—	—	—	?	?	?	?
	PRAM	?	—	—	—	—	?	?	?	?

1) The module also supports LMB 2-Word and 4-Word Block read and write accesses.

2) The module also supports FPI 4-Word and 8-Word Block read and write accesses.

8.7 Side Effects from Modules to LDRAM

Please note that the LDRAM is also used by Boot routine and can be used by the CPU for system tasks:

- the Boot routine copies some devices informations during the startup into the LDRAM (see chapter 'BootROM Content')

LDRAM can be used as context save area (for details see chapter 'CPU Subsystem')

9 General Purpose I/O Ports and Peripheral I/O Lines (Ports)

The TC1728 has 133 digital General Purpose Input/Output (GPIO) port lines which are connected to the on-chip peripheral units.

9.1 Basic Port Operation

Figure 9-1 is a general block diagram of a TC1728 GPIO port slice.

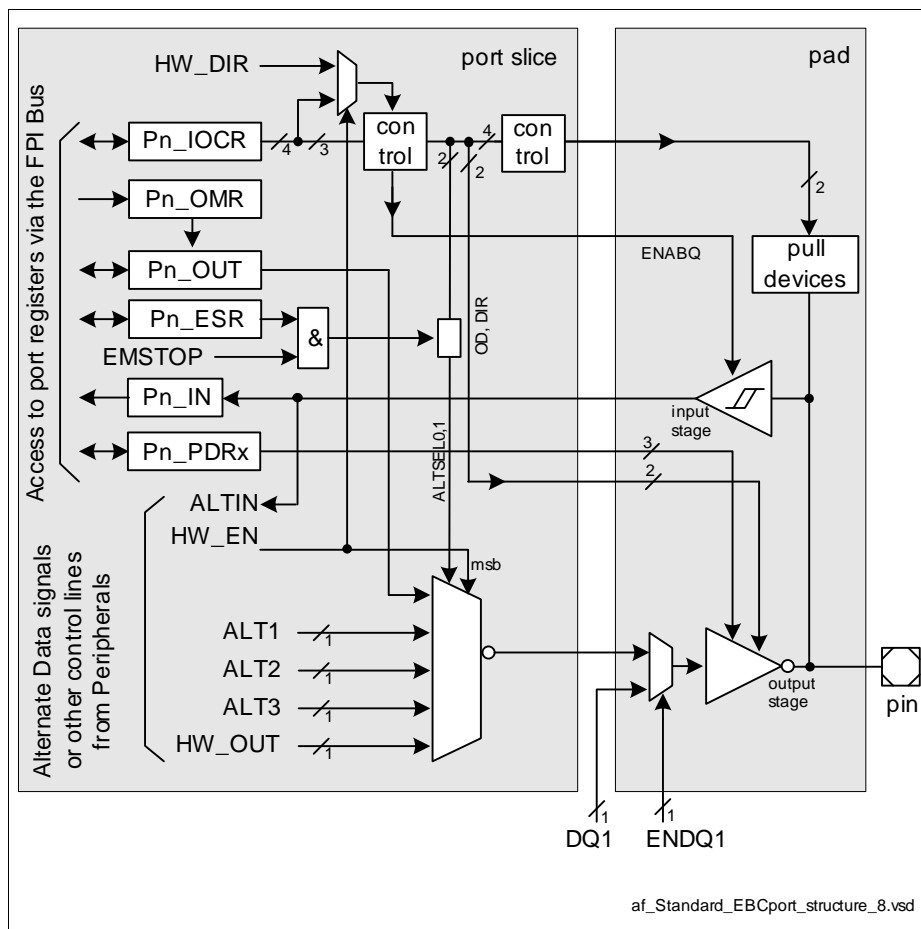


Figure 9-1 General Structure of a Port Pin

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Each port line has a number of control and data bits, enabling very flexible usage of the line. Each port pin can be configured for input or output operation. In input mode (default after reset), the output driver is switched off (high-impedance). The actual voltage level present at the port pin is translated into a logical 0 or 1 via a Schmitt-Trigger device and can be read via the read-only register Pn_IN. An input signal can also be connected directly to the various inputs of the peripheral units (AltDataIn). The function of the input line from the pin to the input register Pn_IN and to AltDataIn is independent of whether the port pin operates as input or output. This means that when the port is in output mode, the level of the pin can be read by software via Pn_IN or a peripheral can use the pin level as an input.

In output mode, the output driver is activated and drives the value supplied through the multiplexer to the port pin. Switching between input and output mode is accomplished through the Pn_IOCR register, which enables or disables the output driver. If a peripheral unit uses a GPIO port line as a bi-directional I/O line, register Pn_IOCR has to be written for input or output selection. The Pn_IOCR register further controls the driver type of the output driver, and determines whether an internal weak pull-up or pull-down device is alternatively connected to the pin when used as an input. This offers additional advantages in an application.

The output multiplexer in front of the output driver selects the signal source for the GPIO line when used as output. If the pin is used as general-purpose output, the multiplexer is switched by software (Pn_IOCR register) to the Output Data Register Pn_OUT. Software can set or clear the bit in Pn_OUT, and therefore it can directly influence the state of the port pin. If the on-chip peripheral units use the pin for output signals, the alternate output lines ALT1 to ALT3 can be switched via the multiplexer to the output driver. The data written into the output register Pn_OUT by software can be used as input data to an on-chip peripheral. This enables, for example, peripheral tests via software without external circuitry.

When selected as general-purpose output line, the logic state of each port pin can be changed individually by programming the pin-related bits in the Output Modification Register Pn_OMR. The bits in Pn_OMR make it possible to set, reset, toggle, or leave the bits in the Pn_OUT register unchanged.

When selected as general-purpose output line, the actual logic level at the pin can be examined through reading Pn_IN and compared against the applied output level (either applied through software via the output register Pn_OUT, or via an alternate output function of a peripheral unit). This can be used to detect some electrical failures at the pin caused through external circuitry. In addition, software-supported arbitration schemes can be implemented in this way using the open-drain configuration and an external wired-And circuitry. Collisions on the external communication lines can be detected when a high level (1) is output, but a low level (0) is seen when reading the pin value via the input register Pn_IN.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

All GPIO lines of the TC1728 that are used by the GPTA module (GPTA0) have an emergency stop logic. This logic makes it possible to individually disconnect GPTA outputs from the driving GPTA module outputs and to put them onto a well defined logic state in an emergency case. In an emergency case, the content of the port output register Pn_OUT is driven at the output pin instead of the GPTA module output. The Emergency Stop Register Pn_EMR determines whether a GPTA output is enabled or disabled in an emergency case.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.2 Description Scheme for the Port IO Functions

The following two general building block can be used to describe each GPIO pin:

Table 9-1 Port x Input/Output Functions

Port Pin	I/O	Select	Connected Signal(s)	From / to Module
Px.y	Input		Signal(s)	module(s)
	Output	GPIO	Signal	module
		ALT1	Signal	module
		ALT2	Signal	module
		ALT3	Signal	module
	HW_DIR	HW_Out	Signal	module; group En

or:

Table 9-2 Port x Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
Px.y	I	GPIOt	Px_IN.Py	Px_IOCRez. PC0	0XXX _B
	O	GPIO	Px_OUT.Py		1X00 _B
					1X01 _B
					1X10 _B
					1X11 _B
	HW_DIR	module; group En	Signal		HW_DIR

- HW_DIR:
The type Alternate Direction signal which is needed if HW_En is active:
 - Out -always output
DIRx - the pins in one port having the same DIRx (x=0, 1, 2, ...), are controlled as a group by a dedicated HW_DIR signal.
SDIR- Single DIR- the pin is controlled by its own, dedicated, single HW_DIR signal.
- grouping indicates if the respective pin is controlled by hardware:

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

- ENx - the pins in one port having the same ENx (x=0, 1, 2, ...), are controlled as a group by a dedicated HW_EN signal.
- SEN - Single EN - the pin is controlled by its own, dedicated, single HW_EN signal
- Digital port slices with HW_DIR defined are the ports described in [Figure 9-1](#).

Note: HW_EN signal has higher priority then Emergency Stop. Emergency Stop is functional when the pins are set in the GPIO mode.

Note: HW_DIR signal, output case, switches the pad to push-pull output state.

HW_DIR signal, input case, switches the pad to the input state with pull-up/down setting as defined by the IOCR register.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3 Port Register Description

The individual control and data bits of each GPIO port are implemented in a number of registers. The registers are used to configure and use the port as general-purpose I/O or alternate function input/output. For some ports, not all registers are implemented. The availability of the registers in the specific ports is described in [Table 9-9](#) on [Page 9-25](#) up to [Table 9-27](#) on [Page 9-83](#).

Note: All port-registers have control bits implemented in groups of four (a nibble), starting from the bit position 0. If a port is do not fit to multiple of four without rest, or starts with a bit number other than zero, then some control bits remain unused. These bits behave as standard read-write bits, but do not have any function. The registers of not implemented groups of bits starting on the position 0 are implemented, but do not have any function. The not implemented bits appear in the boundary-scan chain, although they do not have an external connection.

Port Register Overview

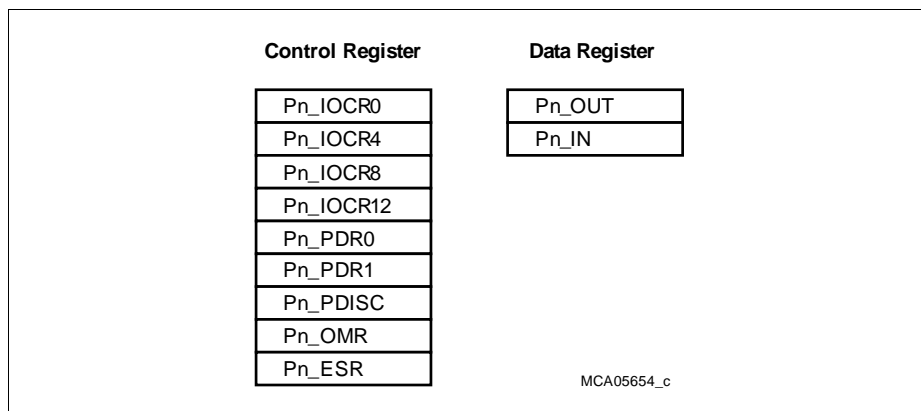


Figure 9-2 Port Registers

Table 9-3 Registers Address Space

Module	Base Address	End Address	Note
P0	F000 0C00 _H	F000 0CFF _H	16
P1	F000 0D00 _H	F000 0DFF _H	16
P2	F000 0E00 _H	F000 0EFF _H	14
P3	F000 0F00 _H	F000 0FFF _H	16
P4	F000 1000 _H	F000 10FF _H	4

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-3 Registers Address Space (cont'd)

Module	Base Address	End Address	Note
P5	F000 1100 _H	F000 11FF _H	16
P6	F000 1200 _H	F000 12FF _H	4
P8	F000 1400 _H	F000 14FF _H	14
P9	F000 1500 _H	F000 15FF _H	9
P10	F000 1600 _H	F000 16FF _H	4
P11	F000 1700 _H	F000 17FF _H	16
P12	F030 0000 _H	F030 00FF _H	4

Table 9-4 Registers Overview

Register Short Name	Register Long Name	Offset Address	Access Mode		Desc. see
			Read	Write	
Pn_OUT	Port n Output Register	0000 _H	U, SV	U, SV	Page 9-19
Pn_OMR	Port n Output Modification Register	0004 _H	U, SV	U, SV	Page 9-20
–	Reserved	0008 _H –000C _H	BE	BE	–
Pn_IOCRO	Port n Input/Output Control Register 0	0010 _H	U, SV	U, SV	Page 9-10
Pn_IOCRA4	Port n Input/Output Control Register 4	0014 _H	U, SV ⁽¹⁾	U, SV ⁽¹⁾	Page 9-11
Pn_IOCRA8	Port n Input/Output Control Register 8	0018 _H	U, SV ⁽²⁾	U, SV ⁽²⁾	Page 9-11
Pn_IOCRA12	Port n Input/Output Control Register 12	001C _H	U, SV ⁽²⁾	U, SV ⁽²⁾	Page 9-12
–	Reserved	0020 _H	BE	BE	–
Pn_IN	Port n Input Register	0024 _H	U, SV	U, SV	Page 9-23
–	Reserved	0028 _H –003C _H	BE	BE	–
Pn_PDR0	Port n Pad Driver Mode 0 Register	0040 _H	U, SV	SV, E	Page 9-15

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-4 Registers Overview (cont'd)

Register Short Name	Register Long Name	Offset Address	Access Mode		Desc. see
			Read	Write	
Pn_PDR1	Port n Pad Driver Mode 1 Register	0044 _H	U, SV ²⁾	SV, E ²⁾	Page 9-16
–	Reserved	0048 _H –004C _H	BE	BE	–
Pn_ESR	Port n Emergency Stop Register	0050 _H	U, SV ³⁾	SV, E ³⁾	Page 9-22
–	Reserved	0054 _H –005C _H	BE	BE	–
Pn_PDISC	Port n Pin Function Decision Control Register	0060 _H	U, SV	SV, E	Page 9-18
–	Reserved	0064 _H –00FC _H	BE	BE	–

1) Applicable to n=0-3, 5, 8-9, 11. Otherwise, this location is reserved and returns “BE” upon read and write accesses.

2) Applicable to n=0-3, 5, 8, 11. Otherwise, this location is reserved and returns “BE” upon read and write accesses.

3) Applicable to n=0-6, 8-9. Otherwise, this location is reserved and returns “BE” upon read and write accesses.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Register Access Rights and Reset Class

Table 9-5 Registers Access Rights and Reset Classes

Register Short Name	Access Rights		Reset Class
	Read	Write	
Pn_OUT	U,SV	U,SV	Class 3
Pn_OMR			
Pn_IOCRO			
Pn_IOCRO4			
Pn_IOCRO8			
Pn_IOCRO12			
Pn_IN			
Pn_PDISC		SV,E	
Pn_PDR0			
Pn_PDR1			
Pn_ESR			

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.1 Port Input/Output Control Registers

The port input/output control registers select the digital output and input driver functionality and characteristics of a GPIO port pin. Port direction (input or output), pull-up or pull-down devices for inputs, and push-pull or open-drain functionality for outputs can be selected by the corresponding bit fields PCx (x = 0-15). Each 32-bit wide port input/output control register controls four GPIO port lines:

Register Pn_IOCR0 controls the Pn.[3:0] port lines

Register Pn_IOCR4 controls the Pn.[7:4] port lines

Register Pn_IOCR8 controls the Pn.[11:8] port lines

Register Pn_IOCR12 controls the Pn.[15:12] port lines

The diagrams below show the register layouts of the port input/output control registers with the PCx bit fields. One PCx bit field controls exactly one port line Pn.x.

Pn_IOCR0 (n=0-6)

Port n Input/Output Control Register 0

(F000 0C10_H + n*100_H)

Reset Value: 2020 2020_H

Pn_IOCR0 (n=8-9)

Port n Input/Output Control Register 0

(F000 0C10_H + n*100_H)

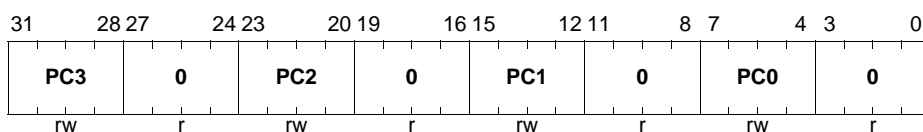
Reset Value: 2020 2020_H

P10_IOCR0

Port 10 Input/Output Control Register 0

(10_H)

Reset Value: 2020 2020_H



Field	Bits	Type	Description
PC0, PC1, PC2, PC3	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin 0 to 3 This bit field determines the Port n line x functionality (x = 0-3) according to the coding table (see Table 9-6).
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Pn_IOC4 (n=0-3)

Port n Input/Output Control Register 4

(F000 0C14_H + n*100_H)

Reset Value: 2020 2020_H

P5_IOC4

Port 5 Input/Output Control Register 4

(14_H)

Reset Value: 2020 2020_H

Pn_IOC4 (n=8-9)

Port n Input/Output Control Register 4

(F000 0C14_H + n*100_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC7	0	PC6	0	PC5	0	PC4	0	
rw	r	rw	r	rw	r	rw	r	

Field	Bits	Type	Description
PC4, PC5, PC6, PC7	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin 4 to 7 This bit field determines the Port n line x functionality (x = 4-7) according to the coding table (see Table 9-6).
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

Pn_IOC8 (n=0-3)

Port n Input/Output Control Register 8

(F000 0C18_H + n*100_H)

Reset Value: 2020 2020_H

P5_IOC8

Port 5 Input/Output Control Register 8

(18_H)

Reset Value: 2020 2020_H

P8_IOC8

Port 8 Input/Output Control Register 8

(18_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC11	0	PC10	0	PC9	0	PC8	0	
rw	r	rw	r	rw	r	rw	r	

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
PC8, PC9, PC10, PC11	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin 8 to 11 This bit field determines the Port n line x functionality (x = 8-11) according to the coding table (see Table 9-6).
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

Pn_IOCR12 (n=0-1)

Port n Input/Output Control Register 12

 $(F000\ 0C1C_H + n*100_H)$

Reset Value: 2020 2020_H

P3_IOCR12

Port 3 Input/Output Control Register 12

 $(1C_H)$

Reset Value: 2020 2020_H

P5_IOCR12

Port 5 Input/Output Control Register 12

 $(1C_H)$

Reset Value: 2020 2020_H

31	28	27	24	23	20	19	16	15	12	11	8	7	4	3	0
PC15	0	PC14	0	PC13	0	PC12	0								
rw	r	rw	r	rw	r	rw	r								

Field	Bits	Type	Description
PC12, PC13, PC14, PC15	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin 12 to 15 This bit field determines the Port n line x functionality (x = 12-15) according to the coding table (see Table 9-6).
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

Depending on the GPIO port functionality (number of GPIO lines of a port), not all of the port input/output control registers are implemented.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

The structure with one control bit field for each port pin located in different register bytes offers the possibility to configure the port pin functionality of a single pin with byte-oriented accesses without accessing the other PCx bit fields.

Port Control Coding

Table 9-6 describes the coding of the PCx bit fields that determine the port line functionality. Port 4 has a different PCx coding than the other ports (in input mode, no pull devices can be connected).

Table 9-6 PCx Coding

PCx[3:0]	I/O	Output Characteristics	Selected Pull-up / Pull-down / Selected Output Function
0X00 _B	Input	–	No input pull device connected
0X01 _B			Input pull-down device connected
0X10 _B			Input pull-up device connected ¹⁾
0X11 _B			No input pull device connected
1000 _B	Output	Push-pull	General-purpose output
1001 _B			Alternate output function 1
1010 _B			Alternate output function 2
1011 _B			Alternate output function 3
1100 _B		Open-drain	General-purpose output
1101 _B			Alternate output function 1
1110 _B			Alternate output function 2
1111 _B			Alternate output function 3

1) This is the default pull device setting after reset.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.2 Pad Driver Mode Register

Overview

The pad structure of the TC1728 GPIO lines offers the possibility to select the output driver strength and the slew rate. These two parameters are controlled by the bit fields in the pad driver mode registers Pn_PDR0/1, independently from input/output and pull-up/pull-down control functionality as programmed in the Pn_IOCR register. Pn_PDR0 and Pn_PDR1 registers are assigned to each port.

There are five classes of GPIO pads:

- Class A1 pins (low speed 3.3V LVTTL outputs)
- Class A2 pins (high speed 3.3V LVTTL outputs. e.g. for serial outputs)

The assignment of each port pin to one of these pad classes is shown in the port configuration figures. Further details about pad driver classes that are available in the TC1728 are summarized in the “Electrical Specification” chapter.

Depending on the assigned pad class, the 3-bit wide pad driver mode selection bit fields PDx in the pad driver mode registers Pn_PDR make it possible to select the port line functionality as shown in [Table 9-7](#). Note that the pad driver mode registers are specific for each port. Therefore, the Pn_PDR layout is described for each port in the port-specific sections.

Class A1 pins make it possible to select between medium and weak output drivers. Class A2 pins make it possible to select between strong/medium/weak output drivers. In the case of strong driver type, the signal transition edge can be additionally selected as sharp/medium/soft.

Table 9-7 Pad Driver Mode Selection

Pad Class	PDx.2	PDx.1	PDx.0	Functionality
A1	X	X	0	Medium driver
			1	Weak driver
A1+	0	X	0	Strong driver soft edge
	0	X	1	Strong driver slow edge
	1	X	0	Medium driver
	1	X	1	Weak driver

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-7 Pad Driver Mode Selection (cont'd)

Pad Class	PDx.2	PDx.1	PDx.0	Functionality
A2/B1/B2	0	0	0	Strong driver, sharp edge
	0	0	1	Strong driver, medium edge
	0	1	0	Strong driver, soft edge
	0	1	1	Reserved
	1	0	0	Medium driver
	1	0	1	
	1	1	0	Reserved
	1	1	1	Weak driver

Note: TC1728 Data Sheet describes the DC characteristics of all pad classes.

Pad Driver Mode Registers

This is the general description of the PDR registers. Each port contains its own specific PDR registers, described additionally at each port, that can contain between one and eight PDx fields for PDR0 and PDR1 registers, respectively. Each field controls 1 pin. For coding of PDx, see [Page 9-14](#).

Pn_PDR0 (n=0-3)

Port n Pad Driver Mode 0 Register(F000 0C40_H+n*100_H) Reset Value: 0000 0000_H

P5_PDR0

Port 5 Pad Driver Mode 0 Register (40_H) Reset Value: 0000 0000_H

Pn_PDR0 (n=8-9)

Port n Pad Driver Mode 0 Register(F000 0C40_H+n*100_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PD7			0	PD6			0	PD5			0	PD4		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PD3			0	PD2			0	PD1			0	PD0		
r	rw			r	rw			r	rw			r	rw		

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
PD0	[2:0]	rw	Pad Driver Mode for Pn.0
PD1	[6:4]	rw	Pad Driver Mode for Pn.1
PD2	[10:8]	rw	Pad Driver Mode for Pn.2
PD3	[14:12]	rw	Pad Driver Mode for Pn.3
PD4	[18:16]	rw	Pad Driver Mode for Pn.4
PD5	[22:20]	rw	Pad Driver Mode for Pn.5
PD6	[26:24]	rw	Pad Driver Mode for Pn.6
PD7	[30:28]	rw	Pad Driver Mode for Pn.7
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

Pn_PDR1 (n=0-1)

Port n Pad Driver Mode 1 Register(F000 0C44_H+n*100_H) Reset Value: 0000 0000_H

P3_PDR1

Port 3 Pad Driver Mode 1 Register (44_H) Reset Value: 0000 0000_H

P5_PDR1

Port 5 Pad Driver Mode 1 Register (44_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PD15			0	PD14			0	PD13			0	PD12		
r	rw			r	rw			r	rw			r	rw		

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PD11			0	PD10			0	PD9			0	PD8		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
PD8	[2:0]	rw	Pad Driver Mode for Pn.8
PD9	[6:4]	rw	Pad Driver Mode for Pn.9
PD10	[10:8]	rw	Pad Driver Mode for Pn.10
PD11	[14:12]	rw	Pad Driver Mode for Pn.11

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
PD12	[18:16]	rw	Pad Driver Mode for Pn.12
PD13	[22:20]	rw	Pad Driver Mode for Pn.13
PD14	[26:24]	rw	Pad Driver Mode for Pn.14
PD15	[30:28]	rw	Pad Driver Mode for Pn.15
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.3 Pin Function Decision Control Register

Pin Function Decision Control Register

The pad structure of the TC1728 GPIO lines offers the possibility to select digital input or analog ADC input functionalities at Port 11 and Port 12. For the selection of digital input, the parameters defined for Class S pads must be met. This feature can be controlled by individual bits in the Pn_PDISC register, independently from input/output and pull-up/pull-down control functionality as programmed in the Pn_IOCR register.

P11_PDISC

Port 11 Pin Function Decision Control Register(60_H) **Reset Value: 0000 FFFF_H**

P12_PDISC

Port 12 Pin Function Decision Control Register(60_H) **Reset Value: 0000 000F_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
PDISx (x = 0-15)	x	rw	Pin Function Decision Control for Pin x This bit selects the function of the port pad. 0 _B Pad Pn.x is selected for function X. 1 _B Pad Pn.x is selected for function Y.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.4 Port Output Register

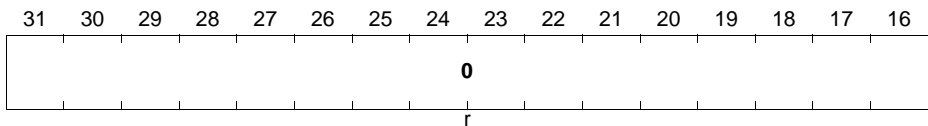
The port output register determines the value of a GPIO pin when it is selected by Pn_IOCR_x as output. Writing a 0 to a Pn_OUT.P_x (x = 0-15) bit position delivers a low level at the corresponding output pin. A high level is output when the corresponding bit is written with a 1. Note that the bits of Pn_OUT.P_x can be individually set/reset by writing appropriate values into the port output modification register Pn_OMR.

Pn_OUT (n=0-6)

Port n Output Register (F000 0C00_H + n*100_H) **Reset Value: 0000 0000_H**

Pn_OUT (n=8-10)

Port n Output Register (F000 0C00_H + n*100_H) **Reset Value: 0000 0000_H**



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
P15	P14	P13	P12	P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
Px (x = 0-15)	x	rwh	Port n Output Bit x This bit determines the level at the output pin Pn.x if the output is selected as GPIO output. 0 _B The output level of Pn.x is 0. 1 _B The output level of Pn.x is 1. Pn.x can also be set/reset by control bits of the Pn_OMR register.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: Only Port 0, 1, 3, 5 are 16-bit wide ports. The Pn_OUT registers of the other ports have a reduced number of Px bits (see Pn_OUT register descriptions in the corresponding port sections).

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.5 Port Output Modification Register

The port output modification register contains control bits that make it possible to individually set, reset, or toggle the logic state of a single port line by manipulating the output register.

Pn_OMR (n=0-6)

Port n Output Modification Register (F000 0C04_H + n*100_H)

Reset Value:

0000 0000_H

Pn_OMR (n=8-10)

Port n Output Modification Register (F000 0C04_H + n*100_H)

Reset Value:

0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PR 15	PR 14	PR 13	PR 12	PR 11	PR 10	PR 9	PR 8	PR 7	PR 6	PR 5	PR 4	PR 3	PR 2	PR 1	PR 0
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PS 15	PS 14	PS 13	PS 12	PS 11	PS 10	PS 9	PS 8	PS 7	PS 6	PS 5	PS 4	PS 3	PS 2	PS 1	PS 0
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
PSx (x = 0-15)	x	w	Port n Set Bit x Setting this bit will set or toggle the corresponding bit in the port output register Pn_OUT. The function of this bit is shown in Table 9-8 .
PRx (x = 0-15)	x + 16	w	Port n Reset Bit x Setting this bit will reset or toggle the corresponding bit in the port output register Pn_OUT. The function of this bit is shown in Table 9-8 .

Note: Register Pn_OMR is virtual and does not contain any flip-flop. A read action delivers the value of 0. One 8 or 16-bits write behaves as a 32-bit write padded with zeros.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)**Table 9-8 Function of the Bits PRx and PSx**

PRx	PSx	Function
0	0	Bit Pn_OUT.Px is not changed.
0	1	Bit Pn_OUT.Px is set.
1	0	Bit Pn_OUT.Px is reset.
1	1	Bit Pn_OUT.Px is toggled.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.3.6 Emergency Stop Register

All GPIO lines which are used by the GPTA module (GPTA0) have an emergency stop logic implemented (see [Figure 9-1](#)). These GPTA related GPIO lines are:

- P0.[15:0], P1.[11:0], P2.[7:0], P3.[4:0], P3.[15:7], P4.[3:0], P5.[15:0], P6.[3:0], P8.[13:0], P9.[4:2], P9.[8:7]

Each of these GPIO lines has its own emergency stop enable bit ENx that is located in the emergency stop register Pn_ESR of Port n. If the emergency stop signal becomes active, one of two states can be selected:

- Emergency stop function disabled (ENx = 0):
A GPTA output line remains connected to the GPTA module (alternate function).
- Emergency stop function enabled (ENx = 1):
A GPTA output line is disconnected from the GPTA module (alternate function) and connected to the corresponding bit of the Pn_OUT output register (the content of the corresponding PCx bit fields in register Pn_IOCR is discarded).

Pn_ESR (n=0-6)

Port n Emergency Stop Register (F000 0C50_H + n*100_H) Reset Value: 0000 0000_H

Pn_ESR (n=8-9)

Port n Emergency Stop Register (F000 0C50_H + n*100_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
ENx (x = 0-15)	x	rw	Emergency Stop Enable for Port n Pin x This bit enables the emergency stop function for GPIO lines used as GPTA outputs. If the emergency stop condition is met and enabled, the output selection is automatically switched from alternate (GPTA output) function to GPIO output function. 0 _B Emergency stop function for Pn.x is disabled. 1 _B Emergency stop function for Pn.x is enabled.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: Ports 0 and 5 are 16-bit wide ports entirely used by the GPTA modules. The Pn_ESR registers of the other ports have a reduced number of bits (see Pn_ESR register descriptions in the corresponding port sections).

9.3.7 Port Input Register

The logic level of a GPIO pin can be read via the read-only port input register Pn_IN. Reading the Pn_IN register always returns the current logical value at the GPIO pin independently whether the pin is selected as input or output.

Pn_IN (n=0-6)

Port n Input Register (F000 0C24_H + n*100_H) **Reset Value: 0000 XXXX_H**

Pn_IN (n=8-11)

Port n Input Register (F000 0C24_H + n*100_H) **Reset Value: 0000 XXXX_H**

P12_IN

Port 12 Input Register (24_H) **Reset Value: 0000 XXXX_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
							0								

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
P15	P14	P13	P12	P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
Px (x = 0-15)	x	rh	Port n Input Bit x This bit indicates the level at the input pinPn.x. 0 _B The input level of Pn.x is 0. 1 _B The input level of Pn.x is 1.
0	[31:16]	r	Reserved Read as 0.

Note: Only Port 0, 1, 3, and 5 are 16-bit wide ports. The Pn_IN registers of the other ports have a reduced number of Px bits (see Pn_IN register descriptions in the corresponding port sections).

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.4 Port 0

This section describes the Port 0 functionality in detail.

9.4.1 Port 0 Configuration

Port 0 is a 16-bit bi-directional general-purpose I/O port that can be alternatively used for the GPTA I/O lines, HWCFG, CCU6, MSC0, SCU, ERAY and CAN functions.

9.4.2 Port 0 Function Table

Table 9-9 summarizes the I/O control selection functions of each Port 0 line.

Table 9-9 Port 0 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P0.0	I	General-purpose input	P0_IN.P0	P0_IOCRR0. PC0	0XXX _B
		GPTA input	IN0		
		SCU input	HWCFG0		
		CCU60	CC60INA		
		CCU61	CC60INB		
	O	General-purpose output	P0_OUT.P0		1X00 _B
		GPTA output	OUT0		1X01 _B
		GPTA output	OUT56		1X10 _B
		CCU60	CC60		1X11 _B
P0.1	I	General-purpose input	P0_IN.P1	P0_IOCRR0. PC1	0XXX _B
		GPTA input	IN1		
		SCU input	HWCFG1		
		MSC0 Serial Data input	SDI1		
	O	General-purpose output	P0_OUT.P1		1X00 _B
		GPTA output	OUT1		1X01 _B
		GPTA output	OUT57		1X10 _B
		CCU60	COUT60		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-9 Port 0 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P0.2	I	General-purpose input	P0_IN.P2	P0_IOCR0. PC2	0XXX _B
		GPTA input	IN2		
		SCU input	HWCFG2		
	O	General-purpose output	P0_OUT.P2		1X00 _B
		GPTA output	OUT2		1X01 _B
		GPTA output	OUT58		1X10 _B
		Reserved	–		1X11 _B
P0.3	I	General-purpose input	P0_IN.P3	P0_IOCR0. PC3	0XXX _B
		GPTA input	IN3		
		SCU input	HWCFG3		
	O	General-purpose output	P0_OUT.P3		1X00 _B
		GPTA output	OUT3		1X01 _B
		GPTA output	OUT59		1X10 _B
		Reserved	–		1X11 _B
P0.4	I	General-purpose input	P0_IN.P4	P0_IOCR4. PC4	0XXX _B
		GPTA input	IN4		
		SCU input	HWCFG4		
	O	General-purpose output	P0_OUT.P4		1X00 _B
		GPTA output	OUT4		1X01 _B
		GPTA output	OUT60		1X10 _B
		MCDS output	EVTO0		1X11 _B
P0.5	I	General-purpose input	P0_IN.P5	P0_IOCR4. PC5	0XXX _B
		GPTA input	IN5		
		SCU input	HWCFG5		
	O	General-purpose output	P0_OUT.P5		1X00 _B
		GPTA output	OUT5		1X01 _B
		GPTA output	OUT61		1X10 _B
		MCDS output	EVTO1		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-9 Port 0 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P0.6	I	General-purpose input	P0_IN.P6	P0_IOCRA4. PC6	0XXX _B
		GPTA input	IN6		
		SCU input	HWCFG6		
		SCU input	REQ2		
	O	General-purpose output	P0_OUT.P6		1X00 _B
		GPTA output	OUT6		1X01 _B
		GPTA output	OUT62		1X10 _B
		MCDS output	EVTO2		1X11 _B
P0.7	I	General-purpose input	P0_IN.P7	P0_IOCRA4. PC7	0XXX _B
		GPTA input	IN7		
		SCU input	HWCFG7		
		SCU input	REQ3		
	O	General-purpose output	P0_OUT.P7		1X00 _B
		GPTA output	OUT7		1X01 _B
		GPTA output	OUT63		1X10 _B
		MCDS output	EVTO3		1X11 _B
P0.8	I	General-purpose input	P0_IN.P8	P0_IOCRA8. PC8	0XXX _B
		GPTA input	IN8		
		ERAY input	RXDA0		
	O	General-purpose output	P0_OUT.P8		1X00 _B
		GPTA output	OUT8		1X01 _B
		GPTA output	OUT64		1X10 _B
		GPT121	T3OUT		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-9 Port 0 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P0.9	I	General-purpose input	P0_IN.P9	P0_IOC8. PC9	0XXX _B
		GPTA input	IN9		
		ERAY input	RXDB0		
	O	General-purpose output	P0_OUT.P9		1X00 _B
		GPTA output	OUT9		1X01 _B
		GPTA output	OUT65		1X10 _B
		GPT121	T6OUT		1X11 _B
P0.10	I	General-purpose input	P0_IN.P10	P0_IOC8. PC10	0XXX _B
		GPTA input	IN10		
	O	General-purpose output	P0_OUT.P10		1X00 _B
		GPTA output	OUT10		1X01 _B
		GPTA output	OUT66		1X10 _B
		ERAY output	TXDA0		1X11 _B
P0.11	I	General-purpose input	P0_IN.P11	P0_IOC8. PC11	0XXX _B
		GPTA input	IN11		
		SCU input	REQ9		
	O	General-purpose output	P0_OUT.P11		1X00 _B
		GPTA output	OUT11		1X01 _B
		GPTA output	OUT67		1X10 _B
		ERAY output	TXDB0		1X11 _B
P0.12	I	General-purpose input	P0_IN.P12	P0_IOC12. PC12	0XXX _B
		GPTA input	IN12		
		CCU60	CTRAPB		
		CCU61	T13HRE		
	O	General-purpose output	P0_OUT.P12		1X00 _B
		GPTA output	OUT12		1X01 _B
		GPTA output	OUT68		1X10 _B
		ERAY output	TXENA		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-9 Port 0 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P0.13	I	General-purpose input	P0_IN.P13	P0_IOC12. PC13	0XXX _B
		GPTA input	IN13		
	O	General-purpose output	P0_OUT.P13		1X00 _B
		GPTA output	OUT13		1X01 _B
		GPTA output	OUT69		1X10 _B
		ERAY output	TXENB		1X11 _B
P0.14	I	General-purpose input	P0_IN.P14	P0_IOC12. PC14	0XXX _B
		GPTA input	IN14		
		SCU input	REQ4		
		CCU61	CC61INC		
	O	General-purpose output	P0_OUT.P14		1X00 _B
		GPTA output	OUT14		1X01 _B
		GPTA output	OUT70		1X10 _B
		CCU60	CC61		1X11 _B
P0.15	I	General-purpose input	P0_IN.P15	P0_IOC12. PC15	0XXX _B
		GPTA input	IN15		
		SCU input	REQ5		
	O	General-purpose output	P0_OUT.P15		1X00 _B
		GPTA output	OUT15		1X01 _B
		GPTA output	OUT71		1X10 _B
		CCU60	COUT61		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.4.3 Port 0 Registers

The following registers are available on Port 0:

Table 9-10 Port 0 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P0_OUT	Port 0 Output Register	0000 _H	Page 9-19
P0_OMR	Port 0 Output Modification Register	0004 _H	Page 9-20
P0_IOCRO	Port 0 Input/Output Control Register 0	0010 _H	Page 9-10
P0_IOCRR4	Port 0 Input/Output Control Register 4	0014 _H	Page 9-11
P0_IOCRR8	Port 0 Input/Output Control Register 8	0018 _H	Page 9-11
P0_IOCRR12	Port 0 Input/Output Control Register 12	001C _H	Page 9-12
P0_IN	Port 0 Input Register	0024 _H	Page 9-23
P0_PDR0	Port 0 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P0_PDR1	Port 0 Pad Driver Mode 1 Register	0044 _H	Page 9-16
P0_ESR	Port 0 Emergency Stop Register	0050 _H	Page 9-22

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

General Purpose I/O Ports and Peripheral I/O Lines (Ports)**9.5 Port 1**

This section describes the Port 1 functionality in detail.

9.5.1 Port 1 Configuration

Port 1 is a 16-bit bi-directional general-purpose I/O port that can be alternatively used for the SCU, OCDS, GPTA I/O lines, CCU6/GPT12, SSC1 and the ADC0 external multiplexers functions.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.5.2 Port 1 Function Table

Table 9-11 summarizes the I/O control selection functions of each Port 1 line.

Table 9-11 Port 1 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.0	I	General-purpose input	P1_IN.P0	P1_IOCRO. PC0	0XXX _B
		SCU input	REQ15		
		GPTA input	IN16		
		OCDS input	BRKIN		
	O	General-purpose output	P1_OUT.P0		1X00 _B
		GPTA output	OUT16		1X01 _B
		GPTA output	OUT72		1X10 _B
		GPT120	T3OUT		1X11 _B
	DIR8	OCDS; EN8	BRKOUT	HW_Out	
P1.1	I	General-purpose input	P1_IN.P1	P1_IOCRO. PC1	0XXX _B
		GPTA input	IN17		
		CCU60	T13HRE		
		CCU61	CTRAPB		
	O	General-purpose output	P1_OUT.P1		1X00 _B
		GPTA output	OUT17		1X01 _B
		GPTA output	OUT73		1X10 _B
		Reserved	–		1X11 _B
P1.2	I	General-purpose input	P1_IN.P2	P1_IOCRO. PC2	0XXX _B
		GPTA input	IN18		
	O	General-purpose output	P1_OUT.P2		1X00 _B
		GPTA output	OUT18		1X01 _B
		GPTA output	OUT74		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-11 Port 1 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.3	I	General-purpose input	P1_IN.P3	P1_IOCRR0. PC3	0XXX _B
		GPTA input	IN19		
	O	General-purpose output	P1_OUT.P3		1X00 _B
		GPTA output	OUT19		1X01 _B
		GPTA output	OUT75		1X10 _B
		CCU61	COUT63		1X11 _B
P1.4	I	General-purpose input	P1_IN.P4	P1_IOCRR4. PC4	0XXX _B
		GPTA input	IN20		
		SCU input	EMGSTOP		
	O	General-purpose output	P1_OUT.P4		1X00 _B
		GPTA output	OUT20		1X01 _B
		GPTA output	OUT76		1X10 _B
		CCU61	COUT61		1X11 _B
P1.5	I	General-purpose input	P1_IN.P5	P1_IOCRR4. PC5	0XXX _B
		GPTA input	IN21		
	O	General-purpose output	P1_OUT.P5		1X00 _B
		GPTA output	OUT21		1X01 _B
		GPTA output	OUT77		1X10 _B
		Reserved	–		1X11 _B
P1.6	I	General-purpose input	P1_IN.P6	P1_IOCRR4. PC6	0XXX _B
		GPTA input	IN22		
	O	General-purpose output	P1_OUT.P6		1X00 _B
		GPTA output	OUT22		1X01 _B
		GPTA output	OUT78		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-11 Port 1 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.7	I	General-purpose input	P1_IN.P7	P1_IOCR4. PC7	0XXX _B
		GPTA input	IN23		
	O	General-purpose output	P1_OUT.P7		1X00 _B
		GPTA output	OUT23		1X01 _B
		GPTA output	OUT79		1X10 _B
		Reserved	—		1X11 _B
P1.8	I	General-purpose input	P1_IN.P8	P1_IOCR8. PC8	0XXX _B
		GPTA input	IN24		
		GPTA input	IN48		
		SSC1input (Slave Mode)	MTSR1B		
		CCU61	CCPOS2C		
		GPT120	T4EUDB		
		GPT121	T4EUDA		
	O	General-purpose output	P1_OUT.P8		1X00 _B
		GPTA output	OUT24		1X01 _B
		GPTA output	OUT48		1X10 _B
		SSC1 output (Master Mode)	MTSR1B		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-11 Port 1 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.9	I	General-purpose input	P1_IN.P9	P1_IOC8. PC9	0XXX _B
		GPTA input	IN25		
		GPTA input	IN49		
		SSC1input (Master Mode)	MRST1B		
		CCU61	CCPOS1C		
		GPT120	T2EUDB		
		GPT121	T2EUDA		
	O	General-purpose output	P1_OUT.P9		1X00 _B
		GPTA output	OUT25		1X01 _B
		GPTA output	OUT49		1X10 _B
		SSC1 output (Slave Mode)	MRST1B		1X11 _B
P1.10	I	General-purpose input	P1_IN.P10	P1_IOC8. PC10	0XXX _B
		GPTA input	IN26		
		GPTA input	IN50		
	O	General-purpose output	P1_OUT.P10		1X00 _B
		GPTA output	OUT26		1X01 _B
		GPTA output	OUT50		1X10 _B
		SSC1 output	SLSO17		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-11 Port 1 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.11	I	General-purpose input	P1_IN.P11	P1_IOC8. PC11	0XXX _B
		GPTA input	IN27		
		GPTA input	IN51		
		SSC1input	SCLK1B		
		CCU61	CCPOS0C		
		GPT120	T2INB		
		GPT121	T2INA		
	O	General-purpose output	P1_OUT.P11		1X00 _B
		GPTA output	OUT27		1X01 _B
		GPTA output	OUT51		1X10 _B
		SSC1 output	SCLK1B		1X11 _B
P1.12	I	General-purpose input	P1_IN.P12	P1_IOC12. PC12	0XXX _B
	O	General-purpose output	P1_OUT.P12		1X00 _B
		ADC0	AD0EMUX0		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B
P1.13	I	General-purpose input	P1_IN.P13	P1_IOC12. PC13	0XXX _B
	O	General-purpose output	P1_OUT.P13		1X00 _B
		ADC0	AD0EMUX1		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B
P1.14	I	General-purpose input	P1_IN.P14	P1_IOC12. PC14	0XXX _B
	O	General-purpose output	P1_OUT.P14		1X00 _B
		ADC0	AD0EMUX2		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-11 Port 1 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P1.15	I	General-purpose input	P1_IN.P15	P1_IOCRR12. PC15	0XXX _B
		OCDS	BRKIN		
	O	General-purpose output	P1_OUT.P15		1X00 _B
		Reserved	–		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B
	DIR8	OCDS; EN8	BRKOUT	HW_Out	

9.5.3 Port 1 Registers

The following registers are available on Port 1:

Table 9-12 Port 1 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P1_OUT	Port 1 Output Register	0000 _H	Page 9-19
P1_OMR	Port 1 Output Modification Register	0004 _H	Page 9-20
P1_IOCRR0	Port 1 Input/Output Control Register 0	0010 _H	Page 9-10
P1_IOCRR4	Port 1 Input/Output Control Register 4	0014 _H	Page 9-11
P1_IOCRR8	Port 1 Input/Output Control Register 8	0018 _H	Page 9-11
P1_IOCRR12	Port 1 Input/Output Control Register 12	001C _H	Page 9-12
P1_IN	Port 1 Input Register	0024 _H	Page 9-23
P1_PDR0	Port 1 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P1_PDR1	Port 1 Pad Driver Mode 1 Register	0044 _H	Page 9-16
P1_ESR	Port 1 Emergency Stop Register	0050 _H	Page 9-37

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

9.5.3.1 Port 1 Emergency Stop Register

The basic P1_ESR register functionality is described on [Page 9-22](#). At Port 1, only port lines P1.[11:0] have GPTA outputs. Therefore, the P1_ESR bits EN[15:12] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.6 Port 2

This section describes the Port 2 functionality in detail.

9.6.1 Port 2 Configuration

Port 2 is a 14-bit bi-directional general-purpose I/O port that can be used either for the SSC0/SSC1, MSC0, MLI0, CCU6/GPT12 or GPTA0 I/O lines.

9.6.2 Port 2 Function Table

Table 9-13 summarizes the I/O control selection functions of each Port 2 line.

Table 9-13 Port 2 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P2.0	I	General-purpose input	P2_IN.P0	P2_IOCR0. PC0	0XXX _B
		GPTA input	IN32		
		CCU60	CC62INB		
		CCU61	CC62INA		
	O	General-purpose output	P2_OUT.P0		1X00 _B
		GPTA output	OUT32		1X01 _B
		MLI0 output	TCLK0		1X10 _B
		CCU61	CC62		1X11 _B
P2.1	I	General-purpose input	P2_IN.P1	P2_IOCR0. PC1	0XXX _B
		GPTA input	IN33		
		MLI0 input	TREADY0A		
		CCU61	CCPOS0A		
		CCU60	T12HRB		
		GPT120	T2INA		
		GPT121	T2INB		
	O	General-purpose output	P2_OUT.P1		1X00 _B
		GPTA output	OUT33		1X01 _B
		SSC0 output	SLSO03		1X10 _B
		SSC1 output	SLSO13		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-13 Port 2 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P2.2	I	General-purpose input	P2_IN.P2	P2_IOCR0. PC2	0XXX _B
		GPTA input	IN34		
		CCU60	CC61INB		
		CCU61	CC61INA		
	O	General-purpose output	P2_OUT.P2		1X00 _B
		GPTA output	OUT34		1X01 _B
		MLI0 output	TVALID0A		1X10 _B
		CCU61	CC61		1X11 _B
P2.3	I	General-purpose input	P2_IN.P3	P2_IOCR0. PC3	0XXX _B
		GPTA input	IN35		
		CCU60	T12HRC		
		CCU60	T13HRC		
		CCU61	CCPOS2A		
		GPT120	T4EUDA		
		GPT121	T4EUDB		
	O	General-purpose output	P2_OUT.P3		1X00 _B
		GPTA output	OUT35		1X01 _B
		MLI0 output	TDATA0		1X10 _B
		Reserved	–		1X11 _B
P2.4	I	General-purpose input	P2_IN.P4	P2_IOCR4. PC4	0XXX _B
		GPTA input	IN36		
		MLI0 input	RCLK0A		
	O	General-purpose output	P2_OUT.P4		1X00 _B
		GPTA output	OUT36		1X01 _B
		CCU61	COU63		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-13 Port 2 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P2.5	I	General-purpose input	P2_IN.P5	P2_IOC4. PC5	0XXX _B
		GPTA input	IN37		
		CCU60	CC60INB		
		CCU61	CC60INA		
	O	General-purpose output	P2_OUT.P5		1X00 _B
		GPTA output	OUT37		1X01 _B
		MLI0 output	RREADY0A		1X10 _B
		CCU61	CC60		1X11 _B
P2.6	I	General-purpose input	P2_IN.P6	P2_IOC4. PC6	0XXX _B
		GPTA input	IN38		
		MLI0 input	RVALID0A		
	O	General-purpose output	P2_OUT.P6		1X00 _B
		GPTA output	OUT38		1X01 _B
		CCU61	COU62		1X10 _B
		Reserved	—		1X11 _B
P2.7	I	General-purpose input	P2_IN.P7	P2_IOC4. PC7	0XXX _B
		GPTA input	IN39		
		MLI0 input	RDATA0A		
	O	General-purpose output	P2_OUT.P7		1X00 _B
		GPTA output	OUT39		1X01 _B
		CCU61	COU60		1X10 _B
		Reserved	—		1X11 _B
P2.8	I	General-purpose input	P2_IN.P8	P2_IOC8. PC8	0XXX _B
	O	General-purpose output	P2_OUT.P8		1X00 _B
		SSC0 output	SLSO04		1X01 _B
		SSC1 input	SLSO14		1X10 _B
		MSC0 output	EN00		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-13 Port 2 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P2.9	I	General-purpose input	P2_IN.P9	P2_IOC8. PC9	0XXX _B
	O	General-purpose output	P2_OUT.P9		1X00 _B
		SSC0 output	SLSO05		1X01 _B
		SSC1 output	SLSO15		1X10 _B
		MSC0 output	EN01		1X11 _B
P2.10	I	General-purpose input	P2_IN.P10	P2_IOC8. PC10	0XXX _B
		SSC1 input	MRST1A		
	O	General-purpose output	P2_OUT.P10		1X00 _B
		SSC1 output	MRST1A		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B
P2.11	I	General-purpose input	P2_IN.P11	P2_IOC8. PC11	0XXX _B
		SSC1 input	SCLK1A		
	O	General-purpose output	P2_OUT.P11		1X00 _B
		SSC1 output	SCLK1A		1X01 _B
		Reserved	–		1X10 _B
P2.12	I	General-purpose input	P2_IN.P12	P2_IOC8. PC12	0XXX _B
		SSC1 input	MTSR1A		
	O	General-purpose output	P2_OUT.P12		1X00 _B
		SSC1 output	MTSR1A		1X01 _B
		Reserved	–		1X10 _B
		MSC0 output	SOP0B		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-13 Port 2 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P2.13	I	General-purpose input	P2_IN.P13	P2_IOC1 2.PC13	0XXX _B
		SSC1 input	SLSI1		
		MSC0 input	SDI0		
		CCU60	CTRAPA		
		CCU61	T12HRE		
	O	General-purpose output	P2_OUT.P13		1X00 _B
		Reserved	—		1X01 _B
		SSC1 output	SLSO16		1X10 _B
		GPT120	T6OUT		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.6.3 Port 2 Registers

The following registers are available on Port 2:

Table 9-14 Port 2 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P2_OUT	Port 2 Output Register	0000 _H	below ²⁾
P2_OMR	Port 2 Output Modification Register	0004 _H	
P2_IOCRO	Port 2 Input/Output Control Register 0	0010 _H	Page 9-10
P2_IOCRR4	Port 2 Input/Output Control Register 4	0014 _H	Page 9-11
P2_IOCRR8	Port 2 Input/Output Control Register 8	0018 _H	Page 9-11
P2_IOCRR12	Port 2 Input/Output Control Register 12	001C _H	Page 9-44 ²⁾
P2_IN	Port 2 Input Register	0024 _H	Page 9-44 ²⁾
P2_PDR0	Port 2 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P2_PDR1	Port 2 Pad Driver Mode 1 Register	0044 _H	Page 9-45 ²⁾
P2_ESR	Port 2 Emergency Stop Register	0050 _H	Page 9-45 ²⁾

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 2 section because they differ from the general port register description given in [Section 9.3](#).

9.6.3.1 Port 2 Output Register

The basic P2_OUT register functionality is described on [Page 9-19](#). Port lines P2.[15:14] are not connected. Reading the P2_OUT bits P[15:14] returns the value that was last written (0 after reset). These bits can be also set/reset by the corresponding P2_OMR bits.

9.6.3.2 Port 2 Output Modification Register

The basic P2_OMR register functionality is described on [Page 9-20](#). However, port lines P2.[15:14] are not connected. The P2_OMR bits PS[15:14] and PR[15:14] have no direct effect on port lines but only on register bits P2_OUT.P[15:14].

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9.6.3.3 Port 2 Input/Output Control Register 12

The PC14 and PC15 bit fields in register P2_IOC12 are not connected.

P2_IOC12

Port 2 Input/Output Control Register 12

(1C_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC15	0	PC14	0	PC13	0	PC12	0	
rw	r	rw	r	rw	r	rw	r	

Field	Bits	Type	Description
PC14, PC15	[23:20], [31:28]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
PC12	[7:4]	rw	Port Control for Port 2.12 (coding see Table 9-6 on Page 9-13)
PC13	[15:12]	rw	Port Control for Port 2.13 (coding see Table 9-6 on Page 9-13)
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

9.6.3.4 Port 2 Input Register

The basic P2_IN register functionality is described on [Page 9-23](#). However, port lines P2.[15:14] are not connected. Therefore, bits P[15:14] in register P2_IN are always read as 0.

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9.6.3.5 Port 2 Pad Driver Mode 1 Register

The basic P2_PDR1 register functionality is described on [Page 9-16](#).

P2_PDR1

Port 2 Pad Driver Mode 1 Register (44_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PD15			0	PD14			0	PD13			0	PD12		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PD11			0	PD10			0	PD9			0	PD8		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
PD8	[2:0]	rw	Pad Driver Mode for Pn.8
PD9	[6:4]	rw	Pad Driver Mode for Pn.9
PD10	[10:8]	rw	Pad Driver Mode for Pn.10
PD11	[14:12]	rw	Pad Driver Mode for Pn.11
PD12	[18:16]	rw	Pad Driver Mode for Pn.12
PD13	[22:20]	rw	Pad Driver Mode for Pn.13
PD14	[26:24]	rw	Reserved Read as 000 _B after reset; returns value that was written.
PD15	[30:28]	rw	Reserved Read as 000 _B after reset; returns value that was written.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

9.6.3.6 Port 2 Emergency Stop Register

The basic P2_ESR register functionality is described on [Page 9-22](#). At Port 2, only port lines P2.[7:0] are connected to GPTA I/O lines. Therefore, only these port lines of Port 2

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

can be controlled for the emergency stop function. The P2_ESR bits EN[15:8] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.7 Port 3

This section describes the Port 3 functionality in detail.

9.7.1 Port 3 Configuration

Port 3 is a 16-bit bi-directional general-purpose I/O port that can be used for the GPTA0 I/O lines, ASC0/ASC1, SCU, SSC0/SSC1, MultiCAN, MSC0 functions.

9.7.2 Port 3 Function Table

Table 9-15 summarizes the I/O control selection functions of each Port 3 line.

Table 9-15 Port 3 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P3.0	I	General-purpose input	P3_IN.P0	P3_IOCR0. PC0	0XXX _B
		ASC0 input	RXD0A (Async./Sync. Mode)		
		SCU input	REQ6		
	O	General-purpose output	P3_OUT.P0		1X00 _B
		ASC0 output (Synchronous Mode)	RXD0A		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT84		1X11 _B
P3.1	I	General-purpose input	P3_IN.P1	P3_IOCR0. PC1	0XXX _B
	O	General-purpose output	P3_OUT.P1		1X00 _B
		ASC0 output	TXD0A		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT85		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-15 Port 3 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P3.2	I	General-purpose input	P3_IN.P2	P3_IOCRO. PC2	0XXX _B
		SSC0 input (Slave Mode)	SCLK0		
	O	General-purpose output	P3_OUT.P2		1X00 _B
		SSC0 output (Master Mode)	SCLK0		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT86		1X11 _B
P3.3	I	General-purpose input	P3_IN.P3	P3_IOCRO. PC3	0XXX _B
		SSC0 input (Master Mode)	MRST0		
	O	General-purpose output	P3_OUT.P3		1X00 _B
		SSC0 output (Slave Mode)	MRST0		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT87		1X11 _B
P3.4	I	General-purpose input	P3_IN.P4	P3_IOCRO4. PC4	0XXX _B
		SSC0 input (Slave Mode)	MTSR0		
	O	General-purpose output	P3_OUT.P4		1X00 _B
		SSC0 output (Master Mode)	MTSR0		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT88		1X11 _B
P3.5	I	General-purpose input	P3_IN.P5	P3_IOCRO4. PC5	0XXX _B
	O	General-purpose output	P3_OUT.P5		1X00 _B
		SSC0 output	SLSO00		1X01 _B
		SSC1 output	SLSO10		1X10 _B
		SSC1 output	SLSOAND00		1X11 _B

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Table 9-15 Port 3 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P3.6	I	General-purpose input	P3_IN.P6	P3_IOC4. PC6	0XXX _B
	O	General-purpose output	P3_OUT.P6		1X00 _B
		SSC0 output	SLSO01		1X01 _B
		SSC1 output	SLSO11		1X10 _B
		SSC1 output	SLSOAND01		1X11 _B
P3.7	I	General-purpose input	P3_IN.P7	P3_IOC4. PC7	0XXX _B
		SSC0 input	SLSI0		
	O	General-purpose output	P3_OUT.P7		1X00 _B
		SSC0 output	SLSO02		1X01 _B
		SSC1 output	SLSO12		1X10 _B
		GPTA0 output	OUT89		1X11 _B
P3.8	I	General-purpose input	P3_IN.P8	P3_IOC8. PC8	0XXX _B
		SCU input	REQ14		
	O	General-purpose output	P3_OUT.P8		1X00 _B
		SSC0 output	SLSO06		1X01 _B
		ASC1 output	TXD1		1X10 _B
		GPTA0 output	OUT90		1X11 _B
P3.9	I	General-purpose input	P3_IN.P9	P3_IOC8. PC9	0XXX _B
		ASC1 input (Asynchronous Mode/Synchronous Mode)	RXD1A		
	O	General-purpose output	P3_OUT.P9		1X00 _B
		ASC1 output (Synchronous Mode)	RXD1A		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT91		1X11 _B

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Table 9-15 Port 3 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P3.10	I	General-purpose input	P3_IN.P10	P3_IOC8. PC10	0XXX _B
		SCU input	REQ0		
	O	General-purpose output	P3_OUT.P10		1X00 _B
		Reserved	–		1X01 _B
		Reserved	–		1X10 _B
		GPTA output	OUT92		1X11 _B
P3.11	I	General-purpose input	P3_IN.P11	P3_IOC8. PC11	0XXX _B
		SCU input	REQ1		
	O	General-purpose output	P3_OUT.P11		1X00 _B
		Reserved	–		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT93		1X11 _B
P3.12	I	General-purpose input	P3_IN.P12	P3_IOC12. PC12	0XXX _B
		CAN node 0 receive input 0	RXDCAN0		
		ASC0 input (Asynchronous Mode /Synchronous Mode)	RXD0B		
	O	General-purpose output	P3_OUT.P12		1X00 _B
		ASC0 output (Synchronous Mode)	RXD0B		1X01 _B
		Reserved	–		1X10 _B
		GPTA0 output	OUT94		1X11 _B
P3.13	I	General-purpose input	P3_IN.P13	P3_IOC12. PC13	0XXX _B
	O	General-purpose output	P3_OUT.P13		1X00 _B
		CAN node 0 output	TXDCAN0		1X01 _B
		ASC0 output (Synchronous Mode)	TXD0		1X10 _B
		GPTA0 output	OUT95		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-15 Port 3 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P3.14	I	General-purpose input	P3_IN.P14	P3_IOC12.PC14	0XXX _B
		CAN node 1 receive input 0	RXDCAN1		
		ASC1 input (Asynchronous Mode/Synchronous Mode)	RXD1B		
		MSC0 Serial Data input	SDI2		
	O	General-purpose output	P3_OUT.P14		1X00 _B
		ASC1 output (Synchronous Mode)	RXD1B		1X01 _B
		Reserved	—		1X10 _B
		GPTA0 output	OUT96		1X11 _B
P3.15	I	General-purpose input	P3_IN.P15	P3_IOC12.PC15	0XXX _B
	O	General-purpose output	P3_OUT.P15		1X00 _B
		CAN node 1output	TXDCAN1		1X01 _B
		ASC1 output (Synchronous Mode)	TXD1		1X10 _B
		GPTA0 output	OUT97		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.7.3 Port 3 Registers

The following registers are available on Port 3:

Table 9-16 Port 3 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P3_OUT	Port 3 Output Register	0000 _H	Page 9-19
P3_OMR	Port 3 Output Modification Register	0004 _H	Page 9-20
P3_IOCRO	Port 3 Input/Output Control Register 0	0010 _H	Page 9-10
P3_IOCRR4	Port 3 Input/Output Control Register 4	0014 _H	Page 9-11
P3_IOCRR8	Port 3 Input/Output Control Register 8	0018 _H	Page 9-11
P3_IOCRR12	Port 3 Input/Output Control Register 12	001C _H	Page 9-12
P3_IN	Port 3 Input Register	0024 _H	Page 9-23
P3_PDR0	Port 3 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P3_PDR1	Port 3 Pad Driver Mode 1 Register	0044 _H	Page 9-16
P3_ESR	Port 3 Emergency Stop Register	0050 _H	Page 9-52 ²⁾

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 3 section because they differ from the general port register description given in [Section 9.3](#).

9.7.3.1 Port 3 Emergency Stop Register

The basic P3_ESR register functionality is described on [Page 9-22](#). At Port 3, the port lines P3.[4:0] and P3.[15:7] are connected to GPTA I/O lines. Therefore, only these port lines of Port 3 can be controlled for the emergency stop function. The P3_ESR bits EN[6:5] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.8 Port 4

This section describes the Port 4 functionality in detail.

9.8.1 Port 4 Configuration

Port 4 is a 4-bit bi-directional general-purpose I/O port that can be used for the GPTA0 I/O lines, MultiCAN, CCU6/GPT12 and SCU functions.

9.8.2 Port 4 Function Table

Table 9-17 summarizes the I/O control selection functions of each Port 4 line.

Table 9-17 Port 4 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select. ¹⁾	
				Reg./Bit Field	Value
P4.0	I	General-purpose input	P4_IN.P0	P4_IOCRO.PC0	0XXX _B
		GPTA input	IN28		
		GPTA input	IN52		
		CAN node 2 receive input	RXDCAN2		
	O	General-purpose output	P4_OUT.P0		1X00 _B
		GPTA output	OUT28		1X01 _B
		GPTA output	OUT52		1X10 _B
		Reserved ¹⁾	—		1X11 _B
P4.1	I	General-purpose input	P4_IN.P1	P4_IOCRO.PC1	0XXX _B
		GPTA input	IN29		
		GPTA input	IN53		
	O	General-purpose output	P4_OUT.P1		1X00 _B
		GPTA output	OUT29		1X01 _B
		GPTA output	OUT53		1X10 _B
		CAN node 2 output	TXDCAN2		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-17 Port 4 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select. ¹⁾	
				Reg./Bit Field	Value
P4.2	I	General-purpose input	P4_IN.P2	P4_IOCRO.PC2	0XXX _B
		GPTA input	IN30		
		GPTA input	IN54		
		CCU60	T13HRB		
		CCU61	CCPOS1A		
		GPT120	T2EUDA		
		GPT121	T2EUDB		
	O	General-purpose output	P4_OUT.P2		1X00 _B
		GPTA output	OUT30		1X01 _B
		GPTA output	OUT54		1X10 _B
		SCU output	EXTCLK1		1X11 _B
P4.3	I	General-purpose input	P4_IN.P3	P4_IOCRO.PC3	0XXX _B
		GPTA input	IN31		
		GPTA input	IN55		
		CCU60	T12HRE		
		CCU61	CTRAPA		
	O	General-purpose output	P4_OUT.P3		1X00 _B
		GPTA output	OUT31		1X01 _B
		GPTA output	OUT55		1X10 _B
		SCU output	EXTCLK0		1X11 _B

1) The port I/O control values P4_IOC Rx.Py that are assigned to this reserved alternate output control selection should not be used.

9.8.3 Port 4 Registers

The following registers are available on Port 4:

Table 9-18 Port 4 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P4_OUT	Port 4 Output Register	0000 _H	Page 9-55²⁾
P4_OMR	Port 4 Output Modification Register	0004 _H	Page 9-55²⁾

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-18 Port 4 Registers (cont'd)

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P4_IOCRO	Port 4 Input/Output Control Register 0	0010 _H	Page 9-10
P4_IN	Port 4 Input Register	0024 _H	Page 9-55 ²⁾
P4_PDR0	Port 4 Pad Driver Mode 0 Register	0040 _H	Page 9-56
P4_ESR	Port 4 Emergency Stop Register	0050 _H	Page 9-56 ²⁾

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 4 section because they differ from the general port register description given in [Section 9.3](#).

9.8.3.1 Port 4 Output Register

The basic P4_OUT register functionality is described on [Page 9-19](#). Port lines P4.[15:4] are not available. P4_OUT bits P4.[15:4] is read as 0 after reset and should be written with 0.

9.8.3.2 Port 4 Output Modification Register

The basic P4_OMR register functionality is described on [Page 9-20](#). However, port line P4.[15:4] are not available. The P4_OMR bits PS.[15:4] and PR.[15:4] have no effect on register bits P4_OUT.P[15:4].

9.8.3.3 Port 4 Input/Output Control Register x (x = 4, 8 and 12)

Port lines P4.[15:4] are not connected. The PC bit fields; PC[15:4] in registers P4_IOCRO, P4_IOCRO8 and P4_IOCRO12 are not connected.

9.8.3.4 Port 4 Input Register

The basic P4_IN register functionality is described on [Page 9-23](#). However, port line P4.[15:4] are not connected. Therefore, bits P[15:4] in register P4_IN are always read as 0.

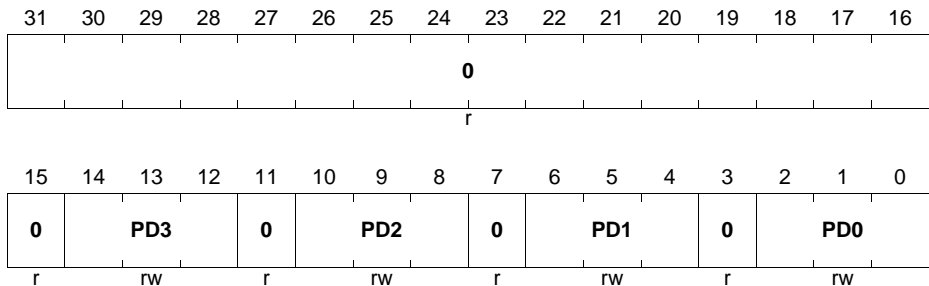
General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.8.3.5 Port 4 Pad Driver Mode 0 Register

The basic P4_PDR0 register functionality is described on [Page 9-15](#). However, port lines P4.[15:4] are not connected.

P4_PDR0

Port 4 Pad Driver Mode 0 Register (40_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
PD0	[2:0]	rw	Pad Driver Mode for Pn.0
PD1	[6:4]	rw	Pad Driver Mode for Pn.1
PD2	[10:8]	rw	Pad Driver Mode for Pn.2
PD3	[14:12]	rw	Pad Driver Mode for Pn.3
0	3, 7, 11, [31:15]	r	Reserved Read as 0; should be written with 0.

9.8.3.6 Port 4 Emergency Stop Register

The basic P4_ESR register functionality is described on [Page 9-22](#). At Port 4, port lines P4.[3:0] have GPTA outputs. Therefore, the P4_ESR bits EN[15:4] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.9 Port 5

9.9.1 Port 5 Configuration

Port 5 is a 16-bit bi-directional general-purpose I/O port which can be used for the CCU6/GPT12, GPTA I/O lines, SSC0/SSC2, SCU, ERAY, MultiCAN and ADC1 external multiplexers functions.

9.9.2 Port 5 Function Table

Table 9-19 summarizes the I/O control selection functions of each Port 5 line.

Table 9-19 Port 5 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P5.0	I	General-purpose input	P5_IN.P0	P5_IOCRO. PC0	0XXX _B
		SCU input	REQ7		
		GPTA input	IN40		
		GPT120	CAPINB		
		GPT121	CAPINA		
		CCU60	CC62INA		
		CCU61	CC62INB		
	O	General-purpose output	P5_OUT.P0		1X00 _B
		GPTA output	OUT40		1X01 _B
		CCU60	CC62		1X10 _B
		SSC2 output	SLSO20		1X11 _B
P5.1	I	General-purpose input	P5_IN.P1	P5_IOCRO. PC1	0XXX _B
		GPTA input	IN41		
	O	General-purpose output	P5_OUT.P1		1X00 _B
		GPTA output	OUT41		1X01 _B
		Reserved	—		1X10 _B
		SSC2 output	SLSO21		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-19 Port 5 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P5.2	I	General-purpose input	P5_IN.P2	P5_IOCRO. PC2	0XXX _B
		GPTA input	IN42		
	O	General-purpose output	P5_OUT.P2		1X00 _B
		GPTA output	OUT42		1X01 _B
		CCU60	COU62		1X10 _B
		SSC2 output	SLSO22		1X11 _B
P5.3	I	General-purpose input	P5_IN.P3	P5_IOCRO. PC3	0XXX _B
		GPTA input	IN43		
	O	General-purpose output	P5_OUT.P3		1X00 _B
		GPTA output	OUT43		1X01 _B
		Reserved	–		1X10 _B
		SSC2 output	SLSO23		1X11 _B
P5.4	I	General-purpose input	P5_IN.P4	P5_IOCRO4. PC4	0XXX _B
		GPTA input	IN44		
		SSC2 input	SLSI2A		
	O	General-purpose output	P5_OUT.P4		1X00 _B
		GPTA output	OUT44		1X01 _B
		Reserved	–		1X10 _B
		SSC2 output	SLSO24		1X11 _B
P5.5	I	General-purpose input	P5_IN.P5	P5_IOCRO4. PC5	0XXX _B
		GPTA input	IN45		
		SSC2 input	MRST2A		
	O	General-purpose output	P5_OUT.P5		1X00 _B
		GPTA output	OUT45		1X01 _B
		Reserved	–		1X10 _B
		SSC2 output	MRST2		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-19 Port 5 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P5.6	I	General-purpose input	P5_IN.P6	P5_IOCR4. PC6	0XXX _B
		GPTA input	IN46		
		SSC2 input	MTSR2A		
	O	General-purpose output	P5_OUT.P6		1X00 _B
		GPTA output	OUT46		1X01 _B
		Reserved	–		1X10 _B
		SSC2 output	MTSR2		1X11 _B
P5.7	I	General-purpose input	P5_IN.P7	P5_IOCR4. PC7	0XXX _B
		GPTA input	IN47		
		SSC2 input	SCLK2A		
	O	General-purpose output	P5_OUT.P7		1X00 _B
		GPTA output	OUT47		1X01 _B
		Reserved	–		1X10 _B
		SSC2 output	SCLK2		1X11 _B
P5.8	I	General-purpose input	P5_IN.P8	P5_IOCR8. PC8	0XXX _B
		CCU60	CCU61INA		
		CCU61	CCU61INB		
	O	General-purpose output	P5_OUT.P8		1X00 _B
		GPTA output	OUT6		1X01 _B
		ERAY output	TXDA1		1X10 _B
		CCU60	CC61		1X11 _B
P5.9	I	General-purpose input	P5_IN.P9	P5_IOCR8. PC9	0XXX _B
		CAN node 0 input	RXDCAN0		
	O	General-purpose output	P5_OUT.P9		1X00 _B
		GPTA output	OUT7		1X01 _B
		ERAY output	TXDB1		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-19 Port 5 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P5.10	I	General-purpose input	P5_IN.P10	P5_IOC8. PC10	0XXX _B
	O	General-purpose output	P5_OUT.P10		1X00 _B
		GPTA output	OUT8		1X01 _B
		ERAY output	TXENA		1X10 _B
		CCU60	COUT61		1X11 _B
P5.11	I	General-purpose input	P5_IN.P11	P5_IOC8. PC11	0XXX _B
	O	General-purpose output	P5_OUT.P11		1X00 _B
		GPTA output	OUT9		1X01 _B
		ERAY output	TXENB		1X10 _B
		CCU60	COUT63		1X11 _B
P5.12	I	General-purpose input	P5_IN.P12	P5_IOC12 .PC12	0XXX _B
		CCU60	CCPOS0A		
		CCU61	T12HRB		
		GPT120	T3INA		
		GPT121	T3INB		
	O	General-purpose output	P5_OUT.P12		1X00 _B
		GPTA output	OUT19		1X01 _B
		SSC0 output	SLSO7		1X10 _B
		ADC1	ADC1EMUX0		1X11 _B
P5.13	I	General-purpose input	P5_IN.P13	P5_IOC12 .PC13	0XXX _B
		CCU60	CCPOS1A		
		CCU61	T13HRB		
		GPT120	T3EUDA		
		GPT121	T3EADB		
	O	General-purpose output	P5_OUT.P13		1X00 _B
		GPTA output	OUT20		1X01 _B
		Reserved	—		1X10 _B
		ADC1	ADC1EMUX1		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-19 Port 5 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P5.14	I	General-purpose input	P5_IN.P14	P5_IOC12.PC14	0XXX _B
		ERAY input	RXDA1		
		CCU60	CCPOS2A		
		CCU61	T12HRC		
		CCU61	T13HRC		
		GPT120	T4INA		
		GPT121	T4INB		
	O	General-purpose output	P5_OUT.P14		1X00 _B
		GPTA output	OUT36		1X01 _B
		Reserved	—		1X10 _B
		ADC1	ADC1EMUX2		1X11 _B
P5.15	I	General-purpose input	P5_IN.P15	P5_IOC12.PC15	0XXX _B
		ERAY input	RXDB1		
	O	General-purpose output	P5_OUT.P15		1X00 _B
		GPTA output	OUT37		1X01 _B
		Reserved	—		1X10 _B
		CAN node 0 output	TXDCAN0		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.9.3 Port 5 Registers

The following registers are available on Port 5:

Table 9-20 Port 5 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P5_OUT	Port 5 Output Register	0000 _H	Page 9-19
P5_OMR	Port 5 Output Modification Register	0004 _H	Page 9-20
P5_IOCRO	Port 5 Input/Output Control Register 0	0010 _H	Page 9-10
P5_IOCRR4	Port 5 Input/Output Control Register 4	0014 _H	Page 9-11
P5_IOCRR8	Port 5 Input/Output Control Register 8	0018 _H	Page 9-11
P5_IOCRR12	Port 5 Input/Output Control Register 12	001C _H	Page 9-12
P5_IN	Port 5 Input Register	0024 _H	Page 9-23
P5_PDR0	Port 5 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P5_PDR1	Port 5 Pad Driver Mode 1 Register	0044 _H	Page 9-16
P5_ESR	Port 5 Emergency Stop Register	0050 _H	Page 9-22

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.10 Port 6

Port 6 is an 4-bit GPIO port. Pins associated to it be used in two ways:

- as a CMOS Port where each pin outputs one signal, as any other port (only exception - no open drain mode available), and
- as an output LVDS port where a pin pair (two pins) outputs one differential MSC signal.

The switching between the two modes is done via the PDR registers.

The switching between Input/Output and Pull-Up/Pull-Down control is done via the IOCR register.

Attention: In the LVDS mode the IOCR.PC_x bit field of each pin of the LVDS pair must be programmed as output, that is 1xxx_B.

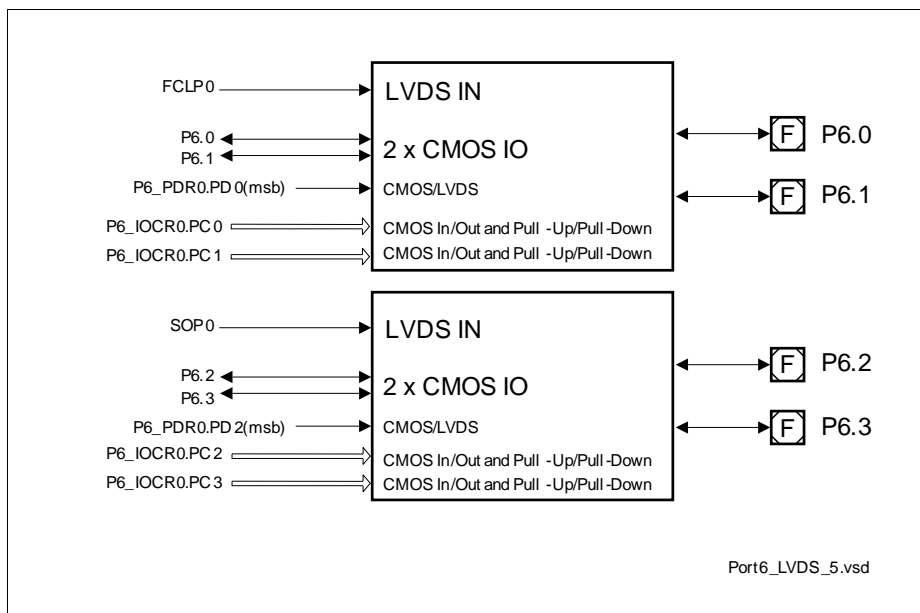


Figure 9-3 Port 6 Pad Connections

9.10.1 Port 6 Configuration

Port 6 is a 4-bit bi-directional general-purpose I/O port which can be used for the MSC0 and GPTA0 I/O lines.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.10.2 Port 6 Function Table

Table 9-21 summarizes the I/O control selection functions of each Port 6 line.

Table 9-21 Port 6 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P6.0	I	General-purpose input	P6_IN.P0	P6_IOCR0.PC0	0XXX _B
	O	General-purpose output	P6_OUT.P0		1X00 _B
		MSC0 output	FCLN0		1X01 _B
		GPTA0 output	OUT80		1X10 _B
		Reserved	—		1X11 _B
P6.1	I	General-purpose input	P6_IN.P1	P6_IOCR0.PC1	0XXX _B
	O	General-purpose output	P6_OUT.P1		1X00 _B
		MSC0 output	FCLP0A		1X01 _B
		GPTA0 output	OUT81		1X10 _B
		Reserved	—		1X11 _B
P6.2	I	General-purpose input	P6_IN.P2	P6_IOCR0.PC2	0XXX _B
	O	General-purpose output	P6_OUT.P2		1X00 _B
		MSC0 output	SON0		1X01 _B
		GPTA0 output	OUT82		1X10 _B
		Reserved	—		1X11 _B
P6.3	I	General-purpose input	P6_IN.P3	P6_IOCR0.PC3	0XXX _B
	O	General-purpose output	P6_OUT.P3		1X00 _B
		MSC0 output	SOP0A		1X01 _B
		GPTA0 output	OUT83		1X10 _B
		Reserved	—		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.10.3 Port 6 Registers

The following registers are available on Port 6:

Table 9-22 Port 6 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P6_OUT	Port 6 Output Register	0000 _H	below ²⁾
P6_OMR	Port 6 Output Modification Register	0004 _H	
P6_IOCRO	Port 6 Input/Output Control Register 0	0010 _H	Page 9-10
P6_IN	Port 6 Input Register	0024 _H	below ²⁾
P6_PDR0	Port 6 Pad Driver Mode 0 Register	0040 _H	Page 9-66
P6_ESR	Port 6 Emergency Stop Register	0050 _H	Page 9-67

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 6 section because they differ from the general port register description given in [Section 9.3](#).

9.10.3.1 Port 6 Output Register

The basic P6_OUT register functionality is described on [Page 9-19](#). Port lines P6.[15:4] are not connected. P6_OUT bits P[15:4] is read as 0 after reset and should be written with 0.

9.10.3.2 Port 6 Output Modification Register

The basic P6_OMR register functionality is described on [Page 9-20](#). Port lines P6.[15:4] are not connected. The P6_OMR bits PS[15:4] and PR[15:4] have no effect on register bits P6_OUT.P[15:4].

9.10.3.3 Port 6 Input Register

The basic P6_IN register functionality is described on [Page 9-23](#). Port lines P6.[15:4] are not available. Therefore, the P6_IN bits P[15:4] are always read as 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.10.3.4 Port 6 Pad Driver Mode 0 Register

The basic P6_PDR0 register functionality is described on [Page 9-15](#). However, port lines P6.[15:4] are not available.

P6_PDR0

Port 6 Pad Driver Mode 0 Register (40_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PD3		0	PD2		0	PD1		0	PD0					
r	rw		r	rw		r	rw		r	rw					

Field	Bits	Type	Description
PD0	[2:0]	rw	Pad Driver Mode for Port 6 Pin [1:0] The MSB of PDx switches between CMOS (default) and LVDS modes. 0XX _B CMOS input or output (depending on IOCRx setting) 1XX _B LVDS output (pull-up or pull-down must be switched off via IOCRx)
PD2	[10:8]	rw	Pad Driver Mode for Port 6 Pin [3:2] The MSB of PDx switches between CMOS (default) and LVDS modes. 0XX _B CMOS input or output (depending on IOCRx setting) 1XX _B LVDS output (pull-up or pull-down must be switched off via IOCRx)
PD1, PD3	[6:4], [14:12]	rw	Reserved Read as 000 _B after reset; returns value that was written.
0	3, 7, 11, [31:15]	r	Reserved Read as 0; should be written with 0.

9.10.3.5 Port 6 Emergency Stop Register

The basic P6_ESR register functionality is described on [Page 9-22](#). At Port 6, port lines P6.[3:0] have GPTA outputs. Therefore, the P6_ESR bits EN[15:4] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.11 Port 8

This section describes the Port 8 functionality in detail.

9.11.1 Port 8 Configuration

Port 8 is an 14-bit bi-directional general-purpose I/O port which can be used for CCU6/GPT12, SSC3 and the GPTA0 I/O lines.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.11.2 Port 8 Function Table

Table 9-23 summarizes the I/O control selection functions of each Port 8 line.

Table 9-23 Port 8 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P8.0	I	General-purpose input	P8_IN.P0	P8_IOCRO. PC0	0XXX _B
		SSC3 input (Slave Mode)	SCLK3		
		CCU60	CCPOS0C		
		GPT120	T3INB		
		GPT121	T3INA		
	O	General-purpose output	P8_OUT.P0		1X00 _B
		Reserved	–		1X01 _B
		GPTA0 output	OUT48		1X10 _B
		SSC3 output (Master Mode)	SCLK3		1X11 _B
P8.1	I	General-purpose input	P8_IN.P1	P8_IOCRO. PC1	0XXX _B
		SSC3 input (Master Mode)	MRST3		
		CCU60	CCPOS1C		
		GPT120	T3EUDB		
		GPT121	T3EUDA		
	O	General-purpose output	P8_OUT.P1		1X00 _B
		Reserved	–		1X01 _B
		GPTA0 output	OUT49		1X10 _B
		SSC3 output (Slave Mode)	MRST3		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-23 Port 8 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P8.2	I	General-purpose input	P8_IN.P2	P8_IOCRO. PC2	0XXX _B
		SSC3 input (Master Mode)	MTSR3		
		CCU60	CCPOS2C		
		GPT120	T4INB		
		GPT121	T4INA		
	O	General-purpose output	P8_OUT.P2		1X00 _B
		Reserved	–		1X01 _B
		GPTA0 output	OUT50		1X10 _B
		SSC3 output (Slave Mode)	MTSR3		1X11 _B
P8.3	I	General-purpose input	P8_IN.P3	P8_IOCRO. PC3	0XXX _B
		SSC3 input	SLSI3		
		CCU60	CC61INC		
	O	General-purpose output	P8_OUT.P3		1X00 _B
		CCU61	CC61		1X01 _B
		GPTA0 output	OUT51		1X10 _B
		SSC3 output	SLSO30		1X11 _B
P8.4	I	General-purpose input	P8_IN.P4	P8_IOCRO4. PC4	0XXX _B
	O	General-purpose output	P8_OUT.P4		1X00 _B
		GPTA0 Output	OUT99		1X01 _B
		CCU61	COUT62		1X10 _B
		SSC3 output	SLSO31		1X11 _B
P8.5	I	General-purpose input	P8_IN.P5	P8_IOCRO4. PC5	0XXX _B
		CCU60	CC60INC		
	O	General-purpose output	P8_OUT.P5		1X00 _B
		GPTA0 Output	OUT100		1X01 _B
		CCU61	CC60		1X10 _B
		SSC3 output	SLSO32		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-23 Port 8 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P8.6	I	General-purpose input	P8_IN.P6	P8_IOCR4. PC6	0XXX _B
	O	General-purpose output	P8_OUT.P6		1X00 _B
		GPTA0 Output	OUT101		1X01 _B
		Reserved	–		1X10 _B
		CCU61	COUT61		1X11 _B
P8.7	I	General-purpose input	P8_IN.P8	P8_IOCR4. PC7	0XXX _B
		CCU60	CC62INC		0XXX _B
	O	General-purpose output	P8_OUT.P8		1X00 _B
		GPTA0 Output	OUT102		1X01 _B
		Reserved	–		1X10 _B
		CCU61	CC62		1X11 _B
P8.8	I	General-purpose input	P8_IN.P8	P8_IOCR8. PC8	0XXX _B
	O	General-purpose output	P8_OUT.P8		1X00 _B
		Reserved	–		1X01 _B
		GPTA0 Output	OUT56		1X10 _B
		SSC3 output	SLSO33		1X11 _B
P8.9	I	General-purpose input	P8_IN.P9	P8_IOCR8. PC9	0XXX _B
	O	General-purpose output	P8_OUT.P9		1X00 _B
		Reserved	–		1X01 _B
		GPTA0 Output	OUT57		1X10 _B
		SSC3 output	SLSO34		1X11 _B
P8.10	I	General-purpose input	P8_IN.P10	P8_IOCR8. PC10	0XXX _B
	O	General-purpose output	P8_OUT.P10		1X00 _B
		GPTA0 Output	OUT105		1X01 _B
		Reserved	–		1X10 _B
		Reserved	-		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-23 Port 8 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P8.11	I	General-purpose input	P8_IN.P11	P8_IOC8. PC11	0XXX _B
	O	General-purpose output	P8_OUT.P11		1X00 _B
		GPTA0 Output	OUT106		1X01 _B
		Reserved	–		1X10 _B
		Reserved	-		1X11 _B
P8.12	I	General-purpose input	P8_IN.P12	P8_IOC12. PC12	0XXX _B
	O	General-purpose output	P8_OUT.P12		1X00 _B
		GPTA0 Output	OUT107		1X01 _B
		Reserved	–		1X10 _B
		Reserved	-		1X11 _B
P8.13	I	General-purpose input	P8_IN.P12	P8_IOC12. PC13	0XXX _B
	O	General-purpose output	P8_OUT.P12		1X00 _B
		GPTA0 Output	OUT4		1X01 _B
		Reserved	–		1X10 _B
		CCU61	COUT60		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.11.3 Port 8 Register

The following registers are available on Port 8:

Table 9-24 Port 8 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P8_OUT	Port 8 Output Register	0000 _H	below ²⁾
P8_OMR	Port 8 Output Modification Register	0004 _H	
P8_IOCRO	Port 8 Input/Output Control Register 0	0010 _H	Page 9-10
P8_IOCRR4	Port 8 Input/Output Control Register 4	0014 _H	Page 9-11
P8_IOCRR8	Port 8 Input/Output Control Register 8	0018 _H	Page 9-11
P8_IOCRR12	Port 8 Input/Output Control Register 12	001C _H	Page 9-74
P8_IN	Port 8 Input Register	0024 _H	below ²⁾
P8_PDR0	Port 8 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P8_PDR1	Port 8 Pad Driver Mode 1 Register	0044 _H	Page 9-75
P8_ESR	Port 8 Emergency Stop Register	0050 _H	Page 9-22

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed here in the Port 8 section because they differ from the general port register description given in [Section 9.3](#).

9.11.3.1 Port 8 Output Register

The basic P8_OUT register functionality is described on [Page 9-19](#). Port lines P8.[15:14] are not connected. Reading the P8_OUT bits P[15:14] returns the value that was last written (0 after reset). These bits can be also set/reset by the corresponding P8_OMR bits.

9.11.3.2 Port 8 Output Modification Register

The basic P8_OMR register functionality is described on [Page 9-20](#). Port lines P8.[15:14] are not connected. P8_OMR bits PS[15:14] and PR[15:14] have no direct effect on port lines but only on register bits P8_OUT.P[15:14].

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.11.3.3 Port 8 Input/Output Control Register 12

PC14 and PC15 bit fields in register P8_IOCRL2 are not connected.

P8_IOCRL2

Port 8 Input/Output Control Register 12

(1C_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC15	0	PC14	0	PC13	0	PC12	0	
rw	r	rw	r	rw	r	rw	r	

Field	Bits	Type	Description
PC12	[7:4]	rw	Port Control for Port 8.12 (coding see Table 9-6 on Page 9-13)
PC13	[15:12]	rw	Port Control for Port 8.13 (coding see Table 9-6 on Page 9-13)
PC14	[23:20]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
PC15	[31:28]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

9.11.3.4 Port 8 Input Register

The basic P8_IN register functionality is described on [Page 9-23](#). Port lines P8.[15:14] are not connected. Therefore, the P8_IN bits P8.[15:14] are always read as 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.11.3.5 Port 8 Pad Driver Mode 1 Register

The basic P8_PDR1 register functionality is described on [Page 9-15](#).

P8_PDR1

Port 8 Pad Driver Mode 1 Register

(44_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PD15			0	PD14			0	PD13			0	PD12		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PD11			0	PD10			0	PD9			0	PD8		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
PD8	[2:0]	rw	Pad Driver Mode for P8.8
PD9	[6:4]	rw	Pad Driver Mode for P8.9
PD10	[10:8]	rw	Pad Driver Mode for P8.10
PD11	[14:12]	rw	Pad Driver Mode for P8.11
PD12	[18:16]	rw	Pad Driver Mode for P8.12
PD13	[22:20]	rw	Pad Driver Mode for P8.13
PD14	[26:24]	rw	Reserved Read as 000 _B after reset; returns value that was written.
PD15	[30:28]	rw	Reserved Read as 000 _B after reset; returns value that was written.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.12 Port 9

This section describes the Port 9 functionality in detail.

9.12.1 Port 9 Configuration

Port 9 is a 9-bit bi-directional general-purpose I/O port which can be used for the CCU6 and GPTA0 I/O lines and OCDS/JTAG.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.12.2 Port 9 Function Table

Table 9-25 summarizes the I/O control selection functions of each Port 9 line.

Table 9-25 Port 9 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P9.0	I	General-purpose input	P9_IN.P0	P9_IOCR0.PC0	0XXX _B
		CAN2 input	RXDCAN2		
	O	General-purpose output	P9_OUT.P0		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT80		1X10 _B
		Reserved	—		1X11 _B
P9.1	I	General-purpose input	P9_IN.P1	P9_IOCR0.PC1	0XXX _B
	O	General-purpose output	P9_OUT.P1		1X00 _B
		CAN2 output	TXDCAN2		1X01 _B
		GPTA0 output	OUT81		1X10 _B
		Reserved	—		1X11 _B
P9.2	I	General-purpose input	P9_IN.P2	P9_IOCR0.PC2	0XXX _B
	O	General-purpose output	P9_OUT.P2		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT82		1X10 _B
		CCU60	COUT63		1X11 _B
P9.3	I	General-purpose input	P9_IN.P3	P9_IOCR0.PC3	0XXX _B
	O	General-purpose output	P9_OUT.P3		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT83		1X10 _B
		CCU60	COUT62		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-25 Port 9 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P9.4	I	General-purpose input	P9_IN.P4	P9_IOC4.PC4	0XXX _B
		CCU61	CC62INC		
	O	General-purpose output	P9_OUT.P4		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT84		1X10 _B
		CCU60	CC62		1X11 _B
P9.5	I	General-purpose input	P9_IN.P5	P9_IOC4.PC5	0XXX _B
		OCDS input	²⁾ TDI		
		OCDS input	BRKIN ²⁾		
	O	General-purpose output	P9_OUT.P5		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		Reserved ¹⁾	—		1X10 _B
		Reserved ¹⁾	—		1X11 _B
		OCDS output	BRKOUT ²⁾		
P9.6	I	General-purpose input	P9_IN.P6	P9_IOC4.PC6	0XXX _B
		OCDS input	TDO ³⁾		
		OCDS input	BRKIN ³⁾		
	O	General-purpose output	P9_OUT.P6		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		Reserved ¹⁾	—		1X10 _B
		Reserved ¹⁾	—		1X11 _B
		OCDS output	BRKOUT ³⁾		
		OCDS output	TDO ³⁾		

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-25 Port 9 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P9.7	I	General-purpose input	P9_IN.P7	P9_IOCR4.PC7	0XXX _B
		CCU61	CC60INC		
	O	General-purpose output	P9_OUT.P7		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT87		1X10 _B
		CCU60	CC60		1X11 _B
P9.8	I	General-purpose input	P9_IN.P8	P9_IOCR8.PC8	0XXX _B
	O	General-purpose output	P9_OUT.P8		1X00 _B
		Reserved ¹⁾	—		1X01 _B
		GPTA0 output	OUT88		1X10 _B
		CCU60	COUT60		1X11 _B

1) The port I/O control values P9_IOCRx.Py that are assigned to this reserved alternate output control selection should not be used.

2) If the functionality of TDI/BRKIN/BRKOUT is not selected, this pin can be used as GPIO.

3) If the functionality of TDO/BRKIN/BRKOUT is not selected, this pin can be used as GPIO.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.12.3 Port 9 Registers

The following registers are available on Port 9:

Table 9-26 Port 9 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P9_OUT	Port 9 Output Register	0000 _H	below ²⁾
P9_OMR	Port 9 Output Modification Register	0004 _H	
P9_IOCRO	Port 9 Input/Output Control Register 0	0010 _H	Page 9-10
P9_IOCRR4	Port 9 Input/Output Control Register 4	0014 _H	Page 9-11
P9_IOCRR8	Port 9 Input/Output Control Register 8	0018 _H	Page 9-81
P9_IN	Port 9 Input Register	0024 _H	Page 9-81 ²⁾
P9_PDR0	Port 9 Pad Driver Mode 0 Register	0040 _H	Page 9-15
P9_PDR1	Port 9 Pad Driver Mode 1 Register	0044 _H	Page 9-82
P9_ESR	Port 9 Emergency Stop Register	0050 _H	Page 9-82 ²⁾

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 9 section because they differ from the general port register description given in [Section 9.3](#).

9.12.3.1 Port 9 Output Register

The basic P9_OUT register functionality is described on [Page 9-19](#). Port lines P9.[15:9] are not connected. The P9_OUT bits [15:12] should be written with 0 and is always read as 0. P9_OUT bits [11:9] is read as 0 after reset and returns the value that was last written.

9.12.3.2 Port 9 Output Modification Register

The basic P9_OMR register functionality is described on [Page 9-20](#). Port lines P9.[15:9] are not connected. P9_OMR bits PS[15:12] and PR[15:12] are not implemented. These bits should always be written with 0. P9_OMR bits PS[11:9] and PR[11:9] is read as 0 after reset and returns the value that was last written.

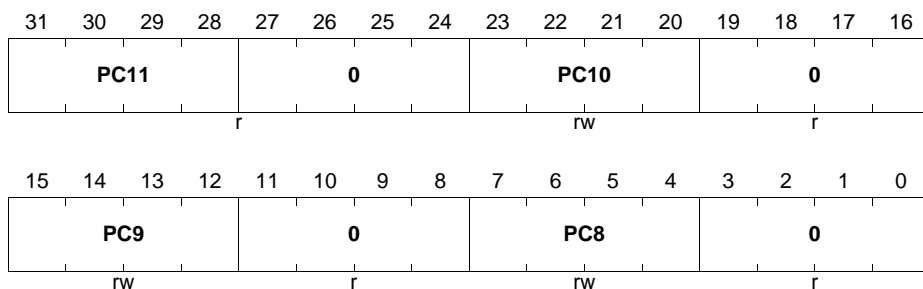
General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.12.3.3 Port 9 Input/Output Control Register 8

P9_IOC8

Port 9 Input/Output Control Register 8

(18_H)

Reset Value: 2020 2020_H


Field	Bits	Type	Description
PC8	[7:4]	rw	Port Control for P9.8 This bit field determines the P9.8 functionality.
PC9	[15:12]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
PC10	[23:20]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
PC11	[31:28]	rw	Reserved Read as 0010 _B after reset; returns value that was written.
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

9.12.3.4 Port 9 Input Register

The basic P9_IN register functionality is described on [Page 9-23](#). Port line P9.[15:9] are not connected. P9_IN bit P9.[15:9] are always read as 0.

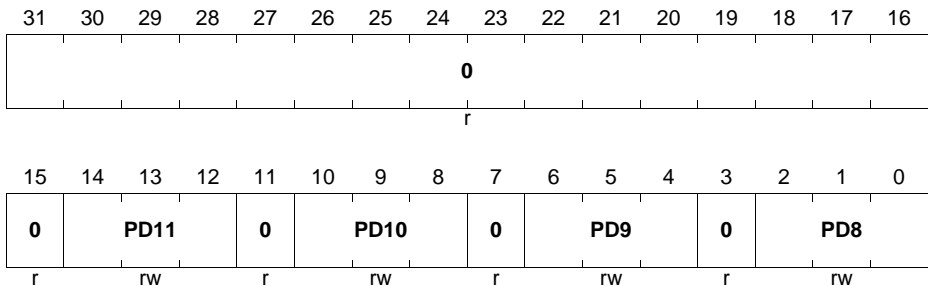
General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.12.3.5 Port 9 Pad Driver Mode 1 Register

The basic P9_PDR1 register functionality is described on [Page 9-15](#). However, port lines P9.[15:9] are not connected.

P9_PDR1

Port 9 Pad Driver Mode 1 Register (44_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
PD8	[2:0]	rw	Pad Driver Mode for P9.8
PD9	[6:4]	rw	Reserved Read as 000 _B after reset; returns value that was written.
PD10	[10:8]	rw	Reserved Read as 000 _B after reset; returns value that was written.
PD11	[14:12]	rw	Reserved Read as 000 _B after reset; returns value that was written.
0	3, 7, 11, [31:15]	r	Reserved Read as 0; should be written with 0.

9.12.3.6 Port 9 Emergency Stop Register

The basic P9_ESR register functionality is described on [Page 9-22](#). At Port 9, port lines P9.[4:0] and P9.[8:7] have GPTA outputs. Therefore, the P9_ESR bits EN[6:5] and EN[15:9] are not implemented. They are always read as 0 and should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.13 Port 10

This section describes the Port 10 functionality in detail.

9.13.1 Port 10 Configuration

Port 10 is a 4-bit bi-directional general-purpose I/O port which can be used for SSC2 functions.

9.13.2 Port 10 Function Table

Table 9-27 summarizes the I/O control selection functions of each line.

Table 9-27 Port 10 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P10.0	I	General-purpose input	P10_IN.P0	P10_IOCR0. PC0	0XXX _B
		SSC2 input (Master Mode)	MRST2B		
	O	General-purpose output	P10_OUT.P0		1X00 _B
		SSC2 output (Slave Mode)	MRST2		1X01 _B
		Reserved	—		1X10 _B
		Reserved	—		1X11 _B
P10.1	I	General-purpose input	P10_IN.P1	P10_IOCR0. PC1	0XXX _B
		SSC2 input (Slave Mode)	MTSR2B		
	O	General-purpose output	P10_OUT.P1		1X00 _B
		SSC2 output (Master Mode)	MTSR2		1X01 _B
		Reserved	—		1X10 _B
		Reserved	—		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-27 Port 10 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ I/O Line	Port I/O Control Select.	
				Reg./Bit Field	Value
P10.2	I	General-purpose input	P10_IN.P2	P10_IOC0.PC2	0XXX _B
		SSC2 input	SCLK2B		
	O	General-purpose output	P10_OUT.P2		1X00 _B
		SSC2 output	SCLK2		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B
P10.3	I	General-purpose input	P10_IN.P3	P10_IOC0.PC3	0XXX _B
		SSC2 input	SLSI2B		
	O	General-purpose output	P10_OUT.P3		1X00 _B
		SSC2 output	SLSO20		1X01 _B
		Reserved	–		1X10 _B
		Reserved	–		1X11 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.13.3 Port 10 Registers

The following registers are available on Port 10:

Table 9-28 Port 10 Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
P10_OUT	Port 10 Output Register	0000 _H	Page 9-85
P10_OMR	Port 10 Output Modification Register	0004 _H	Page 9-85
P10_IOCRO	Port 10 Input/Output Control Register 0	0010 _H	Page 9-10
P10_IN	Port 10 Input Register	0024 _H	Page 9-85 ²⁾
P10_PDR0	Port 10 Pad Driver Mode 0 Register	0040 _H	Page 9-86

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed and noted here in the Port 10 section because they differ from the general port register description given in [Section 9.3](#).

Note: Register P10_IN makes it possible to read the actual logic levels of the Port 10 inputs.

9.13.3.1 Port 10 Output Register

The basic P10_OUT register functionality is described on [Page 9-19](#). Port lines P10.[15:4] are not available. P10_OUT bits P[15:4] is read as 0 after reset and should be written with 0.

9.13.3.2 Port 10 Output Modification Register

The basic P10_OMR register functionality is described on [Page 9-20](#). However, port lines P10.[15:4] are not available. P10_OMR bits PS[15:4] and PR[15:4] have no effect on register bits P10_OUT.P[15:4].

9.13.3.3 Port 10 Input Register

The basic P10_IN register functionality is described on [Page 9-23](#). Port lines P10.[15:4] are not available. Therefore, the P10_IN bits P[15:4] are always read as 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

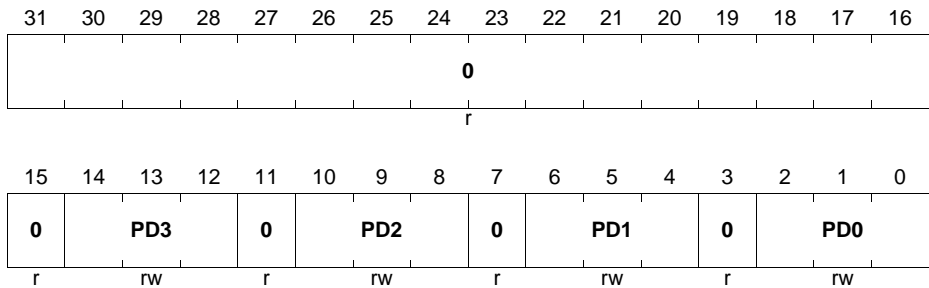
9.13.3.4 Port 10 Pad Driver Mode 0 Register

The basic P10_PDR0 register functionality is described on [Page 9-15](#). However, port lines P10.[15:4] are not available.

P10_PDR0

Port 10 Pad Driver Mode 0 Register (40_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
PD0	[2:0]	rw	Pad Driver Mode for P10.0
PD1	[6:4]	rw	Pad Driver Mode for P10.1
PD2	[10:8]	rw	Pad Driver Mode for P10.2
PD3	[14:12]	rw	Pad Driver Mode for P10.3
0	3, 7, 11, [31:15]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)**9.14 Port 11**

This section describes the Port 11 functionality in detail.

9.14.1 Port 11 Configuration

Port 11 is a 16-bit input port.

Table 9-29 summarizes the input control selection functions of each Port 11 line.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.14.2 Port 11 Function Table

Table 9-29 summarizes the input control selection functions of each Port 11 line. If digital input functionality is selected, the digital input needs to meet the criteria defined for the Class S pads.

Table 9-29 Port 11 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ Input Line	Port Functionality Control Select	
				Reg./Bit Field	Value
P11.0	I	ADC Analog Input	AN16	P11_PDISC.PDIS0	1 _B
		Digital Input	DIG0		0 _B
P11.1	I	ADC Analog Input	AN17	P11_PDISC.PDIS1	1 _B
		Digital Input	DIG1		0 _B
P11.2	I	ADC Analog Input	AN18	P11_PDISC.PDIS2	1 _B
		Digital Input	DIG2		0 _B
P11.3	I	ADC Analog Input	AN19	P11_PDISC.PDIS3	1 _B
		Digital Input	DIG3		0 _B
P11.4	I	ADC Analog Input	AN20	P11_PDISC.PDIS4	1 _B
		Digital Input	DIG4		0 _B
P11.5	I	ADC Analog Input	AN21	P11_PDISC.PDIS5	1 _B
		Digital Input	DIG5		0 _B
P11.6	I	ADC Analog Input	AN22	P11_PDISC.PDIS6	1 _B
		Digital Input	DIG6		0 _B
P11.7	I	ADC Analog Input	AN23	P11_PDISC.PDIS7	1 _B
		Digital Input	DIG7		0 _B
P11.8	I	ADC Analog Input	AN24	P11_PDISC.PDIS8	1 _B
		Digital Input	DIG8		0 _B
P11.9	I	ADC Analog Input	AN25	P11_PDISC.PDIS9	1 _B
		Digital Input	DIG9		0 _B
P11.10	I	ADC Analog Input	AN26	P11_PDISC.PDIS10	1 _B
		Digital Input	DIG10		0 _B
P11.11	I	ADC Analog Input	AN27	P11_PDISC.PDIS11	1 _B
		Digital Input	DIG11		0 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Table 9-29 Port 11 Functions (cont'd)

Port Pin	I/O	Pin Functionality	Associated Reg./ Input Line	Port Functionality Control Select	
				Reg./Bit Field	Value
P11.12	I	ADC Analog Input	AN28	P11_PDISC.PDIS12	1 _B
		Digital Input	DIG12		0 _B
P11.13	I	ADC Analog Input	AN29	P11_PDISC.PDIS13	1 _B
		Digital Input	DIG13		0 _B
P11.14	I	ADC Analog Input	AN30	P11_PDISC.PDIS14	1 _B
		Digital Input	DIG14		0 _B
P11.15	I	ADC Analog Input	AN31	P11_PDISC.PDIS15	1 _B
		Digital Input	DIG15		0 _B

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.14.3 Port 11 Registers

The following registers are available on Port 11:

Table 9-30 Port 11 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P11_IOCRO	Port 11 Input/Output Control Register 0	0010 _H	Page 9-91 ²⁾
P11_IOCRO4	Port 11 Input/Output Control Register 4	0014 _H	Page 9-91 ²⁾
P11_IOCRO8	Port 11 Input/Output Control Register 8	0018 _H	Page 9-91 ²⁾
P11_IOCRO12	Port 11 Input/Output Control Register 12	001C _H	Page 9-91 ²⁾
P11_IN	Port 11 Input Register	0024 _H	Page 9-23
P11_PDISC	Port 11 Pin Function Decision Control Register	0060 _H	Page 9-94 ²⁾

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed here in the Port 11 section because they differ from the general port register description given in [Section 9.3](#).

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.14.4 Port 11 Input/Output Control Registers

P11_IOCRO

Port 11 Input/Output Control Register 0

(10_H)

Reset Value: 2020 2020_H

31	28	27	24	23	20	19	16	15	12	11	8	7	4	3	0
PC3	0	PC2	0	PC1	0	PC0	0								
rw	r	rw	r	rw	r	rw	r								

Field	Bits	Type	Description
PC0, PC1, PC2, PC3	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin x This bit field defines the Port n line x functionality according to Table 9-31 .
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

P11_IOC4

Port 11 Input/Output Control Register 4

(14_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC7	0	PC6	0	PC5	0	PC4	0	
rw	r	rw	r	rw	r	rw	r	

Field	Bits	Type	Description
PC4, PC5, PC6, PC7	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin x This bit field defines the Port n line x functionality according to Table 9-31 .
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

P11_IOC8

Port 11 Input/Output Control Register 8

(18_H)

Reset Value: 2020 2020_H

31	28 27	24 23	20 19	16 15	12 11	8 7	4 3	0
PC11	0	PC10	0	PC9	0	PC8	0	
rw	r	rw	r	rw	r	rw	r	

Field	Bits	Type	Description
PC8, PC9, PC10, PC11	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin x This bit field defines the Port n line x functionality according to Table 9-31 .
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

P11_IOCR12

Port 11 Input/Output Control Register 12

(1C_H)

Reset Value: 2020 2020_H

31	28	27	24	23	20	19	16	15	12	11	8	7	4	3	0
PC15	0		PC14	0			PC13	0			PC12	0			
rw	r		rw	r			rw	r			rw	r			

Field	Bits	Type	Description
PC12, PC13, PC14, PC15	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin x This bit field defines the Port n line x functionality according to Table 9-31 .
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

Table 9-31 PCx Coding for Port 11

PCx[3:0]	I/O	Output Characteristics	Selected Pull-up / Pull-down / Selected Output Function
0X00 _B	Input	—	No input pull device connected
0X01 _B			Input pull-down device connected
0X10 _B			Input pull-up device connected ¹⁾
0X11 _B			No input pull device connected

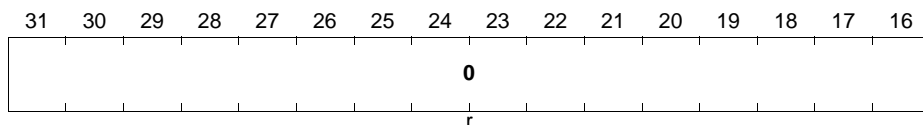
1) This is the default pull-up state after reset.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.14.5 Port 11 Pin Function Decision Control Register

P11_PDISC

Port 11 Pin Function Decision Control Register(60_H) **Reset Value: 0000 FFFF_H**



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS	PDIS
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
PDIS0	0	rw	Pin Function Decision Control for Pin 0 The bit selects the function of P11.0 The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 0. 1 _B Pad is used for ADC analog input 16.
PDIS1	1	rw	Pin Function Decision Control for Pin 1 The bit selects the function of P11.1 The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 1. 1 _B Pad is used for ADC analog input 17.
PDIS2	2	rw	Pin Function Decision Control for Pin 2 The bit selects the function of P11.2. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 2. 1 _B Pad is used for ADC analog input 18.
PDIS3	3	rw	Pin Function Decision Control for Pin 3 The bit selects the function of P11.3. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 3. 1 _B Pad is used for ADC analog input 19.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
PDIS4	4	rw	Pin Function Decision Control for Pin 4 The bit selects the function of P11.4. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 4. 1 _B Pad is used for ADC analog input 20.
PDIS5	5	rw	Pin Function Decision Control for Pin 5 The bit selects the function of P11.5. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 5. 1 _B Pad is used for ADC analog input 21.
PDIS6	6	rw	Pin Function Decision Control for Pin 6 The bit selects the function of P11.6. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 6. 1 _B Pad is used for ADC analog input 22.
PDIS7	7	rw	Pin Function Decision Control for Pin 7 The bit selects the function of P11.7. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 7. 1 _B Pad is used for ADC analog input 23.
PDIS8	8	rw	Pin Function Decision Control for Pin 8 The bit selects the function of P11.8. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 8. 1 _B Pad is used for ADC analog input 24.
PDIS9	9	rw	Pin Function Decision Control for Pin 9 The bit selects the function of P11.9. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 9. 1 _B Pad is used for ADC analog input 25.
PDIS10	10	rw	Pin Function Decision Control for Pin 10 The bit selects the function of P11.10. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 10. 1 _B Pad is used for ADC analog input 26.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
PDIS11	11	rw	Pin Function Decision Control for Pin 11 The bit selects the function of P11.11. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 11. 1 _B Pad is used for ADC analog input 27.
PDIS12	12	rw	Pin Function Decision Control for Pin 12 The bit selects the function of P11.12. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 12. 1 _B Pad is used for ADC analog input 28.
PDIS13	13	rw	Pin Function Decision Control for Pin 13 The bit selects the function of P11.13. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 13. 1 _B Pad is used for ADC analog input 29.
PDIS14	14	rw	Pin Function Decision Control for Pin 14 The bit selects the function of P11.14. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 14. 1 _B Pad is used for ADC analog input 30.
PDIS15	15	rw	Pin Function Decision Control for Pin 15 The bit selects the function of P11.15. The default state of the pad selects the ADC analog input. 0 _B Pad is used for digital input 15. 1 _B Pad is used for ADC analog input 31.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)**9.15 Port 12**

This section describes the Port 12 functionality in detail.

9.15.1 Port 12 Configuration

Port 12 is a 4-bit input port.

Table 9-32 summarizes the input control selection functions of each Port 12 line.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

9.15.2 Port 12 Function Table

Table 9-32 summarizes the input control selection functions of each Port 12 line. If digital input functionality is selected, the digital input needs to meet the criteria defined for the Class S pads.

Table 9-32 Port 12 Functions

Port Pin	I/O	Pin Functionality	Associated Reg./ Input Line	Port Functionality Control Select	
				Reg./Bit Field	Value
P12.0	I	ADC Analog Input	AN36	P12_PDISC.PDIS0	1 _B
		Digital Input	DIG16		0 _B
P12.1	I	ADC Analog Input	AN37	P12_PDISC.PDIS1	1 _B
		Digital Input	DIG17		0 _B
P12.2	I	ADC Analog Input	AN38	P12_PDISC.PDIS2	1 _B
		Digital Input	DIG18		0 _B
P12.3	I	ADC Analog Input	AN39	P12_PDISC.PDIS3	1 _B
		Digital Input	DIG19		0 _B

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9.15.3 Port 12 Registers

The following registers are available on Port 12:

Table 9-33 Port 12 Registers

Register Short Name	Register Long Name	Offset ¹⁾ Address	Description see
P12_IOCRO	Port 12 Input/Output Control Register 0	0010 _H	Page 9-100 ²⁾
P12_IN	Port 12 Input Register	0024 _H	Page 9-23
P12_PDISC	Port 12 Pin Function Decision Control Register	0060 _H	Page 9-101

1) The absolute addresses are calculated by adding the offset address to the module base address (see [Table 9-3](#))

2) These registers are listed here in the Port 12 section because they differ from the general port register description given in [Section 9.3](#).

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9.15.4 Port 12 Input/Output Control Registers

P12_IOCR0

Port 12 Input/Output Control Register 0

(10_H)

Reset Value: 2020 2020_H

31	28	27	24	23	20	19	16	15	12	11	8	7	4	3	0
PC3	0	PC2	0	PC1	0	PC0	0								
rw	r	rw	r	rw	r	rw	r								

Field	Bits	Type	Description
PC0, PC1, PC2, PC3	[7:4], [15:12], [23:20], [31:28]	rw	Port Control for Port n Pin x This bit field defines the Port n line x functionality according to Table 9-34 .
0	[3:0], [11:8], [19:16], [27:24]	r	Reserved Read as 0; should be written with 0.

Table 9-34 PCx Coding for Port 12

PCx[3:0]	I/O	Output Characteristics	Selected Pull-up / Pull-down / Selected Output Function
0X00 _B	Input	—	No input pull device connected
0X01 _B			Input pull-down device connected
0X10 _B			Input pull-up device connected ¹⁾
0X11 _B			No input pull device connected

1) This is the default pull-up state after reset.

General Purpose I/O Ports and Peripheral I/O Lines (Ports)

Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0; should be written with 0.

10 Peripheral Control Processor (PCP)

This chapter describes the Peripheral Control Processor (PCP), its architecture, programming model, registers, and instructions. The TC1728's PCP is an enhanced version of the TC1767's and TC1797's PCP peripheral control processor, which is an enhanced version of the TC1766's and TC1796's PCP, which is again an enhanced version of the TC1775 PCP.

Section 10.2 of this chapter describes the TC1728's PCP in general. TC1728 implementation-specific details are described in **Section 10.22**.

10.1 PCP Feature/Enhancement History List

The following table lists all PCP enhancements sequentially, for all versions of the PCP. The table will therefore list enhancements that may not apply to the PCP version included in TC1728.

Table 21 PCP Feature/Enhancement History List

Version	Enhancement
TC1775	<ul style="list-style-type: none"> First released version of PCP
TC1766, TC1796	<ul style="list-style-type: none"> Optimised Context switching Support for nested interrupts Enhanced instruction set Enhanced instruction execution speed Enhanced interrupt queueing
TC1767, TC1797	<ul style="list-style-type: none"> Enhanced PCP core to support higher clock frequencies Multiple clock ratios PCP:FPI 1:1 and 2:1 Adaption of PCP Trace Interface to PAL-MCDS Implementation of Parity
TC1387, TC1784, TC1798, TC172x Only enhancements in this row and above are included in TC1728	<ul style="list-style-type: none"> Support for High Integrity Operation (see Chapter 10.2.1). <ul style="list-style-type: none"> Programmable ENDINIT write <u>protection</u> for all Registers. Programmable write protection for CMEM. Programmable write protection for PRAM. Programmable limit of FPI addresses than can be written by the PCP. Implementation of ECC (replacing Parity) Various Errata fixes.

Peripheral Control Processor (PCP)

10.1.1 Switchable Core Clock Ratio

For shorter interrupt latency, shorter uninterruptible task time and increased computing power the PCP is improved to allow operation with a core clock that is faster than the FPI clock (of the FPI Bus to which the PCP is connected). The available clocking ratios (f_{FPI}/f_{PCP}) are 1:1 and 1:2. The clock is controlled and generated in the SCU. The PCP has separate clock inputs for the core and for the FPI-bus related circuits.

10.2 Peripheral Control Processor Overview

The PCP in the TC1728 performs tasks that would normally be performed by the combination of a DMA controller and its supporting CPU interrupt service routines in a traditional computer system. It could easily be considered as the host processor's first line of defence as an interrupt-handling engine. The PCP can unload the CPU from having to service time-critical interrupts. This provides many benefits, including:

- Avoiding large interrupt-driven task context-switching latencies in the host processor
- Reducing the cost of interrupts in terms of processor register and memory overhead
- Improving the responsiveness of interrupt service routines to data-capture and data-transfer operations
- Easing the implementation of multitasking operating systems.

The PCP has an architecture that efficiently supports DMA-type transactions to and from arbitrary devices and memory addresses within the TC1728 and also has reasonable stand-alone computational capabilities.

10.2.1 High Integrity Operation

The PCP can be used in High Integrity Systems to perform various system critical tasks. It follows that, when using the PCP for this function, a fundamental requirement is that the operation of the software running on the PCP must be robust against interference by an external agent (e.g. TriCore). Otherwise a system failure outside PCP could impact the operation of the PCP which might, in turn, cause the system critical task (running on the PCP) to fail.

This concept of immunity is further extended such the PCP can be configured to operate with a number of "Protected" channel programs. These channels are protected not only against failure of external agents but also against software failures in other "Unprotected" channel programs running on the PCP itself.

For High Integrity Systems it is also necessary to prevent the PCP from generating unwanted FPI writes to critical locations in the event of a PCP software malfunction. For this reason a programmable Memory Protection feature is provided to control (in hardware) the address range that can be written to by the PCP.

Peripheral Control Processor (PCP)

10.3 PCP Architecture

The PCP is made up of several modular blocks as follows. Please refer to [Figure 16](#).

- PCP Processor Core
- Code Memory (CMEM)
- Parameter Memory (PRAM)
- PCP Interrupt Control Unit (PICU)
- PCP Service Request Nodes (PSRN)
- System bus interface to the Flexible Peripheral Interface (FPI Bus)

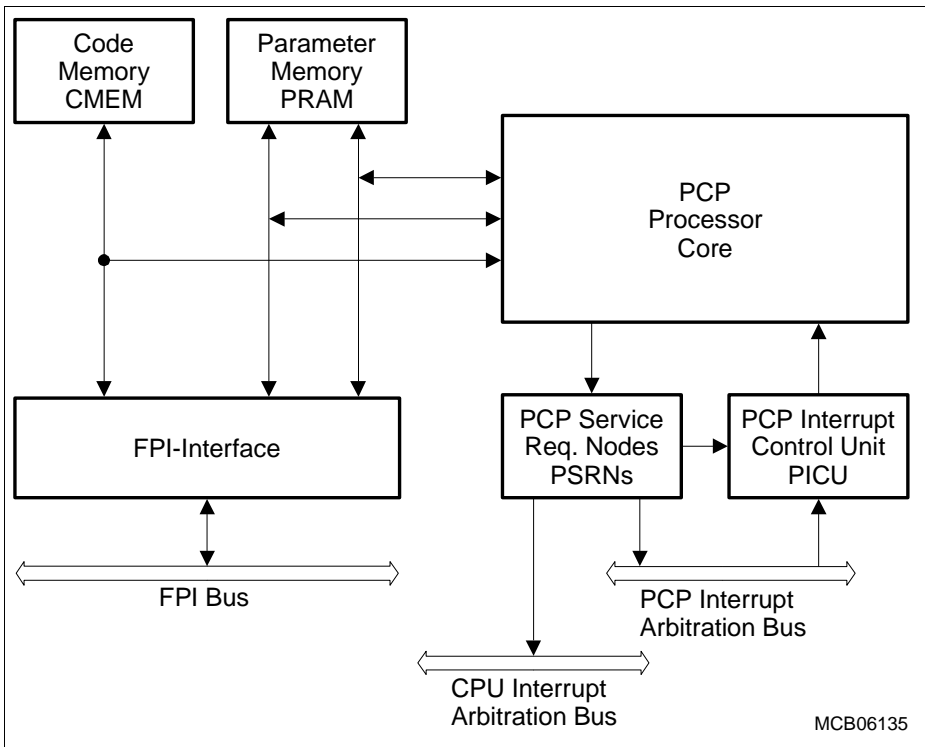


Figure 16 PCP Block Diagram

Peripheral Control Processor (PCP)

10.3.1 PCP Processor

The PCP Processor is the main engine of the PCP. It contains an instruction pipeline, a set of GPRs, an arithmetic/logic unit (ALU), as well as control and status registers and logic. Its instruction set is optimized especially for the tasks it has to perform. [Table 22](#) provides an overview of the PCP instruction set.

The PCP Processor Core receives service requests from peripherals or other modules in the system via its PCP Interrupt Control Unit (PICU) and executes a channel program (see [Page 8](#)) selected via the priority number of each service request. It first restores the channel program's context from the PRAM and then starts to execute the channel program's instructions stored in the Code Memory (CMEM). Upon an exit condition, it terminates the channel program and saves its context into PRAM. It is then ready to receive the next service request.

The PCP Processor Core is capable of suspending execution of a Channel Program on receipt of a service request with a higher priority than the channel currently being executed. The Core will automatically resume processing of the original Channel Program once the higher-priority request (or requests) has been processed. A channel that has been suspended in this way is termed as "Suspended Channel".

The PCP is fully interrupt-driven, meaning it is only activated through service requests; there is no main program running in the background as with a conventional processor.

Table 22 PCP Instruction Set Overview

Instruction Group	Description
DMA Primitives	Efficient DMA channel implementation
Load/Store	Transfer data between PRAM or FPI memory and the GPRs, as well as move or exchange values between registers
Arithmetic	Add, subtract, compare and complement
Divide/Multiply	Divide and multiply
Logical	And, Or, Exclusive Or, Negate
Shift	Shift right or left, rotate right or left, prioritize
Bit Manipulation	Set, clear, insert, and test bits
Flow Control	Jump conditionally, jump long, exit
Miscellaneous	No operation, Debug

10.3.2 PCP Code Memory

The Code Memory (CMEM) of the PCP holds the channel programs, consisting of PCP instructions. All instructions of the PCP are 16 bits long; thus, the PCP accesses its CMEM in 16-bit (half-word) quantities. With the 16-bit Program Counter (PC) of the PCP, a maximum of 64 K instructions can be addressed. This results in a maximum size of the PCP code memory of 128 Kbytes. The actual type (Flash, ROM, SRAM, etc.) and size of the code memory is implementation-specific; see [Page 159](#) for the implemented type and size of the code memory in the TC1728.

The PCP CMEM is viewed from the FPI Bus as a 32-bit wide memory, that must be accessed with 32-bit (word) accesses, and is addressed with byte addresses. Thus, care has to be taken when calculating PCP instruction FPI addresses. See [Page 58](#) for details.

Note: The PCP has a “Harvard” architecture and therefore cannot directly access the CMEM other than reading instructions from it. It is recommended that the PCP should not access CMEM via the FPI Bus.

10.3.2.1 CMEM Protection

To allow the PCP to handle system critical tasks it is necessary to ensure that the PCP can operate properly regardless of a failure in another part of the system or the PCP itself. This means that it is necessary to protect the content of the CMEM from such failures.

CMEM content can only be modified via the FPI. Protection of CMEM therefore consists of prevention of unwanted FPI writes to CMEM.

The normal model of PCP operation is that the program code (i.e. CMEM) is loaded at system initialization and remains unchanged for the duration of operation of the system. Thus a simple locking scheme is provided to prevent any write to CMEM once the content has been loaded during initialization. When CMEM has been loaded (at system initialization) the memory can be locked such that all incoming FPI write accesses are issued with an error response and the CMEM content will remain unmodified.

Regardless of protection the entire CMEM remains readable via FPI.

This function is controlled by the [PCP_CPROT](#) register (see [Page 88](#)).

10.3.3 PCP Parameter RAM

The PCP Parameter RAM (PRAM) is the local holding place for each channel program's context, and for general data storage. It is also an area that the PCP and the host processor or other FPI Bus masters can use to communicate and share data.

While a portion of the PRAM is always implicitly used for the Context Save Areas (CSAs) of the channel programs (see [Chapter 10.4.2.2](#)), the remaining area can be used for channel-specific or general data storage. A programmable 8-bit Data Pointer (DPTR),

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concatenated with a 6-bit offset, is provided for arbitrary access to the PRAM. The effective address is a 14-bit word address, allowing a PRAM size of up to 64 Kbytes. The actual type (SRAM, DRAM, etc.) and size of the parameter RAM is implementation-specific; see [Page 159](#) for the implemented size of the PRAM in this derivative.

Both the PCP and FPI Bus masters address the PRAM as 32-bit words. There is no concept of half-word or byte accesses to PRAM. FPI Bus masters must, however, use byte addresses in order to access the PRAM. As for the CMEM, care has to be taken when calculating PRAM FPI addresses. See [Page 58](#) for details.

10.3.3.1 PRAM Protection

To allow the PCP to handle system critical tasks it is necessary to ensure that the PCP can operate properly regardless of a failure in another part of the system or the PCP itself. This means that it is necessary to protect all or part of the content of the PRAM from such failures.

All or part of PRAM can be protected from FPI writes using the [PCP_PPROT](#) register (see [Page 89](#)). This register also allows a region of PRAM to be selected which can only be used by Protected PCP channel programs.

10.3.4 FPI Bus Interface

The PCP can access all peripheral units on the FPI Bus and other resources through the FPI Bus interface. The PCP can become an FPI Bus slave, so that other FPI Bus master may access CMEM and PRAM and the control and status registers in the PCP.

The CMEM and PRAM blocks are visible to FPI Bus masters as a block of memory on the FPI Bus. If an FPI Bus master accesses CMEM or PRAM memory concurrently with the PCP, the external FPI Bus master is given precedence over the PCP to avoid deadlocks. The PCP access is stalled for several cycles until the FPI Bus master has completed its access. If an FPI Bus master performs an atomic read-modify-write access to a PCP memory block, any concurrent PCP access to that block is stalled for the duration of the atomic operation.

10.3.5 PCP Interrupt Control Unit and Service Request Nodes

The PCP is activated in response to an interrupt request programmed for PCP service in one of the Service Request Nodes (SRNs) of the system (nodes associated with a peripheral, the CPU, external interrupts, etc.). The PCP Interrupt Control Unit (PICU) determines the request with the currently highest priority and routes the request together with its priority number to the PCP Processor Core. It also acknowledges the requesting source when the PCP starts the service of this interrupt.

The PCP itself can generate service requests to either the CPU or itself through a number of PCP Service Request Nodes (PSRNs). The PSRNs are also used to store all information required by the PCP Processor Core to allow the later restart of a channel

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program when it is suspended in favor of a higher-priority Service Request. Please refer to [Section 10.6.3](#) for more detailed information on the operation of these nodes.

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10.4 PCP Programming Model

The PCP programming model can be viewed as a set of autonomous programs, or tasks, called channel programs, that share the processing resources of the PCP. Channel programs may be short and simple, or very complex; but they can coexist persistently within the PCP.

From the programming point of view, the individual parts of a channel program are its instruction sequence in the CMEM and its context in the PRAM. It uses the instruction set and the GPRs (R0 - R7) of the PCP Processor Core to perform the necessary operations, and to communicate with the various resources of the on-chip and off-chip system depending on its task in the application.

These parts of the programming model are discussed in the following sections (with the obvious exception of the system environment outside of the scope of the PCP).

10.4.1 General Purpose Register Set of the PCP

The program-accessible register file of the PCP is composed of eight 32-bit General Purpose Registers (GPRs). These registers are all accessible by PCP programs directly as part of the PCP instruction set. Source and destination registers must be specified in most instructions. These registers are referenced to in this document as Rn or R[n], where n is in the range 0 to 7.

Table 23 Directly Accessible Registers

Register	Implicit Use	Description
R0	Accumulator	Implicit target for some arithmetic and logical instructions
R1	–	32-bit general-use register
R2	Return Address	32-bit general-use register
R3	–	32-bit general-use register
R4	SRC (Source)	Source Pointer for BCOPY/COPY instructions
R5	DST (Destination)	Destination Pointer for BCOPY/COPY instruction
R6	CPPN/SRPN/TOS/CNT1	CNT1: Transfer Count for COPY TOS: Type-of-Service SRPN: 8-bit field used for posting interrupt on EXIT instruction CPPN: Current PCP Priority Number
R7	DPTR/Flags	PRAM Data Pointer (DPTR) and Status Flags

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R7 is the only one of the eight registers that may not be used as a full GPR. The most significant 16 bits of R7 may not be written, and will always read back as 0. However, no error will occur when writing to the most significant 16 bits.

Note: The GPRs of the PCP are not memory-mapped into the overall address space. They can only be directly accessed through PCP instructions. The contents of all or some of the registers are part of a channel program's context stored in the PRAM between executions of the channel program. This context is then accessible from outside the PCP.

10.4.1.1 Register R0

R0 is used as an implicit operand destination for some instructions. These are detailed in the individual instruction descriptions.

10.4.1.2 Registers R1, R2, and R3

R1, R2, and R3 are general-use registers. It is recommended that, by convention, R2 should be used as a return address register when call and return program structures are used.

10.4.1.3 Registers R4 and R5

Registers R4 and R5 are also general-use registers. However, the BCOPY/COPY instructions implicitly use R4 and R5 as full 32-bit address pointers (R4 is used as the source address and R5 as the destination address). As the BCOPY/COPY instructions use these registers to maintain the address pointers, either or both R4 and R5 values may or may not be modified by the BCOPY/COPY instructions, depending on the options used in the instructions.

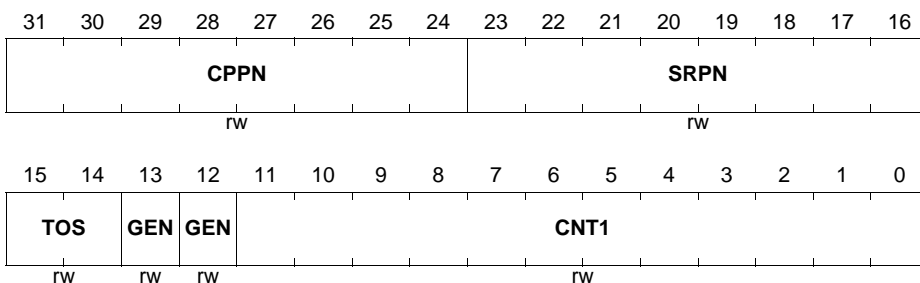
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10.4.1.4 Register R6

Register R6 may also be used as a general-use register. Again however, there are some instructions that use fields within R6. If the COPY or EXIT instructions are used, then the field R6.CNT1 can optionally be used implicitly as a counter. If an EXIT instruction is used that causes an interrupt, R6.SRPN and R6.TOS must be configured properly prior to execution of the EXIT. If interrupt priority management is used, then R6.CPPN must be set to the priority level at which the channel shall run at its next invocation, before the EXIT is executed. The fields for R6 are shown below.

PCP Register R6

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CPPN	[31:24]	rw	General-use/PCP Priority Number Posted to PICU
SRPN	[23:16]	rw	General-use/Service Request Priority Number for EXIT Interrupt
TOS	[15:14]	rw	General-use/Type-of-Service for EXIT Interrupt Upper bit of TOS is always forced to 0 when transferred into the PCP SRNs, regardless of the value specified in R6[15].
GEN	13	rw	General-use
GEN	12	rw	General-use
CNT1	[11:0]	rw	General-use/Outer Loop count for COPY Instruction or EXIT Instruction

10.4.1.5 Register R7

Register R7 is an exception with respect to the other registers in that not all bits within the register can be written, and the implicit use of the remaining bits virtually excludes the use of R7 as a GPR. R7 serves similar purposes as those in the Program Status Word found in traditional processors.

R7 holds the flag bits, a channel enable/disable control bit, and the PRAM Data Pointer (DPTR). The upper 16 bits of R7 are reserved.

Most instructions of the PCP update the flags (CN1Z, V, C, N, Z) in R7 according to the result of their operation. See [Table 37](#) on [Page 136](#) for details on the flag updates of the individual instructions. The values of the flag bits in R7 maintain their state until another instruction that updates their state is executed.

Note: Implicit updates to the flags caused by instruction take precedence over any bits that are explicitly moved to R7. For example, if a MOV instruction is used to place 0000FF07_H in R7, then the bit positions for the C (carry), Z (zero) and N (negative) flags are being written with 1. The MOV instruction, however, implicitly updates the Z and N flag bits in R7 as a result of its operation. Because the number is not negative, and not zero, it will update the Z and N flags to 0. As a result, the value left in R7 after the MOV is complete will be 0000FF04_H (i.e C = 1, Z = 0, N = 0). It is recommended that only SET and CLR instructions should be used to explicitly modify flags in R7.

The Data Pointer, R7.DPTR, is the means of accessing PRAM variables programmatically. It points to a 64-word PRAM segment that may be addressed by instructions that can use the PRAM for source or destination operands (xx.P and xx.PI instructions). The 8 bits of the DPTR are concatenated with a 6-bit offset value (either specified in the instruction as an immediate value or contained in one of the registers) to give a 14-bit (word) address. A program is able to update the DPTR value dynamically, in order to index more than 64 words of PRAM.

Note: Care must be taken when updating R7.DPTR to ensure that other bits within R7 (e.g. R7.CEN) are not inadvertently corrupted.

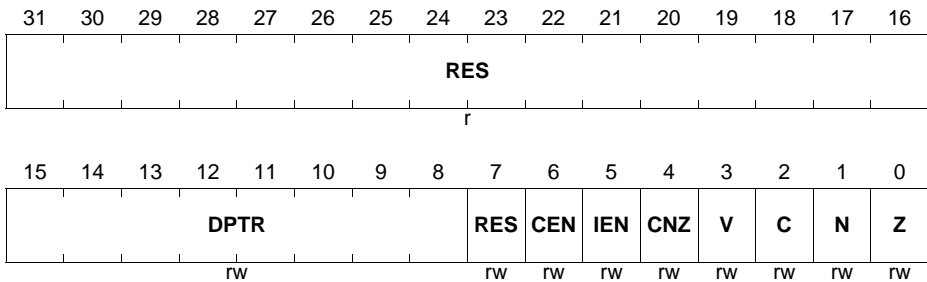
The channel enable control bit, R7.CEN, allows the enabling or disabling of specific channel programs. If an interrupt request is received for a channel that is disabled an error exit is forced, and an error interrupt to the CPU is activated.

The interrupt enable control bit, R7.IEN, allows the enabling or disabling of channel interruption on a channel to channel basis. When R7.IEN is 0, the channel will continue its execution regardless of the priority of any new service requests. When R7.IEN is 1, and conditions allow, the channel will be suspended on receipt of a higher-priority service request.

Note: See [Section 10.21.3.1](#) regarding the use of R7.IEN.

Peripheral Control Processor (PCP)

PCP Register R7

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RES	[31:16]	r	Reserved read as 0; should be written with 0.
DPTR	[15:8]	rw	Data Pointer Segment Address for PRAM accesses
RES	7	rw	Reserved should always be written with 0.
CEN	6	rw	Channel Enable Control Bit
IEN	5	rw	Interrupt Enable 0 _B Channel is not interruptible 1 _B Channel can be suspended in favor of a higher-priority service request
CNZ	4	rw	Outer Loop Counter 1 Zero Flag
V	3	rw	Overflow
C	2	rw	Carry
N	1	rw	Negative
Z	0	rw	Zero

10.4.2 Contexts and Context Models

After initialization, the instruction sequence of a PCP channel program is permanently stored (i.e. usually at least as long as the application is running) in the CMEM, and data parameters are held in the PRAM. These will remain stored regardless of whether a particular channel program is currently idle or is executing (although, of course, the value of data variables in the PRAM might be modified by the PCP or external FPI Bus masters). The contents of the GPRs of the PCP (used as address pointers, data variables, intermediate results, etc.) however, are usually only valid for a given channel program as long as it is executing. If another channel program is executed, the channel program will re-use the GPRs according to its needs.

Thus, the state of the GPRs of a channel program (termed the “Context” of the channel) needs to be preserved while a channel program is not being executed. The content of the registers needs to be saved when execution of a channel program finishes, and needs to be restored before execution starts again.

The PCP implements automatic handling of these context save and restore operations. On termination of a channel program, the state of all or some of the GPRs is automatically copied to a defined area in the PRAM (Context Save). If the same channel program is re-activated, the contents of the registers are restored by copying the values from the same defined PRAM area into the appropriate registers (Context Restore).

The defined area in the PRAM for the context save and restore operations is called the CSA. Each channel program has its own individual, predefined region in the CSA. When a service request is accepted by the PCP, the service request priority number (SRPN) associated with the request is used to select the channel program and its respective CSA region.

10.4.2.1 Context Models

A Context Model is a means of selecting whether some or all of the registers are saved and restored when a context switch occurs. In order to serve different application needs in terms of PRAM space usage, the PCP offers a choice between three different Context Models:

- Full Context Model: Eight Registers (8×32 -bit words) are saved/restored per channel.
- Small Context Model: Four Registers (4×32 -bit words) are saved/restored per channel.
- Minimum Context Model: Two Registers (2×32 -bit words) are saved/restored.

As illustrated in [Figure 17](#), the contents of R0 through R7 constitute the Full Context of a channel program. A Small Context consists of R4 through R7. Use of the Small Context Model allows for correct operation of DMA channels, as well as channels which are not required to save large amounts of data in their contexts between invocations. A Minimum Context saves and restores only R6 and R7.

Peripheral Control Processor (PCP)

To distinguish the actual register contents from the copies stored in the PRAM context regions, the term CRx is used throughout the rest of this document to refer to the register values in the context regions. Registers R6 and R7 are always handled in a special way during context save and restore operations, this is described in detail in [Section 10.4.2.3](#).

The Context Model is selected via bit field (PCP_CS.CS), this is a global setting (i.e. the selected Context Model is used for all channels). Once a context model has been selected (during PCP configuration) and the PCP has been started the PCP must continue to use that Context Model. Attempting to change the Context Model in use during PCP operation will lead to invalid context restore operations which will in turn lead to invalid PCP operation.

In the case of Small and Minimum Context Models, the unsaved and un-restored registers (shaded in [Figure 17](#)) can be thought of as global registers that any channel program can use or change, or reference as constants – for example as base address pointers (see [Section 10.20.2](#) for more detail).

Note: Special care must be taken when using Minimum or Small Context Model with nested interrupts (see [Page 153](#)).

Peripheral Control Processor (PCP)

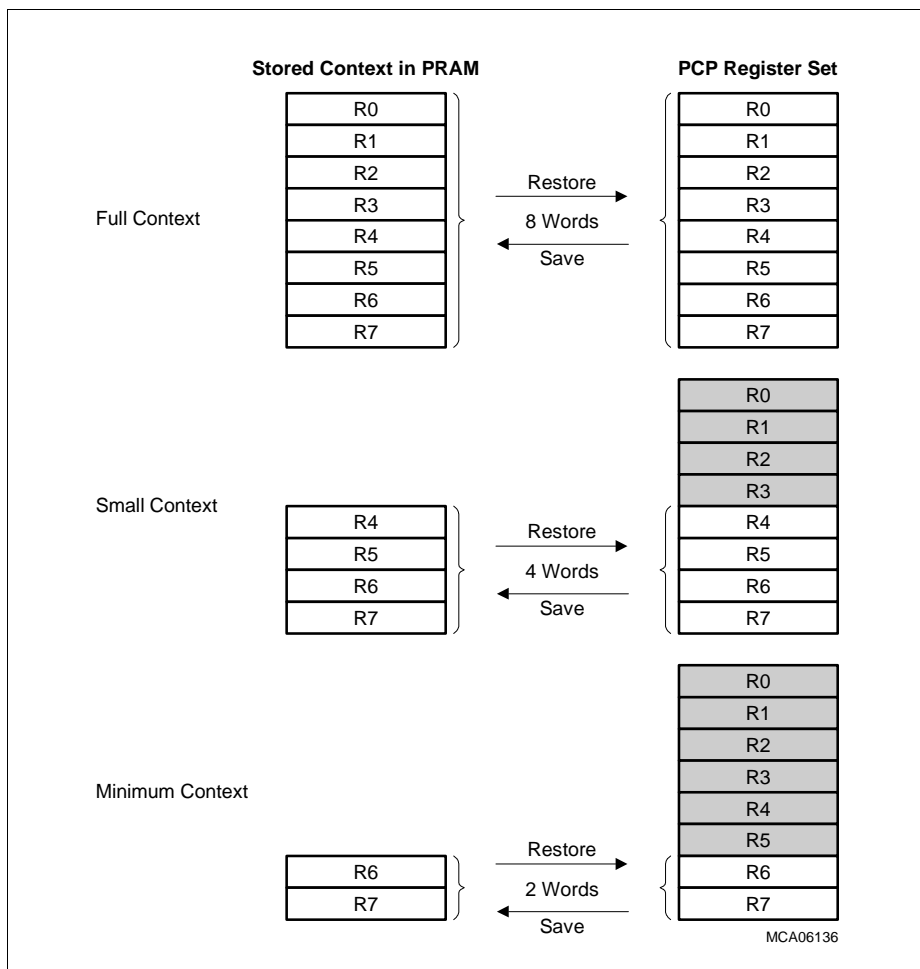


Figure 17 PCP Context Models

10.4.2.2 Context Save Area

The Context Save Area (CSA) is a region in PRAM reserved for storing the contexts for all channel programs (while any particular channel is not executing). Each channel's context is stored in a region of the CSA based on the channel number. The channel number is equal to the priority number (SRPN) of the service request. The PCP uses this number to calculate the start address of the context of the associated channel program. The size of a context is determined by the Context Model that the PCP has been initialized to use. As all channels use the same context size, the PRAM address (word address) of the context for a particular channel is simply calculated by multiplying the channel number by the number of registers in the context (8 for Full Context, 4 for Small Context and 2 for Minimum Context). [Figure 18](#) shows the resulting PRAM layout, and from this it can be seen that changing the Context Model also changes the base address for all regions within the CSA. Thus, the chosen Context Model may only be set when the PCP is initialized, and may not be changed during operation.

The CSA in the PRAM starts at address 00_H and grows upward. It is partitioned into equally sized regions, where the size of these regions is determined by the selected Context Model. The priority number (SRPN) of a service request is used to access the appropriate context region for the associated channel program. Since a request with an SRPN of 00_H is not considered as valid request in the TriCore Architecture, the bottom region (context region 0) of the CSA is never used for an actual context.

The total size of the CSA depends on the Context Model and the number of service request numbers used in a given system. Each priority number used in a service request node which can activate interrupts to the PCP must be represented through a dedicated context region in the PRAM. The highest address range in the PRAM used for a context region is determined by the highest priority number presented to the PCP with a service request.

The range of usable priority numbers is further determined by the size of the implemented PRAM and by the space required for other variables and global data located in the PRAM. See [Page 159](#) for the implemented size of the PRAM in the TC1728. As an example, a PRAM of 2 Kbytes, solely used for the CSA, can store up to 255 Minimum Contexts, allowing the highest SRPN used for a PCP service request to be 255 (remember, an SRPN of 0 and an associated context region is never used; the valid SRPNs and the context and channel numbers range from 1 to 255). With a Small Context Model, 127 contexts can be stored, resulting in 127 being the highest usable SRPN in this configuration. Finally, a Full Context Model allows 63 context areas, with 63 being the highest usable SRPN. Interrupt requests to the PCP with priority numbers that would cause loading of a context from outside the available PRAM area must not be generated. Invalid PCP operation will result should this situation be allowed to occur. The PCP can be optionally configured such that if an interrupt request is received that would cause loading of a context from outside the available PRAM area then an error exit is forced, and an error interrupt to the CPU is activated (see [Page 44](#)).

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If portions of the PRAM are used for other variables and global data, the space available for the CSA and the range of valid SRPNs is reduced by the memory space required for this data. For best utilization of PRAM, it is advisable to have the CSA grow upwards as a contiguous area without any “holes”, meaning that all SRPNs in the range 1 ... max. are actually used to place interrupt requests on the PCP. Unused regions within the CSA (that is, the unused region at the base of the CSA and any context regions associated with unused channels) cannot be used for general variable storage.

Peripheral Control Processor (PCP)

When choosing the Context Model for a given application, the following considerations can be helpful. When choosing the Small or the Minimum Context Models, save and restore operations for registers not handled in the automatic context operations can still be handled through explicit load and store instructions under control of the user. This may be advantageous for applications in which the majority of the channels do not need the Full Context, and only some would require more context to be saved. In this case, a Smaller Context Model can be used, and the channels which would require more register to be saved/restored would do this via explicit load and store instructions. This is especially advantageous if the channel program can be designed such that the initial real-time response operations can be executed using only the registers which have been automatically restored. Then, as the timing requirements of the service are relaxed, further register contents can be restored from PRAM through regular load instructions. Of course, the contents of these registers needs to be explicitly saved, through regular store instructions, before the exit of the channel program.

Note: Special care must be exercised when using Minimum or Small Context Models in conjunction with nested interrupts (see [Page 153](#)).

The criteria for choosing the Context Model are listed in the following:

- Size of PRAM implemented in a given derivative
- Amount of channels (= SRPNs) that need to be used in a system
- Amount of PRAM used for general variables and global's
- Amount of context (register content) which need to be saved and restored quickly by most of the most important channels

While registers R0 through R5 are always restored in a normal manner (according to the context size), registers R6 and R7 merit discussion regarding context restore operations. The memory location CR7 in a context region is used to hold two different pieces of information: The lower part of register R7, and the PC value of the channel. Similarly, the memory location CR6 in a context region can also be used to hold two different pieces of information: The value to be restored to register R6, and the Operating Priority (CPPN) value of the channel. This leads to the Restore/Save operations described in the following two sections.

10.4.2.3 Context Restore Operation for CR6 and CR7

The operation of R6 and R7 context restore varies according to whether the channel program that is starting is a “new” channel program (i.e. a channel program that is starting in response to the receipt of a new service request) or is a “suspended” channel program (i.e. a channel program that is re-starting after being suspended in favor of a higher-priority channel program). In addition, when a “new” channel program is starting, the context restore operation depends on the channel start mode that has been selected (see [Page 27](#)).

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Channel Resume Mode

Figure 19 illustrates the operation of a context restore for a “new” channel program when Channel Resume Mode has been selected (see [Page 28](#)). The PC is loaded from CR7[31:16], and the lower half of R7 is loaded from CR7[15:0]. The operating priority of the channel is taken from CR6[31:24] and all of R6 is loaded from CR6.

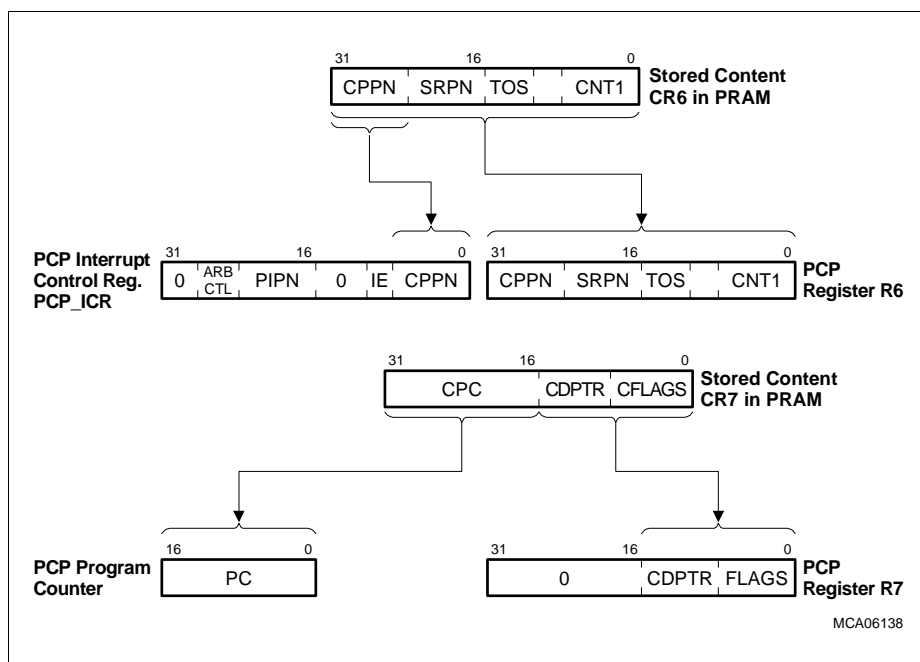


Figure 19 Context Restore: Channel Start in “Channel Resume Mode”

Peripheral Control Processor (PCP)

Channel Restart Mode

Figure 20 illustrates the operation of a context restore for a “new” channel program when Channel Restart Mode has been selected (see [Page 27](#)). The PC is loaded with the channel entry table address, and the lower half of R7 is loaded from CR7[15:0]. The upper half of CR6 is discarded. The operating priority of the channel is taken from CR6[31:24] and all of R6 is loaded from CR6.

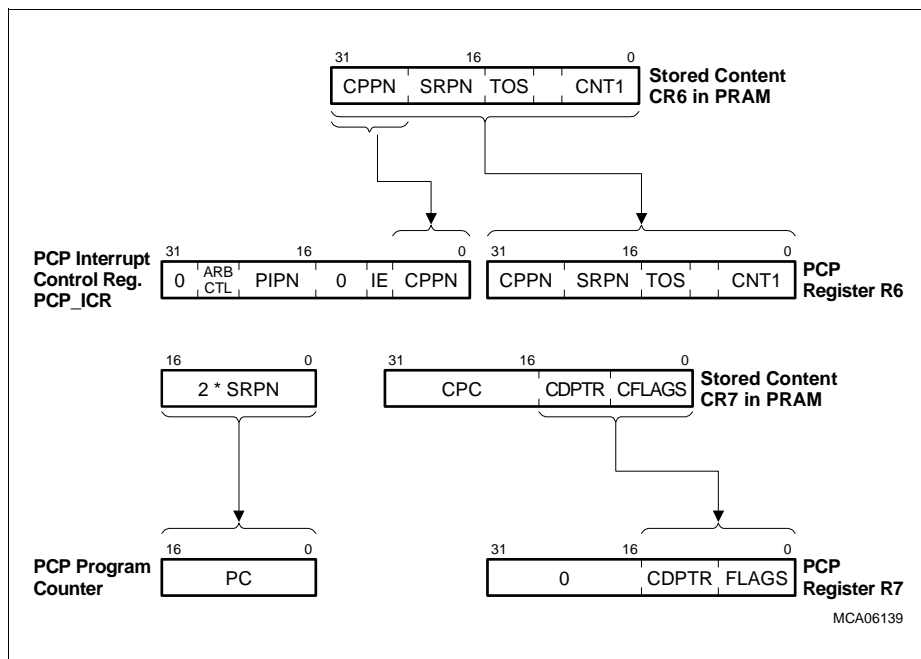


Figure 20 Context Restore: Channel Start in Channel Restart Mode

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Suspended Channel Restart

Figure 21 illustrates the operation of a context restore for a “suspended” channel program. The PC is loaded from CR7[31:16] (regardless of the Channel Start Mode), and the lower half of R7 is loaded from CR7[15:0]. All of R6 is loaded from CR6. The figure also shows how the operating priority of the channel (PCP_IR.CPPN) is restored from the Service Request Node that was used to store the Suspended Interrupt Request (see [Page 98](#)).

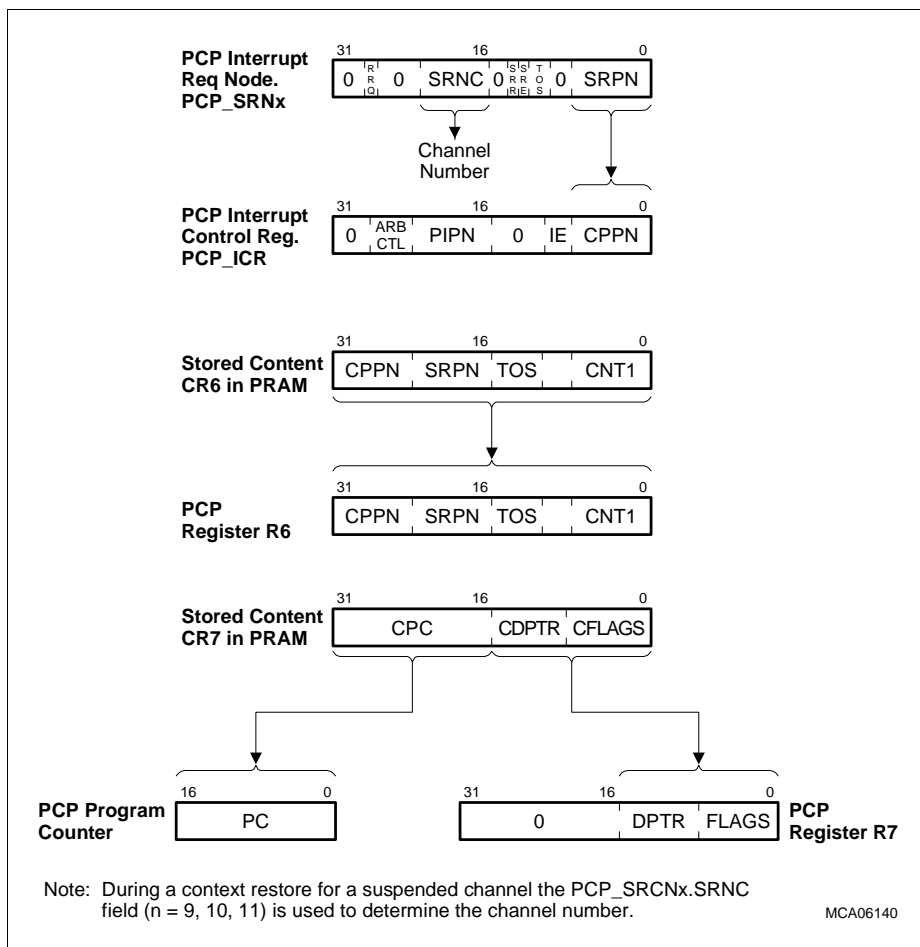


Figure 21 Context Restore: Suspended Channel Restart

Peripheral Control Processor (PCP)

10.4.2.4 Context Save Operation for CR6 and CR7

The operation of R6 and R7 context save varies according to whether the save operation is the result of a channel exit condition, or whether the channel is being suspended in favor of a higher-priority channel program.

Channel Resume Mode

Figure 22 illustrates the operation of a context save for a channel exit when Channel Resume Mode has been selected. The value written to CR7 is created by concatenating the 16-bit PC value with the lower 16 bits of R7. CR6 is written with the value taken from R6.

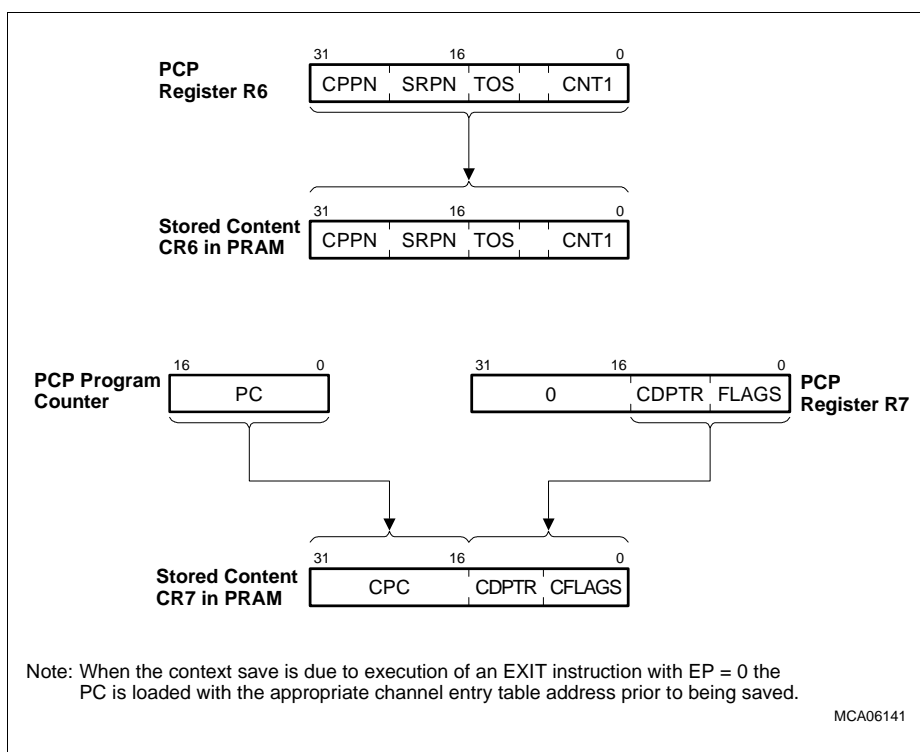


Figure 22 Context Save: Channel Exit in Channel Resume Mode

Peripheral Control Processor (PCP)

Channel Restart Mode

Figure 23 illustrates the operation of a context save for a channel exit when Channel Restart Mode has been selected. This is the same as for Channel Resume mode except that the PC value is discarded, and the appropriate Channel Entry Table address is written to CR7[31:16].

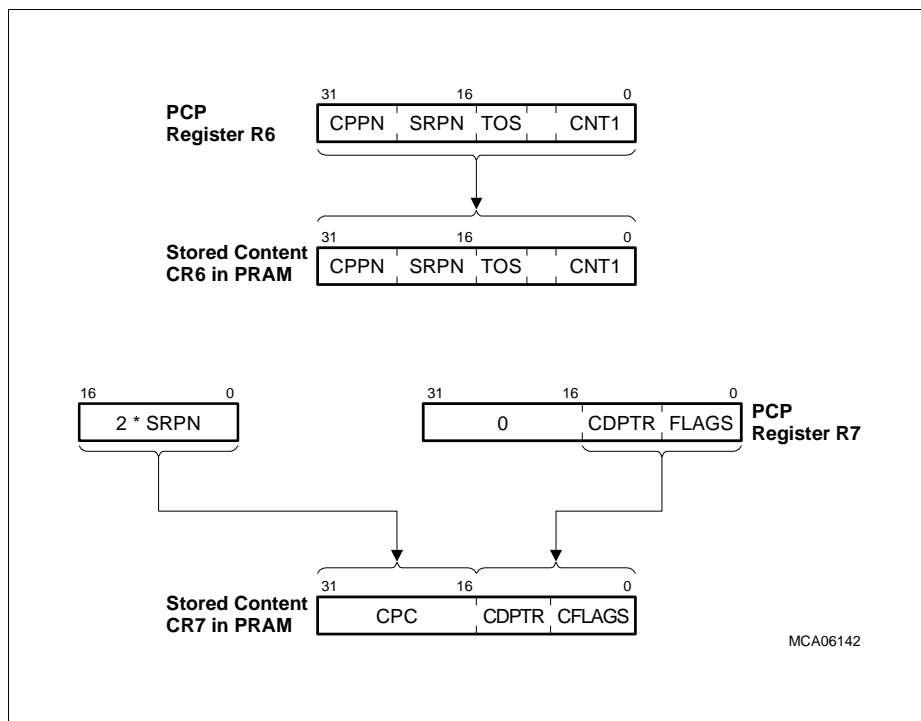


Figure 23 Context Save: Channel Exit in Channel Restart Mode

Peripheral Control Processor (PCP)

Channel Suspend

Figure 24 illustrates the operation of a context save for a channel that is being suspended. This is the same as for Channel Resume mode except that an interrupt request is created to allow the channel to be restarted at a later time. This restore operation utilizes one of three specially extended SRNs (see [Page 98](#)) to store the interrupt request. The information stored as part of the interrupt request is the channel number (SRPN), and the operating priority (CPPN) with which the channel was operating prior to being suspended. This operation in conjunction with the suspended channel restore operation shown in [Figure 21](#) allows the temporary suspension of a channel in favor of a higher-priority channel.

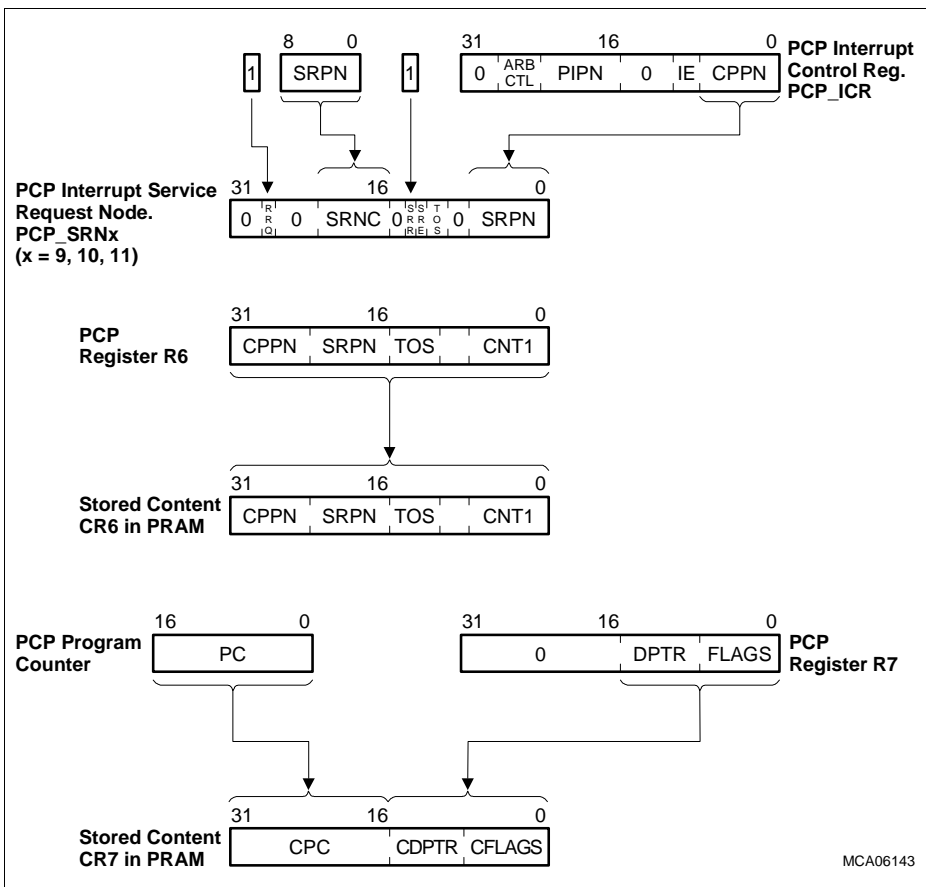


Figure 24 Context Save: Channel Suspend

Peripheral Control Processor (PCP)

10.4.2.5 Initialization of the Contexts

The programmer is responsible for configuring each channel program's context before commencing operation. Because this must be done by writing to the PCP across the FPI Bus, it is important to understand exactly where each channel program's context is from the FPI Bus perspective (see [Page 59](#) for details).

10.4.2.6 Context Save Optimization

The PCP has an optimized context-switching strategy consisting of optimization of both context load and store. During a context load in which the channel that is starting is also the last channel that the PCP was running then the PCP GPRs already contain the values appropriate to the channel. In this case there is no need to reload the context (i.e. the PCP can immediately continue operation at the appropriate point in the code without having to perform a context load). During a Context Store (i.e. the PCP exits a channel as a result of EXIT or DEBUG instructions or exits in response to a higher-priority channel interrupt), only those registers that have been updated (i.e. written to) since the context was loaded are saved to the CSA.

10.4.3 Channel Programs

The PCP CMEM is used to store the instruction sequences, the channel programs, for each of the PCP channels. The individual channel programs for the individual PCP service requests can usually be viewed as independent and separate programs. There is no background program defined and running for the PCP in TC1728 as there would be with traditional processors.

When the PCP receives a service request for a specific channel program, it needs to determine exactly which channel program to activate and where to start its execution. To accommodate different application needs, the PCP architecture allows the selection of two different entry methods into the channel programs:

- Channel Restart Mode
- Channel Resume Mode

Channel Restart Mode forces the PCP to begin each channel program from a known fixed point in the CMEM that is related to the interrupt number. At the entry point related to the interrupt number in question, there will typically be a jump instruction which vectors the PCP to the main body of the channel program. This is identical to the traditional interrupt vector jump table. In Channel Restart Mode, channel code execution will always start at the same address in the interrupt entry table each time the channel is requested.

Channel Resume Mode allows the PCP to begin execution at the PC address restored as part of the channel program context. This mode allows code to be contiguous and start at any arbitrary address. It also allows for the implementation of interrupt-driven state machines, and even the sharing of code across multiple programs with different context.

The selection of one of the two modes is a global PCP setting, that is, it applies to all channels. Selection is made via the PCP_CS.RCB bit in the PCP configuration register PCP_CS (see [Page 70](#)).

10.4.3.1 Channel Restart Mode

Channel Restart Mode is selected with PCP_CS.RCB = 1. In this mode, the PCP views the CMEM as being partitioned into an interrupt entry table at the beginning of the CMEM, and a general code storage area above this table.

The interrupt entry table consists of two instruction slots (2×16 -bit) for each channel. When a PCP service request is received, the PCP calculates the start PC for the requested channel by a simple equation based on the SRPN of that request ($PC = 2 \times SRPN$). It then executes the instruction found on that address. If more than two instructions are required for the operation of the channel program, then one of the instructions within the interrupt entry table must be a jump to the remainder of the channel's code. The PCP executes the channel's code until an exit condition or higher-priority interrupt is detected.

Peripheral Control Processor (PCP)

It is recommended that all EXIT instructions for all channels should use the EP = 0 setting when the PCP is operated in Channel Restart Mode (see [Page 117](#)).

Note that when Channel Restart Mode is in use a Channel Entry Table must be provided with a valid entry for every channel being used. [Figure 25](#) shows an example of CMEM organization when Channel Restart Mode has been selected. Failure to provide a valid entry for all channels that are in use will lead to invalid PCP operation.

10.4.3.2 Channel Resume Mode

Channel Resume Mode is selected with PCP_CS.RCB = 0. In this mode, the user can arbitrarily determine the address at which the channel program will be started the next time it is invoked. For this purpose, the PC is saved and restored as part of the context of a PCP channel.

Additional flexibility is available when Channel Resume Mode is globally selected by configuring each EXIT instruction to determine the channel start address to be used on the next invocation of a channel (see [Page 117](#)). When the EP = 0 setting is used, the PC value saved in the channel's context (saved in CPC) is the address of the appropriate location in the channel entry table. This forces the channel to start at the appropriate location in the interrupt entry table at next invocation. When the EP = 1 setting is used, the PC value saved in the channel's context is the address of the instruction immediately following the EXIT instruction. The use of the EP = x setting with the EXIT instruction allows the mixture of channels that use a Channel Restart strategy with others using a Channel Resume strategy, and also allows individual channels to use either strategy as appropriate on different invocations.

Note: A valid entry within a Channel Entry Table must be provided for every channel that uses an EXIT instruction with the EP = 0 setting when Channel Resume Mode has been selected. Failure to provide a valid entry for such channels will lead to invalid PCP operation.

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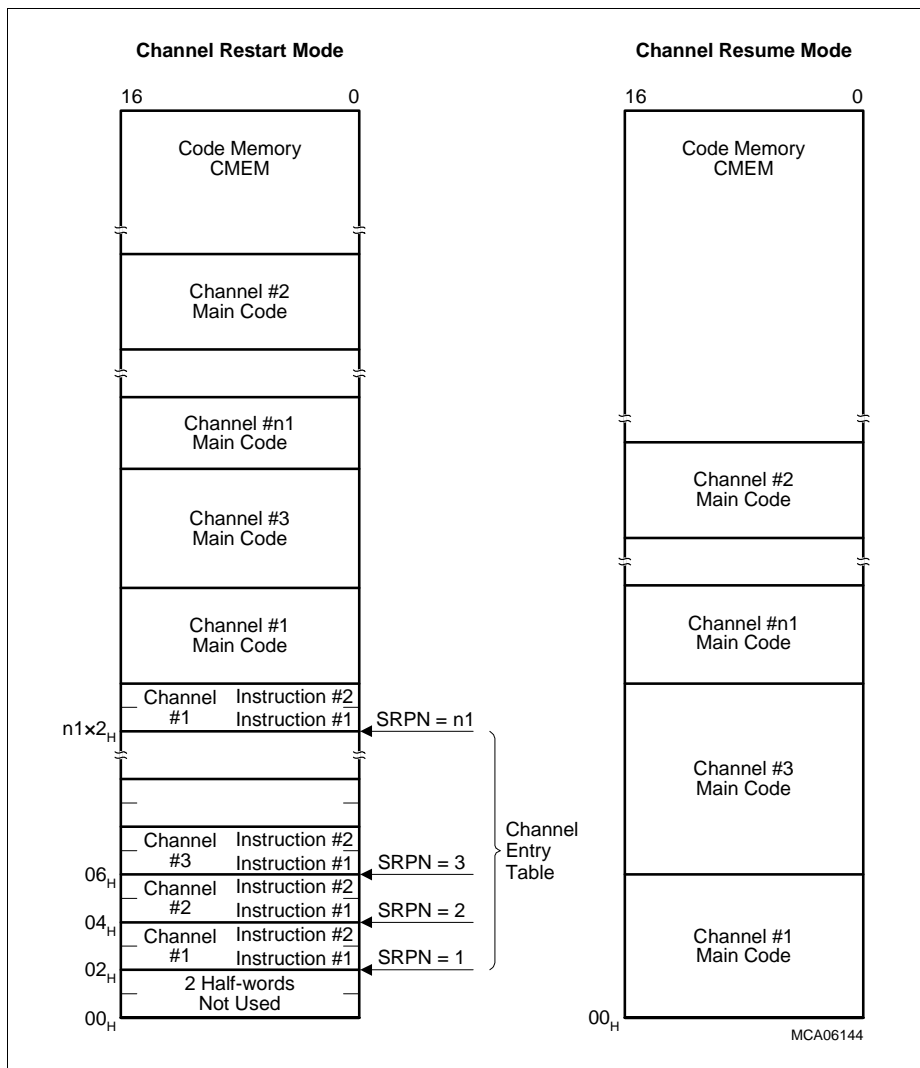


Figure 25 Examples of Code Memory Organization for Channel Restart and Channel Resume Modes

Note: The CMEM address offsets in the above figure are shown as PCP instruction (half-word) offsets. To obtain FPI address offsets (byte offset) multiply each offset by two.

Peripheral Control Processor (PCP)

10.5 PCP Operation

This section describes how to initialize the PCP, how to invoke a channel program, and the general operation of the PCP.

10.5.1 PCP Initialization

The PCP is placed in a quiescent state when the TC1728 is first powered-on or reset. Before a channel program can be enabled, the PCP as a whole must be initialized by some other FPI Bus master, typically the CPU. Initialization steps include:

- Configure global PCP registers.
 - Initialize PCP Control and Status Register (with PCP_CS.EN = 0).
 - Configure interrupt system via PCP_ICR.
- Load channel programs into the CMEM.
- Load initial context (if/as required) of channel programs in PRAM (R0 - R7 for Maximum context, R4 - R7 for Small Context, R6 - R7 for Minimum Context). Only those registers in each channel whose initial content is required on first invocation of the channel need to be loaded. This may need to include the initial PC, depending on the value of PCP_CS.RCB.
- Clear R7 in the context for unused channels.
- Enable PCP operation PCP_CS.EN = 1.

Now, the PCP is able to begin accepting interrupts and executing channel programs.

10.5.2 Channel Invocation and Context Restore Operation

A channel program is started when one or other of the following conditions occurs:

- The current round of PCP interrupt arbitration results in a winning interrupt number (SRPN) and the PCP is currently quiescent (has exited the previous channel and stored the context for that channel).
- The current round of PCP interrupt arbitration results in a winning interrupt number (SRPN) that has to be greater than the current channel priority (SRPN > CPPN), if suitable Service Request Node space is available in the PSRN to store a suspended interrupt request and the current channel allows interrupts (R7.IEN = 1). See also [Page 35](#)).

When this happens the winning SRPN becomes the current interrupt, and a context restore operation occurs before the new channel program can begin operation, as follows:

- The context of the channel (= winning SRPN) is restored from PRAM into the GPRs from the appropriate address within the CSA. Depending on the value of PCP_CS.CS, a Full, Small, or Minimum Context restore is performed.
- The new priority level of the PCP is taken from R6.CPPN field and is written to PCP_ICR.CPPN. This value can be useful during debugging, as the CPPN of the currently executing or last-executed channel program can be read from PCP_ICR.

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After the channel program starts, the value of R6 may be changed without altering the value of the effective CPPN, because updates to the value of R6.CPPN have no effect until the next invocation of the channel program.

- If the R7.CEN bit is clear (0), then an error has occurred because a disabled channel program has been invoked, the PCP_ES.DCR bit is set to flag the error, and the channel program performs an error exit (see [Page 31](#)).
- If the R7.CEN bit is set (1), then code execution begins at the value of the restored PC or at the address of the interrupt routine in the Channel Entry Table, depending on the value of PCP_CS.RCB.

Special care needs to be taken regarding the number of clock cycles required to switch context when the last state of the PCP before channel exit was execution of channel “N” (SRPN = “N”), and the current service request is also SRPN = “N”. In this case, the PCP Processor Core should not load the context (as the PCP GPRs already contain the correct content), but continue operation from the current point and state (noting that the PC value should be set to the appropriate channel entry point if PCP_CS.RCB = 1).

10.5.3 Channel Exit and Context Save Operation

The context of a channel program must be saved when it terminates. Three events can cause the termination of a channel program:

- Execution of the EXIT instruction (normal termination)
- Occurrence of an error
- Execution of the DEBUG instruction (channel termination is optional). The DEBUG instruction must only be used in DEBUG mode; otherwise an “Illegal Operation” (IOP) error will be generated

These channel termination possibilities are described in the next sections.

10.5.3.1 Normal Exit

Under normal circumstances, a channel program finishes by executing an EXIT instruction. This instruction has several setting fields that allow the user to specify a number of optional actions to be performed during the channel exit sequence (see [Page 117](#)). These optional actions are:

- Decrement counter CNT1
- Set the start PC for the next channel invocation to the next instruction address (Channel Resume) or to the channel entry address (Channel Restart)
- Disable further invocations of this channel
- Generate an interrupt request to the CPU or to the PCP itself

When the EXIT instruction is executed, the following sequence occurs:

- If EC = 1 is specified Counter R6.CNT1 is decremented and the CN1Z flag is updated.

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- If ST = 1 is specified bit R7.CEN (Channel Enable) is cleared (i.e. the channel is disabled).
- If EP = 0 is specified **or** PCP_CS.RCB = 1 (Channel Restart Mode has been selected), the PCP program counter to be saved to context location CR7.PC is set to the appropriate channel entry table address. If EP = 1 is specified **and** PCP_CS.RCB = 1 (Channel Resume Mode has been selected), the PCP program counter to be saved to context location CR7.PC is set to the address of the instruction immediately following the EXIT instruction.
- If INT = 1 is specified **and** the specified condition cc_B is True, then an interrupt request is raised according to the SRPN value held in R6.SRPN. The interrupt is asserted via one of the PCP_SRCx registers, where x is determined by the combination of the value of R6.TOS and the list of free entries. This allows the conditional creation of a service request to the CPU or PCP with the SRPN value indicated in register R6.SRPN.
- The channel program's context (including all register modifications caused within this EXIT sequence) is saved to the appropriate region in the PRAM Context Save Area. Depending on the value of PCP_CS.CS, either a Full, Small, or Minimum Context save is used.

Special care needs to be taken to optimize the number of clock cycles required to perform a Context Save. During a Context Save, the PCP Processor Core needs only to save those registers that have been written since the last Context Restore was performed.

Note: Particular attention must be paid to the values of R6 and R7 prior to execution of the EXIT instruction. When posting an interrupt request, the user must ensure that R6.SRPN and R6.TOS contain the correct values to generate the required interrupt request. When using the Outer Loop Counter (CNT1), the user must ensure that the value in R6.CNT1 will provide the required function. When using interrupt priority management, the user must ensure that R6.CPPN contains the interrupt priority with which the channel is to run on next invocation. If the channel is to be subsequently re-invoked, the user must ensure that the Channel Enable Bit (R7.CEN) is set.

10.5.3.2 Error Condition Channel Exit

PCP error conditions can occur for a variety of reasons (e.g. an invalid operation code was executed by a channel program, or an FPI Bus error occurred). When an error condition occurs, the PCP Error Status Register (PCP_ES) is updated to reflect the error, and the channel program is aborted. The error exit sequence is as follows:

- The channel enable bit R7.CEN is cleared. This means the channel program will be unable to restart until another FPI Bus master has re-configured the channel program's stored context to set CR7.CEN to 1 again.

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- The PC of the instruction that was executing when the error occurred is stored in PCP_ES.EPC.
- The number of the channel program that was executing when the error occurred is stored in PCP_ES.EPN.
- The error type is set in the appropriate field of register PCP_ES.
- The context is saved back to the PRAM CSA. Depending on the chosen context size (PCP_ES.CS) a Full, Small, or Minimum Context save is performed.
- If the error condition was not due to an FPI Bus error or a DEBUG instruction, then an interrupt request to the CPU is generated with the priority number stored in register PCP_CS.ESR.

The repetitive posting of PCP error interrupts will not cause an overwhelming number of interrupts to the CPU. In this situation, the PCP's CPU service request queue (see [Page 35](#)) will quickly fill, and force the PCP to stall until the CPU can resolve the situation.

Note: An error condition (other than an FPI Bus error) will result in an interrupt being sent to the CPU. The interrupt routine that responds to this interrupt must be capable of dealing with the cause as recorded in PCP_ES, and it must be able to restore the channel program to operation. The minimum required to restart the channel program is to set the context value of CR7.CEN = 1.

10.5.3.3 Debug Exit

If the DEBUG instruction is programmed to stop the channel program execution (SDB = 1 has been specified), the PCP performs an exit sequence that is very similar to the error exit sequence, with the exception that no interrupt request to the CPU is generated. This sequence is:

- If RTA = 0, then the channel enable bit R7.CEN is cleared. This means the channel program will be unable to restart until another FPI Bus master has re-configured the channel program's stored context to set CR7.CEN to 1 again. Otherwise, the R7.CEN bit remains unchanged, and the PC is decremented (such that it points to the DEBUG instruction)
- If EDA = 1, a break-point event is generated
- If DAC = 1, then the PCP_CS.EN bit is cleared. This means that the PCP will not execute any further channel programs until the PCP_CS.EN bit is set by another FPI Bus master
- The address of the DEBUG instruction (i.e. the current PC) is stored in register PCP_ES.PC
- The current channel number is stored in register PCP_ES.PN

The execution of the current channel program is stopped at the point of the DEBUG instruction. This instruction only disables the current channel; the PCP will continue to operate, accepting service requests for other channels as they arise.

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Note: The DEBUG instruction must be only used in DEBUG mode; otherwise an “Illegal Operation” (IOP) error will be generated.

10.6 PCP Interrupt Operation

The PICU and the PSRNs (PCP_SRC[11:0]) are similar to the CPU's ICU and all other SRNs in the system. They do, however, have some special characteristics, which are described in the following sections. **Figure 26** shows an overview of the PCP interrupt scheme.

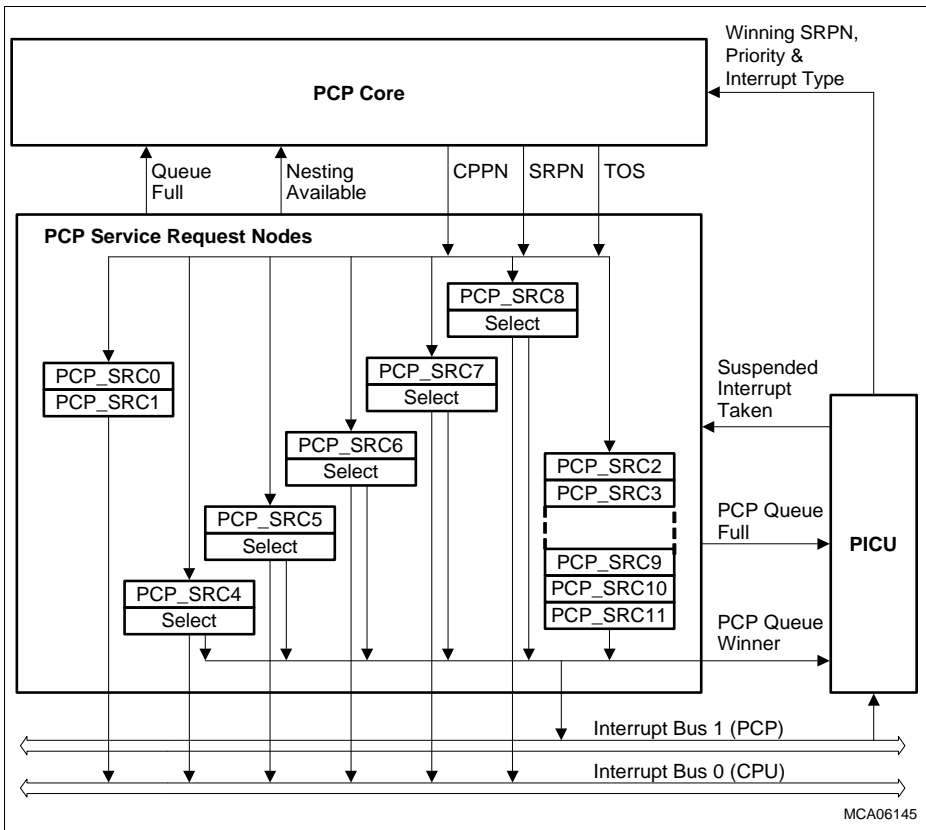


Figure 26 PCP Interrupt Block Diagram

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10.6.1 Issuing Service Requests to CPU or PCP

The PCP may use one of two mechanisms to raise an interrupt request to the CPU or itself. The first, and most inefficient, method for a PCP channel program is to issue service requests by performing an FPI Bus write operation to an external service request node (SRN). Alternately, the PCP can raise a service request using one of its own internal SRNs. An interrupt can only be generated by the PCP via an internal SRN when executing an EXIT instruction, or when an error condition occurs. In the following descriptions, PCP service requests triggered through an EXIT instruction or the occurrence of an error are called “implicit” PCP service requests to distinguish them from the “explicit” way of generating a service request through an FPI Bus write to a service request node external to the PCP.

10.6.2 PCP Interrupt Control Unit

The PICU operates in a similar manner to the ICU of the CPU. The PICU manages the PCP service request arbitration bus, and handles the communication of service requests and priority numbers to and from the PCP kernel. The PCP_ICR register is provided to control and monitor the arbitration process.

When one or more service requests to the PCP are activated, the PICU performs an arbitration round to determine the request with the highest priority. It then places the priority number of this “winning” service request into the PIPN field of register PCP_ICR, and generates a service request to the PCP kernel.

If the PCP kernel is currently busy processing a channel program, the new request is left pending until the current channel program has finished.

When the PCP kernel is ready to accept a new service request, it calculates the context start address from the Pending Interrupt Priority Number, PIPN, stored in register ICR, and begins with the context restore. It notifies the PICU of the acceptance of this request, and in turn the PICU acknowledges the winner of the last arbitration round. This service request node then resets its Service Request Flag, SRR.

There is one special condition in which the PICU operates differently from the way that the CPU Interrupt Control Unit operates. This special operation is described on [Page 38](#).

The PCP interrupt arbitration can be adapted to the application's needs and characteristics through controls in register PCP_ICR. Bit field PCP_ICR.PARBCYC controls the number of arbitration cycles per arbitration round (one through four cycles), while bit PCP_ICR.PONECYC controls whether one arbitration cycle equals one or two system (FPI Bus) clock cycles.

10.6.3 PCP Service Request Nodes

The PCP contains twelve service request nodes, including twelve service request control registers, PCP_SRC0 to PCP_SRC11, which are provided for implicit PCP service requests. The service request control registers differ from standard SRC registers in that

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they are fully controlled by the PCP kernel; they are read-only registers during PCP operation. The user cannot generate interrupts by writing to them.

The twelve service request nodes are split into four groups.

- The first group, containing registers PCP_SRC0 and PCP_SRC1, handles implicit PCP service requests targeted to the CPU. The Type-of-Service control fields, TOS, of these registers are hard-wired to 00_B, directing the requests to the CPU.
- The second group, registers PCP_SRC2 and PCP_SRC3, handles the service requests targeted to the PCP itself. The respective TOS field of these registers are hard-wired to 01_B, directing the requests to the PCP.
- The third group, containing registers PCP_SRC4 to PCP_SRC8, have programmable TOS fields which allow these registers to be assigned (at configuration time) to any of the available interrupt buses.
- The fourth group, containing registers PCP_SRC9, PCP_SRC10 and PCP_SRC11, are an extended version of a standard Service Request Node. These handle service requests targeted to the PCP itself, including service requests representing a suspended interrupt. The respective TOS field of these registers are hard-wired to 01_B, directing the requests to the PCP.

The service request enable bits, SRE, of the PCP_SRCx registers are hard-wired to 1, meaning these service requests are always enabled.

Note: The number of interrupt buses is device-dependent. Programming a PCP_SRCx register ($x = 4$ to 8) with a TOS value representing a non-available interrupt bus (10_B or 11_B in the TC1728) will disable Service Request Node x.

The actual service request flag and the service request priority number of the PCP_SRCx registers are updated by the PCP when it generates an implicit service request. The way this is performed is described in the following section.

The service request nodes in each of the groups described above are implemented as queues with the appropriate number of entries. When the PCP generates an implicit service request, it places the request into the next available free entry of the appropriate queue rather than writing it into a specific register. Queue management logic automatically ensures proper handling of the queue. If all entries of a queue are filled with pending service requests, the queue management reports this condition to the PCP kernel via a “queue full” signal.

In the following descriptions, the terms “CPU Queue” and “PCP Queue” are used to refer to the queues in the two groups of PCP service request nodes.

10.6.4 Issuing PCP Service Requests

The PCP can issue implicit service requests on the execution of an EXIT instruction, when suspending a channel, or when an error occurs during a channel program execution. While the service request generation for the EXIT instruction is optional, a service request is always generated when a channel is suspended or an error occurs.

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Further differences between these three mechanisms are detailed in the following sections.

10.6.4.1 Service Request on EXIT Instruction

An implicit PCP service request is issued when the INT field of the EXIT instruction is set to 1 and the specified condition code, cc_B, of this instruction is true. Such a service request can be issued to any of the available interrupt buses, depending on the programmed value in the TOS field of register R6. The PCP examines the TOS field in register R6 and issues a service request to the appropriate queue of the service request nodes. Along with this request, it passes the service request priority number stored in the SRPN field of register R6 to the queue. If the queue has a free entry left, the service request flag, SRR, of the associated service request register, PCP_SRCx, will be set, and the service request priority number will be written to the SRPN field of the SRC register. Please see [Page 38](#) for the case where there is no free entry in the queue.

Because the desired service request is programmed through the TOS and SRPN fields in register R6, each channel program can issue its individual service request. Note that this register needs to be programmed properly if a service request is to be generated by the EXIT instruction.

10.6.4.2 Service Request on Suspension of Interrupt

An implicit PCP service request is issued when the PCP suspends execution of the ongoing channel program in favor of a service request with a higher priority. Such a service request is always issued to the PCP's own interrupt bus and is stored in one of the three extended Service Request Nodes (PCP_SCR9, PCP_SRC10, PCP_SRC11). Along with this request, it passes the current channel operating priority (CPPN) as an SRPN and also the channel number (the original SRPN). The service request flag, SRR, and the Restart Request flag, RRQ, of the associated service request register, PCP_SRCx, will be set, the Operating Priority will be written to the SRPN field, and the channel number will be written to the SRNC field of the SRC register.

Use of the Operating Priority as the SRPN for resumption of the channel program ensures that during subsequent arbitration rounds the PCP will resume execution of the suspended channel program at the appropriate time.

The PCP treats an interrupt request with the RRQ bit set in a special fashion. In this case the PCP clears the interrupt request bit in the appropriate internal Service Request Node but does not issue an interrupt acknowledge to any external nodes. This prevents the unwanted clearing of external service requests with an SRPN that matches the priority of a suspended channel.

Note: The PCP will only suspend channel operation when there are two or more free SRNs with the appropriate TOS value for the PCP, and one of the free SRNs is an

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Extended Service Request Node. This allows for the posting of an interrupt request to the PCP on exit from the new channel program.

10.6.4.3 Service Request on Error

While a service request triggered through an EXIT instruction is optional and can be issued either to the CPU or to the PCP itself, a service request due to an error condition will always be automatically issued and will always be directed to the CPU. The PCP issues a service request to the CPU queue of the service request nodes. Along with this request, it passes the SRPN stored in the ESR field of register PCP_CS to the queue. If the queue has a free entry left, the SRR flag of the associated service request register, PCP_SRCx, will be set, and the SRPN will be written to the SRPN field of the SRC register. See next section for the case where there is no free entry in the queue (queue full).

Due to the fact that the priority number is stored in the global control register PCP_CS, all channel programs share the same service request routine in case of an error. The exact cause of the error and the channel number of the program that was executed when the error occurred can be determined through examination of the contents of the Error/Debug Status Register, PCP_ES.

10.6.4.4 Queue Full Operation

Queuing the implicit service requests typically allows the PCP to continue with the next service request without stalling. The depth of the queue and the number of channel programs using them determines the stall rate. Depending on the selected service provider (via R6.TOS in case of an EXIT interrupt or always to the CPU in case of an error interrupt), the request is routed to a free entry in the appropriate queue.

If no free entries are available in a queue at the time the PCP wants to post a request to that queue, the PCP is forced to stall until an entry becomes clear. This ensures that the PCP does not lose any interrupts. An entry in a queue becomes free when its SRR flag, is cleared through an acknowledge from the PICU (that is, the CPU or PCP, as appropriate, has started to service this request).

One special case needs to be resolved for the PCP-related queue through special operation of the PICU. Consider the case in which the PCP queue is full, meaning registers PCP_SRC2, PCP_SRC3 and PCP_SRC9 to PCP_SRC11 are already loaded with pending service requests to the PCP. If the PCP kernel now needed to post an additional service request into that queue, a deadlock situation would be generated: The PCP would stall, since there is not a free entry in the PCP queue in which to place the request. In turn, as the PCP is stalled, it cannot accept new service requests and so the PCP service request queue cannot be emptied. This would result in a deadlock of the PCP.

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To avoid such a deadlock, the PICU performs a special arbitration round as soon as the PCP queue becomes full. In this arbitration round, only the service request nodes assigned to the PCP queue are allowed to participate; all service requests from nodes external to the PCP are excluded, regardless of whether their priorities are higher or lower than those of the PCP queue. In this way, it is guaranteed that one entry in the PCP queue gets serviced, freeing one slot in the queue.

The PCP programmer needs to carefully consider this special operation. It ensures that deadlocks are avoided, but it implies that if too many PCP channel programs post service requests to the PCP (self-interrupt), the PCP will have to service these rather than outside interrupt sources. Depending on the priority given to these requests, this could undermine an otherwise appropriate use of the interrupt priority scheme. It is recommended that the system be designed such that in most cases, high-priority numbers can be assigned to these self-interrupts, so that they can win normal arbitration rounds, avoiding the situation where the PCP queue becomes full.

Note: If the CPU queue is full, the PCP can continue to operate until it needs to post another service request to the CPU queue.

10.7 PRAM Protection

To allow the PCP to handle system critical tasks it is necessary to ensure that the PCP can operate properly regardless of a failure in another part of the system or the PCP itself. This means that it is necessary to protect all or part of the content of the PRAM from such failures.

By default, after reset, the PRAM can be considered to be a single memory space writeable both by FPI Masters and by instructions executed by the PCP itself. However the PCP contains a programmable protection scheme allowing the definition of up to four memory regions with different protection from FPI PRAM writes and internally generated PRAM writes. This is illustrated in [Figure 27](#) below:-

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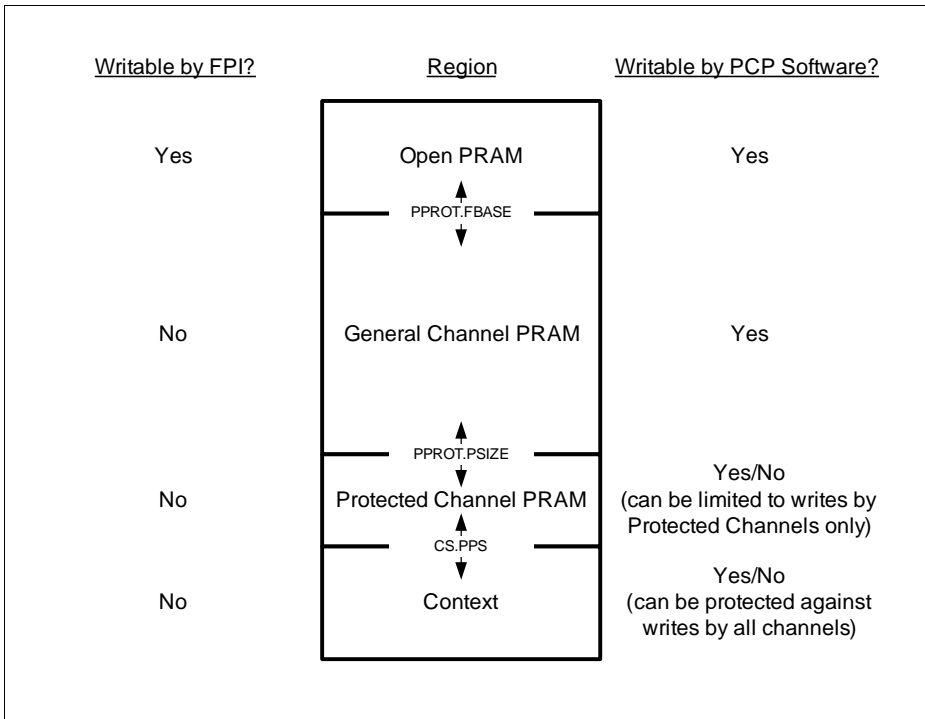


Figure 27 PRAM Regions

*Note: **Figure 27** shows a typical configuration that might be used. Configuration is sufficiently flexible, however, that all of, none of, or any combination of the above regions can be implemented and that the region boundaries can be set with a granularity of at least 256 bytes.*

While **Figure 27** shows four regions, in reality the protection scheme can be seen from two viewpoints:-

- Protection from FPI writes (see [Section 10.7.1](#)).
- Protection from internally generated PRAM writes (see [Section 10.7.2](#)).

Protection of PRAM is provided to allow running of system critical tasks on the PCP. Protection means that such tasks can be made immune from failures outside of the PCP or indeed from software failures in non-critical tasks running on the PCP itself.

PRAM protection is based around the concept of “Protected” and “Unprotected” Channel Programs. A “Protected” channel program is one that is running a critical system task and is termed “Protected” since it (and any other Protected Channel Programs) have

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write access to an area of PRAM that cannot be modified by an Unprotected Channel Program.

Determination of whether a channel is Protected or Unprotected is performed by examination of the channel number against a programmable threshold (programmed via PCP_PPROT.PTHRES). In addition to the threshold the user can select (via PCP_PPROT.PCAT) whether Channel Programs above (and including the threshold) are Protected or whether Channel Programs below (and including the threshold) are Protected.

10.7.1 Protection of PRAM against FPI Writes

The PRAM FPI protection function is provided so that once the PRAM has been loaded (typically at system initialization) the PRAM can be partially or totally protected against FPI write accesses. This function is controlled by the PCP_PPROT register (**“PRAM Protection Register, PCP_PPROT” on Page 89**).

When the protection function is enabled (via PCP_PPROT.EN) any incoming FPI write access outside a defined PRAM address range (defined by PCP_PPROT.FBASE) is issued with an error response and the PRAM content remains unmodified.

The address range can be select such that an “Open Window” of PRAM (based at the top of PRAM) remains available for incoming FPI write accesses. The “Open Window” is provided as PRAM is often used for implementation of a “mail-box” to allow communication between the PCP and other on-chip cores.

Regardless of the enabling of write protection the entire PRAM content remains readable via FPI.

Note: The PCP internal PRAM write instructions (i.e. instructions that modify the PRAM content) are unaffected by this protection.

10.7.2 Protection of PRAM against Internally Generated PRAM Writes

Protection of PRAM against internal writes is performed via two regions:-

- Context Save Region
- Protected Channel PRAM

10.7.2.1 Context Save Region Protection

The Context Save Region can be protected by the PRAM Partitioning Scheme (see **“PCP Control and Status Register, PCP_CS” on Page 70**). This protection is enabled via PCP_CS.PPE and the size of the context area being protected is defined by PCP_CS.PPS. When enabled the context region is protected from writes by any Channel Program (i.e. regardless of whether Protected or Unprotected).

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Note: This scheme also limits the number of Channel Programs that can be invoked.

Note: FPI PRAM write accesses to PRAM are unaffected by this protection.

10.7.2.2 Protected Channel PRAM Protection

To ensure that an Unprotected Channel Program cannot corrupt the PRAM assigned to a protected channel program it is necessary to protect the PRAM space used by the protected channels from instruction executed by non-protected channels. The PCP provides a protection scheme which prevents corruption of a programmable range of locations at the base of PRAM by writes generated by a non-protected channel. This region is termed the “Protected Channel PRAM”. Protection is enabled via PPROT.ENI and the size of the protected region is controlled by PPROT.PSIZE. This function is controlled by the PCP_PPROT register (“[PRAM Protection Register, PCP_PPROT](#)” [on Page 89](#)).

Whenever a Unprotected Channel Program executes a PRAM write instruction (and protection is enabled) the target address will be examined to determine whether it lies within the Protected Channel PRAM region. If the address lies within the region then the PRAM write will not take place and the PCP will exit the channel with an IOP (Illegal Operation) error.

Note: FPI PRAM write accesses to PRAM are unaffected by this protection.

10.8 FPI Interface

The PCP operates both as an FPI Master and an FPI Slave.

10.8.1 Operation as an FPI Master

The PCP generates FPI read and write transactions in response to execution of PCP FPI instructions. The PCP can generate Byte, Half-word and Word single transactions and bursts of length two, four and eight. All FPI transactions are generated in Supervisor Mode.

For High Integrity Systems it is necessary to prevent the PCP from generating unwanted FPI writes to critical locations in the event of a PCP malfunction. To address this problem a Memory Protection feature is provided to control the address range that can be written to by the PCP. The scheme is based around a user definable FPI address window. Along with defining the window base address and size the user can select whether:-

- Writes are allowed only to addresses that are within the window (Limit).
- Writes are allowed only to addresses that are outside the window (Exclude).

Whenever the PCP executes an FPI instruction that will result in an FPI write accesses the destination address is checked to ensure that it is to an allowed address. If a write access is to an address that is not allowed then the write will not take place and the PCP will exit the channel with an IOP (Illegal Operation) error.

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This function is controlled by the **PCP_FWWIN** register (see [Page 93](#)).

10.8.2 Operation as an FPI Slave

The PCP is visible to FPI Masters as a 256 Kbyte R/W block of memory on the System Bus. The PCP must be accessed only with word (32 bit) accesses. Accessing an unassigned address (i.e. an address outside the range of Control & Status Registers, PRAM and CMEM) will generate an FPI bus error. All PCP locations can be read in either User or Supervisor Modes. All writes must be performed in Supervisor Mode. Attempting to write to any PCP location in User Mode will generate an FPI error. Some Control and Status Registers are ENDINIT protected.

There are some additional user selectable FPI write protection options to support High Integrity operation:-

- Some/all Control and Status registers can be programmed to be ENDINIT protected.
- CMEM can be programmed to be read only.
- PRAM can be programmed to be partially or wholly read-only.

10.9 PCP Error Handling

The PCP contains a number of fail-safe mechanisms to ensure that error conditions are handled gracefully and predictably. In addition to providing an extra level of system robustness suitable for high integrity and safety-critical systems, these mechanisms can often ease the task of finding programming errors during the development process. Whenever an error is detected, the channel program that was executing exits and the PCP_ES register is updated with information to allow determination of the error that occurred, the instruction address, and the channel program that was executing when the error occurred (see [Page 32](#)).

10.9.1 PRAM Protection Violation

PRAM can be considered as being split into a number of distinct areas (see [Section 10.7](#)).

The default configuration of the PCP allows the PCP to use PRAM as a single area. While this default configuration allows complete flexibility regarding the use of PRAM, this flexibility also introduces the possibility of invalid PCP operation as a result of the following issues:

- Any channel program is allowed to write to any PRAM location (including any location in the CSA). This means that a channel program may be inadvertently programmed to corrupt the context save region or PRAM storage belonging to another channel, causing invalid operation of the corrupted channel when it next executes.
- Generation of an interrupt request to the PCP with a priority number that would cause loading of a context from outside the CSA will cause the spurious execution of a channel program with an invalid context loaded from outside the CSA.

10.9.1.1 Enforced PRAM Partitioning

The lowest of the PRAM areas is the CSA (see [Page 16](#)) which is used for storing context information for each active channel while the channel program is not actually executing.

To avoid spurious PCP operation as a result of programming errors, the PCP can be optionally configured via the global PCP control and status register (PCP_CS) to enforce strict partitioning of PRAM between the CSA and the remainder of PRAM. PRAM partitioning is selected by programming PCP_CS.PPE = 1 and the size of the CSA in use is selected via the PCP_CS.PPS bit field (see [Page 70](#)). When PRAM partitioning has been enabled, a PCP Error will be generated on either one of the following events:

- A channel program executes a PRAM write instruction with a target area within the CSA. This prevents a channel from corrupting the context save region of any other channel.

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- An incoming interrupt request causes the PCP to attempt to load a context from outside the CSA. This prevents the PCP from running an invalid channel program as a result of an invalid interrupt request.

Note: Enabling PRAM partitioning (PCP_CS.PPE = 1) with a CSA size of zero (PCP_CS.PPS = 0) is an invalid setting and will cause a PCP error event whenever any interrupt request is received by the PCP.

10.9.1.2 Protected Channel PRAM

When a Protected Channel PRAM area has been programmed (see [Section 10.7.2.2](#)) then any attempt by an Unprotected Channel Program to write to the Protected Channel PRAM area will generate a PCP error.

10.9.2 FPI Write Window Violation

When an FPI Write Window has been programmed (see [Section 10.8.1](#)) then any attempt by a Channel Program to write to an FPI address that has been disallowed will generate a PCP error.

10.9.3 Channel Watchdog

The Channel Watchdog is a PCP internal watchdog that optionally allows the user to ensure that the PCP will not become locked into executing a single channel due to an endless loop or unexpected software sequence. As each channel executes, the PCP maintains an internal count of the number of instructions that have been read from CMEM since the channel started. If the watchdog function is enabled (by programming PCP_CS.CWE = 1) and the internal instruction fetch counter reaches the threshold programmed by the user (programmed via PCP_CS.CWT), a PCP Error is generated. The threshold setting (PCP_CS.CWT) is global to all channels. From this it follows that the threshold must be selected to be greater than the maximum number of instructions that can be fetched by any channel program, taking all channels into consideration. It should be noted that the instruction width of the PCP is 16 bits and that therefore execution of an instruction that is encoded into 32 bits (e.g. LDL.IL) will generate two CMEM instruction reads. That will therefore cause the internal watchdog counter to be incremented twice.

Note: Enabling the Channel Watchdog function (PCP_CS.CWE = 1) with a threshold of zero (PCP_CS.CWT = 0) is an invalid setting and will cause a PCP error event whenever any interrupt request is received by the PCP.

10.9.4 Invalid Opcode

The PCP includes the Invalid Opcode mechanism to check that each instruction fetched from CMEM is a legal instruction. If the PCP attempts to execute an illegal instruction, then a PCP error is generated.

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Note: The DEBUG instruction must be only used in DEBUG mode otherwise it will be considered to be an illegal operation and will generate an IOP error.

10.9.5 Instruction Address Error

An Instruction Address Error is generated if the PCP attempts to execute an instruction from an illegal address. An address is considered to be illegal if:

- The address is outside the available CMEM area (see [Page 159](#) for the CMEM size implemented in this derivative)

and/or

- The specified address could not be contained in the 16-bit PC (i.e. an address calculation yielded a 16-bit unsigned overflow).

The second of these cases can result from an address calculation either from the execution of a PC relative jump instruction (either a JC, JC.I, or JL instruction), or the PC being incremented following execution of the previous instruction.

10.10 Software In-System Test Support

The PCP protects against memory integrity errors by ECC protection of the PCP memories. This has the unfortunate side-effect of requiring memory blocks wider than the normal data access path to the memory. The additional ECC storage bits are not easily accessible via the existing data paths, causing significant problems where SIST based testing of the memories is required. In order to address this problem the PCP includes improved SIST support, allowing all PCP memory arrays to be accessed to allow the test and debug of the fault tolerant memory systems.

The mapping of hidden memory ECC bits into the PCP address space is controlled by the setting of bits within the SIST Mode Access Control Register (SMACON). The existence of the SMACON register is architecturally defined. However, the fields within SMACON and the effect of the fields on the memory map of the PCP are implementation specific.

Hidden ECC bits are mapped into the CMEM and PRAM areas by setting bits in the SMACON register. The SMACON register is a SFR which can only be written in supervisor mode and is endit protected. The definition of the SMACON register for the PCP is shown on [Page 82](#).

The control fields within the SMACON register allow individual control of the local memories. Each memory may be mapped to operate in a number of different modes.

Normal Operation, No Mapping, error detection/correction enabled

No mapping of the ECC bits is performed and normal operation is possible. Error detection/correction is active.

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Data Array Mapping, no error detection/correction

No mapping of the ECC bits is performed. Writes to the memory will not affect the ECC bits. Error correction/detection for the memory is disabled. Normal operation (with the exception that ECC protection is not operational) is possible.

Check Array Mapping, no error detection/correction

The ECC bit array (only) of the memory is made visible in the address map (i.e. the memory data array cannot be accessed). Writes to the memory will not affect the data bits. Error correction/detection for the memory is disabled. The PCP must be disabled before, and remain disabled while, this mode is selected for any of the PCP memories.

When this mode is selected the memory ECC bit array replaces the memory data array in the address map. During a read the value of the ECC bits for a location can be determined from bits 6 to 0 of the value read from the location (all other bits read as '0'). During a write the ECC bits are updated from bits 6 to 0 of the written value. The written value of all bits other than bits 6 to 0 is discarded.

Data Array Mapping, error detection/correction enabled.

No mapping of the ECC bits is performed and normal operation is possible.

Note: Unlike TriCore the PCP has no hidden memory arrays (i.e. all PCP memories reside permanently in the system address map). As a result, for the PCP, this mode is identical to "Normal Operation". This mode is retained for compatibility with TriCore SIST.

10.11 Memory Integrity Error Detection and Correction

The PCP includes support for Memory Integrity Error Detection and Correction logic to address the increasing occurrence of memory errors in deep sub-micron CMOS technologies. Soft errors are transient errors in state (not permanent) typically caused by alpha particle hits to the die, causing induced charge which flips the state of storage elements. In current process geometries SRAM arrays are most susceptible to soft error events due to their small size and low stored charge. The detection and deterministic recovery from such memory integrity errors is especially important for automotive applications, such as electronic braking systems and engine management.

The PCP includes the following SRAM arrays:

- Code Memory (CMEM)
- Parameter Memory (PRAM)

Each of these memory arrays will be protected from memory integrity errors, with the specific mechanisms described in the following sections.

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Note: Before enabling Error Detection/Correction on an SRAM (i.e. CMEM or PRAM) the user must ensure that all locations within the SRAM have been initialised. If this is not done then unwanted spurious memory errors can be generated.

10.11.1 Definitions

In the following sections memory integrity errors are considered to be either Correctable or Un-correctable. These are defined as follows:-

Un-correctable Memory Integrity Error

If on accessing a memory element containing a memory integrity error hardware is not able to provide the expected data to the core, the integrity error is defined as being Un-correctable.

Correctable Memory Integrity Error

If on accessing a memory element containing a memory integrity error hardware is able to provide the expected data to the core, the integrity error is defined as being correctable.

10.11.2 Architectural Extensions - Registers

A number of additional Special Function Registers (SFRs) have been added to the PCP in order to fully support memory integrity error handling. The function of these registers is explained below while the specific register information is detailed in [Section 10.15](#).

10.11.3 Memory Integrity Error Control

The MIECON register controls whether memory errors generate a notification to the SCU or not. MIECON may only be written in supervisor mode and is ENDINIT protected.

A pair of architecturally visible registers (MIECON, MIECON2) are included to allow software to control the memory integrity error detection / correction mechanisms. The existence of the MIECON and MIECON2 registers is architecturally defined. However, the fields within these registers are implementation specific.

The xxIEE and xxSECE bits for a given memory type exist in different registers (MIECON and MIECON2 respectively) due to different protection requirements for these SFR bits. Both the xxIEE and xxSECE bits and the appropriate SMACON field settings interact to perform the following general function:

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Table 24 Memory Integrity Error Modes

xSECE	xIEE	SMACON	Description
x	x	01 _B or 10 _B	Array Mapping. All single and double-bit memory integrity errors ignored.
0	0	00 _B or 11 _B	No Memory Integrity Handling. All single and double-bit memory integrity errors ignored.
0	1	00 _B or 11 _B	Error Detection Mode Single and double-bit errors treated as un-correctable errors.
1	0	00 _B or 11 _B	SEC Only Mode Single-bit errors corrected by ECC, double-bit errors ignored.
1	1	00 _B or 11 _B	SECEDED Mode Single-bit errors corrected by ECC, double-bit errors treated as un-correctable errors.

Two status registers (MIESTATP for PRAM and MIESTATC for CMEM) are provided to allow software to easily identify locations that have generated memory error events. The xxIEE and xxSECE bits and the appropriate SMACON field settings interact to control the update of these registers.

Table 25 Memory Integrity Error Status Register Updates

xSECE	xIEE	SMACON	Description
x	x	01 _B or 10 _B	MIESTATx not updated on any error
0	0	00 _B or 11 _B	MIESTATx not updated on any error
0	1	00 _B or 11 _B	MIESTATx updated on both single and double-bit error
1	0	00 _B or 11 _B	MIESTATx not updated on any error
1	1	00 _B or 11 _B	MIESTATx updated only on double-bit error

Errors are reported and the MIESTATx registers are updated only when data read from the memory is actually being utilized (i.e. the memory is either being read via FPI or by the core). In the event of error detection being enabled, a PRAM (double word) location containing an error in both word lanes and the PCP performing a double word read (only during a context restore) the MIESTATP register will be updated as though the error was in the lower word of PRAM.

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10.12 Instruction Set Overview

The following sections present an overview of the instruction set and the available addressing modes of the PCP in the TC1728.

10.12.1 DMA Primitives

Table 18 describes the two DMA instructions of the PCP.

Table 26 DMA Transfer Instructions

DMA Transfer	BCOPY	Move block of data value from FPI Bus source address location to FPI Bus destination address location. Optionally increment or decrement source and destination pointer registers. Optionally repeat instruction until counter CNT1 reaches 0.
	COPY	Move value from FPI Bus source address location to FPI Bus destination address location. Optionally increment or decrement source and destination pointer registers. Optionally repeat instruction until counter CNT1 reaches 0.

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10.12.2 Load and Store

Table 19 describes the load and store instructions of the PCP.

Note: If a conditional instruction's condition code is false, the operation will be treated as a "No Operation". Register values will not be changed and the flags will not be updated.

Table 27 Load and Store Instructions

Load	LD.F	Load value from FPI Bus address location into register (FPI Bus address = register content)
	LD.I	Load immediate value into register
	LD.IF	Load value from FPI Bus address location into register (FPI Bus address = register content + immediate offset)
	LD.P	Load value from PRAM address location into register (PRAM address = DPTR + register offset)
	LD.PI	Load value from PRAM address location into register (PRAM address = DPTR + immediate offset)
	LDL.IL	Load 16-bit immediate value into lower bits [15:0] of register
	LDL.IU	Load 16-bit immediate value into upper bits [31:16] of register
Store	ST.F	Store register value to FPI Bus address location (FPI Bus address = register content)
	ST.IF	Store register value to FPI Bus address location (FPI Bus address = register content + immediate offset)
	ST.P	Store register value to PRAM address location (PRAM address = DPTR + register offset)
	ST.PI	Store register value to PRAM address location (PRAM address = DPTR + immediate offset)
Move	MOV	Conditionally move register value to register

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10.12.3 Arithmetic and Logical Instructions

Arithmetic instructions that are fully register-based execute conditionally depending on the specified Condition Code A (see [Page 101](#)). All other arithmetic instructions such as PRAM (.PI), indirect (.I), and FPI (.F and .IF) execute unconditionally.

Note: If a conditional instruction's condition code is false, the operation will be treated as a "No Operation". Register values will not be changed and the flags will not be updated.

Table 28 Arithmetic Instructions

Add	ADD	Add register to register (conditionally)
	ADD.I	Add immediate value to register
	ADD.F	Add content of FPI Bus address location to register (byte, half-word or word)
	ADD.PI	Add content of PRAM address location to register
Subtract	SUB	Subtract register from register (conditionally)
	SUB.I	Subtract immediate value from register
	SUB.F	Subtract content of FPI Bus address location from register (byte, half-word or word)
	SUB.PI	Subtract content of PRAM address location from register
Compare	COMP	Compare register to register (conditionally)
	COMP.I	Compare immediate value to register
	COMP.F	Compare content of FPI Bus address location to register (byte, half-word or word)
	COMP.PI	Compare content of PRAM address location to register
Negate	NEG	Negate register (2's complement, conditionally)

Logical instructions that are fully register-based execute conditionally as determined by the specified Condition Code A. All other logical instructions, such as PRAM (.PI), indirect (.I), and FPI (.F and .IF) execute unconditionally.

Table 29 Logical Instructions

Logical And	AND	Register AND register (conditionally)
	AND.F	Content of FPI Bus address location AND register (byte, half-word or word)
	AND.PI	Content of PRAM address location AND register
	MCLR.PI	Clear specified bits within a PRAM location

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Table 29 Logical Instructions

Logical Or	OR	Register OR register (conditionally)
	OR.F	Content of FPI Bus address location OR register (byte, half-word or word)
	OR.PI	Content of PRAM address location OR register
	MSET.PI	Set specified bits within a PRAM location
Logical Exclusive-Or	XOR	Register XOR register (conditionally)
	XOR.F	Content of FPI Bus address location XOR register (byte, half-word or word)
	XOR.PI	Content of PRAM address location XOR register
Logical Not	NOT	Invert register (1's complement, conditionally)
Shift	SHL	Shift left register
	SHR	Shift right register
Rotate	RL	Rotate left register
	RR	Rotate right register
Prioritize	PRI	Calculate position of first set bit (1-bit) in register, from left

Note: If a conditional instruction's condition code is false, the operation will be treated as a "No Operation". Register values will not be changed and the flags will not be updated.

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10.12.4 Bit Manipulation

All bit manipulation instructions except INB are executed unconditionally. If conditional bit handling is required, INB should be used.

Table 30 Bit Manipulation Instructions

Set Bit	SET	Set bit in register
	SET.F	Set bit in FPI Bus address location
Clear Bit	CLR	Clear bit in register
	CLR.F	Clear bit in FPI Bus address location
Insert Bit	INB	Insert carry flag into register (position given by content of a register)
	INB.I	Insert carry flag into register (position given by immediate value)
Check Bit	CHKB	Set carry flag depending on value of specified register bit

10.12.5 Flow Control

Table 23 describes flow control instructions of the PCP in the TC1728.

Table 31 Flow Control Instructions

Jump	JC	Jump conditionally to PC + short immediate offset address
	JC.A	Jump conditionally to immediate absolute address
	JC.I	Jump conditionally to PC + register offset address
	JC.IA	Jump conditionally to register absolute address
	JL	Jump unconditionally to PC + long immediate offset address
Exit Channel	EXIT	Unconditionally exit channel program execution (optionally generate interrupt request and/or inhibit channel)
No Operation	NOP	Low-power No-Operation
Debug	DEBUG	Conditionally generate debug event (optionally stop channel program execution)

10.12.6 Addressing Modes

The PCP needs to address locations in memory in different ways, as determined by the type of memory being accessed and the type of action being performed on that location.

10.12.6.1 FPI Bus Addressing

All FPI Bus accesses from the PCP are indirect to some extent. The main indirect addressing on the FPI Bus uses a 32-bit absolute address located in the GPR indicated in the instruction. This address must be properly aligned for the type of data access – byte, half-word or word. If it is not aligned, the results are undefined.

- Effective Target Address [31:0] = $\langle R[a] \rangle$

where a is the number of the register, for instance, R2. Instructions using this address mode are indicated through the “.F” suffix.

For indirect-plus-immediate addressing on the FPI Bus, the 32-bit absolute address located in the GPR indicated in the instruction is added to the immediate 5-bit offset value encoded in the instruction. This address must be properly aligned for the type of data access (byte, half-word or word). If it is not aligned, the results are undefined.

- Effective Target Address [31:0] = $\langle R[a] \rangle + \#offset5$

where a is the number of the register and $\#offset5$ is a 5-bit immediate offset value. Instructions using this addressing mode are indicated through the “.IF” suffix (only available for load and store, LD.IF and ST.IF).

This addressing mode is particularly useful for managing peripherals, where the peripheral base address is held in $R[a]$, and the offset can index directly into a specific control register.

The BCOPY and COPY instructions use the indirect absolute addressing with predefined PCP registers. Register R4 is used as the source address pointer, while R5 represents the destination address pointer.

- Effective Source Address [31:0] = $\langle R4 \rangle$
- Effective Destination Address [31:0] = $\langle R5 \rangle$

Note: All FPI Bus accesses by the PCP are performed in Supervisor mode.

Note: The PCP is not allowed to access its own registers via instructions executed in the PCP.

10.12.6.2 PRAM Addressing

The PRAM is always addressed indirectly by the PCP. The normal address used is the value of the R7.DPTR field (8 bits) concatenated with an immediate 6-bit offset value encoded in the instruction, yielding a 14-bit word address. This enables access to 16 Kwords (64 Kbytes). Because R7.DPTR is part of a channel program's context, a channel program may alter the DPTR value at any time.

- Effective PRAM Address[13:0] = <R7.DPTR> << 6 + #offset6

Instructions using this addressing mode are indicated through the “.PI” suffix.

To provide effective indexing into large tables or stores of data, an alternate form of indirect addressing can also be used on load and store operations to PRAM. The value of the DPTR field (8 bits) is concatenated with the least significant 6 bits of R[a], again yielding a 14-bit word address. The most significant bits [31:6] of R[a] are ignored.

- Effective PRAM Address[13:0] = <R7.DPTR> << 6 + <R[a][5:0]>

Instructions using this addressing mode are indicated through the “.P” suffix (load and store only, LD.P and ST.P).

10.12.6.3 Bit Addressing

Single bits can be addressed in the PCP GPRs or in FPI Bus address locations. A 5-bit value indicates the location of a bit in the register specified in the instruction. This bit location is either given through an immediate value in the instruction or through the lower five bits of a second register (indirect addressing).

- Effective Bit Position[31:0] = #imm5
- Effective Bit Position[31:0] = <R[a][5:0]>

The immediate bit addressing is used by instructions SET and CLR and their variants as well as by INB.I and CHKB. Indirect bit addressing is used by the INB instruction only.

10.12.6.4 Flow Control Destination Addressing

The jump instructions are split into two groups: PC-relative jumps, and jumps to an absolute address.

For PC-relative jumps, the destination address is a positive or negative offset from the PC of the next instruction. The offset is either contained in the lower 16 bits of a register (the upper 16 bits are ignored), or is given as immediate value of the instruction. The immediate values are sign-extended to 16 bits. If the effective jump address is outside the available CMEM area (or the jump address calculation caused an overflow), then a PCP error condition has occurred.

- Effective JUMP Address[15:0] = NextPC + Signed(R[a][15:0]); +/- 32K instructions
- Effective JUMP Address[15:0] = NextPC + Sign-Extend(#offset10);
+/- 512 instructions

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- Effective JUMP Address[15:0] = NextPC + Sign-Extend(#offset6);
+/- 32 instructions

The function NextPC indicates the instruction that would be fetched next by the program counter. Instructions using this addressing are JL, JC and JC.I.

For absolute addressing, the actual address in CMEM where program flow is to resume is either an immediate value #imm16 in the CMEM location immediately following the jump instruction, or it is contained in the lower 16 bits of a register. If the value is greater than the PC size implemented, an error condition has occurred.

- Effective JUMP Address[15:0] = #imm16
- Effective JUMP Address[15:0] = <R[a]>

Instructions using these addressing modes are JC.A (immediate absolute address) and JC.IA (indirect absolute address).

10.13 FPI Interface

Any FPI Bus master (on the TC1728's System Peripheral Bus) can access the three distinct PCP address ranges from the FPI Bus side, on the other hand the PCP master interface can also access any address on the FPI bus. Normally, the CPU initializes the control registers via FPI Bus access. Thereafter, the PCP should not access its control registers itself through PCP instructions. Apart from the access via FPI Bus, there is no direct way to the PCP control registers.

Accesses to the PCP control and status register, the PRAM, and the CMEM are detailed in the following sections.

10.13.1 Access to the PCP Control Registers from the FPI Bus

FPI Bus accesses to the PCP control registers must always be performed in Supervisor Mode with word accesses; byte or half-word accesses will result in a bus error.

All PCP control registers can be read at any time. Register PCP_CS can be optionally Endinit-protected via bit PCP_CS.EIE (see [Page 70](#)). If CS.EIE & ENDINIT = True, then any write access to this register is inhibited. The clock control register PCP_CLC is endinit-protected. The Software In-System Test register is also endinit-protected.

Additionally (see below) for High Integrity applications the entire Register content can be ENDINIT protected (see below).

10.13.1.1 PCP Control Register Protection

To allow the PCP to handle system critical tasks it is necessary to ensure that the PCP can operate properly regardless of a failure in another part of the system or the PCP itself. This means that it is necessary to protect the Control and Status Registers from such failures.

The configuration register content can only be modified via the FPI. Protection of the PCP configuration therefore consists of prevention of unwanted FPI writes to the PCP registers.

The normal model of PCP operation is that the PCP is configured at system initialization and the configuration remains unchanged for the duration of operation of the system. Protection therefore consists of a simple locking scheme to prevent any write to registers once the PCP has been configured. Once the PCP has been configured (at system initialization) the Registers can be locked such that, unless ENDINIT is clear, all incoming FPI write accesses are issued with an error response and the PCP configuration will remain unmodified.

If it is required to modify content of the registers once they have been locked it is necessary to clear the ENDINIT bit (via the system Watchdog Timer) such that the Registers become writeable again.

Regardless of protection the entire Register content remains readable via FPI.

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This function is controlled by the RPROT register ([“Register Protection Register, PCP_RPROT” on Page 87](#)).

10.13.2 Access to the PRAM from the FPI Bus

FPI Bus accesses to the PRAM must always be performed with word accesses; byte or half-word accesses will result in a bus error.

Attention needs to be paid when accessing the CSAs and data sections of the PCP channel programs. The location of a specific channel's CSA is dependent on the chosen Context Model, Full, Small or Minimum Context. [Table 32](#) shows these addresses.

Table 32 FPI Bus Access to CSAs

Channel	Full Context	Small Context	Minimum Context
0 (see note)	PRAM Base Address + 00 _H	PRAM Base Address + 00 _H	PRAM Base Address + 00 _H
1	PRAM Base Address + 20 _H	PRAM Base Address + 10 _H	PRAM Base Address + 08 _H
2	PRAM Base Address + 40 _H	PRAM Base Address + 20 _H	PRAM Base Address + 10 _H
3	PRAM Base Address + 60 _H	PRAM Base Address + 30 _H	PRAM Base Address + 18 _H
n	PRAM Base Address + n × 20 _H	PRAM Base Address + n × 10 _H	PRAM Base Address + n × 08 _H

Note: Since channel 0 is not defined (no service request with SRPN = 0), the first area is not an actual CSA. It is recommended that this area should not be used by PCP channel programs.

The FPI Bus address of a word location pointed to by the Data Pointer R7_DPTR is calculated by the following formula:

- Effective FPI Bus address[31:0] = (PRAM Base Address) + (<DPTR> << 6)

10.13.3 Access to the CMEM from the FPI Bus

FPI Bus accesses to the CMEM must always be performed with word accesses; byte or half-word accesses will result in a bus error.

When using a channel entry table, the FPI Bus address of a specific channel's entry location is given by the following formula:

- Effective FPI Bus address[31:0] = (CMEM Base Address) + 04_H × channel number

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The FPI Bus address of an instruction pointed to by the PCP program counter, PC, is calculated by the following formula:

- Effective FPI Bus address[31:0] = (CMEM Base Address) + <PC> << 1

10.14 Debugging the PCP

For debugging the PCP, a special instruction, DEBUG, is provided. This instruction can only be used when the PCP is in Debug Mode. It can be placed at important locations inside the code to track and trace program execution. The execution of the instruction depends on a condition code specified with the instruction. The actions programmed for this instruction will only take place if the specified condition is true.

The following actions are performed when the DEBUG instruction is executed and the condition code is true:

- Store the current PC, i.e. the address of the DEBUG instruction, in register PCP_ES.EPC
- Store the current channel number in register PCP_ES.EPN

In addition, the following operations can be programmed through fields in the DEBUG instruction:

- Optionally stop the channel program execution (instruction field SDB)
- Optionally generate an external debug event at pin BRKOUT (instruction field EDA)
- Optionally prevent the PCP from executing any further channel programs (instruction field DAC)
- Optionally cause the PCP to decrement the PC prior to saving the channel context (instruction field RTA)

If the DEBUG instruction is programmed to stop the channel program execution, the action taken by the PCP depends on the value of the RTA instruction field:

- If RTA = 0, the PCP disables further invocations of the current channel through clearing bit R7.CEN, and then performs a context save. The execution of this channel is stopped at the point of the DEBUG instruction. If the DAC instruction field = 0, the PCP will continue to operate, accepting service requests for other channels as they arise. Since the stopped channel was disabled before saving its context, service requests for this channel will result in an error exit (see [Page 32](#)). When re-enabling the channel, its enable bit CEN in the saved context location CR7 must be set.
- If RTA = 1, the PCP does not modify bit R7.CEN (i.e. the channel remains enabled), decrements the PC (so that it again points to the DEBUG instruction), and then performs a context save. The execution of this channel is stopped at the point of the DEBUG instruction. If the DAC instruction field = 0, the PCP will continue to operate, accepting service requests for channels as they arise. Since the stopped channel was not disabled before saving its context, service requests for this channel will not result in an error exit, but will simply cause re-execution of the DEBUG instruction and hence a repeat of the channel exit.

Note: When a channel is stopped by DEBUG, the context of the stopped channel will be saved to the appropriate region of the CSA before the channel terminates. Where a Small or Minimum Context model is being used, the values of the GPRs not included in the context will not be saved, and indeed these register values may be

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changed by the operation of another active channel. In this case, the required registers should be explicitly saved to PRAM by store instructions prior to execution of the DEBUG instruction.

If the DEBUG instruction is programmed to stop all channel program execution, the PCP disables further invocations of any channel by clearing bit PCP_CS.EN. The execution of this channel is only stopped according to the SDB instruction field value. The PCP will only start to reaccept service requests when PCP_CS.EN is written to 1.

Note: The DEBUG instruction must be only used in DEBUG mode; otherwise it will generate an IOP error.

Note: If PCP_CS.RCB = 0 (Channel Resume Mode), then the channel program will begin executing at whichever PC is restored from the context location CR7.PC. If PCP_CS.RCB = 1 (Channel Restart Mode), then the channel program is forced to always start at its channel entry table location, no matter what the restored context value is for the PC. This means that in Channel Restart Mode, it is not possible to restart the channel program from where it was halted by the debug event. It is recommended that when using Channel Restart Mode, the user should also program all EXIT instructions with the "EP = 0" setting to allow selection of Channel Resume Mode for debugging without changing operation of the channel programs.

Peripheral Control Processor (PCP)**10.15 PCP Registers**

The PCP can be viewed as being a peripheral on the FPI Bus. As with any other peripheral, there are control registers, normally set by the CPU acting as an external FPI Bus master to the PCP during initialization. Control registers select the operating modes of the PCP, and status registers provide information about the current state of the PCP to the external FPI Bus master.

Accessing of Control Registers

The control registers are accessible by any master via the FPI Bus. The control registers must be configured at initialization and then left unaltered. This is typically done by the CPU. The only setting that can be dynamically modified is the PCP_CS.EN bit. All other bits must only be modified when PCP_CS.EN = 0 and PCP_CS.RS = 0.

The PCP control and status registers are accessible only to the CPU when it is operating in Supervisor mode. PCP control and status registers must be accessed with 32-bit read and write operations only.

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Control Registers	Interrupt Registers
PCP_CLC	PCP_SRC0
PCP_CS	PCP_SRC1
PCP_ES	PCP_SRC2
PCP_ICR	PCP_SRC3
PCP_ITR	PCP_SRC4
PCP_ICON	PCP_SRC5
PCP_SSR	PCP_SRC6
PCP_RPROT	PCP_SRC7
PCP_CPROT	PCP_SRC8
PCP_PPROT	PCP_SRC9
PCP_FWWIN	PCP_SRC10
PCP_SMACON	PCP_SRC11
PCP_MIECON	
PCP_MIESTATP	
PCP_MIESTATC	

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Figure 28 PCP Registers

The figure above is for a Target Spec with Protection

PCP Register Overview

The address map of the PCP starts at its base address as shown in [Table 41](#). The address offsets of the PCP registers are described in [Table 33](#).

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Table 33 Register Overview of PCP

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
PCP_CLC	Clock Control Register	00 _H	U, SV, 32	SV, 32, E	FPI Reset	Page 68
PCP_ID	Module Identification Register	08 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 69
PCP_CS	Control/Status Register	10 _H	U, SV, 32	SV, 32, E ³⁾	FPI Reset	Page 70
PCP_ES	Error/Debug Status Register	14 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 72
PCP_ICR	Interrupt Control Register	20 _H	U, SV, 32	SV, 32	FPI Reset	Page 75
PCP_ITR	Interrupt Threshold Control Register	24 _H	U, SV, 32	SV, 32	FPI Reset	Page 77
PCP_ICON	Interrupt Configuration Register	28 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 78
PCP_SSR	Stall Status Register	2C _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 80
PCP_SMACON	SIST Mode Access Control Register	40 _H	U, SV, 32	SV, 32	FPI Reset	Page 82
PCP_MIECON	Memory Integrity Error Control Register	50 _H	U, SV, 32	SV, E, 32	FPI Reset	Page 83
PCP_MIECON 2	Memory Integrity Error Control 2 Register	54 _H	U, SV, 32 ⁴⁾	SV, E, 32 ⁴⁾	FPI Reset	Page 84
PCP_MIESTAT P	Memory Integrity Error Status for PRAM Register	58 _H	U, SV, 32	SV, 32	FPI Reset	Page 85
PCP_MIESTAT C	Memory Integrity Error Status for CMEM Register	5C _H	U, SV, 32	SV, 32	FPI Reset	Page 86
PCP_RPROT	Register Protection Register	70 _H	U, SV, 32	SV, E, 32	FPI Reset	Page 87

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Table 33 Register Overview of PCP

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
PCP_CPROT	CMEM Protection Register	74 _H	U, SV, 32	SV, E, 32	FPI Reset	Page 88
PCP_PPROT	PRAM Protection Register	78 _H	U, SV, 32	SV, E, 32	FPI Reset	Page 89
PCP_FWWIN	FPI Write Window Register	7C _H	U, SV, 32	SV, E, 32	FPI Reset	Page 93
PCP_SRC11	Service Request Control Register 11	D0 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 98
PCP_SRC10	Service Request Control Register 10	D4 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 98
PCP_SRC9	Service Request Control Register 9	D8 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 98
PCP_SRC8	Service Request Control Register 8	DC _H	U, SV, 32	SV, 32	FPI Reset	Page 97
PCP_SRC7	Service Request Control Register 7	E0 _H	U, SV, 32	SV, 32	FPI Reset	Page 97
PCP_SRC6	Service Request Control Register 6	E4 _H	U, SV, 32	SV, 32	FPI Reset	Page 97
PCP_SRC5	Service Request Control Register 5	E8 _H	U, SV, 32	SV, 32	FPI Reset	Page 97
PCP_SRC4	Service Request Control Register 4	EC _H	U, SV, 32	SV, 32	FPI Reset	Page 97
PCP_SRC3	Service Request Control Register 3	F0 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 96
PCP_SRC2	Service Request Control Register 2	F4 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 96
PCP_SRC1	Service Request Control Register 1	F8 _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 94
PCP_SRC0	Service Request Control Register 0	FC _H	U, SV, 32	SV, 32 ²⁾	FPI Reset	Page 94

1) The absolute register address is calculated as follows:

Module Base Address + Offset Address (shown in this column)

2) A write access is allowed to this register (i.e. no bus error is generated) but as there are no writable bits the register value is unaffected by the write.

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- 3) Endinit protection is controlled by the EIE bit.
- 4) The register is only accessible when the "pcp_sec_con_en_i" input is asserted. Any access to this register when "pcp_sec_con_en_i" is not asserted will generate an FPI error response.

10.16 PCP Registers Address Space

Table 34 **Registers Address Space**

Module	Base Address	End Address	Note
PCP	F004 3F00 _H	F004 3FFF _H	

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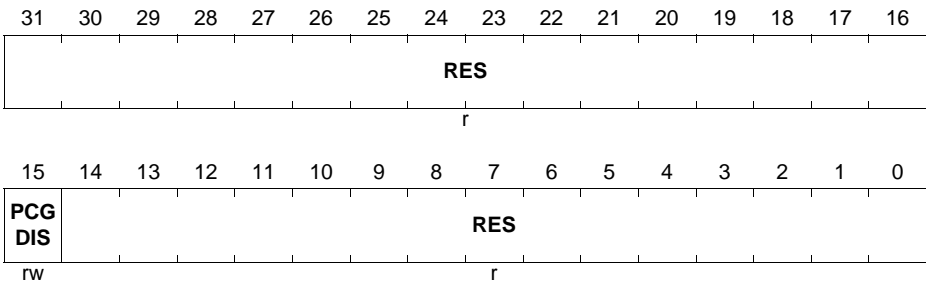
10.17.1 PCP Clock Control Register, PCP_CLC

PCP_CLC

PCP Clock Control Register

(00_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RES	[31:16]	r	Reserved Read as 0; should be written with 0.
PCGDIS	15	rw	Clock Gating Disable Bit Allows clock gating to be disabled. 0 _B PCP Internal Clock stops when PCP is idle (default after reset) 1 _B PCP Internal Clock always runs
RES	[14:0]	r	Reserved Read as 0; should be written with 0.

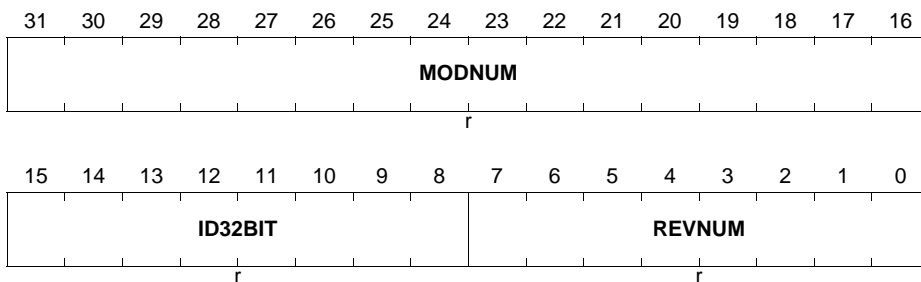
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10.17.2 PCP Module Identification Register, PCP_ID

PCP_ID

PCP Module Identification Register (08_H)

Reset Value: 0020 C009_H



Field	Bits	Type	Description
MODNUM	[31:16]	r	PCP Identification Number value = 0020 _H
ID32BIT	[15:8]	r	32-bit Module Identification Number Marker value = C0 _H
REVNUM	[7:0]	r	PCP Revision Number Implementation specific

Peripheral Control Processor (PCP)

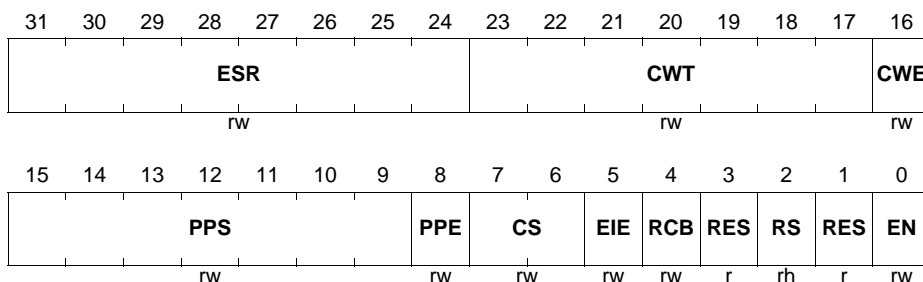
10.17.3 PCP Control and Status Register, PCP_CS

This register can be Endinit-protected via bit EIE.

PCP_CS

PCP Control/Status Register

(10_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ESR	[31:24]	rw	Error Service Request Number SRPN for interrupt to CPU on an error condition. 00 _H No interrupt request posted (default) 01 _H Post an SRPN interrupt to CPU on an error condition 10 _H Post an SRPN interrupt to CPU on an error condition
CWT	[23:17]	rw	Channel Watchdog Threshold 0 _D Reserved 1 _D Threshold = 16 instructions ... 127 _D From 1 _D up to 127 _D (n), the threshold = 16 × 'n' instructions
CWE	16	rw	Channel Watchdog Enable 0 _B Disable Channel Watchdog 1 _B Enable Channel Watchdog <i>Note: When enabled, the Channel Watchdog counts the number of instructions executed since the channel started. If this number exceeds the Channel Watchdog Threshold, a PCP error is generated.</i>

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
PPS	[15:9]	rw	PRAM Partition Size 0_D Default, only allowed with PPE = 0 1_D CSA contains 3 context save regions ... 127_D CSA contains $1 + 2 \times 127$ context save regions <i>Note: The actual size of the CSA (in words) is given by the formula $(2 \times n + 1) \times m$, where m is the number of registers in the selected Context Model.</i> <i>If PPE = 1 and the PCP attempts to perform a data write to PRAM addresses below the CSA, an error condition has occurred.</i> <i>This setting also controls the maximum channel number (MCN) used in system. The maximum channel number is $MCN = 2 \times n$. If the SRPN is greater than MCN, an error condition has occurred.</i> <i>For example, setting PPS to $n = 3$ will give a CSA containing 7 context save regions. As channel 0 cannot be used and $MCN = 6$, channels 1 to 6 are allowed.</i>
PPE	8	rw	PRAM Partitioning Enable 0_B PRAM is not partitioned 1_B PRAM is partitioned <i>Note: When partitioned, the PRAM is divided into two areas (CSA and remainder). A PCP error will be generated on an inappropriate action in either region (PCP write operation with a target address in the CSA, or context restore from outside the CSA).</i>
CS	[7:6]	rw	Context Size Selection 00_B Use Full Context for all channels 01_B Use Small Context for all channels 10_B Use Minimum Context for all channels 11_B Reserved
EIE	5	rw	Endinit Enable 0_B PCP_CS is not Endinit protected. 1_B PCP_CS is Endinit protected.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
RCB	4	rw	Channel Start Mode Control 0_B Channel resume operation mode selected; channel start PC is taken from restored context 1_B Channel restart operation mode selected; channel start PC is derived from the requested channel number (= priority number of service request) <i>Note: This is a global control bit and applies to all channels.</i>
RES	3	r	Reserved Read as 0; should be written with 0.
RS	2	rh	PCP Run/Stop Status Flag 0_B PCP is stopped or idle (default) 1_B PCP is currently running
RES	1	r	Reserved Read as 0; should be written with 0.
EN	0	rw	PCP Enable 0_B PCP is disabled for operation (default) 1_B PCP is enabled for operation <i>Note: This bit does not enable/disable clocks for power saving. It stops the PCP from accepting new service requests.</i>

10.17.4 PCP Error/Debug Status Register, PCP_ES

This is a read-only register, providing state information about error and debug conditions.

PCP_ES

PCP Error/Debug Status Register (14_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EPC															
rh															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EPN								PPC	CWD	ME	DBE	IAE	DCR	IOP	BER
rh								rh	rh	rh	rh	rh	rh	rh	rh

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
EPC	[31:16]	rh	Error PC PC value of the instruction that was executing when an error or debug event occurred. Default = 0000 _H .
EPN	[15:8]	rh	Error Service Request Priority Number Channel number of the channel that was operating when the last error/debug event occurred. The value stored is the SRPN which invoked this channel (= channel number), NOT the current PCP priority number stored in field CPPN in register PICR. Default = 00 _H .
PPC	7	rh	PRAM Partitioning Check Set if the last error/debug event was an error generated by a channel program attempting to perform a write to a PRAM address within the CSA, or receipt of an interrupt request that would have caused a context restore from outside the CSA.
CWD	6	rh	Channel Watchdog Triggered Set if the last error/debug event was an error generated by a channel program attempting to execute more instructions than allowed by PCP_CS.CWT.
ME	5	rh	Memory Error This bit is set if a PCP internal memory error has occurred. See Table 10.22 “Implementation of the PCP in the TC1728” on Page 159 for TC1728 specific implementation.
DBE	4	rh	Debug Event Flag Set if the last error/debug event was a debug event. <i>Note: A debug event does not cause the posting of an interrupt to the CPU.</i>
IAE	3	rh	Instruction Address Error Set if the last error/debug event was an error generated by the PCP attempting to fetch an instruction from an address outside the implemented CMEM range as a result of a jump or branch instruction; otherwise, clear.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
DCR	2	rh	Disabled Channel Request Flag Set if the last error/debug event was an error generated by receipt of an interrupt request with an SRPN that attempted to start a disabled PCP channel; otherwise, clear.
IOP	1	rh	Invalid Opcode Set if the last error/debug event was an error generated by the PCP attempting to execute an Invalid Opcode (i.e. the value fetched from CMEM for execution by the PCP did not represent a valid instruction), otherwise clear.
BER	0	rh	Bus Error Flag Set if the last error/debug event was an error generated by an FPI Bus error or an invalid address access; otherwise, clear. <i>Note: An FPI Bus error event does not cause the PCP to post an error interrupt to the CPU. An FPI Bus error interrupt is, however, generated by the FPI control logic.</i>

Note: An interrupt request with the SRPN held in PCP_CS.ESR is posted to the CPU whenever a PCP error event, other than an FPI Bus error occurs. FPI Bus error interrupt generation is automatically handled by the FPI Bus control logic, rather than by the PCP. The execution of a DEBUG instruction is not classed as an error event and does not therefore generate an interrupt request to the CPU. The entire contents of the register are updated whenever there is a debug or an error event detected (i.e. all status/error bits, other than the bit representing the last PCP error/debug event, are cleared). This register therefore only provides a record of the last error/debug event encountered. The only way to clear this register is to reset the PCP.

10.17.5 PCP Interrupt Control Register, PCP_ICR

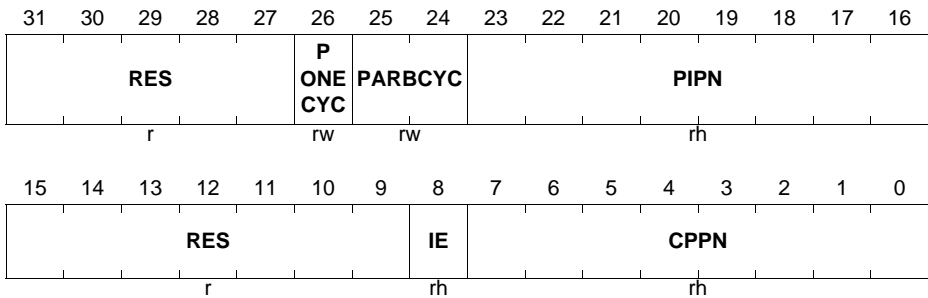
This register controls the operation of the PCP Interrupt Control Unit (PICU).

Peripheral Control Processor (PCP)

PCP_ICR

PCP Interrupt Control Register

(20_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RES	[31:27]	r	Reserved Read as 0; should be written with 0.
PONECYC	26	rw	Clocks per Arbitration Cycle Control This bit determines the number of clocks per arbitration cycle. 0 _B Two clocks per arbitration cycle (default) 1 _B One clock per arbitration cycle
PARBCYC	[25:24]	rw	Number of Arbitration Cycles Control This bit field controls the number of arbitration cycles used to determine the request with the highest priority. It follows the same coding scheme as described for the CPU interrupt arbitration. 00 _B Four arbitration cycles (default) 01 _B Three arbitration cycles 10 _B Two arbitration cycles 11 _B One arbitration cycle
PIPN	[23:16]	rh	Pending Interrupt Priority Number This read-only field is updated by the PICU at the end of each arbitration process, and indicates the priority number of a pending request. PIPN is set to 00 _H when no request is pending and at the beginning of a new arbitration process.
RES	[15:9]	r	Reserved Read as 0; should be written with 0.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
IE	8	rh	Reserved
CPPN	[7:0]	rh	Current PCP Priority Number This field indicates the current priority level of the PCP and is automatically updated by hardware on entry into an interrupt service routine.

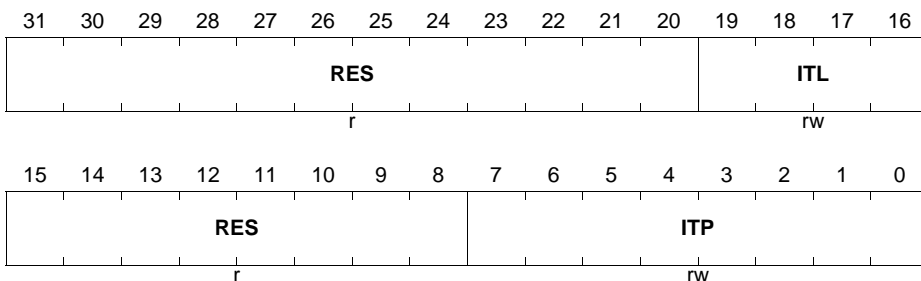
Peripheral Control Processor (PCP)

10.17.6 PCP Interrupt Threshold Register, PCP_ITR

PCP_ITR

PCP Interrupt Threshold Control Register

(24_H)

Reset Value: 0000 0000_H


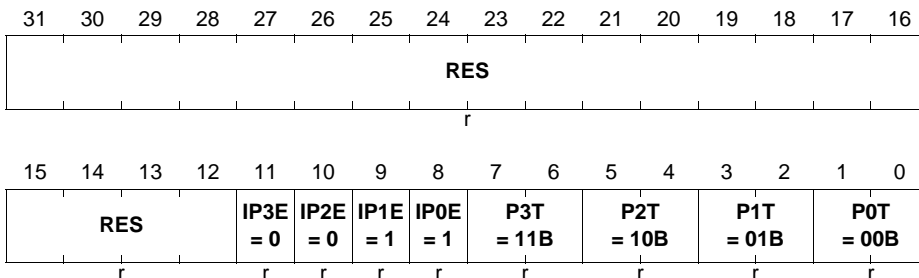
Field	Bits	Type	Description
RES	[31:20]	r	Reserved Read as 0; should be written with 0.
ITL	[19:16]	rw	Interrupt Threshold Level This bit field specifies the number of active interrupt entries at which an warning interrupt should be issued to the interrupt queue associated with interrupt bus 0 (i.e. when the number of active port 0 interrupt requests stored in all SRCx registers reaches this value then an interrupt is posted to port 0 with the priority programmed into the ITP field). When ITL is programmed to 0 or is \geq the number of SRCx registers that can contain port 0 interrupt requests, the threshold warning mechanism is disabled).
RES	[15:8]	r	Reserved Read as 0; should be written with 0.
ITP	[7:0]	rw	PCP Interrupt Threshold Service Request Priority Number This field contains the interrupt priority that is to be posted to the interrupt queue associated with interrupt bus 0 when the threshold condition is reached (setting this value to 0 or disables the threshold detection mechanism).

Peripheral Control Processor (PCP)

10.17.7 PCP Interrupt Configuration Register, PCP_ICON

PCP_ICON

PCP Interrupt Configuration Register (28_H)

Reset Value: 0000 03E4_H


Field	Bits	Type	Description
RES	[31:12]	r	Reserved Read as 0.
IP3E	11	r	PCP Interrupt Bus 3 Enable This bit reflects the status of interrupt bus 3. Interrupt bus 3 is always disabled (not implemented in the TC1728).
IP2E	10	r	PCP Interrupt Bus 2 Enable This bit reflects the status of interrupt bus 2. Interrupt bus 2 is always disabled (not implemented in the TC1728).
IP1E	9	r	PCP Interrupt Bus 1 Enable This bit reflects the status of interrupt bus 1 (PCP interrupt arbitration bus). Interrupt bus 1 is always enabled.
IP0E	8	r	PCP Interrupt Bus 0 Enable This bit reflects the status of interrupt bus 0 (CPU interrupt arbitration bus). Interrupt bus 0 is always enabled.
P3T	[7:6]	r	PCP Interrupt Bus 3 TOS Mapping This field reflects the TOS associated with interrupt bus 3. <i>Note: Interrupt bus 3 is not available in the TC1728.</i>

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
P2T	[5:4]	r	PCP Interrupt Bus 2 TOS Mapping This field reflects the TOS associated with interrupt bus 2. <i>Note: Interrupt bus 2 is not available in the TC1728.</i>
P1T	[3:2]	r	PCP Interrupt Bus 1 TOS Mapping This field reflects the TOS associated with interrupt bus 1 (PCP interrupt arbitration bus). The PCP should use this value in R6.TOS when it wishes to raise an interrupt request to itself (the PCP is always connected to interrupt bus 1).
P0T	[1:0]	r	PCP Interrupt Bus 0 TOS Mapping This field reflects the TOS associated with interrupt bus 0 (CPU interrupt arbitration bus). The PCP should use this value in R6.TOS when it wishes to raise an interrupt request via interrupt bus 0.

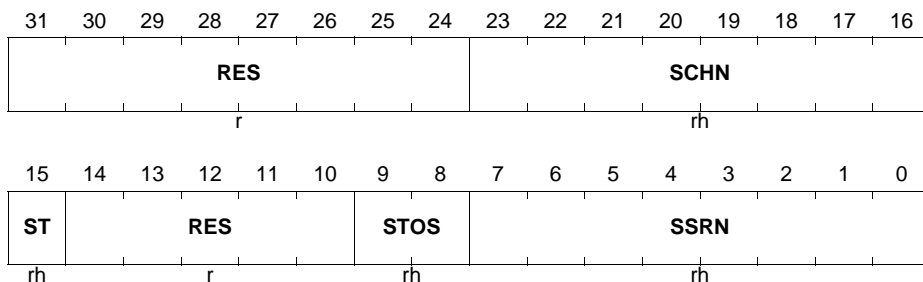
Peripheral Control Processor (PCP)

10.17.8 PCP Stall Status Register, PCP_SSR

PCP_SSR

PCP Stall Status Register

(2C_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RES	[31:24]	r	Reserved Read as 0.
SCHN	[23:16]	rh	PCP Stalled Channel Number This field shows the channel number of the channel that was executing when the last (or present) stall condition occurred. This field can only be cleared by a reset.
ST	15	rh	PCP Stalled Status This bit shows the stalled status of the PCP 0 _B PCP is not stalled 1 _B PCP is stalled
RES	[14:10]	r	Reserved Read as 0.
STOS	[9:8]	rh	PCP Stalled Type-of-Service This field shows the Type-Of-Service to which an interrupt was being posted that caused the last (or present) stall condition (i.e. the service request queue that was full when the PCP attempted to post a request to it). This field can only be cleared by a reset.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
SSRN	[7:0]	rh	PCP Stalled Service Request Number This field shows the Service Request Number that was being posted when the last (or present) stall condition occurred. This field can only be cleared by a reset.

Peripheral Control Processor (PCP)

10.17.9 SIST Mode Access Control Register, PCP_SMACON

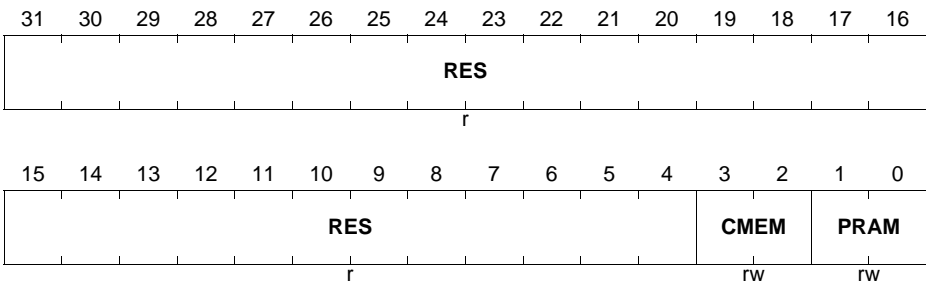
Note: Please see [Section 10.10](#) on [Page 46](#) for more information regarding the use of this register.

This register is ENDINIT protected.

PCP_SMACON

SIST Mode Access Control Register (40_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RES	[31:4]	r	Reserved returns '0' if read; should be written with '0'.
CMEM	[3:2]	rw	CMEM SIST mode access control 00 _B Normal Operation, No Mapping 01 _B Data Array Mapping, no error detection/correction 10 _B Check Array Mapping, no error detection/correction 11 _B Data Array Mapping, error detection/correction enabled
PRAM	[1:0]	rw	PRAM SIST mode access control 00 _B Normal Operation, No Mapping 01 _B Data Array Mapping, no error detection/correction 10 _B Check Array Mapping, no error detection/correction 11 _B Data Array Mapping, error detection/correction enabled

Peripheral Control Processor (PCP)

10.17.10 Memory Integrity Error Control Register, PCP_MIECON

Note: Please see [Section 10.11](#) on [Page 47](#) for more information regarding the use of this register.

This register is ENDINIT protected.

PCP_MIECON

SIST Mode Access Control Register (50_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RES															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RES														CIEE	PIEE
r														rw	rw

Field	Bits	Type	Description
RES	[31:2]	r	Reserved returns '0' if read; should be written with '0'.
CIEE	1	rw	CMEM Integrity Error Enable Enables the integrity error handling for CMEM.
PIEE	0	rw	PRAM Integrity Error Enable Enables the integrity error handling for PRAM.

Peripheral Control Processor (PCP)

10.17.11 Memory Integrity Error Control 2 Register, PCP_MIECON2

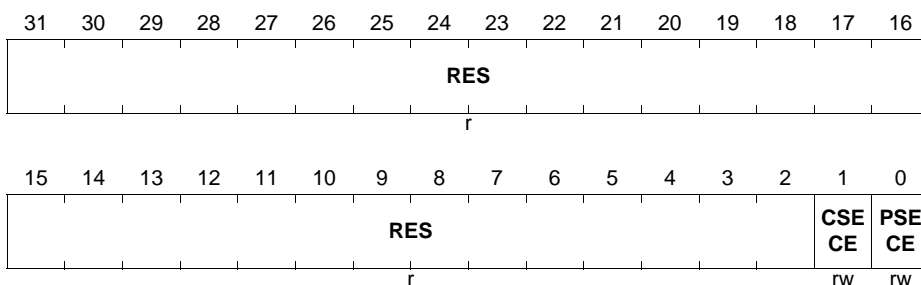
Note: Please see [Section 10.11](#) on [Page 47](#) for more information regarding the use of this register.

This register is ENDINIT protected, in addition the register cannot be accessed unless the “pcp_sec_con_en_i” input is asserted.

PCP_MIECON2

SIST Mode Access Control 2 Register (54_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RES	[31:2]	r	Reserved Returns '0' if read; should be written with '0'.
CSECE	1	rw	CMEM Single Error Correction Enable Enables single bit error correction for CMEM
PSECE	0	rw	PRAM Single Error Correction Enable Enables single bit error correction for PRAM

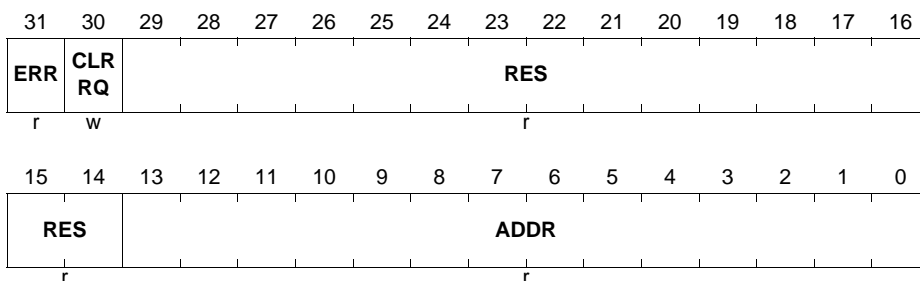
Peripheral Control Processor (PCP)

10.17.12 Memory Integrity Error Status Register for PRAM, PCP_MIESTATP

Note: Please see [Section 10.11](#) on [Page 47](#) for more information regarding the use of this register.

PCP_MIESTATP

Memory Integrity Error Status Register for PRAM(58_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
ERR	31	r	PRAM Memory Integrity Error Flag Set when a memory integrity error is encountered . This bit remains set until the CLRRQ bit is written with '1' or the PCP is reset.
CLRRQ	30	w	Clear Status Request Bit When written with '1' this causes all other bits within the register to be cleared.
RES	[29:14]	r	Reserved returns '0' if read; should be written with '0'.
ADDR	[13:0]	r	PRAM Error Address The (word) address of the PRAM location containing an error which caused the ERR bit to transition from '0' to '1'.

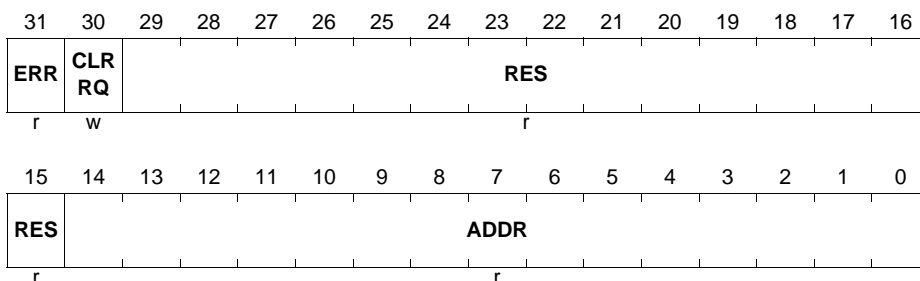
Peripheral Control Processor (PCP)

10.17.13 Memory Integrity Error Status Register for CMEM, PCP_MIESTATC

Note: Please see [Section 10.11](#) on [Page 47](#) for more information regarding the use of this register.

PCP_MIESTATC

Memory Integrity Error Status Register for CMEM(5C_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
ERR	31	r	CMEM Memory Integrity Error Flag Set when a memory integrity error is encountered. This bit remains set until the CLRRQ bit is written with '1' or the PCP is reset.
CLRRQ	30	w	Clear Status Request Bit When written with '1' this causes all other bits within the register to be cleared.
RES	[29:15]	r	Reserved returns '0' if read; should be written with '0'.
ADDR	[14:0]	r	CMEM Error Address The (word) address of the CMEM location containing an error which caused the ERR bit to transition from '0' to '1'.

Peripheral Control Processor (PCP)

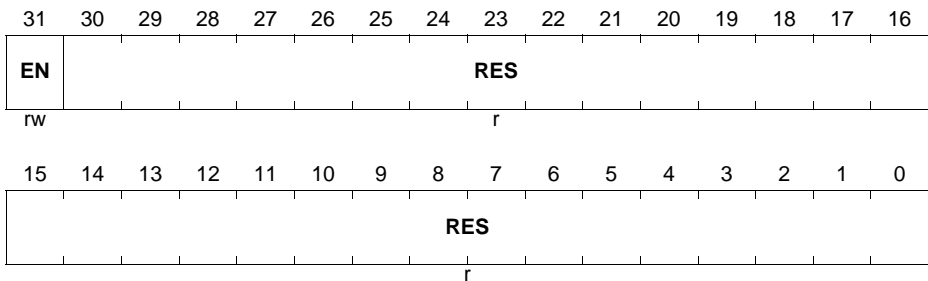
10.17.14 Register Protection Register, PCP_RPROT

This register is ENDINIT protected.

PCP_RPROT

Register Protection Register

(70_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
EN	31	rw	Register Protection Enable 0 _B Registers are not protected and can be written at any time. 1 _B Registers are protected and can only be written when ENDINT is '0'.
RES	[30:0]	r	Reserved returns '0' if read; should be written with '0'.

Peripheral Control Processor (PCP)

10.17.15 CMEM Protection Register, PCP_CPROT

Note: Please see [Section 10.13.3](#) on [Page 59](#) for more information regarding the use of this register.

This register is ENDINIT protected.

PCP_CPROT

CMEM Protection Register

(74_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EN								RES							
rw								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								RES							
								r							

Field	Bits	Type	Description
EN	31	rw	Register Protection Enable 0 _B CMEM is not protected and can be written at any time. 1 _B CMEM is protected and can not be written.
RES	[30:0]	r	Reserved returns '0' if read; should be written with '0'.

Peripheral Control Processor (PCP)

10.17.16 PRAM Protection Register, PCP_PPROT

This register is ENDINIT protected.

PCP_PPROT

PRAM Protection Register

(78_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EN	ENI	RES					PCA T	PTHRES							
rw	rw	r					rw	rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSIZE								FBASE							
rw								rw							

Field	Bits	Type	Description
EN	31	rw	PRAM Protection Enable for FPI Writes 0 _B PRAM is not protected and can be written via FPI at any time. 1 _B All PRAM outside the Open Window is protected and can not be written via FPI. PRAM inside the Open Window remains writable via FPI.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
ENI	30	rw	<p>PRAM Protection Enable for Internal Writes</p> <p>0_B The entire PRAM (subject to PRAM partitioning) is not protected and can be written using PCP PRAM write instructions.</p> <p>1_B All PRAM outside the Protected Window (and subject to PRAM partitioning) is not protected and can be written using PCP PRAM write instructions. PRAM inside the Protected Window remains writable using PCP PRAM write instructions only by a protected channel (subject to PRAM partitioning).</p> <p><i>Note: PRAM partitioning (which is enabled/controlled by CS.PPE and CS.PPS) takes precedence over PRAM protection. Therefore if PRAM Partitioning is enabled, the entire Context Region will be protected against PCP PRAM write instructions, regardless of the Protection settings or whether the channel is Protected or not.</i></p>
RES	[29:25]	r	<p>Reserved</p> <p>Returns '0' if read.</p> <p>Should be written with '0'.</p>
PCAT	24	rw	<p>Protected Channels Above Threshold</p> <p>When ENI (above) is '0', this bit has no effect.</p> <p>When ENI is '1', this bit defines whether the Channel number defined in the PTHRES represents the lowest of the highest protected Channel;</p> <p>0_B The Channel with the number defined by PPROT.PTHRES is the highest Channel Program that is treated as protected. All Channel's with numbers below the value of PPROT.PTHRES are also treated as protected.</p> <p>1_B The Channel with the number defined by PPROT.PTHRES is the lowest Channel program that is treated as protected. All Channel's with numbers above the value of PPROT.PTHRES are also treated as protected.</p>

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
PTHRES	[23:16]	rw	<p>Protected Channel Threshold</p> <p>When PPROT.ENI is '0', this field has no effect. When PPROT.ENI is '1', this field defines the Channel number which is used to distinguish between protected and non-protected Channels.</p>
PSIZE	[15:8]	rw	<p>PRAM Internally Protected Window Size</p> <p>When PPROT.ENI is '0', this field has no effect. When PPROT.ENI is '1', this field defines the size (in multiples of 256 bytes) of the region at the bottom of PRAM that can only be written (using PRAM write instructions) by Protected Channels.</p> <p><i>Note: Each value n, from 1_D, up to the maximum 255_D, is multiplied by 256 Bytes</i></p> <p>0_D 0 Bytes (i.e. there is no Protected Window; the entire PRAM (subject to PRAM Partitioning) can be written by the use of PRAM write instructions by any Channel).</p> <p>1_D 256 Bytes (i.e. the lowest 64 words of PRAM are protected against PRAM write instructions executed by non-protected Channels).</p> <p>...</p> <p>255_D 255 * 256 Bytes</p> <p><i>Note: Use of an eight bit field allows for the maximum PRAM size currently supported by the architecture (64Kbytes). Where a PCP is implemented with a smaller PRAM, setting a Protected Window size greater than the actual PRAM size will result in the entire PRAM being protected against PRAM write instructions executed by non-protected Channels.</i></p> <p><i>Note: When enabled, the PRAM Partitioning protection scheme (enabled via CS.PPE and CS.PPE) takes precedence and will protect the Context Save region from modification by PRAM write instructions (regardless of whether an instruction was executed by a Protected Channel or not).</i></p>

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
FBASE	[7:0]	rw	<p>PRAM FPI Open Window Base</p> <p>When PPROT.EN is '0', this field has no effect. When PPROT.EN is '1' (see above) this field defines the base address (in multiples of 256 bytes and relative to the base of PRAM) of the region at the top of PRAM that remains writable by FPI writes.</p> <p><i>Note: From 1_D up to 254_D: Base of PRAM + $n * 256$ Bytes</i></p> <p>0_D Base of PRAM (i.e. the entire PRAM can be written by FPI writes).</p> <p>1_D Base of PRAM + 256 Bytes (i.e. all but the lowest 64 words of PRAM can be written via the FPI bus, the lowest 64 words of PRAM are protected against FPI Writes)</p> <p>...</p> <p>254_D Base of PRAM + $254 * 256$ Bytes.</p> <p>255_D The entire PRAM is protected against FPI writes.</p> <p><i>Note: Use of an eight bit field allows for the maximum PRAM size currently supported by the architecture (64Kbytes). Where a PCP is implemented with a smaller PRAM, setting an Open Window base above the actual top of PRAM will result in the entire PRAM being protected against FPI writes.</i></p> <p><i>Note: There is a small limitation with this scheme in that if a device is implemented with a 64K PRAM then it will not be possible to protect the entire PRAM (the top 64 words cannot be protected in this case). If this is a problem then bit 29 could be used as a "protect entire PRAM bit).</i></p>

Peripheral Control Processor (PCP)

10.17.17 FPI Write Window Register, PCP_FWWIN

Note: Please see [Section 10.8.1](#) on [Page 42](#) for more information regarding the use of this register.

This register is ENDINIT protected.

PCP_FWWIN

FPI Write Window Register

(7C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EN	EX	RES	SIZE					BASE							
rw	rw	r	rw					rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BASE															
rw															

Field	Bits	Type	Description
EN	31	rw	FPI Protection Enable 0 _B The addresses of outgoing FPI writes are not checked. 1 _B During execution of an instruction that generates an FPI write, a check is performed that the target address within the programmed allowed address range. If the address not to an allowed address then an FPI write is not issued and the PCP exits the current Channel with IOP error.
EX	30	rw	Window Mode 0 _B Limit mode. The destination address of FPI write instructions must lie within the defined window. 1 _B Exclude mode. The destination address of FPI write instructions must lie outside the defined window.
RES	29	r	Reserved Returns '0' if read. Should be written with '0'.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
SIZE	[28:24]	rw	Window Size The FPI window size (binary sizing) 0 _D 256 bytes 1 _D 512 bytes ... 31 _D 2 ⁽ⁿ⁺⁸⁾ bytes
BASE	[23:0]	rw	Window Base Address Controls the base address of the FPI window (binary aligned according to the window size. Bit 23 maps to the bit 31 of the FPI byte address. The appropriate number of subsequent bits defines the aligned address according to the window size (e.g. when using a 1Kbyte window, the lower 2 bits of this field are treated as zero, regardless of their actual value, in order to obtain the base address of the window).

10.17.18 PCP Service Request Control Registers m, PCP_SRC[1:0]

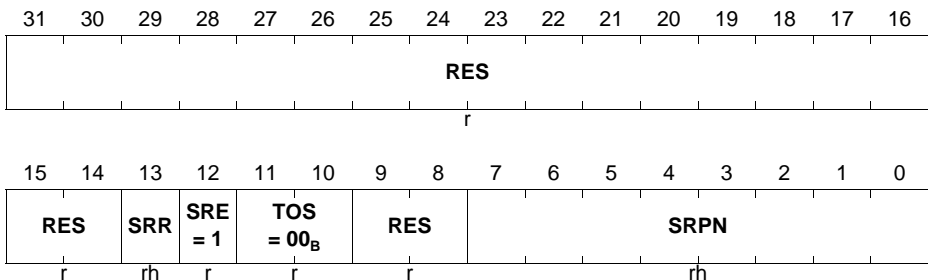
Service request nodes for interrupt bus 0 (CPU interrupt arbitration bus).

PCP_SRCm (m = 0-1)

PCP Service Request Control Register m

(FC_H-m*4_H)

Reset Value: 0000 1000_H



Field	Bits	Type	Description
RES	[31:14]	r	Reserved Read as 0.

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Field	Bits	Type	Description
SRR	13	rh	PCP Node m Service Request Flag 0 _B No service requested (default). 1 _B Valid active service requested.
SRE	12	r	PCP Node m Service Request Enable Always read as 1 (enabled).
TOS	[11:10]	r	PCP Node m Type-of-Service State Always read as 00 _B . This means TOS is associated with interrupt bus 0 (CPU interrupt arbitration bus).
RES	[9:8]	r	Reserved Read as 0.
SRPN	[7:0]	rh	PCP Node m Service Request Priority Number This number is automatically set by the PCP if it needs to place a service request on interrupt bus 0 (CPU interrupt arbitration bus). Default after reset is 00 _H .

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10.17.19 PCP Service Request Control Registers m, PCP_SRC[3:2]

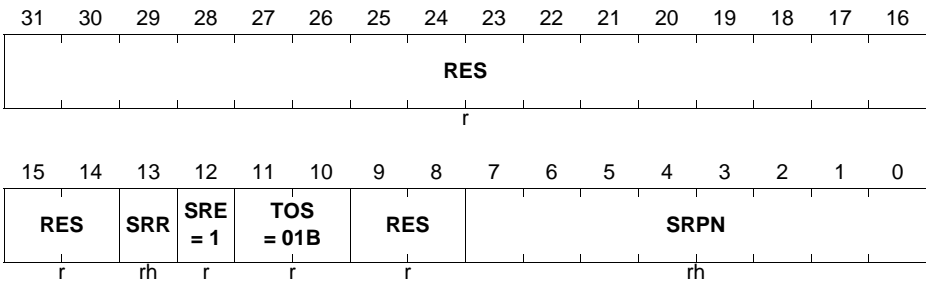
Service request nodes for interrupt bus 1 (PCP interrupt arbitration bus).

PCP_SRCm (m = 2-3)

PCP Service Request Control Register m

(FC_H-m*4_H)

Reset Value: 0000 1400_H



Field	Bits	Type	Description
RES	[31:14]	r	Reserved Read as 0.
SRR	13	rh	PCP Node m Service Request Flag 0 _B No service requested (default). 1 _B Valid active service requested.
SRE	12	r	PCP Node m Service Request Enable Always read as 1 (enabled).
TOS	[11:10]	r	PCP Node m Type-of-Service State Always read as 01 _B . This means TOS is associated with interrupt bus 1 (PCP interrupt arbitration bus).
RES	[9:8]	r	Reserved Read as 0.
SRPN	[7:0]	rh	PCP Node m Service Request Priority Number This number is automatically set by the PCP if it needs to place a service request on interrupt bus 1 (PCP interrupt arbitration bus). Default after reset is 00 _H .

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10.17.20 PCP Service Request Control Registers m, PCP_SRC[8:4]

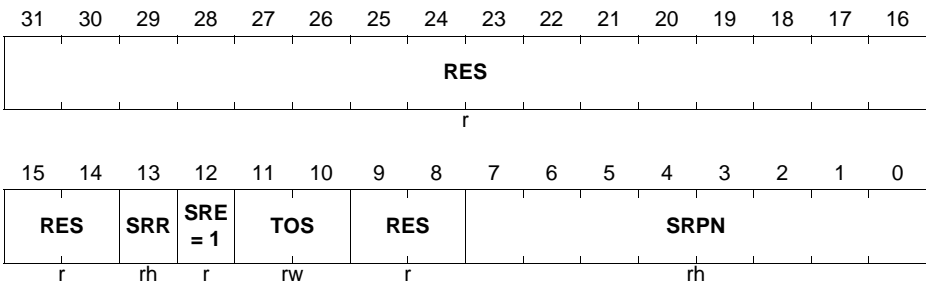
Service request nodes programmable for interrupt bus 0 (CPU interrupt arbitration bus) or 1 (PCP interrupt arbitration bus).

PCP_SRCm (m = 4-8)

PCP Service Request Control Register m

(FC_H-m*4_H)

Reset Value: 0000 1000_H



Field	Bits	Type	Description
RES	[31:14]	r	Reserved Read as 0. Should be written with 0.
SRR	13	rh	PCP Node m Service Request Flag 0 _B No service requested (default). 1 _B Valid active service requested.
SRE	12	r	PCP Node m Service Request Enable Always read as 1 (enabled).
TOS	[11:10]	rw	PCP Node m Type-of-Service State/Control TOS value depends on the interrupt mapping that has been selected (see Page 153). This bit field must be written at PCP configuration time and should not subsequently modified while the PCP is operating.
RES	[9:8]	r	Reserved Read as 0. Should be written with 0.

Peripheral Control Processor (PCP)

Field	Bits	Type	Description
SRPN	[7:0]	rh	PCP Node m Service Request Priority Number This number is automatically set by the PCP if it needs to place a service request on interrupt bus 0 (CPU interrupt arbitration bus) or 1 (PCP interrupt arbitration bus). Default after reset is 00 _H .

10.17.21 PCP Service Request Control Registers m, PCP_SRC[11:9]

Service request nodes for interrupt bus 1 (PCP interrupt arbitration bus) with suspended interrupt capability.

PCP_SRCm (m = 9-11)

PCP Service Request Control Register m

(FC_H-m*4_H)

Reset Value: 0000 1400_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RES			RRQ	RES				SRCN							
r			rh	r				rh							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RES		SRR	SRE = 1	TOS = 01B		RES		SRPN							
r		rh	r	r		r		rh							

Field	Bits	Type	Description
RES	[31:29]	r	Reserved Read as 0.
RRQ	28	rh	PCP Node m Channel Restart Request Set when this service request register n contains an active service request that is associated with a suspended interrupt (i.e. a channel that has been interrupted by a higher-priority channel). 0 _B The interrupt is not suspended 1 _B The interrupt is suspended RRQ is always 0 when SRR is 0.
RES	[27:24]	r	Reserved Read as 0.

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Field	Bits	Type	Description
SRCN	[23:16]	rh	PCP Node m Service Request Channel Number Channel Number Entry (default = 0). When the PCP interrupt request was raised by the PCP Processor Core when executing an EXIT instruction, then this bit field contains the SRPN value taken from R6 when the exit instruction was executed. When the PCP interrupt request was raised by the PCP Processor Core when suspending execution of a channel program in order to service a higher-priority interrupt then this bit field contains the channel number of the channel that was suspended.
RES	[15:14]	r	Reserved Read as 0.
SRR	13	rh	PCP Node m Service Request Flag 0 _B No service requested (default) 1 _B Valid active service requested
SRE	12	r	PCP Node m Service Request Enable Always read as 1 (enabled).
TOS	[11:10]	r	PCP Node m Type-of-Service State Always read as 01 _B . This means TOS is associated with interrupt bus 1 (PCP interrupt arbitration bus).
RES	[9:8]	r	Reserved Read as 0.
SRPN	[7:0]	rh	PCP Node m Service Request Priority Number This number is automatically set by the PCP if it needs to place a service request on interrupt bus 0 (CPU interrupt arbitration bus) or 1 (PCP interrupt arbitration bus). When the PCP interrupt request contained was raised by the PCP Processor Core when executing an EXIT instruction then this bit field contains the SRPN value taken from R6 when the exit instruction was executed. When the PCP interrupt request was raised by the PCP Processor Core when suspending execution of a channel program in order to service a higher-priority interrupt then this bit field contains the CPPN value of the PCP when the interrupt was suspended.

Peripheral Control Processor (PCP)**10.18 PCP Instruction Set Details**

This section describes the instruction set architecture of the PCP in detail.

10.18.1 Instruction Codes and Fields

All PCP instructions use a common set of fields to describe such things as the source register, and the state of flags. Additionally, many instructions (including arithmetic and many flow control instructions), are conditionally executed.

The descriptions of the PCP instructions are based on the following conventions.

>>, <<	Shift left or right, respectively.
[]	Indirect access based on contents of brackets (de-reference).
#immNN	Immediate value encoded into an instruction with width NN.
#offsetNN	Address offset immediate value with width NN.
NextPC	The current executing instruction's address + 1. (The next instruction to be fetched.)
cc_A, cc_B	Condition Code CONDCA/CONDCB.

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10.18.1.1 Conditional Codes

Many PCP instructions have the option of being executed conditionally. The condition code of an instruction is the field that specifies the condition to be tested before the instruction is executed. Depending on the type of instruction there are 8 or 16 condition codes available. The set of 8-condition codes is referred to as CONDCA, while the set of 16-condition codes is referred to as CONDCB. The condition codes are based on an equation of the Flags held in R7. See [Table 35](#).

Table 35 Condition Codes

Description	CONDCA/B	Test (Flag Bits)	Code	Mnemonic
Unconditional	A / B	–	0 _H	cc_UC
Zero/Equal	A / B	Z = 1	1 _H	cc_Z
Not Zero/Not Equal	A / B	Z = 0	2 _H	cc_NZ
Overflow	A / B	v = 1	3 _H	cc_V
Carry/Unsigned Less Than/ Check Bit True	A / B	C = 1	4 _H	cc_C, cc_ULT
Unsigned Greater Than	A / B	C OR Z = 0	5 _H	cc_UGT
Signed Less Than	A / B	N XOR V = 1	6 _H	cc_SLT
Signed Greater Than	A / B	(N XOR V) OR Z = 0	7 _H	cc_SGT
Negative	B	N = 1	8 _H	cc_N
Not Negative	B	N = 0	9 _H	cc_NN
Not Overflow	B	V = 0	A _H	cc_NV
No Carry/Unsigned Greater than or Equal	B	C = 0	B _H	cc_NC, cc_UGE
Signed Greater Than or Equal	B	N XOR V = 0	C _H	cc_SGE
Signed Less than or Equal	B	(N XOR V) OR Z = 1	D _H	cc_SLE
CNT1 Equal Zero	B	CNZ1 = 1	E _H	cc_CNZ
CNT1 Not Equal Zero	B	CNZ1 = 0	F _H	cc_CNN

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10.18.1.2 Instruction Fields

Table 36 lists the instruction field definitions of the PCP instruction set architecture.

Note: The exact syntax for these fields may be different depending on which tool (e.g. assembler) is used. Please refer to the respective tool descriptions.

Table 36 Instruction Field Definitions

Symbol	Syntax	Description
cc_A, cc_B	see Table 35	Condition Code Specifies conditional execution of instruction according to CONDCA or CONDCB.
CNC	<p>CNC = 00_B</p> <p>CNC = 01_B</p> <p>CNC = 10_B</p> <p>CNC = 11_B</p>	<p>Counter Control</p> <p>This field is used by the BCOPY/COPY instructions to control the number of repetitions of the data transfer. For BCOPY operation see Figure 10 - 2 on Page 106. For COPY operation see Figure 10 - 1 on Page 105.</p> <p>Perform the number of transfers specified by CNT0 then proceed to next instruction.</p> <p>Perform the number of transfers specified by CNT0 then decrement CNT1 and proceed to next instruction.</p> <p>Perform the number of transfers specified by CNT0 then decrement CNT1. Repeat until CNT1 = 0, then proceed to next instruction.</p> <p>Reserved.</p>
CNT0	<p>CNT0 = 001_B..111_B</p> <p>CNT0 = 000_B</p> <p>CNT0 = 00_B</p> <p>CNT0 = 10_B</p> <p>CNT0 = 11_B</p> <p>Others</p>	<p>Counter Reload Value (COPY)</p> <p>The COPY instruction uses an implicit counter to generate multiple data transfers. The CNT0 value given in the instruction specifies how many data transfers are to be performed by the instruction. See also Figure 10 - 1 on Page 105.</p> <p>Perform 1..7 data transfers</p> <p>Perform 8 data transfers</p> <p>Block Size (BCOPY)</p> <p>Selects the FPI block size used for a BCOPY instruction.</p> <p>Use block size of 8 words.</p> <p>Use block size of 2 words.</p> <p>Use block size of 4 words.</p> <p>Reserved</p>

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Table 36 Instruction Field Definitions

Symbol	Syntax	Description
DAC	DAC = 0	Stop PCP Allow the PCP to continue to execute channel programs in response to service requests.
	DAC = 1	Prevent the PCP from executing further channel programs (PCP_CS.EN = 0).
DST+-	DST (00 _B)	Destination Address Pointer Control No Change (DST)
	DST+ (01 _B)	Post Increment by Size (DST+)
	DST- (10 _B)	Post Decrement by Size (DST-)
	(11 _B)	Reserved
EC	EC = 0	Exit Count Control No action
	EC = 1	Decrement CNT1
EDA	EDA = 0	External Debug Action No External Debug Action caused
	EDA = 1	Cause an External Debug Action (breakpoint pin etc.)
EP	EP = 0	Entry Point Control Set the PC to channel program Start. EP = 0 assumes that a Channel Entry Table exists in the base of CMEM. Failure to provide such a table will cause improper operation.
	EP = 1	Set the PC to the address contained in NextPC (next instruction) address.
INT	INT = 0	Interrupt Control No Interrupt
	INT = 1	INT = 1 AND (cc_B = True) means Issue Interrupt
RTA	RTA = 0	Action on Debug Exit Stop channel program from accepting new service requests (clear R7.CEN)
	RTA = 1	Allow further channel program execution and decrement PC (so that DEBUG instruction is re-executed on next invocation) <i>Note: This field has no effect if SDB = 0 (see below)</i>
S/C	S/C = 0	Test Bit Control Check for Clear (0)
	S/C = 1	Check for Set (1)
SDB	SDB = 0	Stop on Debug Continue running if debug event triggered
	SDB = 1	Stop PCP if debug event triggered

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Table 36 Instruction Field Definitions

Symbol	Syntax	Description
SIZE		Data Size Control
	SIZE = 00 _B	Byte (8-bit)
	SIZE = 01 _B	Half-word (16-bit)
	SIZE = 10 _B	Word (32-bit)
	SIZE = 11 _B	Reserved
SRC+-		Source Address Pointer Control
	SRC (00 _B)	No Change (SRC)
	SRC+ (01 _B)	Post Increment by Size (SRC+)
	SRC- (10 _B)	Post Decrement by Size (SRC-)
	(11 _B)	Reserved
ST		Stop Channel
	ST = 0	Continue channel execution, leave channel program enabled
	ST = 1	Stop Channel Execution, perform actions according to RTA setting (see above)

10.18.2 Counter Operation for COPY Instruction

Figure 10 - 1 shows the flow of a COPY instruction.

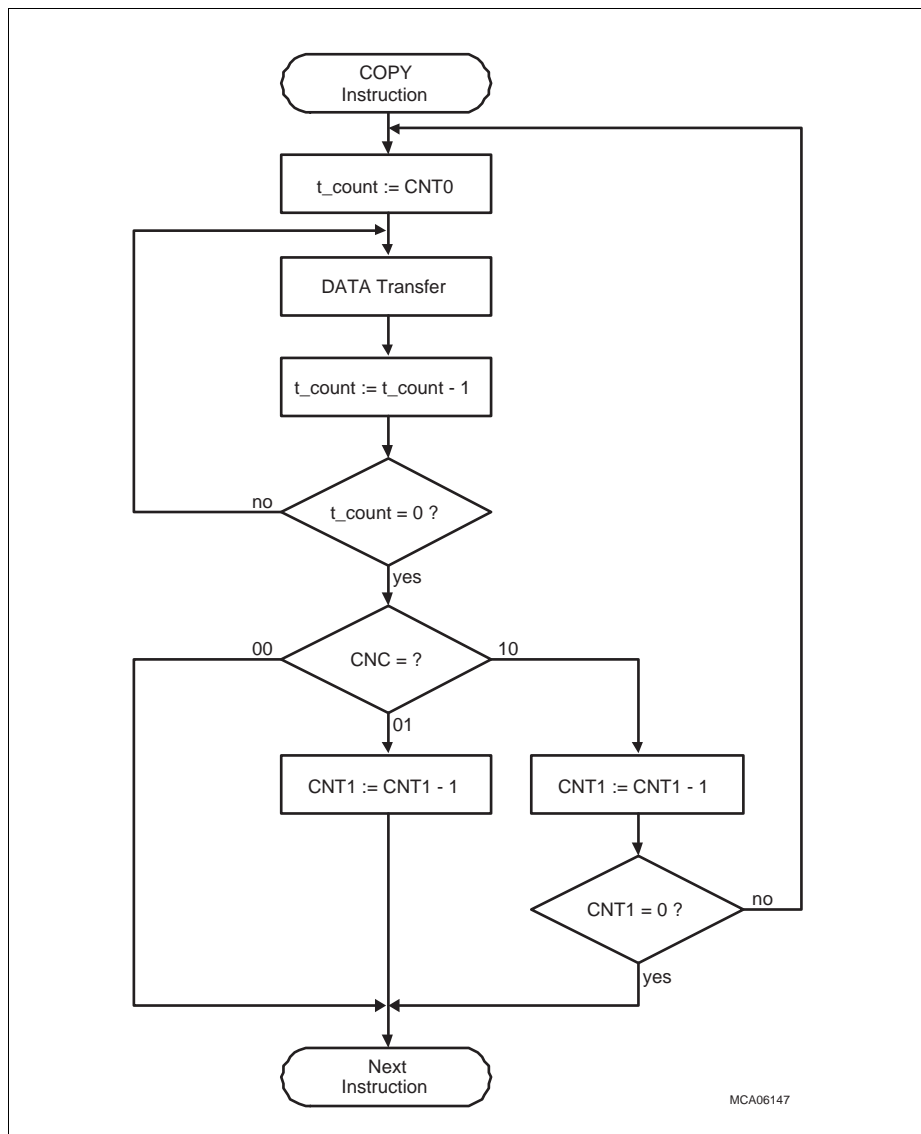


Figure 10 - 1 Counter Operation for COPY Instruction

10.18.3 Counter Operation for BCOPY Instruction

Figure 10 - 2 shows the flow of a BCOPY instruction.

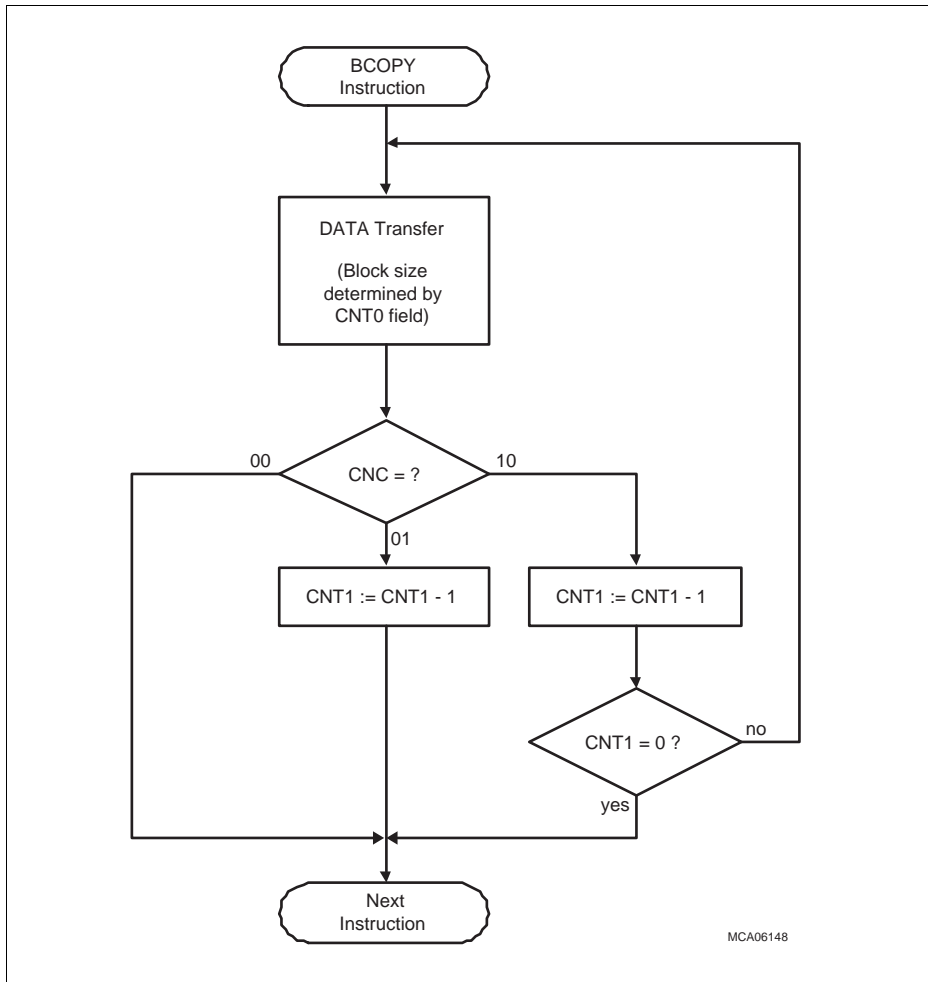


Figure 10 - 2 Counter Operation for BCOPY Instruction

10.18.4 Divide and Multiply Instructions

The PCP has Multiply and Divide capabilities (unsigned values only). All Multiply and divide instructions operate on 8 bits of data (taken from the dividend for divide, from the multiplicand for multiply). This strategy allows the user to implement the appropriate number of instructions ("steps") as required for the user's data format.

Each execution of a divide instruction (DSTEP) performs a division which generates 8 bits of result, and also manipulates the registers being used to allow the execution of consecutive divide (DSTEP) instructions to build divide algorithms in multiples of 8 bits (see [Page 156](#) for more details).

Each execution of a multiply instruction (MSTEP32 and MSTEP64) performs a multiplication on 8 bits of data (taken from the multiplicand) and also manipulates the registers to allow execution of consecutive multiply instructions to build multiply algorithms in multiples of 8 bits (see [Page 157](#) for more details).

The following restrictions apply to the use of Divide and Multiply instructions:

- The first instruction of any divide sequence must be the DINIT (initialization) instruction. Any additional instructions other than MINIT, MSTEP32 or MSTEP64 may also be used within the sequence as long as they do not modify any of the registers used for division (R0, Ra and Rb). All subsequent divide instructions within the sequence (DSTEP) must use the same register for dividend and the same register for divisor as used in the preceding DINIT instruction.
- The first instruction of any multiply sequence must be the MINIT (initialization) instruction. Any additional instructions other than DINIT or DSTEP may also be used within the sequence as long as they do not modify any of the registers used for multiplication (R0, Ra and Rb). All subsequent multiply instructions within the sequence (MSTEP32 and MSTEP64) must use the same register for multiplicand and the same register for multiplier as used in the preceding MINIT instruction.
- Neither of the operand registers (Ra or Rb) may be R0 (which is used implicitly within all the instructions), and the same register may not be supplied as both operand registers of an instruction (e.g. DSTEP R3, R3 is invalid).

Note: Failure to adhere to these restrictions will yield undefined results.

1. *Special care must be taken when using multiply and divide sequences when a channel program is interruptible. In this case it must be ensured that a sequence cannot be corrupted by the execution of multiply or divide instructions executed by a higher-priority channel. The R7.IEN bit can be used to ensure that a sequence is not interruptible (see [Page 155](#)).*

In the descriptions attached to each multiply and divide instruction, a pseudo-code model is supplied to provide an unambiguous definition of the function of the instruction. The models supplied for the DSTEP and MSTEP32 instructions use 32 bit unsigned integer arithmetic, ignoring any possible overflows. The model supplied for the MSTEP64 uses

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a 40-bit unsigned multiply and then shifts this result right by 8 bits (discards the least significant 8 bits of the 40-bit result).

The DSTEP instruction also has some conditions stipulated regarding input values to the instruction. Use of the pseudo-code model for the DSTEP instruction with invalid input values will yield an invalid result.

10.18.5 ADD, 32-bit Addition

This section describes the ADD instructions of the PCP.

ADD	Syntax	ADD Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then add the contents of register Ra to the contents of register Rb; place the result in Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then $R[b] = R[b] + R[a]$ else NOP
	Flags	N, Z, V, C
ADD.I	Syntax	ADD.I Ra, #imm6
	Description	Add the zero-extended immediate value imm6 to the contents of register Ra; place the result in Ra.
	Operation	$R[a] = R[a] + \text{zero_ext}(\text{imm6})$
	Flags	N, Z, V, C
ADD.F	Syntax	ADD.F Rb, [Ra], Size
	Description	Add the contents of the address location specified by the contents of register Ra to the contents of register Rb; place the result in Rb. <i>Note: Byte and Half-word values are zero-extended.</i>
	Operation	$R[b] = R[b] + \text{zero_ext}(\text{FPI}[R[a]])$
	Flags	N, Z, V, C
ADD.PI	Syntax	ADD.PI Ra, [#offset6]
	Description	Add the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6 to the contents of register Ra; place the result in Ra.
	Operation	$R[a] = R[a] + \text{PRAM}[(\text{DPTR} \ll 6) + \text{zero_ext}(\text{\#offset6})]$
	Flags	N, Z, V, C

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10.18.6 AND, 32-bit Logical AND

This section describes the AND instructions of the PCP.

AND	Syntax	AND Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then perform a bit-wise logical AND of the contents of register Ra and the contents of register Rb; place the result in Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = R[b] AND R[a] else NOP
	Flags	N, Z
AND.F	Syntax	AND.F Rb, [Ra], Size
	Description	Perform a bit-wise logical AND of the contents of the address location, specified by the contents of register Ra, and the contents of register Rb; place the result in Rb.
	Operation	R[b] = R[b] AND zero_ext(FPI[R[a]])
	Flags	N, Z
AND.PI	Syntax	AND.PI Ra, [#offset6]
	Description	Perform a bit-wise logical AND of the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6, and the contents of register Ra; place the result in Ra.
	Operation	R[a] = R[a] AND PRAM[(DPTR<<6) + zero_ext(#offset6)]
	Flags	N, Z

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10.18.7 BCOPY, DMA Operation

This section describes the BCOPY instruction of the PCP in the TC1728.

BCOPY	Syntax	BCOPY DST+-, SRC+-, CNC, CNT0
	Description	<p>Allows the PCP to perform DMA type transfers using FPI block transfers.</p> <p>Moves the contents of FPI Bus source location to FPI Bus destination location. Source location is pointed to by the contents of register R4; destination location is pointed to by the contents of register R5. Options (see also Table 36 at Page 102):</p> <p>Source pointer (SRC+-): Increment, decrement or unchanged</p> <p>Destination pointer (SRC+-): Increment, decrement or unchanged</p> <p>Counter control (CNC): see Table 36</p> <p>Block size value (CNT0): see Table 36</p>
	Operation	<p>temp = zero_ext(FPI[R[4]]); value loaded and extended depending on SIZE</p> <p>FPI(R[5]) = temp</p> <p>R4 = R4 +/- n; n depending on SRC+- and CNT0</p> <p>R5 = R5 +/- n; n depending on DST+- and CNT0</p> <p>For counter operation see Figure 10 - 2 on Page 106 and Table 36 on Page 102.</p>
	Flags	CN1Z

See also [Page 159](#) for TC1728 specific details of the BCOPY instruction.

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10.18.8 CHKB, Check Bit

This section describes the CHKB instruction of the PCP.

CHKB	Syntax	CHKB Ra, #imm5, S/C
	Description	If bit imm5 of register Ra is equal to the specified test value S/C then set the carry flag R7.C, else clear the carry flag.
	Operation	if (R[a][imm5] = S/C) then R7_C = 1 else R7_C = 0
	Flags	C

10.18.9 CLR, Clear Bit

This section describes the CLR instructions of the PCP.

CLR	Syntax	CLR Ra, #imm5
	Description	Clear bit imm5 of register Ra to 0.
	Operation	R[a][imm5] = 0
	Flags	None
CLR.F	Syntax	CLR.F [Ra], #imm5, Size
	Description	Clear bit imm5 of the address location specified through the contents of register Ra to 0. This instruction is executed using a locked read-modify-write FPI Bus transaction.
	Operation	FPI[(R[a])][imm5] = 0
	Flags	None

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10.18.10 COMP, 32-bit Compare

This section describes the COMP instructions of the PCP.

COMP	Syntax	COMP Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then subtract the contents of register Ra from the contents of register Rb; set the flags in register R7 according to the result of the subtraction; discard the subtraction result. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R7_FLAGS = Flags(R[b] - R[a])
	Flags	N, Z, V, C
COMP.I	Syntax	COMP.I Ra, #imm6
	Description	Subtract the immediate value imm6 from the contents of register Ra; set the flags in register R7 according to the result of the subtraction; discard the subtraction result.
	Operation	R7_FLAGS = Flags(R[a] - zero_ext(imm6))
	Flags	N, Z, V, C
COMP.F	Syntax	COMP.F Rb, [Ra], Size
	Description	Subtract the contents of the address location specified by the contents of register Ra from the contents of register Rb; set the flags in register R7 according to the result of the subtraction; discard the subtraction result.
	Operation	R7_FLAGS = Flags(R[b] - zero_ext(FPI[R[a]]))
	Flags	N, Z, V, C
COMP.PI	Syntax	COMP.PI Ra, [#offset6]
	Description	Subtract the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6, from the contents of register Ra; set the flags in register R7 according to the result of the subtraction; discard the subtraction result.
	Operation	R7_FLAGS = Flags(R[a] - PRAM[(DPTR<<6) + zero_ext(#offset6)])
	Flags	N, Z, V, C

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10.18.11 COPY, DMA Instruction

This section describes the COMP instruction of the PCP.

COPY	Syntax	COPY DST+-, SRC+-, CNC, CNT0, SIZE
	Description	<p>Moves the contents of FPI Bus source location to FPI Bus destination location. Source location is pointed to by the contents of register R4; destination location is pointed to by the contents of register R5. Options (see also Table 36 on Page 102):</p> <p>Source pointer (SRC+-): Increment, decrement or unchanged</p> <p>Destination pointer (DST+-): Increment, decrement or unchanged</p> <p>Counter control (CNC): see Table 36</p> <p>Counter 0 reload value (CNT0): see Table 36</p> <p>Data transfer width (SIZE): byte, half-word, word (pointers are incremented/decremented based upon SIZE).</p>
	Operation	<p>temp = zero_ext(FPI[R[4]]); value loaded and extended depending on SIZE</p> <p>FPI(R[5]) = temp</p> <p>R4 = R4 +/- n; n depending on SRC+- and SIZE</p> <p>R5 = R5 +/- n; n depending on DST+- and SIZE</p> <p>For counter operation see Figure 10 - 1 on Page 105 and Table 36 on Page 102.</p>
	Flags	CN1Z

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10.18.12 DEBUG, Debug Instruction

This section describes the DEBUG instruction of the PCP.

DEBUG	Syntax	DEBUG EDA, DAC, RTA, SDB, cc_B
	Description	Conditionally cause a debug event if condition CONDCB is true. Optionally stop channel execution (SDB = 1) and/or generate an external debug event (EDA = 1).
	Operation	<pre> if (CONDCB = True) then if (EDA = 1) then activate BRK_OUT pin if (SDB = 1) then if (RTA = 0) then R7_CEN = 0; disable further channel invocation else PC = PC - 1 endif endif save_context idle endif if (DAC = 1) PCP_CS>EN = 0 endif set ES.DBE; indicate debug event ES.PC = NextPC ES.PN = channel_number endif </pre>
	Flags	none

Note: Execution of the DEBUG command when not in Debug Mode will cause the PCP to generate an "Illegal Operation" Error Exit.

10.18.13 DINIT, Divide Initialization

This section describes the DINIT instruction of the PCP.

DINIT	Syntax	DINIT <R0>, Rb, Ra
	Description	Initialize Divide logic ready for divide sequence (Rb / Ra) and Clear R0. If value of Ra is 0 then set V (to flag divide by 0 error); otherwise, clear V. If value of Rb is 0 and value of Ra is not 0 then set Z (to flag a zero result); otherwise, clear Z.
	Operation	R0 = 0
	Flags	Z, V

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10.18.14 DSTEP, Divide Instruction

This section describes the DSTEP instruction of the PCP.

DSTEP	Syntax	DSTEP <R0>, Rb, Ra
	Description	Perform 1 step (eight bits) of an unsigned 32- by 32-bit divide (Rb / Ra). Shift R0 left by 8 bits, copy the most significant byte of Rb into LS byte of R0. Shift Rb left by 8 bits and add (R0 divided by Ra). Load R0 with (the remainder of R0 divided by Ra).
	Operation	$R0 = (R0 \ll 8) + (Rb \gg 24)$ $Rb = (Rb \ll 8) + R0 / Ra$ $R0 = R0 \% Ra$
	Flags	Z

Note: The value in Ra must always be greater than the value in R0 prior to execution of the DSTEP instruction. If the rules specified on [Page 107](#) are followed, then the above description and operation are correct. Failure to adhere to these rules will yield undefined results.

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10.18.15 EXIT, Exit Instruction

This section describes the EXIT instruction of the PCP.

EXIT	Syntax	EXIT EC, ST, INT, EP, cc_B
	Description	Unconditionally exit channel program execution. Optionally decrement counter CNT1 (EC = 1), disable further channel invocation (ST = 1), generate an interrupt request (INT = 1) if condition CONDCB is true. Field EP is used to set the channel code entry point in Channel Resume Mode to either the address of the next instruction (EP = 1) or to the start address of the channel (EP = 0). The EXIT instruction is finished with a context save operation. The EP option is only in effect when Channel Resume operation is globally selected through PCP_CS.RCB = 0. If PCP_CS.RCB = 1, Channel restart mode is selected for all channels, and the EP field of the EXIT instruction is disregarded.
	Operation	if (EC = 1) then CNT1 = CNT1 - 1 if (ST = 1) then R7_CEN = 0 if ((INT = 1) AND (cc_B = True)) then activate_interrupt_request if (EP = 1) then R7_PC = NextPC else R7_PC = channel_entry_point save_context
	Flags	CN1Z

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10.18.16 INB, Insert Bit

This section describes the INB instructions of the PCP.

INB	Syntax	INB Rb, Ra, cc_A
	Description	If CONDCA is true, then insert the carry flag R7.C into register Rb at the bit position specified through bits [4..0] of register Ra. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b][R[a][4:0]] = R7_C else NOP
	Flags	None
INB.I	Syntax	INB.I Ra, #imm5
	Description	Insert the carry flag R7.C into register Ra at the bit position specified through the immediate value imm5.
	Operation	R[a][imm5] = R7_C
	Flags	None

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10.18.17 JC, Jump Conditionally

This section describes the conditional jump instructions of the PCP.

JC	Syntax	JC offset6, cc_B
	Description	If CONDCB is true, then add the sign-extended value specified by offset6 to the contents of the PC, and jump to that address. If CONDCB is false, no operation is performed.
	Operation	if (CONDCB = True) then (PC = PC + sign_ext(offset6)) else NOP
	Flags	None
JC.A	Syntax	JC.A #address16, cc_B
	Description	If CONDCB is true, then load the value specified by address16 into the PC, and jump to that address. If CONDCB is false, no operation is performed.
	Operation	if (CONDCB = True) then (PC = address16) else NOP
	Flags	None
JC.I	Syntax	JC.I Ra, cc_B
	Description	If CONDCB is true, then add the value specified by Ra[15:0] to the contents of the PC, and jump to that address. Value Ra[15:0] is treated as a signed 16-bit number. If CONDCB is false, no operation is performed.
	Operation	if (CONDCB = True) then (PC = PC + (R[a][15:0])) else NOP
	Flags	None
JC.IA	Syntax	JC.IA Ra, cc_B
	Description	If CONDCB is true, then load the value specified by Ra[15:0] into the PC, and jump to that address. Value Ra[15:0] is treated as an unsigned 16-bit number. If CONDCB is false, no operation is performed.
	Operation	if (CONDCB = True) then (PC = (R[a][15:0])) else NOP
	Flags	None

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10.18.18 JL, Jump Long Unconditional

This section describes the long jump instruction JL of the PCP.

JL	Syntax	JL offset10
	Description	Add the sign-extended value specified by offset10 to the contents of the PC, and jump to that address.
	Operation	PC = PC + sign_ext(offset10)
	Flags	None

10.18.19 LD, Load

This section describes the LD instructions of the PCP.

LD.F	Syntax	LD.F Rb, [Ra], Size
	Description	Load the zero-extended contents of the address location specified by the contents of register Ra into register Rb.
	Operation	R[b] = zero_ext(FPI[R[a]])
	Flags	N, Z
LD.I	Syntax	LD.I Ra, #imm6
	Description	Load the zero-extended value specified by imm6 into register Ra.
	Operation	R[a] = zero_ext(imm6)
	Flags	N, Z
LD.IF	Syntax	LD.IF [Ra], #offset5, Size
	Description	Load the zero-extended contents of the address location, specified by the addition of the contents of register Ra and the value specified by imm5, into register R0.
	Operation	R[0] = zero_ext(FPI[R[a] + zero_ext(imm5)])
	Flags	N, Z

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LD.P	Syntax	LD.P Rb, [Ra], cc_A
	Description	If condition CONDCA is true, then load the contents of the PRAM address location, specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value Ra[5:0] into register Rb. If condition CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = PRAM[(DPTR<<6) + zero_ext(R[a][5:0])] else NOP
	Flags	N, Z
LD.PI	Syntax	LD.PI Ra, [#offset6]
	Description	Load the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6 into register Ra.
	Operation	R[a] = PRAM[(DPTR<<6) + zero_ext(offset6)]
	Flags	N, Z

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10.18.20 LDL, Load 16-bit Value

This section describes the LDL instructions of the PCP.

LDL.IL	Syntax	LDL.IL Ra, #imm16
	Description	Load the immediate value imm16 into the lower bits of register Ra (bits [15:0]). Bits [31:16] of register Ra are unaffected. Value imm16 is treated as an unsigned 16-bit number.
	Operation	$R[a][15:0] = \text{imm16}$
	Flags	N, Z
LDL.IU	Syntax	LDL.IU Ra, #imm16
	Description	Load the immediate value imm16 into the upper bits of register Ra (bits [31:16]). Bits [15:0] of register Ra are unaffected.
	Operation	$R[a][31:16] = \text{imm16}$
	Flags	N, Z

10.18.21 MINIT, Multiply Initialization

This section describes the MINIT instruction of the PCP.

MINIT	Syntax	MINIT <R0>, Rb, Ra
	Description	Initialize Multiply logic ready for multiply sequence. Clear R0. If value of Ra is zero or value of Rb is zero then set Z (to flag zero result) else clear Z.
	Operation	$R0 = 0$
	Flags	Z

10.18.22 MOV, Move Register to Register

This section describes the MOV instruction of the PCP.

MOV	Syntax	MOV Rb, Ra, cc_A
	Description	If condition CONDCA is true, then move the contents of register Ra into register Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = R[a] else NOP
	Flags	N, Z

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10.18.23 Multiply Instructions

This section describes the multiply instructions of the PCP.

MSTEP32	Syntax	MSTEP32 <R0>, Rb, Ra
	Description	Perform an unsigned multiply step, using eight bits of data taken from Rb, keeping the least significant 32 bits of a potential 64-bit result. Left rotate Rb by 8 bits. Shift R0 left by 8 bits. Add (Ra multiplied by the least significant 8 bits of Rb) to R0. If value of R0 is zero then set Z (to signal zero result) else clear Z.
	Operation	$Rb = (Rb \ll 8) + (Rb \gg 24)$ $R0 = (R0 \ll 8) + (Rb \& 0xff) \times Ra$
	Flags	Z
MSTEP64	Syntax	MSTEP64 <R0>, Rb, Ra
	Description	Perform an unsigned multiply step, using eight bits of data taken from Rb, keeping 40 bits of a potential 64-bit result. Add (Ra multiplied by the least significant 8 bits of Rb) to R0 and retain the 40 bit result (shown as temp below). Store the most significant 32 bits of the result (temp) in R0. Shift Rb right by 8 bits. Store the least significant 8 bits of the first result (temp) in the most significant 8 bits of Rb. If value of R0 is zero then set Z (to signal zero result) else clear Z.
	Operation	$temp = R0 + Ra \times (Rb \& 0xff)$ $R0 = temp \gg 8$ $Rb = (Rb \gg 8) + ((temp \& 0xff) \ll 24)$
	Flags	Z

Note: In the case of the MSTEP64 instruction above, the “temp” variable is a 40-bit variable and all calculations are performed using 40-bit unsigned arithmetic. All other calculations use 32-bit unsigned arithmetic.

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10.18.24 NEG, Negate

This section describes the NEG instruction of the PCP.

NEG	Syntax	NEG Rb, Ra, cc_A
	Description	If condition CONDCA is true, then move the 2's complement of the contents of register Ra into register Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = (- R[a]) else NOP
	Flags	N, Z, V, C

10.18.25 NOP, No Operation

This section describes the NOP instruction of the PCP.

NOP	Syntax	NOP
	Description	No operation. The NOP instruction puts the PCP in low-power operation.
	Operation	no operation
	Flags	None

10.18.26 NOT, Logical NOT

This section describes the NOT instruction of the PCP.

NOT	Syntax	NOT Rb, Ra, cc_A
	Description	If condition CONDCA is true, then move the 1's complement of the contents of register Ra into register Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = NOT(R[a]) else NOP
	Flags	N, Z

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10.18.27 OR, Logical OR

This section describes the OR instructions of the PCP.

OR	Syntax	OR Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then perform a bit-wise logical OR of the contents of register Ra and the contents of register Rb; place the result in Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = R[b] OR R[a] else NOP
	Flags	N, Z
OR.F	Syntax	OR.F Rb, [Ra], Size
	Description	Perform a bit-wise logical OR of the contents of the address location, specified by the contents of register Ra, and the contents of register Rb; place the result in Rb.
	Operation	R[b] = R[b] OR zero_ext(FPI[R[a]])
	Flags	N, Z
OR.PI	Syntax	OR.PI Ra, [#offset6]
	Description	Perform a bit-wise logical OR of the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6, and the contents of register Ra; place the result in Ra.
	Operation	R[a] = R[a] OR PRAM[(DPTR<<6) + zero_ext(#offset6)]
	Flags	N, Z

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10.18.28 PRAM Bit Operations

This section describes the MCLR and MSET instructions of the PCP.

MCLR	Syntax	MCLR.PI Ra, [#offset6]
	Description	Perform an 'AND' of the contents of the specified register with the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset. Write the result back to the PRAM location.
	Operation	$R[a] = R[a].AND.PRAM[DPTR \ll 6 + \#offset6]$ $PRAM[DPTR \ll 6 + \#offset6] = R[a]$
	Flags	N, Z
MSET	Syntax	MSET.PI Ra, [#offset6]
	Description	Perform an 'OR' of the contents of the specified register with the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset. Write the result back to the PRAM location.
	Operation	$R[a] = R[a].OR.PRAM[DPTR \ll 6 + \#offset6]$ $PRAM[DPTR \ll 6 + \#offset6] = R[a]$
	Flags	N, Z

Note: MCLR and MSET are read/modify/write operations that cannot be interrupted by an access from another FPI master. They can be used to implement semaphore systems.

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10.18.29 PRI, Prioritize

This section describes the PRI instruction of the PCP.

PRI _{id}	Syntax	PRI Rb, Ra, cc_A
	Description	If condition CONDCA is true, then find the bit position of the most significant 1 in register Ra and put the number into register Rb. The bit location, 31-0, is encoded as a 5-bit number stored in Rb[4:0]. If the contents of Ra is zero, bit Rb[5] is set, while all other bits in Rb are cleared. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = False) then NOP else if (R[a] = 0) then R[b] = 0x20 else R[b] = bit_pos(most_significant_1(R[a]))
	Flags	N, Z

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10.18.30 RL, Rotate Left

This section describes the RL instruction of the PCP.

RL	Syntax	RL Ra, #imm5
	Description	Rotate the contents of register Ra to the left by the number of bit positions specified through the 5-bit value imm5. The values defined for imm5 are 1, 2, 4 and 8. The carry flag, R7.C, is set to the last bit shifted out of bit 31 of register Ra.
	Operation	<pre> tmp = R[a] R[a] = R[a] << imm5; imm5 = 1, 2, 4, 8 R7_C = last bit shifted out of R[a] tmp = tmp >> 32 - imm5 R[a] = tmp OR R[a] </pre>
	Flags	N, Z

10.18.31 RR, Rotate Right

This section describes the RR instruction of the PCP.

RR	Syntax	RR Ra, #imm5
	Description	Rotate the contents of register Ra to the right by the number of bit positions specified through the 5-bit value imm5. The values allowed for imm5 are 1, 2, 4 and 8.
	Operation	<pre> tmp = R[a] R[a] = R[a] >> imm5; imm5 = 1, 2, 4, 8 tmp = tmp << 32 - imm5 R[a] = tmp OR R[a] </pre>
	Flags	N, Z

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10.18.32 SET, Set Bit

This section describes the SET bit instruction of the PCP.

SET	Syntax	SET Ra, #imm5
	Description	Set bit imm5 of register Ra to 1.
	Operation	$R[a][imm5] = 1$
	Flags	None
SET.F	Syntax	SET.F [Ra], #imm5, Size
	Description	Set bit imm5 of the address location specified through the contents of register Ra to 1. This instruction is executed using a locked read-modify-write FPI Bus transaction.
	Operation	$FPI[(R[a])][imm5] = 1$
	Flags	None

10.18.33 SHL, Shift Left

This section describes the SHL instruction of the PCP.

SHL	Syntax	SHL Ra, #imm5
	Description	Shift the contents of register Ra to the left by the number of bit positions specified through the 5-bit value imm5. The values allowed for imm5 are 1, 2, 4 and 8. The carry flag, R7.C, is set to the last bit shifted out of bit 31 of register Ra. Zeros are shifted in from right.
	Operation	$R[a] = R[a] \ll imm5$; imm5 = 1, 2, 4, 8 R7_C = last bit shifted out of R[a]
	Flags	N, Z, C

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10.18.34 SHR, Shift Right

This section describes the SHR instruction of the PCP.

SHR	Syntax	SHR Ra, #imm5
	Description	Shift the contents of register Ra to the right by the number of bit positions specified through the 5-bit value imm5. The values allowed for imm5 are 1, 2, 4 and 8. Zeros are shifted in from left.
	Operation	$R[a] = R[a] \gg \text{imm5}$; imm5 = 1, 2, 4, 8
	Flags	N, Z

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10.18.35 ST, Store

This section describes the ST instructions of the PCP.

ST.F	Syntax	ST.F Rb, [Ra], Size
	Description	Store the contents of register Rb to the address location specified by the contents of register Ra. When the Size is byte or half-word, the data is stored with the internal LSB (bit 0) properly aligned to the correct FPI Bus byte or half-word lane.
	Operation	$FPI[R[a]] = R[b]$
	Flags	None
ST.IF	Syntax	ST.IF [Ra], #offset5, Size
	Description	Store the contents of R0 to the address location specified by the addition of the contents of register Ra and the value specified by imm5. When the Size is byte or half-word, the data is stored with the internal LSB (bit 0) properly aligned to the correct FPI Bus byte or half-word lane.
	Operation	$FPI[R[a] + \text{zero_ext}(\text{imm5})] = R[0]$
	Flags	None
ST.P	Syntax	ST.P Rb, [Ra], cc_A
	Description	If condition CONDCA is true, then store the contents of Rb to the PRAM address location specified by the addition of the contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value Ra[5:0]. If condition CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then $PRAM[(DPTR \ll 6) + \text{zero_ext}(R[a][5:0])] = R[b]$ else NOP
	Flags	None
ST.PI	Syntax	ST.PI Rb, [#offset6]
	Description	Store the contents of register Rb to the PRAM location specified by the addition of the contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6.
	Operation	$PRAM[(DPTR \ll 6) + \text{zero_ext}(\text{offset6})] = R[b]$
	Flags	None

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10.18.36 SUB, 32-bit Subtract

This section describes the SUB instructions of the PCP.

SUB	Syntax	SUB Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then subtract the contents of register Ra from the contents of register Rb; place the result in Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then $R[b] = R[b] - R[a]$ else NOP
	Flags	N, Z, V, C
SUB.I	Syntax	SUB.I Ra, #imm6
	Description	Subtract the zero-extended immediate value imm6 from the contents of register Ra; place the result in Ra.
	Operation	$R[a] = R[a] - \text{zero_ext}(\text{imm6})$
	Flags	N, Z, V, C
SUB.F	Syntax	SUB.F Rb, [Ra], Size
	Description	Subtract the zero-extended contents of the address location specified by the contents of register Ra from the contents of register Rb; place the result in Rb.
	Operation	$R[b] = R[b] - \text{zero_ext}(\text{FPI}[R[a]])$
	Flags	N, Z, V, C
SUB.PI	Syntax	SUB.PI Ra, [#offset6]
	Description	Subtract the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6 from the contents of register Ra; place the result in Ra.
	Operation	$R[a] = R[a] - \text{PRAM}[(\text{DPTR} \ll 6) + \text{zero_ext}(\text{\#offset6})]$
	Flags	N, Z, V, C

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10.18.37 XCH, Exchange

This section describes the XCH instructions of the PCP.

XCH.F	Syntax	XCH.F Rb, [Ra], Size
	Description	Exchange contents of R[b] and FPI[R[a]] when Size is byte or half-word, the value is stored with the internal LSB (bit 0) properly aligned to the correct FPI byte or half-word lane. The exchange is done via a locked FPI bus transfer.
	Operation	temp = R[b] R[b] = zero_ext(FPI[R[a]]) FPI[R[a]] = temp
	Flags	N, Z
XCH.PI	Syntax	XCH.PI Ra, [#offset6]
	Description	Exchange contents of R[a] and PRAM[DPTR << 6 + #offset6]. <i>Note: The exchange is un-interruptible, and locks out external accesses; it will not be interrupted by any external FPI bus master transfer requests.</i>
	Operation	temp = R[a] R[a] = PRAM[(DPTR << 6) + zero_ext(#offset6)] PRAM[(DPTR << 6) + zero_ext(#offset6)] = temp
	Flags	N, Z

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10.18.38 XOR, 32-bit Logical Exclusive OR

This section describes the XOR instructions of the PCP.

XOR	Syntax	XOR Rb, Ra, cc_A
	Description	If the condition CONDCA is true, then perform a bit-wise logical Exclusive-OR of the contents of register Ra and the contents of register Rb; place the result in Rb. If CONDCA is false, no operation is performed.
	Operation	if (CONDCA = True) then R[b] = R[b] XOR R[a] else NOP
	Flags	N, Z
XOR.F	Syntax	XOR.F Rb, [Ra], Size
	Description	Perform a bit-wise logical Exclusive-OR of the contents of the address location, specified by the contents of register Ra, and the contents of register Rb; place the result in Rb.
	Operation	R[b] = R[b] XOR zero_ext(FPI[R[a]])
	Flags	N, Z
XOR.PI	Syntax	XOR.PI Ra, [#offset6]
	Description	Perform a bit-wise logical Exclusive-OR of the contents of the PRAM location specified by the addition of contents of the PRAM Data Pointer, shifted left by six bits, and the zero-extended 6-bit value offset6, and the contents of register Ra; place the result in Ra.
	Operation	R[a] = R[a] XOR PRAM[(DPTR<<6) + zero_ext(#offset6)]
	Flags	N, Z

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10.18.39 Flag Updates of Instructions

Most instructions update the state flags in R7. In [Table 37](#), each instruction is shown with the flags that it updates.

Table 37 Flag Updates

Instruction	CN1Z	V	C	N	Z
ADD	–	yes	yes	yes	yes
AND	–	–	–	yes	yes
BCOPY	yes ¹⁾	–	–	–	–
CHKB	–	–	yes	–	–
CLR	–	–	–	–	–
COMP	–	yes	yes	yes	yes
COPY	yes ¹⁾	–	–	–	–
DEBUG	–	–	–	–	–
DINIT	–	yes	–	–	yes
DSTEP	–	–	–	–	yes
EXIT	yes ¹⁾	–	–	–	–
INB	–	–	–	–	–
JC	–	–	–	–	–
JL	–	–	–	–	–
LD	–	–	–	yes ²⁾	yes
LDL	–	–	–	yes	yes
MCLR	–	–	–	yes	yes
MSET	–	–	–	yes	yes
MOV	–	–	–	yes	yes
NEG	–	yes	yes	yes	yes
NOP	–	–	–	–	–
NOT	–	–	–	yes	yes
OR	–	–	–	yes	yes
PRI	–	–	–	yes ³⁾	yes
RR	–	–	–	yes	yes
RL	–	–	yes	yes	yes
SET	–	–	–	–	–

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Table 37 Flag Updates

Instruction	CN1Z	V	C	N	Z
SHR	–	–	–	yes ³⁾	yes
SHL	–	–	yes	yes	yes
ST	–	–	–	–	–
SUB	–	yes	yes	yes	yes
XCH	–	–	–	yes	yes
XOR	–	–	–	yes	yes

- 1) CN1Z is only modified by the BCOPY, COPY or EXIT instructions if the instruction has been configured to decrement R6.CNT1 (for BCOPY/COPY CNC = 1 or CNC = 2, for EXIT EC = 1). All other instructions have no effect on the CN1Z flag.
- 2) For the LD.I type of instruction, flag N is always cleared, as bit 31 of the result is always 0.
- 3) Flag N is always cleared, as bit 31 of the result is always 0.

10.18.40 Instruction Timing

This section gives some information about the duration of PCP instructions. Please note that there are various conditions that can further affect the duration of PCP instructions (e.g. external FPI accesses from another FPI Bus master to the PCP memories stall the PCP Processor Core).

Note: The clock cycles listed in [Table 38](#) are PCP core clock cycles. When running in 2:1 clocking mode the maximum allowed PCP core clock frequency is 180 MHz (resulting in a minimum PCP core clock cycle time of 5.6ns). When running in 1:1 clocking mode the maximum PCP core clock frequency is the same as the maximum System Peripheral Bus frequency. In the TC1728 the System Peripheral Bus (which is an FPI Bus) is clocked with f_{SYS} , resulting in a minimum PCP core clock cycle time of 11.1ns (in 1:1 clocking mode).

*Note: Where an execution time is stated for an FPI instruction this is always a **minimum** value. A number of FPI instructions must wait for the completion of an FPI transaction (or transactions). When running in 2:1 mode each FPI clock cycle consists of two core clock frequencies. Where this applies the cycle count is shown with an “FPI” superscript designation (e.g. “3^{FPI}”). In addition there may be an additional single core clock cycle taken according to alignment of execution of an FPI instruction relative to an FPI clock edge.*

Table 38 Instruction Timing

Instruction	Number of Clock Cycles	Comments	Notes
Control			
NOP	1	–	–

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Table 38 Instruction Timing

Instruction	Number of Clock Cycles	Comments	Notes
COPY	–	–	1)
EXIT	f = 9, s = 7, m = 6	–	2)
BCOPY	–	–	1)

FPI Access

ADD.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
AND.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
COMP.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
LD.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
OR.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
ST.F	5 min.	2 int. + 3 ^{FPI} min. for FPI write	3)
SUB.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
XCH.F	8 min.	4 int. + 4 ^{FPI} min. for FPI read and write	3)
XOR.F	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)

PRAM Access

ADD.PI	2	–	–
AND.PI	2	–	–
COMP.PI	2	–	–
LD.PI	2	–	–
MCLR.PI	6	–	–
MSET.PI	6	–	–
OR.PI	2	–	–
ST.PI	4	–	–
SUB.PI	2	–	–
XCH.PI	5	–	–
XOR.PI	2	–	–

Arithmetic (Conditional)

ADD	1	–	–
AND	1	–	–
COMP	1	–	–
INB	1	–	–

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Table 38 Instruction Timing

Instruction	Number of Clock Cycles	Comments	Notes
LD.P	2	—	—
MOV	1	—	—
NEG	1	—	—
NOT	1	—	—
OR	1	—	—
PRI	1	—	—
ST.P	4	—	—
SUB	1	—	—
XOR	1	—	—

Immediate Access

ADD.I	1	—	—
CHKB	1	—	—
CLR	1	—	—
COMP.I	1	—	—
INB.I	1	—	—
LD.I	1	—	—
LDL.IL	1	—	—
LDL.IU	1	—	—
RL	1	—	—
RR	1	—	—
SET	1	—	—
SHL	1	—	—
SHR	1	—	—
SUB.I	1	—	—

FPI + Immediate Access

CLR.F	8 min.	4 int. + 4 ^{FPI} min. for locked FPI RMW (Read, Modify, Write)	4)
LD.IF	8 min.	5 int. + 3 ^{FPI} min. for FPI read	3)
SET.F	8 min.	4 int. + 4 ^{FPI} min. for locked FPI RMW (Read, Modify, Write)	4)
ST.IF	5 min.	2 int. + 3 ^{FPI} min. for FPI write	5)

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Table 38 Instruction Timing

Instruction	Number of Clock Cycles	Comments	Notes
Complex Math			
DINIT	1	—	6)
DSTEP	10	—	6)
MINIT	1	—	7)
MSTEP.L	10	—	7)
MSTEP.U	11	—	7)
Jump			
DEBUG	sdb - 0 = 2 sdb - 1 = exit_time	—	8)
JC	y = 4, n = 2	—	9)
JC.A	y = 4, n = 2	—	8)
JC.I	y = 4, n = 2	—	8)
JC.IA	y = 4, n = 2	—	8)
JL	4	—	—

- 1) The number of clock cycles for these instructions depends on several parameters such as the amount of data to be copied, the type of memory, and the effective bus load.
- 2) f = Full Context save, s = Small Context save, m = Minimum Context save time extended until any previous ST.F instruction has completed.
- 3) Cycles = 5 internal + 3 minimum for FPI read (with 0 wait cycles + 1 cycle for bus arbitration and assuming 1:1 clocking mode)
- 4) Cycles = 4 internal + 4 minimum for FPI read/modify/write (with 0 wait cycles + 1 cycle bus arbitration and assuming 1:1 clocking mode)
- 5) Cycles = 2 internal + 3 minimum for FPI write (with 0 wait cycles + 1 cycle for bus arbitration and assuming 1:1 clocking mode)
Time starts after any previous ST.F instruction has completed.
- 6) 32/32 bit divide requires instruction DINIT + JC + 4 × DSTEP = 1 + 4(2) + 4 × 10 = 45 cycles
8/32 bit divide requires instruction RR + DINIT + JC + DSTEP = 1 + 1 + 4(2) + 10 = 16 cycles
- 7) 32 × 8 bit multiply requires instructions RR + MINIT + MSTEP.L = 1 + 1 + 10 = 12 cycles
32 × 16 bit multiply requires instructions 2 × RR + MINIT + 2 × MSTEP.L = 2 × 1 + 1 + 2 × 10 = 23 cycles
32 × 32 bit multiply requires instructions MINIT + 4 × MSTEP.U = 1 + 4 × 11 = 45 cycles
- 8) sdb - 0 = Stop_on_Debug bit in instruction = 0 (disabling stop)
sdb - 1 = Stop_on_Debug bit in instruction = 1 (enabling stop)
exit_time = same time as for an exit instruction
- 9) y = jump taken, n = jump not taken

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10.19 Instruction Encoding

Most instructions are encoded in 16 bits.

This allows two instruction to be fetched out of 32 bit instruction memory per access.

For example, a COPY and an EXIT instruction can be fetched simultaneously, performing a simple DMA transaction.

Table 39 Field Definitions

Symbol	Name	Description
CNC	Counter Control	00: Perform the number/type of transfers appropriate to the instruction, and proceed to the next instruction. 01: Perform the number/type of transfers appropriate to the instruction, then decrement CNT1 and proceed to next instruction. 10: Use CNT1 as an “outer loop counter”. Perform the number/type of transfers appropriate to the instruction, then decrement CNT1. Repeat until CNT1 = 0, then proceed to next instruction. If R[7].IEN = True (interrupts enabled) the instruction may be interrupted at the end of each iteration of the “outer loop”. 11: N/A (error)
CNT0	Internal Loop Counter /Block Size Control	Internal Loop Counter for COPY: 000: Perform a sequence of 8 read/write transfers n: Perform a sequence of n (1 <= n <= 7) read/write transfers Block Size control for BCOPY: 000: 8 Words 001: N/A (error) 010: 2 Words 011: 4 Words 1xx: N/A (error)
CONDCA/B	Condition Code	Condition Code for conditional execution of instruction.
DAC	Disable All Channels Control	0: no action 1: Clear CS.EN which stops the PCP executing and further channel programs.
DST+/-	Destination Address Increment / Decrement	00: No Change 01: Post Increment by Size 10: Post Decrement by Size 11: N/A (error)

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Table 39 Field Definitions

Symbol	Name	Description
EC	Exit Count Control	0: no action 1: decrement CNT1
EDA	External Debug Action	0: No External Debug Action caused 1: Cause an External Debug Action (breakpoint pin etc.)
EP	Entry Point	Entry Point on next Channel Invocation: 0: Set the PC to Channel Start 1: Set the PC to the address contained in NextPC (next instruction) address. Note: EP=0 assumes that a Channel Entry Table exists in the base of Code Memory. Failure to provide one will cause improper operation.
INT	Interrupt	Issue interrupt 0: No 1: Yes if (CONDCB = True)
RTA	Return to This Address	0: The channel is disabled (R7.CEN=0) and the PC value stored in the context is NextPC. 1: The channel remains enabled and the PC value stored in the context is NextPC - 1.
SDB	Stop on Debug	0: Continue running if Debug Event Triggered 1: Stop PCP Channel if Debug Event Triggered
Set/Clr	Set/Clear	0: Check for Clear (0) 1: Check for Set (1)
SIZE	Data Size	00: Byte (8-bit) 01: Half Word (16-bit) 10: Word (32-bit) 11: Reserved
SRC+/-	Source Address Increment / Decrement	00: No Change 01: Post Increment by Size 10: Post Decrement by Size 11: N/A (error)
ST	Stop Channel	0: Leave Channel enabled 1: Stop Channel from accepting new Service Requests (clear R[7].CEN)

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Table 40 Instruction Encoding

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0 -:Control			fmt	Ins tr	DST + -		SRC + -		CNC		CNT0			Size	
NOP			0	0											
COPY			0	1											
					ST	INT	EP	EC	-		-	CONDC B			
EXIT			1	0								Condition for Interrupt			
			fmt	Ins tr	DST + -		SRC + -		CNC		-	CNT0	-		
BCOPY			1	1											
1 -:FPI			Instruction				R[b]			R[a]			-	Size	
ADD.F			0												
SUB.F			1												
COMP.F			2												
error			3												
error			4												
AND.F			5												
error			6												
OR.F			7												
XOR.F			8												
LD.F			9												
ST.F			A												
XCH.F			B												
error			C												
error			D												
error			E												
error			F												
2 -:PRAM			Instruction				R[a]			Offset 6 - bit					
ADD.PI			0												
SUB.PI			1												
COMP.PI			2												

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Table 40 Instruction Encoding

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
error			3												
MCLR.PI			4												
AND.PI			5												
MSET.PI			6												
OR.PI			7												
XOR.PI			8												
LD.PI			9												
ST.PI			A												
XCH.PI			B												
error			C												
error			D												
error			E												
error			F												
3 --Arithmetic			Instruction				R[b]			R[a]			CONDC A		
ADD			0												
SUB			1												
COMP			2												
NEG			3												
NOT			4												
AND			5												
error			6												
OR			7												
XOR			8												
LD.P			9												
ST.P			A												
error			B												
MOV			C												
INB			D												
PRI			E												
error			F												

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Table 40 Instruction Encoding

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
4 - Immediate			Instruction				R[a]			Immediate 6 - bit					
SUB.I			1												
ADD.I			0												
COMP.I			2												
error			3												
SHR			4												
SHL			5												
RR			6												
RL			7												
LDL.IU			8							following #imm16 instruction					
LDL.IL			9							following #imm16 instruction					
SET			A												
CLR			B												
LD.I			C												
INB.I			D												
CHKB			E							S/C					
error			F												
5 -:FPI Immediate			Instruction		Siz e1		R[a]			Siz e0		Immediate 5 - bit			
error			0												
error			1												
error			2												
SET.F			3												
CLR.F			4												
LD.IF			5												
ST.IF			6												
error			7												
6 -:Complex Maths			op2:Instruction				R[b]			R[a]			Reserved		
DINIT			0												
DSTEP			1												

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Table 40 Instruction Encoding

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MINIT			2												
MSTEP.L			3												
MSTEP.U			4												
error			5												
error			6												
error			7												
error			8												
error			9												
error			A												
error			B												
error			C												
error			D												
error			E												
error			F												
7 -:JUMP			op2:Instr			Offset 10 - bit									
JL			0	0	0										
			op2:Instr			CONDC B				Offset 6 - bit					
JC			0	0	1										
JC.A			0	1	0					Absolute Destination in next 16 bits					
error			0	1	1										
			op2:Instr			CONDCB				R[a]		-	-	-	
JC.I			1	0	0										
JC.IA			1	0	1										
error			1	1	0										
			op2:Instr			CONDCB				-	-	DA C	RT A	ED A	SD B
DEBUG			1	1	1										

10.20 Programming of the PCP

In this section, several techniques are outlined to help design channel programs. There are also examples on configuring a channel program's context.

10.20.1 Initial PC of a Channel Program

A channel program can begin operation at the Channel Entry Table location corresponding to the priority of the interrupt. This is much like an interrupt vector location for that channel in a traditional processor architecture. When the channel program is started, the PC is set to two-times the channel number (SRPN). Since the base of the Channel Entry Table is the bottom of the CMEM address range, and since each entry in the table is two instructions long, this address computation results in the first instruction of the channel program for that SRPN being fetched from memory for execution.

Alternately, the channel program can be made to begin executing at whatever address its restored context holds in R7.PC.

If PCP_CS.RCB = 1, then the channel program is forced to always start at its Channel Entry Table location regardless of the PC value stored in the CSA. If PCP_CS.RCB = 0, then the channel program will simply begin executing at whatever PC value is restored in the context R7.PC.

It is important to be aware of the implications of these two approaches on how CMEM should be configured, and what the initial value of the PC should be in the channel program's context that is loaded in the PRAM CSA at boot time.

10.20.1.1 Channel Entry Table

When PCP_CS.RCB = 1, the program counter of the PCP is vectored to the appropriate channel entry table each time a channel program is invoked by the receipt of an interrupt. The PCP is forced to start executing from its channel entry table location, regardless of its previous context or PC state.

If the EXIT instruction is executed with EP = 0, the PC saved during the context save operation will be the channel entry table location for that channel. That means that the next time the channel program is started, it will begin operation at the appropriate location in the Channel Entry Table.

Note: If EP = 0 is set in any channel program, or if PCP_CS.RCB = 1, a Channel Entry Table must be provided at the base of CMEM. Otherwise this table is not needed.

10.20.1.2 Channel Resume

When `PCP_CS.RCB = 0`, the program counter of the PCP is vectored to the address that is restored from the channel program's context. This means that before exiting, a channel program must itself arrange for where it will resume execution by configuring the value of its PC in its saved context so that it restarts at the desired location.

In this way, arbitrarily complex interrupt-driven state machines can be created as individual channel programs. Channel programs can be constructed that always start at their beginning, pick up where they left off, or pick up elsewhere, or have a mix of these approaches.

An example of a restarting channel program is shown below. Before exiting, the channel branches back to the address of the `START` label minus 1 (note that `START - 1 = CH16`) and then exits. This will leave the next value of the PC in the channel program's context as the address of the `START` label.

```
CH16:                                ;channel program 16
      EXIT EC=1 ST=0 INT=0 EP=1 cc_UC
                                      ;exit, no intr., leave PC @ next
START:                                ;nominal channel start address
      ST.IFbase #0x8 SIZE=32          ;output note from R0
      JC   CH16, cc_UC                ;loop back before exit
```

Note that when the channel program is originally configured by the programmer, the PC field in the R7 context of this channel program should also be set to the address of the `START` label.

Similarly, an interrupt-driven state machine can be created by exiting with the next PC value pointing to the start of the next state in a state machine implemented by the channel program. The next example below shows a program starting at the address to the `STATE0` label. It proceeds after the first interrupt to `STATE1 - 1`, where the channel program is left ready for the next state, `STATE1` in the state machine. After the next interrupt, it executes to address `STATE2 - 1` and the channel program is left ready for the next state, `STATE2`. After another interrupt, it proceeds through `STATE2`. The channel program jumps back to `START`, which is `STATE0 - 1`. The state machine has gone through one cycle and it is ready to restart in `STATE0`.

```
;This program is intended to test the sequence of exit/operate
;just as if you were implementing an interrupt driven
;state machine.
;It requires a periodic sequence of interrupts.
```

```
START:
      EXIT EC=1,ST=0,INT=0,EP=1,cc_UC;begin exit
STATE0:
      COMP.I    R5,#0x0              ;compare to interrupt number
                                      ;it should be
```


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```

JC          ERROR,cc_NZ      ;jump to error routine
                                ;if not correct

ADD.I       R5,#0x1          ;increment state number
EXIT EC=1,ST=0,INT=0,EP=1,cc_UC      ;begin exit
STATE1:
COMP.I       R5,#0x1          ;compare to interrupt number
                                ;it should be

JC          ERROR,cc_NZ      ;jump to error routine
                                ;if not correct

ADD.I       R5,#0x1          ;increment state number
EXIT EC=1,ST=0,INT=0,EP=1,cc_UC      ;begin exit
STATE2:
COMP.I       R5,#0x2          ;compare to interrupt number
                                ;it should be

JC          ERROR,cc_NZ      ;jump to error routine if
                                ;not correct

LD.I        R5,#0x0          ;reset state number
JC          START,cc_UC      ;jump back to start of
                                ;state machine

```

The last state could just as easily have ended with an EXIT that resets the PC to the Channel Entry Table (EP = 0) rather than jumping back to START.

10.20.2 Channel Management for Small and Minimum Contexts

If Small or Minimum Contexts are being used, only some of the registers are saved and restored. The integrity of the GPRs that are **not** included in the context must be handled explicitly by channel programs, since these are not saved and restored with the context of the interrupted channel program.

Channel programs may still use all registers reliably. Channel programs can be so designed that they either ignore the values in unsaved registers, or use those registers to store constants that no channel program changes. Hence, they never need to be saved and restored. Alternately, channel programs can use these unused GPRs as temporary variables as long as the values of such registers cannot be corrupted by the interrupt of the channel program by a higher-priority channel (see [Page 153](#)).

10.20.3 Unused Registers as Global's or Constants

Registers R0 through R3 (for the Small Context Model), or R0 through R5 (for the Minimum Context Model) can be used to store constants such as addresses that are available to all channel programs. Hence, these registers hold global data, and no channel program is allowed to change them.

Since the GPRs of the PCP are not directly accessible from the FPI Bus, there does need to be an initial channel program that sets these values at or near boot time. There are

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two choices here. A boot-time interrupt channel program can be invoked once to perform initialization, or there can be a program that routinely loads these values as a matter of course, and is invoked at boot time or as upon receipt of the very first interrupt.

10.20.4 Dispatch of Low Priority Tasks

A higher-priority channel program may wish to start a low-priority background task, or periodically pause and re-start itself later when there is no other action required at the moment. This can be accomplished in several ways:

- Post an SRPN to a free SRN on the FPI Bus, then EXIT.
- Perform an EXIT, posting the interrupt to the PCP, and indicating the channel number to be started.
- Use a single channel program as a list-driven or state-driven task dispatcher.

The first approach is straightforward to program, but uses a system SRN resource. Its advantage is that it allows continuous channel operation without using the interrupt queue, or risk blocking other uses of the PCP.

The second approach can be implemented by having a looping channel program continue operation in the background. It will also always be superseded by any higher-priority tasks.

The third approach uses a channel program to dispatch other non-interrupt-driven channel programs in an arbitrary order determined by the channel program dispatcher. In this way, multiple tasks could be continuously operated without over-using the PCP service-request queue. This approach would be useful when the aim is to poll for service requests in the peripheral SRNs rather than having them started by PCP hardware.

10.20.5 Code Reuse Across Channels (Call and Return)

A special jump instruction is included in the PCP instruction set to allow subroutines to be called from multiple channel programs. A routine may be jumped to directly, and then returned from using the JC.IA instruction. JC.IA allows a calling channel program to set aside a register for its return address, which will typically be the value of the next PC. The called subprogram can then execute a JC.IA, to the address stored in the register specified, causing a return-from-subroutine operation. The programmer must adopt and enforce a calling convention to determine which register holds the return address. Register R2 is normally used for this purpose.

For example:

Main Routine:		Subroutine:
LD.IL R2, #RETURN		SUB: MOV...
JC.A #SUB		ADD...
RETURN: MOV...		...
...		JC.IA R2

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10.20.6 Case-like Code Switches (Computed Go-To)

The JC.I instruction can be used to implement a multi-way branch for branch-on-bit or branch-on-state conditional branches. This instruction allows a conditional relative jump based on an index held in a register. If this instruction is combined with a table of jump addresses, a switch-type statement can be implemented. The default case, that is when the condition code = False, is the next instruction, as is the jump with register index = 0. The table can be any arbitrary length. The index register should be checked for range before the jump into the table is performed.

For Example:

```

COMP R3,#5      ;compare R3 to #5 - the number
                 ;of entries in the table

JC.I R3,cc_ULE

DEFAULT: JL #case_0 ;destination if R3 = 0 or
                 ;condition = false

          JL #case_1 ;destination if R3 = 1
          JL #case_2 ;destination if R3 = 2
          JL #case_3 ;destination if R3 = 3
          JL #case_4 ;destination if R3 = 4
          JL #case_5 ;destination if R3 = 5

```

10.20.7 Simple DMA Operation

A simple interrupt-driven DMA requires at least the Small Context Model to operate properly. Its operation is consists of three stages:

- The device interrupts the PCP to indicate it can receive or provide data.
- The PCP moves the amount of data it is programmed to move.
- The PCP eventually finishes and interrupts the CPU to notify it that the DMA is complete.

There are two options for implementing a simple DMA operation, copy and burst copy.

10.20.7.1 COPY Instruction

A simple DMA channel program can consist of only two instructions. In the example below, a device interrupts the PCP to notify it that it has data in its output buffer, which is 4 words deep. The COPY instruction copies 4 words to memory at a time. It decrements CNT1 (which is initialized by the CPU in CR6_CNT1 context) after each 4 word transfer. The EXIT command then executes, and if CNT1 was decremented to 0, the condition code causes it to issue an interrupt with the value held R6_SRPN.

```

COPY DST+,SRC,CNC=1,BRST=4,SIZE=32 ;do peripheral -> memory DMA
EXIT EC=0,ST=0,INT=1,EP=0,cc_CNZ  ;transfer done, so exit

```

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In the example above, the COPY instruction increments the destination held in R5 (DST+), and the source address is left constant in R4 (SRC). All permutations of decrement, increment or do not modify can be applied to either pointer register (R4 and R5) by use of the SRC and DST fields (SRC-, SRC+ or SRC and DST-, DST+ or DST).

Building on this basic DMA method, scatter-gather DMA channels can be created.

10.20.7.2 BCOPY Instruction (Burst Copy)

The BCOPY instruction is in principle similar to the COPY instruction except that it uses the FPI Burst mode to perform the transfers rather than performing individual reads/writes. As for the COPY instruction, the FPI Bus is locked between the burst read and burst write to ensure that a valid set of data is transferred. The BCOPY instruction allows support of all burst sizes supported by FPI Burst Mode except a burst size of 1 (i.e. 2, 4 or 8 words). The CNT0 field is used to control the burst size. Both the source and destination addresses (R4 and R5) must be correctly aligned for the burst size being used (see the FPI Bus description for details). If either address is incorrectly aligned, the PCP will generate an Illegal Operation Error Exit.

See also [Page 159](#) for TC1728 specific details of the BCOPY instruction.

10.21 PCP Programming Notes and Tips

This section discusses constraints on the use of the PCP and points out some non-obvious issues.

10.21.1 Notes on PCP Configuration

For configuring of the PCP, some notes should be regarded.

- Only one Context Model may be used at a time for all channels, and the PCP must remain in that Context Model once started and configured.
- In order for a specific channel program to be enabled, its context must have $R7.CEN = 1$. If $R7.CEN = 0$, the channel program will terminate when invoked, and cause a Disabled Channel Request error.
- The Channel Context Address from the FPI Bus as viewed during channel configuration is as follows:
 - Full Context Model: $PRAM\ Base + 20_H \times n$
 - Small Context Model: $PRAM\ Base + 10_H \times n$
 - Minimum Context Model: $PRAM\ Base + 08_H \times n$where n is the channel number.
- $PCP_CS.RCB$ and context must be consistent. If RCB is configured to 0, then each channel program will start at the PC restored from its context. If the wrong address is pre-configured in the context, the channel program will not operate properly.
- The programmer of the PCP may lock PCP_CS by setting $PCP_CS.EIE = 1$. When the global $ENDINIT$ bit is set, the PCP_CS register will no longer be writable, and attempting to do so will cause an FPI Bus error.
- An error condition will result in an interrupt being sent to the local FPI Bus master. The targeted interrupt service routine must be capable of dealing with the cause as recorded in PCP_ES , and, if required, it must be able to return the halted channel program to operation. The minimum required to do that is to set the context value of $R7.CEN = 1$.
- The only PCP Register bit that can be dynamically modified during PCP operation is the $PCP_CS.EN$ bit. When writing to any other PCP Register bits, the user must ensure that the PCP is disabled ($PCP_CS.EN = 0$) and that the PCP is quiescent ($PCP_CS.RS = 0$).

10.21.2 General Purpose Register Use

When using the general purpose registers of the PCP, some notes should be regarded.

- The most significant 16 bits of $R7$ may not be written, and will always read back as 0. However, no error will occur if a write to the most significant 16 bits occurs.
- Care must be taken with the use of $R6$ as a general-use register to ensure that $R6$ contains the correct value prior to execution of the $EXIT$ command. As $R6$ contains the $CNT1$ (counter used in $COPY$ and optionally in $EXIT$ instructions), $SRPN$ and

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TOS (service request number to use during optional interrupt at channel program EXIT) fields, R6 should not be used to pass values from one invocation of a channel program to the next invocation.

- If PRAM is to be accessed programmatically, then R7.DPTR must be configured properly as a pointer into the PRAM. This points to the 64-word segment that may be addressed by the xx.P instructions and the xx.PI instructions. It is not recommended to set R7.DTPR to point into the CSA. Special care must be taken that the Context PRAM is not overwritten.
- The programmer must be careful not to inadvertently clear R7.CEN when updating R7.DTPR (or any other field in R7). This would cause the channel program to generate a disabled channel interrupt to the CPU when the next interrupt request to the channel occurs.
- Any update to the Flags that is caused by an instruction (e.g. MOV R7, R0 which updates Z and N) takes precedence over any explicit bits that are moved to R7. See [Page 11](#).
- The interrupt system assumes SRPN 0 is not a request. Full Context packing leaves the least significant 8×32 -bit entries where channel 0 would normally be unused. That is, PRAM Base \rightarrow PRAM Base + 1 channel. In addition, for Small Context, the least significant 4×32 -bit entries are unused, and for Minimum Context the least significant 2×32 -bit entries are un-used. These “unused” entries should not be used by channel programs.
- If EP = 0 is used, or if PCP_CS.RCB = 1, a Channel Entry Table must be provided at the base of CMEM.
- If there is a plan to use the Small or Minimum Context Model, and the lower registers are to hold global values, then there needs to be an initial channel program that sets these values at or near boot time. There are at least two choices for implementing this. For instance, a boot interrupt channel program can be invoked once to perform initialization, or there can be a program that routinely loads these values as a matter of course, and it is invoked at boot time, or at the very first interrupt. See [Page 149](#).
- When using Small or Minimum Context models and allowing a channel to be interrupted, care must be taken to ensure that the value of any registers that are not included in the context but are being used by a channel are not corrupted by interruption of the channel and subsequent operation of a higher-priority channel. Particular care must be taken when using instructions that use R0 implicitly. If necessary, critical instruction sequences should be protected by use of the R7.IEN bit (see [Page 155](#)).

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10.21.3 Use of Channel Interruption

For channel interruption, the following note should be regarded.

- When a channel program consists of only a few instructions, it is best to configure the channel to be non-interruptible. This increases overall efficiency by removing the context save/restore overhead that would be incurred if the channel were to be interruptible.

10.21.3.1 Dynamic Interrupt Masking

A channel program can dynamically control whether it can be interrupted by use of the R7.IEN bit. When masking interrupts (by clearing R7.IEN), it must be noted that there is a delay of one instruction before the mask becomes effective. As a result the instruction that clears R7.IEN must be placed at least one instruction before the instruction sequence that is to be un-interruptible. As an example, consider the following sequence:

```
CLR  R7,IEN      ;Clear the R7.IEN bit
                        ;<< Interrupt can occur here
NOP
                        ;<< Interrupt can occur here
                        ;First instruction of non-interruptible
                        ;code sequence
```

10.21.3.2 Control of Channel Priority (CPPN)

The PCP has three extended Service Request Nodes (PCP_SRC9, PCP_SRC10 and PCP_SRC11) that allow storage of suspended channel interrupt requests. This allows interrupt nesting to a depth of four. This limit on the nesting depth carries the danger that a high-priority service request will not be serviced because the PCP's interrupt nesting depth has been exceeded.

It is recommended that a four-level "grouping" scheme should be adopted to avoid this problem. All PCP interrupt sources should be listed in order of their SRPNs. This list should then be subdivided into four contiguous groups, Group 0 being the lowest priority and Group 3 the highest. The CSA for each channel program should be configured such that CR6.CPPN contains the SRPN value of the highest channel program within the group to which the channel belongs. As each channel starts, the Operating Priority (CPPN) of the channel is loaded from the context. Using the scheme recommended above, any channel program will run with the priority of the highest SRPN within the group. As a result, the channel can only be interrupted by a service request from a higher-priority group (e.g. a Group 0 channel program can be interrupted by a new service request for a channel in any group from 1 to 3, a group 2 channel program can only be interrupted by a new service request for a channel in group 3).

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Note: When using this scheme, each channel program must ensure prior to channel exit that the R6.CPPN field contains the appropriate value, so that when the channel is next invoked, it will run at the correct priority.

10.21.4 Implementing Divide Algorithms

As discussed in [Section 10.18.4](#), a divide algorithm **must** always start with a DINIT instruction followed by a number of DSTEP instructions (up to four depending on the data width that is required). Prior to execution of any DSTEP instruction, R0 always contains either 0 (if this is the first DSTEP instruction in a divide sequence R0 contains 0 due to the preceding DINIT instruction, or the remainder from the previous DSTEP instruction). The dividend to be used in this step is generated in R0 by taking $256 \times$ the remainder of the last DSTEP instruction ($R0 \ll 8$) and adding the most significant byte of Rb ($Rb \gg 24$) as the LSB of the new dividend.

Since the remainder of the last DSTEP instruction is by definition always less than the divisor (Ra), it can be guaranteed that the result of the division of the dividend (calculated as above) by the divisor (Ra) can always be contained within an 8-bit result. The description given on [Page 116](#) only holds true under this condition. If the restrictions on the use of the DSTEP instruction (specified on [Page 107](#)) are adhered to, the above condition will always be met and this description of the instruction is correct. Failure to adhere to these conditions will lead to invalid results, which are outside the scope of this document.

During execution of a divide sequence, Rb is used both to compile the final divide result and to hold the remnants of the original dividend. For example, in a 32-/32-bit divide sequence (which consists of 4 DSTEP instructions - see below), Rb will have the following content:

- After the 1st DSTEP instruction:
The least significant 3 bytes (24 bits) of the original 32-bit dividend (held in the most significant 3 bytes of Rb) and the most significant byte of the final result (held in the least significant byte of Rb).
- After the 2nd DSTEP instruction:
The least significant 2 bytes (16 bits) of the original 32-bit dividend (held in the most significant 2 bytes of Rb) and the most significant 2 bytes of the final result (held in the least significant 2 bytes of Rb).
- After the 3rd DSTEP instruction:
The least significant byte of the original 32-bit dividend (held in the most significant byte of Rb) and the most significant 3 bytes of the final result (held in the least significant 3 bytes of Rb).
- After the final DSTEP instruction:
The 32 bit final result.

Note that the DSTEP instruction **always** uses the divisor as a 32 bit value. In any divide sequence, the dividend can be 8, 16, 24 or 32 bits (according to the number of DSTEP

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instructions in the sequence) but the divisor is **always** 32 bits. Prior to the DINIT instruction, the dividend must always occupy the appropriate most significant bits within the 32-bit dividend register (Rb).

Divide Examples

Example of a 32/32 bit divide (R5 / R3):

```
DINIT    R5, R3      ;Initialize ready for the divide
JC       HANDLE_DIVIDE_BY_ZERO, cc_V      ;V flag was set
                                                ;so jump to divide
                                                ;by zero error handler
DSTEP    R5, R3      ;4 DSTEP instructions
                                                ;(4 * 8 = 32 bit
DSTEP    R5, R3      ;divide)
DSTEP    R5, R3
DSTEP    R5, R3
```

After this sequence, R5 holds the result, R0 the remainder and R3 is unchanged.

Example of a 8/32 bit divide (R4 / R2):

```
RR       R4, 8       ;Rotate R4 right by 8 to move
                                                ;least significant byte into
                                                ;most significant byte
DINIT    R4, R2      ;Initialize ready for the divide
JC       HANDLE_DIVIDE_BY_ZERO, cc_V      ;V flag was set
                                                ;so jump to divide
                                                ;by zero error handler
DSTEP    R4, R2      ;DSTEP instruction
                                                ;(1 * 8 = 8 bit divide)
```

After this sequence, R4 holds the result, R0 the remainder and R2 is unchanged.

Note that the above example is specified as being a 8/32 bit divide rather than an 8/8 bit divide (see comments above).

10.21.5 Implementing Multiply Algorithms

As discussed in [Section 10.18.4](#), a multiply algorithm **must** always start with a MINIT instruction, followed by a number of MSTEP32 or MSTEP64 instructions. The MSTEP32 instruction is used to compile a multiplication result contained in 32 bits, discarding any overflows. The MSTEP64 instruction is used to compile a 64-bit multiplication result with the least significant 32 bits of the result contained in Rb and the most significant 32 bits of the result contained in R0.

Multiply Examples

Example of a 32 × 8 bit multiply (R4 × R1) yielding a 32 bit result (R4 = 32 bit, R1 = 8 bit):

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```

RR          R1, 8      ;Rotate least significant byte of R1
                    ;to most significant byte
MINIT       R1, R4     ;Initialize ready for multiply
MSTEP32     R1, R4     ;Perform one MSTEP32 instruction
                    ;(8 bit multiply)

```

After this sequence, R0 holds the result, R1 is left unchanged (right rotated by RR instruction then left rotated by MSTEP32 instruction), and R4 is unchanged. The result is only valid if there is no overflow (i.e. the product of the 8-bit number in R1 multiplied by the 32-bit number in R4 can be contained within 32 bits). It is the user's responsibility to ensure that this is the case. The overflow condition cannot be detected after execution of the multiply sequence.

Example of a 32×16 bit multiply ($R3 \times R2$) yielding a 32 bit result
(R3 = 32 bit, R2 = 16 bit):

```

RR          R2, 8      ;Perform two 8 bit rotations
                    ;(RR instructions) to get original
                    ;least significant 16 bits into
                    ;most significant 16 bits
RR          R2, 8
MINIT       R2, R3     ;Initialize ready for multiply
MSTEP32     R2, R3     ;Perform two MSTEP32 instructions
                    ;(16 bit multiply)
MSTEP32     R2, R3

```

After this sequence, R0 holds the result, R2 is left unchanged (right rotated by two RR instructions, then left rotated by two MSTEP32 instructions), R3 is unchanged. The comment above regarding overflow also applies to this sequence.

Example of a 32×32 bit multiply ($R5 \times R2$) yielding a 64 bit result
(R5 = 32 bit, R2 = 32 bit):

```

MINIT       R2, R5     ;Initialize ready for multiply
MSTEP64     R2, R5     ;Perform 4 MSTEP64 instructions
                    ;(64-bit multiply)
MSTEP64     R2, R5
MSTEP64     R2, R5
MSTEP64     R2, R5

```

After this sequence R0 and R2 hold the result (most significant word in R0, least significant word in R2), R5 is unchanged. There is no possibility of overflow as the result of 32×32 bits can always be contained in 64 bits.

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10.22 Implementation of the PCP in the TC1728

The addresses of the PCP registers and memories in the TC1728 are given in the following subsections:

10.22.1 PCP Memories

In the TC1728, the location of the registers and the memories sizes of the PRAM and the CMEM are given in [Table 41](#).

Table 41 PCP General Block Address Map

PCP Address Map	Address Range	Access Mode		Size
		Read	Write	
Reserved	F004 0000 _H - F004 3EFF _H	BE	BE	—
Registers	F004 3F00 _H - F004 3FFF _H	U, SV, 32	SV, 32	256 byte
Reserved	F004 4000 _H - F004 FFFF _H	BE	BE	—
Data Memory (PRAM)	F005 0000 _H - F005 1FFF _H	U, SV, 32	SV, 32	8 Kbyte
Reserved	F005 2000 _H - F005 FFFF _H	BE	BE	—
Code Memory (CMEM)	F006 0000 _H - F006 5FFF _H	U, SV, 32	SV, 32	24 Kbyte
Reserved	F006 6000 _H - F007 FFFF _H	BE	BE	—

Notes

1. BE - Accessing this address region causes a Bus Error to be generated.
2. U - Access permitted in User-1 mode.
3. SV - Access permitted in Supervisor mode.

10.22.2 BCOPY Instruction

In the TC1728, the BCOPY instruction can be used to perform burst transfers (2, 4, or 8 words) with DMI memories (Local data RAM) and the PCP memories. Other internal and external memories can be accessed using a burst size of 2 words only (CNT0 = 10_B).

10.22.3 PCP Reset Operation

The PCP module can be reset by a system hardware signal (hard reset).

PCP Hard Reset

A PCP hard reset is always triggered if at least one of these TC1728 reset sources becomes active:

- Watchdog Timer Reset
- Hardware Reset
- Power-on Reset

Each of these reset sources forces a hardware reset of the functional blocks within the PCP module. The effect of hard reset within the PCP is to:

- Halt any operating channel
- Reset all control registers to their reset values
- Reset the PCP Processor Core to its default state
- Reset the FPI Bus interface

Direct Memory Access Controller (DMA)

11 Direct Memory Access Controller (DMA)

This chapter describes the Direct Memory Access (DMA) Controller and the Memory Checker Module (MCHK) of the TC1728. It contains the following sections:

- Functional description of the DMA controller kernel (see [Section 11.2](#))
- DMA controller module register description (see [Section 11.3](#))
- TC1728 implementation-specific details of the DMA controller (interrupt control, address decoding, clock control, see [Section 11.4](#))
- Functional description of the Memory Checker (MCHK) module (see [Section 11.5](#))
- Memory Checker module register description (see [Section 11.5.2](#))

Note: The DMA kernel register names described in [Section 11.3](#) are referenced in the TC1728 User's Manual by the module name prefix "DMA_".

11.1 What is new

Major differences of the AudioFuture DMA compared to AudioNG:

- A new mode for the shadow address register was introduced to support endless channel re-starts without CPU intervention. In this new mode, the shadow address register can be written directly and it is not re-set automatically when loaded into target or destination address register ([Page 11-7](#) and [Page 11-93](#) / [Page 11-99](#)). The new Shadow Register Write Enable bit was added to the register DMA_ADRCR1/0x.
- The DMA channels are supporting now transactions with data moves > 32 KB with wrap around after 32 KB (bit fields CHCR.TREL and CHSR.TCOUNT are extended to 10 bit. See [Page 11-86](#) / [Page 11-86](#) and [Page 11-90](#) / [Page 11-90](#). See also DMA_ADRCR.CBLS/CBLD [Page 11-93](#) / [Page 11-93](#)).
- As a central module of the AudioFuture system on chip architecture, the DMA is now directly connected to the LMB with an own LMB master interface. The DMA master interface to the RPB was removed as the AudioFuture system architecture is based on a single LMB and single FPI (SPB) bus.
- The RPB BCU control registers were removed as there is no remote peripheral bus any more in AudioFuture).
- The Cerberus module is now connected to the DMA Peripheral Interface. This enables the Cerberus module to have direct access to the FPI and to the LMB bus via the DMA master interfaces either with the highest or with the lowest priority on LMB / FPI.
- 3-level programmable priority of the DMA Sub-Block at the on chip bus interfaces (2-level in AudioNG). The bit field DMAPRIO is expanded to 2 bits in the Channel Control register to support the three DMA on chip bus priorities ([Page 11-86](#)). The new structure is on the one hand compatible to the AudioNG channel priorities on the SPB, on the other hand it allows to use DMA channels for low priority background tasks on LMB like memory scrubbing. Additionally the DMA On Chip Bus priorities ([Page 11-24](#)) and the DMA bus switch priorities are adapted ([Page 11-22](#)).

Direct Memory Access Controller (DMA)

- The System Interrupt Registers are removed from the DMA module (moved to CPU, SCU and PMU).
- The DMA module has now 8 Service Requests nodes in general. *DMA interrupt outputs DMA SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel request inputs (DMA_SRCn (n = 0-7)).*
- Up to 16 selectable request inputs per DMA channel (upt to 8 in AudoNG). To allow a more flexible usage of the Move Engine Channels, the number of channel request inputs was increased to 16 (DMA_CHRC0x/1x.PRSEL expanded from 3 bit to 4 bit, [Page 11-86](#)) and the DMA request wiring matrix was re-defined ([Page 11-102](#)).
- Adapted the DMA access protection assignment to the AudoFuture address map ([Page 11-112](#)). The address protection sub-ranges are mapped to OVRAM, PCP PRAM, LDRAM, and SPRAM.
- In general the DMA control registers where adapted to the new structure (one FPI master interface and one LMB master interface instead of two FPI master interfaces).
- A figure with the detailed implementation of the Memory Checker algorithm was added to the Memory Checker chapter ([Page 11-127](#)).

Major differences of the AudoMax DMA compared to AudoFuture:

- SSC2 request lines to the DMA where added to the DMA request wiring matrix table ([Page 11-102](#))

Direct Memory Access Controller (DMA)

11.2 DMA Controller Kernel Description

The DMA Controller of the TC1728 transfers data from data source locations to data destination locations without intervention of the CPU or other on-chip devices. One data move operation is controlled by one DMA channel. Eight DMA channels are provided in one DMA Sub-Block. The Bus Switch provides the connection of the DMA Sub-Blocks to the two On Chip Bus interfaces and a DMA Peripheral interface. In the TC1728, the two On Chip Bus interfaces are connected to the System Peripheral Bus and the LMB Bus. The DMA Peripheral interface provides a connection to the Cerberus module, Micro Link Interface module and other DMA-related devices (Memory Checker module in the TC1728). Clock control, address decoding, DMA request wiring, and DMA interrupt service request control are implementation-specific and are managed outside the DMA controller kernel.

The index “m” in the following block diagram refers to the DMA Sub-Block number (m = 0-1).

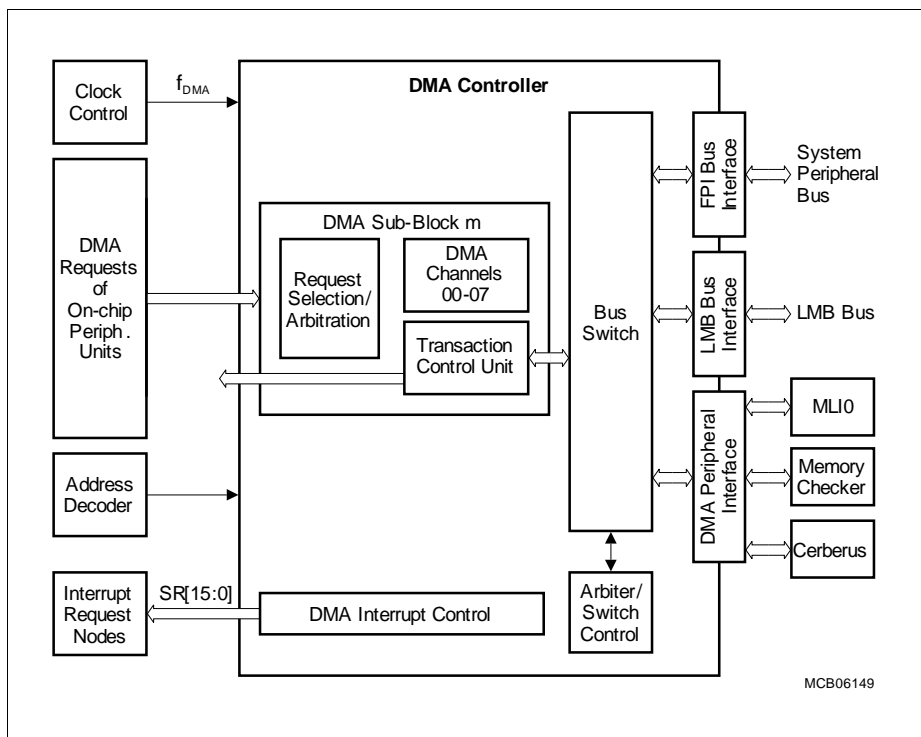


Figure 11-1 DMA Block Diagram

Direct Memory Access Controller (DMA)**11.2.1 Features**

The DMA controller has the following features:

- 16 independent DMA channels
 - 2 DMA Sub-Blocks with (8 DMA channels per DMA Sub-Block)
 - DMA Sub-Blocks with support of parallel channel execution (1 channel per Sub-Block, both Sub-Blocks in parallel)
 - Up to 16 selectable request inputs per DMA channel
 - 2-level programmable priority of DMA channels within the DMA Sub-Block
 - Software and hardware DMA request
 - Hardware requests by selected on-chip peripherals and external inputs
- Programmable priority of the DMA Sub-Blocks on the bus interfaces
- LMB Master Interface with 64-bit read buffer for read accesses to cached areas (Segment 8).
- Individually programmable operation modes for each DMA channel
 - Single Mode: stops and disables DMA channel after a predefined number of DMA transfers
 - Continuous Mode: DMA channel remains enabled after a predefined number of DMA transfers; DMA transaction can be repeated
 - Programmable address modification
 - Two shadow register modes (with / w/o automatic reset and direct write access).
- Full 32-bit addressing capability of each DMA channel
 - 4 Gbyte address range
 - Data block move > 32 Kbyte per DMA transaction
 - Circular buffer addressing mode with flexible circular buffer sizes
- Programmable data width of DMA transfer/transaction: 8-bit, 16-bit, or 32-bit
- Register set for each DMA channel
 - Source and destination address register
 - Channel control and status register
 - Transfer count register
- Flexible interrupt generation (the service request node logic for the MLI channels is also implemented in the DMA modules)
- DMA module is working on FPI frequency, LMB interface on LMB frequency.
- Dependant on the target/destination address, Read/write requests from the Move Engines are directed to the FPI Bus, LMB Bus, MLI modules or to the Cerberus module.

Direct Memory Access Controller (DMA)

11.2.2 Definition of Terms

Some basic terms must be defined for the functional description of the DMA controller.

DMA Move

A DMA move is an operation that always consists of two parts:

1. A read move that loads data from a data source into the DMA controller
2. A write move that puts data from the DMA controller to a data destination

Within a DMA move, data is always moved from the data source via the DMA controller to the data destination. Data is temporarily stored in the DMA controller. The data widths of read move and write move are always identical (8-bit, 16-bit or 32-bit). Data assembly or disassembly is not supported.

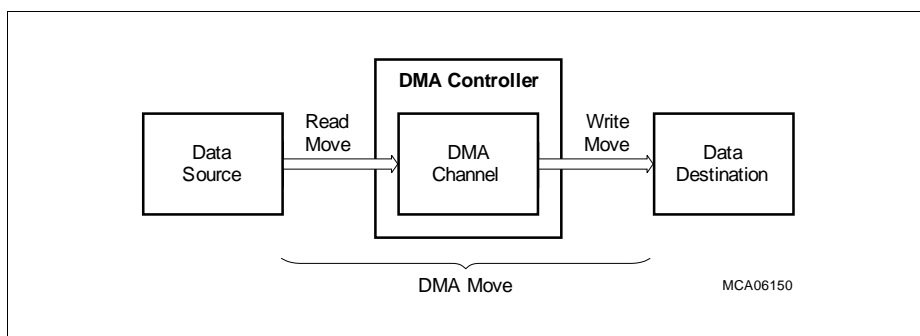


Figure 11-2 DMA Definition of Terms

DMA Transfer

A DMA transfer can be composed of 1, 2, 4, 8 or 16 DMA moves.

DMA Transaction

A DMA transaction is composed of several (at least one) DMA transfers. The Transfer Count determines the number of DMA transfers within one DMA transaction.

Example:

1024 word (32-bit wide) transactions can be composed of 256 transfers of four DMA word moves, or 128 transfers of eight DMA word moves.

Direct Memory Access Controller (DMA)

11.2.3 DMA Principles

The DMA controller supports DMA moves from one address location to another one. DMA moves can be requested either by hardware or by software. DMA hardware requests are triggered by specific request lines from the peripheral modules or from other DMA channels (see [Figure 11-3](#)). The number of available DMA request lines from a peripheral module varies depending on the module functionality. Typically, the parallel occurrence of DMA requests and interrupts requests for DMA channels is possible. Therefore, the interrupt control unit and the DMA controller can react independently to interrupt and DMA requests that have been generated by one source.

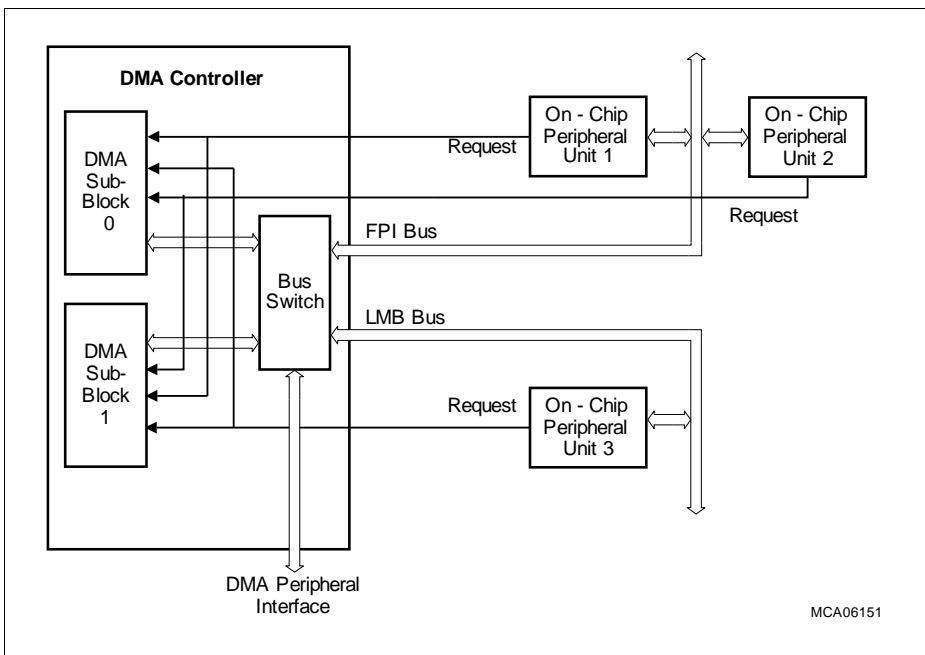


Figure 11-3 DMA Principle

The DMA controller mainly consists of two DMA Sub-Blocks and a Bus Switch. Once configured, the DMA Sub-Blocks are able to act as a master on the FPI Bus and on the LMB Bus.

Direct Memory Access Controller (DMA)

11.2.4 DMA Channel Functionality

Each of the 16 DMA channels has one associated register set containing seven 32-bit registers. These registers are numbered by one index to indicate the related DMA Sub-Block and one index to indicate the related DMA channel: Index “m” refers to the DMA Sub-Block number ($m = 0-1$) and Index “n” refers to the channel number ($n = 0-7$) within the DMA Sub-Block.

Example: CHCR04 is the Control Register of DMA channel 4 in Sub-Block 0.

The register set of a DMA channel register contains the following registers:

- Channel mn Control Register CHCR0n (for details, see [Page 11-86](#))
- Channel mn Status Register CHSR0n (for details, see [Page 11-90](#))
- Channel mn Interrupt Control Register CHICR0n (for details, see [Page 11-91](#))
- Channel mn Address Control Register ADRCR0n (for details, see [Page 11-93](#))
- Channel mn Source Address Register SADR0n (for details, see [Page 11-98](#))
- Channel mn Destination Address Register DADR0n (for details, see [Page 11-99](#))
- Channel mn Shadow Address Register SHADR0n (for details, see [Page 11-100](#))

11.2.4.1 Shadowed Source or Destination Address

As a typical application, an ASC module that receives data (fixed source address) has to deliver it to a memory buffer using a DMA transaction (variable destination address). After a certain amount of data has been transferred, a new DMA transaction should be initiated to deliver further ASC data into another memory buffer. While the destination address register is updated during a running DMA transaction with the actual destination address, a shadow mechanism allows programming of a new destination address without disturbing the content of the destination address register. In this case, the new destination address is written into a buffer register, i.e. the shadow address register. At the start of the next DMA transaction, the new address is transferred from this shadow address register to the destination address register without CPU intervention. This shadow mechanism avoids the CPU having to check for the end of a DMA transaction before reprogramming address registers.

The shadow address register can be used also to store a source address. However, it cannot store source and destination address at the same time. This means that the shadow mechanism makes it possible to automatically update either a new source address, or a new destination address at the start of a DMA transaction. If both address registers (for source and destination address) have to be updated for the next DMA transaction, a running DMA transaction for this channel must be finished. After that, source and destination address registers can be written before the next DMA transaction is started.

Figure 11-4 shows the actions that take place when a source address register is updated. The update of a destination register happens in an equivalent manner.

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When writing a new address to the (address of) the source or destination address register and no DMA transaction is running, the new address value is directly written into the source or destination address register. In this case, no buffering of the address is required. When writing a new address to the (address of) the source or destination address register and a DMA transaction is running, no transfer to an address register can take place and SHADRMn holds the new address value that was written. For this operation, bit field ADRCRMn.SHCT must be set either to 01_B (address is a source address) or 10_B (new address is a destination address). At the start of the next DMA transaction, the shadow transfer takes place and the content of SHADRMn is written either into SADRMn or DADRMn (ADRCRMn.SHCT must be set accordingly). After the shadow transfer, SHADRMn is set to $0000\ 0000_H$ if the shadow register write enable bit is set to 0 (ADRCRMn.SHWEN = 0). In this case (ADRCRMn.SHWEN = 0), the software can check by reading the shadow address register whether or not the shadow transfer has already taken place.

Only one address register can be shadowed while a transaction is running, because the shadow register can only be assigned either to the source or to the destination address register. Note that the shadow address register transfer has the same behavior in Single and Continuous Mode. When the shadow mechanism is disabled (ADRCRMn.SHCT = 00_B), SHADRMn is always read as $0000\ 0000_H$.

If the shadow address register write enable bit is set to 1 (ADRCRMn.SHWEN = 1), the shadow register SHADRMn can be directly written. In this case (ADRCRMn.SHWEN = 1) the value stored in the SHADRMn is not modified when the shadow transfer takes place, and the shadow mechanism remains active and the shadow transfer will be repeated until Channel mn is reset or until the value in SHADR is $0000\ 0000_H$, is written into the shadow register (direct or indirect by writing to the source or destination address register according to the shadow control register ADRCRMn.SHCT).

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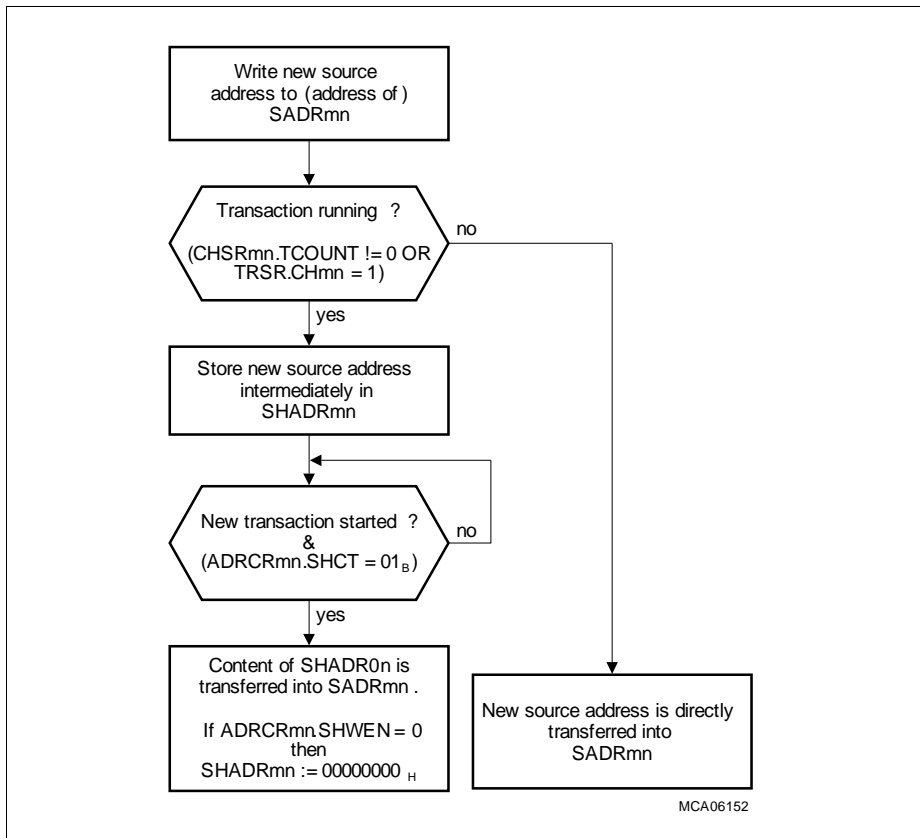


Figure 11-4 Source Address Update (m = 0-1)

The transfer count of a DMA transaction, stored in bit field CHCRmn.TREL, can also be programmed if the DMA transaction is running. At the start of a DMA transaction, TREL is transferred to bit field CHSRmn.TCOUNT, which is then updated during the DMA transaction.

No reload of address or counter will be done if TCOUNT is not equal to 0.

The reprogramming of channel specific values (except for the selected address shadow register) should be avoided while a DMA channel is active.

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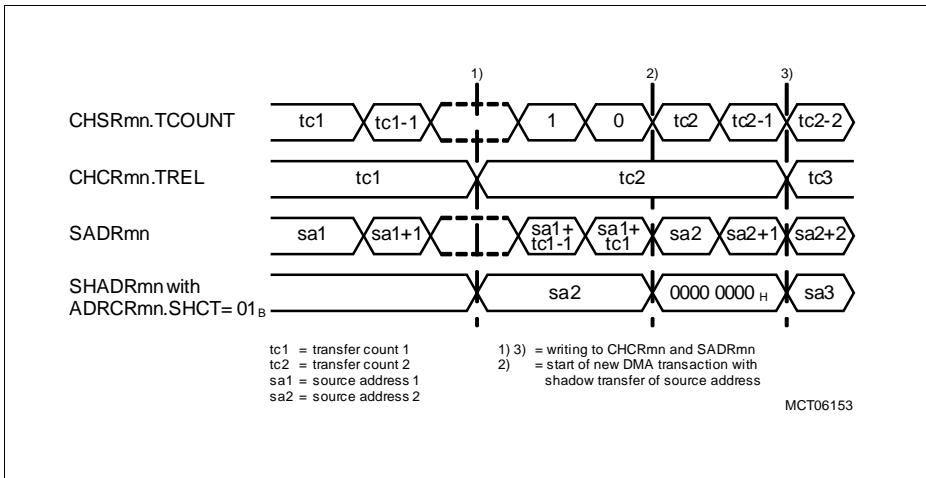


Figure 11-5 Shadow Source Address and Transfer Count Update with ADRCRmn.SHWEN = 0 (m = 0-1)

Figure 11-5 shows how the contents of the source address register SADRmn and the transfer count CHSRmn.TCOUNT are updated during two DMA transactions with a shadowed source address and transfer count update.

At reference point 2) the DMA transaction 1 is finished and DMA transaction 2 is started. At 1) the DMA channel is reprogrammed with two new parameters for the next DMA transaction: Transfer count tc2 and source address sa2. Source address sa2 is buffered in SADRmn and transferred to SADRmn when the new DMA transaction is started at 2). At this time, transfer count tc2 is also transferred to CHSRmn.TCOUNT. Pls. note that the shadow address register is only reset by hardware to 0000 0000_H as shown in this example, if the write enable bit is set to 0 (ADRCRmn.SHWEN = 0).

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11.2.4.2 DMA Channel Request Control

Figure 11-6 shows the control logic for DMA requests that is implemented for each DMA channel.

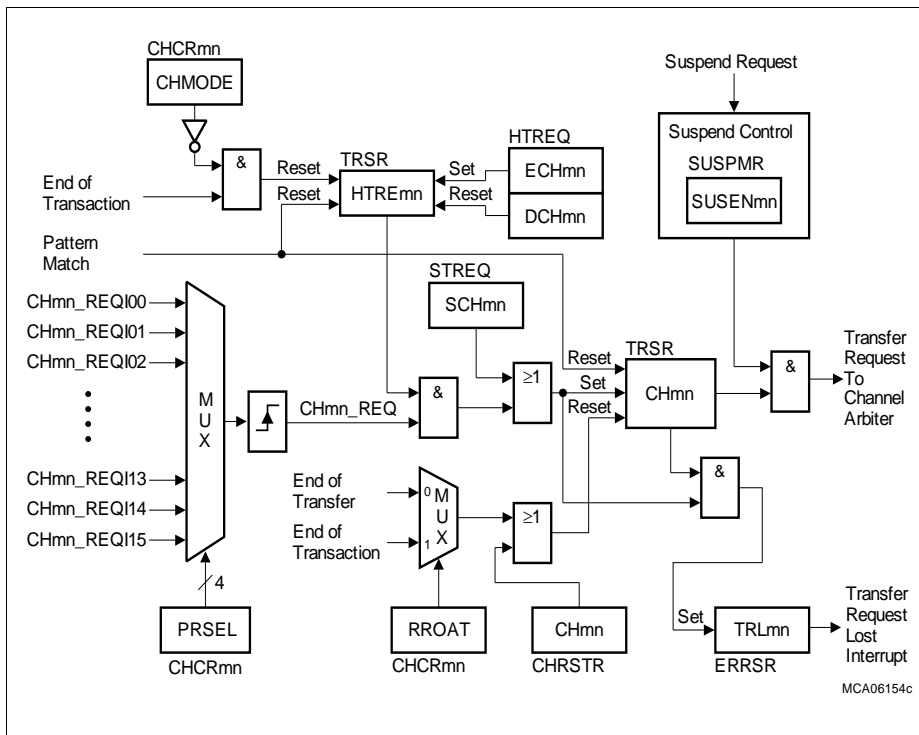


Figure 11-6 Channel Request Control (m = 0-1)

Two different types of DMA requests are possible:

- Hardware DMA requests
- Software DMA requests

The hardware request CHmn_REQ can be connected to one of sixteen possible hardware request input lines as selected by bit field CHCRmn.PRSEL. The hardware request input structure for CHCRmn.PRSEL includes a 'positive edge detector' as the DMA channels requires single pulse requests.

Hardware requests are enabled/disabled by status bit TRSR.HTREmn. HTREmn can be set/reset by software or by hardware in Single Mode at the end of a DMA transaction. A software request can be generated by setting bit STREQ.SCHmn.

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Status flag TRSR.CHmn indicates whether or not a software or hardware generated DMA request for DMA channel mn is pending. TRSR.CHmn can be reset by software or by hardware at the end of a DMA transfer (RROAT = 0) or at the end of a DMA transaction (RROAT = 1).

If a software or a hardware DMA request is detected for channel mn while TRSR.CHmn is set, a request lost event occurs. This error event indicates that the DMA is already processing a transfer and that another transfer has been requested before the end of the previous one. In this case, bit ERRSR.TRLmn will be set and a transfer lost interrupt can be generated.

11.2.4.3 DMA Channel Operation Modes

The operation mode of a DMA channel is individually programmable for each DMA channel mn. Basically, a DMA channel can operate in the following modes:

- Software controlled mode
- Hardware controlled mode, in Single or Continuous Mode

In software-controlled mode, a DMA channel request is generated by setting a control bit. In hardware-controlled mode, a DMA channel request is generated by request signals typically generated by on-chip peripheral units.

In hardware-controlled Single Mode, a DMA channel mn becomes disabled by hardware after the last DMA transfer of its DMA transaction. In hardware-controlled Continuous Mode, a DMA channel mn remains enabled after the last DMA transfer of its DMA transaction.

In hardware- and software-controlled mode, a DMA request signal can be configured to trigger a complete DMA transaction or one single transfer.

Software-controlled Modes

In software-controlled mode, one software request starts one complete DMA transaction or one single DMA transfer. Software-controlled modes are selected by writing HTREQ.DCHmn = 1. This forces status flag TRSR.HTREmn = 0 (hardware request of DMA channel mn is disabled).

The software-controlled mode that initiates one complete DMA transaction to be executed is selected for DMA channel mn by the following write operations:

- CHCRmn.RROAT = 1
- STREQ.SCHmn = 1

Setting STREQ.SCHmn to 1 (this is the software request) causes the DMA transaction of DMA channel mn to be started and TRSR.CHmn to be set. At the start of the DMA transaction, the value of CHCRmn.TREL is loaded into CHSRmn.TCOUNT (transfer count or tc) and the DMA transfers are executed. After each DMA transfer, TCOUNT becomes decremented and next source and destination addresses are calculated.

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When TCOUNT reaches the 0, DMA channel mn becomes disabled and status flag TRSR.CHmn is reset. Setting STREQ.SCHmn again starts a new DMA transaction of DMA channel mn with the parameters as actually defined in the channel register set.

The software-controlled mode that initiates a single DMA transfer to be executed is selected for DMA channel mn by the following write operations:

- CHCRmn.RROAT = 0
- STREQ.SCHmn = 1, repeated for each DMA transfer

When CHCRmn.RROAT = 0, TRSR.CHmn becomes reset after each DMA transfer of the DMA transaction and a new software request (writing STREQ.SCHmn = 1) must be generated for starting the next DMA transfer.

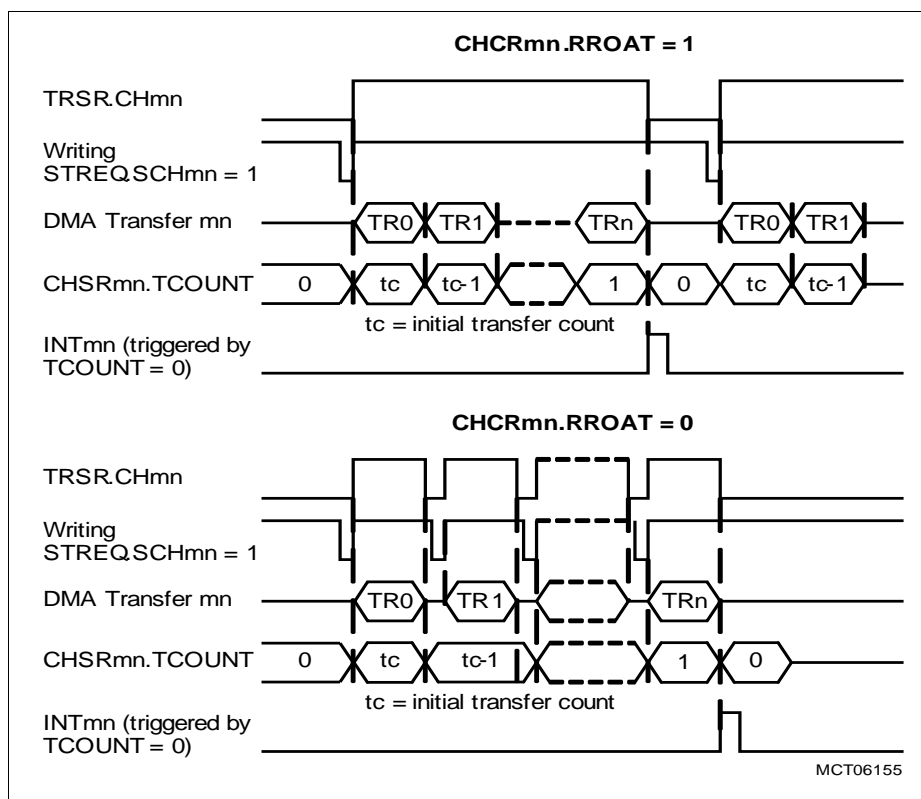


Figure 11-7 Software Controlled Mode Operation (m = 0-1)

Direct Memory Access Controller (DMA)

Hardware-controlled Modes

In hardware-controlled modes, a hardware request signal starts a DMA transaction or a single DMA transfer. There are two hardware-controlled modes available:

- **Single Mode:**
Hardware requests are disabled by hardware after a DMA transaction
- **Continuous Mode:**
Hardware requests are not disabled by hardware after a DMA transaction

Hardware-controlled Single Mode

In hardware-controlled Single Modes, one hardware request starts one complete DMA transaction or one single DMA transfer. The hardware-controlled Single Mode that initiates one complete DMA transaction to be executed for DMA channel mn is selected by the following operations:

- CHCRmn.CHMODE = 0
- CHCRmn.RROAT = 1
- Selecting one of the sixteen hardware request inputs via CHCRmn.PRSEL
- HTREQ.ECHmn = 1

Setting HTREQ.ECHmn to 1 causes the hardware request CHmn_REQ of channel mn to be enabled (TRSR.HTREmn = 1). Whenever the hardware request CHmn_REQ becomes active, the value of CHCRmn.TREL is loaded into CHSRmn.TCOUNT and the DMA transaction is started by executing its first DMA transfer. After each DMA transfer, TCOUNT becomes decremented and next source and destination addresses are calculated. When TCOUNT reaches the 0, DMA channel 0n becomes disabled and status flags TRSR.CHmn and TRSR.HTREmn are reset. In order to start a new hardware-controlled DMA transaction, hardware requests must be enabled again by setting TRSR.HTREmn through HTREQ.ECHmn = 1. The hardware request disable function in Single Mode is typically needed when a reprogramming of the DMA channel register set (addresses, transfer count) is required before the next hardware triggered DMA transaction is started.

The hardware-controlled Single Mode in which each single DMA transfer has to be requested by a hardware request signal is selected as described above, with one difference:

- CHCRmn.RROAT = 0

In this operation mode, TRSR.CHmn becomes reset after each DMA transfer of the DMA transaction, and a new hardware request at CHmn_REQ must be generated for starting the next DMA transfer.

Direct Memory Access Controller (DMA)

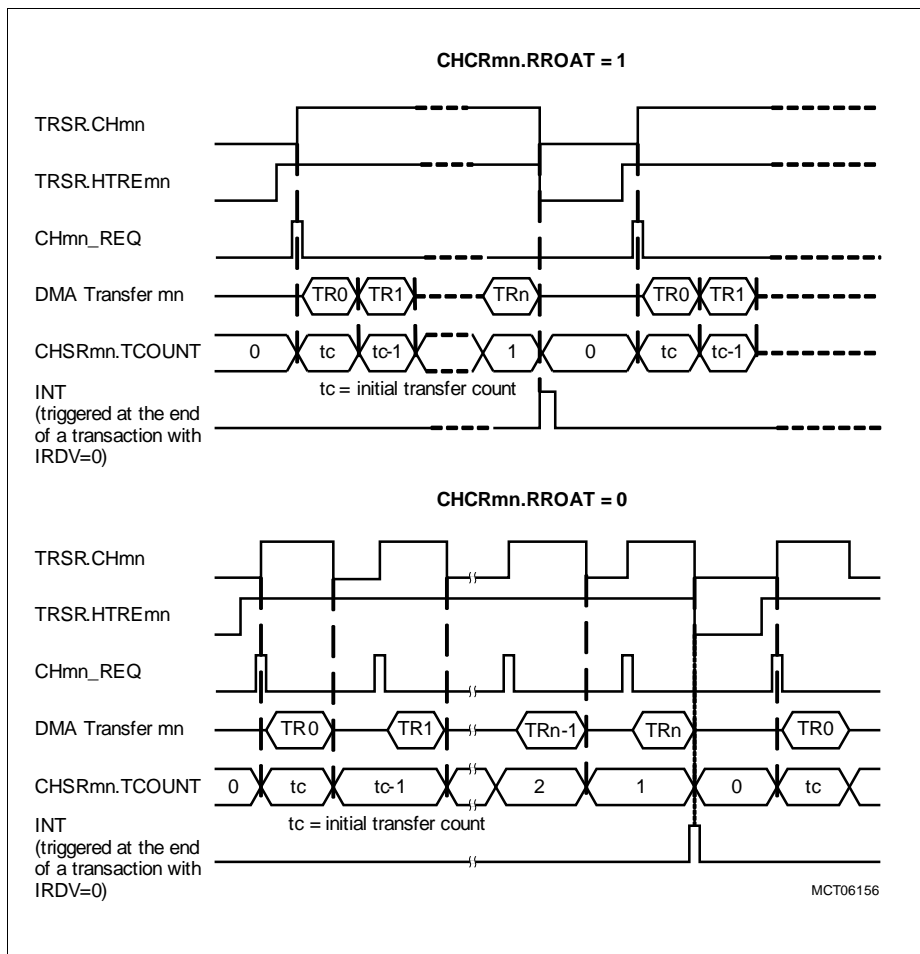


Figure 11-8 Hardware-controlled Single Mode Operation (m = 0-1)

Hardware-controlled Continuous Mode

In hardware-controlled Continuous Mode (CHCRmn.CHMODE = 1), the hardware transaction request enable bit HTREmn is not reset at the end of a DMA transaction. A new transaction of DMA channel mn with the parameters actually stored in the channel register set of DMA channel mn is started each time when CHSRmn.TCOUNT = 0 at the end of the DMA transaction. No software re-enable for a hardware request at CHmn_REQ is required.

Direct Memory Access Controller (DMA)

Combined Software/Hardware-controlled Mode

Figure 11-9 shows how software- and hardware-controlled modes can be combined. In the example, the first DMA transfer is triggered by software when setting STREQ.SCHmn. Hardware requests are still disabled. After hardware requests have been enabled by setting HTREQ.ECHmn, subsequent DMA transfers are triggered now by hardware request coming from the CHmn_REQ line.

In the example, DMA channel mn operates in Single Mode (CHCRmn.CHMODE = 0). In this mode, TRSR.HTREmn becomes reset by hardware when CHSRmn.TCOUNT = 0 at the end of the DMA transaction.

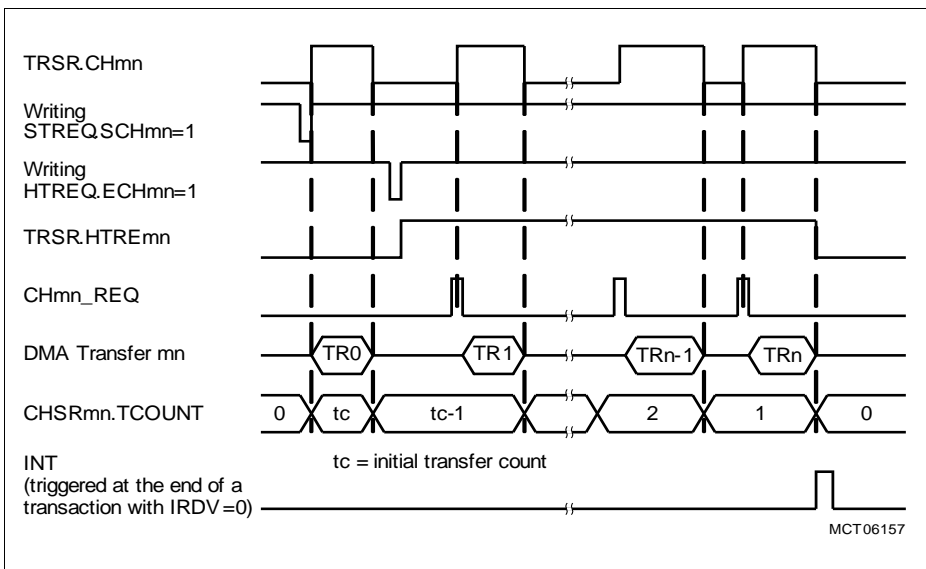


Figure 11-9 Transaction Start by Software, Continuation by Hardware (m = 0-1)

11.2.4.4 Error Conditions

The bus error flag ERRSR.FPIER indicates an FPI Bus error (SPB) that occurred during a source move (read or write) of a DMA module transaction. The bus error flag ERRSR.LMBER indicates an LMB Bus error that occurred during a source move (read or write) of a DMA module transaction.

The source error flags ERRSR.MEmSER indicates than an error occurred during source move (read) of a DMA transaction of DMA Sub-Block m.

The destination error flags ERRSR.MEmDER indicates than an error occurred during destination move (write) of a DMA transaction of DMA Sub-Block m

Direct Memory Access Controller (DMA)

The transaction lost error flag ERRSR.TRLmn indicates if a DMA request for a DMA channel mn has been lost.

In the case of a read error, the write action is not executed, but the destination address is updated.

In the case of multiple errors, the error bits are set according to the error situations. This means that more than bus error flag can be set and that source/destination flags can be set.

11.2.4.5 Channel Reset Operation

A DMA transaction of DMA channel mn can be stopped (channel is reset) by setting bit CHRSTR.CHmn. When a read or write On Chip Bus transaction of DMA channel mn is executed at the time when CHRSTR.CH0n is set, this On Chip Bus transaction is finished normally. This behavior guarantees data consistency.

When CHRST.CHmn is set to 1:

- Bits TRSR.HTREmn, TRSR.CHmn, ERRSR.TRLmn, INTSR.ICHmn, INTSR.IPMmn, WRPSR.WRPDmn, WRPSR.WRPSmn, CHSRmn.LXO, and bit field CHSRmn.TCOUNT are reset.
- Source and destination address register will be set to the wrap boundary. SHADRmn will be cleared.
- All automatic functions are stopped for channel mn.

A user program must execute the following steps for resetting a DMA channel:

1. If hardware requests are enabled for the DMA channel mn, disable the DMA channel mn hardware requests by setting HTREQ.DCHmn = 1.
2. Writing a 1 to CHRST.CHmn.
3. Waiting (polling) until CHRST.CHmn = 0.

A user program should execute the following steps for restarting a DMA channel after it was reset:

1. Optionally (re-)configuring the address and other channel registers.
2. Restarting the DMA channel mn by setting HTREQ.ECHmn = 1 for hardware requests or STREQ.SCHmn = 1 for software requests.

The value of CHCRmn.TREL is copied to CHSRmn.TCOUNT when a new DMA transaction is requested and shadow address register contents is not equal 0000 0000_H.

Direct Memory Access Controller (DMA)

11.2.4.6 Transfer Count and Move Count

The move count determines the number of moves (consisting of one read and one write each) to be done in each transfer. It allows the user to indicate to the DMA the number of moves to be done after one request. The number of moves per transfer is selected by the block mode settings (CHCRmn.BLMK).

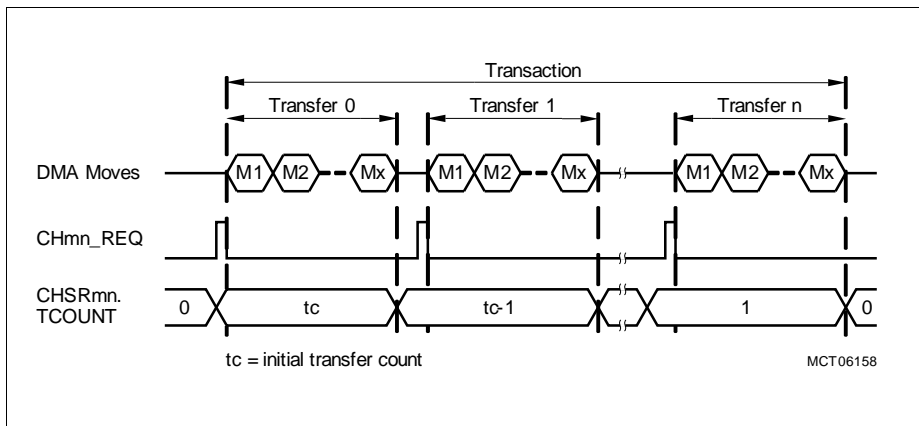


Figure 11-10 Transfer and Move Count ($m = 0-1$)

After a DMA move, the next source and destination addresses are calculated. Source and destination addresses are calculated independently of each other. The following address calculation parameters can be selected:

- The address offset, which is a multiple of the selected data width
- The offset direction: addition, subtraction, or none (unchanged address)

Control bits in address control register ADRCRmn determine how the addresses are incremented/decremented. Further, the data width as defined in CHCRmn.CHDW is taken into account for the address calculation.

Figure 11-11 and **Figure 11-12** show two examples of address calculation. In both examples, a data width of 16-bit (CHCRmn.CHDW = 01_B) is assumed.

Direct Memory Access Controller (DMA)

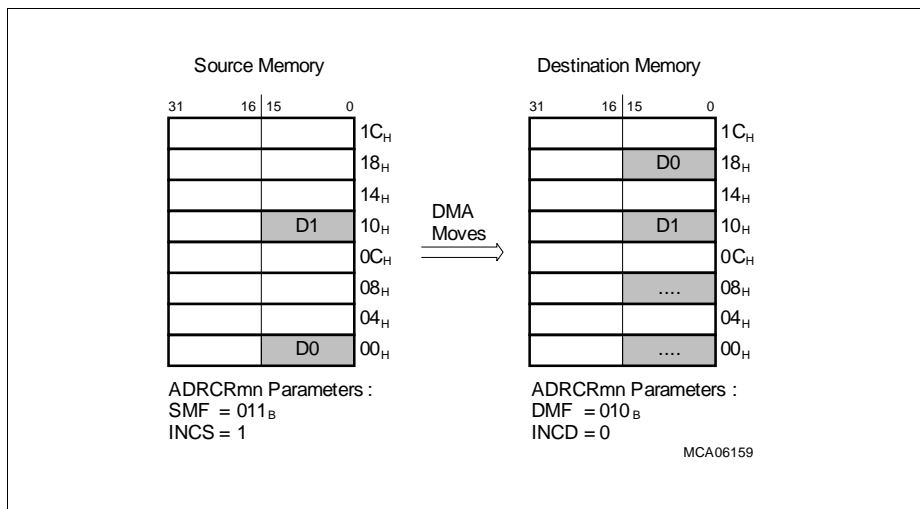


Figure 11-11 Programmable Address Modification - Example 1 (m = 0-1)

In **Figure 11-11**, 16-bit half-words are transferred from a source memory with an incrementing source address offset of 10_H to a destination memory with decrementing destination addresses offset of 08_H.

In **Figure 11-12**, 16-bit half-words are transferred from a source memory with an incrementing source address offset of 02_H to a destination memory with incrementing destination addresses offset of 04_H.

Direct Memory Access Controller (DMA)

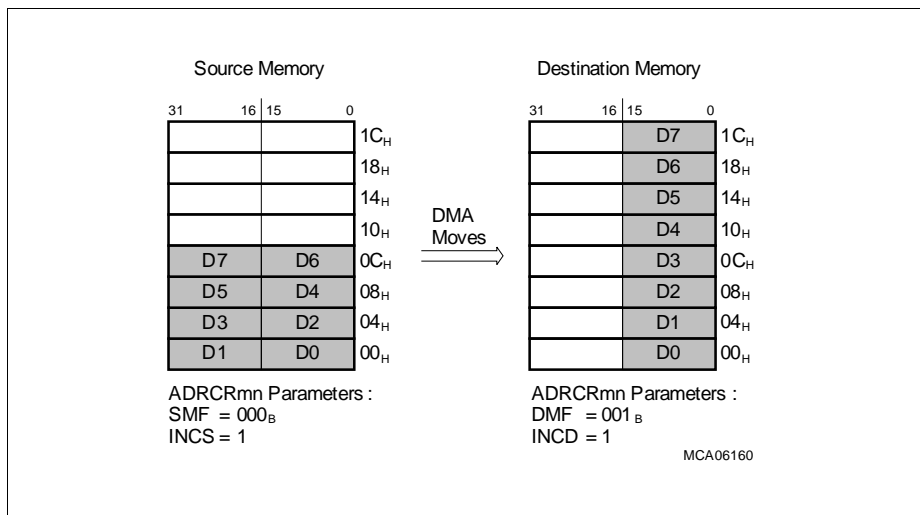


Figure 11-12 Programmable Address Modification - Example 2 (m = 0-1)

11.2.4.7 Circular Buffer

Destination and source address can be configured to build a circular buffer separately for source and destination data. Within this circular buffer, addresses are updated as defined in [Figure 11-11](#) and [Figure 11-12](#) with a wrap-around at the buffer limits. The circular buffer length is determined by bit fields ADRCRmn.CBLS (for the source buffer) and ADRCRmn.CBLD (for the destination buffer). These 4-bit wide bit fields determine which bits of the 32-bit address remain unchanged at an address update. Possible buffer sizes of the circular buffers can be 2^{CBLS} or 2^{CBLD} bytes (= 1, 2, 4, 8, 16, ... up to 32k bytes).

When source or destination addresses are updated (incremented or decremented) after a DMA move, all upper bits [31:CBLS] of source address and [31:CBLD] of destination address are frozen and remain unchanged, even if a wrap-around from the lower address bits [CBLS:0] or [CBLD:0] occurred. This address-freezing mechanism always causes the circular buffers to be aligned to a multiple integer value of its size.

If the circular buffer size is less or equal than the selected address offset (see [Table 11-10](#)), the same circular buffer address will always be accessed.

Direct Memory Access Controller (DMA)

11.2.5 Transaction Control Engine

Each DMA Sub-Block has a Transaction Control Unit. The Transaction Control Unit in the DMA Sub-Block, as shown in the DMA Controller block diagram in [Figure 11-1](#), contains a Channel Arbiter and a Move Engine.

The Channel Arbiter arbitrates the transfer requests of the DMA channels, and submits the transfers parameters of the DMA channel with the highest channel priority that are needed for a DMA transfer to the Move Engine. DMA channels within a DMA Sub-Block have a two-level programmable channel priority as defined by bit CHCRmn.CHPRIO. When two transfer requests of two different DMA channels with identical channel priority become active at the same time, the DMA channel with the lowest channel number (n) is serviced first.

The Move Engine handles the execution of a DMA transfer that has been detected by the Channel Arbiter to be the next one. The Move Engine requests the required buses and loads or stores data according to the parameters of a DMA transfer. It is able to wait if a targeted bus is not available. In the Move Engine, a DMA transfer of a DMA transaction cannot be interrupted and always get finished. This means that a DMA transfer, which can also be composed of several data moves (read move and write move), cannot be interrupted by a transfer of another DMA channel.

After a DMA transfer is finished, the Move Engine will send back the actualized address register information to the related DMA channel. Possible error conditions are also reported.

Direct Memory Access Controller (DMA)

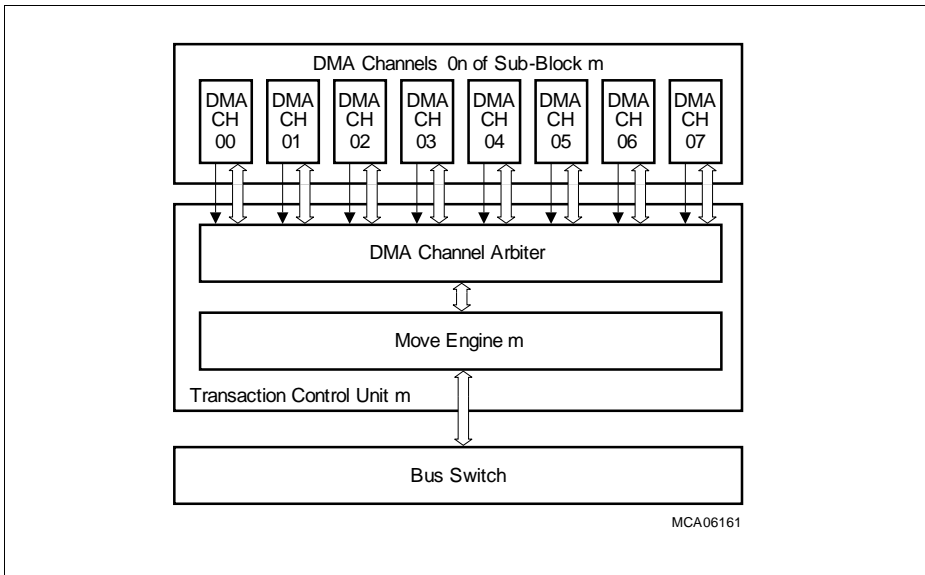


Figure 11-13 Transaction Control Engine (m = 0-1)

11.2.6 Bus Switch, Bus Switch Priorities

The Bus Switch of the DMA controller provides the connection from the DMA Sub-Blocks to the two On Chip Bus master interfaces (connected to System Peripheral Bus and LMB Bus) and to the DMA Peripheral Interface (see [Figure 11-14](#)).

The FPI Bus interface of the DMA includes a slave interface which provides the access to the DMA and the peripherals connected to the DMA Peripheral Interface (MLI, Cerberus and Memory Checker modules).

The LMB Bus interface of the DMA is a master interface.

The DMA module, the DMA Sub-Blocks as well as the MLI, the Memory Checker and the Cerberus module working frequencies are identical to the FPI Bus frequency. The working frequency of the LMB master interface is identical to the LMB/CPU working frequency.

Direct Memory Access Controller (DMA)

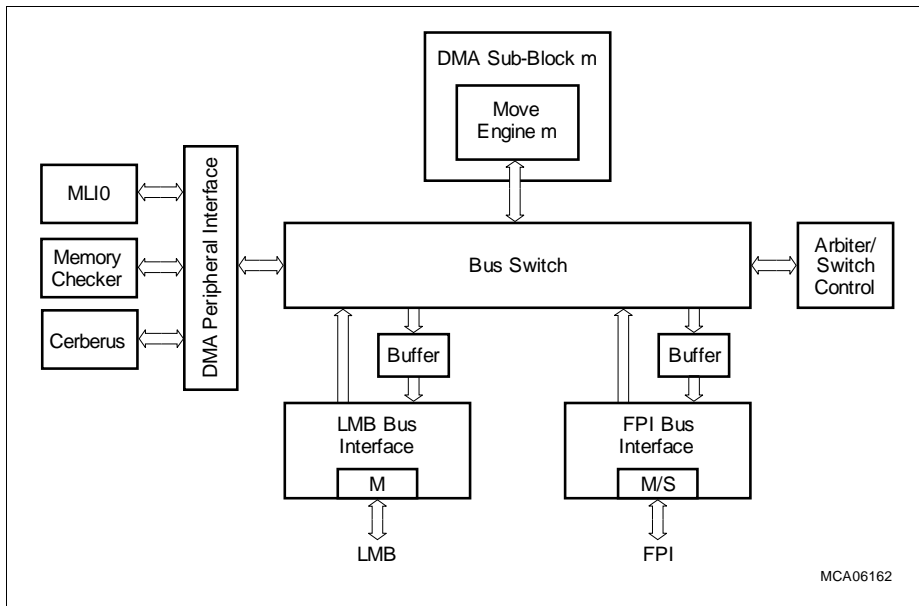


Figure 11-14 Bus Switch

One access can be buffered in the bus interfaces.

Note: The accesses of the DMA Move Engine's bus interfaces to the On Chip Bus interfaces are always done in Supervisor Mode.

The arbiter/switch control unit arbitrates the requests from the connected active interfaces (FPI Bus Interface, DMA Move Engines, MLI, Cerberus, ...) and grants the buses connected to the switch for data transfers. [Table 11-1](#) and [Table 11-2](#) are defining the Bus Switch priorities for requests to the same On Chip Bus Interface. The arbitration scheme is valid in case of a collision of requests from active peripherals connected to the DMA Bus Switch (Move Engine, MLI, Cerberus) for the same resource (FPI Bus Interface, LMB Bus Interface, DMA Peripheral Interface, Move Engine). The arbitration is done for each Bus Switch request.

The general overview of the Bus Switch Priorities is given in [Table 11-1](#). Additional detailed information about the Move Engine priorities for concurrent on the Bus Switch is described in [Table 11-2](#).

In case of a collision of the DMA Move Engine requests on the DMA Bus switch for the the same resource, a Move Engine Write has priority over a Move Engine Read. In case of a collision of both Move Engines with concurrent read requests or concurrent write requests for the same resource, the Move Engine number together with the

Direct Memory Access Controller (DMA)

CHCRmn.DMAPRIO value determines the priority on the DMA Bus Switch (see [Table 11-2](#)).

Table 11-1 DMA Bus Switch Priorities

Priority	Agent Requests	Comment
Highest	Cerberus to On Chip Bus High	Priority selection by software in Cerberus.
	FPI Bus to DMA Peripheral Interface accesses	Reason: minimizing wait states on the FPI Bus.
	DMA Move Engine Write	The detailed Bus Switch priorities for the two Engines with concurrent reads or concurrent writes are listed in Table 11-2 .
	DMA Move Engine Read	The detailed Bus Switch priorities for the two Engines with concurrent reads or concurrent writes are listed in Table 11-2 .
	MLIO access	—
Lowest	Cerberus to On Chip Bus Low	Priority selection by software in Cerberus.

Table 11-2 DMA Bus Switch Priorities of DMA Move Engines

Priority	DMA Move Engine Request	Comment
Highest	Move Engine 0 CHCR0x.DMAPRIO = "11" or CHCR0x.DMAPRIO = "01"	(x=7-0). x reflects the channel of Move 0 that won the Move Engine internal arbitration.
	Move Engine 1 CHCR1y.DMAPRIO = "11" or CHCR1y.DMAPRIO = "01"	(y=7-0). y reflects the channel of Move 1 that won the Move Engine internal arbitration.
	Move Engine 0 CHCR0x.DMAPRIO = "00"	(x=7-0). x reflects the channel of Move 0 that won the Move Engine internal arbitration.
	Move Engine 1 CHCR1x.DMAPRIO = "00"	(y=7-0). y reflects the channel of Move 1 that won the Move Engine internal arbitration.
Lowest		

11.2.7 DMA Module Priorities on On Chip Busses (FPI Bus, LMB Bus)

Every active peripheral connected to the DMA Bus Switch that requests for access to FPI Bus or LMB Bus has to go through two arbitration stages before accessing the On Chip Bus: DMA Module internal arbitration at the DMA Bus Switch and DMA Module external arbitration at the On Chip Bus.

Direct Memory Access Controller (DMA)

The DMA Module is connected to the FPI Bus and to the LMB Bus with master interfaces. The DMA LMB Master and the DMA FPI Master is each connected with three priorities to its On Chip Bus (low, medium and high priority), where it competes against the other bus masters connected to the On Chip Bus for bus access. The mapping of the Move Engines and the peripherals connected to the DMA Peripheral Interface to the DMA Module priorities on the FPI Bus and on the LMB Bus is described in [Table 11-3](#).

The MLI module is mapped to the low priority On Chip Bus requests of the DMA Module, while the mapping of the Cerberus and the Move Engines to the On Chip Bus requests is selected by software (control register bits).

The complete list of FPI master priorities can be found in the FPI Bus Control Unit Chapter.

The complete list of LMB master priorities can be found in the Local Memory Bus Controller Unit Chapter.

Table 11-3 DMA Module Priorities on On Chip Busses

On Chip Bus Priority	DMA On Chip Bus Request	Comment
High	Cerberus High	Priority selection by SW in Cerberus.
	Move Engine m: CHCRmx.DMAPRIO = "11"	Priority selection by SW in Move Engine. (x=7-0) (m=1-0)
Medium	Move Engine m: CHCRmx.DMAPRIO = "01"	Priority selection by SW in Move Engine. (x=7-0) (m=1-0)
Low	Move Engine m: CHCRmx.DMAPRIO = "00"	Priority selection by SW in Move Engine. (x=7-0) (m=1-0)
	MLIO	-
	Cerberus Low	Priority selection by SW in Cerberus.

11.2.8 DMA Module: On Chip Bus Access Rights, RMW support

All accesses triggered by the DMA Move Engines, the MLI module or the Cerberus module are always done in SV mode.

The DMA module does not support read/modify write instructions to the peripherals connected to the DMA Peripheral Interface (the MLI, Memory Checker and Cerberus modules).

11.2.9 DMA Module On Chip Bus Master Interfaces

This chapter describes the features of the DMA On Chip Bus Master Interfaces to the FPI Bus and to the LMB Bus.

Direct Memory Access Controller (DMA)

The DMA FPI master interface supports:

- single data read and write transactions (8bit, 16bit, 32bit)
- generation of pipelined FPI transactions from different sources (Move Engines, Cerberus, MLI)
- de-assertion of request after retry in order to prevent bus blocking.
- out of order transactions from different sources in order to avoid side effects (blocking) between the different sources (Move Engines, Cerberus, MLI)
- three dedicated FPI requests (medium, low, high priority. See [Table 11-3](#))¹.

A single move engine supports only one transaction at a time. Due to the fact that the move engines do generate read - write sequences, it is unlikely that the DMA module generates permanent, pipelined, high priority requests.

The DMA LMB master interface supports:

- single data read and write transactions (8bit, 16bit, 32bit)
- single data read transactions (64bit) for read accesses to Segment 8 (cached area)
- pipelined transactions from different sources (Move Engines, Cerberus, MLI)
- de-assertion of request after retry in order to prevent bus blocking.
- out of order transactions from different sources in order to avoid side effects (blocking) between the different sources (Move Engines, Cerberus, MLI)
- three dedicated LMB requests (medium, low, high priority. See [Table 11-3](#))².

A single move engine supports only one transaction at a time. Due to the fact that the move engines do generate read - write sequences, it is unlikely that the DMA module generates permanent, pipelined, high priority requests.

DMA LMB Master Read Buffer:

The DMA LMB master interface includes a 64bit buffer for read accesses to cached addresses (Segment 8). The DMA LMB Master Interface contains a data read buffer for read accesses to cached addresses. The read buffer allows to read one line of 8byte (=64 bit) of data read from specific memory areas on LMB side (Segment 8: 8000 0000_H - 8FFF FFFF_H)

A read request to an Segment 8 address (8bit, 16bit or 32bit) will be translated by the DMA LMB master interface into an LMB 64 bit single data read. The DMA LMB master will forward the requested 8bit, 16bit or 32bit data to the DMA Bus switch and save the 64bit read data together with the related 64bit aligned address in the DMA LMB master read buffer. If the next and subsequent read access to a segment 8 address is identical (64bit aligned) to the actual read buffer contents, the requested read data will be read from the read buffer by the DMA LMB master instead of reading it from the LMB bus.

1) The complete list of FPI master priorities can be found in the FPI Bus Control Unit Chapter.

2) The complete list of LMB master priorities can be found in the Local Memory Bus Controller Unit Chapter.

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If the next read to a segment 8 address is not identical (64bit aligned) to the actual read buffer contents, the contents of the read buffer is invalidated. A 64bit LMB read is generated by the DMA LMB master interface, the requested 8bit, 16bit or 32 bit data is forwarded to the DMA Bus switch and the read buffer is updated with the new 64bit data and its related address.

A DMA write to a segment 8 address (8bit, 16bit, 32bit write, 64bit write is not supported) invalidates the read buffer.

11.2.10 DMA Module Bridge Functionality

The DMA module includes bridge functionality:

- from the FPI Bus to the DMA Peripheral Interface
- from the DMA Peripheral Interface to the FPI Bus and LMB Bus.

FPI Bus -> LMB Bus

The DMA module does not forward transaction from the FPI Bus to the LMB Bus. The DMA module does not support / include bridge functionality between FPI Bus and LMB Bus.

FPI Bus -> DMA Peripheral Interface (MLI, Memory Check, Cerberus, ...)

The DMA module forwards transactions from the FPI bus to the DMA Peripheral Interface (FPI -> MLI, Memory Check, Cerberus, ...). The identification of the target module on the DMA Peripheral Interface is done by address decoding.

DMA Peripheral Interface -> On Chip Bus (FPI Bus, LMB Bus)

The DMA module forwards transactions from the active modules that are connected to the DMA Peripheral Interface (Cerberus, MLI, ...) to the FPI Bus and LMB Bus. The identification of the target On Chip Bus is done by address decoding.

Direct Memory Access Controller (DMA)

11.2.11 On-Chip Debug Capabilities

The DMA controller in the TC1728 provides some debugging capabilities. These debug features support:

- Soft-suspend Mode of DMA channels
- Break signal generation
- Trace signal generation

In Soft-suspend mode, the operations of DMA channels are stopped. Pending read or write transfers in the DMA module On Chip Bus Master Interfaces (LMB Master Interface, FPI Master Interface) are finished. Under certain conditions also a break signal is generated for the on-chip debug support logic. Further, DMA trace information can be output.

In Soft-suspend mode, the DMA module provides access to all control registers of the DMA module (incl. Move Engines and Memory Checker Module) and to the peripherals connected to the DMA Peripheral Interface.

11.2.11.1 Hard-suspend Mode

The Hard-Suspend Mode is controlled in the TC1728 DMA module CLC register but should not be used in order to guarantee access to the device via JTAG (Cerberus). Possible support of the Hard-suspend mode by the peripherals connected to the DMA Peripheral Interface is described in the related module chapters.

11.2.11.2 Soft-suspend Mode

The TC1728 on-chip debug control unit is able to generate a Soft-suspend Mode request (SUSREQ) for the DMA controller. When this soft-suspend request becomes active, the state of a DMA channel becomes frozen regarding hardware changes to ensure that the state of the DMA channels can be analyzed by reading the register contents. Pending read or write transfers in the DMA module On Chip Bus Master Interfaces (LMB Master Interface, FPI Master Interface) are finished. The DMA controller signals its soft suspend mode back to the on-chip debug control via an Soft-suspend acknowledge. The Soft-suspend acknowledge becomes active when all DMA channels *mn* that are enabled for the Soft-suspend Mode have set its suspend active status flag SUSPMR.SUSACmn.

Soft-suspend Mode of DMA channel *mn* is entered if its suspend enable bit SUSENmn in the Suspend Mode Register SUSPMR is set. When SUSREQ becomes active, the operation of all DMA channels *mn* that are enabled for Soft-suspend Mode is stopped automatically after its current DMA transfers have been finished in the transaction control unit. Afterwards, the suspend active status flag SUSPMR.SUSACmn is set, indicating that DMA channel *mn* is in Soft-suspend Mode. DMA channels that are disabled for Suspend Mode (SUSENmn = 0) continue with its normal operation.

In Soft-suspend Mode, register contents can be modified. These modifications are taken into account for further DMA transactions or DMA transfers of the related DMA channel

Direct Memory Access Controller (DMA)

after Suspend Mode has been left again. Suspend Mode of DMA channel m n is left and its normal operation continues if either the SUSREQ signal becomes inactive, or if the enable bit SUSEN m n is reset by software.

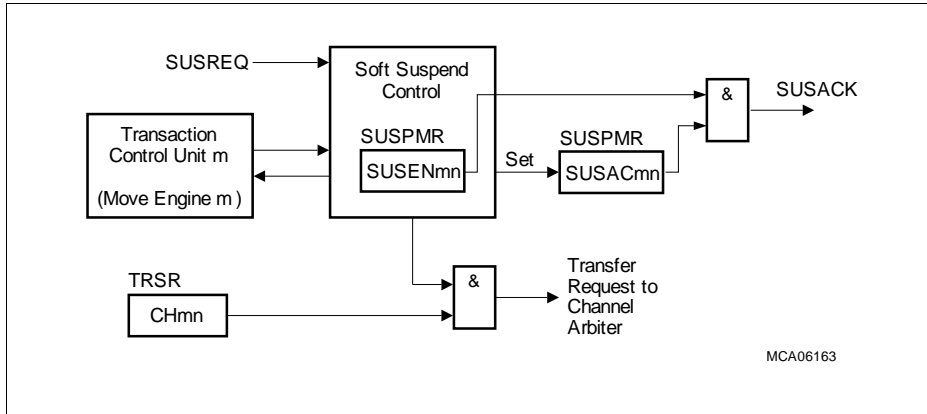


Figure 11-15 Soft-suspend Mode Control ($m = 0-1$)

11.2.11.3 Break Signal Generation

The DMA controller provides one BREAK output signal that is generated for the on-chip debug support logic (see [Figure 11-16](#)). The DMA sub-block is able to detect two break conditions:

- Transaction lost interrupt has occurred
- DMA request transitions, indicated by bits TRSR.CH m n

The output lines of the two break conditions in the DMA sub-block are OR-ed together to the BREAK output signal.

A transaction lost break condition occurs in DMA Sub-Block m whenever at least one of its eight transaction lost interrupts becomes active, and when enable bit OCDSR.BRL0 is set. The transaction lost interrupts do not generate a break condition if OCDSR.BRL0 = 0. Transaction interrupt control is described in [Section 11.2.12.2](#).

The second break condition of DMA Sub-Block m becomes active when the transaction request bit TRSR.CH m n of one of its eight DMA channels n (as selected by OCDSR.BCHSn) indicates a transition of its state. The CH m n transition type (change from 'no request is pending' to 'request is pending', change from 'request is pending' to 'no request is pending', changes in both directions) is selected by bit field OCDSR.BTCR n .

Direct Memory Access Controller (DMA)

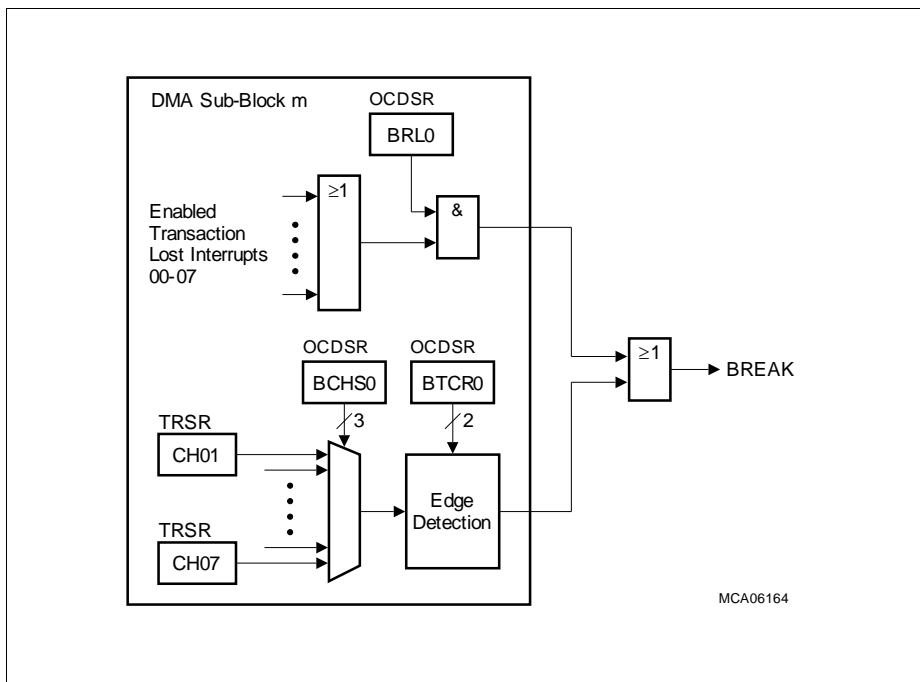


Figure 11-16 DMA Break Event Generation (m = 0-1)

Direct Memory Access Controller (DMA)**11.2.12 Interrupts**

The interrupt structure of the DMA controller is a very flexible control logic that allows an interrupt coming from an interrupt source within four interrupt source types to be connected to each of the sixteen interrupt outputs. This permits, for example, DMA channels that very rarely generate interrupts to share one interrupt node. The remaining interrupt nodes can be assigned to dedicated DMA channels to reduce the interrupt overhead for these channels. The four interrupt source types are:

- Channel interrupts
- Transaction lost interrupt
- Move Engine interrupts
- Wrap buffer interrupts

Some of the interrupt functions are common to all of the four interrupt source types. An interrupt event, internally generated as a request pulse, is always stored in an interrupt status flag. This interrupt status flag can be reset by software. Further, the interrupt event can be enabled or disabled. When an interrupt event is enabled, a 4-bit Interrupt Node Pointer determines which of the sixteen interrupt outputs will be activated.

The following sections describe each of the four interrupt source types in more detail.

11.2.12.1 Channel Interrupts

Each DMA channel *mn* has one associated channel interrupt. It can always be activated after a DMA transfer, or when *CHSRmn.TCOUNT* matches with the value of bit field *CHSRmn.IRDV* after it has been decremented after a DMA transfer. The pattern detection interrupts that are combined with the channel interrupts (one common Interrupt Node Pointer *CHICRmn.INTP*) are activated when the pattern detection interrupt of DMA channel *mn* becomes active (when enabled by *CHCRmn.PATSEL* not equal 00_B).

A channel interrupt of DMA channel *mn* is indicated when status flag *INTSR.ICHmn* is set. The status flags *ICHmn* and *IPMmn* can be reset together by software when setting bit *INTCR.CICHmn* (or *CHRSTR.CHmn*). The channel interrupt of DMA channel *mn* is enabled when bit *CHICRmn.INTCT[1]* is set. The channel interrupt pointer *CHICRmn.INTP* determines which of the interrupt outputs *SR[15:0]*¹⁾ will be activated on an active channel interrupt or pattern detection interrupt. Note that the signal that is set signal for the *ICHmn* flag is available as *CHmn_OUT* signal at the DMA module boundary.

Bit *CHICRmn.INTCT[0]* selects these two types of interrupt sources. For the compare operation, bit field *IRDV* (4-bit) is zero-extended to 10-bit and then compared with the 10-bit *TCOUNT* value. This means that a *TCOUNT* match interrupt can be generated after one of the last 16 DMA transfers of a DMA transaction. Note that with

1) In the TC1728, only *SR[7:0]* are connected to interrupt nodes. *SR[8:15]* are used for DMA channel triggering/connections.

Direct Memory Access Controller (DMA)

11.2.12.2 Transaction Lost Interrupt

Each DMA channel mn is able to detect a transaction request lost condition. This condition becomes true when a new hardware or software DMA request occurs while the previous transaction or transfer on DMA channel mn is not finished, indicated by $TRSR.CHmn$ still set. If such a transaction request lost condition occurs, bit $ERRSR.TRLmn$ is set. The transaction lost interrupts of all DMA channels are OR-ed together to one common transaction lost interrupt that can be directed to one of the interrupt outputs $SR[15:0]$ ¹⁾ by setting the transaction lost interrupt pointer $EER.TRLINP$ with a corresponding value.

A transaction request lost condition of DMA channel mn is indicated by status flag $ERRSR.TRLmn$, which can be reset by setting bit $CLRE.CTLmn$ or $CHRSTR.CHmn$. The transaction lost interrupt for DMA channel mn is enabled when bit $EER.ETRLmn$ is set.

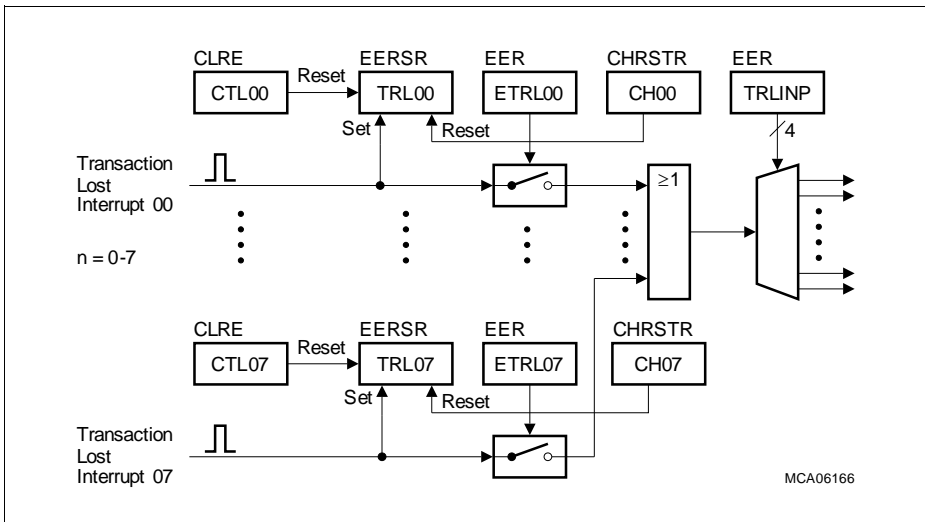


Figure 11-18 Transaction Lost Interrupt

1) In the TC1728 $SR[7:0]$ are connected to interrupt nodes. $SR[15:8]$ are used as DMA channel trigger signals.

Direct Memory Access Controller (DMA)

11.2.12.3 Move Engine Interrupts

The Move Engine is able to detect error conditions that occur during accesses to the FPI Bus and LMB Bus interfaces of the Bus Switch (see [Figure 11-14](#)). Two error conditions can be detected:

- Source error
- Destination error

A source error indicates an FPI Bus or LMB Bus error that occurred during a read move from the data source. A destination error indicates an FPI Bus or LMB Bus error that occurred during a write move to the data destination.

A source error of Move Engine 0 is indicated by the status flag ERRSR.ME0SER. Status flag ME0SER can be reset by software when setting bit CLRE.CME0SER. The source error interrupt of Move Engine 0 is enabled when bit EER.EME0SER is set. Separate reset, status, and enable bits are available in the Move Engines for source error condition, as well as for destination error condition. The Move Engine's interrupts can be directed to one of the interrupt outputs SR[15:0]¹⁾ by setting the Move Engine interrupt pointer EER.ME0INP with a corresponding value.

Note that in case of a read move error, the write move is not executed but the destination address is updated.

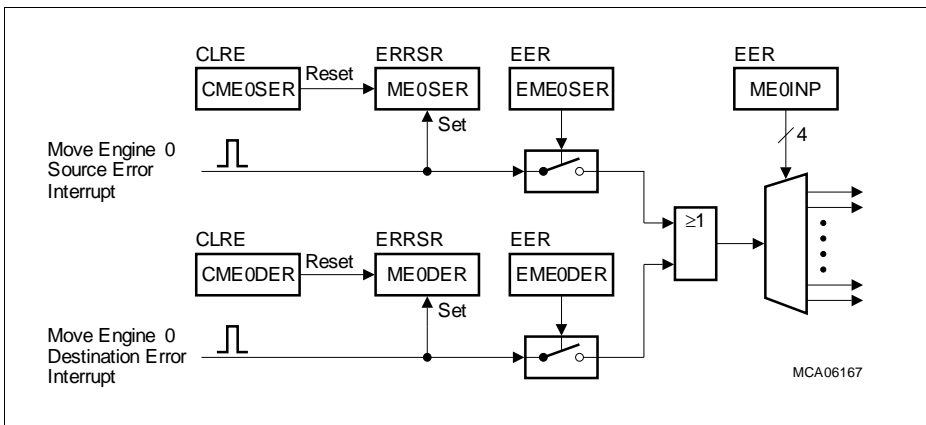


Figure 11-19 Move Engine Interrupts

1) In the TC1728 SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel trigger signals.

Direct Memory Access Controller (DMA)

When a Move Engine 0 source or destination error occurs, additional status bits and bit fields are provided in the error status register ERRSR to indicate the following two status conditions:

- At which On Chip Bus interface a Move Engine 0 error occurred (FPI or LMB)
- For which DMA channel a Move Engine 0 read or write move error was reported (LECME0)

These error status bits and bit fields are required by error handler software to detect in detail at which On Chip Bus interface and DMA channel the Move Engine error has been generated. ERRSR.FPIER or ERRSR.LMBER is reset when bits CLRE.CFPI0ER or CLRE.CFPI1ER is respectively set.

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11.2.12.4 Wrap Buffer Interrupts

Each DMA channel mn is able to generate a wrap buffer interrupt for source buffer or destination buffer overflow. Further details on the pattern detection are described in [Section 11.2.13](#).

A wrap source buffer interrupt of DMA channel mn is indicated by status flag $WRPSR.WRPSmn$. A wrap destination buffer interrupt of DMA channel mn is indicated by the status flag $WRPSR.WRPDmn$. Both interrupt status flags can be reset by software when bit $INTCR.CWRPmn$ (or $CHRSTR.CHmn$ becomes set). The wrap source buffer interrupt is enabled when bit $CHICRmn.WRPSE$ is set. The wrap destination buffer interrupt is enabled when bit $CHICRmn.WRPDE$ is set. The two interrupts for wrap source buffer and wrap destination buffer are OR-ed together to one common wrap buffer interrupt of DMA channel mn that can be directed to one of the interrupt outputs $SR[15:0]$ ¹⁾ by setting the wrap buffer interrupt pointer $CHICRmn.WRPP$ with a corresponding value. Note that the pattern match should not be enabled while a wrap interrupt is enabled for the same channel.

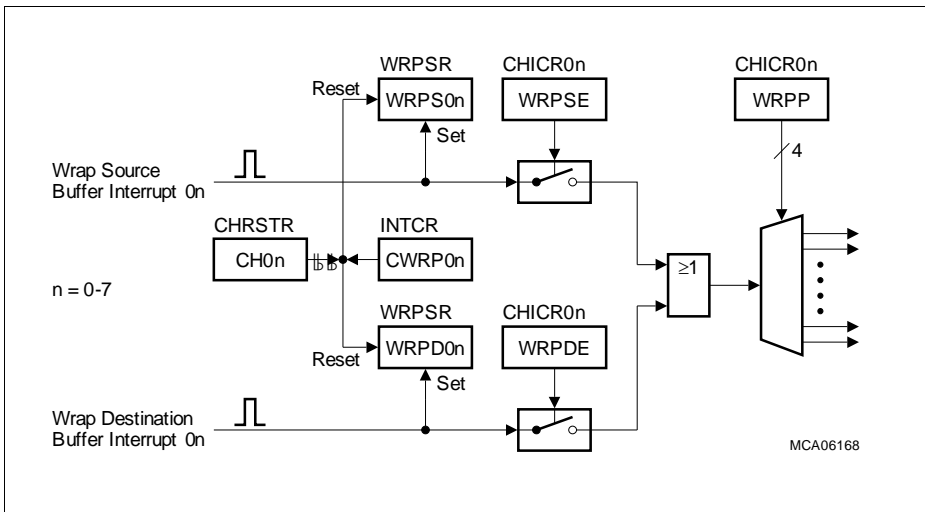


Figure 11-20 DMA Wrap Buffer Interrupts($m = 0-1$)

1) In the TC1728 $SR[7:0]$ are connected to interrupt nodes. $SR[15:8]$ are used as DMA channel trigger signals.

Direct Memory Access Controller (DMA)**11.2.12.5 Interrupt Request Compressor**

The interrupt control logic of the DMA controller uses an interrupt compressing scheme that allows high flexibility in interrupt processing. The request compressor logic as shown in **Figure 11-21** condenses the $8 + 1 + 1 + 8 = 18$ interrupt sources to the sixteen interrupt outputs. Each internal interrupt source can be directed to one of the sixteen interrupt outputs $SR[15:0]$ ¹⁾ by using a 4-bit Interrupt Node Pointer. This also allows the connection of more than one interrupt source to one interrupt output SRx . Each interrupt output $SR[15:0]$ ¹⁾ can also be activated by writing a 1 to the corresponding bit $GINTR.SIDMAX$.

1) In the TC1728 $SR[7:0]$ are connected to interrupt nodes. $SR[15:8]$ are used as DMA channel trigger signals.

Direct Memory Access Controller (DMA)

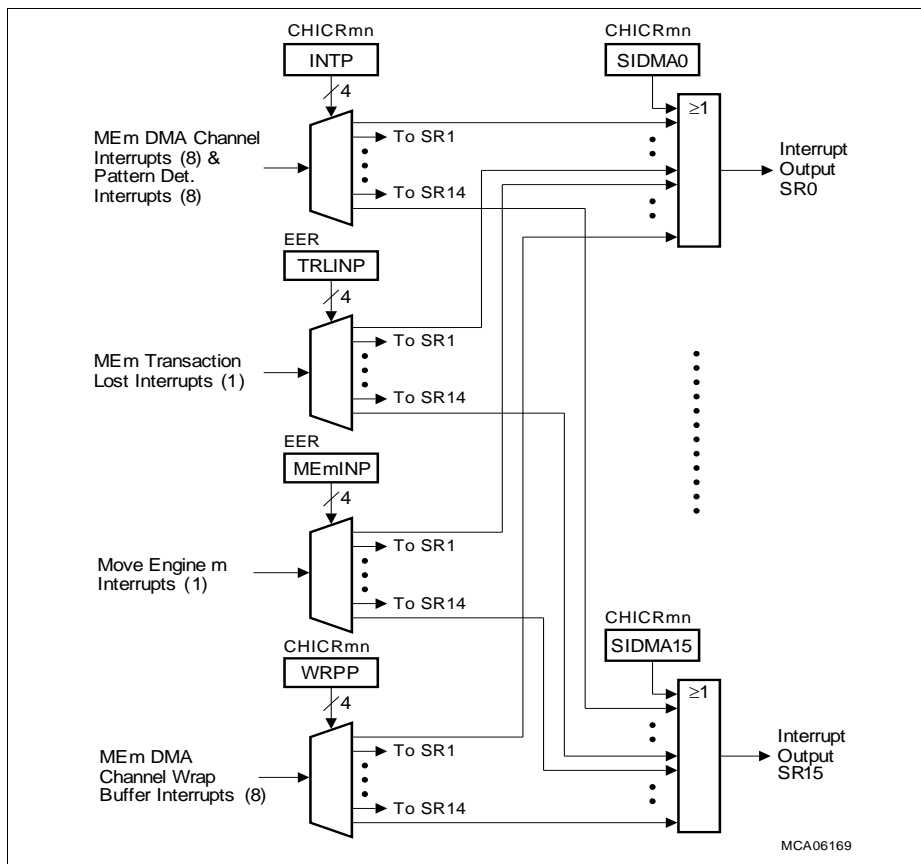


Figure 11-21 DMA Interrupt Request Compressor (m = 0-1)

11.2.13 Pattern Detection

The Move Engine in the DMA Sub-Block provides a register MEOR that contains the data that was read during the last read move. Parts of this read move data can be compared after the read move to data that is stored in the Move Engine pattern register MEOPR of DMA Sub-Block 0. The result of this pattern compare match is always stored in a bit (LXO) of the channel status register of the DMA channel mn that is currently executing the DMA move. Therefore, the pattern match result LXO of the previous read move can also be combined together with the pattern match result of the actual read move. MEOR is overwritten with each read move.

Direct Memory Access Controller (DMA)

As the compare match patterns are stored in the Move Engine 0 (register ME0PR), its compare patterns are used for all DMA channels that are assigned to Move Engine 0 (all DMA channels of the DMA Sub-Block 0).

The configuration and capabilities of the pattern detection logic further depends on the settings of CHCRmn.CHDW. CHDW determines the data width for the read and write moves individually for each DMA channel mn. Another control bit, CHCRmn.PATSEL, selects among the different operating modes for a specific value of CHDW.

Depending on CHCRmn.PATSEL and on the positive result of the comparison, two actions follow (if CHCRmn.PATSEL=00, no action will be taken when a pattern match is detected, so the wrap interrupt can be used):

- The activation of the interrupt corresponding to the current active channel mn using the Interrupt Pointer defined in CHICRmn.INTP.
- Reset TRSR.HTREmn and TRSR.CHmn in order to stop the current transaction (Hardware and Software request enable). The value of CHSRmn.TCOUNT can be read out by the interrupt software.

The software will have to service the interrupt and to activate again the channel.

Direct Memory Access Controller (DMA)

11.2.13.1 Pattern Compare Logic

Read move data and compare match patterns are compared on a bit-wise level. The logic as shown in **Figure 11-22** is implemented in each COMP block of **Figure 11-23**, **Figure 11-24**, and **Figure 11-25**. One COMP block controls either 8 bits or 16 bits of data and makes it possible to mask each data bit for the compare operation.

In the compare logic for one bit of the COMP block, a data bit from register ME0R is compared to the corresponding pattern bit stored in register ME0PR. If both bits are equal and a pattern mask bit stored in another part of register ME0PR is 0, the compare matched condition becomes active. When the pattern mask bit is set to 1, the compare matched condition is always active (set) for the related bit. When the compare matched conditions for each bit within a COMP block are true, the compare match output line of the COMP block becomes active.

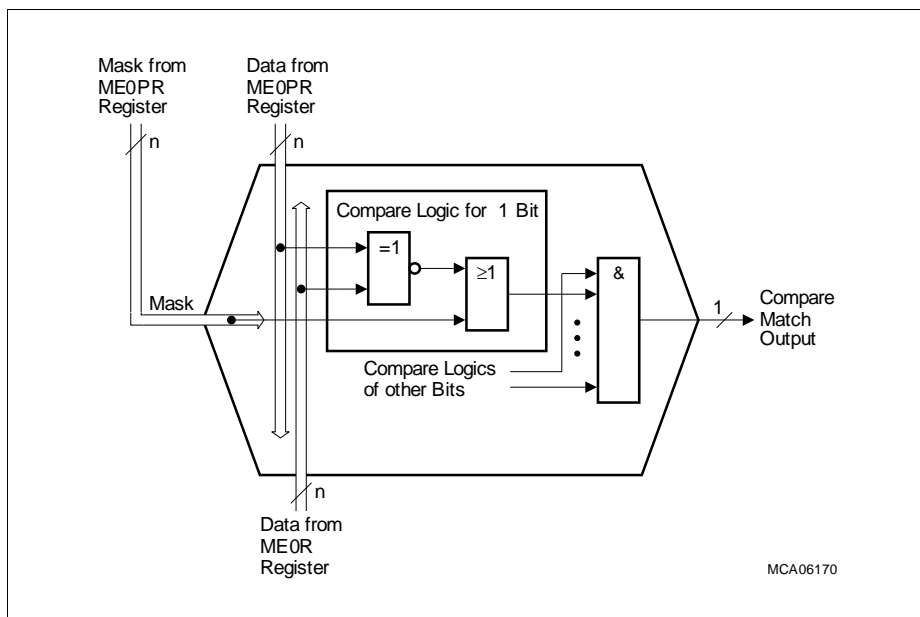


Figure 11-22 Pattern Compare Logic (COMP Block)

Direct Memory Access Controller (DMA)

11.2.13.2 Pattern Detection for 8-bit Data Width

When 8-bit channel data width is selected ($\text{CHCRmn.CHDW} = 00_{\text{B}}$), the pattern detection logic is configured as shown in [Figure 11-23](#). Three compare match configurations are possible.

Table 11-4 Pattern Detection for 8-bit Data Width

CHCRmn. PATSEL	Pattern Detection Operating Modes
00 _B	Pattern detection disabled
01 _B	Pattern compare of RD00 to PAT00, masked by PAT02
10 _B	Pattern compare of RD00 to PAT01, masked by PAT03
11 _B	Pattern compare of RD00 to PAT00, masked by PAT02 of the <u>actual</u> read move and Pattern compare of RD00 to PAT01, masked by PAT03 of the <u>previous</u> read move of DMA channel mn

When 8-bit channel data width is selected, the pattern detection logic allows the byte of one read move to be compared with two different patterns. Further, after each read move the pattern match result “RD00 with PAT01, masked by PAT03” is stored in bit CHCRmn.LXO. This operating mode allows, for example, two-byte sequences to be detected in an 8-bit data stream coming from a serial peripheral unit with 8-bit data width (e.g.: recognition of carriage-return, line-feed characters). A mask operation of each compared bit is possible.

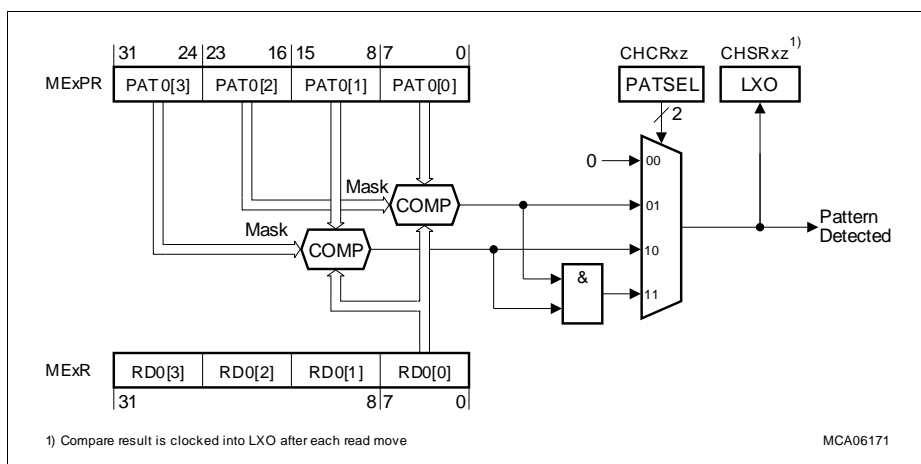


Figure 11-23 Pattern Detection for 8-bit Data Width ($\text{CHCRmn.CHDW} = 00_{\text{B}}$) ($m = 0-$

Direct Memory Access Controller (DMA)

1)

11.2.13.3 Pattern Detection for 16-bit Data Width

When 16-bit channel data width is selected (CHCRmn.CHDW = 01_B) the pattern detection logic can be configured as shown in [Figure 11-24](#). Three compare match configurations are possible.

Table 11-5 Pattern Detection for 16-bit Data Width

CHCRmn. PATSEL	ADRCRmn. INCS	Pattern Detection Operating Modes
00 _B	–	Pattern detection disabled
01 _B	–	Aligned Mode: Pattern compare of RD0[1:0] to PAT0[1:0], masked by PAT0[3:2]
10 _B	0	Unaligned Mode 1 (Source Address Decrement): Pattern compare of RD01 to PAT00, masked by PAT02 of the <u>actual</u> read move and Pattern compare of RD00 to PAT01, masked by PAT03 (LXO) of the <u>previous</u> read move of DMA channel mn
	1	Unaligned Mode 2 (Source Address Increment): Pattern compare of RD00 to PAT01, masked by PAT03 of the <u>actual</u> read move and Pattern compare of RD01 to PAT00, masked by PAT02 (LXO) of the <u>previous</u> read move of DMA channel mn
11 _B	0 or 1	Combined Mode: Pattern compare for aligned mode (PATSEL = 01 _B) or unaligned modes (PATSEL = 10 _B)

When 16-bit channel data width is selected, the pattern detection logic makes it possible to compare the complete half-word of one read move only (aligned mode) or to compare upper and lower byte of two consecutive read moves (unaligned modes). Both modes can be combined (combined mode) too. A mask operation of each compared bit is possible.

In unaligned mode 1 (source address decremented), the high byte (RD01) of the current and the low byte (RD00) of the previous 16-bit read move are compared.

In unaligned mode 2 (source address incremented), the low byte (RD00) of the current and the high byte (RD01) of the previous 16-bit read move are compared.

If it is not known on which byte boundary (even or odd address) the 16-bit pattern to be detected is located, the combined mode should be used. This mode is the most flexible

Direct Memory Access Controller (DMA)

mode that combines the pattern search capability for aligned and unaligned 16-bit data searches.

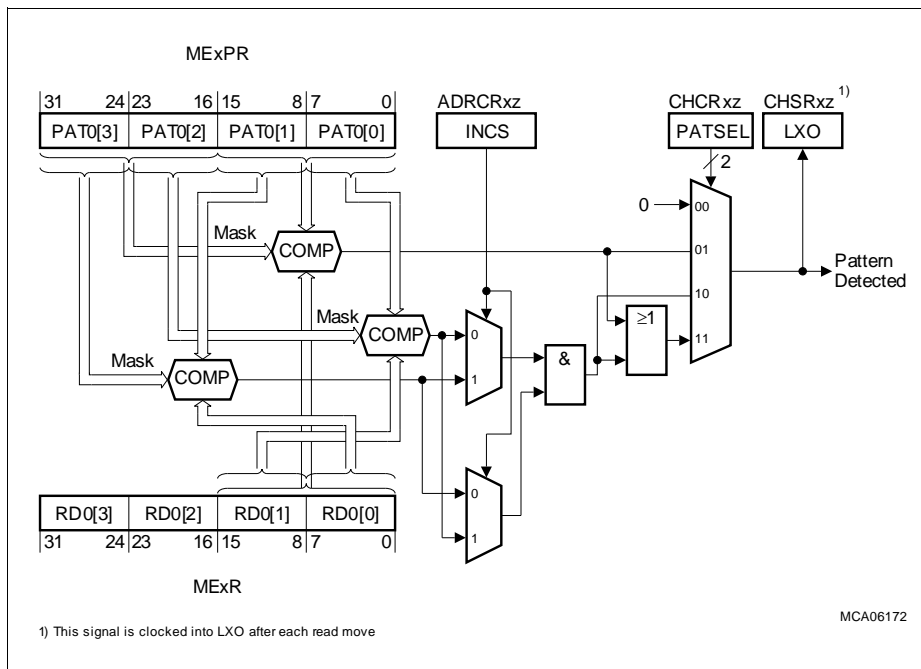


Figure 11-24 Pattern Detection for 16-bit Data Width (CHCRmn.CHDW = 01_B) (m = 0-1)

Direct Memory Access Controller (DMA)

11.2.13.4 Pattern Detection for 32-bit Data Width

When 32-bit channel data width is selected ($\text{CHCRmn.CHDW} = 10_{\text{B}}$) the pattern detection logic is configured as shown in [Figure 11-25](#). Three compare match configurations are possible.

Table 11-6 Pattern Detection for 32-bit Data Width

CHCRmn. PATSEL	Pattern Detection Operating Modes
00 _B	Pattern detection disabled
01 _B	Unmasked pattern compare of RD0[1:0] to PAT0[1:0]
10 _B	Unmasked pattern compare of RD0[3:2] to PAT0[3:2]
11 _B	Unmasked pattern compare of RD0[3:0] to PAT0[3:0]

In 32-bit channel data width mode, the pattern detection logic makes it possible to compare the lower half-word only, the upper half-word only, or the complete 32-bit word with a pattern stored in the ME0PR register. A mask operation is not possible.

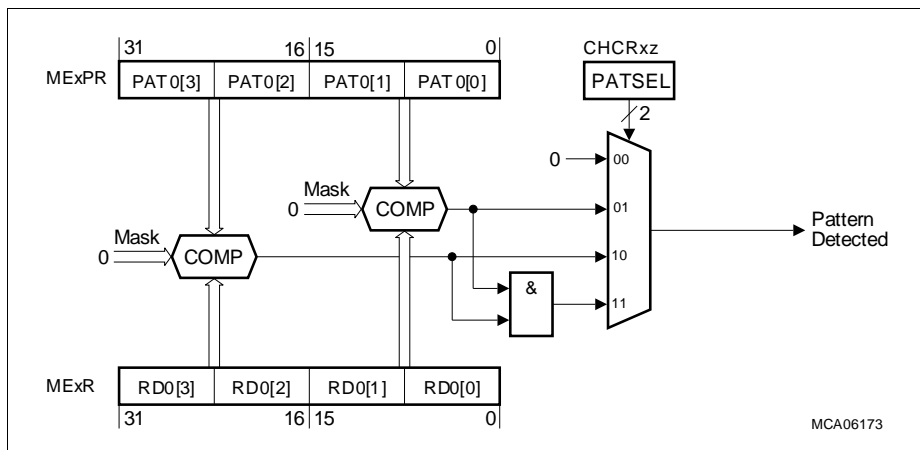


Figure 11-25 Pattern Detection for 32-bit Data Width ($\text{CHCRmn.CHDW} = 10_{\text{B}}$)
($m = 0-1$)

Direct Memory Access Controller (DMA)

11.2.14 Access Protection

The DMA controller provides an access protection logic that makes it possible to disable read and write accesses of the Move Engines to specific parts of the memory map. Each address of a read move and a write move is always checked to determine if it is within an address range that is enabled for read/write access. If no address range is valid for an actual move address, a Move Engine interrupt can be generated.

The access protection logic handles two levels of address range definitions:

- Fixed address range
- Programmable address range extension

There are 32 fixed address ranges available that can be individually enabled/disabled in the Move Engine by the address range enable bits AENx (x = 0-31): These bits are located in the Move Engine 0/1 Access Enable Register ME0AENR/ME1AENR. If bit AENx is set, read/write accesses to the associated address range x are allowed. If bit AENx is cleared (default after reset), read/write accesses to the associated address range x are not executed and a Move Engine interrupt for source or destination move is generated (see also [Section 11.2.12.3](#)).

Additionally four programmable address range extensions are available for each of the two Move Engines that are fixed assigned to the OVRAM, the PCP PRAM, the PMI SPRAM and the DMI LDRAM (see also [Section 11.4.2](#)). Each programmable address range extension makes it possible to define a sub-range within the corresponding address range where an access will be executed by the corresponding Move Engine if the address range is not disabled by the corresponding AENx bit. An access to the address range outside the defined sub-range will not be executed by the corresponding Move Engine. The parameters for the sub-ranges are stored in the Move Engine 0/1 Access Range Register ME0ARR/ME1ARR. The programmable address range extension is a feature that is applicable for memory access protection of memory blocks. In such an application, several memory sections are defined as sub-ranges of a complete memory block.

Figure 11-26 shows the two levels of address range definitions with the resulting address sub-ranges of the programmable address range extension. In a fixed address range, the width of fixed and variable address bits is constant. Number “a” determines the lowest bit position of the fixed address, and is fixed individually and product-specific for each of the 32 fixed address ranges. With the programmable address range extension, the variable address part of the fixed address range definition (as defined by AENx) is reduced by the definition of a programmable number (up to 32) of sub-ranges. Bit field ME0ARR.SIZE/ME1ARR.SIZE determines the sub-range size and bit field ME0ARR.SLICE/ME1ARR.SLICE determines which of the sub-ranges is currently selected for access protection control. The two parameters (SIZE, SLICE) of the four address range extensions of a move engine are numbered by index “n” (n = 0-3).

In the TC1728 the number “a” is defined in the following way:

Direct Memory Access Controller (DMA)

- SIZE0/SLIZE0 covering the SPRAM , “a” = 17
- SIZE1/SLIZE1 covering the OVRAM , “a” = 16
- SIZE2/SLIZE2 covering the LDRAM , “a” = 17
- SIZE3/SLIZE3 covering the PRAM, “a” = 16

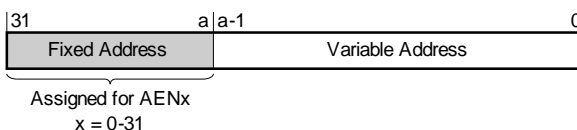
Two sub-range examples (see [Figure 11-26](#)):

- $2^3 = 8$ sub-ranges are available with SIZE = 100_B. SLICE[2:0] selects one out of the eight sub-ranges. SLICE[4:3] is “don’t care”.
- $2^7 = 128$ sub-ranges are basically available with SIZE_n = 000_B. SLICE_n[4:0] selects one out of the lowest 32 sub-ranges. The upper $3 \times 32 = 96$ sub-ranges are not selectable (fixed address bits a-1 and a-2).

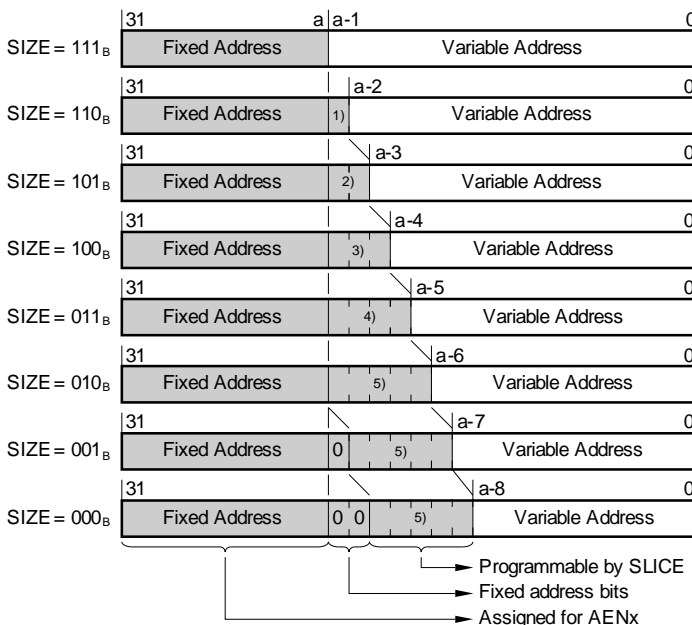
Note: The definition of the fixed address ranges x and the assignment of each sub-range to one of the fixed address ranges is product-specific. The definitions of the address ranges for the DMA controller as implemented in the TC1728 are defined on [Page 11-112](#).

Direct Memory Access Controller (DMA)

Fixed Address Range



Programmable Address Range Extension



- 1) This bit is defined by SLICE[0]
- 2) These 2 bits are defined by SLICE[1:0]
- 3) These 3 bits are defined by SLICE[2:0]
- 4) These 4 bits are defined by SLICE[3:0]
- 5) These 5 bits are defined by SLICE[4:0]

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Figure 11-26 Access Protection Address Range Definitions

Direct Memory Access Controller (DMA)

11.3 DMA Module Registers

Figure 11-27 and **Table 11-8** show all registers associated with the DMA Controller Kernel. Additionally, **Table 11-8** includes the DMA module specific registers that are also showed in **Table 11-29**. All DMA kernel register names described in this section are also referenced in other parts of the TC1728 User's Manual by the module name prefix "DMA_".

The registers are numbered by one index to indicate the related DMA Sub-Block and one index to indicate the related DMA channel: Index "m" refers to the DMA Sub-Block number (m = 0-1) and Index "n" or "x" refers to the channel number (n = 0-7 or x = 0-7) within the DMA Sub-Block.

DMA Registers Overview

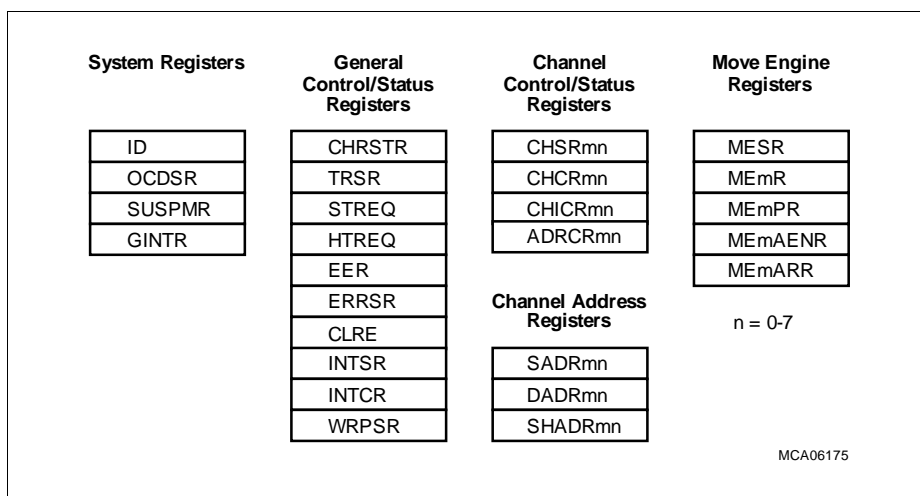


Figure 11-27 DMA Kernel Registers

Table 11-7 Registers Address Space - DMA Module

Module	Base Address	End Address	Note
DMA	F000 3C00 _H	F000 3EFF _H	

Direct Memory Access Controller (DMA)

Table 11-8 Registers Overview - DMA Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
DMA_CLC	DMA Clock Control Register	000 _H	U, SV	SV, E	3	Page 11-122
-	Reserved	004 _H	nBE	SV	-	-
DMA_ID	DMA Module Identification Register	008 _H	U, SV	BE	-	Page 11-54
-	Reserved	00C _H	BE	BE	-	-
DMA_CHR STR	DMA Channel Reset Request Register	010 _H	U, SV	SV	3	Page 11-60
DMA_TRS R	DMA Transaction Request State Register	014 _H	U, SV	BE	3	Page 11-61
DMA_STR EQ	DMA Software Transaction Request Register	018 _H	U, SV	SV	3	Page 11-63
DMA_HTR EQ	DMA Hardware Transaction Request Register	01C _H	U, SV	SV	3	Page 11-64
DMA_EER	DMA Enable Error Register	020 _H	U, SV	SV	3	Page 11-66
DMA_ERR SR	DMA Error Status Register	024 _H	U, SV	BE	3	Page 11-69
DMA_CLR E	DMA Clear Error Register	028 _H	U, SV	SV	3	Page 11-72
DMA_GIN TR	DMA Global Interrupt Set Register	02C _H	U, SV	SV	3	Page 11-59
DMA_MES R	DMA Move Engine Status Register	030 _H	U, SV	BE	3	Page 11-79
DMA_ME0 R	DMA Move Engine 0 Read Register	034 _H	U, SV	BE	3	Page 11-81
DMA_ME1 R	DMA Move Engine 1 Read Register	038 _H	U, SV	BE	3	Page 11-81
DMA_ME0 PR	DMA Move Engine 0 Pattern Register	03C _H	U, SV	SV	3	Page 11-81

Direct Memory Access Controller (DMA)

Table 11-8 Registers Overview - DMA Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
DMA_ME1 PR	DMA Move Engine 1 Pattern Register	040 _H	U, SV	SV	3	Page 11-81
DMA_ME0AENR	DMA Move Engine 0 Access Enable Register	044 _H	U, SV	SV, E	3	Page 11-82
DMA_ME0 ARR	DMA Move Engine 0 Access Range Register	048 _H	U, SV	SV, E	3	Page 11-84
DMA_ME1AENR	DMA Move Engine 1 Access Enable Register	04C _H	U, SV	SV, E	3	Page 11-82
DMA_ME1 ARR	DMA Move Engine 1 Access Range Register	050 _H	U, SV	SV, E	3	Page 11-84
DMA_INTS R	DMA Interrupt Status Register	054 _H	U, SV	BE	3	Page 11-74
DMA_INTC R	DMA Interrupt Clear Register	058 _H	U, SV	SV	3	Page 11-78
DMA_WRP SR	DMA Wrap Status Register	05C _H	U, SV	BE	3	Page 11-76
-	Reserved	060 _H	BE	BE	-	-
DMA_OCD SR	DMA OCDS Register	064 _H	U, SV	SV, E	1	Page 11-55
DMA_SUS PMR	DMA Suspend Mode Register	068 _H	U, SV	SV, E	1	Page 11-57
-	Reserved	06C _H -07C _H	BE	BE	-	-
DMA_CHS Rmn	DMA Channel mn Status Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 080 _H	U, SV	BE	3	Page 11-90

Direct Memory Access Controller (DMA)

Table 11-8 Registers Overview - DMA Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
DMA_CHC Rmn	DMA Channel mn Control Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 084 _H	U, SV	SV	3	Page 11-86
DMA_CHI CRmn	DMA Channel mn Interrupt Control Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 088 _H	U, SV	SV	3	Page 11-91
DMA_ADRCRmn	DMA Channel mn Address Control Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 08C _H	U, SV	SV	3	Page 11-93
DMA_SAD Rmn	DMA Channel mn Source Address Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 090 _H	U, SV	SV	3	Page 11-98
DMA_DAD Rmn	DMA Channel mn Destination Address Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 094 _H	U, SV	SV	3	Page 11-99
DMA_SHA DRmn	DMA Channel mn Shadow Address Register (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 098 _H	U, SV	BE / SV ²⁾	3	Page 11-100
-	Reserved (n = 0-7, m = 0-1)	(n x 20 _H) + (m x 100 _H) + 09C _H	BE	BE	-	-

Direct Memory Access Controller (DMA)

Table 11-8 Registers Overview - DMA Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
-	Reserved	280 _H - 29C _H	BE	BE	-	-
DMA_MLI0SRC3	DMA MLI0 Service Request Control Reg. 3	2A0 _H	U, SV	SV	3	Page 11-124
DMA_MLI0SRC2	DMA MLI0 Service Request Control Reg. 2	2A4 _H	U, SV	SV	3	Page 11-124
DMA_MLI0SRC1	DMA MLI0 Service Request Control Reg. 1	2A8 _H	U, SV	SV	3	Page 11-124
DMA_MLI0SRC0	DMA MLI0 Service Request Control Reg. 0	2AC _H	U, SV	SV	3	Page 11-124
–	Reserved	2B0 _H - 2DC _H	BE	BE	-	-
DMA_SRC7	DMA Service Request Control Register 7	2E0 _H	U, SV	SV	3	Page 11-123
DMA_SRC6	DMA Service Request Control Register 6	2E4 _H	U, SV	SV	3	Page 11-123
DMA_SRC5	DMA Service Request Control Register 5	2E8 _H	U, SV	SV	3	Page 11-123
DMA_SRC4	DMA Service Request Control Register 4	2EC _H	U, SV	SV	3	Page 11-123
DMA_SRC3	DMA Service Request Control Register 3	2F0 _H	U, SV	SV	3	Page 11-123
DMA_SRC2	DMA Service Request Control Register 2	2F4 _H	U, SV	SV	3	Page 11-123
DMA_SRC1	DMA Service Request Control Register 1	2F8 _H	U, SV	SV	3	Page 11-123
DMA_SRC0	DMA Service Request Control Register 0	2FC _H	U, SV	SV	3	Page 11-123

1) The absolute register address is calculated as follows:

Module Base Address ([Table 11-7](#)) + Offset Address (shown in this column)

Further, the following ranges for parameters i, k, x, and n are valid: i = 0-7, k = 0-7, x = 0-1, n = 0-63.

Direct Memory Access Controller (DMA)

- 2) Write access mode to DMA_SHADRMn is controlled by the register bit DMA_ADRCRMn.SHWEN.
DMA_ADRCRMn.SHWEN='0' -> Access Mode Write for DMA_SHADRMn is BE.
DMA_ADRCRMn.SHWEN='1' -> Access Mode Write for DMA_SHADRMn is SV.

Note: Register bits marked "w" in the following register description are virtual registers and do not contain flip-flops. They are always read as 0.

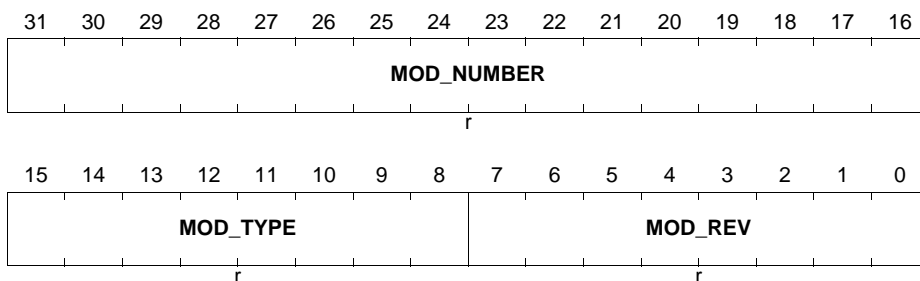
Direct Memory Access Controller (DMA)

11.3.1 System Registers

DMA Module Identification Register.

DMA_ID

Module Identification Register (008_H) **Reset Value: 001A C0XX_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the Memory Checker module is 001A _H .

The OCDS Register describes the break capability of the DMA module. OCDSR is only reset with the OCDS Reset.

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DMA_OCDSR

DMA OCDS Register

(064_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	BRL 1	BCHS1		BTRC1		0		BRL 0	BCHS0		BTRC0				
r	rw	rw		rw		r		rw	rw		rw		rw		

Field	Bits	Type	Description
BTRC0	[1:0]	rw	Break Trigger Condition In Sub-Block 0 This bit field determines the transition type for the transaction request bit TRSR.CH0n that leads to a break condition in DMA Sub-Block 0. 00 _B No break condition is generated 01 _B A break condition is generated when TRSR.CH0n changes from 0 to 1 10 _B A break condition is generated when TRSR.CH0n changes from 1 to 0 11 _B A break condition is generated when TRSR.CH0n changes its state
BCHS0	[4:2]	rw	Break Channel Select In Sub-Block 0 This bit field determines the DMA channel n of DMA Sub-Block 0 whose transaction request bit TRSR.CH0n is observed for signal transitions as defined by BTRC0. 000 _B DMA channel 00 selected 001 _B DMA channel 01 selected ... _B ... 110 _B DMA channel 06 selected 111 _B DMA channel 07 selected

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
BRL0	5	rw	Break On Request Lost in Sub-Block 0 This bit field determines whether a BREAK signal is generated for DMA Sub-Block 0 when at least one of its eight transaction lost interrupts becomes active. 0 _B No break condition is generated 1 _B A break condition is generated for DMA Sub-Block 0 when at least one of its eight transaction lost interrupts becomes active
BTRC1	[9:8]	rw	Break Trigger Condition In Sub-Block 1 This bit field determines the transition type for the transaction request bit TRSR.CH1n that leads to a break condition in DMA Sub-Block 1. 00 _B No break condition is generated 01 _B A break condition is generated when TRSR.CH1n changes from 0 to 1 10 _B A break condition is generated when TRSR.CH1n changes from 1 to 0 11 _B A break condition is generated when TRSR.CH1n changes its state
BCHS1	[12:10]	rw	Break Channel Select In Sub-Block 1 This bit field determines the DMA channel n of DMA Sub-Block 1 whose transaction request bit TRSR.CH1n is observed for signal transitions as defined by BTRC1. 000 _B DMA channel 10 selected 001 _B DMA channel 11 selected ... _B ... 110 _B DMA channel 16 selected 111 _B DMA channel 17 selected
BRL1	13	rw	Break On Request Lost in Sub-Block 1 This bit field determines whether a BREAK signal is generated for DMA Sub-Block 1 when at least one of its eight transaction lost interrupts becomes active. 0 _B No break condition is generated 1 _B A break condition is generated for DMA Sub-Block 1 when at least one of its eight transaction lost interrupts becomes active
0	[7:6], [31:14]	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Suspend Mode Register contains bits for each DMA channel that make it possible to enable/disable its Soft-suspend Mode capability and that indicate its suspend status.

DMA_SUSPMR

DMA Suspend Mode Register

(068_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS
AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS	SUS
EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
SUSEN0n (n = 0-7)	n	rw	Suspend Enable for DMA Channel 1n This bit enables the soft suspend capability individually for each DMA channel 0n. 0 _B DMA channel 0n is disabled for Soft-suspend Mode. The DMA channel 0n does not react on an active suspend request signal SUSREQ. 1 _B DMA channel 0n is enabled for Soft-suspend Mode. If the suspend request signal SUSREQ becomes active, a DMA transaction of DMA channel 0n is stopped after the current DMA transfer has been finished Soft-suspend Mode can be terminated when SUSEN0n is written with 0.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
SUSEN1n (n = 0-7)	8+n	rw	Suspend Enable for DMA Channel 1n This bit enables the soft suspend capability individually for each DMA channel 1n. 0 _B DMA channel 1n is disabled for Soft-suspend Mode. The DMA channel 1n does not react on an active suspend request signal SUSREQ 1 _B DMA channel 1n is enabled for Soft-suspend Mode. If the suspend request signal SUSREQ becomes active, a DMA transaction of DMA channel 1n is stopped after the current DMA transfer has been finished Soft-suspend Mode can be terminated when SUSENmn is written with 0.
SUSAC0n (n = 0-7)	16+n	rh	Suspend Active for DMA Channel 0n This status bit indicates whether DMA channel 0n is in Soft-suspend Mode or not. 0 _B DMA channel 0n is not in Soft-suspend Mode or internal actions are not yet finished after the Soft-suspend Mode was requested 1 _B DMA channel 0n is in Soft-suspend Mode
SUSAC1n (n = 0-7)	24+n	rh	Suspend Active for DMA Channel 1n This status bit indicates whether DMA channel 1n is in Soft-suspend Mode or not. 0 _B DMA channel 1n is not in Soft-suspend Mode or internal actions are not yet finished after the Soft-suspend Mode was requested 1 _B DMA channel 1n is in Soft-suspend Mode

Note: This register is only reset by the Debug reset.

The Global Interrupt Set Register allows the interrupt output lines of the DMA to be activated by software.

Direct Memory Access Controller (DMA)

DMA_GINTR

DMA Global Interrupt Set Register (02C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SI DMA 15	SI DMA 14	SI DMA 13	SI DMA 12	SI DMA 11	SI DMA 10	SI DMA 9	SI DMA 8	SI DMA 7	SI DMA 6	SI DMA 5	SI DMA 4	SI DMA 3	SI DMA 2	SI DMA 1	SI DMA 0
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
SIDMAx (x = 0-15)	x	w	Set DMA Interrupt Output Line x 0 _B No action 1 _B DMA interrupt output line SRx will be activated. Reading this bit returns a 0
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: In the TC1728, SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel request inputs ([Page 11-102](#)).

Direct Memory Access Controller (DMA)

The bits in the Transaction Request State Register indicates which DMA channel is processing a request, and which DMA channel has hardware transaction requests enabled.

DMA_TRSR

DMA Transaction Request State Register

(014_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
HT RE 17	HT RE 16	HT RE 15	HT RE 14	HT RE 13	HT RE 12	HT RE 11	HT RE 10	HT RE 07	HT RE 06	HT RE 05	HT RE 04	HT RE 03	HT RE 02	HT RE 01	HT RE 00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 17	CH 16	CH 15	CH 14	CH 13	CH 12	CH 11	CH 10	CH 07	CH 06	CH 05	CH 04	CH 03	CH 02	CH 01	CH 00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
CH0n (n = 0-7)	n	rh	Transaction Request State of DMA Channel 0n 0 _B No DMA request is pending for channel 0n. 1 _B A DMA request is pending for channel 0n.
CH1n (n = 0-7)	8+n	rh	Transaction Request State of DMA Channel 1n 0 _B No DMA request is pending for channel 1n. 1 _B A DMA request is pending for channel 1n.
HTRE0n (n = 0-7)	16+n	rh	Hardware Transaction Request Enable State of DMA Channel 0n 0 _B Hardware transaction request for DMA Channel 0n is disabled. An input DMA request will not trigger the channel 0n. 1 _B Hardware transaction request for DMA Channel 0n is enabled. The transfers of a DMA transaction are controlled by the corresponding channel request line of the DMA requesting source. HTRE0n is set to 0 when CHSR0n.TCOUNT is decremented and CHSR0n.TCOUNT = 0. HTRE0n can be enabled and disabled with HTREQ.ECH0n or HTREQ.DCH0n.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
HTRE1n (n = 0-7)	24+n	rh	<p>Hardware Transaction Request Enable State of DMA Channel 1n</p> <p>0_B Hardware transaction request for DMA Channel 1n is disabled. An input DMA request will not trigger the channel 1n.</p> <p>1_B Hardware transaction request for DMA Channel 1n is enabled. The transfers of a DMA transaction are controlled by the corresponding channel request line of the DMA requesting source.</p> <p>HTRE1n is set to 0 when CHSR1n.TCOUNT is decremented and CHSR1n.TCOUNT = 0. HTRE1n can be enabled and disabled with HTREQ.ECH1n or HTREQ.DCH1n.</p>

Direct Memory Access Controller (DMA)

The bits in the Software Transaction Request Register are used to generate a DMA transaction request by software.

DMA_STREQ

DMA Software Transaction Request Register

(018_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCH 17	SCH 16	SCH 15	SCH 14	SCH 13	SCH 12	SCH 11	SCH 10	SCH 07	SCH 06	SCH 05	SCH 04	SCH 03	SCH 02	SCH 01	SCH 00
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
SCH0n (n = 0-7)	n	w	Set Transaction Request for DMA Channel 0n 0 _B No action. 1 _B A transaction for DMA channel 0n is requested. When setting SCH0n, TRSR.CH0n becomes set to indicate that a DMA request is pending for DMA channel 0n.
SCH1n (n = 0-7)	8+n	w	Set Transaction Request for DMA Channel 1n 0 _B No action. 1 _B A transaction for DMA channel 1n is requested. When setting SCH1n, TRSR.CH1n becomes set to indicate that a DMA request is pending for DMA channel 1n.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: Register bits marked with “w” are virtual and are not stored in flip-flops. Reading STREQ returns 0 when read.

Direct Memory Access Controller (DMA)

The bits in the Hardware Transaction Request Register enable or disable DMA hardware requests.

DMA_HTREQ

DMA Hardware Transaction Request Register

(01C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH	DCH
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH	ECH
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
ECH0n (n = 0-7)	n	w	Enable Hardware Transfer Request for DMA Channel 0n see table below
ECH1n (n = 0-7)	8+n	w	Enable Hardware Transfer Request for DMA Channel 1n see table below
DCH0n (n = 0-7)	16+n	w	Disable Hardware Transfer Request for DMA Channel 0n see table below
DCH1n (n = 0-7)	24+n	w	Disable Hardware Transfer Request for DMA Channel 1n see table below

Table 11-9 Conditions to Set/Reset the Bits TRSR.HTREmn

HTREQ.ECHmn	HTREQ.DCHmn	Transaction Finishes ¹⁾ for Channel mn	Modification of TRSR.HTREmn
0	0	0	Unchanged
1	0	0	Set

Direct Memory Access Controller (DMA)

Table 11-9 Conditions to Set/Reset the Bits TRSR.HTREmn (cont'd)

HTREQ.ECHmn	HTREQ.DCHmn	Transaction Finishes ¹⁾ for Channel mn	Modification of TRSR.HTREmn
X	1	X	Reset
X	X	1	Reset

1) In Single Mode only. In Continuous Mode, the end of a transaction has no impact.

Direct Memory Access Controller (DMA)

The Enable Error Register describes how the DMA controller reacts to errors. It enables the interrupts for the loss of a transaction request or Move Engine errors.

DMA_EER

DMA Enable Error Register

(020_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TRLINP				ME1INP				ME0INP				E ME1 DER	E ME1 SER	E ME0 DER	E ME0 SER
rw				rw				rw				rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
E TRL 17	E TRL 16	E TRL 15	E TRL 14	E TRL 13	E TRL 12	E TRL 11	E TRL 10	E TRL 07	E TRL 06	E TRL 05	E TRL 04	E TRL 03	E TRL 02	E TRL 01	E TRL 00
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ETRL0n (n = 0-7)	n	rw	Enable Transaction Request Lost for DMA Channel 0n This bit enables the generation of an interrupt when the set condition for ERRSR.TRL0n is detected. 0 _B The interrupt generation for a request lost event for channel 0n is disabled. 1 _B The interrupt generation for a request lost event for channel 0n is enabled.
ETRL1n (n = 0-7)	8+n	rw	Enable Transaction Request Lost for DMA Channel 1n This bit enables the generation of an interrupt when the set condition for ERRSR.TRL1n is detected. 0 _B The interrupt generation for a request lost event for channel 1n is disabled. 1 _B The interrupt generation for a request lost event for channel 1n is enabled.
EME0SER	16	rw	Enable Move Engine 0 Source Error This bit enables the generation of a Move Engine 0 source error interrupt. 0 _B Move Engine 0 source error interrupt is disabled. 1 _B Move Engine 0 source error interrupt is enabled.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
EME0DER	17	rw	Enable Move Engine 0 Destination Error This bit enables the generation of a Move Engine 0 destination error interrupt. 0 _B Move Engine 0 destination error interrupt is disabled. 1 _B Move Engine 0 destination error interrupt is enabled.
EME1SER	18	rw	Enable Move Engine 1 Source Error This bit enables the generation of a Move Engine 1 source error interrupt. 0 _B Move Engine 1 source error interrupt is disabled. 1 _B Move Engine 1 source error interrupt is enabled.
EME1DER	19	rw	Enable Move Engine 0 Destination Error This bit enables the generation of a Move Engine 0 destination error interrupt. 0 _B Move Engine 1 destination error interrupt is disabled. 1 _B Move Engine 1 destination error interrupt is enabled.
ME0INP	[23:20]	rw	Move Engine 0 Error Interrupt Node Pointer ME0INP determines the number n (n = 0-15) of the service request output SRn that becomes active on a Move Engine 0 source or destination interrupt. 0000 _B SR0 selected for Move Engine 0 interrupt 0001 _B SR1 selected for Move Engine 0 interrupt ... _B ... 1111 _B SR15 selected for Move Engine 0 interrupt <i>Note: In the TC1728, SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel request inputs (Page 11-102).</i>

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
ME1INP	[27:24]	rw	<p>Move Engine 1 Error Interrupt Node Pointer</p> <p>ME1INP determines the number n ($n = 0-15$) of the service request output SR_n that becomes active on a Move Engine 1 source or destination interrupt.</p> <p>0000_B SR0 selected for Move Engine 1 interrupt 0001_B SR1 selected for Move Engine 1 interrupt ..._B ... 1111_B SR15 selected for Move Engine 1 interrupt</p> <p><i>Note: In the TC1728, $SR[7:0]$ are connected to interrupt nodes. $SR[15:8]$ are used as DMA channel request inputs (Page 11-102).</i></p>
TRLINP	[31:28]	rw	<p>Transaction Lost Interrupt Node Pointer</p> <p>TRLINP determines the number n ($n = 0-15$) of the service request output SR_n that becomes active on a transaction lost interrupt.</p> <p>0000_B SR0 selected for transaction lost interrupt 0001_B SR1 selected for transaction lost interrupt ..._B ... 1111_B SR15 selected for transaction lost interrupt</p> <p><i>Note: In the TC1728, $SR[7:0]$ are connected to interrupt nodes. $SR[15:8]$ are used as DMA channel request inputs (Page 11-102).</i></p>

Direct Memory Access Controller (DMA)

The Error Status Register indicates if the DMA controller could not answer to a request because the previous request was not terminated (see [Section 11.2.4.4](#)). It indicates also the FPI Bus accesses that have been terminated with errors.

DMA_ERRSR

DMA Error Status Register

(024_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	LEC ME1			MLI0		LEC ME0		0	CER BER USE R	LMB ER	FPIE R	ME1 DER	ME1 SER	ME0 DER	ME0 SER
r	rh			rh		rh		r	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TRL 17	TRL 16	TRL 15	TRL 14	TRL 13	TRL 12	TRL 11	TRL 10	TRL 07	TRL 06	TRL 05	TRL 04	TRL 03	TRL 02	TRL 01	TRL 00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
TRL0n (n = 0-7)	n	rh	Transaction/Transfer Request Lost of DMA Channel 0n 0 _B 0 No request lost event has been detected for channel 0n. 1 _B 1 A new DMA request was detected while TRSR.CH0n=1 (request lost event). This bit is reset by software when writing a 1 to CLRE.CTL0n, or by a channel reset (writing CHRSTR.CH0n = 1).
TRL1n (n = 0-7)	8+n	rh	Transaction/Transfer Request Lost of DMA Channel 1n 0 _B No request lost event has been detected for channel 1n. 1 _B A new DMA request was detected while TRSR.CH1n=1 (request lost event). This bit is reset by software when writing a 1 to CLRE.CTL1n, or by a channel reset (writing CHRSTR.CH1n = 1).

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
ME0SER	16	rh	Move Engine 0 Source Error This bit is set whenever a Move Engine 0 error occurred during a source (read) move of a DMA transfer, or a request could not been serviced due to the access protection. 0 _B No Move Engine 0 source error has occurred. 1 _B A Move Engine 0 source error has occurred.
ME0DER	17	rh	Move Engine 0 Destination Error This bit is set whenever a Move Engine 0 error occurred during a destination (write) move of a DMA transfer, or a request could not been serviced due to the access protection. 0 _B No Move Engine 0 destination error has occurred. 1 _B A Move Engine 0 destination error has occurred.
ME1SER	18	rh	Move Engine 1 Source Error This bit is set whenever a Move Engine 1 error occurred during a source (read) move of a DMA transfer, or a request could not been serviced due to the access protection. 0 _B No Move Engine 1 source error has occurred. 1 _B A Move Engine 1 source error has occurred.
ME1DER	19	rh	Move Engine 1 Destination Error This bit is set whenever a Move Engine 1 error occurred during a destination (write) move of a DMA transfer, or a request could not been serviced due to the access protection. 0 _B No Move Engine 1 destination error has occurred. 1 _B A Move Engine 1 destination error has occurred.
FPIER	20	rh	SPB Error This bit is set whenever a move that has been started by the DMA/MLI FPI master interface leads to an error on the FPI Bus. 0 _B No error occurred. 1 _B An error occurred on FPI Bus interface.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
LMBER	21	rh	LMB Error This bit is set whenever a move that has been started by the DMA/MLI LMB master interface leads to an error on the LMB Bus. 0 _B No error occurred. 1 _B An error occurred on LMB Bus interface.
CERBERUS	22	rh	Cerberus Error Source This bit is set whenever an On Chip Bus error occurred due to an action of Cerberus. 0 _B No On Chip Bus error occurred due to Cerberus. 1 _B An On Chip Bus error occurred due to Cerberus.
LECME0	[26:24]	rh	Last Error Channel Move Engine 0 This bit field indicates the channel number of the last channel of Move Engine 0 leading to an On Chip Bus error that has occurred.
MLIO	27	rh	MLIO Error Source This bit is set whenever an On Chip Bus error occurred due to an action of MLIO. 0 _B No On Chip Bus error occurred due to MLIO. 1 _B An On Chip Bus error occurred due to MLIO.
LECME1	[30:28]	rh	Last Error Channel Move Engine 1 This bit field indicates the channel number of the last channel of Move Engine 1 leading to an On Chip Bus error that has occurred.
0	23, 31	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Clear Error contains bits that make it possible to clear the Transaction Request Lost flags or the Move Engine error flags.

DMA_CLRE

DMA Clear Error Register

(028_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		0		CLR MLI0			0		CLC ERB ERU S	C LMB ER	C FPIE R	C ME1 DER	C ME1 SER	C ME0 DER	C ME0 SER
r		r		w			r		w	w	w	rw	rw	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTL 17	CTL 16	CTL 15	CTL 14	CTL 13	CTL 12	CTL 11	CTL 10	CTL 07	CTL 06	CTL 05	CTL 04	CTL 03	CTL 02	CTL 01	CTL 00
rw	rw	rw	rw	rw	rw	rw	rw	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
CTL0n (n = 0-7)	n	w	Clear Transaction Request Lost for DMA Channel 0n 0 _B No action 1 _B Clear DMA channel 0n transaction request lost flag ERRSR.TRL0n
CTL1n (n = 0-7)	n+8	w	Clear Transaction Request Lost for DMA Channel 1n 0 _B No action 1 _B Clear DMA channel 1n transaction request lost flag ERRSR.TRL1n
CME0SER	16	w	Clear Move Engine 0 Source Error 0 _B No action 1 _B Clear source error flag ERRSR.ME0SER.
CME0DER	17	w	Clear Move Engine 0 Destination Error 0 _B No action 1 _B Clear destination error flag ERRSR.ME0DER.
CME1SER	18	w	Clear Move Engine 1 Source Error 0 _B No action 1 _B Clear source error flag ERRSR.ME1SER.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
CME1DER	19	w	Clear Move Engine 1 Destination Error 0 _B No action 1 _B Clear destination error flag ERRSR.ME1DER.
CFPIER	20	w	Clear FPI Error 0 _B No action 1 _B Clear error flag ERRSR.FPIER.
CLMBER	21	w	Clear LMB Error 0 _B No action 1 _B Clear error flag ERRSR.LMBER.
CLCERBERUS	22	w	Clear Cerberus Error 0 _B No action 1 _B Clear error flag ERRSR.Cerberus.
CLRMLI0	27	w	Clear MLI0 Error 0 _B No action 1 _B Clear error flag ERRSR.MLI0.
0	[26:23], [30:28], 31	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Interrupt Status Register indicates if CHSRmn.TCOUNT matches with CHCRmn.IRDV, or if CHSRmn.TCOUNT has been decremented (depending on CHICRmn.INTCT[0]), or if a pattern has been detected. These conditions can also generate an interrupt if enabled (see [Figure 11-17](#) on [Page 11-32](#)).

DMA_INTSR

DMA Interrupt Status Register

(054_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IPM 17	IPM 16	IPM 15	IPM 14	IPM 13	IPM 12	IPM 11	IPM 10	IPM 07	IPM 06	IPM 05	IPM 04	IPM 03	IPM 02	IPM 01	IPM 00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ICH 17	ICH 16	ICH 15	ICH 14	ICH 13	ICH 12	ICH 11	ICH 10	ICH 07	ICH 06	ICH 05	ICH 04	ICH 03	ICH 02	ICH 01	ICH 00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
ICH0n (n = 0-7)	n	rh	Interrupt from Channel 0n This bit indicates that channel 0n has raised an interrupt for TCOUNT = IRDV or if TCOUNT has been decremented (depending on CHICR.INTCT[0]. This bit (and IP0n) is reset by software when writing a 1 to INTCR.CICH0n or by a channel reset (writing CHRSTR.CH0n = 1). 0 _B A channel interrupt has not been detected. 1 _B A channel interrupt has been detected.
ICH1n (n = 0-7)	8+n	rh	Interrupt from Channel 1n This bit indicates that channel 1n has raised an interrupt for TCOUNT = IRDV or if TCOUNT has been decremented (depending on CHICR.INTCT[0]. This bit (and IP1n) is reset by software when writing a 1 to INTCR.CICH1n or by a channel reset (writing CHRSTR.CH1n = 1). 0 _B A channel interrupt has not been detected. 1 _B A channel interrupt has been detected.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
IPM0n (n = 0-7)	16+n	rh	Pattern Detection from Channel 0n This bit indicates that a pattern has been detected for channel 0n while the pattern detection has been enabled. This bit (and ICH0n) is reset by software when writing a 1 to INTCR.CICH0n or by a channel reset (writing CHRSTR.CH0n = 1). 0 _B A pattern has not been detected. 1 _B A pattern has been detected.
IPM1n (n = 0-7)	24+n	rh	Pattern Detection from Channel 1n This bit indicates that a pattern has been detected for channel 1n while the pattern detection has been enabled. This bit (and ICH1n) is reset by software when writing a 1 to INTCR.CICH1n or by a channel reset (writing CHRSTR.CH1n = 1). 0 _B A pattern has not been detected. 1 _B A pattern has been detected.

Direct Memory Access Controller (DMA)

The Wrap Status Register gives information about the channels that did a wrap-around on their source or destination buffer(s). This condition can also lead to an interrupt if it is enabled.

DMA_WRPSR

DMA Wrap Status Register

(05C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
WRP D17	WRP D16	WRP D15	WRP D14	WRP D13	WRP D12	WRP D11	WRP D10	WRP D07	WRP D06	WRP D05	WRP D04	WRP D03	WRP D02	WRP D01	WRP D00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WRP S17	WRP S16	WRP S15	WRP S14	WRP S13	WRP S12	WRP S11	WRP S10	WRP S07	WRP S06	WRP S05	WRP S04	WRP S03	WRP S02	WRP S01	WRP S00
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
WRPS0n (n = 0-7)	n	rh	Wrap Source Buffer for Channel 0n These bits indicate which channels have done a wrap-around of their source buffer(s). 0 _B No wrap-around occurred for channel 0n. 1 _B A wrap-around occurred for channel 0n. This bit is reset by software by writing a 1 to INTCR.CWRP0n or CHRSTR.CH0n.
WRPS1n (n = 0-7)	8+n	rh	Wrap Source Buffer for Channel 1n These bits indicate which channels have done a wrap-around of their source buffer(s). 0 _B No wrap-around occurred for channel 1n. 1 _B A wrap-around occurred for channel 1n. This bit is reset by software by writing a 1 to INTCR.CWRP1n or CHRSTR.CH1n.
WRPD0n (n = 0-7)	16+n	rh	Wrap Destination Buffer for Channel 0n These bits indicate which channels have done a wrap-around of their destination buffer(s). 0 _B No wrap-around occurred for channel 0n. 1 _B A wrap-around occurred for channel 0n. This bit is reset by software by writing a 1 to INTCR.CWRP0n or CHRSTR.CH0n.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
WRPD1n (n = 0-7)	24+n	rh	Wrap Destination Buffer for Channel 1n These bits indicate which channels have done a wrap-around of their destination buffer(s). 0 _B No wrap-around occurred for channel 1n. 1 _B A wrap-around occurred for channel 1n. This bit is reset by software by writing a 1 to INTCR.CWRP1n or CHRSTR.CH1n.

Direct Memory Access Controller (DMA)

The bits in the Interrupt Clear Register make it possible to reset the channel interrupt flags and the wrap buffer interrupt flags for DMA Channels mn.

DMA_INTCR

DMA Interrupt Clear Register

(058_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP	WRP
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH	ICH
17	16	15	14	13	12	11	10	07	06	05	04	03	02	01	00
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
CICH0n (n = 0-7)	n	w	Clear Interrupt for DMA Channel 0n These bits make it possible to reset the channel interrupt flags INTSR.ICH0n and INTSR.IPM0n of DMA channel 0n by software. 0 _B No action. 1 _B Bits INTSR.ICH0n and INTSR.IPM0n are reset.
CICH1n (n = 0-7)	8+n	w	Clear Interrupt for DMA Channel 1n These bits make it possible to reset the channel interrupt flags INTSR.ICH1n and INTSR.IPM1n of DMA channel 1n by software. 0 _B No action. 1 _B Bits INTSR.ICH1n and INTSR.IPM1n are reset.
CWRP0n (n = 0-7)	16+n	w	Clear Wrap Buffer Interrupt for DMA Channel 0n These bits make it possible to reset the wrap source buffer interrupt flag WRPSR.WRPS0n and the wrap destination buffer interrupt flag WRPSR.WRPD0n (both together) of DMA channel 0n by software. 0 _B No action. 1 _B Bits WRPSR.WRPS0n and WRPSR.WRPD0n are reset.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
CWRP1n (n = 0-7)	24+n	w	Clear Wrap Buffer Interrupt for DMA Channel 1n These bits make it possible to reset the wrap source buffer interrupt flag WRPSR.WRPS1n and the wrap destination buffer interrupt flag WRPSR.WRPD1n (both together) of DMA channel 1n by software. 0 _B No action. 1 _B Bits WRPSR.WRPS1n and WRPSR.WRPD1n are reset.

11.3.3 Move Engine Registers

The Move Engine Status Register is a read-only register that holds status information about the transaction handled by the Move Engines.

DMA_MESR

DMA Move Engine Status Register (030_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RBTLMB		ME1WS		CH1		ME1RS		RBTFP1		ME0WS		CH0		ME0RS	
rh		rh		rh		rh		rh		rh		rh		rh	

Field	Bits	Type	Description
ME0RS	0	rh	Move Engine 0 Read Status 0 _B Move Engine 0 is not performing a read. 1 _B Move Engine 0 is performing a read.
CH0	[3:1]	rh	Reading Channel in Move Engine 0 This bit field indicates which channel number is currently being processed by the Move Engine 0.
ME0WS	4	rh	Move Engine 0 Write Status 0 _B Move Engine 0 is not performing a write. 1 _B Move Engine 0 is performing a write.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
RBTFPI	[7:5]	rh	Read Buffer Trace for FPI Bus Interface This bit field contains trace information from the buffer in the FPI Bus Interface. In the TC1728 it indicates the source of a bus access to the FPI Bus. 000 _B Default value. 001 _B DMA Move Engine 0 010 _B DMA Move Engine 1 011 _B MLI0 101 _B Cerberus Other bit combinations are reserved. RBTFPI is useful for emulation purposes. It is not recommended to evaluate this bit field during normal operation of the TC1728.
ME1RS	8	rh	Move Engine 1 Read Status 0 _B Move Engine 1 is not performing a read. 1 _B Move Engine 1 is performing a read.
CH1	[11:9]	rh	Reading Channel in Move Engine 1 These bit field indicates which channel number is currently being processed by the Move Engine 1.
ME1WS	12	rh	Move Engine 1 Write Status 0 _B Move Engine 1 is not performing a write. 1 _B Move Engine 1 is performing a write.
RBTLMB	[15:13]	rh	Read Buffer Trace for LMB Bus Interface This bit field contains trace information from the buffer in the LMB Bus Interface. In the TC1728, it indicates the source of a bus access to the LMB Bus. 000 _B Default value 001 _B DMA Move Engine 0 010 _B DMA Move Engine 1 011 _B MLI0 Others Reserved RBTLMB is useful for emulation purposes. It is not recommended to evaluate this bit field during normal operation of the TC1728.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Move Engine 0 Read Register indicates the value that has just been read by Move Engine 0. The value in this register is compared to the bits in register ME0PR according to the bit fields CHCRmn.PATSEL.

DMA_ME0R

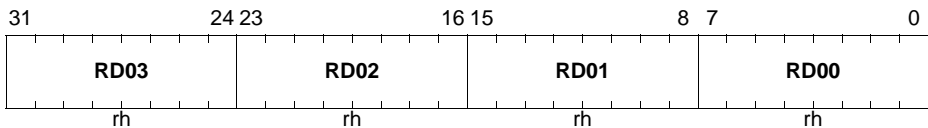
DMA Move Engine 0 Read Register (034_H)

Reset Value: 0000 0000_H

DMA_ME1R

DMA Move Engine 1 Read Register (038_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RD00, RD01, RD02, RD03	[7:0], [15:8], [23:16], [31:24]	rh	Read Value for Move Engine 0 Contains the 32-bit read data (four bytes RD0[3:0]) that is stored in the Move Engine 0 after each read move. The content of ME0R is overwritten after each read move of a DMA channel belonging to DMA Sub-block 0.

The Move Engine 0 Pattern Register contains the patterns (mask and/or compare bits) to be processed by the pattern detection logic in Move Engine 0.

DMA_ME0PR

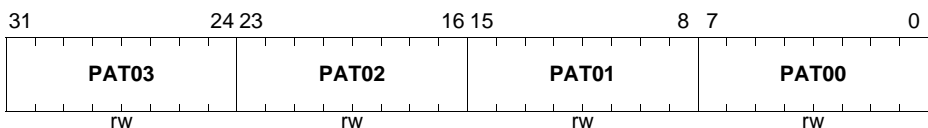
DMA Move Engine 0 Pattern Register (03C_H)

Reset Value: 0000 0000_H

DMA_ME1PR

DMA Move Engine 1 Pattern Register (040_H)

Reset Value: 0000 0000_H



Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
PAT00, PAT01, PAT02, PAT03	[7:0], [15:8], [23:16], [31:24]	rw	Pattern for Move Engine 0 Determines up to four 8-bit compare patterns/mask patterns to be processed by the pattern detection logic in Move Engine 0. Depending on the pattern detection configuration (CHCR0n.PATSEL) and channel data width (CHCR0n.CHDW), the patterns are processed as bytes or half-words.

The DMA Move Engine 0 Access Enable Register controls the access protection. It enables/disables the address protection ranges x (x = 0-31) for Move Engine 0.

DMA_ME0AENR

DMA Move Engine 0 Access Enable Register
(044_H)

Reset Value: 0000 0000_H

DMA_ME1AENR

DMA Move Engine 1 Access Enable Register
(04C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN	AEN
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
AENx (x = 0-31)	x	rw	Address Range x Enable This bit enables the read and write capability of the DMA Move Engines for address range x (x = 0-31). 0 _B DMA read and write moves to address range x are disabled 1 _B DMA read and write moves to address range x are enabled If AENx = 0 for a read/write move to address range x, the read/write move is not executed and a source/destination Move Engine interrupt is generated.

Note: See [Table 11-13](#) on [Page 11-112](#) for the TC1728-specific address range definition.

Direct Memory Access Controller (DMA)

The DMA Move Engine 0 Access Range Register determines number and size of the sub-ranges for address range extension n (n = 0-3). See also [Figure 11-26](#) for bit field definitions.

DMA_ME0ARR

DMA Move Engine 0 Access Range Register
(048_H)

Reset Value: 0000 0000_H

DMA_ME1ARR

DMA Move Engine 1 Access Range Register
(050_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SIZE3				SLICE3				SIZE2				SLICE2			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIZE1				SLICE1				SIZE0				SLICE0			
rw				rw				rw				rw			

Field	Bits	Type	Description
SLICE0	[4:0]	rw	Address Slice 0 SLICE0 selects a specific sub-range within address range extension 0.
SIZE0	[7:5]	rw	Address Size 0 SIZE0 determines the sub-range size within address range extension 0.
SLICE1	[12:8]	rw	Address Slice 1 SLICE1 selects a specific sub-range within address range extension 1.
SIZE1	[15:13]	rw	Address Size 1 SIZE1 determines the sub-range size within address range extension 1.
SLICE2	[20:16]	rw	Address Slice 2 SLICE2 selects a specific sub-range within address range extension 2.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
SIZE2	[23:21]	rw	Address Size 2 SIZE2 determines the sub-range size within address range extension 2.
SLICE3	[28:24]	rw	Address Slice 3 SLICE3 selects a specific sub-range within address range extension 3.
SIZE3	[31:29]	rw	Address Size 3 SIZE3 determines the sub-range size within address range extension 3.

Note: See [Section 11.4.2](#) on [Page 11-112](#) for the TC1728-specific address range and address range extension definitions.

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
PRSEL	[15:12]	rw	Peripheral Request Select This bit field controls the hardware request input multiplexer of DMA channel mn (see Figure 11-6 on Page 11-11). 0000 _B Input CHmn_REQI0 selected 0001 _B Input CHmn_REQI1 selected 0010 _B Input CHmn_REQI2 selected 0011 _B Input CHmn_REQI3 selected 0100 _B Input CHmn_REQI4 selected 0101 _B Input CHmn_REQI5 selected 0110 _B Input CHmn_REQI6 selected 0111 _B Input CHmn_REQI7 selected 1000 _B Input CHmn_REQI8 selected 1001 _B Input CHmn_REQI9 selected 1010 _B Input CHmn_REQI10 selected 1011 _B Input CHmn_REQI11 selected 1100 _B Input CHmn_REQI12 selected 1101 _B Input CHmn_REQI13 selected 1110 _B Input CHmn_REQI14 selected 1111 _B Input CHmn_REQI15 selected
BLKM	[18:16]	rw	Block Mode BLKM determines the number of DMA moves executed during one DMA transfer. 000 _B One DMA transfer has 1 DMA move 001 _B One DMA transfer has 2 DMA move 010 _B One DMA transfer has 4 DMA move 011 _B One DMA transfer has 8 DMA move 100 _B One DMA transfer has 16 DMA move Other bit combinations are reserved and must not be used. See also Figure 11-10 on Page 11-18 .
RROAT	19	rw	Reset Request Only After Transaction RROAT determines whether or not the TRSR.CHmn transfer request state flag is reset after each transfer. 0 _B TRSR.CHmn is reset after each transfer. A transfer request is required for each transfer. 1 _B TRSR.CHmn is reset when CHSRmn.TCOUNT = 0 after a transfer. One transfer request starts a complete DMA transaction

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
CHMODE	20	rw	<p>Channel Operation Mode</p> <p>CHMODE determines the reset condition for control bit TRSR.HTREmn of DMA channel mn.</p> <p>0_B Single Mode operation is selected for DMA channel mn. After a transaction, DMA channel mn is disabled for further hardware requests (TRSR.HTREmn is reset by hardware) TRSR.HTREmn must be set again by software for starting a new transaction.</p> <p>1_B Continuous Mode operation is selected for DMA channel mn. After a transaction, bit TRSR.HTREmn remains set</p>
CHDW	[22:21]	rw	<p>Channel Data Width</p> <p>CHDW determines the data width for the read and write moves of DMA channel mn.</p> <p>00_B 8-bit (byte) data width for moves selected</p> <p>01_B 16-bit (half-word) data width for moves selected</p> <p>10_B 32-bit (word) data width for moves selected</p> <p>11_B Reserved</p>
PATSEL	[25:24]	rw	<p>Pattern Select</p> <p>This bit field selects the mode of the pattern detection logic. Depending on the channel data width, PATSEL selects different pattern detection configurations. If pattern detection is enabled (PATSEL not equal 00_B), the pattern detection interrupt line will be activated on the selected pattern match.</p> <p>8-bit channel data width (CHDW = 00_B): Selected pattern detection configuration see Table 11-4 on Page 11-41.</p> <p>16-bit channel data width (CHDW = 01_B): Selected pattern detection configuration see Table 11-5 on Page 11-42.</p> <p>32-bit channel data width (CHDW = 10_B): Selected pattern detection configuration see Table 11-6 on Page 11-44.</p>

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
CHPRIO	28	rw	Channel Priority CHPRIO determines the priority of DMA channel n for the Move Engine minternal channel arbitration. This priority is used for the case when multiple channels of Move Engine m are triggered in parallel. 0 _B DMA channel mn has a low channel priority 1 _B DMA channel mn has a high channel priority
DMAprio	[31:30]	rw	DMA Priority This bit determines the DMA the request priority that is used when a move operation related to channel mn is requesting an On Chip Bus. This bit has no effect in channel prioritization inside the Move Engine m in. 00 _B Low priority selected 01 _B Medium priority selected 10 _B Reserved 11 _B High priority selected
0	[11:10], 23, [27:26], 29	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Channel Status Register contains the current transfer count and a pattern detection compare result.

DMA_CHSR0x (x = 0-7)

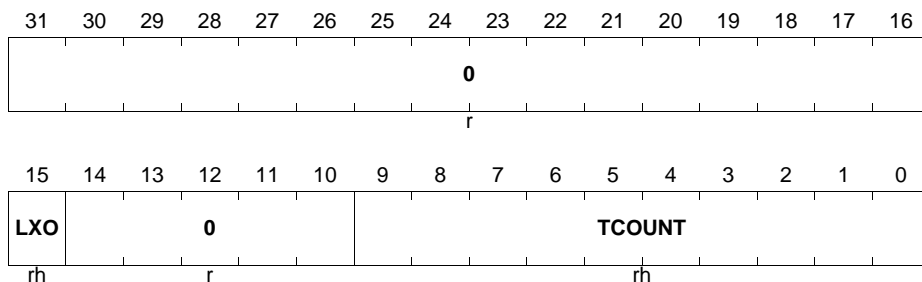
DMA Channel 0x Status Register (080_H+x*20_H)

Reset Value: 0000 0000_H

DMA_CHSR1x (x = 0-7)

DMA Channel 1x Status Register (180_H+x*20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TCOUNT	[9:0]	rh	Transfer Count Status TCOUNT holds the actual value of the DMA transfer count for DMA channel mx. TCOUNT is loaded with the value of CHCRmx.TREL when TRSR.CHmx becomes set (and TCOUNT = 0). After each DMA transfer, TCOUNT is decremented by 1.
LXO	15	rh	Old Value of Pattern Detection This bit contains the compare result of a pattern compare operation when 8-bit or 16-bit data width is selected. <u>8-bit data width:</u> see Table 11-4 and Figure 11-23 <u>16-bit data width:</u> see Table 11-5 and Figure 11-24 0 _B The corresponding pattern compare operation did not find a pattern match on the last move 1 _B The corresponding pattern compare operation found a pattern match at the last move
0	[14:10], [31:16]	r	Reserved Read as 0; should be written with 0.

Direct Memory Access Controller (DMA)

The Channel Interrupt Control Register controls the interrupts generation.

DMA_CHICR0x (x = 0-7)

DMA Channel 0x Interrupt Control Register

(088_H+x*20_H)

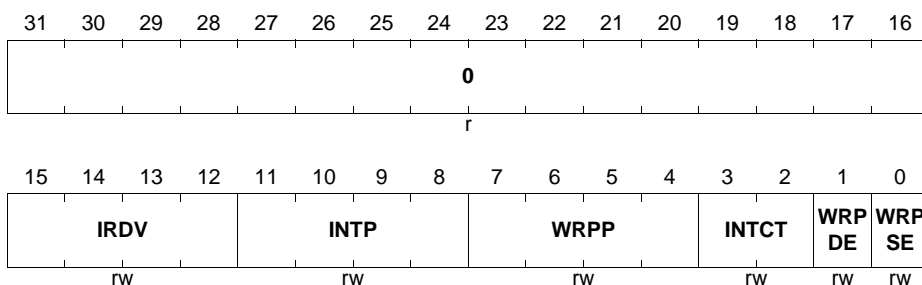
Reset Value: 0000 0000_H

DMA_CHICR1x (x = 0-7)

DMA Channel 1x Interrupt Control Register

(188_H+x*20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
WRPSE	0	rw	Wrap Source Enable 0 _B Wrap source buffer interrupt disabled 1 _B Wrap source buffer interrupt enabled
WRPDE	1	rw	Wrap Destination Enable 0 _B Wrap destination buffer interrupt disabled 1 _B Wrap destination buffer interrupt enabled
INTCT	[3:2]	rw	Interrupt Control 00 _B No interrupt will be generated on changing the TCOUNT value. The bit INTSR.ICHmx is set when TCOUNT equals IRDV. 01 _B No interrupt will be generated on changing the TCOUNT value. The bit INTSR.ICHmx is set when TCOUNT is decremented 10 _B An interrupt is generated and bit INTSR.ICHmx is set each time TCOUNT equals IRDV 11 _B Interrupt is generated and bit INTSR.ICHmx is set each time TCOUNT is decremented <i>Note: see Figure 11-17.</i>

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
WRPP	[7:4]	rw	Wrap Pointer WRPP determines the number n (n = 0-15) of the service request output SRn that becomes active on a wrap buffer interrupt. 0000 _B SR0 selected for channel mx wrap buffer interrupt 0001 _B SR1 selected for channel mx wrap buffer interrupt ... 1111 _B SR15 selected for channel mx wrap buffer interrupt <i>Note: In the TC1728, SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel request inputs (Page 11-102).</i>
INTP	[11:8]	rw	Interrupt Pointer INTP determines the number n (n = 0-15) of the service request output SRn that becomes active on a channel interrupt. 0000 _B SR0 selected for channel mx interrupt 0001 _B SR1 selected for channel mx interrupt ... 1111 _B SR15 selected for channel mx interrupt <i>Note: In the TC1728, SR[7:0] are connected to interrupt nodes. SR[15:8] are used as DMA channel request inputs (Page 11-102).</i>
IRDV	[15:12]	rw	Interrupt Raise Detect Value These bits specify the value of CHSRmx.TCOUNT for which the Interrupt Threshold Limit should be raised.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: The interrupt node of the wrap-around interrupts is shared with the pattern match interrupt. In order to support interrupt generation in case of a pattern match, the wrap-around interrupt should be disabled. If the wrap-around interrupts are used, the pattern match interrupt should not be used. The settings are independent for each DMA channel.

Direct Memory Access Controller (DMA)

The Address Control Register controls how source and destination addresses are updated after a DMA move. Furthermore, it determines whether or not a source or destination address register update is shadowed.

DMA_ADRCR0x (x = 0-7)

DMA Channel 0x Address Control Register

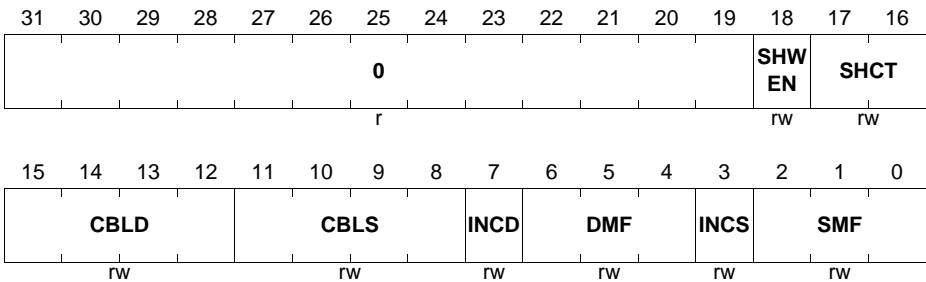
 $(08C_H + x * 20_H)$

Reset Value: 0000 0000_H

DMA_ADRCR1x (x = 0-7)

DMA Channel 1x Address Control Register

 $(18C_H + x * 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
SMF	[2:0]	rw	Source Address Modification Factor This bit field and the data width as defined in CHCRmx.CHDW determine an address offset value by which the source address is modified after each DMA move. See also Table 11-10 . 000 _B Address offset is 1 x CHCRmx.CHDW 001 _B Address offset is 2 x CHCRmx.CHDW 010 _B Address offset is 4 x CHCRmx.CHDW 011 _B Address offset is 8 x CHCRmx.CHDW 100 _B Address offset is 16 x CHCRmx.CHDW 101 _B Address offset is 32 x CHCRmx.CHDW 110 _B Address offset is 64 x CHCRmx.CHDW 111 _B Address offset is 128 x CHCRmx.CHDW

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
INCS	3	rw	Increment of Source Address This bit determines whether the address offset as selected by SMF will be added to or subtracted from the source address after each DMA move. The source address is not modified if CBLS = 0000 _B . 0 _B Address offset will be subtracted 1 _B Address offset will be added.
DMF	[6:4]	rw	Destination Address Modification Factor This bit field and the data width as defined in CHCRmx.CHDW determines an address offset value by which the destination address is modified after each DMA move. The destination address is not modified if CBLD = 0000 _B . See also Table 11-10 . 000 _B Address offset is 1 x CHDW 001 _B Address offset is 2 x CHDW 010 _B Address offset is 4 x CHDW 011 _B Address offset is 8 x CHDW 100 _B Address offset is 16 x CHDW 101 _B Address offset is 32 x CHDW 110 _B Address offset is 64 x CHDW 111 _B Address offset is 128 x CHDW
INCD	7	rw	Increment of Destination Address This bit determines whether the address offset as selected by DMF will be added to or subtracted from the destination address after each DMA move. The destination address is not modified if CBLD = 0000 _B . 0 _B Address offset will be subtracted 1 _B Address offset will be added

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
CBLS	[11:8]	rw	<p>Circular Buffer Length Source</p> <p>This bit field determines which part of the 32-bit source address register remains unchanged and is not updated after a DMA move operation (see also Section 11.2.4.7).</p> <p>Therefore, CBLS also determines the size of the circular source buffer.</p> <p>0000_B Source address SADR[31:0] is not updated 0001_B Source address SADR[31:1] is not updated 0010_B Source address SADR[31:2] is not updated 0011_B Source address SADR[31:3] is not updated ..._B ... 1110_B Source address SADR[31:14] is not updated 1111_B Source address SADR[31:15] is not updated</p>
CBLD	[15:12]	rw	<p>Circular Buffer Length Destination</p> <p>This bit field determines which part of the 32-bit destination address register remains unchanged and is not updated after a DMA move operation (see also Page 11-20). Therefore, CBLD also determines the size of the circular destination buffer.</p> <p>0000_B Destination address DADR[31:0] is not updated 0001_B Destination address DADR[31:1] is not updated 0010_B Destination address DADR[31:2] is not updated 0011_B Destination address DADR[31:3] is not updated ..._B ... 1110_B Destination address DADR[31:14] is not updated 1111_B Destination address DADR[31:15] is not updated</p>

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
SHCT	[17:16]	rw	<p>Shadow Control</p> <p>This bit field determines whether an address is transferred into the shadow address register when writing to source or destination address register.</p> <p>00_B Shadow address register not used. Source and destination address register are written directly</p> <p>01_B Shadow address register used for source address buffering. When writing to SADDRmx, the address is buffered in SHADDRmx and transferred to SADDRmx with the start of the next DMA transaction</p> <p>10_B Shadow address register used for destination address buffering. When writing to DADDRmx, the address is buffered in SHADDRmx and transferred to DADDRmx with the start of the next DMA transaction</p> <p>11_B Reserved</p> <p>In case of SHCT = 01_B or 10_B, SHCT must not be changed until the next DMA transaction has been started.</p>
SHWEN	18	rw	<p>Shadow Address Register Write Enable</p> <p>This bit determines whether the shadow address register SHADDRmx is read only and automatically set to 0000 0000_H or if the shadow register can also be directly written and not modified when and shadow transfer takes place.</p> <p>0_B Shadow address register is read only and the value stored in the SHADDRmx is automatically set to 0000 0000_H when the shadow transfer takes place</p> <p>1_B Shadow address register SHADDRmx can be read and can be directly written. The value stored in the SHADDRmx is not automatically modified when the shadow transfer takes place</p>
0	[31:19]	r	<p>Reserved</p> <p>Read as 0; should be written with 0.</p>

Direct Memory Access Controller (DMA)

Table 11-10 shows the offset values that are added or subtracted to/from a source or destination address register after a DMA move. Bit field SMF and bit INCS determine the offset value for the source address. Bit field DMF and bit INCD determine the offset value for the destination address.

Table 11-10 Address Offset Calculation Table

CHCRmn.CHDW = 00 _B (8-bit Data Width)			CHCRmn.CHDW = 01 _B (16-bit Data Width)			CHCRmn.CHDW = 10 _B (32-bit Data Width)		
SMF DMF	INCS INCD	Address Offset	SMF DMF	INCS INCD	Address Offset	SMF DMF	INCS INCD	Address Offset
000 _B	0	-1	000 _B	0	-2	000 _B	0	-4
	1	+1		1	+2		1	+4
001 _B	0	-2	001 _B	0	-4	001 _B	0	-8
	1	+2		1	+4		1	+8
010 _B	0	-4	010 _B	0	-8	010 _B	0	-16
	1	+4		1	+8		1	+16
011 _B	0	-8	011 _B	0	-16	011 _B	0	-32
	1	+8		1	+16		1	+32
100 _B	0	-16	100 _B	0	-32	100 _B	0	-64
	1	+16		1	+32		1	+64
101 _B	0	-32	101 _B	0	-64	101 _B	0	-128
	1	+32		1	+64		1	+128
110 _B	0	-64	110 _B	0	-128	110 _B	0	-256
	1	+64		1	+128		1	+256
111 _B	0	-128	111 _B	0	-256	111 _B	0	-512
	1	+128		1	+256		1	+512

Note: CHCRmn.CHDW = 11_B is reserved and should not be used.

Direct Memory Access Controller (DMA)

11.3.5 Channel Address Registers

The Source Address Register contains the 32-bit source address. If a DMA channel mn is active, $SADRMn$ is updated continuously (if programmed) and shows the actual source address that is used for read moves within DMA transfers.

DMA_SADR0x (x = 0-7)

DMA Channel 0x Source Address Register

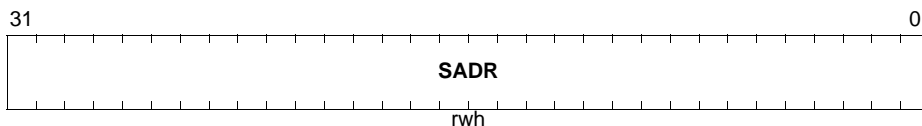
 $(090_H + x \cdot 20_H)$

Reset Value: 0000 0000_H

DMA_SADR1x (x = 0-7)

DMA Channel 1x Source Address Register

 $(190_H + x \cdot 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
SADR	[31:0]	rwh	Source Start Address This bit field holds the actual 32-bit source address of DMA channel mx that is used for read moves.

A write to $SADRMn$ is executed directly only when the DMA channel mn is inactive ($CHSRmn.TCOUNT = 0$ and $TRSR.CHmn = 0$). If DMA channel mn is active when writing to $SADRMn$, the source address will not be written into $SADRMn$ directly but will be buffered in the shadow register $SHADRMn$ until the start of the next DMA transaction. During this shadowed address register operation, bit field $ADRCRmn.SHCT$ must be set to 01_B.

Direct Memory Access Controller (DMA)

The Destination Address Register contains the 32-bit destination address. If a DMA channel is active, DADR_{mn} is updated continuously (if programmed) and shows the actual destination address that is used for write moves within DMA transfers.

DMA_DADR0x (x = 0-7)

DMA Channel 0x Destination Address Register

(094_H+x*20_H)

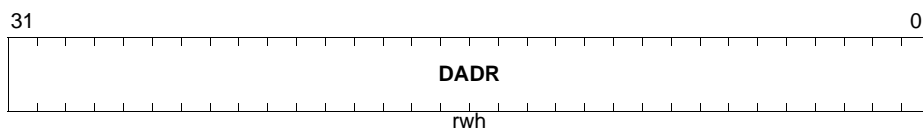
Reset Value: 0000 0000_H

DMA_DADR1x (x = 0-7)

DMA Channel 1x Destination Address Register

(194_H+x*20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DADR	[31:0]	rwh	Destination Address This bit field holds the actual 32-bit destination address of DMA channel mx that is used for write moves.

A write to DADR_{mn} is executed directly only when the DMA channel mn is inactive (CHSR_{mn}.TCOUNT = 0 and TRSR.CH_{mn} = 0). If DMA channel mn is active when writing to DADR_{mn}, the source address will not be written into DADR_{mn} directly but will be buffered in the shadow register SHADR_{mn} until the start of the next DMA transaction. During this shadowed address register operation, bit field ADRCR_{mn}.SHCT must be set to 10_B.

Direct Memory Access Controller (DMA)

The Shadow Address Register holds the shadowed source or destination address before it is written into the source or destination address register. SHADRMn can be read only.

DMA_SHADR0x (x = 0-7)

DMA Channel 0x Shadow Address Register

(098_H+x*20_H)

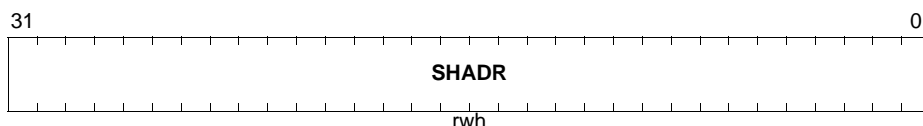
Reset Value: 0000 0000_H

DMA_SHADR1x (x = 0-7)

DMA Channel 1x Shadow Address Register

(198_H+x*20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SHADR	[31:0]	rwh	Shadowed Address This bit field holds the shadowed 32-bit source or destination address of DMA channel mx.

SHADRMn is written when source or destination address buffering is selected (ADRCRMn.SHCT = 01_B or ADRCRMn.SHCT = 10_B) and a transaction is running. While the shadow mechanism is disabled, SHADR is set to 0000 0000_H.

If ADRCRMn.SHWEN = 0 the value stored in the SHADR is automatically set to 0000 0000_H when the shadow transfer takes place. The user can read the shadow register in order to detect if the shadow transfer has already taken place. If the value in SHADR is 0000 0000_H, no shadow transfer can take place and the corresponding address register is modified according to the circular buffer rules.

If ADRCRMn.SHWEN = 1 shadow register SHADRMn can be directly written. The value stored in the SHADRMn is not modified when the shadow transfer takes place, the shadow mechanism remains active and the shadow transfer will be repeated until Channel mn is reset or until the value in SHADR is 0000 0000_H, is written into the shadow register.

Direct Memory Access Controller (DMA)

11.4 DMA Module Implementation

This section describes the TC1728 DMA module interfaces with the clock control, interrupt control, and address decoding.

Figure 11-28 shows the TC1728-specific implementation details and interconnections of the DMA module. The DMA module is supplied with a separate clock control, address decoding, interrupt control, and the request input wiring matrix.

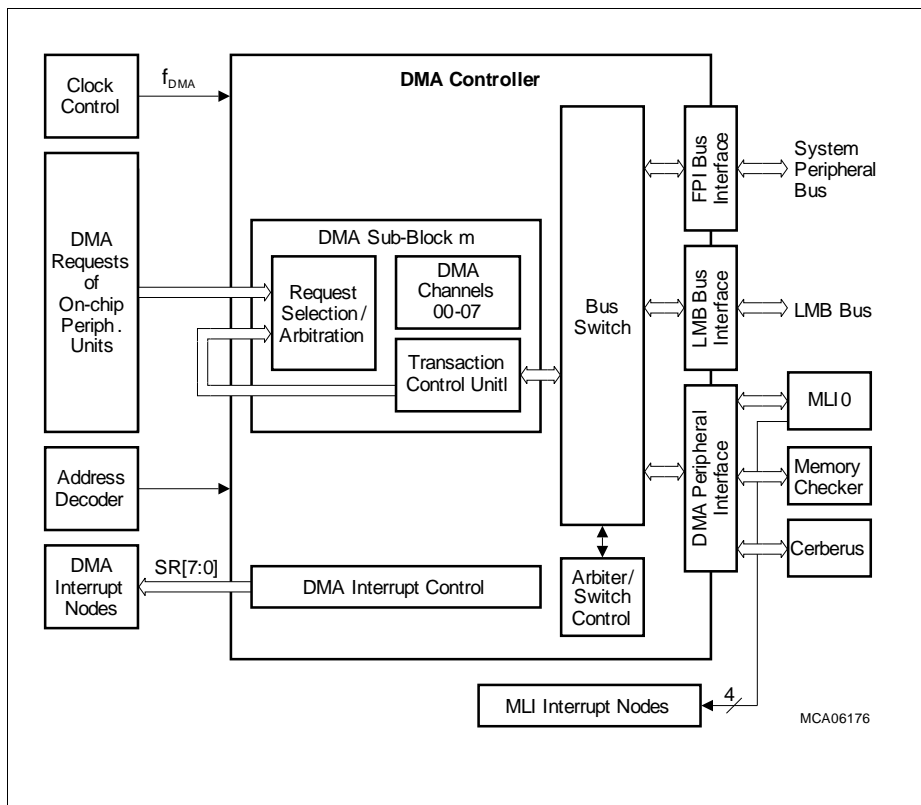


Figure 11-28 DMA Module Implementation and Interconnections

The request sources of the peripheral modules (ADC0, MSC0, MLI0, FADC, MultiCAN, and SCU) are associated with Interrupt Node Pointers and individual interrupt enable bits. As a result, each of the internal requests of a module can be routed independently to any of the interrupt output lines (INT_Ox) of the module.

Direct Memory Access Controller (DMA)

11.4.1 DMA Request Wiring Matrix

The DMA request input lines of each DMA channel within DMA Sub-Block 0 and DMA Sub-Block 1 are connected to request output lines from the peripheral modules according to [Table 11-11](#).

Table 11-11 DMA Request Assignment for DMA Sub-Block 0

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
00	DMA_SR08	DMA(INT_O08)	CHCR00.PRSEL = 0000 _B
	IOUT0	SCU (ERU)	CHCR00.PRSEL = 0001 _B
	FADC_SR00	FADC	CHCR00.PRSEL = 0010 _B
	ADC_SR00	ADC	CHCR00.PRSEL = 0011 _B
	SSC0_RDR	SSC0	CHCR00.PRSEL = 0100 _B
	ASC0_RDR	ASC0	CHCR00.PRSEL = 0101 _B
	CAN_INT_O0	MultiCAN	CHCR00.PRSEL = 0110 _B
	MLI0_SR4	MLI0	CHCR00.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR00.PRSEL = 1000 _B
	GPTA_TRIG00	GPTA ¹⁾	CHCR00.PRSEL = 1001 _B
	GPTA_TRIG10	GPTA ¹⁾	CHCR00.PRSEL = 1010 _B
	INT1SRC	ERAY	CHCR00.PRSEL = 1011 _B
	IBUSY	ERAY	CHCR00.PRSEL = 1100 _B
	SSC2_RDR	SSC2	CHCR00.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR00.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR00.PRSEL = 1111 _B
01	DMA_SR09	DMA(INT_O09)	CHCR01.PRSEL = 0000 _B
	IOUT1	SCU (ERU)	CHCR01.PRSEL = 0001 _B
	FADC_SR01	FADC	CHCR01.PRSEL = 0010 _B
	ADC_SR01	ADC	CHCR01.PRSEL = 0011 _B
	SSC1_RDR	SSC1	CHCR01.PRSEL = 0100 _B
	ASC1_RDR	ASC1	CHCR01.PRSEL = 0101 _B
	CAN_INT_O1	MultiCAN	CHCR01.PRSEL = 0110 _B
	MLI0_SR5	MLI0	CHCR01.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR01.PRSEL = 1000 _B

Direct Memory Access Controller (DMA)

Table 11-11 DMA Request Assignment for DMA Sub-Block 0 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	GPTA_TRIG01	GPTA ¹⁾	CHCR01.PRSEL = 1001 _B
	GPTA_TRIG11	GPTA ¹⁾	CHCR01.PRSEL = 1010 _B
	TINT0SRC	ERAY	CHCR01.PRSEL = 1011 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1100 _B
	CCU60_SR0	CCU60_SR0	CHCR01.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1111 _B
02	DMA_SR10	DMA(INT_O10)	CHCR02.PRSEL = 0000 _B
	IOUT2	SCU (ERU)	CHCR02.PRSEL = 0001 _B
	FADC_SR02	FADC	CHCR02.PRSEL = 0010 _B
	ADC_SR02	ADC	CHCR02.PRSEL = 0011 _B
	SSC0_TDR	SSC0	CHCR02.PRSEL = 0100 _B
	ASC0_TDR	ASC0	CHCR02.PRSEL = 0101 _B
	MSC0_SR2	MSC0	CHCR02.PRSEL = 0110 _B
	MLI0_SR6	MLI0	CHCR02.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR02.PRSEL = 1000 _B
	GPTA_TRIG02	GPTA ¹⁾	CHCR02.PRSEL = 1001 _B
	GPTA_TRIG12	GPTA ¹⁾	CHCR02.PRSEL = 1010 _B
	NDAT1SRC	ERAY	CHCR02.PRSEL = 1011 _B
	ASC0_TBDR	ASC0	CHCR02.PRSEL = 1100 _B
	SSC2_TDR	SSC2	CHCR02.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR02.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR02.PRSEL = 1111 _B
03	DMA_SR11	DMA(INT_O11)	CHCR03.PRSEL = 0000 _B
	IOUT3	SCU (ERU)	CHCR03.PRSEL = 0001 _B
	FADC_SR03	FADC	CHCR03.PRSEL = 0010 _B
	ADC_SR03	ADC	CHCR03.PRSEL = 0011 _B
	SSC1_TDR	SSC1	CHCR03.PRSEL = 0100 _B
	ASC1_TDR	ASC1	CHCR03.PRSEL = 0101 _B
	MSC0_SR3	MSC0	CHCR03.PRSEL = 0110 _B

Direct Memory Access Controller (DMA)

Table 11-11 DMA Request Assignment for DMA Sub-Block 0 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	MLI0_SR7	MLI0	CHCR03.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR03.PRSEL = 1000 _B
	GPTA_TRIG03	GPTA ¹⁾	CHCR03.PRSEL = 1001 _B
	GPTA_TRIG13	GPTA ¹⁾	CHCR03.PRSEL = 1010 _B
	MBSC1SRC	ERAY	CHCR03.PRSEL = 1011 _B
	ASC1_TBDR	ASC1	CHCR03.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR03.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR03.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR03.PRSEL = 1111 _B
04	DMA_SR12	DMA(INT_O12)	CHCR04.PRSEL = 0000 _B
	IOUT0	SCU (ERU)	CHCR04.PRSEL = 0001 _B
	FADC_SR00	FADC	CHCR04.PRSEL = 0010 _B
	ADC_SR04	ADC	CHCR04.PRSEL = 0011 _B
	SSC0_TDR	SSC0	CHCR04.PRSEL = 0100 _B
	ASC0_TDR	ASC0	CHCR04.PRSEL = 0101 _B
	MSC0_SR2	MSC0	CHCR04.PRSEL = 0110 _B
	MLI0_SR4	MLI0	CHCR04.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR04.PRSEL = 1000 _B
	GPTA_TRIG04	GPTA ¹⁾	CHCR04.PRSEL = 1001 _B
	GPTA_TRIG14	GPTA ¹⁾	CHCR04.PRSEL = 1010 _B
	INT1SRC	ERAY	CHCR04.PRSEL = 1011 _B
	ASC0_TBDR	ASC0	CHCR04.PRSEL = 1100 _B
	OBUSY	ERAY	CHCR04.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR04.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR04.PRSEL = 1111 _B
05	DMA_SR13	DMA(INT_O13)	CHCR05.PRSEL = 0000 _B
	IOUT1	SCU (ERU)	CHCR05.PRSEL = 0001 _B
	FADC_SR01	FADC	CHCR05.PRSEL = 0010 _B
	ADC_SR05	ADC	CHCR05.PRSEL = 0011 _B
	SSC1_TDR	SSC1	CHCR05.PRSEL = 0100 _B

Direct Memory Access Controller (DMA)

Table 11-11 DMA Request Assignment for DMA Sub-Block 0 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	ASC1_TDR	ASC1	CHCR05.PRSEL = 0101 _B
	MSC0_SR3	MSC0	CHCR05.PRSEL = 0110 _B
	MLI0_SR5	MLI0	CHCR05.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR05.PRSEL = 1000 _B
	GPTA_TRIG05	GPTA ¹⁾	CHCR05.PRSEL = 1001 _B
	GPTA_TRIG15	GPTA ¹⁾	CHCR05.PRSEL = 1010 _B
	TINT1SRC	ERAY	CHCR05.PRSEL = 1011 _B
	ASC1_TBDR	ASC1	CHCR05.PRSEL = 1100 _B
	CCU61_SR0	CCU61_SR0	CHCR05.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR05.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR05.PRSEL = 1111 _B
06	DMA_SR14	DMA(INT_O14)	CHCR06.PRSEL = 0000 _B
	IOUT2	SCU (ERU)	CHCR06.PRSEL = 0001 _B
	FADC_SR02	FADC	CHCR06.PRSEL = 0010 _B
	ADC_SR06	ADC	CHCR06.PRSEL = 0011 _B
	SSC0_RDR	SSC0	CHCR06.PRSEL = 0100 _B
	ASC0_RDR	ASC0	CHCR06.PRSEL = 0101 _B
	CAN_INT_O0	MultiCAN	CHCR06.PRSEL = 0110 _B
	MLI0_SR6	MLI0	CHCR06.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR06.PRSEL = 1000 _B
	GPTA_TRIG06	GPTA ¹⁾	CHCR06.PRSEL = 1001 _B
	GPTA_TRIG16	GPTA ¹⁾	CHCR06.PRSEL = 1010 _B
	NDAT1SRC	ERAY	CHCR06.PRSEL = 1011 _B
	SSC3_TDR	SSC3	CHCR06.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1111 _B
07	DMA_SR15	DMA(INT_O15)	CHCR07.PRSEL = 0000 _B
	IOUT3	SCU (ERU)	CHCR07.PRSEL = 0001 _B
	FADC_SR03	FADC	CHCR07.PRSEL = 0010 _B

Direct Memory Access Controller (DMA)

Table 11-11 DMA Request Assignment for DMA Sub-Block 0 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	ADC_SR07	ADC	CHCR07.PRSEL = 0011 _B
	SSC1_RDR	SSC1	CHCR07.PRSEL = 0100 _B
	ASC1_RDR	ASC1	CHCR07.PRSEL = 0101 _B
	CAN_INT_O1	MultiCAN	CHCR07.PRSEL = 0110 _B
	MLI0_SR7	MLI0	CHCR07.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR07.PRSEL = 1000 _B
	GPTA_TRIG07	GPTA ¹⁾	CHCR07.PRSEL = 1001 _B
	GPTA_TRIG17	GPTA ¹⁾	CHCR07.PRSEL = 1010 _B
	MBSC1SRC	ERAY	CHCR07.PRSEL = 1011 _B
	SSC3_RDR	SSC3	CHCR07.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1111 _B

1) GPTA_TRIG signals are per default level sensitive signals while a DMA channel is activated with every active request signal cycle. The DMA internal positive edge detection will generate the channel request with the rising edge of the GPTA_TRIG signal, if selected. If channel requests for the positive and/or negative GPTA_TRIG signal is required, this can be realized either via the ERU (some GPTA_TRIG signals are mapped to it) or via GPTA programming by using additional GPTA cells.

2) Reserved PRSEL combinations do not result to DMA Channel requests.

Table 11-12 DMA Request Assignment for DMA Sub-Block 1

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
10	DMA_SR08	DMA(INT_O08)	CHCR00.PRSEL = 0000 _B
	IOUT0	SCU (ERU)	CHCR00.PRSEL = 0001 _B
	FADC_SR00	FADC	CHCR00.PRSEL = 0010 _B
	ADC_SR00	ADC	CHCR00.PRSEL = 0011 _B
	SSC0_RDR	SSC0	CHCR00.PRSEL = 0100 _B
	ASC0_RDR	ASC0	CHCR00.PRSEL = 0101 _B
	CAN_INT_O0	MultiCAN	CHCR00.PRSEL = 0110 _B
	MLI0_SR4	MLI0	CHCR00.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR00.PRSEL = 1000 _B

Direct Memory Access Controller (DMA)

Table 11-12 DMA Request Assignment for DMA Sub-Block 1 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	GPTA_TRIG00	GPTA ¹⁾	CHCR00.PRSEL = 1001 _B
	GPTA_TRIG10	GPTA ¹⁾	CHCR00.PRSEL = 1010 _B
	INT1SRC	ERAY	CHCR00.PRSEL = 1011 _B
	IBUSY	ERAY	CHCR00.PRSEL = 1100 _B
	SSC2_RDR	SSC2	CHCR00.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR00.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR00.PRSEL = 1111 _B
11	DMA_SR09	DMA(INT_O09)	CHCR01.PRSEL = 0000 _B
	IOUT1	SCU (ERU)	CHCR01.PRSEL = 0001 _B
	FADC_SR01	FADC	CHCR01.PRSEL = 0010 _B
	ADC_SR01	ADC	CHCR01.PRSEL = 0011 _B
	SSC1_RDR	SSC1	CHCR01.PRSEL = 0100 _B
	ASC1_RDR	ASC1	CHCR01.PRSEL = 0101 _B
	CAN_INT_O1	MultiCAN	CHCR01.PRSEL = 0110 _B
	MLI0_SR5	MLI0	CHCR01.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR01.PRSEL = 1000 _B
	GPTA_TRIG01	GPTA ¹⁾	CHCR01.PRSEL = 1001 _B
	GPTA_TRIG11	GPTA ¹⁾	CHCR01.PRSEL = 1010 _B
	TINT0SRC	ERAY	CHCR01.PRSEL = 1011 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1100 _B
	CCU60_SR0	CCU60_SR0	CHCR01.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR01.PRSEL = 1111 _B
12	DMA_SR10	DMA(INT_O10)	CHCR02.PRSEL = 0000 _B
	IOUT2	SCU (ERU)	CHCR02.PRSEL = 0001 _B
	FADC_SR02	FADC	CHCR02.PRSEL = 0010 _B
	ADC_SR02	ADC	CHCR02.PRSEL = 0011 _B
	SSC0_TDR	SSC0	CHCR02.PRSEL = 0100 _B
	ASC0_TDR	ASC0	CHCR02.PRSEL = 0101 _B
	MSC0_SR2	MSC0	CHCR02.PRSEL = 0110 _B

Direct Memory Access Controller (DMA)

Table 11-12 DMA Request Assignment for DMA Sub-Block 1 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	MLI0_SR6	MLI0	CHCR02.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR02.PRSEL = 1000 _B
	GPTA_TRIG02	GPTA ¹⁾	CHCR02.PRSEL = 1001 _B
	GPTA_TRIG12	GPTA ¹⁾	CHCR02.PRSEL = 1010 _B
	NDAT1SRC	ERAY	CHCR02.PRSEL = 1011 _B
	ASC0_TBDR	ASC0	CHCR02.PRSEL = 1100 _B
	SSC2_TDR	SSC2	CHCR02.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR02.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR02.PRSEL = 1111 _B
13	DMA_SR11	DMA(INT_O11)	CHCR03.PRSEL = 0000 _B
	IOUT3	SCU (ERU)	CHCR03.PRSEL = 0001 _B
	FADC_SR03	FADC	CHCR03.PRSEL = 0010 _B
	ADC_SR03	ADC	CHCR03.PRSEL = 0011 _B
	SSC1_TDR	SSC1	CHCR03.PRSEL = 0100 _B
	ASC1_TDR	ASC1	CHCR03.PRSEL = 0101 _B
	MSC0_SR3	MSC0	CHCR03.PRSEL = 0110 _B
	MLI0_SR7	MLI0	CHCR03.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR03.PRSEL = 1000 _B
	GPTA_TRIG03	GPTA ¹⁾	CHCR03.PRSEL = 1001 _B
	GPTA_TRIG13	GPTA ¹⁾	CHCR03.PRSEL = 1010 _B
	MBSC1SRC	ERAY	CHCR03.PRSEL = 1011 _B
	ASC1_TBDR	ASC1	CHCR03.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR03.PRSEL = 1101 _B
	Reserved	-	CHCR03.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR03.PRSEL = 1111 _B
14	DMA_SR12	DMA(INT_O12)	CHCR04.PRSEL = 0000 _B
	IOUT0	SCU (ERU)	CHCR04.PRSEL = 0001 _B
	FADC_SR00	FADC	CHCR04.PRSEL = 0010 _B
	ADC_SR04	ADC	CHCR04.PRSEL = 0011 _B
	SSC0_TDR	SSC0	CHCR04.PRSEL = 0100 _B

Direct Memory Access Controller (DMA)

Table 11-12 DMA Request Assignment for DMA Sub-Block 1 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	ASC0_TDR	ASC0	CHCR04.PRSEL = 0101 _B
	MSC0_SR2	MSC0	CHCR04.PRSEL = 0110 _B
	MLI0_SR4	MLI0	CHCR04.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR04.PRSEL = 1000 _B
	GPTA_TRIG04	GPTA ¹⁾	CHCR04.PRSEL = 1001 _B
	GPTA_TRIG14	GPTA ¹⁾	CHCR04.PRSEL = 1010 _B
	INT1SRC	ERAY	CHCR04.PRSEL = 1011 _B
	ASC0_TBDR	ASC0	CHCR04.PRSEL = 1100 _B
	OBUSY	ERAY	CHCR04.PRSEL = 1101 _B
	Reserved	-	CHCR04.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR04.PRSEL = 1111 _B
15	DMA_SR13	DMA(INT_O13)	CHCR05.PRSEL = 0000 _B
	IOUT1	SCU (ERU)	CHCR05.PRSEL = 0001 _B
	FADC_SR01	FADC	CHCR05.PRSEL = 0010 _B
	ADC_SR05	ADC	CHCR05.PRSEL = 0011 _B
	SSC1_TDR	SSC1	CHCR05.PRSEL = 0100 _B
	ASC1_TDR	ASC1	CHCR05.PRSEL = 0101 _B
	MSC0_SR3	MSC0	CHCR05.PRSEL = 0110 _B
	MLI0_SR5	MLI0	CHCR05.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR05.PRSEL = 1000 _B
	GPTA_TRIG05	GPTA ¹⁾	CHCR05.PRSEL = 1001 _B
	GPTA_TRIG15	GPTA ¹⁾	CHCR05.PRSEL = 1010 _B
	TINT1SRC	ERAY	CHCR05.PRSEL = 1011 _B
	ASC1_TBDR	ASC1	CHCR05.PRSEL = 1100 _B
	CCU61_SR0	CCU61_SR0	CHCR05.PRSEL = 1101 _B
	Reserved	-	CHCR05.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR05.PRSEL = 1111 _B
16	DMA_SR14	DMA(INT_O14)	CHCR06.PRSEL = 0000 _B
	IOUT2	SCU (ERU)	CHCR06.PRSEL = 0001 _B
	FADC_SR02	FADC	CHCR06.PRSEL = 0010 _B

Direct Memory Access Controller (DMA)

Table 11-12 DMA Request Assignment for DMA Sub-Block 1 (cont'd)

DMA Channel	DMA Request Line	DMA Requesting Unit	Selected by
	ADC_SR06	ADC	CHCR06.PRSEL = 0011 _B
	SSC0_RDR	SSC0	CHCR06.PRSEL = 0100 _B
	ASC0_RDR	ASC0	CHCR06.PRSEL = 0101 _B
	CAN_INT_O0	MultiCAN	CHCR06.PRSEL = 0110 _B
	MLI0_SR6	MLI0	CHCR06.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR06.PRSEL = 1000 _B
	GPTA_TRIG06	GPTA ¹⁾	CHCR06.PRSEL = 1001 _B
	GPTA_TRIG16	GPTA ¹⁾	CHCR06.PRSEL = 1010 _B
	NDAT1SRC	ERAY	CHCR06.PRSEL = 1011 _B
	SSC3_TDR	SSC3	CHCR06.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR06.PRSEL = 1111 _B
17	DMA_SR15	DMA(INT_O15)	CHCR07.PRSEL = 0000 _B
	IOUT3	SCU (ERU)	CHCR07.PRSEL = 0001 _B
	FADC_SR03	FADC	CHCR07.PRSEL = 0010 _B
	ADC_SR07	ADC	CHCR07.PRSEL = 0011 _B
	SSC1_RDR	SSC1	CHCR07.PRSEL = 0100 _B
	ASC1_RDR	ASC1	CHCR07.PRSEL = 0101 _B
	CAN_INT_O1	MultiCAN	CHCR07.PRSEL = 0110 _B
	MLI0_SR7	MLI0	CHCR07.PRSEL = 0111 _B
	STMIRQ0	STM	CHCR07.PRSEL = 1000 _B
	GPTA_TRIG07	GPTA ¹⁾	CHCR07.PRSEL = 1001 _B
	GPTA_TRIG17	GPTA ¹⁾	CHCR07.PRSEL = 1010 _B
	MBSC1SRC	ERAY	CHCR07.PRSEL = 1011 _B
	SSC3_RDR	SSC3	CHCR07.PRSEL = 1100 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1101 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1110 _B
	Reserved ²⁾	-	CHCR07.PRSEL = 1111 _B

Direct Memory Access Controller (DMA)

- 1) GPTA_TRIG signals are per default level sensitive signals while a DMA channel is activated with every active request signal cycle. The DMA internal positive edge detection will generate the channel request with the rising edge of the GPTA_TRIG signal, if selected. If channel requests for the positive and/or negative GPTA_TRIG signal is required, this can be realized either via the ERU (some GPTA_TRIG signals are mapped to it) or via GPTA programming by using additional GPTA cells.
- 2) Reserved PRSEL combinations do not result to DMA Channel requests.

Direct Memory Access Controller (DMA)

11.4.2 Access Protection Assignment

DMA access protection as described on [Page 11-45](#) requires the assignment of 32 fixed address range. [Table 11-13](#) shows this address range assignment as implemented in the TC1728 (see also: [Page 11-82](#), [Page 11-82](#)).

Table 11-13 DMA Access Protection Address Ranges

Access Protection Range			Related Module(s)
No. n	Enable Bit in MEMAENR	Selected Address Range	
0	AEN0	F000 0500 _H - F000 06FF _H F010 C200 _H - F010 C2FF _H	SCU MEMCHK
1	AEN1	F000 0100 _H - F000 01FF _H	SBCU
2	AEN2	F000 0200 _H - F000 02FF _H	STM
3	AEN3	F000 0400 _H - F000 04FF _H	OCDS
4	AEN4	F000 0800 _H to F000 09FF _H	MSC0
5	AEN5	F000 0A00 _H to F000 0AFF _H	ASC0
6	AEN6	F000 0B00 _H to F000 0BFF _H	ASC1
7	AEN7	F000 0C00 _H - F000 17FF _H	Port 0 - Port 5, Port 6, Port 8, Port 9, Port 10, Port 11
8	AEN8	F030 0000 _H - F030 04FF _H	Port 12
9	AEN9	F000 1800 _H - F000 37FF _H	GPTA (GPTA0), CCU60, CCU61, GPT120, GPT121
10	AEN10	F000 3C00 _H - F000 3EFF _H	DMA
11	AEN11	F000 4000 _H - F000 7FFF _H	MultiCAN
12	AEN12	F004 0000 _H - F004 FFFF _H	PCP Registers
13	AEN13	F005 0000 _H - F005 FFFF _H	PCP Data Memory (PRAM)
14	AEN14	F006 0000 _H - F007 FFFF _H	PCP CodeMemory (PCODE)
15	AEN15	F010 0000 _H - F010 00FF _H F010 0100 _H - F010 01FF _H	SSC3, SSC0
16	AEN16	F010 0200 _H - F010 03FF _H	SSC1, SSC2
17	AEN17	F010 0400 _H - F010 05FF _H	FADC
18	AEN18	F010 1000 _H - F010 1BFF _H	ADC0, ADC1

Direct Memory Access Controller (DMA)

Table 11-13 DMA Access Protection Address Ranges (cont'd)

Access Protection Range			Related Module(s)
No. n	Enable Bit in MEMAENR	Selected Address Range	
19	AEN19	F010 C000 _H - F010 C0FF _H F01E 0000 _H - F01E 7FFF _H F020 0000 _H - F023 FFFF _H	MLIO Module, MLIO Small TWs, MLIO Large TWs
20	AEN20	F032 0000 _H - F032 00FF _H	FCE
21	AEN21	F7E0 FF00 _H - F7E0 FFFF _H F7E1 0000 _H - F7E1 FFFF _H F800 0400 _H - F87F FFFF _H	CPS, CPU SFRs & GPRs, PMU, Flash Regs, LBCU, DMI, PMI, LFI
22	AEN22	F032 3000 _H - F032 31FF _H	BMU Registers
23	AEN23	8000 0000 _H - 807F FFFF _H A000 0000 _H - A07F FFFF _H	Program Flash Space
24	AEN24	F032 4000 _H - F032 4FFF _H	BMURAM
25	AEN25	8FE0 0000 _H - 8FE1 FFFF _H AFE0 0000 _H - AFE1 FFFF _H	Data Flash Space
26	AEN26	8FF0 0000 _H - 8FFF BFFF _H AFF0 0000 _H - AFFF BFFF _H	Emulation Device Memory Space
27	AEN27	8FFF C000 _H - 8FFF FFFF _H AFFF C000 _H - AFFF FFFF _H	Boot ROM
28	AEN28	F001 0000 _H - F001 7FFF _H	ERAY
29	AEN29	8FE8 0000 _H - 8FE8 1FFF _H AFE8 0000 _H - AFE8 1FFF _H	OVRAM
30	AEN30	D000 0000 _H - D001 FFFF _H E840 0000 _H - E84F FFFF _H	DMI DMI Image (E84x translated to D00x)
31	AEN31	C000 0000 _H - C401 FFFF _H D400 0000 _H - D401 FFF _H E850 0000 _H - E85F FFFF _H E800 0000 _H - E83F FFFF _H	PMI PMI Image (E85x translated to D40x)

Direct Memory Access Controller (DMA)

In the TC1728, four internal memory areas (SPRAM and LDRAM, PRAM, and OVRAM) are protected by an address range verification in addition to the access enable bits. The address range verification is based on the bit fields SIZE_x and SLIZE_x ($x = 3-0$), which are located in the registers MEmARR ($m = 1-0$). An access to one of these four memory areas is only processed if it is enabled by the corresponding AEN_x bit and if the address is inside the sub-range defined by the corresponding SIZE_x and SLIZE_x. If the address is outside of the defined sub-range, the transfer will not be processed and an error interrupt is generated (indicated by the corresponding MExDER, MExSER bit). If a protected memory is available from DMA under multiple address ranges (LMB, FPI, cached and or un-cached segments), the access protection is valid for all memory views in parallel, starting always with the base address of the memory views, ending always with the end address of the address range.

The address ranges described by SLIZE_x and SIZE_x are defined as follows:

- MEmARR.SLICE0, MEmARR.SIZE0:
24-KB PMI RAM (SPRAM), assigned to address range 31 (AEN31). The sub-ranges are controlled by bit fields MEmARR.SIZE0 and ME0ARR.SLICE0 with a minimum granularity of 0.5 KB (see [Table 11-14](#)).
- MEmARR.SIZE1 and MEmARR.SLICE1:
8-KB OVRAM, assigned to address range 29 (AEN29). The sub-ranges are controlled by bit fields MEmARR.SIZE1 and MEmARR.SLICE1 with a minimum granularity of 0.5 KB (see [Table 11-15](#)).
- MEmARR.SIZE2 and MEmARR.SLICE2:
120-KB DMI RAM (LDRAM), assigned to address range 30 (AEN30). The sub-ranges are controlled by bit fields MEmARR.SIZE2 and MEmARR.SLICE2 with a minimum granularity of 1 KB (see [Table 11-16](#)).
- MEmARR.SIZE3 and MEmARR.SLICE3:
8-Kbyte PCP PRAM, assigned to address range 13 (AEN13). The sub-range is controlled by bit fields ME0mARR.SIZE3 and ME0mARR.SLICE3 with a minimum granularity of 0.5 KB (see [Table 11-17](#)).

Direct Memory Access Controller (DMA)

SIZE0 and SLICE0 bit fields: PMI sub-range access protection

Bit fields SIZE0 and SLICE0 for the PMI memory sub-range access protection (24 KB SPRAM) as shown in [Table 11-14](#).

The PMI memory is protected with a min. granularity of 0.5 KB up to the end address xxx0 5FFF_H¹⁾.

PMI address ranges that are protected by the bit fields SIZE0 and SLICE0:

- D400 0000_H - D400 5FFF_H (PMI SPRAM on LMB)
- E850 0000_H - E850 5FFF_H (LFI translation from E850 to C000)
- C000 0000_H - C000 5FFF_H (PMI SPRAM on LMB)
- E800 0000_H - E800 5FFF_H (LFI translation from E800 to D400)

Table 11-14 PMI Address Protection Sub-Range Definition

SIZE0	Sub-Ranges	SLICE0	Selected Address Range ¹⁾
000 _B	32 sub-ranges of 512 bytes	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 01FF _H xxx0 0200 _H - xxx0 03FF _H ... xxx0 3E00 _H - xxx0 3FFF _H
001 _B	32 sub-ranges of 1 Kbyte	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 03FF _H xxx0 0400 _H - xxx0 07FF _H ... xxx0 7C00 _H - xxx0 7FFF _H
010 _B	32 sub-ranges of 2 Kbytes	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 07FF _H xxx0 0800 _H - xxx0 0FFF _H ... xxx0 F800 _H - xxx0 FFFF _H
011 _B	16 sub-ranges of 4 Kbytes	X0000 _B X0001 _B ... X1111 _B	xxx0 0000 _H - xxx0 0FFF _H xxx0 1000 _H - xxx0 1FFF _H ... xxx0 F000 _H - xxx0 FFFF _H
100 _B	8 sub-ranges of 8 Kbytes	XX000 _B XX001 _B ... XX111 _B	xxx0 0000 _H - xxx0 1FFF _H xxx0 2000 _H - xxx0 3FFF _H xxx0 E000 _H - xxx0 FFFF _H
101 _B	4 sub-ranges of 16 Kbytes	XXX00 _B XXX01 _B XXX10 _B XXX11 _B	xxx0 0000 _H - xxx0 3FFF _H xxx0 4000 _H - xxx0 7FFF _H xxx0 8000 _H - xxx0 BFFF _H xxx0 C000 _H - xxx0 FFFF _H

1) xxx in [Table 11-14](#), column 'Selected Address Range' is the place holder for D40_H, E85_H, C00_H, E80_H.

Direct Memory Access Controller (DMA)

Table 11-14 PMI Address Protection Sub-Range Definition (cont'd)

SIZE0	Sub-Ranges	SLICE0	Selected Address Range ¹⁾
110 _B	2 sub-ranges of 32 Kbytes	XXXX0 _B XXXX1 _B	xxxx 0000 _H - xxxx 7FFF _H xxxx 8000 _H - xxxx FFFF _H
111 _B	64 Kbytes	XXXXX _B	xxxx 0000 _H - xxxx FFFF _H

SIZE1 and SLICE1 bit fields: OVRAM sub-range access protection

Bit fields SIZE1 and SLICE1 for the OVRAM sub-range access protection (with address translation from E800 to C000 in the LFI) are coded as shown in [Table 11-15](#).

The 8 KB OVRAM memory is protected with a min. granularity of 0.5 KB up to it's end address xFE8 1FFF_H¹⁾.

OVRAM address ranges that are protected by the bit fields SIZE1 and SLICE1:

- 8FE8 0000_H - 8FE8 1FFF_H (OVRAM on LMB, cached segment)
- AFE8 0000_H - AFE8 1FFF_H (OVRAM on LMB, un-cached segment)

Table 11-15 OVRAM Address Protection Sub-Range Definition

SIZE1	Sub-Ranges	SLICE1	Selected Address Range ¹⁾
000 _B	32 sub-ranges of 512 bytes	00000 _B 00001 _B ... 11111 _B	xFE0 0000 _H - xFE0 01FF _H xFE0 0200 _H - xFE0 03FF _H ... xFE0 3E00 _H - xFE0 3FFF _H
001 _B	32 sub-ranges of 1 Kbyte	00000 _B 00001 _B ... 11111 _B	xFE0 0000 _H - xFE0 03FF _H xFE0 0400 _H - xFE0 07FF _H ... xFE0 7C00 _H - xFE0 7FFF _H
010 _B	32 sub-ranges of 2 Kbytes	00000 _B 00001 _B ... 11111 _B	xFE0 0000 _H - xFE0 07FF _H xFE0 0800 _H - xFE0 0FFF _H ... xFE0 F800 _H - xFE0 FFFF _H
011 _B	16 sub-ranges of 4 Kbytes	X0000 _B X0001 _B ... X1111 _B	xFE0 0000 _H - xFE0 0FFF _H xFE0 1000 _H - xFE0 1FFF _H ... xFE0 F000 _H - xFE0 FFFF _H

1) x in [Table 11-15](#), column 'Selected Address Range' is the place holder for D_H, and A_H.

Direct Memory Access Controller (DMA)

Table 11-15 OVRAM Address Protection Sub-Range Definition (cont'd)

SIZE1	Sub-Ranges	SLICE1	Selected Address Range ¹⁾
100 _B	8 sub-ranges of 8 Kbytes	XX000 _B XX001 _B ... XX111 _B	xxx0 0000 _H - xxx0 1FFF _H xxx0 2000 _H - xxx0 3FFF _H ... xxx0 E000 _H - xxx0 FFFF _H
101 _B	4 sub-ranges of 16 Kbytes	XXX00 _B XXX01 _B XXX10 _B XXX11 _B	xxx0 0000 _H - xxx0 3FFF _H xxx0 4000 _H - xxx0 7FFF _H xxx0 8000 _H - xxx0 BFFF _H xxx0 C000 _H - xxx0 FFFF _H
110 _B	2 sub-ranges of 32 Kbytes	XXXX0 _B XXXX1 _B	xxxx 0000 _H - xxxx 7FFF _H xxxx 8000 _H - xxxx FFFF _H
111 _B	64 Kbytes	XXXXX _B	xxxx 0000 _H - xxxx FFFF _H

SIZE2 and SLICE2 bit fields: DMI sub-range access protection

Bit fields SIZE2 and SLICE2 for the DMI RAM sub-range access protection. These bit fields are covering the 120KB DMI memory (LDRAM).

The DMI memory is protected with a min. granularity of 1 KB ([Table 11-16](#)) up to it's end address D001 DFFF_H and E841 DFFF_H.

DMI address ranges that are protected by the bit fields SIZE2 and SLICE2:

- D000 0000_H - D001 DFFF_H (DMI LDRAM on LMB)
- E840 0000_H - E841 DFFF_H (LFI translation from E840 to D000)

Table 11-16 DMI Address Protection Sub-Range Defintions

SIZE2	Sub-Ranges	SLICE2	Selected Address Range ¹⁾
000 _B	32 sub-ranges of 1 Kbytes	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 03FF _H xxx0 0400 _H - xxx0 07FF _H ... xxx0 7C00 _H - xxx0 7FFF _H
001 _B	32 sub-ranges of 2 Kbyte	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 07FF _H xxx0 0800 _H - xxx0 0FFF _H ... xxx0 F800 _H - xxx0 FFFF _H
010 _B	32 sub-ranges of 4Kbytes	00000 _B 00001 _B ... 11111 _B	xxx0 0000 _H - xxx0 0FFF _H xxx0 1000 _H - xxx0 1FFF _H ... xxx1 F000 _H - xxx1 FFFF _H

Direct Memory Access Controller (DMA)

Table 11-16 DMI Address Protection Sub-Range Defintions (cont'd)

SIZE2	Sub-Ranges	SLICE2	Selected Address Range ¹⁾
011 _B	16 sub-ranges of 8 Kbytes	X0000 _B X0001 _B ... X1111 _B	xxx0 0000 _H - xxx0 1FFF _H xxx0 2000 _H - xxx0 3FFF _H ... xxx1 E000 _H - xxx1 FFFF _H
100 _B	8 sub-ranges of 16 Kbytes	XX000 _B XX001 _B ... XX111 _B	xxx0 0000 _H - xxx0 3FFF _H xxx0 4000 _H - xxx0 7FFF _H ... xxx1 C000 _H - xxx1 FFFF _H
101 _B	4 sub-ranges of 32 Kbytes	XXX00 _B XXX01 _B XXX10 _B XXX11 _B	xxx0 0000 _H - xxx0 7FFF _H xxx0 8000 _H - xxx0 FFFF _H xxx1 0000 _H - xxx1 7FFF _H xxx1 8000 _H - xxx1 FFFF _H
110 _B	2 sub-ranges of 64 Kbytes	XXXX0 _B XXXX1 _B	xxx0 0000 _H - xxx0 FFFF _H xxx1 0000 _H - xxx1 FFFF _H
111 _B	128 Kbytes	XXXXX _B	xxx0 0000 _H - xxx1 FFFF _H

1) xxx in [Table 11-16](#), column 'Selected Address Range' is the place holder of D00_H and E84_H

SIZE3 and SLICE3 bit fields: PCP PRAM sub-range access protection

Bit fields SIZE3 and SLICE3 for the PCP Parameter RAM (PRAM) sub-range access protection. These bit fields are covering PCP PRAM memory.

The PCP PRAM memory is protected with a min. granularity of 0.5 KB ([Table 11-17](#)) up to it's end address F005 1FFF_H.

PCP PRAM address range that is protected by the bit fields SIZE3 and SLICE3:

- F005 0000_H - F005 1FFF_H (PCP PRAM on FPI Bus, 8 KB)

Table 11-17 PCP PRAM Address Protection Sub-Range DefinitionScheme

SIZE3	Sub-Ranges	SLICE3	Selected Address Range
000 _B	32 sub-ranges of 512 bytes	00000 _B 00001 _B ... 11111 _B	F005 0000 _H - F005 01FF _H F005 0200 _H - F005 03FF _H ... F005 3E00 _H - F005 3FFF _H
001 _B	32 sub-ranges of 1 Kbyte	00000 _B 00001 _B ... 11111 _B	F005 0000 _H - F005 03FF _H F005 0400 _H - F005 07FF _H ... F005 7C00 _H - F005 7FFF _H

Direct Memory Access Controller (DMA)

Table 11-17 PCP PRAM Address Protection Sub-Range Definition Scheme

SIZE ₃	Sub-Ranges	SLICE ₃	Selected Address Range
010 _B	32 sub-ranges of 2 Kbytes	00000 _B 00001 _B ... 11111 _B	F005 0000 _H - F005 07FF _H F005 0800 _H - F005 0FFF _H ... F005 F800 _H - F005 FFFF _H
011 _B	16 sub-ranges of 4 Kbytes	X0000 _B X0001 _B ... X1111 _B	F005 0000 _H - F005 0FFF _H F005 1000 _H - F005 1FFF _H ... F005 F000 _H - F005 FFFF _H
100 _B	8 sub-ranges of 8 Kbytes	XX000 _B XX001 _B ... XX111 _B	F005 0000 _H - F005 1FFF _H F005 2000 _H - F005 3FFF _H ... F005 E000 _H - F005 FFFF _H
101 _B	4 sub-ranges of 16 Kbytes	XXX00 _B XXX01 _B XXX10 _B XXX11 _B	F005 0000 _H - F005 3FFF _H F005 4000 _H - F005 7FFF _H F005 8000 _H - F005 BFFF _H F005 C000 _H - F005 FFFF _H
110 _B	2 sub-ranges of 32 Kbytes	XXXX0 _B XXXX1 _B	F005 0000 _H - F005 7FFF _H F005 8000 _H - F005 FFFF _H
111 _B	64 Kbytes	XXXXX _B	F005 0000 _H - F005 FFFF _H

Direct Memory Access Controller (DMA)

11.4.3 Implementation-specific DMA Registers

The DMA controller as implemented in the TC1728 contains the following additional registers:

- DMA clock control register
- Service request control registers for DMA controller interrupts (DMA_SRCx)
- Service request control registers for MLI module interrupts (DMA_MLI0ySRC.x)

Figure 11-29 provides an overview of these registers.

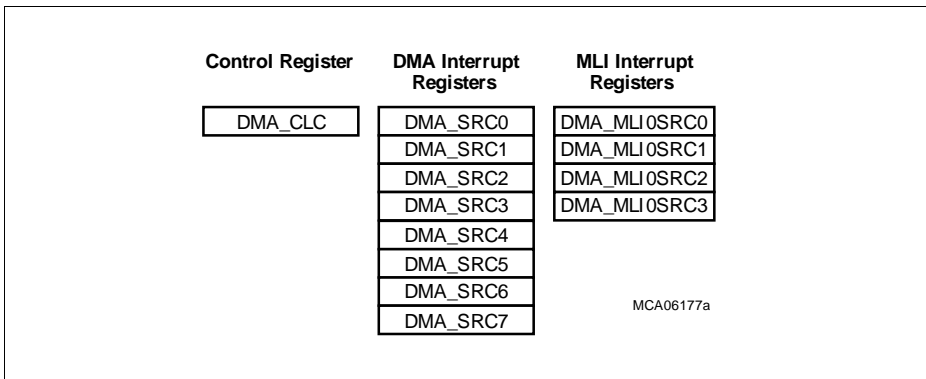


Figure 11-29 DMA Implementation-specific Registers

Note: Further details on interrupt handling and processing are described in the “Interrupt System” chapter of the TC1728 System Units User’s Manual.

The clock generation and interrupt control configuration as implemented in the DMA controller module is shown in **Figure 11-29**.

The DMA controller, the Cerberus and the MLI module (MLI0) are supplied from a common module clock f_{DMA} that has the frequency of the system clock f_{FPI} and is controlled via the DMA_CLC clock control register. The MLI module nor the Cerberus module does not have its own clock control register. Their input clock is derived from the DMA clock divided by separate fractional divider registers.

The control of the suspend and break features is done independently inside each module.

Direct Memory Access Controller (DMA)

The DMA controller module contains in total 12 interrupt request nodes with its interrupt service request control registers:

- Eight interrupt requests $SR[7:0] = INT_O[7:0]$ from the DMA controller; upper eight interrupt requests of the DMA controller $INT_O[15:8]$ are used as DMA channel trigger inputs.
- Four interrupt requests $SR[3:0] = INT_O[3:0]$ from the MLI0 module; upper four interrupt requests of the MLI0 module $INT_O[7:4]$ are not connected.

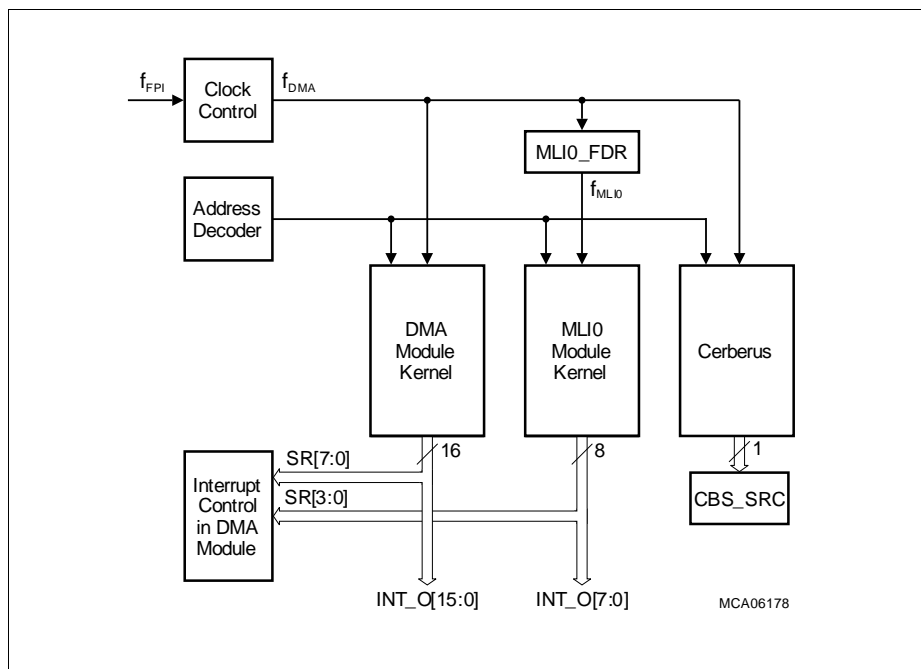


Figure 11-30 Implementation of the DMA Module and the MLI Module

Direct Memory Access Controller (DMA)

11.4.3.1 Clock Control Register

The Clock Control Register controls the DMA module internal f_{DMA} clock signal. This clock is also used for the MLI modules as a common clock that can be individually divided for the MLI modules.

DMA_CLC

DMA Clock Control Register

(000_H)

Reset Value: 0000 0008_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
										0	SB WE	ONE	SP EN	DISS	DISR
										rw	w	rw	rw	r	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the Suspend Mode
ONE	3	rw	Reserved Returns 1 if read; <u>must</u> be written with 1.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
0	5	rw	Reserved ; returns 0 if read; <u>must</u> be written with 0.
0	[31:6]	r	Reserved Read as 0; should be written with 0.

Note: After a hardware reset operation, the DMA module is enabled.

Note: The suspend mode does not modify any of the registers.

Direct Memory Access Controller (DMA)

11.4.3.3 MLI Interrupt Registers

The Service Request Control Registers of the MLI module is located inside the DMA address area, because the MLI module does not have its own FPI Bus interface. The MLI module shares one FPI Bus slave interface with the DMA controller.

The MLI0 module has eight interrupt output lines. Only four of them [3:0] are controlled by the MLI0 service request registers.

DMA_MLI0SRCx (x = 0-3)

DMA MLI0 Service Request Control Register x

 $(2AC_H - x \cdot 4_H)$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0						SRPN			
w	w	rh	rw	r	rw	r						rw			

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP request is initiated
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Note: The bit coding of the MLI0 service request registers is identical to that of the DMA Service Request Control Registers shown on the previous page.

Direct Memory Access Controller (DMA)

11.4.4 Address Map

The DMA controller register block address map is shown in [Figure 11-31](#). It shows how the different register blocks are arranged and adds the absolute address information.

F000 3 EF0 _H	DMA Service Request Control Registers
F000 3 EA0 _H	MLI Service Request Control Registers
F000 3 E8C _H	System Service Request Control Registers
F000 3 C80 _H	DMA Channel 00 - 07 Registers
F000 3 C54 _H	DMA Control/Status Registers
F000 3 C30 _H	Move Engine Registers
F000 3 C10 _H	DMA Control/Status Registers
F000 3 C00 _H	General Module Control

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Figure 11-31 DMA Controller Register Block Address Map

Direct Memory Access Controller (DMA)

11.5 Memory Checker Module

The Memory Checker Module (MCHK) includes two parallel Cyclic Redundancy Checkers (CRCs) that can be used to check the data consistency of two memories in parallel. Each CRC block contains two algorithm engines:

1. A legacy data compaction algorithm based on a Multiple Input Shift Register (MISR) implementation.
2. A CRC-32 ethernet polynomial implementation.

Both algorithm engines use a common input register and simultaneously compute a checksum.

11.5.1 Functional Description

The Memory Checker module is connected to the DMA Peripheral Interface and can be accessed via the SPB. Preferable the module is used in combination with the DMA as it as described hereafter: a DMA channel can be used to read 8-bit, 16-bit, or 32-bit data from an address area and to write the data in one of the two memory checker input register. With each write operation to the chosen memory checker input register a polynomial checksum calculation is triggered and the result of the calculation is stored in the memory checker result register. The MISR algorithm engine supports 8-bit, 16-bit and 32-bit read data accesses. The CRC-32 ethernet polynomial is limited to 32-bit accesses.

In order to start a memory check sequence, the memory checker MISR and CRC-32 Ethernet polynomial result registers must be initialized (e.g. written with FFFFFFFF_H or with a desired start value) and a DMA transaction must be set up (start address, length, etc.). When programming the DMA channel for the memory checker with $\text{CHCRmn.RROAT} = 1$, one DMA transfer request (software or hardware triggered) starts the DMA transaction.

During the read move operations of the DMA transaction, data is always read from the memory and then written into the memory checker input register for the polynomial checksum calculation. At the end of the transaction ($\text{CHSRmn.TCOUNT} = 0$), an interrupt can be generated by the DMA channel (if $\text{CHCRmn.RROAT} = 1$), and the memory checker result register can be read out by software.

The memory checker uses the standard Ethernet CRC-32 polynomial and the MISR polynomial, which is given by:

$$G^{32} = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1 \quad (11.1)$$

Note: Although the polynomial above is used for generation, the generation algorithm differs from the one that is used by the Ethernet protocol.

Direct Memory Access Controller (DMA)

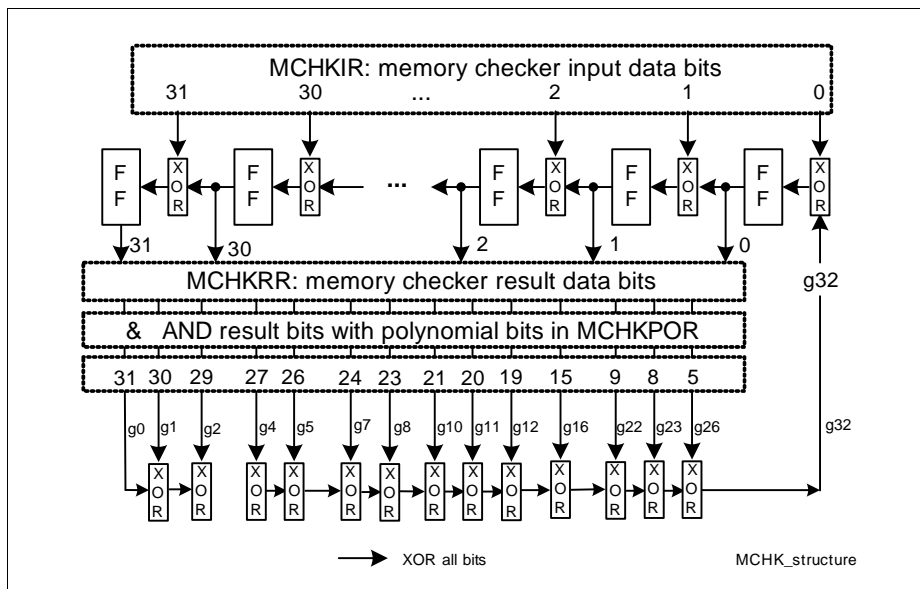


Figure 11-32 Implementation of the Memory Checker algorithm

11.5.1.1 Ethernet CRC-32 Endianness

In order to comply with the Ethernet CRC-32 standard the endianness of the input word needs to be big endian. This is important only when the input stream is made up of bytes, because each CPU architecture may have a different endianness.

TriCore is little endian, and when a byte pointer (to a byte array) is cast into a 32-bit word pointer, the compiler packs the bytes in little endian format and therefore the CRC-32 checksum result provided by the MCHK Ethernet CRC-32 hardware differs from that generated by an Ethernet CRC-32 software model using a byte stream. In order to generate a checksum compliant with the Ethernet CRC-32 checksum then the software must swap the order of the bytes.

Direct Memory Access Controller (DMA)

11.5.2 Memory Checker Module Registers

This section describes the kernel registers of the Memory Checker module.

MCHK Register Overview

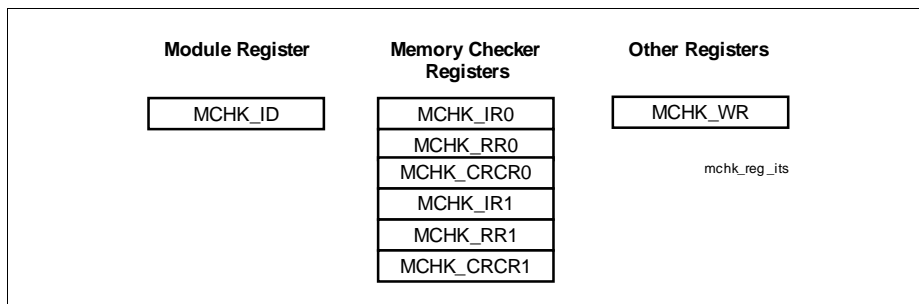


Figure 11-33 Memory Checker Registers

Table 11-18 Registers Address Space - Memory Checker Module Address Space

Module	Base Address	End Address	Note
MCHK	F010 C200 _H	F010 C2FF _H	

Table 11-19 Registers Overview - Memory Checker Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
-	Reserved	000 _H - 004 _H	BE	BE	-	-
MCHK_ID	Module Identification Register	008 _H	US, V	BE	-	Page 11-129
-	Reserved	00C _H	BE	BE	-	-
MCHK_IR0	Memory Checker Input Register	010 _H	U, SV	U, SV	3	Page 11-131
MCHK_RR0	Memory Checker Result Register	014 _H	U, SV	U, SV	3	Page 11-131
MCHK_IR1	Memory Checker Input Register	018 _H	U, SV	U, SV	3	Page 11-131
MCHK_RR1	Memory Checker Result Register	01C _H	U, SV	U, SV	3	Page 11-131

Direct Memory Access Controller (DMA)

Table 11-19 Registers Overview - Memory Checker Module Control Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
MCHK_WR	Memory Checker Write Register	020 _H	U, SV	U, SV	3	Page 11-132
MCHK_CRC R0	Memory Checker Input Register	024 _H	U, SV	U, SV	3	Page 11-132
MCHK_CRC R1	Memory Checker Result Register	028 _H	U, SV	U, SV	3	Page 11-132
-	Reserved	02C _H - 0FC _H	BE	BE	-	-

1) The absolute register address is calculated as follows:

Module Base Address ([Table 11-18](#)) + Offset Address (shown in this column)

11.5.2.1 Memory Checker Module Control Registers

The identification register allows the programmer version-tracking of the module. The table below shows the identification register which is implemented in the MCHK module.

MCHK_ID

Module Identification Register

(008_H)

Reset Value: 001B C0XX_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MOD_NUMBER															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOD_TYPE								MOD_REV							
r								r							

Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).

Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBE R	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the Memory Checker module is 001B _H .

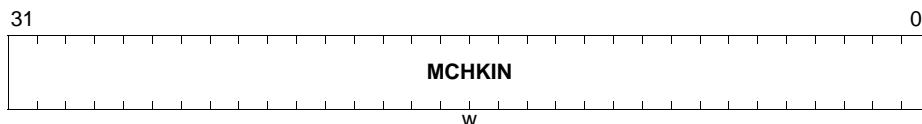
Direct Memory Access Controller (DMA)

A Memory Checker Input Register is used during write moves of a memory checker related DMA transaction as data destination with its fixed register address. If the DMA moves to register, for example MCHK_IR0 are 8-bit or 16-bit wide, the unused register bits of the 32-bit MCHKIN0 value are taken as 0s for the current result calculation.

MCHK_IRx (x = 0-1)

Memory Checker Input Register ($010_H + x * 08_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
MCHKIN	[31:0]	w	Memory Checker Input The value written to MCHKIN is used for the next checksum calculation. Any read action will deliver 0.

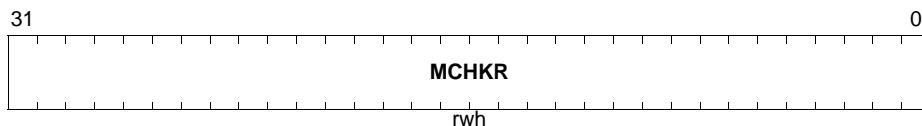
Note: MCHK_IR is a write-only register. Any read action will deliver 0000 0000_H.

A Memory Checker Result Register contains the result of the memory check operation. Before starting a checksum calculation operation, it should be written with an initial checksum calculation value.

MCHK_RRx (x = 0-1)

Memory Checker Result Register ($014_H + x * 08_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
MCHKR	[31:0]	rwh	Memory Checker Result This bit field contains the current result of the memory checksum calculation operation.

Direct Memory Access Controller (DMA)

The Memory Checker Write Register is a dummy write-only register that is located within the memory checker address range.

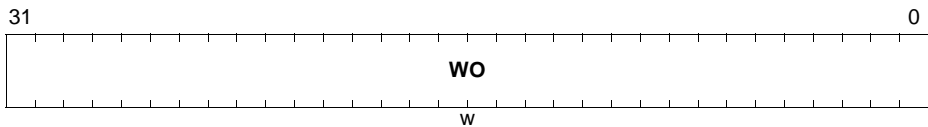
The Memory Checker Write Register can be used as dummy write register at the write back action of the DMA or MLI controller Move Engine when the pattern detection feature of the DMA controller is used. Accessing MCHK_WR with the Move Engine of the MLI or DMA controller via the Bus Switch of the DMA controller (see [Figure 11-14](#)) does not request the two FPI buses of the TC1728, SPB and DMA, because it is near the MLI modules address ranges.

MCHK_WR

Memory Checker Write Register

(020_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
WO	[31:0]	w	Write-Only This write-only bit field is used to write dummy data during DMA pattern detection. The data written to WO is not taken into account for any action. Any read action of WO will deliver 0000 0000 _H .

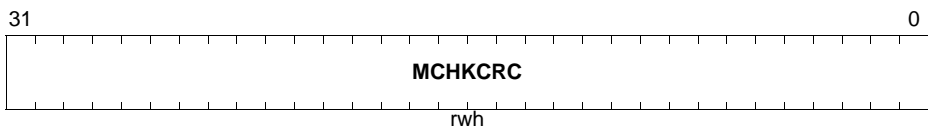
A Memory Checker CRC Register contains the working CRC-32 ethernet polynomial working checksum before it is inverted and reflected.

MCHK_CRCx (x = 0-1)

Memory Checker CRC Register

(024_H+x*04_H)

Reset Value: 0000 0000_H



Direct Memory Access Controller (DMA)

Field	Bits	Type	Description
MCHKCRC	[31:0]	rwh	Memory Checker CRC This bit field contains the working CRC32 ethernet polynomial checksum. The stored value is inverted and reflected prior to a read. Therefore if the register is written with all 1's then the output will be all 0's.

12 Flexible CRC Engine (FCE)

This document describes the Flexible CRC Engine (FCE) module. The FCE provides a parallel implementation of one or more Cyclic Redundancy Code (CRC) algorithms. The current FCE version for the TC1728 microcontroller implements the IEEE 802.3 ethernet CRC32 and the Castagnoli CRC32C polynomials. FCE's generic structure enables it to be extended with multiple CRC polynomials. The primary target of FCE is to be used as an hardware acceleration engine for software applications or operating systems services (compatible with Autosar CRC "specification of CRC Routines") using CRC signatures. CRC algorithms are commonly used to calculate unique message signatures that can be used to check message integrity during transport over communication channels like internal busses or interfaces between micro-controllers. CRC signatures are also suitable to sign blocks of data residing in variable or invariable storage elements. Signatures computed based on polynomial division provide a very high bit error detection capability. The FCE operates as a standard FPI bus slave peripheral and is fully controlled through a set of configuration and control registers.

This chapter is structured as follows:

- **"FCE Features" on Page 12-3**
- **"Operational overview" on Page 12-4**
- **"FCE Functional Description" on Page 12-6**
- **"FCE Module Registers" on Page 12-14**
- **"Interfaces of the FCE Module" on Page 12-13**
- **"Programming Guide" on Page 12-28**
- **"Properties of CRC code" on Page 12-31**

*Note: The FCE kernel register names described in **"FCE Module Registers" on Page 12-14** are referenced in a product User's Manual by the module name prefix "FCE_".*

Note: The FCE may in the future be used as well in a 16-bit microcontroller. There is no such requirement currently, but this possible extension can already be considered during the development phase.

12.1 Related documentation

Input documents

- [D1] A painless guide to CRC Error Detection Algorithms, Ross N. Williams
- [D2] Autosar R3.1 Rev 0001, Specification of CRC Routines V3.0.2
- [D3] 32-Bit Cyclic Redundancy Codes for Internet Applications, Philip Koopman, International Conference on Dependable Systems and Networks (DSN), 2002

Related standards and norms

- [S1] IEEE 802.3 Ethernet 32-bits CRC

12.2 FCE Features

The FCE provides the following features:

- Architecture supports up to 4 different CRC polynomials. Current FCE version implements:
 - IEEE 802.3 CRC32 ethernet polynomial: 0x82608EDB¹⁾ (crc kernel 0)
 - CRC32C Castagnoli polynomial: 0x8F6E37A0 (crc kernel 1)
- Parallel CRC implementation (32-bits wide)
 - Data blocks to be computed by FCE shall be a multiple of 32-bits
 - Start address of Data blocks to be computed by FCE shall be at least 32-bits aligned
- Only 32-bit write accesses are allowed to the kernel input register.
 - 8 or 16-bit write accesses to the configuration registers are supported.
- Register Interface compliant with Autosar specification for CRC routines. Enables to support reentrant software routines via a software-based save/restore mechanism.
- Extended register interface to control reliability of FCE execution.
- Critical Registers controlling the FCE operation are implemented redundant to capture transient errors
- Error notification scheme via dedicated interrupt node for:
 - transient error detection: error interrupt generation (maskable) with local status register (cleared by software)
 - Checksum failure: error interrupt generation (maskable) with local status register (cleared by software)
- FCE implements its own Interrupt Service Node

1) The polynomial hexadecimal representation covers the coefficients 32 down to 1 (x^0 is implicit) enabling to use 32-bits to characterize the polynomial.

12.3 Operational overview

The FCE is a standard FPI slave module. The FCE is fully synchronous with the FPI bus and runs with a 1:1 clock ratio. It connects to the FPI peripheral bus of a micro-controller.

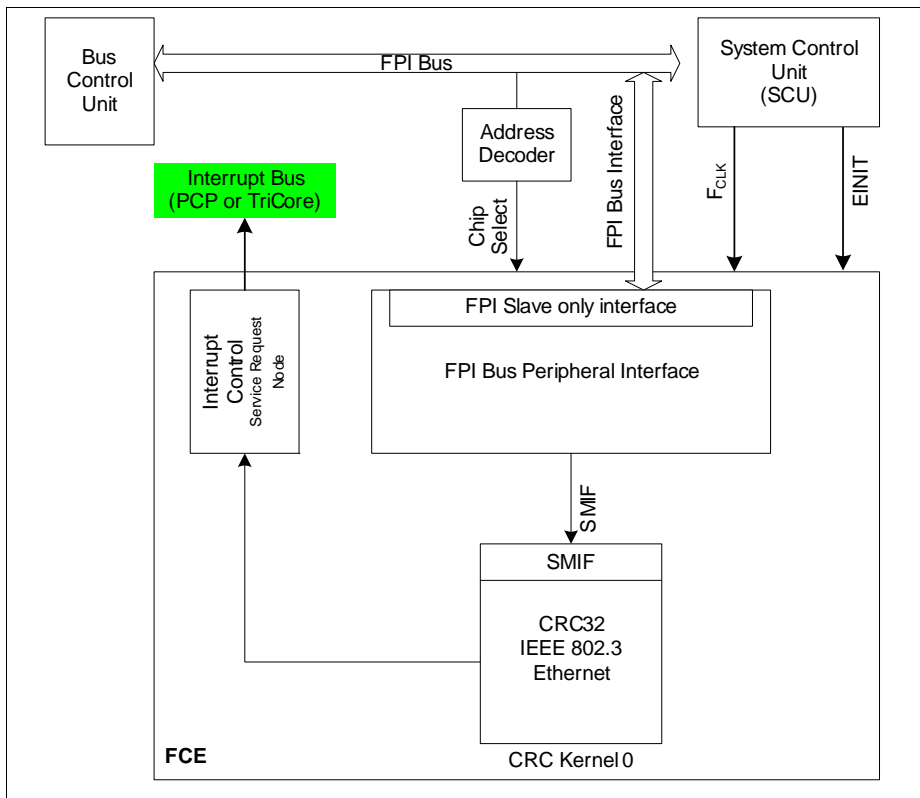


Figure 12-1 FCE system integration: single CRC kernel

The FCE operation is controlled over a set of memory mapped registers. The main purpose is to serve as hardware acceleration for software applications requiring CRC checksum computation. The register set has been designed to enable the FCE. Depending on the hardware configuration the FCE may implement more crc kernels with different CRC polynomials. The specific configuration for a product will be described into the product customizing chapter. Every crc kernel will present the same hardware and software architecture. The rest of this document will focus only on the description of the generic CRC kernel architecture. The [Figure 12-2](#) shows a multi kernel configuration.

Flexible CRC Engine (FCE)

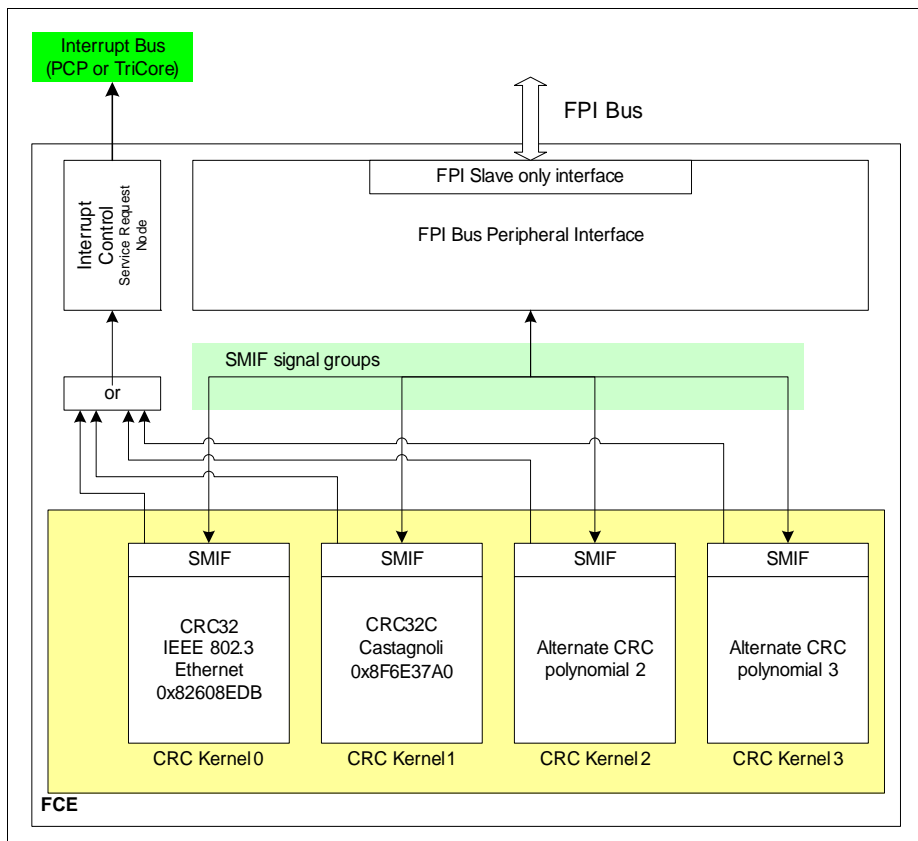


Figure 12-2 FCE system integration: multi-crc kernels

In a multi-kernel implementation the interrupt lines are ored together, the FCE only present a single interrupt node to the system. Each crc kernel implements a status register that enables the software to identify which interrupt source is active. Please refer to the STS register description for a detailed description of the status and interrupt handling.

12.4 FCE Functional Description

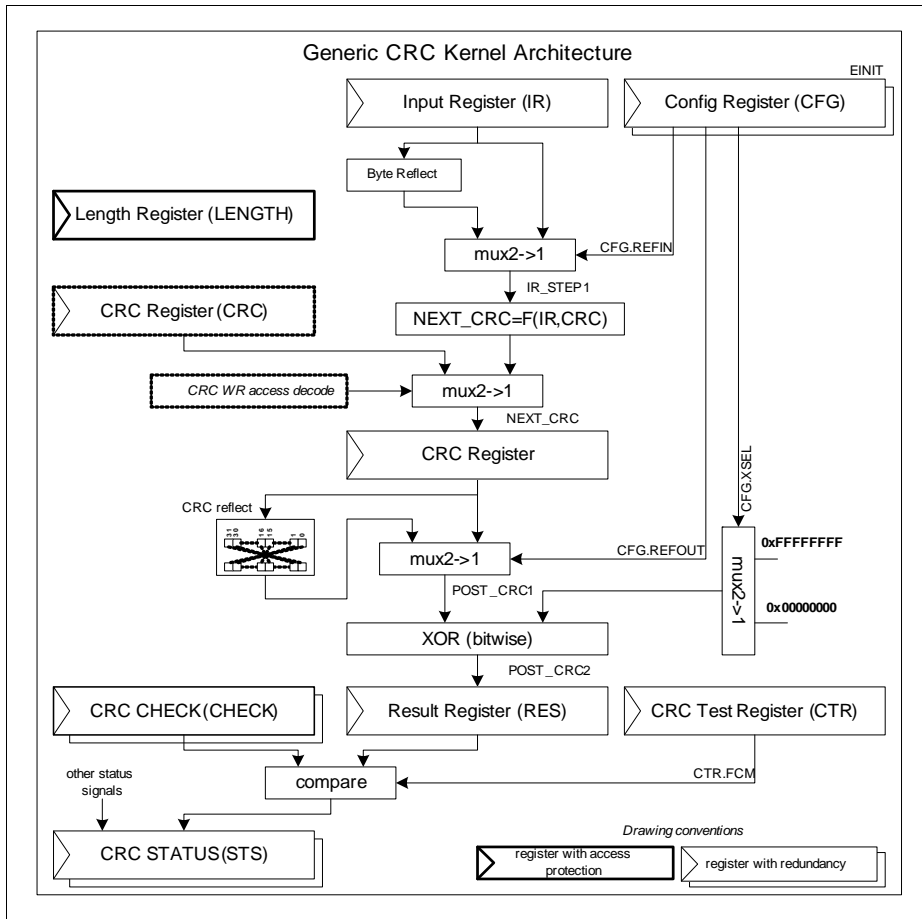


Figure 12-3 CRC kernel architecture

A checksum algorithm based on CRC polynomial division is characterized by the following properties:

- [1] polynomial degree (e.g. 32, that represents the highest power of two of the polynomial)
- [2] polynomial (e.g. 0x04C11DB7: the 33rd bit is omitted because always equal to 1)
- [3] init value: the initial value of the CRC register

Flexible CRC Engine (FCE)

- [4] input data reflected: indicates if each byte of the input parallel data is reflected before being used to compute the CRC
- [4] result data reflected: indicates if the final CRC value is reflected or not
- [5] XOR value: indicates if a final XOR operation is done before returning the CRC result

All the properties are static once a polynomial has been chosen. However the FCE provides the capability to control the two reflection steps and the final xor as depicted in **Figure 12-3** through the CFG register. The reset values are compatible with the implemented algorithm. The final xor control enables to select either 0xFFFFFFFF or 0x00000000 to be xored with the POST_CRC1 (see **Figure 12-3**) value. These two values are those used by the most common CRC polynomials.

Note: The reflection steps and final XOR do not modify the properties of the CRC algorithm in terms of error detection, only the CRC final signature is affected.

CRC operation

Software must first ensure that the CRC kernel is properly configured, especially the initial CRC register value written via the **CRC** register. If the software wishes to use the automatic signature check at the end of a message, the **LENGTH** register and **CHECK** registers must be configured with respectively the length (as number of 32-bit words) of the message and the expected signature (**CHECK**). The **CHECK** value takes into account the final CRC reflection and XOR operation. The self check is enable by the **CFG.CCE** bit field.

Property:

If the input message M1 consists of a message M0 appended with the CRC signature of M0, then the CRC signature of M1 shall be 0.

The software writes as many times as necessary into the **IR** register according to the length of the message. If **CFG.CCE** bit field is set, every time the **IR** register is written, the **LENGTH** register is decremented by one. If **LENGTH** is already at zero but software still writes to **IR** (by mistake) every bit of the **LENGTH** should be set to 1 and hold this value until software initializes it again for the processing of a new message. In such case the **STS.MLF** (Message Length Flag) should be set and an interrupt generated if the **CFG.MLE** (Message length Error) is set. The hardware monitors the transition of the **LENGTH** register from 1 to 0 to detect the end of the message and proceed with the comparison of the **POST_CRC2** (see [Figure 12-3](#)) value with the **CHECK** register value.

The next two figures provides an overview of the control and status features of a CRC kernel.

Flexible CRC Engine (FCE)

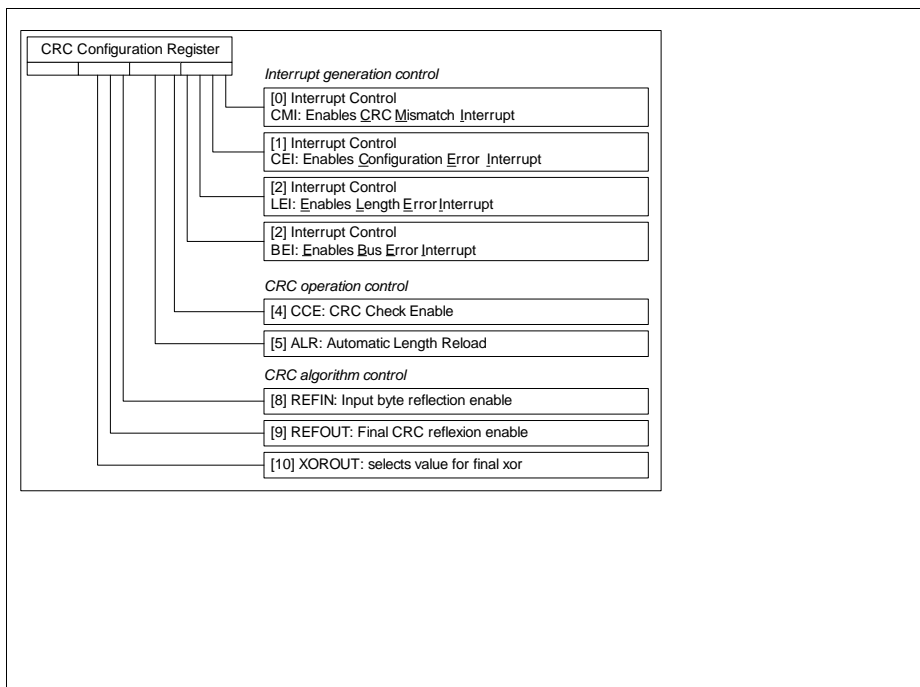


Figure 12-4 CRC kernel configuration register

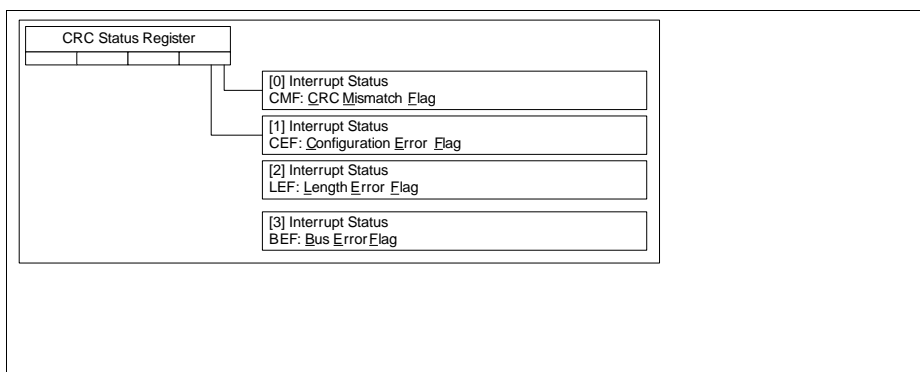


Figure 12-5 CRC kernel status register

Register Protection and Monitoring methods

Register Monitoring: applied to CFG and CHECK registers

Because CFG and CHECK registers are critical to the CRC operation, some mechanisms to detect and log transient errors are provided. Early detection of transient failures enables to improve the failure detection time and assess the severity of the failure. The monitoring mechanisms are implemented using two redundant instances as presented in [Figure 12-6](#).

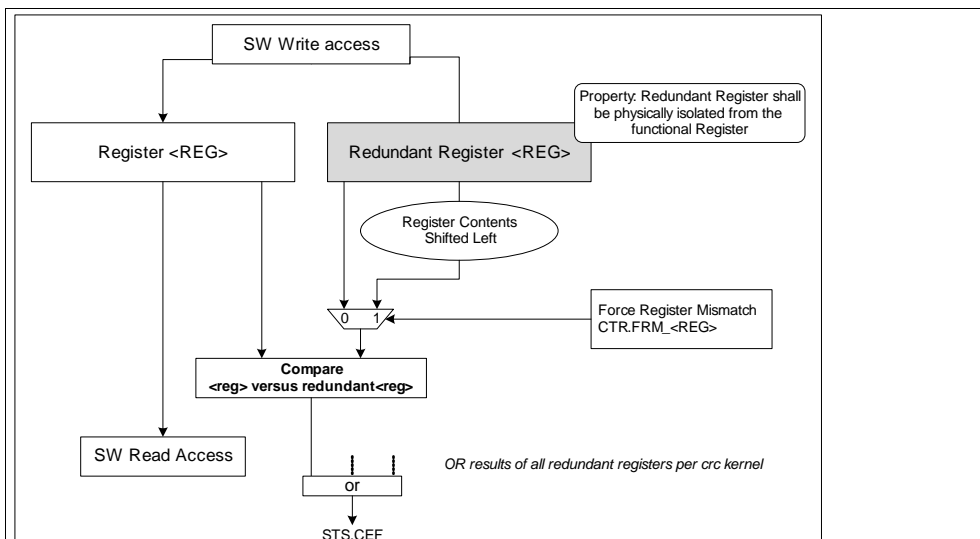


Figure 12-6 Register monitoring scheme

Let <REG> designate either CFG or CHECK registers. When a write to <REG> takes place a copy of the redundant register is also updated. **Redundant registers are not visible to software.** Bits of <REG> reserved have no storage and are not used for redundancy. A compare logic continuously compares the two stored values and provides a signal that indicates if the compare is successful or not. The result of all compare blocks are ored together to provide a single flag information. If a mismatch is detected the **STS.CEF** (Configuration Error Flag) bit is set. For run-time validation of the compare logic a Force Register Mismatch bit field (**CTR.FRM_<REG>**) is provided. When set to 1 by software the contents of the redundant register is shifted left by one bit position (redundant bit 0 position is always replaced by a logical 0 value) and is given to the compare logic instead of the redundant register value. This enables to check the compare logic is functional. Using a walking bit pattern, the software can completely check the full operation of the compare logic.

Flexible CRC Engine (FCE)

Register Access Protection: applies to LENGTH and CHECK registers

In order to reduce the probability of a mis-configuration of the CHECK and LENGTH registers (in the case the automatic check is used), the write access to the CHECK and LENGTH registers must follow the procedure depicted in [Figure 12-7](#):

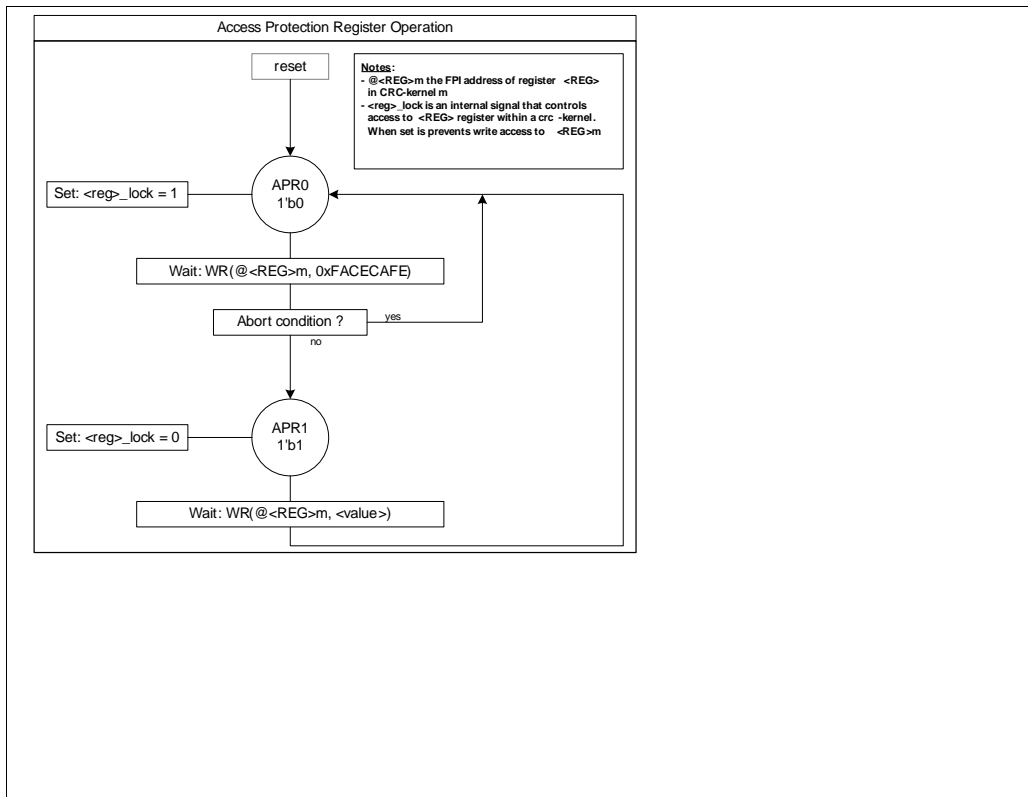


Figure 12-7 Access control to CHECK register

Let <REG> designate **CHECK** or **LENGTH** registers. Before being able to configure a new <value> value into the CHECK register of a crc kernel, software must first write the 0xFACECAFE value to the CHECK address. The 0xFACECAFE is not written into the CHECK register. The next write access will proceed as a normal FPI write access. This procedure will then be repeated every time software wants to configure a new <REG> value. If software reads the CHECK register just after writing 0xFACECAFE it returns the current <REG> contents and not 0xFACECAFE. **A read access to <REG> has no effect on the protection mechanism.**

FCE interrupts

Each FCE crc kernel provides one internal interrupt source. The interrupt lines from each crc kernel are ored together to be sent to the FCE interrupt control block that implements the standard interrupt node logic and register. When multiple crc kernels are present within a FCE, the interrupt lines from each crc kernel are ored together to provide a single interrupt source to the interrupt control block. If the interrupt from the FCE is arbitrated, the FCE interrupt handler must use the status information located within the **STS** status register of each crc kernel.

Each crc kernel provides the following interrupt sources:

- CRC Mismatch Interrupt controlled by **CFG.CMI** bit field and observable via the status bit field **STS.CMF** (CRC Mismatch Flag).
- Configuration Error Interrupt controlled by **CFG.CEI** bit field and observable via the status bit field **STS.CEF** (Configuration Error Flag).
- Length Error Interrupt controlled by **CFG.LEI** bit field and observable via the status bit field **STS.LEF** (Length Error Flag).
- FPI Error Interrupt controlled by **CFG.FEI** bit field and observable via the status bit field **STS.FEF** (FPI Error Flag).

Interrupt generation rules

- A status flag shall be cleared by software by writing a **1** to the corresponding bit position.
- If an status flag is set and a new hardware condition occurs, no new interrupt is generated by the kernel: the STS.<FLAG> bit field masks the generation of a new interrupt from the same source. If a SW access to clear the interrupt status bit takes place and in the same cycle the hardware wants to set the bit, the hardware condition wins the arbitration.

As all the interrupts are caused by an error condition, the interrupt shall be handled by a Error Management software layer. The software services using the FCE as acceleration engine may not directly deal with error conditions but let the upper layer using the service to deal with the error handling.

12.5 Interfaces of the FCE Module

The FCE module implements its own interrupt node, therefore implements an interface to the TriCore and PCP interrupt controllers. For protection purposes it uses the EINIT information to control the configuration of critical resources. The EINIT protection is described in the register chapter.

Table 12-1 Generic FCE Digital Connections

Signal	from/to Module	I/O to FCE
EINIT	SCU	I

12.6 FCE Module Registers

Figure 12-8 and **Table 12-3** show all registers associated with a FCE crc-kernel. All FCE kernel register names are described in this section. They should get the prefix “FCE_” when used in the context of a product specification.

The registers are numbered by one index to indicate the related FCE CRC Kernel (m = 0-1).

FCE Registers Overview

CRC Kernel Register Map			
0x00	Input Register	IRm	
0x04	CRC Result	RESn	
0x08	CRC Configuration Register	CFGn	
0x0C	CRC Kernel Status	STS _m	
0x10	LENGTH Register	LENG	
0x14	CRC Check	CHEC	

Figure 12-8 FCE Kernel Registers

Figure 12-9 shows the FCE module register map. The system registers region comprises the interrupt service request node and module identifier registers.

Flexible CRC Engine (FCE)

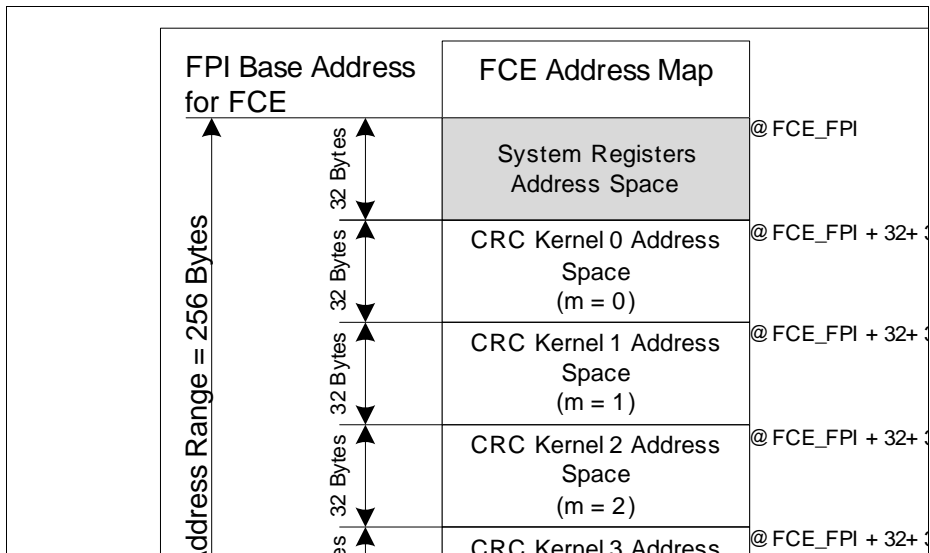


Figure 12-9 FCE Register Map

Table 12-2 Registers Address Space - FCE Module

Module	Base Address	End Address	Note
FCE	F032 0000 _H	F032 00FF _H	

Table 12-3 Registers Overview - CRC Kernel Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
FCE_CLC	Clock Control Register	00 _H	U, SV	E, SV	3	Page 12-17
FCE_ID	Module Identification Register	08 _H	U, SV	BE	3	Page 12-20
IRm	Input Register m	20 _H + m*20 _H	U, SV	U, SV	3	Page 12-21
RESm	CRC Result Register m	24 _H + m*20 _H	U, SV	BE	3	Page 12-21
CFGm	CRC Configuration Register m	28 _H + m*20 _H	U, SV	E, SV	3	Page 12-22

Flexible CRC Engine (FCE)

Table 12-3 Registers Overview - CRC Kernel Registers

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset Class	Description See
			Read	Write		
STSm	CRC Status Register m	$2C_H + m \cdot 20_H$	U, SV	U, SV	3	Page 12-24
LENGTHm	CRC Length Register m	$30_H + m \cdot 20_H$	U, SV	U, SV	3	Page 12-25
CHECKm	CRC Check Register m	$34_H + m \cdot 20_H$	U, SV	U, SV	3	Page 12-25
CRCm	CRC Register m	$38_H + m \cdot 20_H$	U, SV	U, SV	3	Page 12-26
CTRm	CRC Test Register m	$3C_H + m \cdot 20_H$	U, SV	U, SV	3	Page 12-27
FCE_SRC	Service Request Control Register	FC_H	U, SV	SV	3	Page 12-18

1) The absolute register byte address for each crc kernel m is calculated as follows:
CRC kernel register base Address ([Table 12-2](#)) + $m \cdot 20_H$, $m = 0-1$

Access Mode Rules

The [Table 12-3 “Registers Overview - CRC Kernel Registers”](#) on [Page 12-15](#) uses the standard access mode conventions.

- **E** indicates that an access is only possible if the **end of initialization** signal from the System Control Unit is active. In this case Supervisor Mode (SV) is also mandatory.
- When U, SV are both listed it means that a read or write access can be done either in user mode (U) or supervisor mode (V).
- BE stands for Bus Error, NSC stands for No Special Condition.

Flexible CRC Engine (FCE)

Field	Bits	Type	Description
EDIS	3	rw	Sleep Mode Enable Control Used for module Sleep Mode control. 0 _B Sleep Mode request is regarded. Module is enabled to go into Sleep Mode. 1 _B Sleep Mode request is disregarded: Sleep Mode cannot be entered on a request.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected. 0 _B Bits SPEN and FSOE are write-protected 1 _B Bits SPEN and FSOE are overwritten by respective value of SPEN or FSOE Reading this bit returns always 0.
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch-off in Suspend Mode. 0 _B Clock switch-off in Suspend Mode via Disable Control Feature (Secure Clock Switch Off) selected 1 _B Fast clock switch off in Suspend Mode selected This bit can be written only if SBWE is set during the same write operation.
0	[31:6]	r	Reserved Read as 0; should be written with 0.

FCE_SRC

Service Request Control Register (FC_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0	SRPN								
w	w	rwh	rw	r	rw	r	rw								

Flexible CRC Engine (FCE)

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority ... FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP service is initiated
SRE	12	rw	Service Request Enable 0 _B Service request is disabled 1 _B Service request is enabled
SRR	13	rwh	Service Request Flag 0 _B No service request is pending 1 _B A service request is pending ¹⁾
CLRR	14	w	Request Clear Bit CLRR is required to clear SRR. 0 _B No action 1 _B Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 _B No action 1 _B Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

1) The bit field SRR is automatically cleared by hardware at the end of an interrupt arbitration round if the node was the winner, therefore this information is not suitable for interrupt plausibility checks.

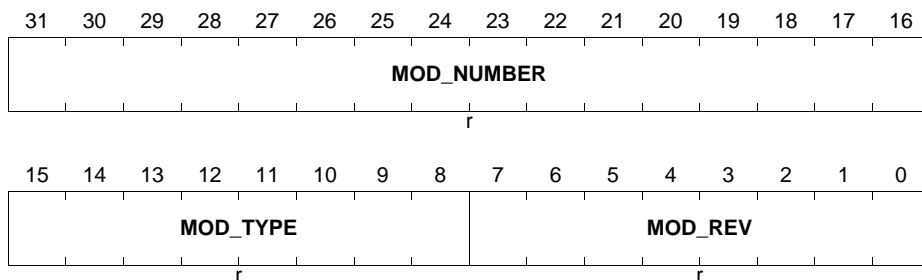
FCE Module Identification Register. This register is global to FCE and not part of a crc kernel.

Flexible CRC Engine (FCE)

FCE_ID

Module Identification Register

(08_H)

Reset Value: 008A C001_H


Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the FCE module is 008A _H .

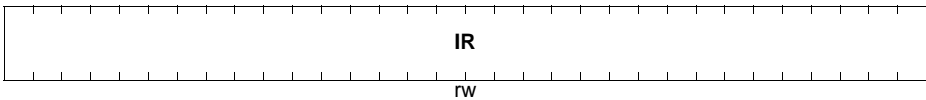
Flexible CRC Engine (FCE)

12.6.2 CRC Kernel Control/Status Registers

IRm (m = 0-1)
Input Register m
(20_H + m*20_H)
Reset Value: 0000 0000_H

31

0



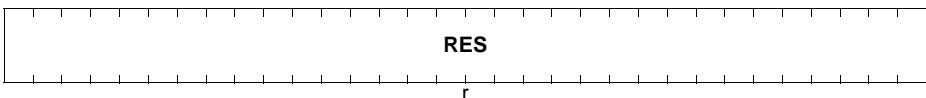
Field	Bits	Type	Description
IR	[31:0]	rw	Input Register This bit field holds the 32-bit data to be computed

A write to IRm triggers the CRC kernel to update the message checksum according to the IR contents and to the current CRC register contents. Only 32-bit write transactions are allowed to IRm registers, any other FPI write transaction will lead to a Bus Error.

RESm (m = 0-1)
CRC Result Register m
(24_H + m*20_H)
Reset Value: FFFF FFFF_H

31

0



Field	Bits	Type	Description
RES	[31:0]	r	Result Register Returns the final CRC value including CRC reflection and final XOR according to the CFG register configuration. Writing to this register has no effect.

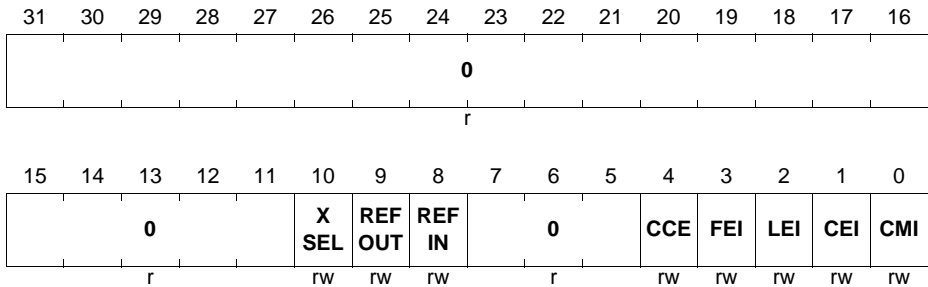
Flexible CRC Engine (FCE)

CFGm (m = 0-1)

CRC Configuration Register m

($28_H + m \cdot 20_H$)

Reset Value: 0000 0700_H



Field	Bits	Type	Description
CMI	0	rw	CRC Mismatch Interrupt 0 _B CRC Mismatch Interrupt is disabled 1 _B CRC Mismatch Interrupt is enabled
CEI	1	rw	Configuration Error Interrupt When enabled, an Configuration Error Interrupt is generated whenever a mismatch is detected in the CFG and CHECK redundant registers. 0 _B Configuration Error Interrupt is disabled 1 _B Configuration Error Interrupt is enabled
LEI	2	rw	Length Error Interrupt When enabled, an Length Error Interrupt is generated if software writes to IR register with LENGTH equal to 0 and CFG.CCE is set to 1. 0 _B Length Error Interrupt is disabled 1 _B Length Error Interrupt is enabled
FEI	3	rw	FPI Error Interrupt When enabled, an interrupt is generated if a FPI write transaction other than 32-bits is issued to the Input register. 0 _B FPI Error Interrupt is disabled 1 _B FPI Error Interrupt is enabled

Flexible CRC Engine (FCE)

Field	Bits	Type	Description
CCE	4	rw	CRC Check Comparison 0 _B CRC check comparison at the end of a message is disabled 1 _B CRC check comparison at the end of a message is enabled
REFIN	8	rw	IR Byte Wise Reflection 0 _B IR Byte Wise Reflection is disabled 1 _B IR Byte Wise Reflection is enabled
REFOUT	9	rw	CRC 32-Bit Wise Reflection 0 _B CRC 32-bit wise is disabled 1 _B CRC 32-bit wise is enabled
XSEL	10	rw	Selects the value to be xored with the final CRC 0 _B 0x00000000 1 _B 0xFFFFFFFF
0	[7:5], [31:11]	r	Reserved Read as 0; should be written with 0.

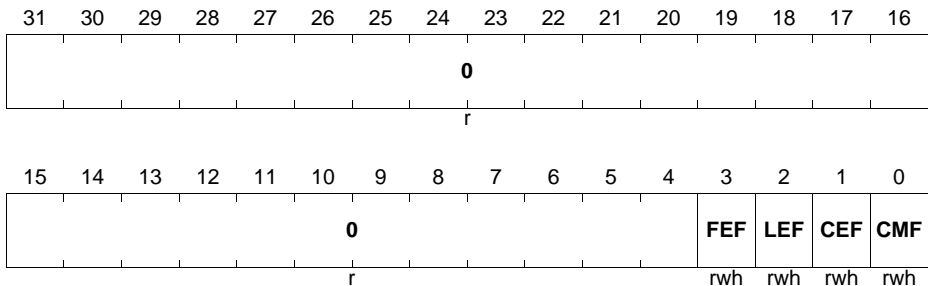
Flexible CRC Engine (FCE)

STSm (m = 0-1)

CRC Status Register m

($2C_H + m \cdot 20_H$)

Reset Value: 0000 0000_H



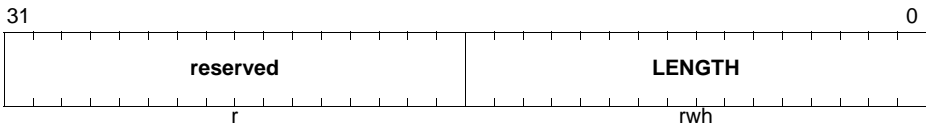
Field	Bits	Type	Description
CMF	0	rwh	CRC Mismatch Flag This bit is set per hardware only. To clear this bit, software must write a 1 to this bit field location. Writing 0 per software has no effect. If this bit is equal to 1 and a new interrupt is raised by hardware, it will not be propagated to the FCE interrupt service node.
CEF	1	rwh	Configuration Error Flag This bit is set per hardware only. To clear this bit, software must write a 1 to this bit field location. Writing 0 per software has no effect. If this bit is equal to 1 and a new interrupt is raised by hardware, it will not be propagated to the FCE interrupt service node.
LEF	2	rwh	Length Error Flag This bit is set per hardware only. To clear this bit, software must write a 1 to this bit field location. Writing 0 per software has no effect. If this bit is equal to 1 and a new interrupt is raised by hardware, it will not be propagated to the FCE interrupt service node.
FEF	3	rwh	FPI Error Flag This bit is set per hardware only. To clear this bit, software must write a 1 to this bit field location. Writing 0 per software has no effect. If this bit is equal to 1 and a new interrupt is raised by hardware, it will not be propagated to the FCE interrupt service node.

Flexible CRC Engine (FCE)

Field	Bits	Type	Description
0	[31:4]	r	Reserved Read as 0; should be written with 0.

LENGTHm (m = 0-1)

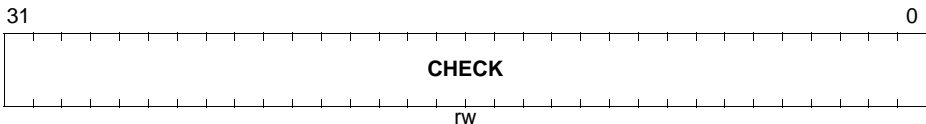
CRC Length Register m $(30_H + m \cdot 20_H)$ **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
LENGTH	[15:0]	rwh	Message Length Register Number of 32-bits words building the message over which the CRC checksum is calculated. This bit field is modified by the hardware: every write to the IR register decrements the value of the LENGTH bit field.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

CHECKm (m = 0-1)

CRC Check Register m $(34_H + m \cdot 20_H)$ **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
CHECK	[31:0]	rw	CHECK Register Expected CRC value to be checked by the hardware upon detection of a 1 to 0 transition of the LENGTH register. The comparison is enabled by the CFG.CCE bit field

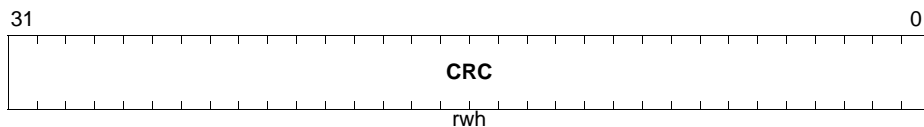
Flexible CRC Engine (FCE)

CRCm (m = 0-1)

CRC Register m

($38_H + m * 20_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CRC	[31:0]	rwh	CRC Register This register enables to directly access the internal CRC register

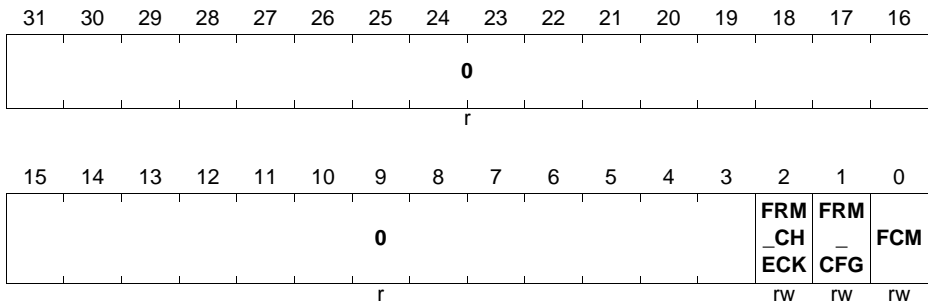
Flexible CRC Engine (FCE)

CTRm (m = 0-1)

CRC Test Register m

($3C_H + m \cdot 20_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
FCM	0	rw	Force CRC Mismatch Forces the CRC compare logic to issue an error regardless of the CHECK and CRC values. The hardware detects a 0 to 1 transition of this bit field and triggers a CRC Mismatch interrupt
FRM_CFG	1	rw	Force CFG Register Mismatch This field is used to control the error injection mechanism used to check the compare logic of the redundant CFG registers. This is a one shot operation. When the hardware detects a 0 to 1 transition of this bit field it triggers a Configuration Mismatch interrupt (if enabled by the corresponding CFGm register).
FRM_CHECK	2	rw	Force Check Register Mismatch This field is used to control the error injection mechanism used to check the compare logic of the redundant CHECK registers. This is a one shot operation. The hardware detects a 0 to 1 transition of this bit field and triggers a Check Register Mismatch interrupt (if enabled by the corresponding CFGm register).
0	[31:3]	r	Reserved Read as 0; should be written with 0.

12.7 Programming Guide

This section provides some guidelines showing how the FCE configuration features can be mapped to the AUTOSAR API for CRC32 routines.

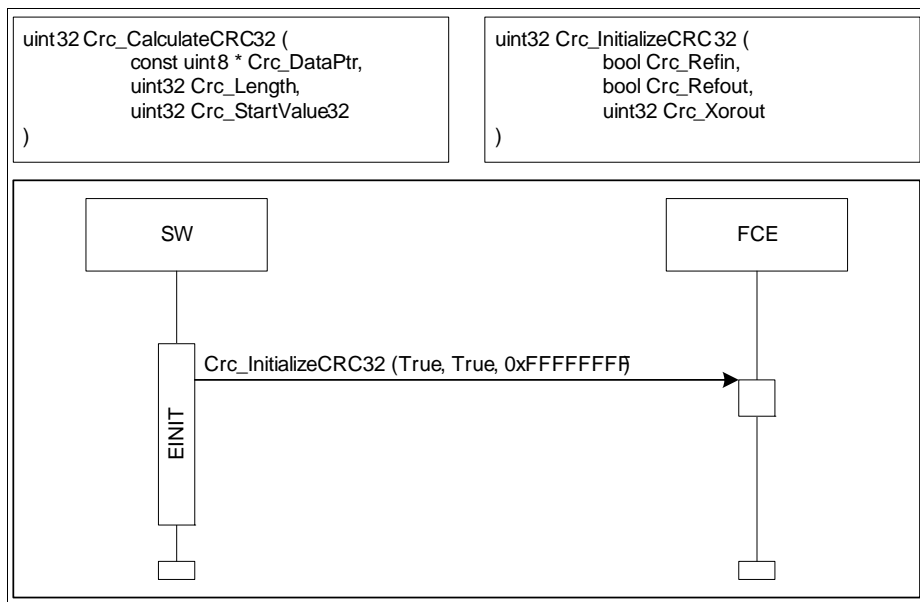


Figure 12-10 Autosar initialization API

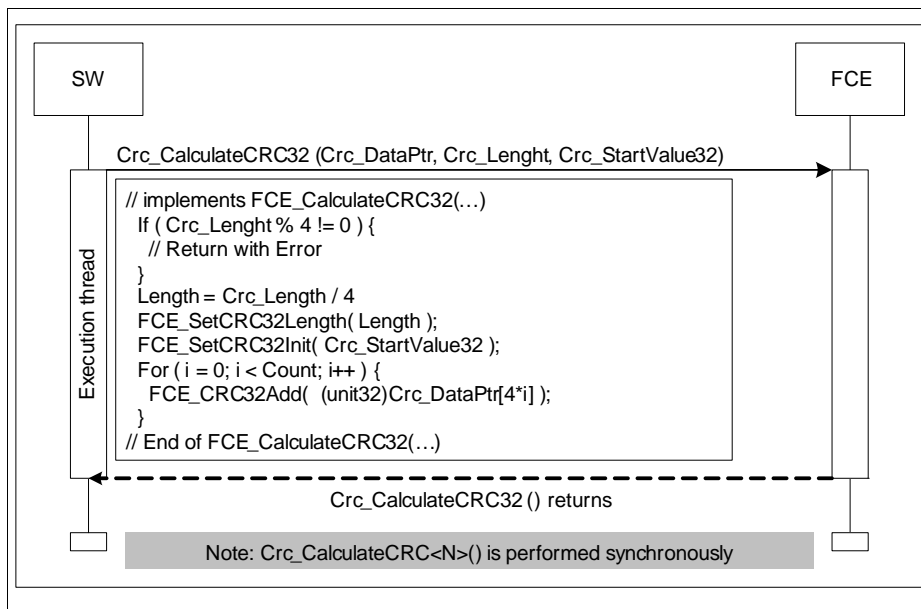


Figure 12-11 Autosar CRC_calculate API

Flexible CRC Engine (FCE)

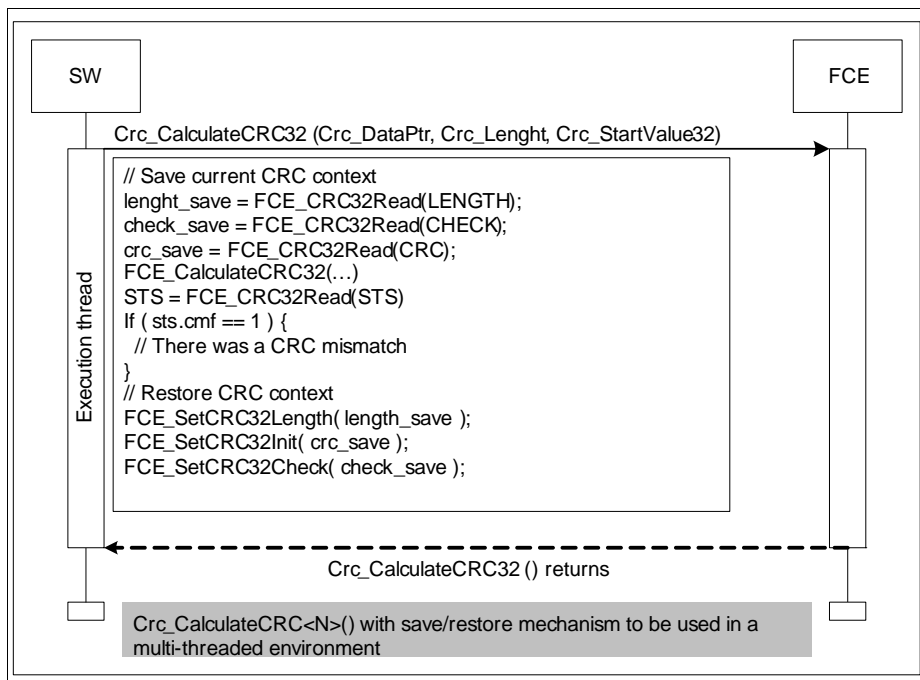


Figure 12-12 Autosar CRC_calculate API with save/restore

12.8 Properties of CRC code

Hamming Distance

The Hamming distance defines the error detection capability of a CRC polynomial. A cyclic code with a Hamming Distance of D can detect all D-1 bit errors. [Table 12-4 “Hamming Distance as a function of message length \(bits\)” on Page 12-31](#) shows the dependency of the Hamming Distance with the length of the message.

Table 12-4 Hamming Distance as a function of message length (bits)¹⁾

Hamming Distance	IEEE CRC32	Castagnoli
15	8 - 10	
14	8 - 10	
13	8 - 10	
12	11 - 12	8 - 17
11	13 - 21	18 - 21
10	22 - 34	22 - 27
9	35 - 57	22 - 27
8	58 - 91	28 - 58
7	92 - 171	59 - 81
6	172 - 268	82 - 1060
5	269 - 2974	1061 - 65504
4	2973 - 91607	1061 - 65504
3	91607 - 131072	65506 - 131072

1) Data from technical paper “32-Bit Cyclic Redundancy Codes for Internet Applications” by Philip Koopman, Carnegie Mellon University, 2002

12.9 Revision history

Table 12-5 Revision history

Date	Description	Name
Version 1.6 -> version 1.7		
02.12.2009	- Changed CLC reset value to 0x3	A. Vilela
Version 1.5 -> version 1.6		
09.09.2009	- Updated Module ID to 0x008A_C001	A. Vilela
Version 1.4 -> version 1.5		
10.06.2009	- Clarified access restrictions to IRm registers - Clarified behavior of CRC Test Register - Fixed text in Figure 12-3 “CRC kernel architecture” on Page 12-6	A. Vilela
Version 1.3 -> version 1.4		
23.05.2009	- Moved FCE_SCR to module offset 0xFC - Fixed UTP entry AI00049903	A. Vilela
Version 1.2 -> version 1.3		
16.03.2009	- Fixed polynomial value in Figure 12-2 “FCE system integration: multi-crc kernels” on Page 12-5 - Updated software register access modes - Clarified FPI register access restrictions - Clarified behavior of FCE upon reception of an aborted write access to a protected register - Added Hamming distance properties	A. Vilela
Version 1.1 -> version 1.2		
15.02.2009	- Added second polynomial (Castagnoli)	A. Vilela
Version 1.0 -> version 1.1		
12.02.2009	- Version 1.0 Review updates - Added description for non-safety mode	A. Vilela
Version 1.0		
23.12.2008	- First ITS version	A. Vilela

13 Interrupt System

The TC1728 interrupt system provides a flexible and time-efficient means of processing interrupts. This chapter describes the interrupt system for the TC1728. Topics covered include the architecture of the interrupt system, interrupt system configuration, and the interrupt operations of the TC1728 peripherals and Central Processing Unit (CPU). General information is also given about the Peripheral Control Processor (PCP).

13.1 Overview

An interrupt request can be serviced either by the CPU or by the PCP. Interrupt requests are called “service requests” rather than “interrupt requests” in this document because they can be serviced by either one of the service providers.

Each peripheral in the TC1728 can generate service requests. Additionally, the Bus Control Units, the Debug Unit, the PCP, and even the CPU itself can generate service requests to either of the two service providers.

As shown in [Figure 13-1](#), each TC1728 unit that can generate service requests is connected to one or more Service Request Nodes (SRNs). Each SRN contains a Service Request Control Register `mod_SRCx`, where “mod” is the identifier of the service requesting unit and “x” an optional index. Two arbitration buses connect the SRNs with two Interrupt Control Units (ICUs), which handle interrupt arbitration among competing interrupt service requests, as follows:

- The Interrupt Control Unit (ICU) arbitrates service requests for the CPU and administers the CPU interrupt arbitration bus.
- The Peripheral Interrupt Control Unit (PICU) arbitrates service requests for the PCP and administers the PCP interrupt arbitration bus.

The PCP can make service requests directly to itself (via the PICU), or it can make service requests to the CPU. The Debug Unit can generate service requests to the PCP or the CPU. The CPU can make service requests directly to itself (via the ICU), or it can make service requests to the PCP. The CPU Service Request Nodes are activated through software.

Interrupt System

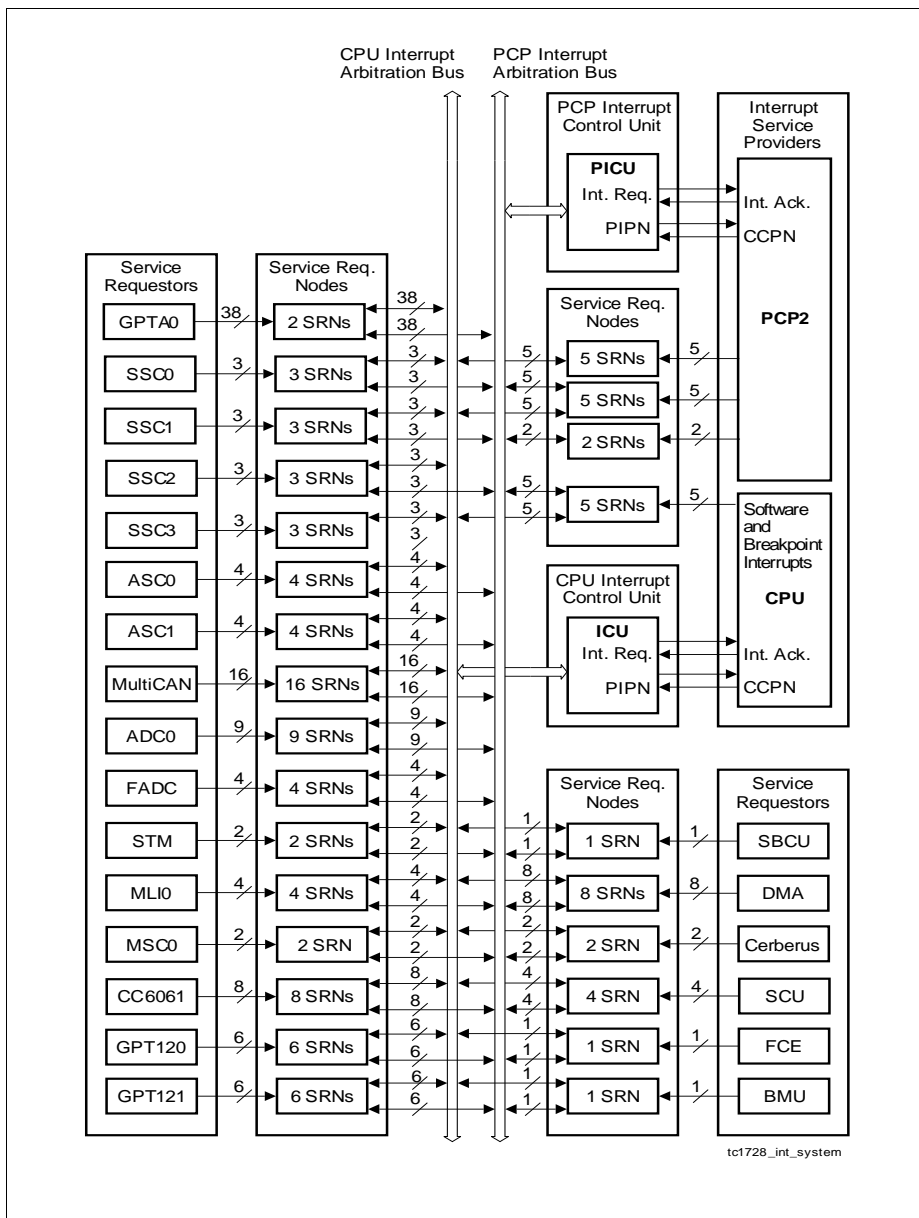


Figure 13-1 Block Diagram of the TC1728 Interrupt System

13.2 Service Request Nodes

Each SRN contains a Service Request Control Register and interface logic that connects it to the triggering unit and to the two interrupt arbitration buses. Some peripheral units of the TC1728 have multiple SRNs.

13.2.1 Service Request Control Registers

All Service Request Control Registers in the TC1728 have the same format. In general, these registers contain:

- Enable/disable information
- Priority information
- Service provider destination
- Service request status bit
- Software-initiated service request set and reset bits

Besides being activated by the associated triggering unit through hardware, each SRN can also be set or reset by software via two software-initiated service request control bits.

The description given in this chapter characterizes all Service Request Control Registers of the TC1728. Information on peripheral module interrupt functions such as enable or request flags is provided in the corresponding sections of the module chapters.

13.2.1.1 General Service Request Control Register Format

The description given in this chapter characterizes all Service Request Control Registers of the TC1728. Information on peripheral module interrupt functions such as enable or request flags is provided in the corresponding sections of the module chapters.

mod_SRC

Service Request Control Register (00_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0	SRPN								
w	w	rh	rw	r	rw	r	rw								

Interrupt System

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 CPU service is initiated 1 PCP request is initiated
SRE	12	rw	Service Request Enable 0 Service request is disabled 1 Service request is enabled
SRR	13	rh	Service Request Flag 0 No service request is pending 1 A service request is pending
CLRR	14	w	Request Clear Bit CLRR is required to reset SRR. 0 No action 1 Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 No action 1 Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

13.2.1.2 Request Set and Clear Bits (SETR, CLRR)

The SETR and CLRR bits allow software to set or clear the service request bit SRR. Writing a 1 to SETR causes bit SRR to be set to 1. Writing a 1 to CLRR causes bit SRR to be cleared to 0. If hardware attempts to modify SRR during a read-modify-write software operation (such as the bit-set or bit-clear instructions), the software operation will succeed and the hardware operation will have no effect.

The value written to SETR or CLRR is not stored. Writing a 0 to these bits has no effect. These bits always return 0 when read. If both, SETR and CLRR, are set to 1 at the same time, SRR is not changed.

13.2.1.3 Enable Bit (SRE)

The SRE bit enables an interrupt to take part in the arbitration for the selected service provider. It does not enable or disable the setting of the request flag SRR; the request flag can be set by hardware or by software (via SETR) independent of the state of the SRE bit. This allows service requests to be handled automatically by hardware or through software polling.

If SRE = 1, pending service requests are passed on to the designated service provider for interrupt arbitration. The SRR bit is automatically set to 0 by hardware when the service request is acknowledged and serviced. It is recommended that in this case, software should not modify the SRR bit to avoid unexpected behavior due to the hardware controlling this bit.

If SRE = 0, pending service requests are not passed on to service providers. Software can poll the SRR bit to check whether a service request is pending. To acknowledge the service request, the SRR bit must then be reset by software by writing a 1 to CLRR.

Note: In this document, 'active source' means an SRN whose Service Request Control Register has its request enable bit SRE set to 1 to allow its service requests to participate in interrupt arbitration.

13.2.1.4 Service Request Flag (SRR)

When set, the SRR flag indicates that a service request is pending. It can be set or reset directly by hardware or indirectly through software using the SETR and CLRR bits. Writing directly to this bit via software has no effect.

The SRR status bit can be directly set or reset by the associated hardware. For instance, in the General Purpose Array Unit, an associated timer event can cause this bit to be set to 1. The details of how hardware events can cause the SRR bit to be set are defined in the individual peripheral/module chapters.

The acknowledgment of the service request by either the Interrupt Control Unit (ICU) or the PCP Interrupt Control Unit (PICU) causes the SRR bit to be cleared.

Interrupt System

SRR can be set or cleared either by hardware or by software regardless of the state of the enable bit SRE. However, the request is only forwarded for service if the enable bit is set. If $SRE = 1$, a pending service request takes part in the interrupt arbitration of the service provider selected by the device's TOS bit. If $SRE = 0$, a pending service request is excluded from interrupt arbitrations.

SRR is automatically reset by hardware when the service request is acknowledged and serviced. Software can poll SRR to check for a pending service request. SRR must be reset by software in this case by writing a 1 to CLRR.

It is not advisable to clear a pending service request flag SRR (writing $CLRR = 1$) and enable the corresponding service request node SRN (writing $SRE = 1$) simultaneously at the same write access to the Service Request Control Register. If this should happen, an unintended interrupt request may be generated. Instead of executing one write access, it is recommended to split the two actions into two consecutive write accesses to the corresponding Service Request Control Register, starting with the clearing of the pending interrupt flag and followed by the enabling of the service request node.

13.2.1.5 Type-Of-Service Control (TOS)

There are two service providers for service requests in the TC1728, the CPU and the PCP. The TOS bit is used to select whether a service request generates an interrupt to the CPU ($TOS = 0$) or to the PCP ($TOS = 1$). Bit 11 of the Service Request Control Register is read-only, returning 0 when read. Writing to this bit position has no effect. However, to ensure compatibility with future extensions, bit 11 should always be written with a 0.

Note that several Service Request Control Registers (e.g. in the PCP) have a hardwired TOS bit (0 or 1) that cannot be written. These registers can only generate an interrupt to one dedicated service provider (PCP or CPU).

Note: Before modifying the content of a TOS bit, the corresponding SRN must be disabled ($SRE = 0$).

13.2.1.6 Service Request Priority Number (SRPN)

The 8-bit Service Request Priority Number (SRPN) indicates the priority of a service request with respect to other sources requesting service from the same service provider, and with respect to the priority of the service provider itself.

Each active source selecting the same service provider must have a unique SRPN value to differentiate its priority. The special SRPN value of 00_H excludes an SRN from taking part in arbitration, regardless of the state of its SRE bit. The SRPN values for active sources selecting different service providers (CPU vs. PCP) may overlap. If a source is not active – meaning its SRE bit is 0 – no restrictions are applied to the service request priority number.

Interrupt System

The SRPN is used by service providers to select an Interrupt Service Routine (ISR)) or Channel Program (in case of the PCP) to service the request. ISRs are associated with Service Request Priority Numbers by an Interrupt Vector Table located in each service provider. This means that the TC1728 Interrupt Vector Table is ordered by priority number. This is unlike traditional interrupt architectures in which their interrupt vector tables are ordered by the source of the interrupt. The TC1728 Interrupt Vector Table allows a single peripheral to have multiple priorities for different purposes.

The range of values for SRPNs used in a system depends on the number of possible active service requests and the user-definable organization of the Interrupt Vector Table. The 8-bit SRPNs permit up to 255 sources to be active at one time (remembering that the special SRPN value of 00_H excludes an SRN from taking part in arbitration).

Note: Before modifying the content of an SRPN bit field, the corresponding SRN must be disabled (SRE = 0).

SRPNs in the TC1728

In the TC1728, interrupt sources selecting the same Service Provider are also allowed to have identical SRPN values. In this case, the software (interrupt service routine) must check which of the interrupt sources with identical SRPN has become active.

Note that module-specific interrupt request flags must be available because the SRR flags cannot be used for this check. SRR flags (meaning all SRR flags of interrupts with identical SRPN values) are in general automatically reset by hardware when a service request is acknowledged and serviced.

Note: This practice with identical SRPN values is not recommended as it is not portable to other TriCore devices.

13.3 Interrupt Control Units

The Interrupt Control Units manage the interrupt system, arbitrate incoming service requests, and determine whether and when to interrupt the service provider. The TC1728 contains two interrupt control units, one for the CPU (called ICU), and one for the PCP (called PICU). Each one controls its associated interrupt arbitration bus and manages the communication with its service provider (see).

13.3.1 Interrupt Control Unit (ICU)

This section describes the interrupt control unit (ICU) for the CPU.

13.3.1.1 ICU Interrupt Control Register (ICR)

The ICU Interrupt Control Register ICR holds the current CPU priority number (CCPN), the global interrupt enable/disable bit (IE), the pending interrupt priority number (PIPn), and bit fields which control the interrupt arbitration process.

ICR

ICU Interrupt Control Register (F7E1FE2C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0					C ONE CYC	CARBCYC			PIPn						
r					rw	rw			rh						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								IE	CCPN						
r								rwh	rwh						

Field	Bits	Type	Description
CCPN	[7:0]	rwh	Current CPU Priority Number The Current CPU Priority Number (CCPN) bit field indicates the current priority level of the CPU. It is automatically updated by hardware on entry and exit of interrupt service routines, and through the execution of a BISR instruction. CCPN can also be updated through an MTCR instruction.

Interrupt System

Field	Bits	Type	Description
IE	8	rwh	Global Interrupt Enable Bit The interrupt enable bit globally enables the CPU service request system. Whether or not a service request is delivered to the CPU depends on the individual Service Request Enable Bits (SRE) in the SRNs, and the current state of the CPU. IE is automatically updated by hardware on entry and exit of an Interrupt Service Routine (ISR). IE is cleared to 0 when an interrupt is taken, and is restored to the previous value when the ISR executes an RFE instruction to terminate itself. IE can also be updated through the execution of the ENABLE, DISABLE, MTCR, and BISR instructions. 0 Interrupt system is globally disabled 1 Interrupt system is globally enabled
PIPN	[23:16]	rh	Pending Interrupt Priority Number PIPN is a read-only bit field that is updated by the ICU at the end of each interrupt arbitration process. It indicates the priority number of the pending service request. PIPN is set to 0 when no request is pending, and at the beginning of each new arbitration process. 00 _H No valid pending request YY _H A request with priority YY _H is pending
CARBCYC	[25:24]	rw	Number of Arbitration Cycles CARBCYC controls the number of arbitration cycles used to determine the request with the highest priority. 00 _B 4 arbitration cycles (default) 01 _B 3 arbitration cycles 10 _B 2 arbitration cycles 11 _B 1 arbitration cycle
CONECYC	26	rw	Number of Clocks per Arbitration Cycle Control The CONECYC bit determines the number of system clocks per arbitration cycle. For the TC1728 this bit can be set to 1 (for SPB frequencies up to the max SPB frequency as defined in the Data Sheet). 0 2 clocks per arbitration cycle (default) 1 1 clock per arbitration cycle
0	[15:9], [31:27]	r	Reserved Read as 0; should be written with 0.

13.3.1.2 Operation of the Interrupt Control Unit (ICU)

Service-request arbitration is performed in the ICU in parallel with normal CPU operation. When a triggering event occurs in one or more interrupt sources, the associated SRNs, if enabled, send service requests to the CPU through the ICU. The ICU determines which service request has the highest priority. The ICU will then forward the service request to the CPU. The service request will be acknowledged by the CPU and serviced, depending upon the state of the CPU.

The ICU arbitration process takes place in one or more arbitration cycles over the CPU interrupt arbitration bus. The ICU begins a new arbitration process when a new service request is detected. At the end of the arbitration process, the ICU will have determined the service request with the highest priority number. This number is stored in the ICR.PIPN bit field and becomes the pending service request.

After the arbitration process, the ICU forwards the pending service request to the CPU by attempting to interrupt it. The CPU can be interrupted only if interrupts are enabled globally (that is, ICR.IE = 1) and if the priority of the service request is higher than the current processor priority (ICR.PIPN > ICR.CCPN). Also, the CPU may be temporarily blocked from taking interrupts, for example, if it is executing a multi-cycle instruction such as an atomic read-modify-write operation. The full list of conditions which could block the CPU from immediately responding to an interrupt request generated by the ICU is:

- Current CPU priority, ICR.CCPN, is equal to or higher than the pending interrupt priority, ICR.PIPN
- Interrupt system is globally disabled (ICR.IE = 0)
- CPU is in the process of entering an interrupt- or trap-service routine
- CPU is executing non-interruptible trap services
- CPU is executing a multi-cycle instruction
- CPU is executing an instruction which modifies the conditions of the global interrupt system, such as modifying the ICR
- CPU detects a trap condition (such as context depletion) when trying to enter a service routine

When the CPU is not otherwise prevented from taking an interrupt, the CPU's program counter will be directed to the Interrupt Service Routine entry point associated with the priority of the service request. Next, the CPU saves the value of ICR.PIPN internally, and acknowledges the ICU. The ICU then forwards the acknowledge signal back to the SRN that is requesting service in order to inform it that it will be serviced by the CPU. The SRR bit in this SRN is then reset to 0.

After sending the acknowledgement, the ICU resets ICR.PIPN to 0 and may start a new arbitration process if there is another pending interrupt request. If not, ICR.PIPN remains at 0 and the ICU enters an idle state, waiting for the next interrupt request to awaken it. If there is a new service request waiting, the priority number of the new request will be written to ICR.PIPN at the end of the new arbitration process and the ICU will deliver the pending interrupt to the CPU according to the rules described in this section.

Interrupt System

If a new service request is received by the ICU before the CPU has acknowledged the pending interrupt request, the ICU deactivates the pending request and starts a new arbitration process. This reduces the latency of service requests posted before the current request is acknowledged. The ICU deactivates the current pending interrupt request by setting the ICR.PIPN bit field to 0, indicating that the ICU has not yet found a new valid pending request. It then executes its arbitration process again. If the new service request has a higher priority than the previous one, its priority will be written to ICR.PIPN. If the new interrupt has a lower priority, the priority of the previous interrupt request will again be written to ICR.PIPN. In any case, the ICU will deliver a new interrupt request to the CPU according to the rules described in this section.

Once the CPU has acknowledged the current pending interrupt request, any new service request generated by an SRN must wait at least until the end of the next service request arbitration process to be serviced.

Essentially, arbitration in the ICU is performed whenever a new service request is detected, regardless of whether or not the CPU is servicing interrupts. Because of this, the ICR.PIPN bit field always reflects the pending service request with the highest priority. This can, for example, be used by software polling techniques to determine high-priority requests while leaving the interrupt system disabled.

13.3.2 PCP Interrupt Control Unit (PICU)

The PCP Interrupt Control Unit (PICU) is closely coupled with the PCP and its Interrupt Control Register (PCP_PICR). The operation of the PICU is very similar to the ICU of the CPU with respect to the overall scheme.

Note: Details of the PICU and the PCP_ICR register are described in the chapter about the PCP.

13.4 Arbitration Process

The arbitration process implemented in the TC1728 uses a number of arbitration cycles to determine the pending interrupt request with the highest priority number, SRPN. In each of these cycles, two bits of the SRPNs of all pending service requests are compared against each other. The sequence starts with the high-order bits of the SRPNs and works downwards, such that in the last cycle, bits [1:0] of the SRPNs are compared. Thus, to perform an arbitration through all 8 bits of an SRPN, four arbitration cycles are required. There are two factors determining the duration of the arbitration process:

- Number of arbitration cycles, and
- Duration of arbitration cycles.

Both of these can be controlled by the user.

13.4.1 Controlling the Number of Arbitration Cycles

In a real-time system where responsiveness is critical, arbitration must be as fast as possible. However, to maintain flexibility, the TC1728 system is designed to have a large range of service priorities. If not all priorities are needed in a system, arbitration can be accelerated by not examining all the bits used to identify all 255 unique priorities.

For instance, if a 6-bit number is enough to identify all priority numbers used in a system (meaning that bits [7:6] of all SRPNs are always 0), it is not necessary to perform arbitration on these two bits. Three arbitration cycles will be enough to find the highest number in bits [5:0] of the SRPNs of all pending requests. Similarly, the number of arbitration cycles can be reduced to two if only bits [3:0] are used in all SRPNs, and the number of arbitration cycles can be reduced to one cycle if only bits [1:0] are used.

The ICR.CARBCYC bit field controls the number of cycles in the arbitration process. Its default value is 0, which selects four arbitration cycles. [Table 13-1](#) gives the options for arbitration cycle control.

Table 13-1 Arbitration Cycle Control

Number of Arbitration Cycles	4	3	2	1
ICR.CARBCYC	00 _B	01 _B	10 _B	11 _B
Relevant bits of the SRPNs	[7:0]	[5:0]	[3:0]	[1:0]
Range of priority numbers covered	1..255	1..63	1..15	1..3

Note: If less than four arbitration cycles are selected, the corresponding upper bits of the SRPNs are not examined, even if they do not contain zeros.

13.4.2 Controlling the Duration of Arbitration Cycles

During each arbitration cycle, the rate of information flow between the SRNs and the ICU can become limited by propagation delays within the TC1728 when it is executing at high system clock frequencies. At high frequencies, arbitration cycles may require two system clocks to execute properly. In order to optimize the arbitration scheme at lower system frequencies, an additional control bit, ICR.CONECYC, is implemented. The default value of 0 of this bit selects two clock cycles per arbitration cycle. Setting this bit to 1 selects one clock cycle per arbitration cycle. The maximum frequency for the ICR.CONECYC='1' setting is defined in the product data sheet. Setting this bit for system frequencies above the specified limit leads to unpredictable behavior of the interrupt system. Correct operation is then not guaranteed.

13.5 Entering an Interrupt Service Routine

When an interrupt request from the ICU is pending and all conditions are met such that the CPU can now service the interrupt request, the CPU performs the following actions in preparation for entering the designated Interrupt Service Routine (ISR):

1. Upper context of the current task is saved¹⁾. The current CPU priority number, ICR.CCPN, and the state of the global interrupt enable bit, ICR.IE, are automatically saved with the PCXI register (bit field PCPN and bit PIE).
2. Interrupt system is globally disabled (ICR.IE is set to 0).
3. Current CPU priority number (ICR.CCPN) is set to the value of ICR.PIPN.
4. PSW is set to a default value:
 - a) All permissions are enabled, that is, PSW.IO = 10_g.
 - b) Memory protection is switched to PRS0, that is, PSW.PRS = 0.
 - c) The stack pointer bit is set to the interrupt stack, that is, PSW.IS = 1.
 - d) The call depth counter is cleared, the call depth limit is set to 63, that is, PSW.CDC = 0.
5. Stack pointer, A10, is reloaded with the contents of the Interrupt Stack Pointer, ISP, if the PSW.IS bit of the interrupted routine was set to 0 (using the user stack); otherwise it is left unaltered.
6. CPU program counter is assigned with an effective address consisting of the contents of the BIV register OR-ed with the ICR.PIPN number left-shifted by 5. This indexes the Interrupt Vector Table entry corresponding to the interrupt priority.
7. Contents at the effective address of the program counter in the Interrupt Vector Table are fetched as the first instruction of the Interrupt Service Routine (ISR). Execution continues linearly from there until the ISR branches or exits.

1) Note that, if a context-switch trap occurs while the CPU is in the process of saving the upper context of the current task, the pending ISR will not be entered, the interrupt request will be left pending, and the CPU will enter the appropriate trap handling routine instead.

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As explained, receipt of further interrupts is disabled ($ICR.IE = 0$) when an Interrupt Service Routine is entered. At the same time, the current CPU priority $ICR.CCPN$ is set by hardware to the priority of the interrupting source ($ICR.PIPN$).

Clearly, before the processor can receive any more interrupts, the ISR must eventually re-enable the interrupt system again by setting $ICR.IE = 1$. Furthermore, the ISR can also modify the priority number $ICR.CCPN$ to allow effective interrupt priority levels. It is up to the user to enable the interrupt system again and optionally modify the priority number $CCPN$ to implement interrupt priority levels or handle special cases.

To simply enable the interrupt system again, the **ENABLE** instruction can be used, which sets $ICR.IE$ bit to 1. The **BISR** instruction offers a convenient way to re-enable the interrupt system, to set $ICR.CCPN$ to a new value, and to save the lower context of the interrupted task. It is also possible to use an **MTCR** instruction to modify $ICR.IE$ and $ICR.CCPN$. However, this should be performed together with an **ISYNC** instruction (which synchronizes the instruction stream) to ensure completion of this operation before the execution of following instructions.

*Note: The lower context can also be saved through execution of an **SVLCX** (Save Lower Context) instruction.*

13.6 Exiting an Interrupt Service Routine

When an ISR exits with an **RFE** (Return From Exception) instruction, the hardware automatically restores the upper context. Register $PCXI$, which holds the Previous CPU Priority Number ($PCPN$) and the Previous Global Interrupt Enable Bit (PIE), is a part of this upper context. The value saved in $PCPN$ is written to $ICR.CCPN$ to set the CPU priority number to the value before the interruption, and bit PIE is written to $ICR.IE$ to restore the state of this bit. The interrupted routine then continues.

*Note: There is no automatic restoring of the lower context on an exit from an Interrupt Service Routine. If the lower context was saved during the execution of the ISR, either through execution of the **BISR** instruction or an **SVLCX** instruction, the ISR must restore the lower context again via the **RSLCX** (Restore Lower Context) instruction before it exits through **RFI** execution.*

13.7 Interrupt Vector Table

Interrupt Service Routines (ISRs) are associated with interrupts at a particular priority by way of the Interrupt Vector Table. The Interrupt Vector Table is an array of ISR entry points.

When the CPU takes an interrupt, it calculates an address in the Interrupt Vector Table that corresponds with the priority of the interrupt (the ICR.PIPN bit field). This address is loaded in the program counter. The CPU begins executing instructions at this address in the Interrupt Vector Table. The code at this address is the start of the selected ISR. Depending on the code size of the ISR, the Interrupt Vector Table may only store the initial portion of the ISR, such as a jump instruction that vectors the CPU to the rest of the ISR elsewhere in memory.

The Interrupt Vector Table is stored in code memory. The BIV register specifies the base address of the Interrupt Vector Table. Interrupt vectors are ordered in the table by increasing priority.

The Base of Interrupt Vector Table register (BIV) stores the base address of the Interrupt Vector Table. It can be assigned to any available code memory. Its default on power-up is fixed at 0000 0000_H. However, the BIV register can be modified using the MTCR instruction during the initialization phase of the system, before interrupts are enabled. With this arrangement, it is possible to have multiple Interrupt Vector Tables and switch between them by changing the contents of the BIV register.

Note: The BIV register is protected by the ENDINIT bit (see chapter describing the watchdog timer). Modifications should only be done while the interrupt system is globally disabled (ICR.IE = 0). Also, an ISYNC instruction should be issued after modifying BIV to ensure completion of this operation before execution of following instructions.

When interrupted, the CPU calculates the entry point of the appropriate ISR from the PIPN and the contents of the BIV register. The PIPN is left-shifted by five bits and OR-ed with the address in the BIV register to generate a pointer into the Interrupt Vector Table. Execution of the ISR begins at this address. Due to this operation, it is recommended that bits [12:5] of register BIV are set to 0 (see [Figure 13-2](#)). Note that bit 0 of the BIV register is always 0 and cannot be written to (instructions have to be aligned on even byte boundaries).

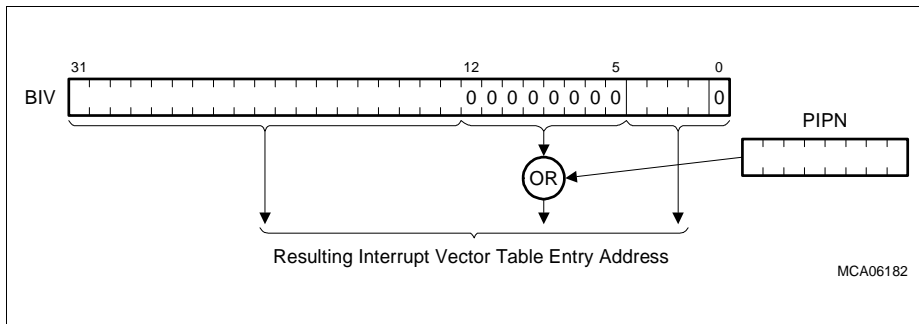


Figure 13-2 Interrupt Vector Table Entry Address Calculation

Left-shifting the PIPN by 5 bits creates entries into the Interrupt Vector Table which are evenly spaced 8 words apart. If an ISR is very short, it may fit entirely within the eight words available in the vector table entry. Otherwise, the code at the entry point must ultimately cause a jump to the rest of the ISR residing elsewhere in memory. Due to the way the vector table is organized according to the interrupt priorities, the TC1728 offers an additional option by allowing spanning several Interrupt Vector Table entries as long as those entries are otherwise unused. [Figure 13-3](#) illustrates this.

The required size of the Interrupt Vector Table depends only on the range of priority numbers actually used in a system. Of the 256 vector entries, 255 may be used. Vector entry 0 is never used, because if ICR.PIPN is 0, the CPU is not interrupted. Distinct interrupt handlers are supported, but systems requiring fewer entries need not dedicate the full memory area required by the largest configurations.

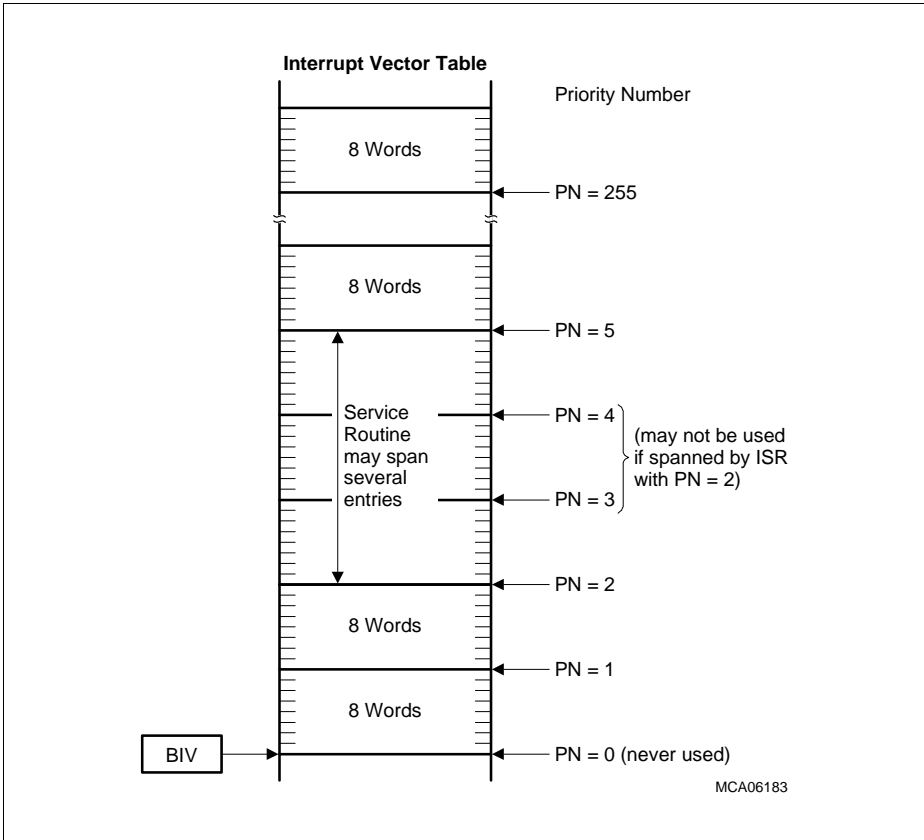


Figure 13-3 Interrupt Vector Table

13.8 Usage of the TC1728 Interrupt System

The following sections provide examples of using the TC1728 interrupt system to solve both typical and special application requirements.

13.8.1 Spanning Interrupt Service Routines Across Vector Entries

Each Interrupt Vector Table entry consists of eight words of memory. If an ISR can be made to fit directly in the Interrupt Vector Table there is no need for a jump instruction to vector to the rest of the interrupt handler elsewhere in memory. However, only the simplest ISRs can fit in the eight words available to a single entry in the table. But it is easy to arrange for ISRs to span across multiple entries, since the Interrupt Vector Table is ordered not by the interrupt source but by interrupt priority. This technique is explained in this section.

In the example of [Figure 13-3](#), entry locations 3 and 4 are occupied by the ISR for entry 2. In [Figure 13-3](#), the next available entry after entry 2 is entry 5. Of course, if this technique is used, it would be improper to allow any SRN to request service at any of the spanned vector priorities. Thus, priority levels 3 and 4 must not be assigned to SRNs requesting CPU service. They can, however, be used to request PCP service.

There is a performance trade-off that may arise when using this technique because the range of priority numbers used increases. This may have an impact on the number of arbitration cycles required to perform arbitration. Consider the case in which a system uses only three active interrupt sources, that is, where there are only three SRNs enabled to request service. If these three active sources are assigned to priority numbers 1, 2, and 3, it would be sufficient to perform the arbitration in just one cycle. However, if the ISR for interrupt priority 2 is spanned across three Interrupt Vector Table entries as shown in [Figure 13-3](#), the priority numbers 1, 2 and 5 would have to be assigned. Thus, two arbitration cycles would have to be used to perform the full arbitration process.

The trade-off between the performance impact of the number of arbitration cycles and the performance gain through spanning service routines can be made by the system designer depending on system needs. Reducing the number of arbitration cycles reduces the service request arbitration latency - spanning service routines reduces the run time of service routines (and therefore also the latency for further interrupts at that priority level or below). For example, if there are multiple fleeting measurements to be made by a system, reducing arbitration latency may be most important. But if keeping total interrupt response time to a minimum is most urgent, spanning Interrupt Vector Table entries may be a solution.

13.8.2 Configuring Ordinary Interrupt Service Routines

When the CPU starts to service an interrupt, the interrupt system is globally disabled and the CPU priority ICR.CCPN is set to the priority of the interrupt now being serviced. This blocks all further interrupts from being serviced until the interrupt system is enabled again.

After an ordinary ISR begins execution, it is usually desirable for the ISR to re-enable global interrupts so that higher-priority interrupts (that is, interrupts that are greater than the current value of ICR.CCPN) can be serviced even during the current ISR's execution. Thus, such an ISR may set ICR.IE = 1 again with, for instance, the ENABLE instruction. If the ISR enables the interrupt system again by setting ICR.IE = 1 but does not change ICR.CCPN, the effect is that from that point on the hardware can be interrupted by higher-priority interrupts but will be blocked from servicing interrupt requests with the same or lower priority than the current value of bit field ICR.CCPN. Since the current ISR is clearly also at this priority level, the hardware is also blocked from delivering further interrupts to it as well. (This condition is clearly necessary so that the ISR can service the interrupt request automatically.)

When the ISR is finished, it exits with an RFE instruction. Hardware then restores the values of ICR.CCPN and ICR.IE to the values of the interrupted program.

13.8.3 Interrupt Priority Groups

It is sometimes useful to create groups of interrupts at the same or different interrupt priorities that cannot interrupt each other's ISRs. For instance, devices that can generate multiple interrupts may need to have interrupts at different priorities interlocked in this way. The TC1728 interrupt architecture can be used to create such interrupt priority groups. It is effected by managing the current CPU priority level ICR.CCPN in a way described in this section.

For example, in order to make an interrupt priority group out of priority numbers 11 and 12, one would not want an ISR executing at priority 11 to be interrupted by a service request at priority 12, since this would be in the same priority group. Only interrupts above 12 should be allowed to interrupt the ISRs in this interrupt priority group. However, under ordinary ISR usage, the ISR at priority 11 would be interrupted by any request with a higher priority number, including priority 12.

If, however, all ISRs in the interrupt priority group set the value of ICR.CCPN to the highest priority level within their group before they re-enable interrupts, then the desired interlocking will occur.

Figure 13-4 shows an example for interrupt priority grouping. The interrupt requests with the priority numbers 11 and 12 form one group, while the requests with priority numbers 14 through 17 form another group. Each ISR in group 1 sets the value of ICR.CCPN to 12, the highest number in that group, before re-enabling the interrupt system. Each ISR in group 2 sets the value of ICR.CCPN to 17 before re-enabling the interrupt system. If,

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for example, interrupt 14 is serviced, it can only be interrupted by requests with a priority number higher than 17; therefore it will not be interrupted by requests from its own priority group or requests with lower priority.

In **Figure 13-4**, the interrupt request with priority number 13 can be said to form an interrupt priority group with just itself as a member.

Setting ICR.CCPN to the maximum value 255 in each service routine has the same effect as not re-enabling the interrupt system; all interrupt requests can then be considered to be in the same group.

Interrupt priority groups demonstrate the power of the TC1728 priority-based interrupt-ordering system. Thus the flexibility of interrupt priority levels ranges from all interrupts in one group to each interrupt request building its own group, and to all possible combinations in between.

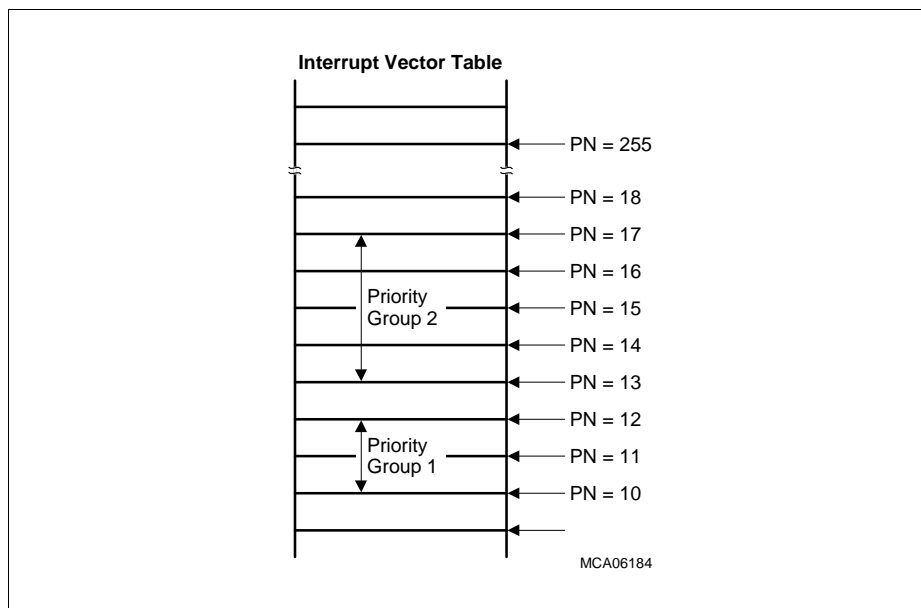


Figure 13-4 Interrupt Priority Groups

13.8.4 Splitting Interrupt Service Across Different Priority Levels

Interrupt service can be divided into multiple ISRs that execute at different priority levels. For example, the beginning stage of interrupt service may be very time-critical, such as reading a data value within a limited time window after the interrupt request activation. However, once the time-critical phase is past, there may still be more to do – for instance,

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to process the observation. During this second phase, it may be acceptable for this ISR to be interrupted by lower-level interrupts. This can be performed as follows.

For example, the initial interrupt priority is fixed very high because response time is critical. The necessary actions are carried out immediately by the ISR at that high-priority level. Then the ISR prepares to invoke another ISR at a lower priority level through software to perform the lower-priority actions.

To invoke an ISR through software, the high-priority ISR directly sets an interrupt request bit in an SRN that will invoke the appropriate low-priority ISR. Then the high-priority ISR exits.

When the high-priority ISR exits, the pending low-priority interrupt will eventually be serviced (depending on the priority of other pending interrupts). When the low-priority ISR eventually executes, the low-priority actions of the interrupt will be performed.

The inverse of this method can also be employed, wherein a low-priority ISR raises its own priority level, or leaves interrupts turned off while it executes. For instance, the priority of a service request might be low because the time to respond to the event is not critical, but once it has been granted service, this service should not be interrupted. In this case, the ISR could raise the value of ICR.CCPN to a priority that would exclude some or all other interrupts, or simply leave interrupts disabled.

13.8.5 Using different Priorities for the same Interrupt Source

For some applications, the urgency of a service request may vary, depending on the current state of the system. To handle this, different priority numbers (SRPNs) can be assigned at different times to a service request depending on the application needs.

Of course, Interrupt Service Routines must be placed in the Interrupt Vector Table at all addresses corresponding to the range of priorities used. If service remains the same at different priorities, copies of the ISR can be placed at the possible different entries, or the entries can all vector to a common ISR. If the ISR should execute different code depending on its priority, one need merely put the appropriate ISR in the appropriate entry of the Interrupt Vector Table.

This flexibility is another advantage of the TC1728 interrupt architecture. In traditional interrupt systems where the interrupt vectors are ordered by interrupting source, the ISR would have to check the current priority of the interrupt request and perform a branch to the appropriate code section, causing a delay in the response to the request. In the TC1728, however, the extra check and branch in the ISR are not necessary, hence reduces the interrupt latency.

Because this approach may necessitate an increase in the range of interrupt priorities, the system designer must trade off this advantage against any possible increase in the number of arbitration cycles.

13.8.6 Interrupt Priority 1

Interrupt Priority 1 is the first and lowest-priority entry in the Interrupt Vector Table. It is generally reserved for ISRs which perform task management. ISRs whose actions cause software-managed tasks to be created post a software interrupt request at priority level 1 to signal the event.

The ISR that triggers this event can then execute a normal return from interrupt. There is no need for it to check whether the ISR is returning to the background-task priority level (priority 0) or is returning to a lower-priority ISR that it interrupted. When there is a pending interrupt at a priority higher than the return context for the current interrupt, this interrupt will then be serviced. When a return to the background-task priority level (level 0) is performed, the software-posted interrupt at priority level 1 will be serviced automatically.

13.8.7 Software-Initiated Interrupts

Software can set the service request bit (SRR) in a SRN by writing to its Service Request Control Register. Thus, software can initiate interrupts that are handled by the same mechanism as hardware interrupts.

After the SRR bit is set in an active SRN, there is no way to distinguish between a software-initiated interrupt request and a hardware interrupt request. For this reason, software should only use SRNs and interrupt priority numbers that are not being used for hardware interrupts.

The TC1728 contains four SRNs that support software-initiated interrupts. These SRNs are not connected to peripheral modules and can only cause interrupts when software sets its SRR bit. These SRNs are called the CPU Service Request Nodes (CPU_SRC[3:0]). The PCP can also cause these four SRNs to generate service requests. See also the TriCore chapter for TC1728-specific implementation details of the four CPU Service Request Control Registers.

Additionally, any otherwise unused SRN can be employed to generate software interrupts.

13.8.8 External Interrupts

Four SRNs (SCU_SRC[3:0]) are reserved to handle external interrupts. The setup for external GPIO port input signals (edge/level triggering, gating etc.) that are able to generate an interrupt request is controlled in the External Request Unit (ERU). The ERU functionality is described in detail in the SCU chapter.

13.9 Service Request Node Table

Table 13-2 shows all TC1728 Service Request Nodes.

Table 13-2 Service Request Nodes in the TC1728

Module	No. of Nodes	Description	SRC Register
CPU	4	CPU Service Request Nodes [3:0]	CPU_SRC[3:0] ¹⁾
	1	Software Breakpoint Request Node	CPU_SBSRC ¹⁾
Cerberus	2	Cerberus/OCDS Request Node[1:0]	CBS_SRC[1:0]
LBCU	1	LBCU Request Node	LBCU_SRC ¹⁾
SBCU	1	SBCU Request Node	SBCU_SRC
DMA	8	DMA Service Request Nodes [7:0]	DMA_SRC[7:0]
	4	MLI0 Service Request Nodes [3:0]	DMA_MLI0SRC [3:0]
PCP	12	PCP Service Request Nodes [11:0]	PCP_SRC[11:0] ¹⁾
STM	2	STM Service Request Nodes [1:0]	STM_SRC[1:0]
SCU	4	SCU Service Request Nodes [3:0]	SCU_SRC[3:0]
ASC0	4	ASC0 Transmit Interrupt Service Request Node	ASC0_TSRC
		ASC0 Receive Interrupt Service Request Node	ASC0_RSRC
		ASC0 Error Interrupt Service Request Node	ASC0_ESRC
		ASC0 Transmit Buffer Interrupt Service Request Node	ASC0_TBSRC
ASC1	4	ASC1 Transmit Interrupt Service Request Node	ASC1_TSRC
		ASC1 Receive Interrupt Service Request Node	ASC1_RSRC
		ASC1 Error Interrupt Service Request Node	ASC1_ESRC
		ASC1 Transmit Buffer Interrupt Service Request Node	ASC1_TBSRC

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Table 13-2 Service Request Nodes in the TC1728 (cont'd)

Module	No. of Nodes	Description	SRC Register
SSC0	3	SSC0 Transmit Interrupt Service Request Node	SSC0_TSRC ⁽¹⁾
		SSC0 Receive Interrupt Service Request Node	SSC0_RSRC ⁽¹⁾
		SSC0 Error Interrupt Service Request Node	SSC0_ESRC ⁽¹⁾
SSC1	3	SSC1 Transmit Interrupt Service Request Node	SSC1_TSRC ⁽¹⁾
		SSC1 Receive Interrupt Service Request Node	SSC1_RSRC ⁽¹⁾
		SSC1 Error Interrupt Service Request Node	SSC1_ESRC ⁽¹⁾
SSC2	3	SSC2 Transmit Interrupt Service Request Node	SSC2_TSRC ⁽¹⁾
		SSC2 Receive Interrupt Service Request Node	SSC2_RSRC ⁽¹⁾
		SSC2 Error Interrupt Service Request Node	SSC2_ESRC ⁽¹⁾
SSC3	3	SSC3 Transmit Interrupt Service Request Node	SSC3_TSRC ⁽¹⁾
		SSC3 Receive Interrupt Service Request Node	SSC3_RSRC ⁽¹⁾
		SSC3 Error Interrupt Service Request Node	SSC3_ESRC ⁽¹⁾
FCE	1	Flexible CRC Engine	FCE_SRC
BMU	1	Bus Monitor Unit	BMU_SRC
MSC0	2	MSC0 Service Request Nodes [1:0]	MSC0_SRC[1:0]
CAN	16	CAN Service Request Nodes [15:0]	CAN_SRC[15:0] ⁽¹⁾
GPTA0	38	GPTA0 Service Request Nodes [37:00]	GPTA0_SRC [37:0]
CC6061	8	CC6061 Service Request Nodes [07:00]	CC6061_SRC[07:00]
GPT120	6	GPT12_0 Service Request Nodes [05:00]	GPT120_SRC[05:00]
GPT121	6	GPT12_1 Service Request Nodes [05:00]	GPT121_SRC[05:00]
ADC0	9	ADC0 Service Request Nodes [8:0]	ADC0_SRC[8:0] ⁽¹⁾
FADC	4	FADC Service Request Nodes [3:0]	FADC_SRC[3:0] ⁽¹⁾

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Table 13-2 Service Request Nodes in the TC1728 (cont'd)

Module	No. of Nodes	Description	SRC Register
E-Ray	10	Interrupt 0 Service Request Control Register	ERAY_INT0SRC ¹⁾
		Interrupt 1 Service Request Control Register	ERAY_INT1SRC ¹⁾
		Timer Interrupt 0 Service Request Control Register	ERAY_TINT0SRC ¹⁾
		Timer Interrupt 1 Service Request Control Register	ERAY_TINT1SRC ¹⁾
		New Data 0 Service Request Control Register	ERAY_NDAT0SRC ¹⁾
		New Data 1 Service Request Control Register	ERAY_NDAT1SRC ¹⁾
		Message Buffer Status Changed 0 Service Request Control Register	ERAY_MBSC0SRC ¹⁾
		Message Buffer Status Changed 1 Service Request Control Register	ERAY_MBSC1SRC ¹⁾
		Output Buffer Busy Service Request Control Register	ERAY_OBUSYSRC ¹⁾
		Input Buffer Busy Service Request Control Register	ERAY_IBUSYSRC ¹⁾

1) These service request registers are not bit-addressable because its register address is outside the first 16 Kbyte of a segment.

14 System Timer (STM)

This chapter describes the System Timer (STM). The TC1728's STM is designed for global system timing applications requiring both high precision and long period.

14.1 Overview

The STM has the following features:

- Free-running 56-bit counter
- All 56 bits can be read synchronously
- Different 32-bit portions of the 56-bit counter can be read synchronously
- Flexible service request generation based on compare match with partial STM content
- Counting starts automatically after a reset operation
- STM registers are reset by an application reset if bit ARSTDIS.STMDIS is cleared. If bit ARSTDIS.STMDIS is set, the STM registers are not reset.¹⁾
- STM can be halted in debug/suspend mode (via STM_CLC register)

Special STM register semantics provide synchronous views of the entire 56-bit counter, or 32-bit subsets at different levels of resolution.

The maximum timer period is $2^{56} \times f_{\text{STM}}$. At $f_{\text{STM}} = 50 \text{ MHz}$, for example, the STM counts 46.85 years before overflowing. Thus, it is capable of continuously timing the entire expected product life time of a system without overflowing.

14.2 Operation

The STM is an upward counter, running either at the FPI-Bus frequency f_{FPI} or at a fraction of it. The STM clock frequency is $f_{\text{STM}} = f_{\text{FPI}}/\text{RMC}$ with $\text{RMC} = 0-7$ (default after reset is $f_{\text{STM}} = f_{\text{FPI}}/2$, selected by $\text{RMC} = 010_{\text{B}}$). RMC is a bit field in register STM_CLC. In case of an application reset, the STM is reset if bit SCU_ARSTDIS.DIS0 is set. After reset, the STM is enabled and immediately starts counting up. It is not possible to affect the content of the timer during normal operation of the TC1728. The timer registers can only be read but not written to.

The STM can be optionally disabled for power-saving purposes, or suspended for debugging purposes via its clock control register. In suspend mode of the TC1728 (initiated by writing an appropriate value to STM_CLC register), the STM clock is stopped but all registers are still readable.

Due to the 56-bit width of the STM, it is not possible to read its entire content with one instruction. It needs to be read with two load instructions. Since the timer would continue to count between the two load operations, there is a chance that the two values read are not consistent (due to possible overflow from the low part of the timer to the high part

¹⁾ "STM registers" means all registers except STM_CLC, STM_SRC0, and STM_SRC1.

System Timer (STM)

between the two read operations). To enable a synchronous and consistent reading of the STM content, a capture register (STM_CAP) is implemented. It latches the content of the high part of the STM each time when one of the registers STM_TIM0 to STM_TIM5 is read. Thus, STM_CAP holds the upper value of the timer at exactly the same time when the lower part is read. The second read operation would then read the content of the STM_CAP to get the complete timer value.

The STM can also be read in sections from seven registers, STM_TIM0 through STM_TIM6, that select increasingly higher-order 32-bit ranges of the STM. These can be viewed as individual 32-bit timers, each with a different resolution and timing range.

The content of the 56-bit System Timer can be compared against the content of two compare values stored in the STM_CMP0 and STM_CMP1 registers. Service requests can be generated on a compare match of the STM with the STM_CMP0 or STM_CMP1 registers.

Figure 14-1 provides an overview on the STM module. It shows the options for reading parts of the STM content.

System Timer (STM)

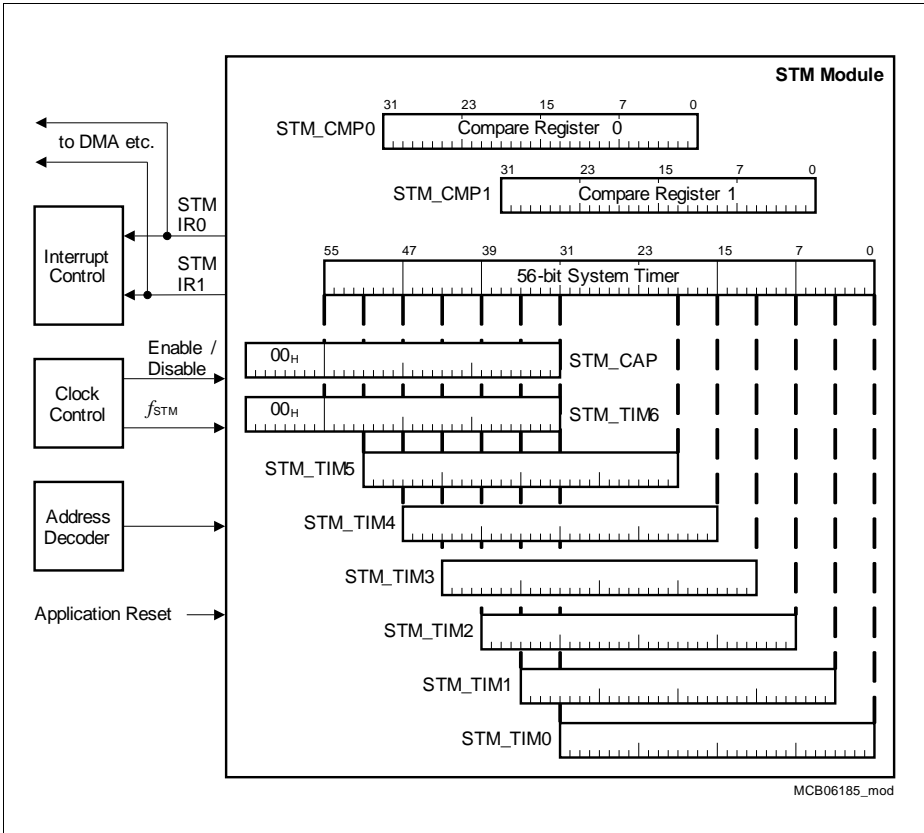


Figure 14-1 General Block Diagram of the STM Module Registers

System Timer (STM)

14.2.1 Resolution and Ranges

Table 14-1 is an overview on the individual timer registers with their resolutions and timing ranges. As an example, the values for 75 MHz STM input clock frequency f_{STM} are given.

Table 14-1 System Timer Resolutions and Ranges

Register	STM Bits	Resolution [s]	Range [s]	Resolution	Range	f_{STM} [MHz]
STM_TIM0	[31:0]	$1 / f_{\text{STM}}$	$2^{32} / f_{\text{STM}}$	13.3 ns	57.3 s	75
STM_TIM1	[35:4]	$16 / f_{\text{STM}}$	$2^{36} / f_{\text{STM}}$	213 ns	916.2 s	
STM_TIM2	[39:8]	$256 / f_{\text{STM}}$	$2^{40} / f_{\text{STM}}$	3.41 μs	244.3 min	
STM_TIM3	[43:12]	$4096 / f_{\text{STM}}$	$2^{44} / f_{\text{STM}}$	54.6 μs	65.1 h	
STM_TIM4	[47:16]	$65536 / f_{\text{STM}}$	$2^{48} / f_{\text{STM}}$	0.874 ms	43.44 days	
STM_TIM5	[51:20]	$2^{20} / f_{\text{STM}}$	$2^{52} / f_{\text{STM}}$	13.98 ms	1.90 yr	
STM_TIM6	[55:32]	$2^{32} / f_{\text{STM}}$	$2^{56} / f_{\text{STM}}$	57.3 s	30.47 yr	
STM_CAP	[55:32]	$2^{32} / f_{\text{STM}}$	$2^{56} / f_{\text{STM}}$	57.3 s	30.47 yr	

14.2.2 Compare Register Operation

The content of the 56-bit STM can be compared against the content of two compare values stored in the STM_CMP0 and STM_CMP1 registers. Service requests can be generated on a compare match of the STM with the STM_CMP0 or STM_CMP1 registers.

Two parameters are programmable for the compare operation:

1. The width of the relevant bits in registers STM_CMP0/STM_CMP1 (compare width MSIZE_x) that is taken for the compare operation can be programmed from 1 to 32.
2. The first bit location in the 56-bit STM that is taken for the compare operation can be programmed from 0 to 24.

These programming capabilities make compare functionality very flexible. It even makes it possible to detect bit transitions of a single bit n ($n = 0$ to 24) within the 56-bit STM by setting MSIZE = 0 and MSTART = n .

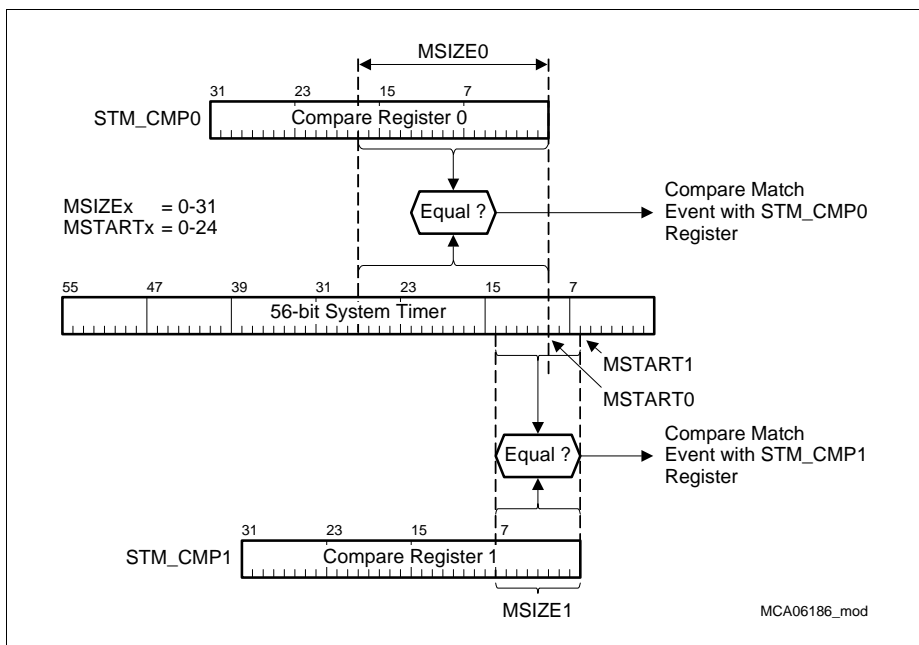


Figure 14-2 Compare Mode Operation

Figure 14-2 shows an example of the compare operation. In this example the following parameters are programmed:

- MSIZE₀ = 10001_B = 17_D; MSTART₀ = 01010_B = 9_D
- MSIZE₁ = 00111_B = 7_D; MSTART₁ = 00111_B = 6_D

System Timer (STM)

A compare operation with MSIZE not equal 0 always implies that the compared value as stored in the CMP register is right-extended with zeros. This means that in the example of **Figure 14-2**, the compare register content STM_CMP0[17:0] plus nine zero bits right-extended is compared with STM[27:0] with STM[8:0] = 000_H. In case of register STM_CMP1, STM[14:0] with STM[5:0] = 00_H are compared with STM_CMP1[8:0] plus six zero bits right-extended.

14.2.3 Compare Match Interrupt Control

The compare match interrupt control logic is shown in **Figure 14-3**. Each STM_CMPx register has its compare match interrupt request flag (STM_ICR.CMPxIR) that is set by hardware on a compare match event. The interrupt request flags can be set (STM_ISSR.CMPxIRS) or cleared (STM_ISSR.CMPxIRR) by software. Note that setting STM_ICR.CMPxIR by writing a 1 into STM_ISSR.CMPxIRS does not generate an interrupt at STMIRx. The compare match interrupts from CMP0 and CMP1 can be further directed by STM_ICR.CMPxOS to either output signal STMIR0 or STMIR1. The STMIR0 and STMIR1 outputs are each connected to interrupt service request control registers, STM_SRC0 and STM_SCR1, respectively.

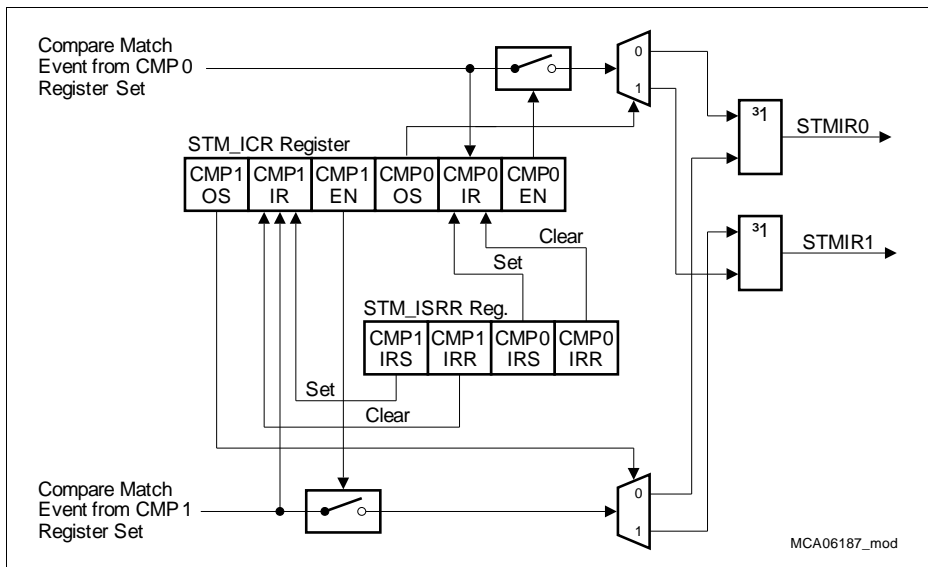


Figure 14-3 STM Interrupt Control

The compare match interrupt flags STM_ICR.CMPxIR are immediately set after an STM reset operation, caused by a compare match event with the reset values of the STM and the compare registers STM_CMPx. This setting of the CMPxIR flags does not directly

System Timer (STM)

generate compare match interrupts because the compare match interrupts are automatically disabled after a STM reset operation ($CMPxEN = 0$). Therefore, before enabling a compare match interrupt after a STM reset operation, the $CMPxIRR$ flags should be cleared by software (writing register STM_ISSR with $CMPxIRR$ set). Otherwise, undesired compare match interrupt events are triggered. Details about DMA connections of $STMIR0$ and $STMIR1$ are given in [Table 14-4](#) on [Page 14-21](#).

14.3 STM Registers

This section describes the STM registers of the STM. The STM registers can be divided into four types, as shown in [Figure 14-4](#).

STM Registers Overview

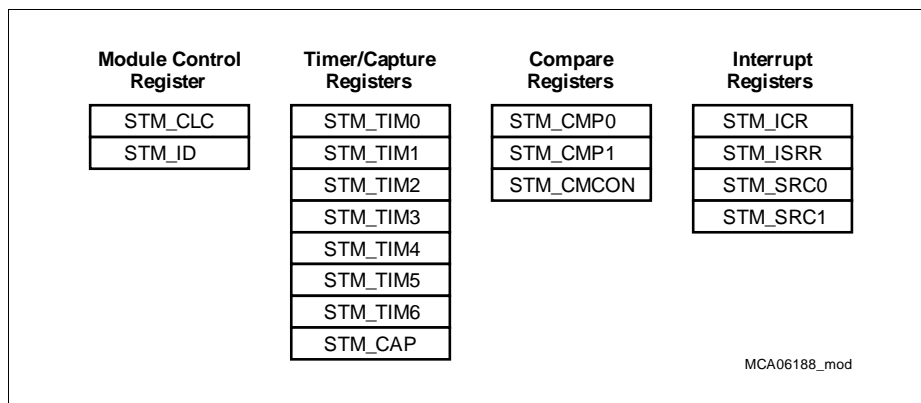


Figure 14-4 STM Registers

In TC1728 all registers are readable is suspend mode. The complete and detailed address map of the STM module with its registers is shown in [Table 14-5](#) on [Page 14-21](#).

Table 14-2 Registers Address Space

Module	Base Address	End Address	Note
STM	F000 0200 _H	F000 02FF _H	-

Table 14-3 Registers Overview - STM Registers

Register Short Name	Register Long Name	Offset Address	Description see
STM_CLC ¹⁾	STM Clock Control Register	00 _H	Page 14-9
STM_ID	STM Module Identification Register	08 _H	Page 14-10
STM_TIM0	STM Timer Register 0	10 _H	Page 14-11
STM_TIM1	STM Timer Register 1	14 _H	Page 14-11
STM_TIM2	STM Timer Register 2	18 _H	Page 14-12
STM_TIM3	STM Timer Register 3	1C _H	Page 14-12
STM_TIM4	STM Timer Register 4	20 _H	Page 14-12
STM_TIM5	STM Timer Register 5	24 _H	Page 14-13
STM_TIM6	STM Timer Register 6	28 _H	Page 14-13
STM_CAP	STM Timer Capture Register	2C _H	Page 14-14
STM_CMP0	STM Compare Register 0	30 _H	Page 14-14
STM_CMP1	STM Compare Register 1	34 _H	Page 14-14
STM_CMCON	STM Compare Match Control Register	38 _H	Page 14-15
STM_ICR	STM Interrupt Control Register	3C _H	Page 14-17
STM_ISRR	STM Interrupt Set/Reset Register	40 _H	Page 14-19
STM_SRC1 ¹⁾	STM Service Request Control Register 1	F8 _H	Page 14-20
STM_SRC0 ¹⁾	STM Service Request Control Register 0	FC _H	Page 14-20

1) These registers are reset by an application reset if bit ARSTDIS.STMDIS is set.

System Timer (STM)

14.3.1 Clock Control Register

The STM clock control register is used to switch the STM on or off and to control its input clock rate. After a power-on reset, the STM is always enabled and starts counting. The STM can be disabled by setting bit DISR to 1.

STM_CLC

STM Clock Control Register

(00_H)

Reset Value: 0000 0200_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		0					RMC		0	FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
		r					rw		r	rw	w	rw	rw	r	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the STM module. 0 _B No disable requested 1 _B Disable requested
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the STM module. 0 _B STM module is enabled 1 _B STM module is disabled
SPEN	2	rw	Module Suspend Enable for OCDS Used for enabling the suspend mode.
EDIS	3	rw	Sleep Mode Enable Control Used for module sleep mode control.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch off in OCDS suspend mode.

System Timer (STM)

14.3.2 Timer/Capture Registers

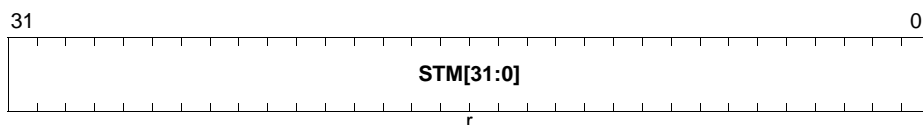
Registers STM_TIM1 to STM_TIM6 provide 32-bit views at varying resolutions of the underlying STM counter.

STM_TIM0

STM Timer Register 0

(10_H)

Reset Value: 0000 0000_H



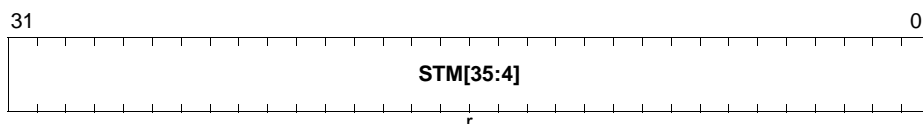
Field	Bits	Type	Description
STM[31:0]	[31:0]	r	System Timer Bits [31:0] This bit field contains bits [31:0] of the 56-bit STM.

STM_TIM1

STM Timer Register 1

(14_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
STM[35:4]	[31:0]	r	System Timer Bits [35:4] This bit field contains bits [35:4] of the 56-bit STM.

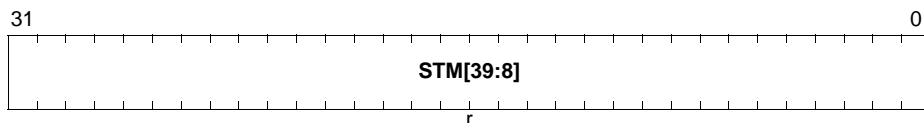
System Timer (STM)

STM_TIM2

STM Timer Register 2

(18_H)

Reset Value: 0000 0000_H



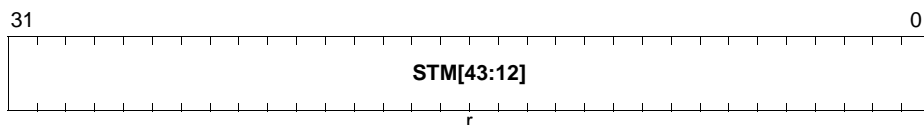
Field	Bits	Type	Description
STM[39:8]	[31:0]	r	System Timer Bits [39:8] This bit field contains bits [39:8] of the 56-bit STM.

STM_TIM3

STM Timer Register 3

(1C_H)

Reset Value: 0000 0000_H



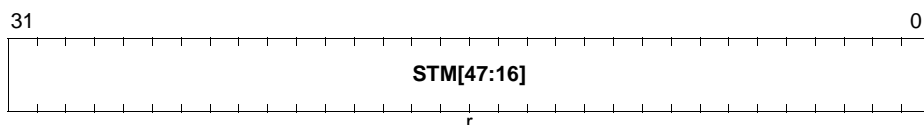
Field	Bits	Type	Description
STM[43:12]	[31:0]	r	System Timer Bits [43:12] This bit field contains bits [43:12] of the 56-bit STM.

STM_TIM4

STM Timer Register 4

(20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
STM[47:16]	[31:0]	r	System Timer Bits [47:16] This bit field contains bits [47:16] of the 56-bit STM.

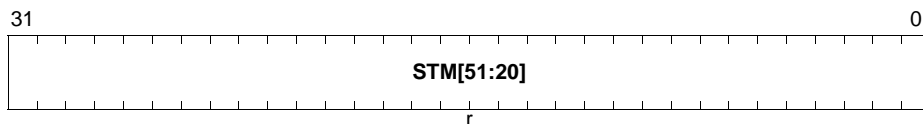
System Timer (STM)

STM_TIM5

STM Timer Register 5

(24_H)

Reset Value: 0000 0000_H



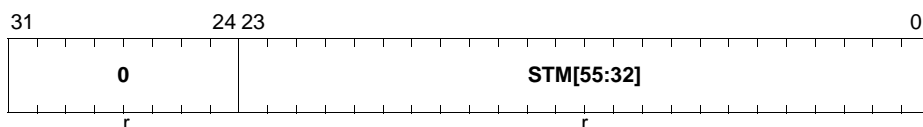
Field	Bits	Type	Description
STM[51:20]	[31:0]	r	System Timer Bits [51:20] This bit field contains bits [51:20] of the 56-bit STM.

STM_TIM6

STM Timer Register 6

(28_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
STM[55:32]	[23:0]	r	System Timer Bits [55:32] This bit field contains bits [55:32] of the 56-bit STM.
0	[31:24]	r	Reserved Read as 0.

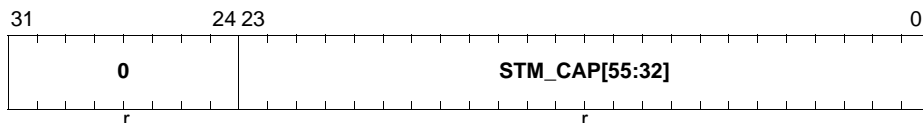
System Timer (STM)

STM_CAP

STM Timer Capture Register

(2C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
STM[55:32]	[23:0]	r	Captured System Timer Bits [55:32] The capture register STM_CAP always captures the STM bits [55:32] when one of the registers STM_TIM0 to STM_TIM5 is read. This capture operation is performed in order to enable software to operate with a coherent value of all the 56 STM bits at one time stamp. This bit field contains bits [55:32] of the 56-bit STM.
0	[31:24]	r	Reserved Read as 0.

Note: The bits in registers STM_CAP to STM_TIM0 are all read-only bits.

14.3.3 Compare Registers

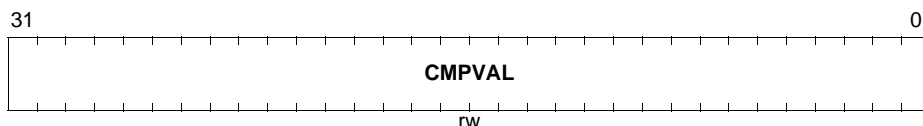
The compare register CMPx holds up to 32-bits; its value is compared to the value of the STM.

STM_CMPx (x = 0-1)

STM Compare Register x

(30_H+x*4_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CMPVAL	[31:0]	rw	Compare Value of Compare Register x This bit field holds up to 32 bits of the compare value (right-adjusted).

System Timer (STM)

The STM Compare Match Control Register controls the parameters of the compare logic.

STM_CMCON

STM Compare Match Control Register

(38_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		MSTART1						0		MSIZE1					
r		rw						r		rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		MSTART0						0		MSIZE0					
r		rw						r		rw					

Field	Bits	Type	Description
MSIZE0	[4:0]	rw	Compare Register Size for CMP0 This bit field determines the number of bits in register CMP0 (starting from bit 0) that are used for the compare operation with the System Timer. 00000 _B CMP0[0] used for compare operation 00001 _B CMP0[1:0] used for compare operation ... 11110 _B CMP0[30:0] used for compare operation 11111 _B CMP0[31:0] used for compare operation
MSTART0	[12:8]	rw	Start Bit Location for CMP0 This bit field determines the lowest bit number of the 56-bit STM that is compared with the content of register CMP0 bit 0. The number of bits to be compared is defined by bit field MSIZE0. 00000 _B STM[0] is the lowest bit number 00001 _B STM[1] is the lowest bit number ... 10111 _B STM[23] is the lowest bit number 11000 _B STM[24] is the lowest bit number Bit combinations 11001 _B to 11111 _B are reserved and must not be used.

System Timer (STM)

Field	Bits	Type	Description
MSIZE1	[20:16]	rw	Compare Register Size for CMP1 This bit field determines the number of bits in register CMP1 (starting from bit 0) that are used for the compare operation with the System Timer. 00000 _B CMP1[0] used for compare operation 00001 _B CMP1[1:0] used for compare operation ... 11110 _B CMP1[30:0] used for compare operation 11111 _B CMP1[31:0] used for compare operation
MSTART1	[28:24]	rw	Start Bit Location for CMP1 This bit field determines the lowest bit number of the 56-bit STM that is compared with the content of register CMP1 bit 0. The number of bits to be compared is defined by bit field MSIZE1. 00000 _B STM[0] is the lowest bit number 00001 _B STM[1] is the lowest bit number ... 10111 _B STM[23] is the lowest bit number 11000 _B STM[24] is the lowest bit number Bit combinations 11001 _B to 11111 _B are reserved and must not be used.
0	[7:5], [15:13], [23:21], [31:29]	r	Reserved Read as 0; should be written with 0.

14.3.4 Interrupt Registers

The two compare match interrupts of the STM are controlled by the STM Interrupt Control Register.

STM_ICR

STM Interrupt Control Register (3C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0									CMP 1	CMP 1	CMP 1		CMP 0	CMP 0	CMP 0
r									OS	IR	EN		OS	IR	EN
									rw	rh	rw		rw	rh	rw

Field	Bits	Type	Description
CMP0EN	0	rw	Compare Register CMP0 Interrupt Enable Control This bit enables the compare match interrupt with compare register CMP0. 0 _B Interrupt on compare match with CMP0 disabled 1 _B Interrupt on compare match with CMP0 enabled
CMP0IR	1	rh	Compare Register CMP0 Interrupt Request Flag This bit indicates whether or not a compare match interrupt request of compare register CMP0 is pending. CMP0IR must be cleared by software. 0 _B A compare match interrupt has not been detected since the bit has been cleared for the last time. 1 _B A compare match interrupt has been detected. CMP0IR must be cleared by software and can be set by software, too (see CMPISRR register). After a STM reset operation, CMP0IR is immediately set as a result of a compare match event with the reset values of the STM and the compare registers CMP0.

System Timer (STM)

Field	Bits	Type	Description
CMP0OS	2	rw	Compare Register CMP0 Interrupt Output Selection This bit determines the interrupt output that is activated on a compare match event of compare register CMP0. 0 _B Interrupt output STMIR0 selected 1 _B Interrupt output STMIR1 selected
CMP1EN	4	rw	Compare Register CMP1 Interrupt Enable Control This bit enables the compare match interrupt with compare register CMP1. 0 _B Interrupt on compare match with CMP1 disabled 1 _B Interrupt on compare match with CMP1 enabled
CMP1IR	5	rh	Compare Register CMP1 Interrupt Request Flag This bit indicates whether or not a compare match interrupt request of compare register CMP1 is pending. CMP1IR must be cleared by software. 0 _B A compare match interrupt has not been detected since the bit has been cleared for the last time. 1 _B A compare match interrupt has been detected. CMP1IR must be cleared by software and can be set by software, too (see CMPISRR register). After a STM reset, CMP1IR is immediately set as a result of a compare match event with the reset values of the STM and the compare register CMP1.
CMP1OS	6	rw	Compare Register CMP1 Interrupt Output Selection This bit determines the interrupt output that is activated on a compare match event of compare register CMP1. 0 _B Interrupt output STMIR0 selected 1 _B Interrupt output STMIR1 selected
0	3, [31:7]	r	Reserved Read as 0; should be written with 0.

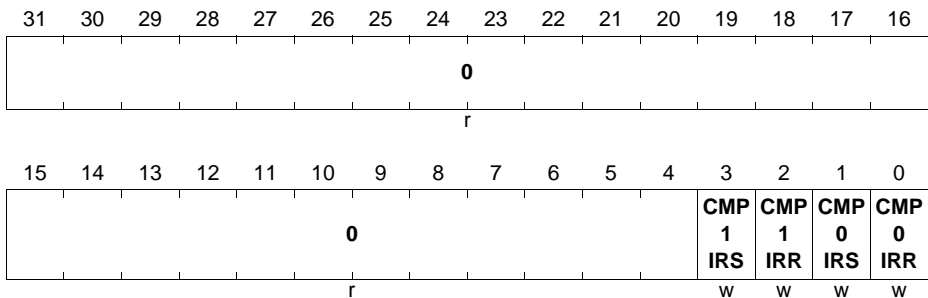
System Timer (STM)

The bits in the STM Interrupt Set/Reset Register make it possible to set or cleared the compare match interrupt request status flags of register ICR.

STM_ISR

STM Interrupt Set/Reset Register

(40_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CMP0IRR	0	w	Reset Compare Register CMP0 Interrupt Flag 0 _B Bit ICR.CMP0IR is not changed. 1 _B Bit ICR.CMP0IR is cleared.
CMP0IRS	1	w	Set Compare Register CMP0 Interrupt Flag 0 _B Bit ICR.CMP0IR is not changed. 1 _B Bit ICR.CMP0IR is set. The state of bit CMP0IRR is "don't care" in this case.
CMP1IRR	2	w	Reset Compare Register CMP1 Interrupt Flag 0 _B Bit ICR.CMP1IR is not changed. 1 _B Bit ICR.CMP1IR is cleared.
CMP1IRS	3	w	Set Compare Register CMP1 Interrupt Flag 0 _B Bit ICR.CMP1IR is not changed. 1 _B Bit ICR.CMP1IR is set. The state of bit CMP1IRR is "don't care" in this case.
0	[31:4]	r	Reserved Read as 0; should be written with 0.

Note: Reading register CMISRR always returns 0000 0000_H.

System Timer (STM)

In the TC1728, the compare match interrupt output signals of the STM, STMIR0 and STMIR1 are controlled by the STM Service Request Control Registers STM_SRC0 and STM_SRC1.

STM_SRC0

STM Service Request Control Register 0

(FC_H)

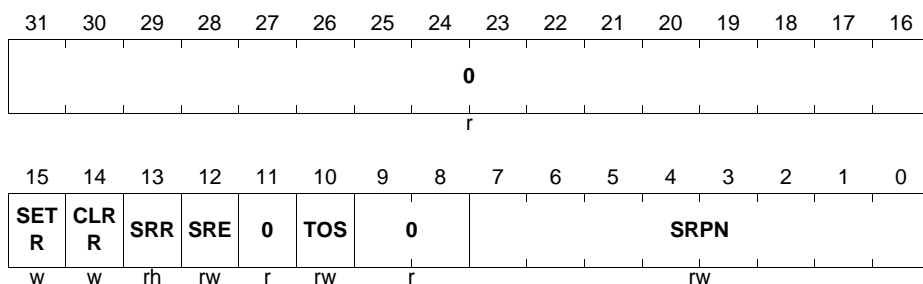
Reset Value: 0000 0000_H

STM_SRC1

STM Service Request Control Register 1

(F8_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

14.4 STM Module Implementation

This section defines implementation specific details of the STM in the TC1728.

14.4.1 On-chip Service Request Connections

The two compare match service request outputs STMIR0 and STMIR1 are connected in the TC1728 to on-chip devices as described in [Table 14-4](#).

Table 14-4 System Timer On-Chip Interconnections

Service Request Signal	Connected to
STMIR0	DMA Channel 00 Request Input 8 DMA Channel 01 Request Input 8 DMA Channel 02 Request Input 8 DMA Channel 03 Request Input 8 DMA Channel 04 Request Input 8 DMA Channel 05 Request Input 8 DMA Channel 06 Request Input 8 DMA Channel 07 Request Input 8
STMIR1	ADC0_REQGT[4:0]_5 ADC1_REQGT[4:0]_5

14.4.2 STM Address Map

[Table 14-5](#) defines the complete address range of the STM with absolute addresses and the read/write access rights.

Table 14-5 Address Map of STM

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
System Timer (STM)					
STM_CLC	STM Clock Control Register	F000 0200 _H	U, SV	SV, E	0000 0200 _H
–	Reserved	F000 0204 _H	BE	BE	–
STM_ID	STM Module Identification Register	F000 0208 _H	U, SV	BE	0000 C0XX _H
–	Reserved	F000 020C _H	BE	BE	–
STM_TIM0	STM Timer Register 0	F000 0210 _H	U, SV	U, SV	0000 0000 _H
STM_TIM1	STM Timer Register 1	F000 0214 _H	U, SV	U, SV	0000 0000 _H

System Timer (STM)

Table 14-5 Address Map of STM (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
STM_TIM2	STM Timer Register 2	F000 0218 _H	U, SV	U, SV	0000 0000 _H
STM_TIM3	STM Timer Register 3	F000 021C _H	U, SV	U, SV	0000 0000 _H
STM_TIM4	STM Timer Register 4	F000 0220 _H	U, SV	U, SV	0000 0000 _H
STM_TIM5	STM Timer Register 5	F000 0224 _H	U, SV	U, SV	0000 0000 _H
STM_TIM6	STM Timer Register 6	F000 0228 _H	U, SV	U, SV	0000 0000 _H
STM_CAP	STM Timer Capture Reg.	F000 022C _H	U, SV	U, SV	0000 0000 _H
STM_CMP0	STM Compare Register 0	F000 0230 _H	U, SV	U, SV	0000 0000 _H
STM_CMP1	STM Compare Register 1	F000 0234 _H	U, SV	U, SV	0000 0000 _H
STM_CMCON	STM Compare Match Control Register	F000 0238 _H	U, SV	U, SV	0000 0000 _H
STM_ICR	STM Interrupt Control Register	F000 023C _H	U, SV	U, SV	0000 0000 _H
STM_ISRR	STM Interrupt Set/Reset Register	F000 0240 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0244 _H - F000 02F4 _H	BE	BE	–
STM_SRC1	STM Service Request Control Register 1	F000 02F8 _H	U, SV	U, SV	0000 0000 _H
STM_SRC0	STM Service Request Control Register 0	F000 02FC _H	U, SV	U, SV	0000 0000 _H

15 Bus Monitor Unit (BMU)

This document describes the functionality of the Bus Monitor Unit (BMU). The BMU is primarily intended to be used in High Integrity Safety Applications. It provides the base hardware mechanisms to simplify the monitoring functions that safety applications need to implement. The core functionality of the BMU consists of logging the peripheral bus write activity. The logged information is stored in a local buffer managed as a cyclic buffer. In non-safety applications the BMU can be used as a PCP data memory extension. The BMU operates as a standard FPI bus slave peripheral and is fully controlled through a set of configuration and control registers. Additionally a dedicated slave interface enables burst accesses to the logged information.

This chapter is structured as follows:

- BMU Features (see [Section 15.2](#))
- An operational overview of the BMU Module (see [Section 15.3](#))
- Functional description of the BMU Module (see [Section 15.4](#))
- Interfaces of the BMU Module (see [Section 15.5](#))
- Description of the BMU Module registers (see [Section 15.6](#))

15.1 Related documentation

Input documents

- [D1] PRO-SIL Safety Concept for Microcontrollers

Related standards and norms

- [S1] IEC61508 standard. Functional safety of electrical/electronic/programmable electronic safety-related systems Parts 2,7.
- [S2] ISO26262 standard. Road vehicles - Functional safety - Part 5: Product development: hardware level

15.2 BMU Features

The BMU implements the following features:

- Fully synchronous module running at the Peripheral Bus clock frequency
- Implements a standard interrupt service node connecting to the TriCore and PCP interrupt busses.
 - Every internal interrupt source can be identified by a dedicated status flag, cleared by software only. New interrupt events with an active status flag do not lead to a new interrupt.
- Logs write transactions to software selectable peripheral address space
 - Uses the System-on-chip Address decoders select lines to qualify target peripherals (no internal address space decoding)
- Implements a Bus Transaction Fifo (BTF) that can be accessed via the FPI slave interface using BTR2, BTR4 or BTR8 FPI read bursts. The size of the BTF can be configured on a product basis. It must be a power of two in size.
 - The BTF entries are protected by Error Correction Codes (ECC) with single-bit error correction and double-bit error detection capability (SECDED) covering the data field.
 - The BTF is accessed as a cyclic buffer with automatic wrap around support. The BTF write and read pointers are controlled by Hardware.
- The BTF entries are made of the following FPI information:
 - FPI_A[27:2] address bits of the FPI transaction.
 - FPI_SVM FPI supervisor mode indication
 - FPI_TAG[3:0] FPI TAG, identifies the FPI bus master
 - FPI_STATUS Transaction completion status. This is not an FPI signal
 - FPI_D[31:0] FPI write data
- Fifo Handler that monitors the fullness of the BTF:
 - implements a configurable threshold register to early detect fullness threshold.
 - detects and prevents overruns and underruns (configurable).
- The BTF can be used as a standard memory mapped SRAM in non-safety applications. The SRAM can only be accessed using BTR2, BTR4 or BTR8 FPI bursts.

15.3 Operational overview

15.3.1 Microcontroller Monitoring Framework

The BMU is a component of the PRO-SIL™ Monitoring Framework that enables to simplify the overall software monitoring requirements a safety application must fulfil. Two practical use cases are presented that directly take benefit of the BMU:

- Break-After-Make flow
- Detection of illegal access to safety-related Configuration and Status Registers (CSFR)

Break-After-Make use case

In a single processing channel (a microcontroller without hardware redundancy at the application level) there are two common architectures dealing with the detection of failures at the execution level:

- two processors running in static lockstep or loosely coupled lockstep mode, executing the same safety code and comparing the results in a near cycle accurate fashion. Any discrepancy between the master CPU and the checker CPU caused by any soft or hardware fault is captured by an independent compare unit. The checker CPU does not produce any data to the peripherals nor to the storage elements (SRAMs). The lockstep flow is presented in [Figure 15-1 “Break-After-Make concept” on Page 15-5](#) (left side).
- a single processor runs sequentially two redundant tasks. The redundant tasks can be implemented with diversity. There is a control task (or control execution thread) that executes and commits its results to the peripherals. The results from the control task need to be saved in order to be checked at a later time. The monitor task (or monitor execution thread) is then scheduled and produces an alternate set of data. The results of both tasks/threads are gathered and compared by an hardware unit independent to the processor. The control flow is presented in [Figure 15-1 “Break-After-Make concept” on Page 15-5](#) (right side). This is the basic scheme used in the PRO-SIL™ safety concept. The combination of the BMU hardware and the BMU driver running on the PCP provide a generic mechanism that can be used by safety applications to monitor specific data flows to safety-relevant peripherals. The BMU software driver specification is not in the scope of this document.

Bus Monitor Unit (BMU)

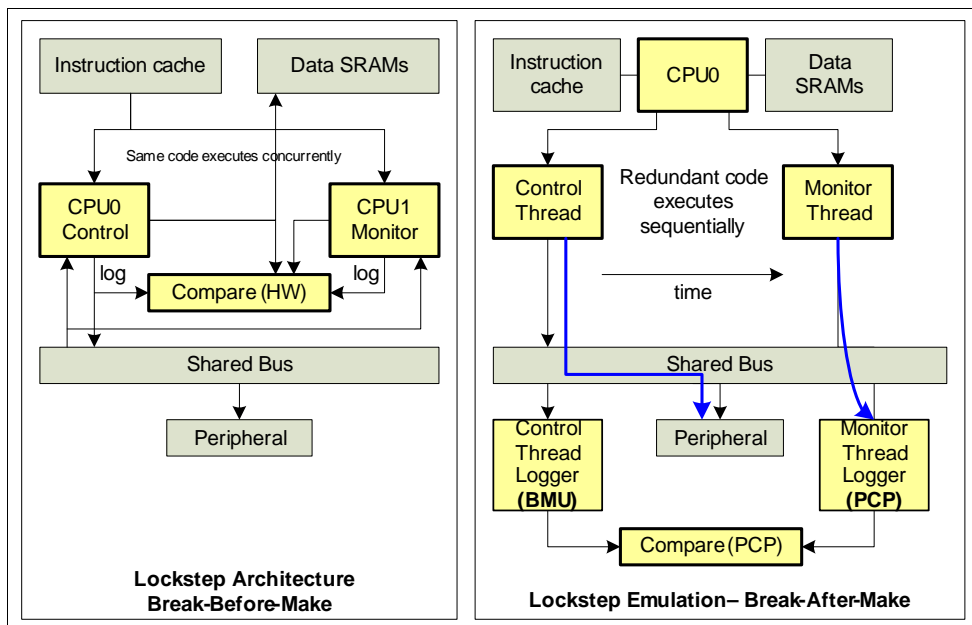


Figure 15-1 Break-After-Make concept

Bus Monitor Unit (BMU)

15.3.2 Bus Monitor Unit Overview

The BMU is a standard FPI slave module that implements a FPI slave interface and a Bus Peripheral Interface (BPI) compliant with the FPI bus architecture. The BMU is not FPI master capable. The BMU is fully synchronous with the FPI bus clock and runs with a 1:1 clock ratio. It does not implement a fractional divider

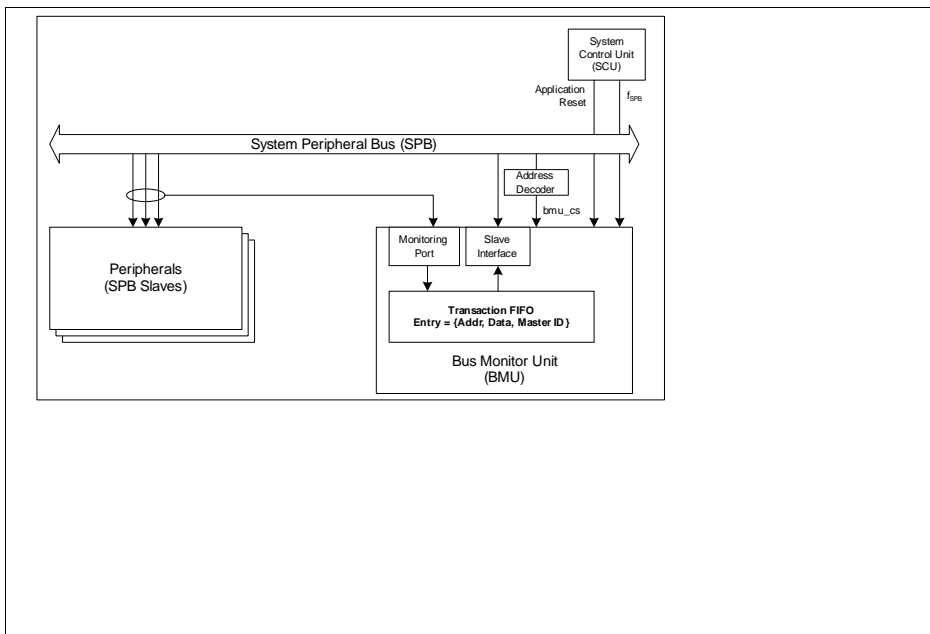


Figure 15-2 BMU overview

In addition to the standard FPI connectivity, the BMU also receives the individual peripheral select signals decoded by the address decoders. **The granularity of each select line is not a peripheral but a FPI region that may include several peripherals.** Each decoded region provides a FPI_ACK[1:0] signal that indicates the completion status of each individual data phase. The FPI_ACK[1:0] of the FPI regions listed in [Table 15-4 “Identification of FPI Regions” on Page 15-22](#) are required by the BMU to determine if write transactions have been normally terminated or not.

Bus Monitor Unit (BMU)

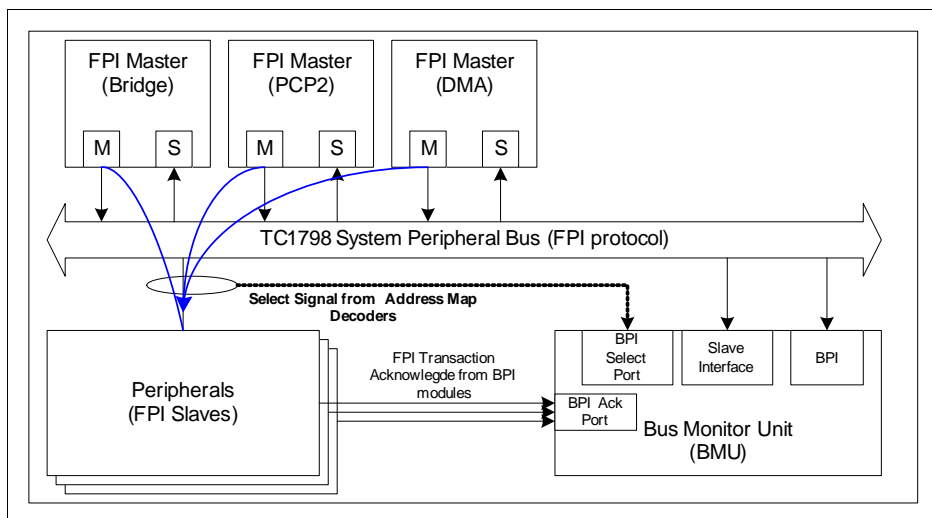


Figure 15-3 BMU operation in TC1728

In a typical microcontroller architecture, the write accesses to the peripherals can be directly controlled by the TriCore CPU or via DMA engines and possibly by the Peripheral Control Processor (PCP).

Bus Monitor Unit (BMU)

15.4 BMU Functional Description

15.4.1 BMU Microarchitecture

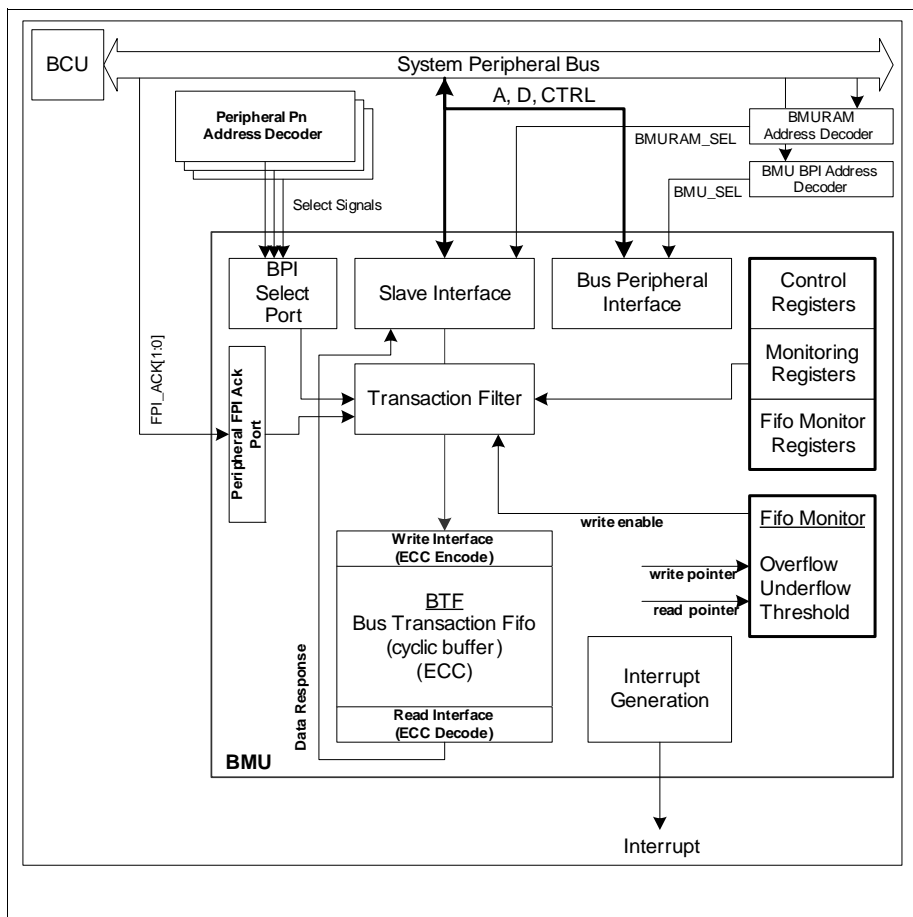


Figure 15-4 BMU Microarchitecture

Bus Monitor Unit (BMU)

The BMU is made of the following functions as represented in [Figure 15-4 “BMU Microarchitecture” on Page 15-8](#):

- a FPI Bus Peripheral Interface (BPI) that allows software to control the features of the BMU and read status information.
- a cyclic buffer called the Bus Transaction Fifo (BTF) where the selected write transaction are stored.
- a Fifo Monitor that monitors the distance between the BTF write and read pointers. The Fifo Monitor is configured with a threshold register [FMTH](#) that enables the BMU to raise an interrupt if the threshold is reached.
- a FPI Slave Interface that provides the following functions:
 - filter write transactions taking place in the bus, and if all conditions are fulfilled write the information inside the BTF. The hardware is responsible for the write pointer wrap around conditions.
 - perform memory mapped read and write accesses to the BMU RAM. **This mode is the default one after power-on reset.** Refer to section [“Usage in non safety applications” on Page 15-20](#) for a description of this mode. The BMU RAM is intended to be use by the PCP processor.
 - perform FIFO-based accesses to the BTF to read the logged information. This mode should be enabled in the [CTL](#) register. In FIFO mode, the FPI_A[31:0] address information is not used to directly access an entry in the BTF. The internal read and write pointers are updated according to the size of the FPI bus burst transaction.
 - [Table 15-1 “FPI Access Modes to BMU FPI Slave Interface” on Page 15-10](#) provides the list of FPI transactions supported by the slave interface in the different modes.
- a Service Request Node that centralizes all internal interrupt sources and enables the BMU to directly send interrupt requests to the PCP or the TriCore CPUs.

Bus Monitor Unit (BMU)

Table 15-1 FPI Access Modes to BMU FPI Slave Interface

FPI Transaction FPI_OPC[3:0]		Transaction Logging in FIFO Mode	Transaction Support in FIFO Mode	Transaction Support in SRAM Mode
SDTB (8-bit single transfer)	Read	Not Applicable	No (Bus Error)	No (Bus Error)
	Write	Yes	No (Bus Error)	No (Bus Error)
SDTH (16-bit single transfer)	Read	Not Applicable	No (Bus Error)	No (Bus Error)
	Write	Yes	No (Bus Error)	No (Bus Error)
SDTW (32-bit single transfer)	Read	Not Applicable	No (Bus Error)	No (Bus Error)
	Write	Yes	No (Bus Error)	No (Bus Error)
BTR2 (2 transfers of 32-bit)	Read	Not Applicable	Yes	Yes
	Write	Yes	No (Bus Error)	Yes
BTR4 (4 transfers of 32-bit)	Read	Not Applicable	Yes	Yes
	Write	Yes	No (Bus Error)	Yes
BTR8 (8 transfers of 32-bit)	Read	Not Applicable	Yes	Yes
	Write	Yes	No (Bus Error)	Yes

*Note: Single transfer transactions (SDTB, SDTH, SDTW) part of a **Read-Modify-Write** are logged as well.*

Note: During any SDTB, SDTH single transfer transactions the whole 32-bit data bus is written. As the FPI opcode and the lower two bits of the FPI address are not logged, it is not possible to know which bytes were valid during the write. This is a limitation that should be considered by the data monitoring applications using the BMU.

15.4.2 Handling of FPI corner cases

There are specific situations that lead to exceptions with respect to the correct termination of a FPI write transaction, like: master aborts, slave retries, time-out,... The flag FPI_STATUS indicates if the write data phase has been normally completed (FPI_STATUS = 1) or not (FPI_STATUS = 0). In the case of an error there is no additional information that defines the nature of the error.

A Data Phase is completed when the target BPI interface issues a FPI_RDY=1; the signal FPI_ACK[1:0] provides additional information about the status of the completion. The BPI can insert wait states in the FPI bus by delaying the assertion of FPI_RDY. The following situations lead to the detection of an error condition indicating that a write data phase has been either aborted by the master or not accepted by the slave:

- The FPI Master FPI_ABORT_N is asserted during the data phase wait states or coincides with the FPI_RDY assertion by the BPI. If this happens during a burst all subsequent data phases are aborted.
- The BPI issues FPI_RDY=1 together with FPI_ACK=2'b11 (ERR).
- The BPI issues FPI_RDY=1 together with FPI_ACK=2'b10 (RTY).
- In the occurrence of a timeout, FPI_TOUT is issued by the Bus Control Unit during one clock cycle and the selected slave must terminate the data transfer with an error condition (FPI_RDY=1 with FPI_ACK=2'b11) in the following cycle. Therefore the FPI_TOUT does not need to be handled by BMU.

Please refer to the FPI specification version V4.2, 2003-11 chapter 6: FPI Bus Termination conditions for a detailed overview.

Bus Monitor Unit (BMU)

15.4.3 Bus Transaction Table

The **Figure 15-5 “Bus Transaction Information” on Page 15-12** defines how each phase of a FPI transaction is written into the BTF. The set of information bits related to a write data is written as a 64-bit value into the BTF. A BTF word or entry is made of:

- the write data itself, referred as the BTF[DataPhase] field and
- the BTF[Control] field

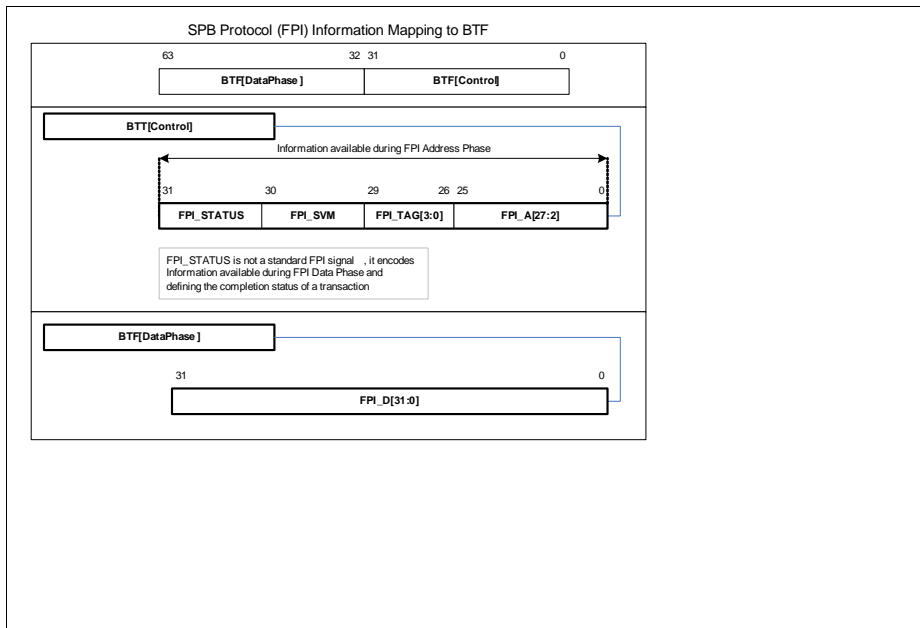


Figure 15-5 Bus Transaction Information

The logging of burst transactions follows the same rules as for single write transactions: the FPI master provides for each data phase the corresponding address information. Examples with single write and burst are given in **Figure 15-6 “Logging information for FPI burst transactions” on Page 15-13**. The address information shown is directly the information present in the FPI bus.

Bus Monitor Unit (BMU)

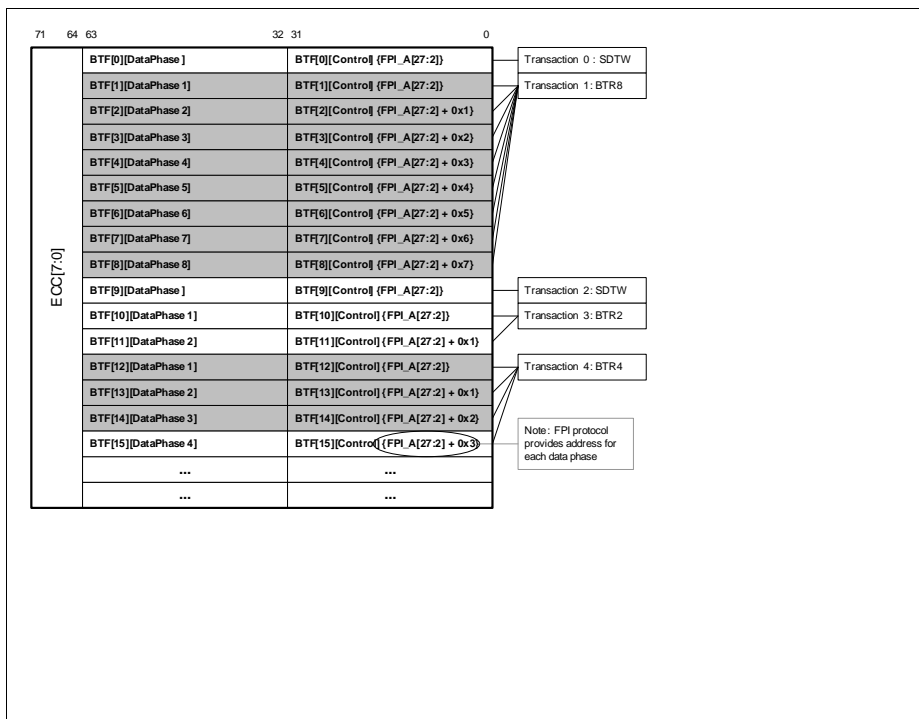


Figure 15-6 Logging information for FPI burst transactions

15.4.4 Write Operation and Fifo Structure

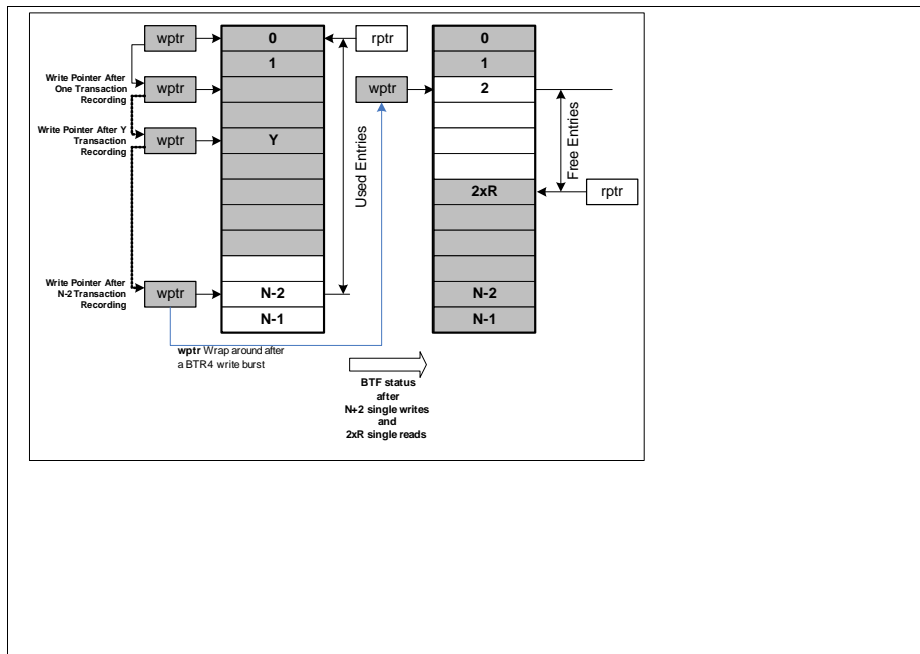


Figure 15-7 BTF Cyclic Buffer Write Pointer Management

The write pointer is controlled by the BMU internal logic. If N is the number of words in the BTF (corresponding a maximum of N single write FPI transactions), when the write pointer reaches the word at position N-1 and a new single write FPI transaction is logged, the new position of the write pointer is 0. If in the meantime no read pointer update took place, the BTF is declared full.

15.4.5 Read Operation and Fifo Structure

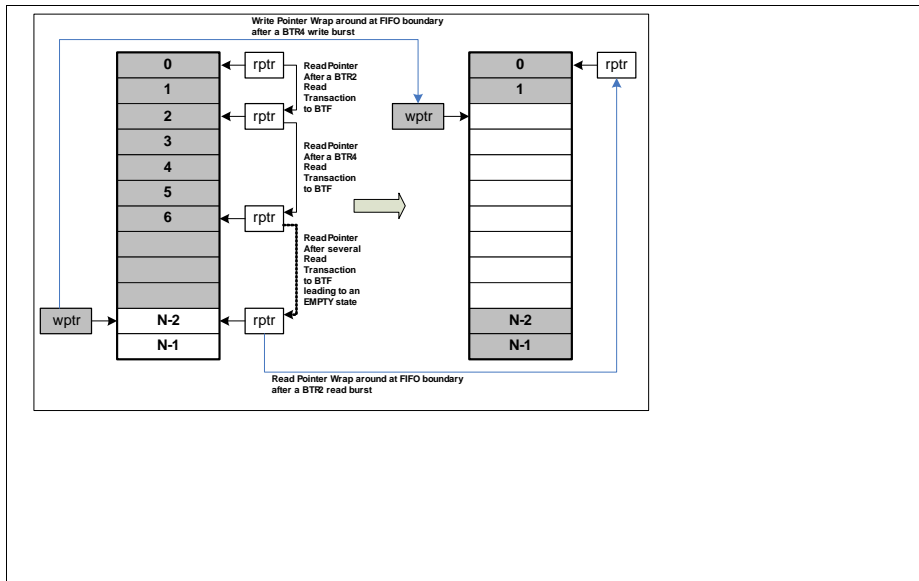


Figure 15-8 BTF Cyclic Buffer Read Pointer Management

The read pointer (rptr in [Figure 15-7](#)) is also only controlled by hardware. **Depending on the FPI transaction size given by the FPI_OPC[3:0] opcode the read pointer is incremented accordingly.** A BTR2 read burst will increment the read pointer by 2 and so on. The FPI_A[31:0] address information is not used to directly access an entry in the BTF. The FPI_A[31:0] shall point to the base address of the BTF SRAM, otherwise a Bus Error will be returned with the first read data terminating the FPI burst.

Having the read pointer controlled by hardware enables to free the fifo space in a faster way, increasing the logging performance.

Bus Monitor Unit (BMU)

15.4.6 Fullness Monitoring

The [Figure 15-9 “BTF Fullness Monitoring” on Page 15-16](#) shows how the fullness is calculated in order to check if the fullness threshold defined by the register **FMTH** is reached or not. The BufferSize is a constant value defining the number of 64-bit words of the internal SRAM building the Bus Transaction Fifo.

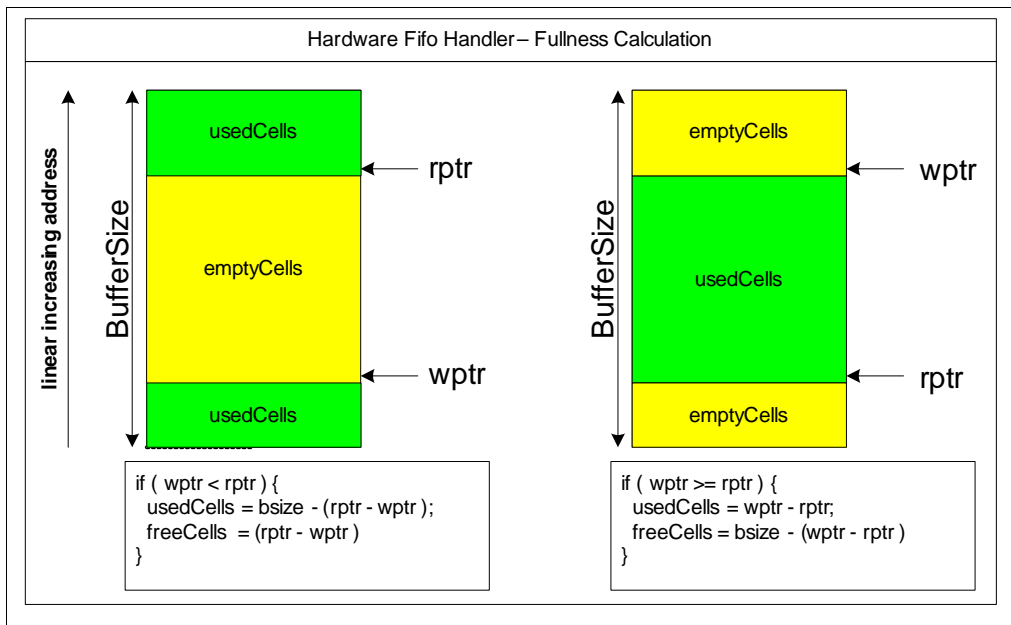


Figure 15-9 BTF Fullness Monitoring

The fullness information is computed dynamically based on the contents of the read and write pointers and the corresponding events (write pulse/read pulse indicators). For convenience the fullness information (see [Figure 15-9 “BTF Fullness Monitoring” on Page 15-16](#)) is made visible to software via the **FULLNESS** registers. If a write event takes place and the next position of the write pointer is identical to the read pointer and if no read event takes place the BTF is declared **FULL**. If a read event only takes place and the value of the read pointer equals the value of the write pointer the BTF is declared **EMPTY**.

Bus Monitor Unit (BMU)

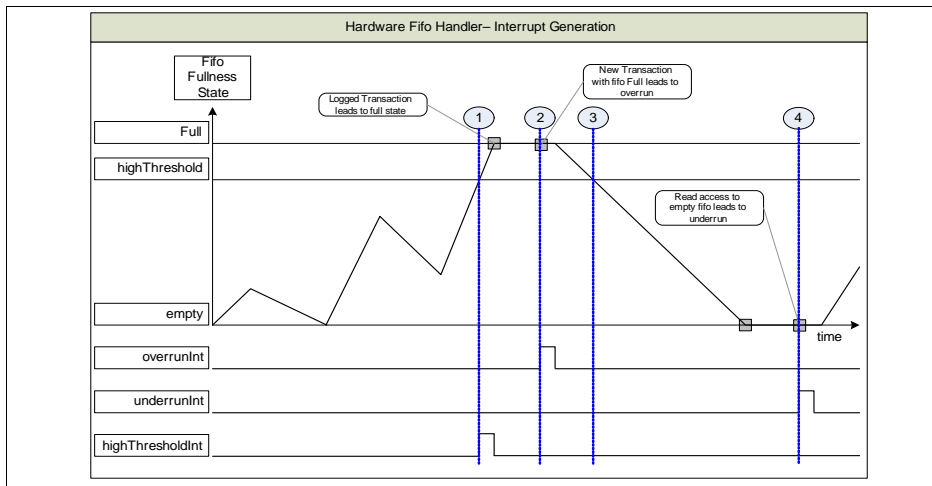


Figure 15-10 BTF Fullness Monitoring - Threshold Interrupts

Figure 15-10 “BTF Fullness Monitoring - Threshold Interrupts” on Page 15-17 shows the fullness conditions that can be reported by the Fifo Monitor:

- [1] The fullness reaches or crosses the High Threshold level as configured in the register **FMTH**. If the corresponding bit is set in the **FMCTL** register an interrupt is triggered to the Interrupt Service Request Node and the corresponding flag is set in the **FMSTS** register. The flag is set regardless of the interrupt generation mode.
- [2] The BTF is full. A new write access is detected leading to an overrun condition. The interrupt reporting is similar to the one described for the case [1]. The write pointer is not incremented and the FPI transaction information is not logged. If the overrun situation occurs during a burst transaction, only the data phases that can not lead to the overrun condition are logged.
- [3] Reaching again the High Threshold value while the fullness is decreasing does not trigger an interrupt.
- [4] The fifo (BTF) is empty, a read takes place leading to an underrun condition. The interrupt reporting is similar to the one described for the case [1]. The read pointer is not incremented. If the underrun condition occurs during a read burst, a data phase error acknowledge will be issued by the BMU. The software handling the BMU should take care to avoid such conditions. However errors taking place in the system caused by soft errors (single event upsets for instance), may lead to such condition.

15.4.7 Error Correction Code (ECC)

The BMU SRAM is protected by information redundancy based on Error Correction Codes with a Hamming Distance of 4. The ECC information redundancy applies to the data bits of each BMU SRAM word. **CTL**

Limitations with ECC accesses

When the ECC mapping is enabled the memory access limitations described in **“Usage in non safety applications” on Page 15-20** apply as well. Therefore the ECC information can only be accessed using FPI BTR2 bursts as described in **Figure 15-11 “ECC information mapping into FPI BTR2 transactions” on Page 15-18**. The burst base address is 8-byte aligned (FPI_A[2:0] = 3'b000).

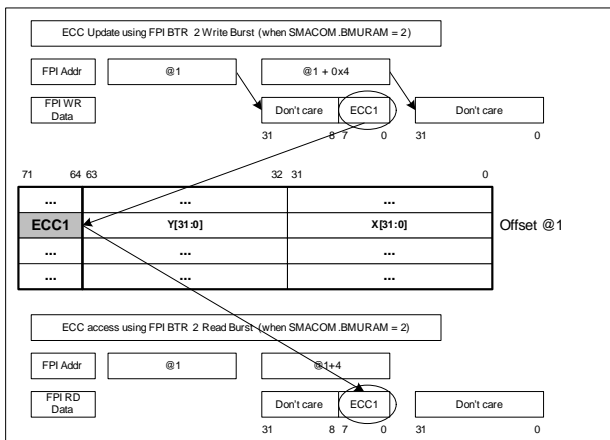


Figure 15-11 ECC information mapping into FPI BTR2 transactions

Memory Integrity Error Control

A pair of architecturally visible registers (MIECON, MIECON2) are included to allow software to control the memory integrity error detection / correction mechanisms. The existence of the MIECON and MIECON2 registers is architecturally defined. However, the fields within these registers are implementation specific. The behavior of MIECON2

Bus Monitor Unit (BMU)

is configured according to the “secwen_i” input to the BMU. “secwen_i” is connected to a Product Configuration bit from the SCU, and is locked after execution of Startup Software (SSW). With “secwen_i” not asserted, and the MIECON2 bits previously set by SSW, single-bit correction of memory integrity errors is transparent to software and may not be disabled or detected.

When “secwen_i” is asserted, MIECON2 may only be written in supervisor mode and is ENDINIT protected. MIECON2 reads return the register contents. When “secwen_i” is not asserted accesses to MIECON2 will generate an FPI error acknowledge.

The DED_EN and SEC_EN bits (located **MIECON** and **MIECON2** respectively) and the appropriate SMACON field settings interact to perform the following general function:

Table 15-2 Memory integrity error modes

SEC_EN	DED_EN	SMACON	Description
X	X	01 _B or 10 _B	Array Mapping All single and double-bit memory integrity errors ignored.
0	0	00 _B or 11 _B	No Memory Integrity Handling All single and double-bit memory integrity errors ignored.
0	1	00 _B or 11 _B	Error Detection Mode Single and double-bit errors treated as un-correctable errors. In this mode the BMU_ECC_ERROR_O is asserted every time a single or double bit error is detected.
1	0	00 _B or 11 _B	SEC Only Mode Single-bit errors corrected by ECC, double-bit errors ignored. BMU_ECC_ERROR_O is never asserted in this mode
1	1	00 _B or 11 _B	SECDED Mode Single-bit errors corrected by ECC, double-bit errors treated as un-correctable errors. BMU_ECC_ERROR_O is asserted every time a double bit error is detected.

Bus Monitor Unit (BMU)

15.4.8 Usage in non safety applications

When the BMU is not used in a safety application the BTF fifo can be accessed as a standard linear memory through the BMU slave interface using BTR2, BTR4 or BTR8 FPI transactions. This mode of operation is controlled by the **CTL.MODE** field. Single word or sub word (8/16-bit) accesses are not allowed; such requests will result in a Bus Error. **The start address of the FPI burst transactions is aligned with the size of the burst.**

Table 15-3 SRAM address map

Module	Base address	End address	Note
Bus Monitoring Unit	F032 4000 _H	F032 4FFF _H	BMURAM

Figure 15-12 “Mapping between FPI Burst transaction and SRAM contents” on Page 15-20 shows how the FPI bus 32-bit data phases are mapped into the 64-bit word of the BMU SRAM. An example with read and write bursts is given.

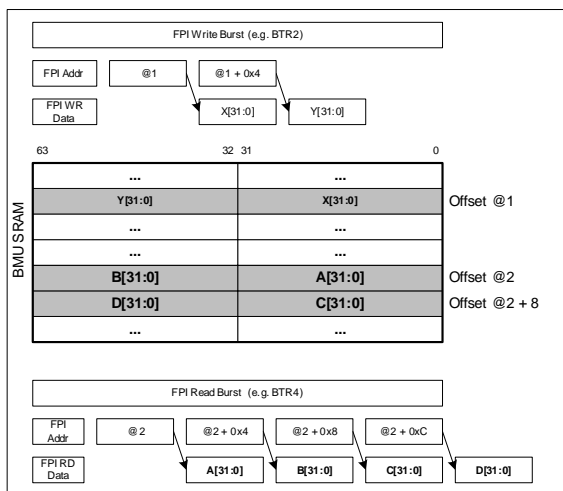


Figure 15-12 Mapping between FPI Burst transaction and SRAM contents

15.4.9 BMU interrupts

Interrupt generation rules

- Each interrupt source has a dedicated status bit that indicates if an interrupt has been issued or not.
- A status flag shall be cleared by software by writing a 1 to the corresponding bit position.
- If a status flag is set and a new hardware condition leading to an interrupt occurs, no new interrupt is generated. **If a software access to clear the interrupt status bit takes place and in the same cycle the hardware wants to set the bit, the hardware condition wins the arbitration.**

15.4.10 Peripheral Monitoring Selection

The **Table 15-4** shows the list of peripherals present in the TC1728 device together with an identifier. The FPI bus infrastructure provides address decoders that are configured to generate chip select signals. The chip select signals are connected to the standard BPI modules or to the FPI Slave Interfaces or directly to custom FPI interfaces (some FPI peripherals have neither a BPI nor a FPI slave interface). Each select line identifies a FPI region that corresponds to the FPI regions defined in the **PSET0** and **PSET1** registers. Behind a decoded FPI region there may be multiple peripherals. This situation is reflected in **Table 15-4**. Peripherals that belong to the DMA subsystem (FPI extension) will all use the DMA identifier. Only the FPI write transactions enabled by **PSET0** and **PSET1** will be stored in the BMU.

Table 15-4 Identification of FPI Regions

Unit	FPI Region Identifier
System Peripheral Bus Control Unit (SBCU)	0
System Timer (STM)	1
System Control Unit (SCU) and Watchdog Timer (WDT)	2
MicroSecond Bus Controller 0 (MSC0)	3
Async./Sync. Serial Interface 0 (ASC0)	5
Async./Sync. Serial Interface 1 (ASC1)	5
Port Group 0	6
Port Group 1	7
Port Group 2	8
General Purpose Timer Array (GPTA0)	10
Capture/Compare Unit 6 0 (CCU60)	11
Capture/Compare Unit 6 1 (CCU61)	11
General Purpose Timer 12 0 (GPT120)	13
General Purpose Timer 12 1 (GPT121)	14
Direct Memory Access Controller (DMA)	16
On-Chip Debug Support (Cerberus)	17 Belongs to DMA region 2
Micro Link Interface 0 (MLI0)	17 Belongs to DMA region 2
Memory Checker (MCHK)	17 Belongs to DMA region 2

Bus Monitor Unit (BMU)

Table 15-4 Identification of FPI Regions

Unit		FPI Region Identifier
MLI0 Small Transfer Windows		17 Belongs to DMA region 2
MLI0 Large Transfer Windows		17 Belongs to DMA region 2
MultiCAN Controller (CAN)		18
FlexRay™ Protocol Controller (E-Ray)		19
PCP	PCP Registers	20
	PCP Data Memory (PRAM)	20
	PCP Code Memory (PCODE)	20
Fast Analog-to-Digital Converter (FADC)		21
Analog-to-Digital Converter 0 (ADC0)		22
Analog-to-Digital Converter 1 (ADC1)		22
Synchronous Serial Interface 0 (SSC0)		23
Synchronous Serial Interface 1 (SSC1)		24
Synchronous Serial Interface 2 (SSC2)		25
Synchronous Serial Interface 3 (SSC3)		26
Flexible CRC Engine (FCE)		31
Peripheral Bus Monitor Registers (BMU)		33
Peripheral Bus Monitor Memory (BMURAM)		Not Logged

Bus Monitor Unit (BMU)

15.5 Interfaces of the BMU Module

This section only describes the signals that do not belong to the system-on-chip standard interfaces (Interrupt Bus, FPI Bus).

Table 15-5 Generic BMU Digital Connections¹⁾

Signal	from/to Module	I/O to BMU	Reset Value
EINIT	SCU (System Control Unit)	I	
FPI_CLK_EN	SCU (System Control Unit)	I	
OCDS_P_SUSPEND	On Chip Debug	I	
SLEEP_N	SCU (System Control Unit)	I	
SECWEN	SCU (System Control Unit) Connects to SCU PRDCFG2.SENAV Single Error Correction Availability Control	I	
BMU_ECC_ERROR	SCU (System Control Unit) un-correctable ECC error detected output	O	0
BMU_SPB_SEL[63:0]	System Peripheral Bus (SPB) Address Decoders	I	
BMU_SPB_ACK[1:0]	Global FPI_ACK[1:0] generated by the FPI bus	I	

1) The postfix indicating the direction of the signal is not part of the signal name specification as it depends on the naming conventions used by the development flow. The I/O column indicated the direction of the signal. When the signal is specific to the BMU module it gets "BMU_" as prefix.

Notes

- FPI_CLK_EN is the FPI clock signal.
- OCDS_P_SUSPEND: the suspend feature is not supported by BMU. The OCDS_P_SUSPEND signal is not used.
- SLEEP_N is used to control the sleep mode. The sleep mode function is not supported by BMU, the SLEEP_N signal is not used.
- The FPI_ACK[1:0] signals from the FPI bus are ored together and sent to all masters (only the granted master interprets the FPI_ACK[1:0] contents). The BMU will see the global FPI_ACK[1:0] signal and not directly the individual FPI_ACK corresponding to a FPI region.
- The width of the BMU_SPB_SEL signal is set to 64 bits to make it independent from the peripheral configuration. The non-used upper bits of BMU_SPB_SEL must be set to the logic value LOW. The order of the select lines is given by [Table 15-4 "Identification of FPI Regions" on Page 15-22](#).

Bus Monitor Unit (BMU)

- The BMU_ECC_ERROR is an active HIGH signal that delivers a pulse of one FPI clock cycle duration. See **Table 15-2 “Memory integrity error modes”** on **Page 15-19** for the un-correctable modes.

Bus Monitor Unit (BMU)

15.6 BMU Module Registers

Figure 15-13 shows the BMU module register map.

Table 1-6 shows the BMU Address Space

Table 15-6 lists all registers implemented in the BMU.

BMU Address Map Overview

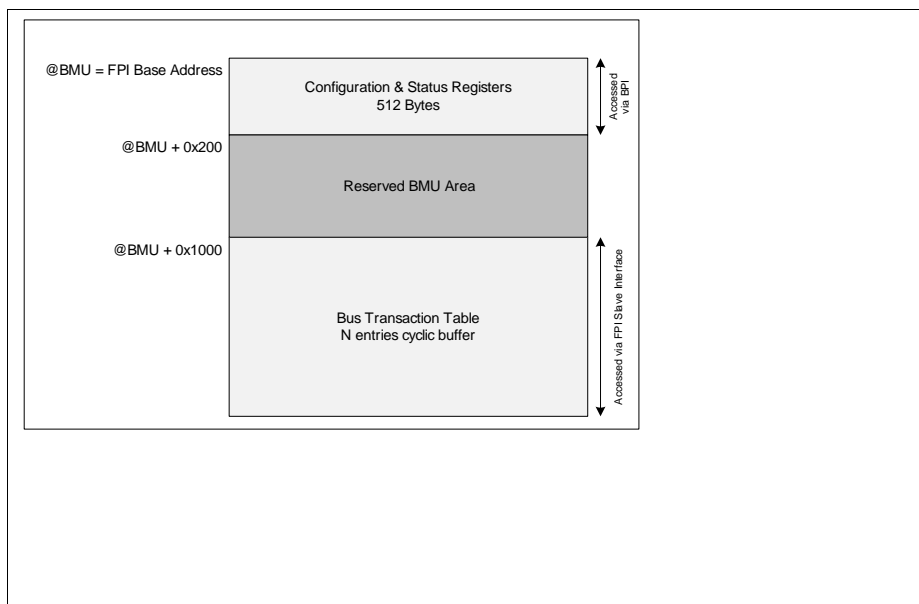


Figure 15-13 BMU Register Map

In TC1728 device the Bus Transaction Table is made of 1024 entries, where each entry is made of 64-bits. **Table 1-6** shows the base address of the addressable SRAM space when the access mode defined by the **CTL.MODE** configuration register is set to 0.

Module	Base Address	End Address	Note
BMU	F032 3000 _H	F032 31FF _H	Registers

Bus Monitor Unit (BMU)

Table 15-6 Registers Overview

Short Name	Description	Offset Addr	Access Mode		Reset Class	Description See
			Read	Write		
System Registers						
CLC	Clock Control Register	00 _H	U, SV	SV, E	3	Page 15-29
ID	Module Identifier	08 _H	U, SV	BE	3	Page 15-31
Global Control over Read access to Bus Transaction Table						
CTL	Transaction Filtering Control Register	20 _H	U, SV	SV, E	3	Page 15-32
PTR	BTF running pointers	24 _H	U, SV	BE	3	Page 15-33
FULLNESS	Fifo Fullness	28 _H	U, SV	BE	3	Page 15-34
Bus Logging Configuration Registers						
PSET0	Peripheral Set 0	30 _H	U, SV	SV, E	3	Page 15-35
PSET1	Peripheral Set 1	34 _H	U, SV	SV, E	3	Page 15-38
TID	Transaction ID Set 0	38 _H	U, SV	SV, E	3	Page 15-41
Fifo Monitoring Configuration and Status Registers						
FMCTL	Control Register	40 _H	U, SV	SV, E	3	Page 15-42
FMSTS	Status Register	44 _H	U, SV	U,SV	3	Page 15-42
FMTH	High Threshold Value	48 _H	U, SV	SV, E	3	Page 15-43
Control of ECC operation						
SMACON	Control of SIST Mode	50 _H	U, SV	SV, E	3	Page 15-45
MIECON	ECC modes control	54 _H	U, SV	SV, E	3	Page 15-46
MIECON2	ECC modes control	58 _H	U, SV	SV, E	3	Page 15-46
Interrupt System Registers						
SRC	Service Request Control	FC _H	U, SV	SV	3	Page 15-48

Access Mode Rules

The [Table 15-6 “Registers Overview” on Page 15-27](#) uses the standard access mode conventions.

- **E** indicates that an access is only possible if the **end of initialization** signal from the System Control Unit is active. In this case Supervisor Mode (SV) is also mandatory.
- When U, SV are both listed it means that a read or write access can be done either in user mode (U) or supervisor mode (V).

Bus Monitor Unit (BMU)

- BE stands for Bus Error, NSC stands for No Special Condition

*Note: Configuration registers that determine the behavior of the BMU are protected by the end of init protection mechanism. They are intended to be only configured once during the initial system startup phase. In safety-related applications the configuration is controlled by the Safety Driver. Registers that need to be updated by the application (run-time interaction) are only protected by supervisor mode: applies to **FMSTS**.*

Register access constraints

The registers that control the operation of the BMU are assumed to be static, they are configured by the safety driver according to the requirements of the safety application(s) during the initial microcontroller configuration. Exceptions will be documented in each register sub-chapter. As indication the list of registers that are assumed to be static are:

- **PSET0, PSET1, TID¹⁾, FMCTL, FMTH**
- **CTL** is only allowed to be change if SIST mode is used during run-time for ECC checks. The necessity to do ECC checks during run-time will depend on the safety monitoring concept.

1) Currently **TID** is a read-only register, this may change in future enhancements of the BMU.

Bus Monitor Unit (BMU)

15.6.1 System Registers description

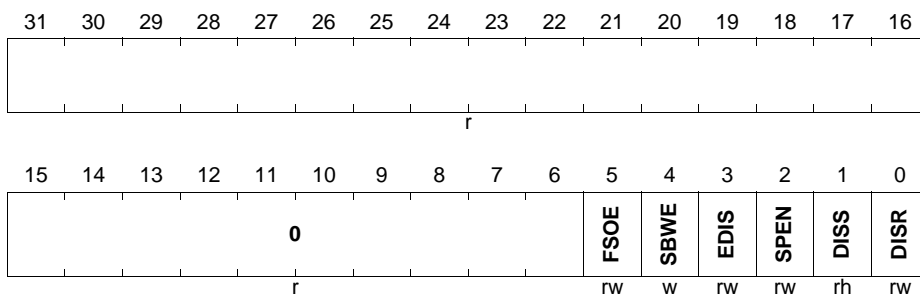
BMU Module Clock Control Register.

CLC

Control Clock Register

(00_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DISR	0	rw	Module Disable Bit Request Used for enable/disable control of the module 0 _B Module disable is not requested 1 _B Module disable is requested
DISS	1	rh	Module Disable Bit Status Bit indicates the current status of the module 0 _B Module is enabled 1 _B Module is disabled
0	[31:2]	r	Reserved Read as 0; write has no effect.

Note: The BMU does not implement a fractional divider.

Note: Sleep and Suspend modes are not supported by BMU, therefore the bit fields controlling those features are not present in the CLC register.

Note: The BMU can be disabled. When the disable state is requested all pending transactions running on the FPI slave interface must be completed before the disabled state is entered. The CLC Register Module Disable Bit Status BMU_CLC.DISS indicates whether the module is currently disabled (DISS = 1). Any attempt to write any of the BPI writable registers with the exception of the CLC Register will generate a bus error. A read operation of BPI registers is allowed and does not generate a bus error. As long as the BMU is disabled no logging is possible (including the write access to the BMU_CLC register to enable again the

Bus Monitor Unit (BMU)

BMU). Logging is possible after software writes 0 to DISR and the DISS field value indicates the enabled state.

Bus Monitor Unit (BMU)

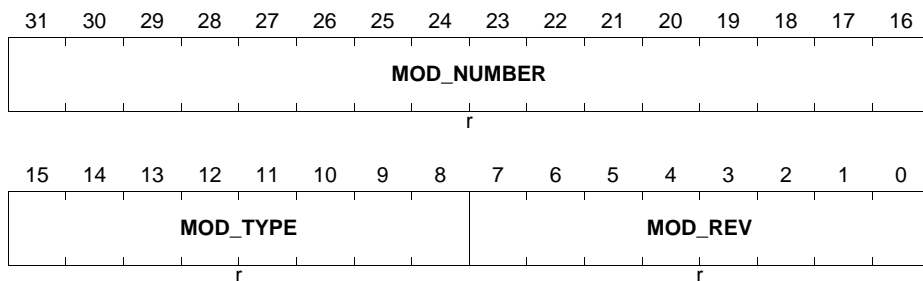
BMU Module Identification Register.

ID

Module Identification Register

(08_H)

Reset Value: 0089 C001_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The bit field is set to C0 _H which defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. The value for the BMU module is 0089 _H .

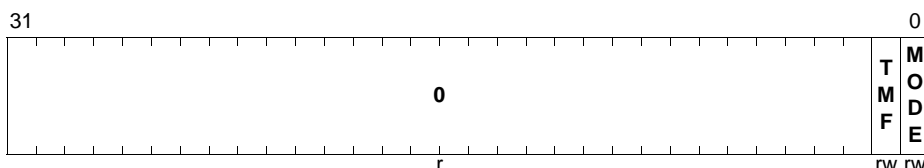
Bus Monitor Unit (BMU)

15.6.2 BMU Control/Status Registers

CTL

Transaction Filtering Control

(20_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
MODE	0	rw	Access Mode 0 _B The BTF is accessed in linear mode as a standard memory mapped SRAM 1 _B The BTF is used in FIFO Mode enabling to log the write transaction to the regions selected in PSET0 and PSET1 registers.
TMF	1	rw	Transaction Master Filtering In FIFO mode, this field enables an additional logging mechanism controlled by the master identifier of a FPI write transaction. 0 _B Logging controlled by the transaction master identifier disabled. 1 _B Logging controlled by the transaction master identifier Enabled.
0	[31:2]	r	reserved bit fields. A write has no effect. Returns 0s on read.

CTL defines the access mode to the internal SRAM and enables to control additional logging mechanisms based on the initiator of the transaction. The operation mode is statically defined for the whole run-time, changes of operating mode are to be avoided.

In the event the BMU is configured in FIFO mode (CTL.MODE = 1) then the CTL register should be polled to confirm the FIFO mode is set before any write transaction on the FPI bus is logged.

However when the BMU is configured in FIFO mode, it may be necessary to switch to SRAM mode if run time diagnostics of the ECC logic is required. It must be ensured at system level that during the time the diagnostics will be performed, the safety application

Bus Monitor Unit (BMU)

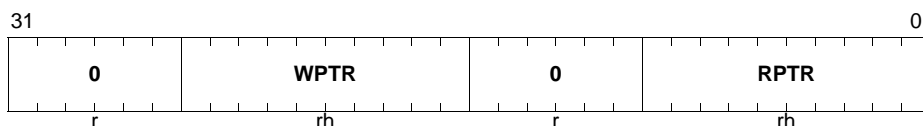
will not be able to use the logging capability of the BMU. If the BMU is intended to be used in SRAM mode only, it is not allowed to switch during run-time to FIFO mode.

In the FPI bus protocol the initiator (also called the master) is uniquely identified by the FPI Transaction Identifier made of 4-bits. When the MODE field and TMF field are both set to 1, the BMU monitors the master identifier of every FPI write transaction. When the master identifier matches with the value(s) present in the **TID** register, the address information of every address phase of the transaction is logged into the BMU FIFO. The logging based on the master identifier monitoring has precedence over the logging based on the FPI region monitoring

PTR

Pointer Information for Bus Transaction Fifo

(24_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RPTR	[9:0]	rh	Read Pointer for a 1024 entry SRAM Indicates the current position of the read pointer. A write to this field has no hardware effect. For debug purposes only.
WPTR	[25:16]	rh	Write Pointer for a 1024 entry SRAM Indicates the current position of the write pointer. A write to this field has no hardware effect. For debug purposes only.
0	[15:10], [31:26]	r	reserved bit fields. A write has no effect. Returns 0s on read.

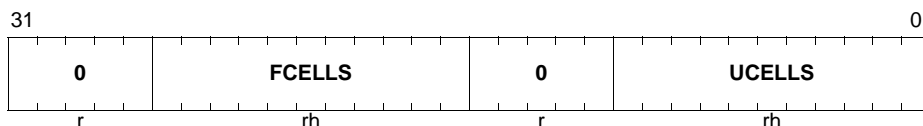
PTR is to be used for debug or verification purposes.

Bus Monitor Unit (BMU)

FULLNESS

Fullness Information for Bus Transaction Fifo

(28_H)

Reset Value: 0400 0000_H


Field	Bits	Type	Description
UCELLS	[10:0]	rh	Number of valid (used) entries in the BTF Fullness of the BTF as a number of words. UCELLS value ranges from 0 to N, where N is the number of fifo entries. UCELLS = N represents a full fifo. Writing to this field has no effect.
FCELLS	[26:16]	rh	Number of free entries in the BTF Writing to this field has no effect. FCELLS value ranges from 0 to N, where N is the number of fifo entries. FCELLS = N represents an empty fifo. Writing to this field has no effect.
0	[15:11], [31:27]	r	reserved bit fields. A write has no effect. Returns 0s on read.

The **UCELLS** and **FCELLS** information can be used to schedule the number of consecutive burst reads that can be made to read the available information from the BTF.

Bus Monitor Unit (BMU)

15.6.3 BMU: Bus Logging Configuration Registers

PSET0

Peripheral Set 0 Configuration

(30_H)

Reset Value: 0000 0000_H

31

0

FPI_SEL31	FPI_SEL30	FPI_SEL29	FPI_SEL28	FPI_SEL27	FPI_SEL26	FPI_SEL25	FPI_SEL24	FPI_SEL23	FPI_SEL22	FPI_SEL21	FPI_SEL20	FPI_SEL19	FPI_SEL18	FPI_SEL17	FPI_SEL16	FPI_SEL15	FPI_SEL14	FPI_SEL13	FPI_SEL12	FPI_SEL11	FPI_SEL10	FPI_SEL9	FPI_SEL8	FPI_SEL7	FPI_SEL6	FPI_SEL5	FPI_SEL4	FPI_SEL3	FPI_SEL2	FPI_SEL1	FPI_SEL0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
FPI_SEL0	0	rw	Select Bit for FPI Region 0 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL1	1	rw	Select Bit for FPI Region 1 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL2	2	rw	Select Bit for FPI Region 2 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL3	3	rw	Select Bit for FPI Region 3 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL4	4	rw	Select Bit for FPI Region 4 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL5	5	rw	Select Bit for FPI Region 5 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL6	6	rw	Select Bit for FPI Region 6 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL7	7	rw	Select Bit for FPI Region 7 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

Field	Bits	Type	Description
FPI_SEL8	8	rw	Select Bit for FPI Region 8 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL9	9	rw	Select Bit for FPI Region 9 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL10	10	rw	Select Bit for FPI Region 10 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL11	11	rw	Select Bit for FPI Region 11 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL12	12	rw	Select Bit for FPI Region 12 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL13	13	rw	Select Bit for FPI Region 13 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL14	14	rw	Select Bit for FPI Region 14 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL15	15	rw	Select Bit for FPI Region 15 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL16	16	rw	Select Bit for FPI Region 16 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL17	17	rw	Select Bit for FPI Region 17 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL18	18	rw	Select Bit for FPI Region 18 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL19	19	rw	Select Bit for FPI Region 19 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

Field	Bits	Type	Description
FPI_SEL20	20	rw	Select Bit for FPI Region 20 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL21	21	rw	Select Bit for FPI Region 21 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL22	22	rw	Select Bit for FPI Region 22 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL23	23	rw	Select Bit for FPI Region 23 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL24	24	rw	Select Bit for FPI Region 24 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL25	25	rw	Select Bit for FPI Region 25 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL26	26	rw	Select Bit for FPI Region 26 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL27	27	rw	Select Bit for FPI Region 27 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL28	28	rw	Select Bit for FPI Region 28 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL29	29	rw	Select Bit for FPI Region 29 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL30	30	rw	Select Bit for FPI Region 30 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL31	31	rw	Select Bit for FPI Region 31 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

PSET1

Peripheral Set 1 Configuration

(34_H)

Reset Value: 0000 0000_H

31

0

FPI_SEL63	rw
FPI_SEL62	rw
FPI_SEL61	rw
FPI_SEL60	rw
FPI_SEL59	rw
FPI_SEL58	rw
FPI_SEL57	rw
FPI_SEL56	rw
FPI_SEL55	rw
FPI_SEL54	rw
FPI_SEL53	rw
FPI_SEL52	rw
FPI_SEL51	rw
FPI_SEL50	rw
FPI_SEL49	rw
FPI_SEL48	rw
FPI_SEL47	rw
FPI_SEL46	rw
FPI_SEL45	rw
FPI_SEL44	rw
FPI_SEL43	rw
FPI_SEL42	rw
FPI_SEL41	rw
FPI_SEL40	rw
FPI_SEL39	rw
FPI_SEL38	rw
FPI_SEL37	rw
FPI_SEL36	rw
FPI_SEL35	rw
FPI_SEL34	rw
FPI_SEL33	rw
FPI_SEL32	rw

Field	Bits	Type	Description
FPI_SEL32	0	rw	Select Bit for FPI Region 32 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL33	1	rw	Select Bit for FPI Region 33 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL34	2	rw	Select Bit for FPI Region 34 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL35	3	rw	Select Bit for FPI Region 35 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL36	4	rw	Select Bit for FPI Region 36 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL37	5	rw	Select Bit for FPI Region 37 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL38	6	rw	Select Bit for FPI Region 38 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL39	7	rw	Select Bit for FPI Region 39 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

Field	Bits	Type	Description
FPI_SEL40	8	rw	Select Bit for FPI Region 40 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL41	9	rw	Select Bit for FPI Region 41 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL42	10	rw	Select Bit for FPI Region 42 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL43	11	rw	Select Bit for FPI Region 43 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL44	12	rw	Select Bit for FPI Region 44 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL45	13	rw	Select Bit for FPI Region 45 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL46	14	rw	Select Bit for FPI Region 46 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL47	15	rw	Select Bit for FPI Region 47 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL48	16	rw	Select Bit for FPI Region 48 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL49	17	rw	Select Bit for FPI Region 49 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL50	18	rw	Select Bit for FPI Region 50 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL51	19	rw	Select Bit for FPI Region 51 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

Field	Bits	Type	Description
FPI_SEL52	20	rw	Select Bit for FPI Region 52 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL53	21	rw	Select Bit for FPI Region 53 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL54	22	rw	Select Bit for FPI Region 54 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL55	23	rw	Select Bit for FPI Region 55 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL56	24	rw	Select Bit for FPI Region 56 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL57	25	rw	Select Bit for FPI Region 57 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL58	26	rw	Select Bit for FPI Region 58 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL59	27	rw	Select Bit for FPI Region 59 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL60	28	rw	Select Bit for FPI Region 60 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL61	29	rw	Select Bit for FPI Region 61 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL62	30	rw	Select Bit for FPI Region 62 0 _B Region Disabled 1 _B Region Enabled
FPI_SEL63	31	rw	Select Bit for FPI Region 63 0 _B Region Disabled 1 _B Region Enabled

Bus Monitor Unit (BMU)

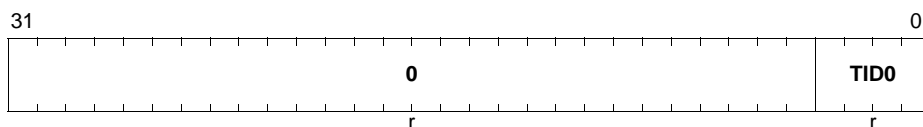
PSET0 and **PSET1** are used to control which FPI region is to be monitored by the BMU.

TID

FPI Transaction ID Set 0 Configuration

(38_H)

Reset Value: 0000 000D_H



Field	Bits	Type	Description
TID0	[3:0]	r	Transaction Identifier 0 This field is statically encoded with the 4'b1101 value that corresponds to a reserved master identifier in the TC1728 device.
0	[31:4]	r	reserved bit fields. A write has no effect. Returns 0s on read.

The Transaction Identifier **TID** enables to perform monitoring actions based on the master identifier provided by the FPI master. This mode can be further extended (in future versions of the BMU) to do broader checks based on the TID: for instance in a multi-processor system, the TID can uniquely identify the CPU core that initiated the transaction. .

Bus Monitor Unit (BMU)

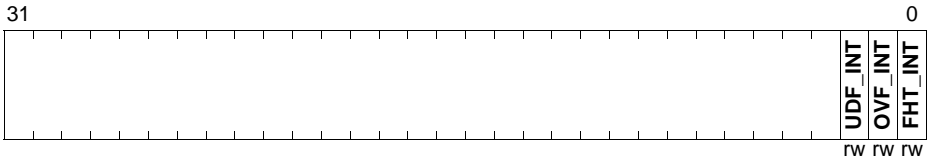
15.6.4 BMU: Fifo Monitoring Registers

FMCTL

Fifo Monitor control register

(40_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
FHT_INT	1	rw	Interrupt Enable for Fifo High Threshold 0 _B interrupt generation disabled 1 _B interrupt generation enabled
OVF_INT	1	rw	Interrupt Enable for Overflow Detection 0 _B interrupt generation disabled 1 _B interrupt generation enabled
UDF_INT	2	rw	Interrupt Enable for Underflow Detection 0 _B interrupt generation disabled 1 _B interrupt generation enabled
0	[31:3]	r	reserved bit fields. A write has no effect. Returns 0s on read.

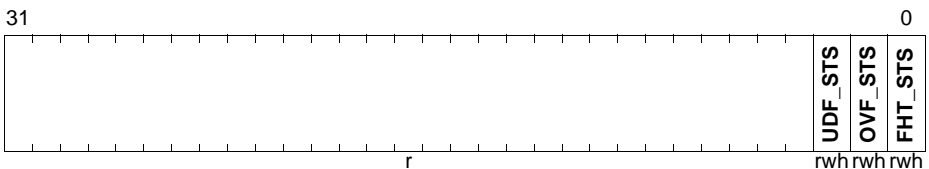
FMCTL controls the interrupt generation related to the Fifo Fullness Monitoring.

FMSTS

Fifo Monitor Status Register

(44_H)

Reset Value: 0000 0000_H



Bus Monitor Unit (BMU)

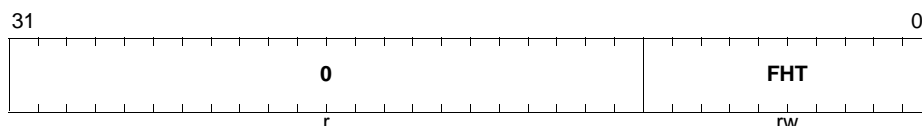
Field	Bits	Type	Description
FHT_STS	0	rwh	Status Flag for Fifo High Threshold interrupt 0_B No interrupt pending 1_B Event related to High Threshold monitoring has been detected. The event leads to an interrupt if $FMCTL.FHT_INT = 1$.
OVF_STS	1	rwh	Status Flag for Overflow interrupt 0_B No interrupt pending 1_B Event related to overflow monitoring has been detected. The event leads to an interrupt if $FMCTL.OVF_INT = 1$.
UDF_STS	2	rwh	Status Flag for Underflow interrupt 0_B No interrupt pending 1_B Event related to underflow monitoring has been detected. The event leads to an interrupt if $FMCTL.UDF_INT = 1$.
0	[31:3]	r	reserved bit fields. A write has no effect. Returns 0s on read.

FMSTS is used to log the status of the interrupt source(s). The bits are set to 1 by hardware. To clear a status bit the software must write a 0 at the bit position corresponding to be bit to be cleared (writing a 1 per software has no effect on the status bits). If software writes a 0 to a status bit that is already cleared and in the same cycle the hardware wants to set the bit, the hardware has priority over the software.

FMTH

Fifo Monitor: Fullness Threshold Register
(48_H)

Reset Value: 0000 0000_H



Bus Monitor Unit (BMU)

Field	Bits	Type	Description
FHT	[9:0]	rw	Fifo High Threshold This field defines a number of used entries defining a threshold. When set to 0 the threshold monitoring is disabled.
0	[31:10]	r	reserved bit fields. A write has no effect. Returns 0s on read.

FMTH defines a boundary for the number of used words in the Bus Transaction Fifo that will be monitored during run-time. When the number of words configured in the **FHT** field is reached (or crossed) and if the **FMCTL.FHT_INT** field is set, an interrupt is triggered. This FHT field must be initialized by SW to the expected threshold before enabling the interrupt generation.

Bus Monitor Unit (BMU)

15.6.5 BMU: SIST Mode Access Control Register

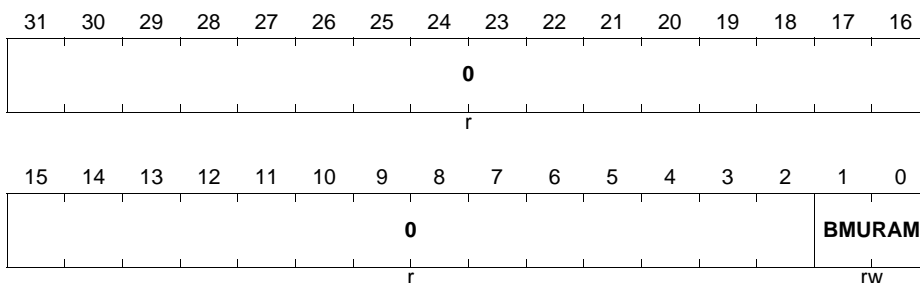
Note: Please see [“Error Correction Code \(ECC\)” on Page 15-18](#) for more information regarding the use of this register.

This register is ENDINIT protected.

SMACON

SIST Mode Access Control Register (50_H)

Reset Value: 0000 0000_H

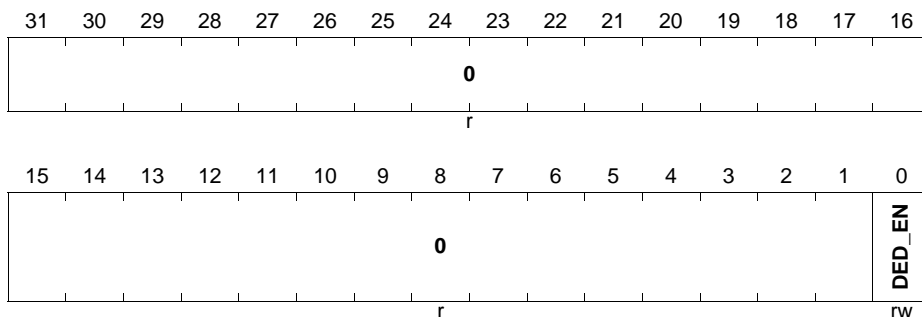


Field	Bits	Type	Description
BMURAM	[1:0]	rw	SIST mode access control 00 _B Normal Operation, No Mapping 01 _B Data Array Mapping, no error detection/correction 10 _B Check Array Mapping, no error detection/correction 11 _B Data Array Mapping, error detection/correction enabled
0	[31:2]	r	reserved returns '0' if read; should be written with '0'.

Bus Monitor Unit (BMU)

MIECON

Memory Integrity Error Control Register(54_H)

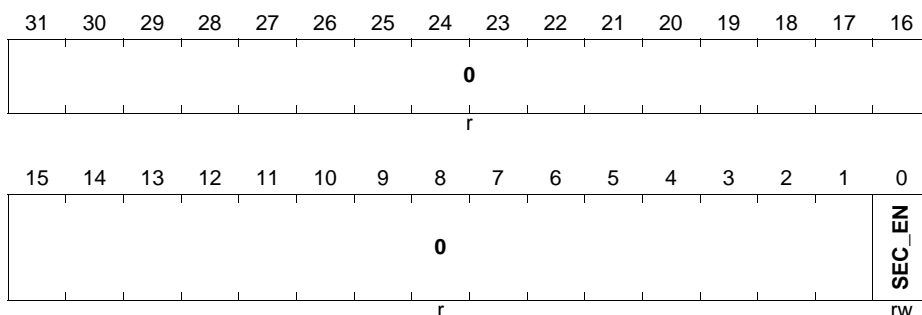
Reset Value: 0000 0000_H


Field	Bits	Type	Description
DED_EN	0	rw	Double error detection enable 0 _B Double bit error detection for BMURAM disabled 1 _B Double bit error detection for BMURAM enabled
0	[31:1]	r	reserved returns '0' if read; should be written with '0'.

Please see **“Error Correction Code (ECC)” on Page 15-18** for more information regarding the use of this register.

MIECON2

Memory Integrity Error Control 2 Register(58_H)

Reset Value: 0000 0000_H


Bus Monitor Unit (BMU)

Field	Bits	Type	Description
SEC_EN	0	rw	Single error correction enable 0_B Single bit error correction for BMURAM disabled 1_B Single bit error correction for BMURAM enabled
0	[31:1]	r	reserved returns '0' if read; should be written with '0'.

Please see **“Error Correction Code (ECC)” on Page 15-18** for more information regarding the use of this register.

*Note: This register is ENDINIT protected, in addition the register cannot be accessed unless the “secwen_i” input is asserted. When “secwen_i” is not asserted accesses to **MIECON2** will generate an FPI error acknowledge.*

Bus Monitor Unit (BMU)

15.6.6 Interrupt System Registers

SRC

Service Request Control Register (FC_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
							0								
							r								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0						SRPN			
w	w	rwh	rw	r	rw	r						rw			

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority ... FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP service is initiated
SRE	12	rw	Service Request Enable 0 _B Service request is disabled 1 _B Service request is enabled
SRR	13	rwh	Service Request Flag 0 _B No service request is pending 1 _B A service request is pending ¹⁾
CLRR	14	w	Request Clear Bit CLRR is required to clear SRR. 0 _B No action 1 _B Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.

Bus Monitor Unit (BMU)

Field	Bits	Type	Description
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 _B No action 1 _B Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

- 1) The bit field SRR is automatically cleared by hardware at the end of an interrupt arbitration round if the node was the winner, therefore this information is not suitable for interrupt plausibility checks.

15.7 Revision History

Table 15-7 Revision history

Date	Description	Name
Version 2.5 -> version 2.6		
30.09.2009	- Described limitations on the usage of the CTL register	A. Vilela
Version 2.4 -> version 2.5		
09.09.2009	- SIST mode is only possible when the BMU is configured in SRAM mode (see CTL register description)	A. Vilela
Version 2.3 -> version 2.4		
31.08.2009	<ul style="list-style-type: none"> - Added MIECON and MIECON2 registers and related description in new Memory Integrity Error Control section. - Added input pin secwen_i - Fixes according to RT #764: BMU_CLC.DISS BPI Register Accesses - Fixes according to RT #7630 Ticket: precise logging behavior when switching from disabled state to enabled state in CLC register section. 	A. Vilela
Version 2.1 -> version 2.2		
16.07.2009	<ul style="list-style-type: none"> - Fixes according to RT #7327 Ticket: SHE master filtering - Fixes according to RT #7325 Ticket: removed redundant SRC register description - Fixes according to RT #7301 Ticket: described data storage in SRAM mode and address alignment restrictions - Removed bit fields in the CLC register controlling the suspend and sleep modes as they are not supported. 	A. Vilela
Version 2.0 -> version 2.1		

Bus Monitor Unit (BMU)

Table 15-7 Revision history

Date	Description	Name
09.07.2009	<ul style="list-style-type: none"> - Fixes according to RT #7274 Ticket: added FPI transaction mapping information for SRAM mode. - Renamed FM_<NAME> registers to FM<NAME> to fulfill register extraction rules. - Removed SRAM area information from register chapter and placed it into Section 15.4.8 to fulfill register extraction rules. SRAM area information controlled by conditional text for product differentiation. - Clarified situation described in RT #7250 in Section 15.4.6 - Fixes according to RT #7264 Ticket in Section 15.6.4 - Fixes according to RT #7274 Ticket - Fixes according to RT #7043 Ticket - Removed ENDINIT protection for SRC register - Fixes according to RT #7010 Ticket - Clarified end of data phase condition 	A. Vilela
Version 1.9 -> version 2.0		
09.06.2009	Version for C4 milestone: <ul style="list-style-type: none"> - Module Number defined - Peripheral Mapping updated - Connection of FPI_ACK[1:0] signals updated - Handling of sleep and OCDS suspend modes documented - Fixes according to RT #6919 Ticket 	A. Vilela
Version 1.8 -> version 1.9		
22.05.2009	- Fixes according to RT #6819 Ticket	A. Vilela
Version 1.7 -> version 1.8		
22.05.2009	- Fixes according to RT #6811 Ticket	A. Vilela
Version 1.6 -> version 1.7		
18.05.2009	<ul style="list-style-type: none"> - Fixes according to RT #6777 Ticket - Fixed bit field in PSET1, only bits 0 to 15 are used 	A. Vilela
Version 1.5 -> version 1.6		
18.05.2009	<ul style="list-style-type: none"> - Added bits 5,4,3,2 to BMU_CLC register - Changed Address of SRC register to 0xFC - Added missing Register Layout information - Resized register field FM_TH.FHT to 9 bits - Added underrun interrupt in FM_CTL register - Added underrun status bit in FM_STS register 	A. Vilela

Bus Monitor Unit (BMU)

Table 15-7 Revision history

Date	Description	Name
Version 1.4 -> version 1.5		
30.04.2009	- ECC handling compatible with SIST concept - Updated Fifo Monitoring Registers	A. Vilela
Version 1.3-> version 1.4		
20.04.2009	- Fixes according to RT #6505 Ticket	A. Vilela
Version 1.2 -> version 1.3		
07.04.2009	- Release for IP C3 - Added support for BTR2 and BTR4 burst logging	A. Vilela
Version 1.1 -> version 1.2		
15.03.2009	- New FPI Transaction Mapping	A. Vilela
Version 1.0 -> version 1.1		
12.02.2009	- Version 1.0 Review updates - Added description for non-safety mode	A. Vilela
Version 1.0		
28.01.2009	- First ITS version	A. Vilela

16 On-Chip Debug Support (OCDS)

This chapter gives an overview about the debug features of the TC1728 device. This chapter does not describe the TC1728 debug functionality and capabilities in detail. For detailed information about the On-Chip Debug Support (OCDS) functionality as required by tool suppliers please contact local Infineon representatives.

16.1 Overview

TC1728 supports OCDS Level 1 and 3.

OCDS Level 1

The OCDS Level 1 is mainly assigned for system software debugging purposes which have a demand for low-cost standard debugger hardware.

The OCDS Level 1 is based on a Debug Interface that is used by the external debug hardware to communicate with the system. The on-chip Cerberus module controls the interactions between the Debug Interface and the on-chip modules and allows in particular to access the whole address space of the device. The memory mapped on-chip debug resources make it possible to trigger on instruction and data addresses as well as to control user program execution (run/stop, breakpoint, single-step).

OCDS Level 3

The OCDS Level 3 is based on a Multi Core Debug Solution (MCDS) using an Emulation Device. This device has the following features required for high-end emulation purposes:

- Emulation Device is available in the same package variants as TC1728
- Higher current consumption due to trace and overlay RAM is the only difference
- TriCore program trace
- TriCore data trace (no register file trace)
- PCP ownership trace
- PCP program trace
- PCP data write to PRAM trace (no register file trace)
- Full visibility of internal peripheral bus (SPB)
- Full visibility of Local Memory Bus (LMB)
- Time aligned parallel trace of all sources
- Breakpoints and watchpoints based on common event generation logic
- Magnitude comparators working on instruction pointers and memory addresses:
A <= IP <= B
- Masked magnitude comparators working on the data busses: DATA = "xxxx55xx"
- Sequential event logic: Counters driven by events and equipped with limit comparators are used as event sources again for breakpoint or trace qualification
- Optimized compression of buffered trace data
- Code and data fetch from Emulation Memory

On-Chip Debug Support (OCDS)

- Highly sophisticated complex qualification- and trigger mechanism
- Pre- and post event trace buffering ("digital oscilloscope")
- Performance counters
- Continuous trace logging and trace data acquisition up to the bandwidth of the used host interface
- Central time stamp unit to correlate traces from different cores or other sources
- Central mechanism to start and stop all cores simultaneously or selectively
- Halt the system when trace memory is full

The Emulation Device includes the product chip part extended with additional emulation hardware. For detailed information about the Emulation Device functionality (e.g. as required by tool suppliers), please contact local Infineon representatives.

Figure 16-1 shows a block diagram of the TC1728 OCDS system.

Components

The OCDS of the TC1728 consists of the following building blocks:

- OCDS System Control Unit (OSCU)
- TriCore OCDS
- PCP OCDS
- DMA OCDS
- SBCU OCDS
- LMB OCDS
- Multi Core Break Switch (MCBS)
- Break Pin Control
- IOClient
- Device Access Port (DAP)
- JTAG Interface
- Overlay Control

Summary of OCDS Features

- OCDS System Control Unit (OSCU)
 - Controls OCDS enabling
 - Automatic Power Saving
 - Reset control of debug resources
 - Halt After Reset
 - Hot attach of a debugger to a running system
 - Key mechanism allows control the device access in a secure way.
 - State-aware watchdog timer suspension during debugging
 - Control of SoC specific OCDS features
 - Interrupt service request node for debug purposes
- TriCore OCDS features
 - Hardware event generation
 - Break by DEBUG instruction or Break signal from break switch
 - Suspend by Suspend bus or Break signal from break switch
 - Full hardware supported single step
 - Concurrent access to memory and SFRs via Cerberus
- PCP OCDS features
 - Break by DEBUG instruction or Break signal from break switch
 - Concurrent access to memory and SFRs via Cerberus
- DMA OCDS features
 - Soft-suspend Mode of DMA channels
 - Break signal generation
 - Trace signal generation
- SBCU OCDS features
 - Event generation on specified transactions

On-Chip Debug Support (OCDS)

- LMB OCDS features
 - Error recording and service request on bus error
- Multi-Core Break Switch (Cerberus MCBS)
 - TriCore, PCP, DMA, break pins and SBCU available as break sources
 - TriCore and PCP available as break targets; other parts can be suspended in addition
 - Synchronous stop and restart of the system
 - Break to Suspend converter

16.2 OCDS Level 1

The basic principle of the TriCore OCDS Level 1 is that all relevant user and debug resources are memory mapped. These resources include on-chip memories, CPU core registers and registers of the peripheral units.

A typical OCDS Level 1 debugging configuration is shown in **Figure 16-2**. It comprises two parts:

- The tool software
- The tool access hardware interface adapter

This configuration makes it possible to realize a cost effective debugging environment that permits comprehensive real-time debugging tasks to be performed.

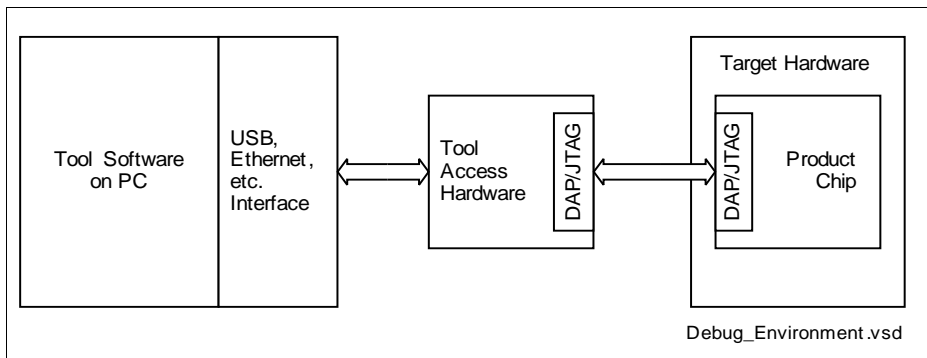


Figure 16-2 Typical OCDS Level 1 Hardware Connections

16.2.1 TriCore CPU OCDS Level 1

This section describes the basic features of the TriCore OCDS Level 1 hardware. For more details please refer to the "TriCore Core Architecture V1.3.1" manual.

Features

- Single-step support by hardware
- Up to 4 programmable hardware breakpoints. Each one can be defined as a combination of program counter and data address:
 - Breaks on program counter (PC) value
 - Two precise PC values or one PC range
 - Break before make (BBM) possible
 - Breaks on data address
 - Two precise data addresses or one data address range
 - No break before make possible (due to pipelined architecture)
 - Combinations of the above break conditions
- Suspend features
 - Core Suspend-Out to suspend bus
 - Configurable Core Suspend-In
- Real-time features
 - Read and write of memory/registers independent of CPU, with minimum intrusion (stealing bus cycles by Cerberus)
 - High-priority requests can still be serviced when the core is in emulation mode - by interrupting the monitor program

16.2.1.1 Basic Concept

The TriCore CPU in the TC1728 provides OCDS with the following two basic parts:

- Debug Event Trigger Generation
- Debug Event Trigger Processing

The first part controls the generation of debug events and the second part controls what actions are taken when a debug event is generated.

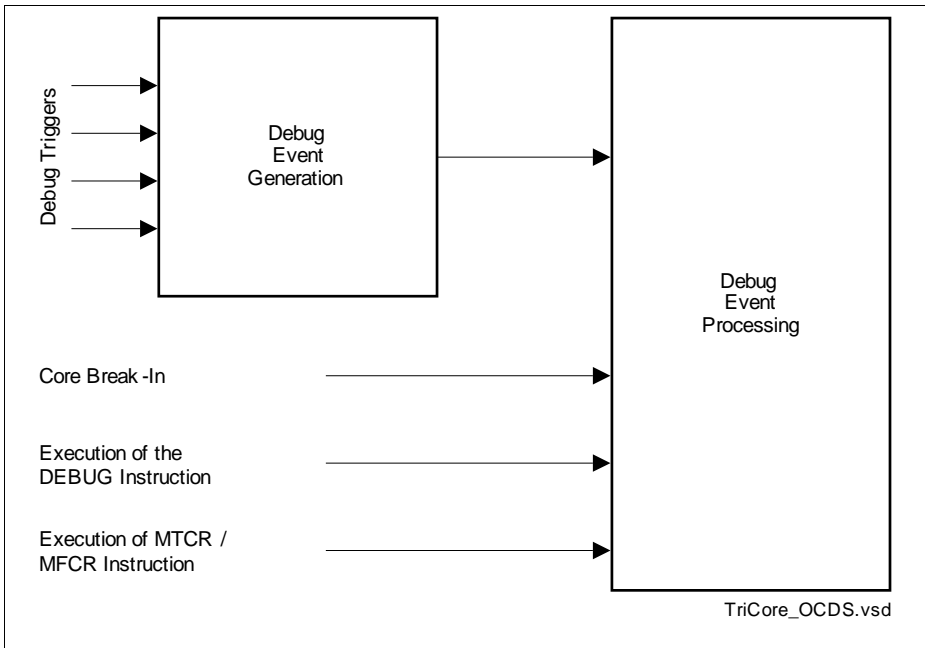


Figure 16-3 Basic TriCore Debug Concept

16.2.1.2 Debug Event Generation

If debug mode is enabled, debug events can be generated by:

- Debug event generation from debug triggers
- Activation of the external Core Break-In signal to the core
- Execution of a DEBUG instruction
- Execution of an MTCR/MFCR instruction

Debug Event Generation from Debug Triggers

The debug event generation unit is responsible for generating debug events when a programmable set of debug triggers is active. Debug triggers can be generated by the code and data protection logic.

These debug triggers provide the inputs to a programmable block of combinational logic that outputs debug events. The aim is to be able to specify the breakpoints that use fairly simple criteria purely in the on-chip debug event generation unit, and to rely on help from the external debug system or debug monitor to implement more complex breakpoints.

Activation of the External Core Break-in signal

When activating the TC1728 device pin $\overline{\text{BRKIN}} = 0$ and if MCBS and port control is configured to forward this event to the Core Break-In signal, a break event is induced as specified in an External Break Input Event Specifier Register EXEVT (Figure 16-4).

Execution of a DEBUG Instruction

The TriCore architecture supports a mechanism through which software can explicitly generate a debug event. This can be used, for instance, by a debugger to patch code held in RAM in order to implement breakpoints. A special DEBUG instruction is defined which is a user mode instruction, and its operation depends on whether the debug mode is enabled. 16-bit and 32-bit forms of the DEBUG instruction are provided.

If debug mode is enabled, the DEBUG instruction causes a debug event to be raised and the action defined in the Software Break Event Specifier Register SWEVT is taken. If the debug mode is not enabled, then the DEBUG instruction is treated as a NOP instruction.

Execution of an MTCR/MFCR Instruction

In order to protect the emulator resource, a debug event is raised whenever an MTCR or MFCR instruction is used to read or modify a user core SFR, but an event is not raised when the user reads or modifies one of the dedicated core debug registers: DBSR, CREVT, SWEVT, EXEVT, TR0EVT, TR1EVT, DMS, DCX or DBGTCR.

The action that is performed when an MTCR or MFCR instruction is executed on user core SFRs defined by the content of the Emulator Resource Protection Event Specifier Register CREVT.

16.2.1.3 Debug Actions

Four types of debug actions are available:

- Assert Core Break-out signal and $\overline{\text{BRKOUT}}$ (Figure 16-4) via MCBS unit and port control
- Halt the CPU core
- Cause a breakpoint trap
- Generate an interrupt request

These debug actions are selected by programming the corresponding Event Specifier registers. Their contents determine which action shall be taken when the corresponding debug event occurs. In parallel the Core Suspend-Out signal can be activated.

16.2.1.4 TriCore OCDS Registers

Please refer to “TriCore Core Architecture V1.3.1” manual.

16.2.2 PCP OCDS Level 1

PCP has no hardware means of generating trigger events.

To set breakpoints, the debugger is expected to patch the code in the PCP code memory (CMEM) with DEBUG instructions. If a DEBUG instruction is executed, the running channel program is terminated, either with Debug Exit or with Error Exit.

The PCP has a suspend input, a break input and a break output. The Break Switch can send an external break request to the PCP, with the same consequence as above (Debug Exit or Error Exit).

16.2.3 SBCU OCDS Level 1

The BCU of the SPB bus in the TC1728 offers very powerful means for trigger generation. The BCU contains comparators for

- the arbitration phase (look for specific bus master)
- the address phase (look for specific address or range)
- the data phase (look for read, write, supervisor mode, etc.)

The results can be combined to generate a break request signal, which is sent to the Break Switch.

The OCDS registers of SBCU are described in chapter "On-Chip System Buses and Bus Bridges" starting from section "System Bus Control Unit Registers".

16.2.4 DMA OCDS Level 1

The DMA controller in the TC1728 provides the following debugging capabilities:

- Hard suspend mode of the DMA controller (for test purposes only)
- Soft suspend mode of DMA channels
- Break signal generation

In suspend modes, the operations of DMA channels or the complete module are stopped. Under certain conditions, a break signal is also generated for the on-chip debug support logic.

More details on the OCDS Level 1 debug capabilities of the DMA controller are provided in section "On-Chip Debug Capabilities" of the DMA chapter.

16.3 Debug Interface (Cerberus)

The Cerberus module is the on-chip unit that controls all OCDS main debug functions. Generally, the Cerberus may not be used by any application software, since this could disturb the emulation tool behavior.

The Cerberus module is built up by three parts (see also [Figure 16-1](#)):

- OCDS System Control Unit - OSCU
- IOClient
- Multi Core Break Switch - MCBS

A tool can be connected to the device in two ways:

- A two line DAP interface via the DAP module receives the debugger commands, converts them and outputs them to the IOClient interface.
- Standard JTAG interface is connected via the JTAG controller with the IOClient interface

Two additional pins are available to handle an external break condition. The external debug hardware can access the Cerberus registers and arbitrary memory locations across the System Peripheral Bus.

Features

- OCDS Level 1 control via
 - 5-pin standard JTAG interface
 - 2-pin DAP interface
- Generation of external break condition via BRKIN/BRKOUT pins possible
- Full access to the complete SPB Bus address space via DAP/JTAG
- No user resources (hardware/software) are required
- No or minimum run-time impact (Cerberus bus priority can be controlled)
- Generic memory read/write functionality
- Write word, half-word and byte
- Block read and write
- Full support for communication between an on-chip monitor program and the external debugger
- Pending reads/writes can be optionally triggered by the OCDS module (memory tracing)
- Download of programs and data via DAP/JTAG
- Control of the OCDS blocks
- Data acquisition

16.3.1 RW Mode

As the name implies, the RW mode is used by a DAP/JTAG host to read or write arbitrary memory locations via the DAP/JTAG interface. The RW mode needs the SPB Bus master interface of the Cerberus to actively request data reads or data writes.

Data Types Supported

- WORD (32-bit): The default data type; used for single word transfers and block transfers.
- HWORD (16-bit): For reading 16-bit registers without getting a bus error, a dedicated IOClient instruction is provided.
- BYTE (8-bit): If the DAP/JTAG host wants to read a byte, it has to read the associated word or half-word. Then the host has to extract the part needed itself.

16.3.2 Communication Mode

In Communication Mode, the Cerberus has no access to the internal buses and communication is established between the external DAP/JTAG host and a software monitor (embedded into the application program) via the Cerberus registers. The communication mode is the default mode after reset.

In Communication Mode, the external DAP/JTAG host is master of all transactions. The host requests the monitor to write or read a value to/from the Cerberus register COMDATA. The difference to RW Mode is that the read or write request is not actively executed by Cerberus. The request just sets bits in the CPU accessible IOSR register to signal the monitor that the debugger wants to send or receive a value. The software monitor has to poll the IOSR register for that.

16.3.3 Triggered Transfers

Triggered transfers can be used to read from or write to a certain memory location when an OCDS trigger becomes active.

The main application for Triggered Transfers is to trace a certain memory location. This can be done, when the OCDS of the CPU activates its break out signal, if this memory location is written by the user program. This event is used as a transfer trigger through the configuration of the MCBS. Cerberus is configured to read the location on this trigger.

16.3.4 Multi Core Break Switch

In TC1728, there are several sources and targets for break signals. For instance the OCDS run control of one processor can break the other processor unit. The Multi Core Break Switch (MCBS) is a part of the Cerberus and allows to propagate break requests from sources to targets in a generic and flexible way. [Figure 16-4](#) shows the break signal interfaces of the MCBS.

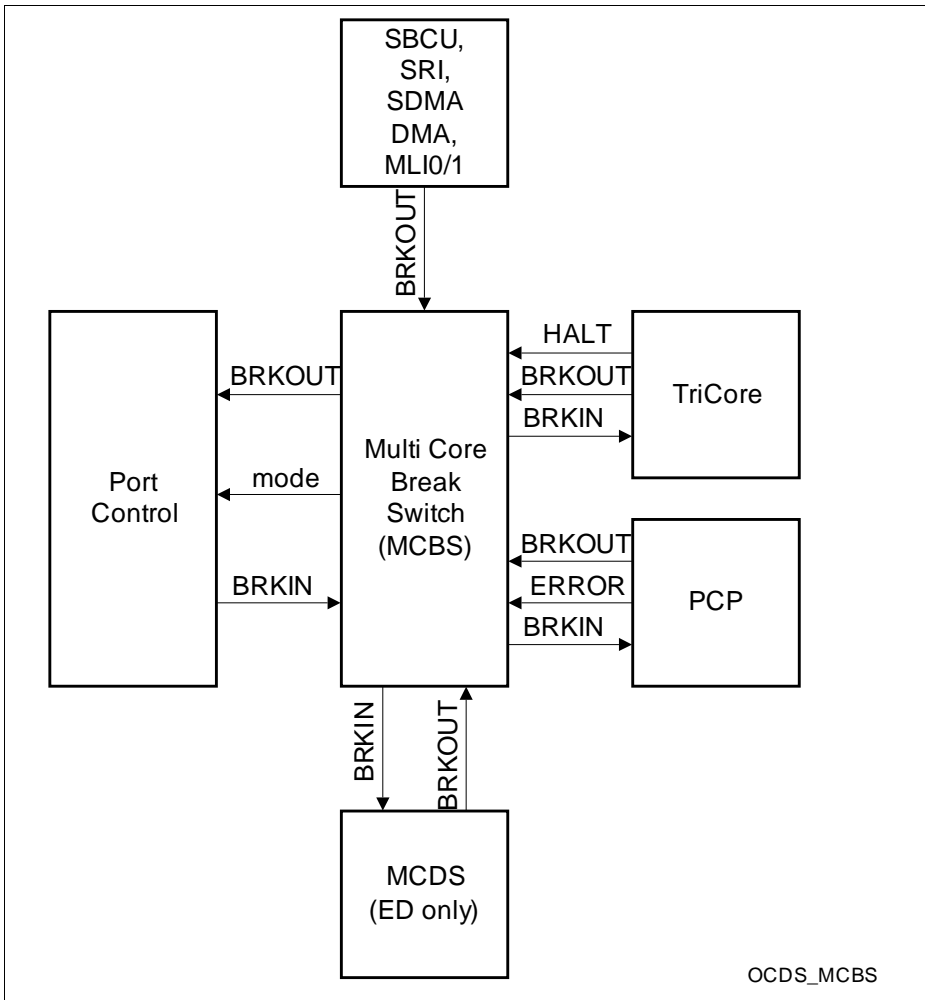


Figure 16-4 Break Switch Interfaces

The MCBS unit supports the following features:

- Break-in sources: TriCore, PCP, DMA, SBCU, MLI0, MLI1
- Up to two device pins configurable as BRKIN/BRKOUT pins
- Two independent break buses
- Suspend generation supports delayed suspend
- Break-to-suspend converter

On-Chip Debug Support (OCDS)

- Create interrupt request with a break coming from a source
- Synchronous restart of the system

16.4 JTAG Interface

The JTAG interface is a standardized unit that is typically used for boundary scan and internal device tests. Because both of these applications are not active during normal device operation in a system, the JTAG port can be used during normal device operation as an ideal interface for debugging tasks.

16.5 Device Access Port (DAP)

The cost inferred by each non-functional pin is a strong argument to reduce the tool access port to as few pins as possible. The standardized Device Access Port (DAP) of Infineon's latest micro controllers offers a convenient method to get the required functionality at the least possible cost. With DAP only two pins (DAP0 for the clock, DAP1 for the bidirectional data) are needed to communicate with the tool.

DAP uses a straightforward half-duplex protocol, i.e. the DAP1 pin is used for data transfer from tool to device and from device to tool at different periods of time while the clock is provided by the tool to the DAP0 input.

16.5.1 DAP Telegram Format

All information transport between tool and device is done in telegrams. Mandatory 6 bit CRC check sums assure secure transport even in noisy environments. Splitting command and reply into separate units transported sequentially allows half-duplex transmission over a single bidirectional line. The physical interface medium can be chosen independently as long as the serial bit stream can be transported.

16.5.2 DAP Telegram Catalog

This chapter lists the telegrams implemented by the TC1728. Other telegrams are silently ignored, resulting in a time-out condition on the tool side.

Three groups of telegrams can be distinguished:

Control Telegrams

These four telegrams are needed to establish and maintain the connection from tool to device as such. No data is transported.

- sync - request synchronization pattern
- turn_off - shut down DAP
- poll - get the current service request
- set_maxwait - adjust the parameter for time out

JTAG Telegrams

The telegrams of this group are simple wrappers around the standard JTAG commands, adding the relaxed timing and increased transmission speed and quality of DAP.

- jtag_mode - switch DAP to BYPASS mode
- jtag_reset - reset the TAP controller
- jtag_setIR - write the TAP's INSTRUCTION register
- jtag_swapIR - write and read the TAP's INSTRUCTION register
- jtag_setDR - write the current JTAG data register
- jtag_swapDR - write and read the current JTAG data register
- jtag_moreDR - write and read part of a long JTAG data register

Client Telegrams

The last group allows direct access to IOClients like Cerberus of the device, completely hiding the asynchronous timing between tool clock and system clock of the device.

The following five telegrams belong to this group:

- client_set - define the current IOClient
- client_get - ask for the index of the current IOClient
- client_reset - reset the current IOClient
- client_write - write to the current IOClient
- client_read - read from the current IOClient

16.6 Cerberus and JTAG Registers

This section summarizes all Cerberus and JTAG registers for reference purposes. Details on these registers are contained in OCDS documents that are available for tool suppliers on request (please contact local Infineon representatives). All CERBERUS registers are prefixed "CBS_" in the register map of a device.

On-Chip Debug Support (OCDS)

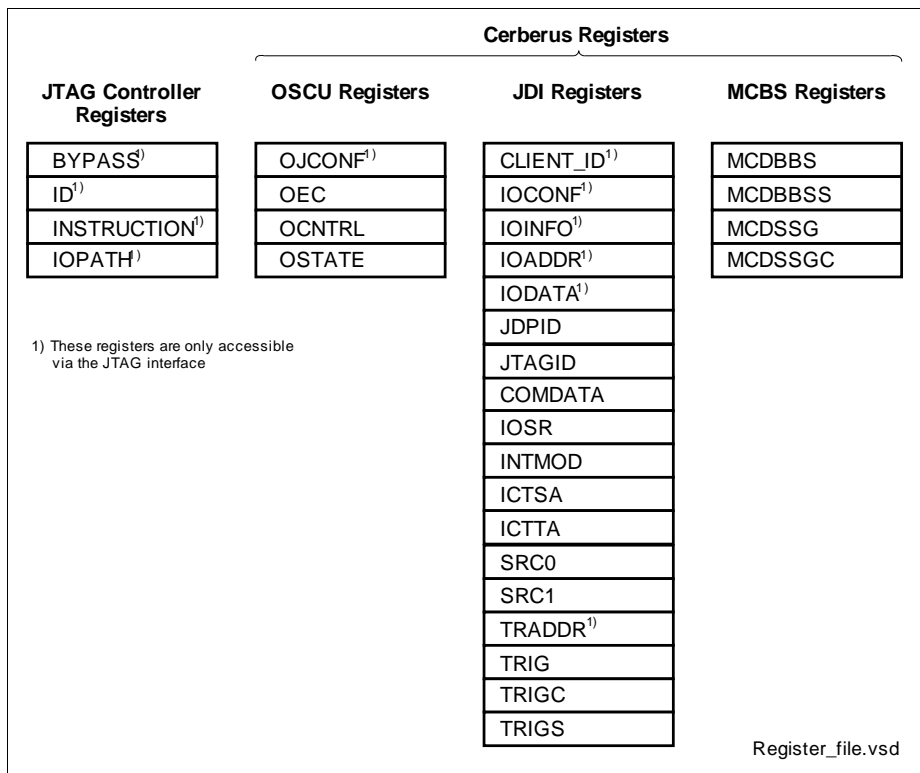


Figure 16-5 JTAG/Cerberus Register Overview

Table 16-1 JTAG/Cerberus Register Overview

Register Short Name	Register Long Name	Address
JTAG Controller Registers		
BYPASS	JTAG Bypass Register (1-bit)	¹⁾
ID	JTAG Device Identification Register (32-bit)	¹⁾
INSTRUCTION	JTAG Instruction Register (8-bit)	¹⁾
IOPATH	IO Client Selection Register (2-bit)	¹⁾
Cerberus Registers		
OJCONF	OSCU Configuration by JTAG Register	¹⁾

On-Chip Debug Support (OCDS)

Table 16-1 JTAG/Cerberus Register Overview (cont'd)

Register Short Name	Register Long Name	Address
OEC	OCDS Enable Control Register	F000 0478 _H
OCNTRL	OSCU Configuration and Control Register	F000 047C _H
OSTATE	OSCU Status Register	F000 0480 _H
CLIENT_ID	JTAG Client Identification Register (32-bit)	¹⁾
IOCONF	Configuration Register (12-bit)	¹⁾
IOINFO	State Information for Error Analysis Register (16-bit)	¹⁾
IOADDR	Address for Data Access Register (32-bit)	¹⁾
IODATA	RW Mode Data Register (32-bit)	¹⁾
JDPID	Cerberus Module Identification Register	F000 0408 _H
JTAGID	JTAG Device Identification Register	F000 0464 _H
COMDATA	Communication Mode Data Register	F000 0468 _H
IOSR	Status Register	F000 046C _H
INTMOD	Internal Mode Status and Control Register	F000 0484 _H
ICTSA	Internal Controlled Trace Source Address Register	F000 0488 _H
ICTTA	Internal Controlled Trace Target Address Register	F000 048C _H
MCDBBS	Break Bus Switch Configuration Register	F000 0470 _H
MCDBBSS	Break Bus Switch Status Register	F000 0490 _H
MCDSSG	Suspend Signal Generation Status and Control Register	F000 0474 _H
MCDSSGC	Suspend Signal Generation Configuration Register	F000 0494 _H
SRC0	Service Request Control Register 0	F000 04FC _H
SRC1	Service Request Control Register 1	F000 04F8 _H
TRADDR	Triggered Transfer Destination Address	¹⁾
TRIG	Trigger to Host	F000 04A8 _H
TRIGC	Clear Trigger to Host	F000 04A4 _H
TRIGS	Set Trigger to Host	F000 04A0 _H

¹⁾ These registers are only accessible via the JTAG interface.

Asynchronous/Synchronous Serial Interface (ASC)

17 Asynchronous/Synchronous Serial Interface (ASC)

This chapter describes the two ASC Asynchronous/Synchronous Serial Interfaces, ASC0 and ASC1, of the TC1728. It contains the following sections:

- Functional description of the ASC kernel, valid for ASC0 and ASC1 (see [Page 17-1](#))
- ASC kernel register description, describes all ASC kernel specific registers (see [Page 17-21](#))
- TC1728 implementation-specific details and registers of the ASC0/ASC1 modules (see [Page 17-32](#)).

Note: The ASC kernel register names described in [Section 17.2](#) are referenced in the TC1728 User's Manual by the module name prefix "ASC0_" for the ASC0 interface and by "ASC1_" for the ASC1 interface.

17.1 ASC Kernel Description

[Figure 17-1](#) shows a global view of the ASC interface.

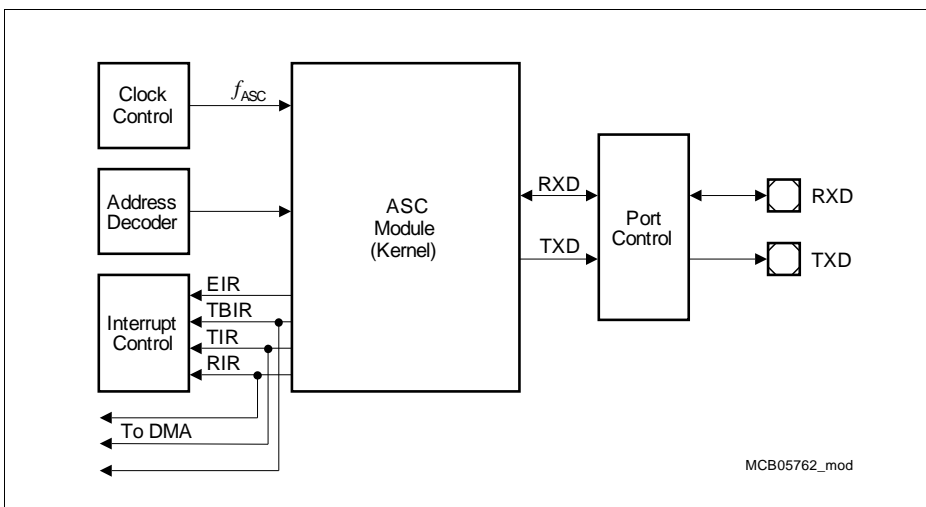


Figure 17-1 General Block Diagram of the ASC Interface

The ASC module communicates with the external world via two I/O lines. The RXD line is the receive data input signal (and also output signal in Synchronous Mode), and TXD is the transmit output signal.

Clock control, address decoding, and interrupt service request control are managed outside the ASC module kernel.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.1 Overview

The ASC provides serial communication between the TC1728 and other microcontrollers, microprocessors, or external peripherals.

The ASC supports full-duplex asynchronous communication and half-duplex synchronous communication. In Synchronous Mode, data is transmitted or received synchronous to a shift clock that is generated by the ASC internally. In Asynchronous Mode, 8-bit or 9-bit data transfer, parity generation, and the number of stop bits can be selected. Parity, framing, and overrun error detection are provided to increase the reliability of data transfers. Transmission and reception of data is double-buffered. For multiprocessor communication, a mechanism is included to distinguish address bytes from data bytes. Testing is supported by a loop-back option. A 13-bit baud rate generator provides the ASC with a separate serial clock signal, which can be accurately adjusted by a prescaler implemented as fractional divider.

Features

- Full-duplex asynchronous operating modes
 - 8-bit or 9-bit data frames, LSB first
 - Parity-bit generation/checking
 - One or two stop bits
 - Baud rate from 6.875 Mbit/s to 1.64 bit/s (@ 110 MHz module clock)
 - Multiprocessor mode for automatic address/data byte detection
 - Loop-back capability
- Half-duplex 8-bit synchronous operating mode
 - Baud rate from 13.75 Mbit/s to 1119 bit/s (@ 110 MHz module clock)
- Double-buffered transmitter/receiver
- Interrupt generation
 - On a transmit buffer empty condition
 - On a transmit last bit of a frame condition
 - On a receive buffer full condition
 - On an error condition (frame, parity, overrun error)
- Implementation features
 - Connections to DMA Controller
 - Connections of receiver input to GPTA (LTC) for baud rate detection and LIN break signal measuring

Asynchronous/Synchronous Serial Interface (ASC)

17.1.2 General Operation

The ASC supports full-duplex asynchronous communication up to Mbit/s and half-duplex synchronous communication up to Mbit/s (@ MHz module clock). In Synchronous Mode, data is transmitted or received synchronous to a shift clock generated by the microcontroller. In Asynchronous Mode, 8-bit or 9-bit data transfer, parity generation, and the number of stop bits can be selected. Parity, framing, and overrun error detection are provided to increase the reliability of data transfers. Transmission and reception of data are double-buffered. For multiprocessor communication, a mechanism is included to distinguish address bytes from data bytes. Testing is supported by a loop-back option. A 13-bit baud rate generator provides the ASC with a separate serial clock signal, which can be accurately adjusted by a prescaler implemented as fractional divider.

A transmission is started by writing to the Transmit Buffer Register, TBUF. Only the number of data bits determined by the selected operating mode will actually be transmitted; that is, bits written to positions 9 through 15 of register TBUF are always insignificant. Data transmission is double-buffered, so a new character may be written to TBUF before the transmission of the previous character is complete. This allows a back-to-back transmission of characters to take place without gaps.

Data reception is enabled by the receiver enable bit CON.REN. After a reception has been completed, the received data and, if provided by the selected operating mode, the received parity bit can be read from the (read-only) receive buffer register RBUF. Unused bits in the upper half of RBUF that are not required in the selected operating mode will be read as zeros.

Data reception is double-buffered, so that reception of a second character may already begin before the previously received character has been read out of the receive buffer register. In all modes, receive buffer overrun error detection can be selected through bit CON.OEN. When enabled, the overrun error status flag CON.OE and the error interrupt request line EIR will be activated when the receive buffer register has not been read by the time reception of a second character is complete. In this case, the previously received character in the receive buffer is overwritten.

The loop-back option (selected by bit CON.LB) allows the data currently being transmitted to be received simultaneously in the receive buffer. This may be used to test serial communication routines at an early stage without having to provide an external network. In loop-back mode, the alternate input/output function of port pins is not required.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.3 Asynchronous Operation

Asynchronous Mode supports full-duplex communication, in which both transmitter and receiver use the same data frame format and have the same baud rate. Data is transmitted on pin TXD and received on pin RXD. **Figure 17-2** shows the block diagram of the ASC when operating in Asynchronous Mode.

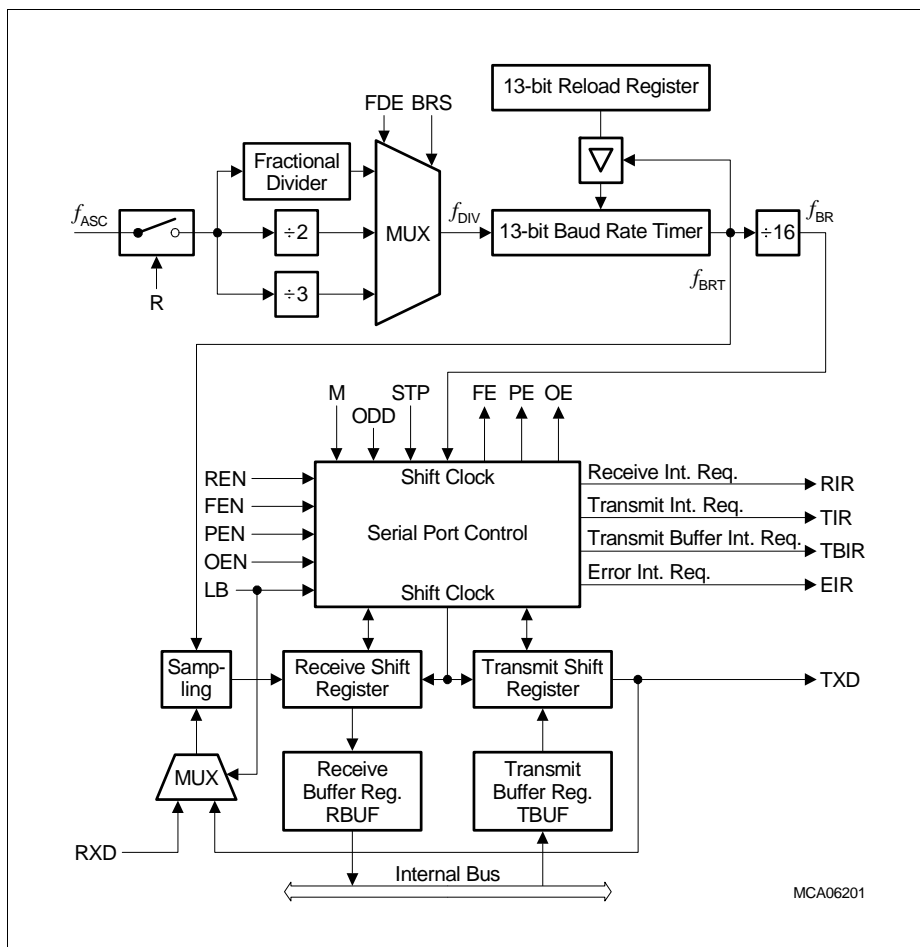


Figure 17-2 Asynchronous Mode of the ASC

Asynchronous/Synchronous Serial Interface (ASC)

17.1.3.1 Asynchronous Data Frames

Asynchronous data frames can consist of 8-bit or 9-bit data frames.

8-bit Data Frames

The 8-bit data frames consist of either eight data bits D7 ... D0 (CON.M = 001_B), or of seven data bits D6 ... D0 plus an automatically generated parity bit (CON.M = 011_B). Parity may be odd or even, depending on bit CON.ODD. An even parity bit will be set if the modulo-2 sum of the seven data bits is 1. An odd parity bit will be cleared in this case. Parity checking is enabled via bit CON.PEN (always OFF in 8-bit data mode). The parity error flag CON.PE will be set, along with the error interrupt request flag, if a wrong parity bit is received. The received parity bit itself will be stored in RBUF too.

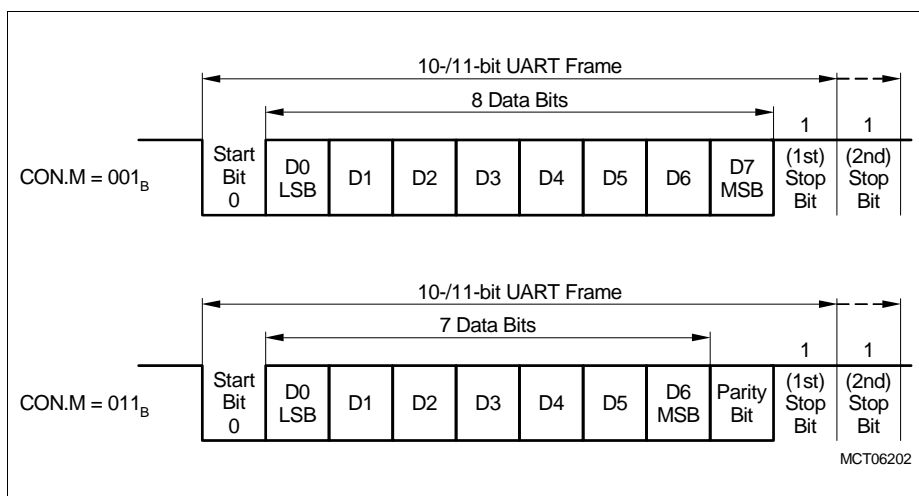


Figure 17-3 Asynchronous 8-bit Frames

Asynchronous/Synchronous Serial Interface (ASC)

9-bit Data Frames

The 9-bit data frames consist of nine data bits D8 ... D0 ($\text{CON.M} = 100_{\text{B}}$), or of eight data bits D7 ... D0 plus an automatically generated parity bit ($\text{CON.M} = 111_{\text{B}}$) or of eight data bits D7 ... D0 plus wake-up bit ($\text{CON.M} = 101_{\text{B}}$). Parity may be odd or even, depending on bit CON.ODD. An even parity bit will be set if the modulo-2-sum of the eight data bits is 1. An odd parity bit will be cleared in this case. Parity checking is enabled via bit CON.PEN (always OFF in 9-bit data and wake-up mode). The parity error flag CON.PE will be set along with the error interrupt request flag if a wrong parity bit is received. The received parity bit itself will be stored in RBUF too.

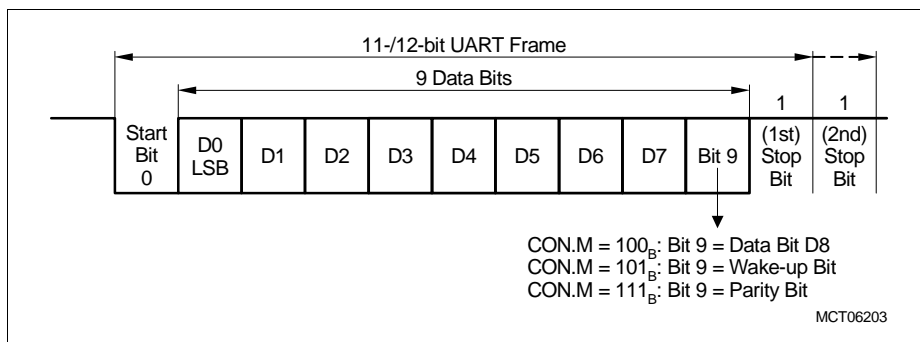


Figure 17-4 Asynchronous 9-bit Frames

In Wake-up Mode ($\text{CON.M} = 101_{\text{B}}$), received frames are transferred to the receive buffer register only if the 9th bit (the wake-up bit) of the frame is 1. If this bit is 0, no receive interrupt request will be activated and no data will be transferred.

This feature can be used to control communication in multi-processor systems, for example:

When the master processor aims to transmit a block of data to one of several slaves, it first sends out an address 'byte' (in this case, a 'byte' consists of nine bits) that identifies the target slave. An address 'byte' differs from a data 'byte' in that the additional 9th bit is a 1 for an address 'byte' but is a 0 for a data 'byte', so, no slave will be interrupted by a data 'byte'. An address 'byte' will interrupt all slaves (operating in 8-bit data + wake-up bit mode), so each slave can examine the eight LSBs of the received character (the address). The addressed slave will switch to 9-bit data mode (for example, by clearing bit CON.M[0]), which enables it to also receive the data bytes that will be coming (having the wake-up bit cleared). The slaves that were not being addressed remain in 8-bit data + wake-up bit mode, ignoring the following data 'bytes'.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.3.2 Asynchronous Transmission

Asynchronous transmission begins when the next overflow of the divide-by-16 baud rate timer (transition of the baud rate clock f_{BR}) occurs, if bit CON.R is set and data has been loaded into TBUF. The transmitted data frame consists of three elements:

1. The start bit
2. The data field (8 or 9 bits, LSB first, including a parity bit, if selected)
3. The delimiter (1 or 2 stop bits)

Data transmission is double-buffered. When the transmitter is idle, the transmit data loaded into TBUF is immediately moved to the transmit shift register; thus, freeing TBUF for the next transmit data to be loaded. This is indicated by the transmit buffer interrupt request line TBIR being activated. TBUF may then be loaded with the next transmit data while transmission of the previous one continues.

The Transmit Interrupt Request line TIR will be activated before the last bit of a frame is transmitted, that is, before the first or the second stop bit is shifted out of the transmit shift register.

Note: A dedicated GPIO device pin which is connected to the module output pin TXD must be configured by software as alternate data output for asynchronous transmission.

17.1.3.3 Asynchronous Reception

Asynchronous reception is initiated by a falling edge (1-to-0 transition) on pin RXD, on the condition that bits CON.R and CON.REN are set. The receive data input pin RXD is sampled at sixteen times the rate of the selected baud rate. A majority decision of the 7th, 8th and 9th sample determines the effective sampled bit value. This avoids erroneous results that may be caused by noise.

If the detected value is not a 0 when the start bit is sampled, the receive circuit is reset and waits for the next 1-to-0 transition at pin RXD. If the start bit proves valid, the receive circuit continues sampling and shifts the incoming data frame into the receive shift register.

When the last stop bit has been received, the contents of the receive shift register are transferred to the Receive Data Buffer Register RBUF. Simultaneously, the receive interrupt request line RIR is activated after the 9th sample in the last stop bit time-slot (as programmed), regardless whether valid stop bits have been received or not. The receive circuit then waits for the next start bit (1-to-0 transition) at the receive data input line.

Note: A dedicated GPIO pin that is connected to the module input pin RXD must be configured by software as input for asynchronous reception.

Asynchronous reception is stopped by clearing bit CON.REN. A currently received frame is completed including generation of the receive interrupt request and an error interrupt request, if appropriate. Start bits that follow this frame will not be recognized.

Asynchronous/Synchronous Serial Interface (ASC)

Note: In wake-up mode, received frames are transferred to the receive buffer register only if the 9th bit (the wake-up bit) is 1. If this bit is 0, no receive interrupt request will be activated and no data will be transferred.

17.1.3.4 RXD/TXD Data Path Selection in Asynchronous Modes

The data paths for the serial input and output data in Asynchronous Modes are affected by control bit CON.LB (loop-back) as shown in [Figure 17-5](#).

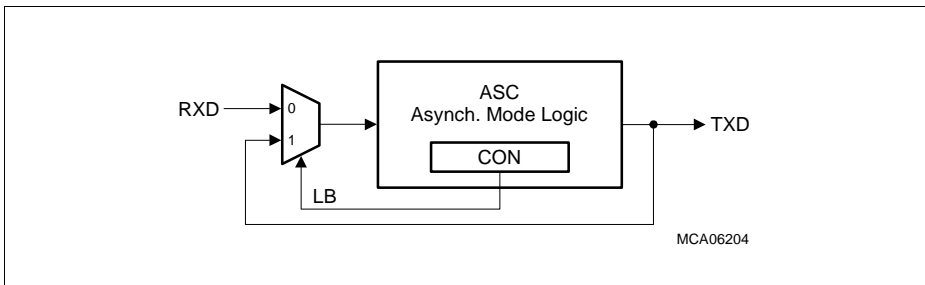


Figure 17-5 RXD/TXD Data Path Selection in Asynchronous Modes

Asynchronous/Synchronous Serial Interface (ASC)

17.1.4 Synchronous Operation

Synchronous Mode supports half-duplex communication, usable for simple I/O expansion via shift registers. Data is transmitted and received via pin RXD while pin TXD outputs the shift clock. These signals are typically connected as alternate functions with GPIO port pins. Synchronous Mode is selected with $CON.M = 000_B$.

Eight data bits are transmitted or received synchronous to a shift clock generated by the internal baud rate generator. The shift clock is active only as long as data bits are transmitted or received.

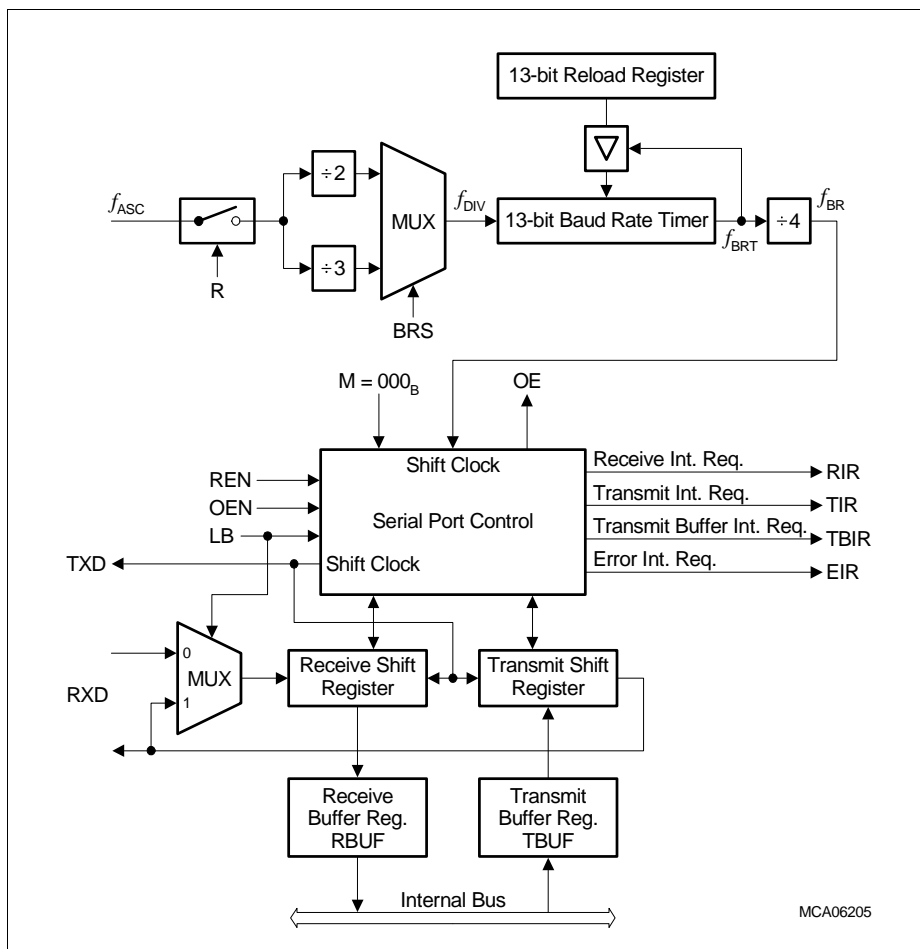


Figure 17-6 Synchronous Mode of Serial Channel ASC

Asynchronous/Synchronous Serial Interface (ASC)

17.1.4.1 Synchronous Transmission

Synchronous transmission begins within four state times after data has been loaded into TBUF, provided that CON.R is set and CON.REN = 0 (half-duplex, no reception), with one exception: in Loop-back Mode (bit CON.LB set), CON.REN must be set for reception of the transmitted byte. Data transmission is double-buffered. When the transmitter is idle, the transmit data loaded into TBUF is immediately moved to the transmit shift register, thus freeing TBUF for the next data to be sent. This is indicated by the transmit buffer interrupt request line TBIR being activated. TBUF may now be loaded with the next data, while transmission of the previous one continues. The data bits are transmitted synchronously with the shift clock. After the bit time for the 8th data bit, both TXD and RXD will be set to high level, the transmit interrupt request line TIR is activated, and serial data transmission stops.

Note: The dedicated GPIO device pins that are connected to TXD and RXD must be configured by software as alternate data outputs in order to provide the shift clock and the output data during synchronous transmission.

17.1.4.2 Synchronous Reception

Synchronous reception is initiated by setting bit CON.REN = 1. If bit CON.R = 1, the data applied at RXD is clocked into the receive shift register synchronously to the clock which is output at TXD. After the 8th bit has been shifted in, the contents of the receive shift register are transferred to the receive data buffer RBUF, the receive interrupt request line RIR is activated, the receiver enable bit CON.REN is reset, and serial data reception stops.

Synchronous reception is stopped by clearing bit CON.REN. Any byte that is currently being received is completed, including the generation of the receive interrupt request and an error interrupt request, if appropriate. Writing to the transmit buffer register while a reception is in progress has no effect on reception and will not start a transmission.

If a previously received byte has not been read out of the receive buffer register by the time the reception of the next byte is complete, both the error interrupt request line EIR and the overrun error status flag CON.OE will be activated/set, provided that the overrun check has been enabled by bit CON.OEN.

Note: The dedicated GPIO device pin that is connected to TXD must be configured by software as alternate data output in order to provide the shift clock. The dedicated GPIO device pin that is connected to RXD must be configured by software as input during synchronous reception.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.4.3 Synchronous Timing

Figure 17-7 shows timing diagrams of the ASC Synchronous Mode data reception and data transmission. In idle state, the shift clock is at high level. With the beginning of a synchronous transmission of a data byte, the data is shifted out at RXD with the falling edge of the shift clock. If a data byte is received through RXD, data is latched with the rising edge of the shift clock.

One shift clock cycle (f_{BR}) delay is inserted between two consecutive receive or transmit data bytes.

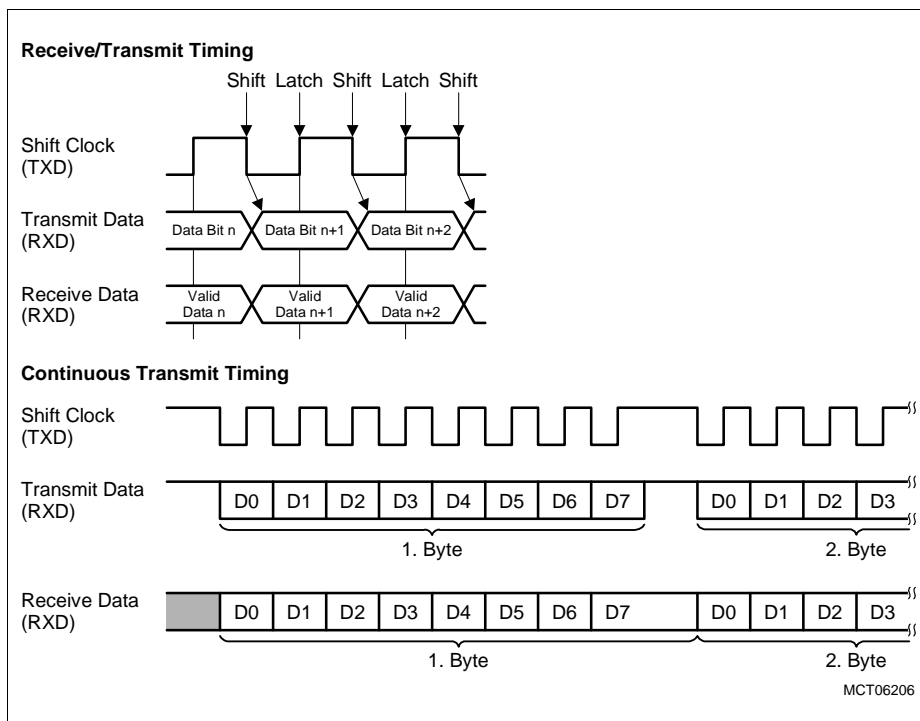


Figure 17-7 ASC Synchronous Mode Waveforms

Asynchronous/Synchronous Serial Interface (ASC)

17.1.5 Baud Rate Generation

The ASC has its own dedicated 13-bit baud rate generator with 13-bit reload capability, allowing baud rate generation independent of other timers.

The baud rate generator is clocked with a clock (f_{DIV}) which is derived via a prescaler from the ASC module clock f_{ASC} . The baud rate timer is counting downwards and can be started or stopped through the baud rate generator run bit CON.R. Each underflow of the timer generates one clock pulse to the serial channel. The timer is reloaded with the value stored in its 13-bit reload register at each underflow. The resulting clock f_{BRT} is again divided by a factor for the baud rate clock ($\div 16$ in asynchronous operating modes and $\div 4$ in synchronous operating mode). The prescaler is selected by the bits CON.BRS and CON.FDE. In the asynchronous operating modes, a fractional divider prescaler unit is available (in addition to the two fixed dividers) that allows selection of prescaler divider ratios of $n/512$ with $n = 0-511$. Therefore, the baud rate of ASC is determined by the module clock, the content of register FDV, the reload value in register BG, and the operating mode (asynchronous or synchronous).

Register BG is the dual-function baud rate generator/reload register. Reading BG returns the contents of the timer in bit field BR_VALUE (bits 31:13 return zero), while writing to BG always updates the reload register (bits 31:13 are insignificant).

An auto-reload of the timer with the contents of the reload register is performed each time BG is written to. However, if CON.R = 0 at the time the write operation to BG is performed, the timer will not be reloaded until the first instruction cycle after CON.R = 1. For a clean baud rate initialization, BG should only be written if CON.R = 0. If BG is written with CON.R = 1, an unpredictable behavior of the ASC may occur during running transmit or receive operations.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.5.1 Baud Rates in Asynchronous Mode

For asynchronous operation, the baud rate generator provides a clock f_{BRT} with sixteen times the rate of the established baud rate. Every received bit is sampled on the 7th, 8th and 9th cycle of this clock. The clock divider circuitry, which generates the input clock f_{DIV} for the 13-bit baud rate timer, is extended by a fractional divider circuitry that allows the adjustment of more accurate baud rates and the extension of the baud rate range.

The baud rate of the baud rate generator depends on the settings of the following bits and register values:

- Input clock f_{ASC}
- Selection of the baud rate timer input clock f_{DIV} by bits CON.FDE and CON.BRS
- If bit CON.FDE = 1 (fractional divider): value of register FDV
- Value of the 13-bit reload register BG

The output clock of the baud rate timer with the reload register is the sample clock in the asynchronous operating modes of the ASC. For baud rate calculations, this baud rate clock f_{BR} is derived from the sample clock f_{BRT} by a division of sixteen.

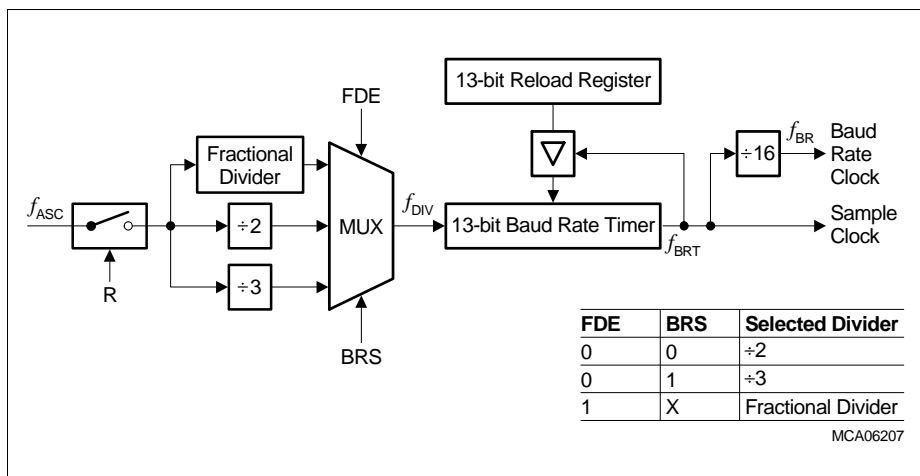


Figure 17-8 ASC Baud Rate Generator Circuitry in Asynchronous Modes

Asynchronous/Synchronous Serial Interface (ASC)

Using the Fixed Input Clock Divider

The baud rate for asynchronous operation of the serial channel ASC when using the fixed input clock divider ratios (CON.FDE = 0) and the required BG reload value for a given baud rate can be determined by the following formulas:

Table 17-1 Asynchronous Baud Rate Formulas using the Fixed Input Clock Dividers

FDE	BRS	BG	Formula
0	0	0 ... 8191	$\text{Baud rate} = \frac{f_{\text{ASC}}}{32 \times (\text{BG} + 1)}$ $\text{BG} = \frac{f_{\text{ASC}}}{32 \times \text{Baud rate}} - 1$
	1		$\text{Baud rate} = \frac{f_{\text{ASC}}}{48 \times (\text{BG} + 1)}$ $\text{BG} = \frac{f_{\text{ASC}}}{48 \times \text{Baud rate}} - 1$

BG represents the content of the reload register bit field BG.BR_VALUE, taken as an unsigned 13-bit integer.

The maximum baud rate that can be achieved for the asynchronous operating modes when using the two fixed clock dividers and a module clock of 110 MHz is 3.4375 Mbit/s. [Table 17-2](#) lists various commonly used baud rates together with the required reload values and the deviation errors compared to the intended baud rate.

Asynchronous/Synchronous Serial Interface (ASC)

Table 17-2 Typical Asynchronous Baud Rates using Fixed Input Clock Dividers

Baud Rate	CON.BRS = 0, $f_{ASC} = 110 \text{ MHz}$		CON.BRS = 1, $f_{ASC} = 110 \text{ MHz}$	
	Deviation Error	Reload Value	Deviation Error	Reload Value
3.4375 Mbit/s	–	0000 _H	–	–
19.2 kbit/s	+0.02% / -0.6%	00B2 _H / 00B3 _H	+0.3% / -0.6%	0076 _H / 0077 _H
9600 bit/s	+0.02% / -0.3%	0165 _H / 0166 _H	+0.3% / -0.1%	00ED _H / 00EE _H
4800 bit/s	+0.02% / -0.1%	02CB _H / 02CC _H	+0.1% / -0.1%	01DC _H / 01DD _H

Note: CON.FDE must be 0 to achieve the baud rates in the table above. The deviation errors given in the table are rounded. Using a baud rate crystal will provide correct baud rates without deviation errors.

Asynchronous/Synchronous Serial Interface (ASC)

Using the Fractional Divider

When the fractional divider is selected, the input clock f_{DIV} for the baud rate timer is derived from the module clock f_{ASC} by a programmable fractional divider. If $CON.FDE = 1$, the fractional divider is activated. It divides f_{ASC} by a fraction of $n/512$ for any value of n from 0 to 511. If $n = 0$, the divider ratio is 1, which means that $f_{DIV} = f_{ASC}$. In general, the fractional divider allows the baud rate to be programmed with much better accuracy than with the two fixed prescaler divider stages.

Note: In fractional divider mode, the clock f_{DIV} can have a maximum period jitter of one f_{ASC} clock period.

Table 17-3 Asynchronous Baud Rate Formulas using the Fractional Input Clock Divider

FDE	BRS	BG	FDV	Formula
1	–	0 ... 8191	1 ... 511	Baud rate = $\frac{FDV}{512} \times \frac{f_{ASC}}{16 \times (BG + 1)}$
			0	Baud rate = $\frac{f_{ASC}}{16 \times (BG + 1)}$

BG represents the content of the reload register bit field BG.BR_VALUE, taken as an unsigned 13-bit integer. FDV represents the contents of the fractional divider register bit field FDV.FD_VALUE, taken as an unsigned 9-bit integer.

Table 17-4 Typical Asynchronous Baud Rates using the Fractional Input Clock Divider

f_{ASC}	Desired Baud Rate	BG	FDV	Resulting Baud Rate	Deviation
110 MHz	115.2 kbit/s	003A _H	1FA _H	115.160 kbit/s	-0.04%
	57.6 kbit/s	0075 _H	1FA _H	57.579 kbit/s	-0.04%

Asynchronous/Synchronous Serial Interface (ASC)

17.1.5.2 Baud Rates in Synchronous Mode

For synchronous operation, the baud rate generator provides a clock f_{BRT} that runs with four times the established baud rate (see [Figure 17-9](#)).

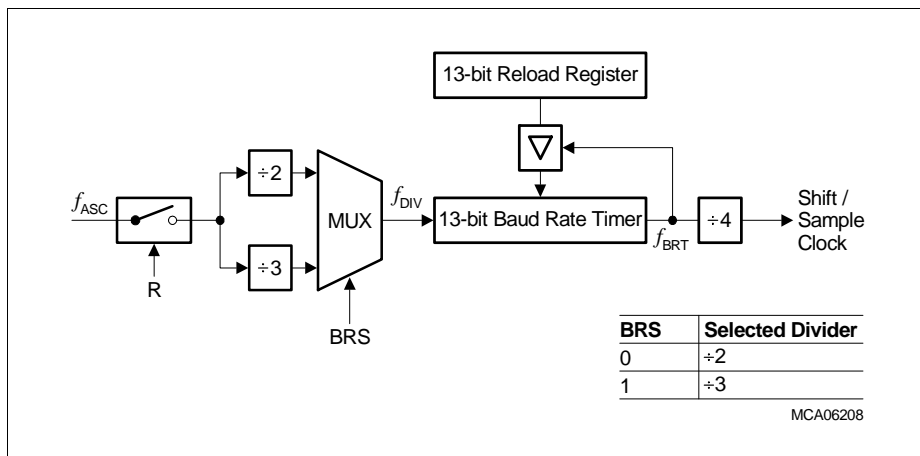


Figure 17-9 ASC Baud Rate Generator Circuitry in Synchronous Mode

The baud rate for synchronous operation of the serial channel ASC can be determined by the formulas as shown in [Table 17-5](#).

Table 17-5 Synchronous Baud Rate Formulas

BRS	BG	Formula
0	0 ... 8191	$\text{Baud rate} = \frac{f_{\text{ASC}}}{8 \times (\text{BG} + 1)} \quad \text{BG} = \frac{f_{\text{ASC}}}{8 \times \text{Baud rate}} - 1$
1		$\text{Baud rate} = \frac{f_{\text{ASC}}}{12 \times (\text{BG} + 1)} \quad \text{BG} = \frac{f_{\text{ASC}}}{12 \times \text{Baud rate}} - 1$

BG represents the content of the reload register bit field BG.BR_VALUE, taken as an unsigned 13-bit integer.

Asynchronous/Synchronous Serial Interface (ASC)

The maximum baud rate that can be achieved in Synchronous Mode when using a module clock of MHz is Mbit/s.

Asynchronous/Synchronous Serial Interface (ASC)

17.1.6 Hardware Error Detection Capabilities

To improve the reliability of serial data exchange, the serial channel ASC provides an error interrupt request flag that indicates the presence of an error and three (selectable) error status flags in register CON that indicate which error has been detected during reception. Upon completion of a reception, the error interrupt request line EIR will be activated simultaneously with the receive interrupt request line RIR, if one or more of the following conditions are met:

- If the framing error detection enable bit CON.FEN is set and any of the expected stop bits is not high, the framing error flag CON.FE is set, indicating that the error interrupt request is due to a framing error (asynchronous operating modes only).
- If the parity error detection enable bit CON.PEN is set in the modes where a parity bit is received and the parity check on the received data bits proves false, the parity error flag CON.PE is set, indicating that the error interrupt request is due to a parity error (asynchronous operating modes only).
- If the overrun error detection enable bit CON.OEN is set and the last character received was not read out of the receive buffer by software or DMA transfer at the time the reception of a new frame is complete, the overrun error flag CON.OE is set indicating that the error interrupt request is due to an overrun error (Asynchronous and Synchronous Modes).

17.1.7 Interrupts

Four interrupt sources are provided for serial channel ASC. Line TIR indicates a transmit interrupt, TBIR indicates a transmit buffer interrupt, RIR indicates a receive interrupt, and EIR indicates an error interrupt of the serial channel. The interrupt output lines TBIR, TIR, RIR, and EIR are activated (active state) for two periods of the module clock f_{ASC} .

The cause of an error interrupt request EIR (framing, parity, overrun error) can be identified by the error status flags CON.FE, CON.PE, and CON.OE.

Note: By contrast to the error interrupt request line EIR, the error status flags CON.FE/CON.PE/CON.OE are not reset automatically but must be cleared by software.

For normal operation (that is, other than error interrupt), the ASC provides three interrupt requests to control data exchange via this serial channel:

- TBIR is activated when data is moved from TBUF to the transmit shift register.
- TIR is activated before the last bit of an asynchronous frame is transmitted, or after the last bit of a synchronous frame has been transmitted.
- RIR is activated when the received frame is moved to RBUF.

While the task of the receive interrupt handler is quite clear, the transmitter is serviced by two interrupt handlers. This provides advantages for the servicing software.

Asynchronous/Synchronous Serial Interface (ASC)

For single transfers, it is sufficient to use the transmitter interrupt (TIR), which indicates that the previously loaded data has been transmitted, except for the last bit of an asynchronous frame.

For multiple back-to-back transfers, it is necessary to load the following piece of data at least before the last bit of the previous frame has been transmitted. In Asynchronous Mode, this leaves just one bit-time for the handler to respond to the transmitter interrupt request; in Synchronous Mode, it is entirely impossible.

Using the Transmit Buffer Interrupt (TBIR) to reload transmit data provides the time necessary to transmit a complete frame for the service routine, as TBUF may be reloaded while the previous data is still being transmitted.

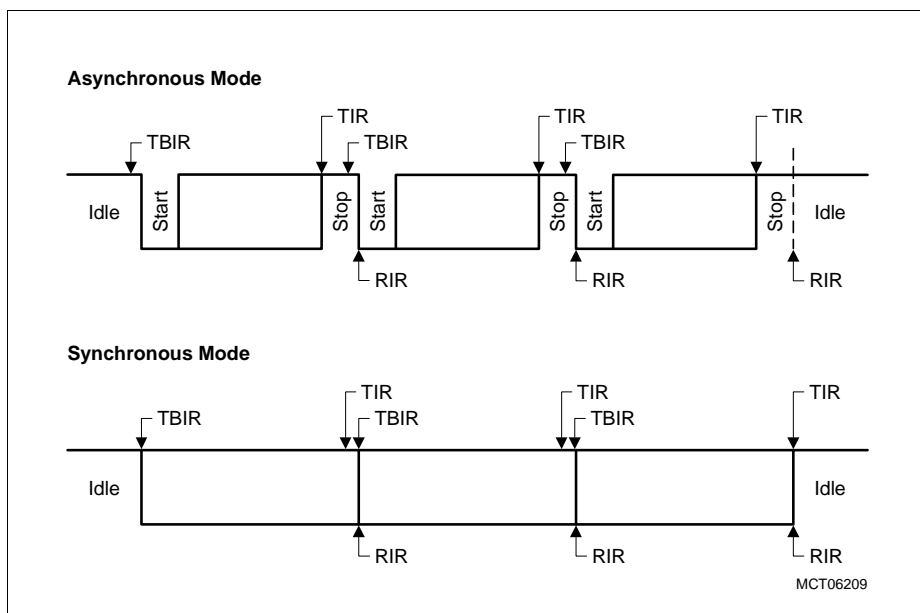


Figure 17-10 ASC Interrupt Generation

As shown in [Figure 17-10](#), TBIR is an early trigger for the reload routine, while TIR indicates the completed transmission. Software using handshake should, therefore, rely on TIR at the end of a data block to ensure that all data has been transmitted.

Asynchronous/Synchronous Serial Interface (ASC)

17.2 ASC Kernel Registers

This section describes the kernel registers of the ASC module. All ASC kernel register names described in this section will be referenced in other parts of the TC1728 User's Manual by the module name prefix "ASC0_" for the ASC0 interface and "ASC1_" for the ASC1 interface.

All registers in the ASC address spaces are reset with the application reset.

ASC Kernel Register Overview

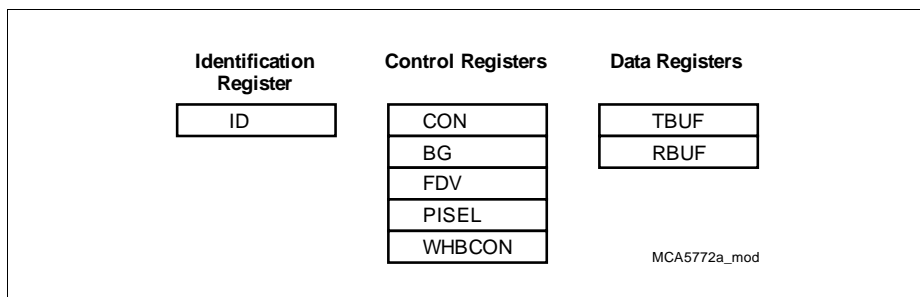


Figure 17-11 ASC Kernel Registers

The complete and detailed address map of the of the ASC module and its registers is described in [Table 17-10](#) on [Page 17-43](#).

Table 17-6 Registers Address Space

Module	Base Address	End Address	Note
ASC0	F000 0A00 _H	F000 0AFF _H	—
ASC1	F000 0B00 _H	F000 0BFF _H	—

Table 17-7 Registers Overview - ASC Kernel Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
PISEL	Peripheral Input Select Register	0004 _H	Page 17-22
ID	Module Identification Register	0008 _H	Page 17-23
CON	Control Register	0010 _H	Page 17-24
BG	Baud Rate Timer Reload Register	0014 _H	Page 17-29
FDV	Fractional Divider Register	0018 _H	Page 17-29
TBUF	Transmit Buffer Register	0020 _H	Page 17-30

Asynchronous/Synchronous Serial Interface (ASC)

Table 17-7 Registers Overview - ASC Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
RBUF	Receive Buffer Register	0024 _H	Page 17-31
WHBCON	Write Hardware Bits Control Register	0050 _H	Page 17-27

1) The absolute register address is calculated as follows:

Module Base Address (([Table 17-6](#) on [Page 17-21](#)) + Offset Address (shown in this column))

17.2.1 Control Registers

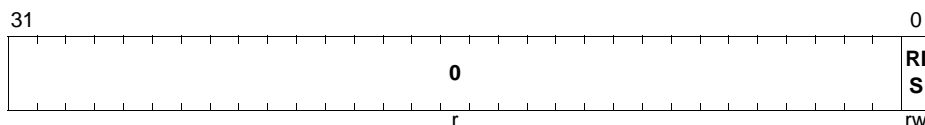
The ASC module kernel provides two receive input lines, RXD_I0 and RXD_I1. Bit RIS in the Peripheral Input Select Register PISEL determines which of these two input lines is taken for RXD receive input purposes.

PISEL

Peripheral Input Select Register

(04_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RIS	0	rw	Receive Input Select 0 _B ASC receiver input RXD_I0 selected 1 _B ASC receiver input RXD_I1 selected
0	[31:1]	r	Reserved Read as 0; should be written with 0.

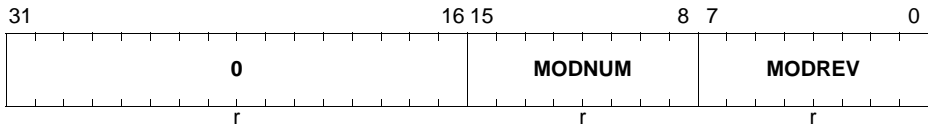
Note: Implementation specific details (RIS functionality) see “[Peripheral Input Select Register](#)” on [Page 17-37](#).

Asynchronous/Synchronous Serial Interface (ASC)

The ASC Module Identification Register ID contains read-only information about the module version.

ID

Module Identification Register (08_H) **Reset Value: 0000 44XX_H**



Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MODNUM	[15:8]	r	Module Number Value This bit field defines the module identification number for the ASC: 44 _H
0	[31:16]	r	Reserved Read as 0.

Asynchronous/Synchronous Serial Interface (ASC)

The serial operating modes of the ASC module are controlled by its Control Register CON. This register contains control bits for mode and error check selection, and status flags for error identification.

CON

Control Register

(10_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LB	BRS	ODD	FDE	OE	FE	PE	OEN	FEN	PEN	REN	STP	M		
rw	rw	rw	rw	rw	rwh	rwh	rwh	rw	rw	rw	rwh	rw			rw

Field	Bits	Type	Description
M	[2:0]	rw	Mode Selection 000 _B 8-bit data Synchronous Mode 001 _B 8-bit data Asynchronous Mode 010 _B Reserved. Do not use this combination. 011 _B 7-bit data + parity Asynchronous Mode 100 _B 9-bit data Asynchronous Mode 101 _B 8-bit data + wake up bit Asynchronous Mode 110 _B Reserved. Do not use this combination. 111 _B 8-bit data + parity Asynchronous Mode
STP	3	rw	Number of Stop Bit Selection 0 _B One stop bit 1 _B Two stop bits
REN	4	rwh	Receiver Enable Control 0 _B Receiver disabled 1 _B Receiver enabled Bit is reset by hardware after reception of a byte in Synchronous Mode.
PEN	5	rw	Parity Check Enable (asynchronous mode only) 0 _B Ignore parity 1 _B Check parity

Asynchronous/Synchronous Serial Interface (ASC)

Field	Bits	Type	Description
FEN	6	rw	Framing Check Enable (asynchronous mode only) 0 _B Ignore framing errors 1 _B Check framing errors
OEN	7	rw	Overrun Check Enable 0 _B Ignore overrun errors 1 _B Check overrun errors
PE	8	rwh	Parity Error Flag Set by hardware on a parity error (PEN = 1). Must be reset by software.
FE	9	rwh	Framing Error Flag Set by hardware on a framing error (FEN = 1). Must be reset by software.
OE	10	rwh	Overrun Error Flag Set by hardware on an overrun error (OEN = 1). Must be reset by software.
FDE	11	rw	Fractional Divider Enable 0 _B Fractional divider disabled 1 _B Fractional divider is enabled and used as prescaler for baud rate timer (bit BRS is don't care)
ODD	12	rw	Parity Selection 0 _B Even parity selected (parity bit = 1 on odd number of 1s in data, parity bit = 0 on even number of 1s in data) 1 _B Odd parity selected (parity bit = 1 on even number of 1s in data, parity bit = 0 on odd number of 1s in data)
BRS	13	rw	Baud Rate Selection 0 _B Baud rate timer prescaler divide-by-2 selected 1 _B Baud rate timer prescaler divide-by-3 selected BRS is don't care if FDE = 1 (fractional divider enabled)
LB	14	rw	Loop-back Mode Enable 0 _B Loop-Back mode disabled 1 _B Loop-Back mode enabled

Asynchronous/Synchronous Serial Interface (ASC)

Field	Bits	Type	Description
R	15	rw	Baud Rate Generator Run Control 0_B Baud rate generator disabled (ASC inactive) 1_B Baud rate generator enabled Register BG should only be written if R = 0.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Serial data transmission or reception is possible only when the run bit CON.R is set to 1. Otherwise, the serial interface is idle. To avoid unpredictable behavior of the serial interface, do not program the mode control field CON.M to one of the reserved combinations.

Critical “rwh” Bits

Register CON contains three error flags: PE, FE, and OE. If the software modifies only one of these error flags, it uses typically a Read-Modify-Write (RMW) instruction. When one of the other error flags that is not intended to be modified by the RMW instruction is changed by hardware after the read access but before the write back access of the RMW instruction, it is overwritten with the old bit value, and the hardware change of the bit gets lost. This problem does not affect the bits that are intended to be modified by the RMW instruction. It only affects bits that were not intended to be changed with the RMW instruction.

The three error flags in register CON and the REN bit can be additionally set or reset by software via register WHBCON. This capability avoids the problem with the CON register RMW instruction access to the error flags. WHBCON is a write-only register. Reading WHBCON always returns 0000 0000_H.

Asynchronous/Synchronous Serial Interface (ASC)

WHBCON

Write Hardware Bits Control Register (50_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	SET OE	SET FE	SET PE	CLR OE	CLR FE	CLR PE		0		SET REN	CLR REN			0	
r	w	w	w	w	w	w		r		w	w			r	

Field	Bits	Type	Description
CLRREN	4	w	Clear Receiver Enable Bit 0 _B No effect 1 _B Bit CON.REN is cleared. Bit is always read as 0.
SETREN	5	w	Set Receiver Enable Bit 0 _B No effect 1 _B Bit CON.REN is set. Bit is always read as 0.
CLRPE	8	w	Clear Parity Error Flag 0 _B No effect 1 _B Bit CON.PE is cleared. Bit is always read as 0.
CLRFE	9	w	Clear Framing Error Flag 0 _B No effect 1 _B Bit CON.FE is cleared. Bit is always read as 0.
CLROE	10	w	Clear Overrun Error Flag 0 _B No effect 1 _B Bit CON.OE is cleared. Bit is always read as 0.
SETPE	11	w	Set Parity Error Flag 0 _B No effect 1 _B Bit CON.PE is set. Bit is always read as 0.

Asynchronous/Synchronous Serial Interface (ASC)

Field	Bits	Type	Description
SETFE	12	w	Set Framing Error Flag 0 _B No effect 1 _B Bit CON.FE is set. Bit is always read as 0.
SETOE	13	w	Set Overrun Error Flag 0 _B No effect 1 _B Bit CON.OE is set. Bit is always read as 0.
0	[3:0], [7:6], [31:14]	r	Reserved Read as 0; should be written with 0.

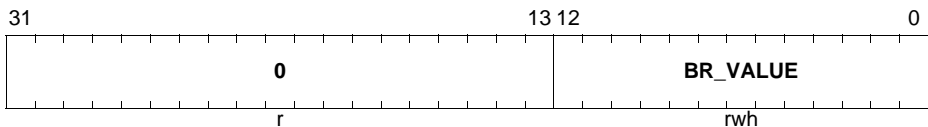
Note: When the set and clear bits for an error flag are set at the same time during a WHBCON write operation (e.g SETPE = CLRPE = 1), the error flag in CON is not affected.

Asynchronous/Synchronous Serial Interface (ASC)

The Baud Rate Timer Reload Register BG of the ASC module contains the 13-bit reload value for the baud rate timer in Asynchronous and Synchronous Modes.

BG

Baud Rate Timer/Reload Register (14_H) **Reset Value: 0000 0000_H**

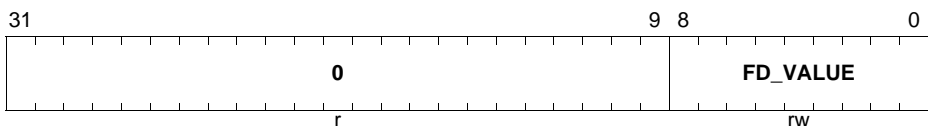


Field	Bits	Type	Description
BR_VALUE	[12:0]	rw	Baud Rate Timer/Reload Register Value Reading BR_VALUE returns the 13-bit content of the baud rate timer. Writing BR_VALUE loads the baud rate timer reload register. BG should only be written if CON.R = 0.
0	[31:13]	r	Reserved Read as 0; should be written with 0.

The Fractional Divider Register FDV of the ASC module contains the 9-bit divider value for the fractional divider (asynchronous mode only).

FDV

Fractional Divider Register (18_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
FD_VALUE	[8:0]	rw	Fractional Divider Register Value FD_VALUE contains the 9-bit value n of the fractional divider which determines the fractional divider ratio n/512 (n = 0-511). With n = 0, the fractional divider is switched off (divider ratio = 1).
0	[31:9]	r	Reserved Read as 0; should be written with 0.

Asynchronous/Synchronous Serial Interface (ASC)

17.2.2 Data Registers

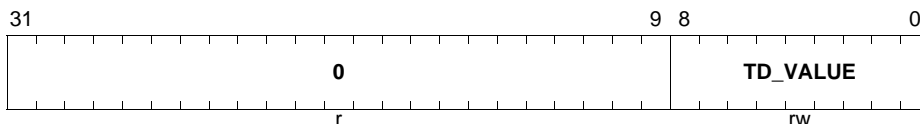
The Transmit Buffer Register TBUF of the ASC module contains the transmit data value in Asynchronous And Synchronous Modes.

TBUF

Transmit Buffer Register

(20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TD_VALUE	[8:0]	rw	Transmit Data Register Value TBUF contains the data to be transmitted in the asynchronous and synchronous operating modes of the ASC. Data transmission is double-buffered; therefore, a new value can be written to TBUF before the transmission of the previous value is complete.
0	[31:9]	r	Reserved Read as 0; should be written with 0.

Asynchronous/Synchronous Serial Interface (ASC)

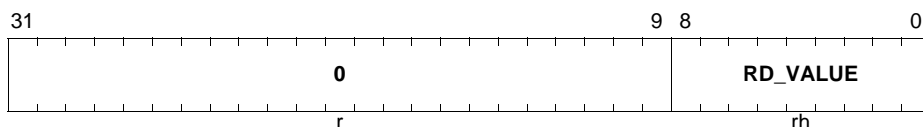
The receive buffer register RBUF of the ASC module contains the receive data value in Asynchronous and Synchronous Modes.

RBUF

Receive Buffer Register

(24_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RD_VALUE	[8:0]	rh	Receive Data Register Value RBUF contains the received data bits and, depending on the selected mode, the parity bit in the asynchronous and synchronous operating modes of the ASC. In Asynchronous Mode, with CON.M = 011 _B (7-bit data + parity), the received parity bit is written into RBUF.7. In Asynchronous Mode, with CON.M = 111 _B (8-bit data + parity), the received parity bit is written into RBUF.8.
0	[31:9]	r	Reserved Read as 0.

Asynchronous/Synchronous Serial Interface (ASC)

17.3 ASC0/ASC1 Module Implementation

This section describes ASC0/ASC1 module interfaces with the clock control, port connections, interrupt control, and address decoding.

17.3.1 Interfaces of the ASC Modules

The serial I/O lines of both modules are connected to Port 3. Each of the ASC modules is further supplied with interrupt control, address decoding, and port control logic. Two DMA requests can be generated by each ASC module. Both ASC modules are supplied by one common clock control unit.

Asynchronous/Synchronous Serial Interface (ASC)

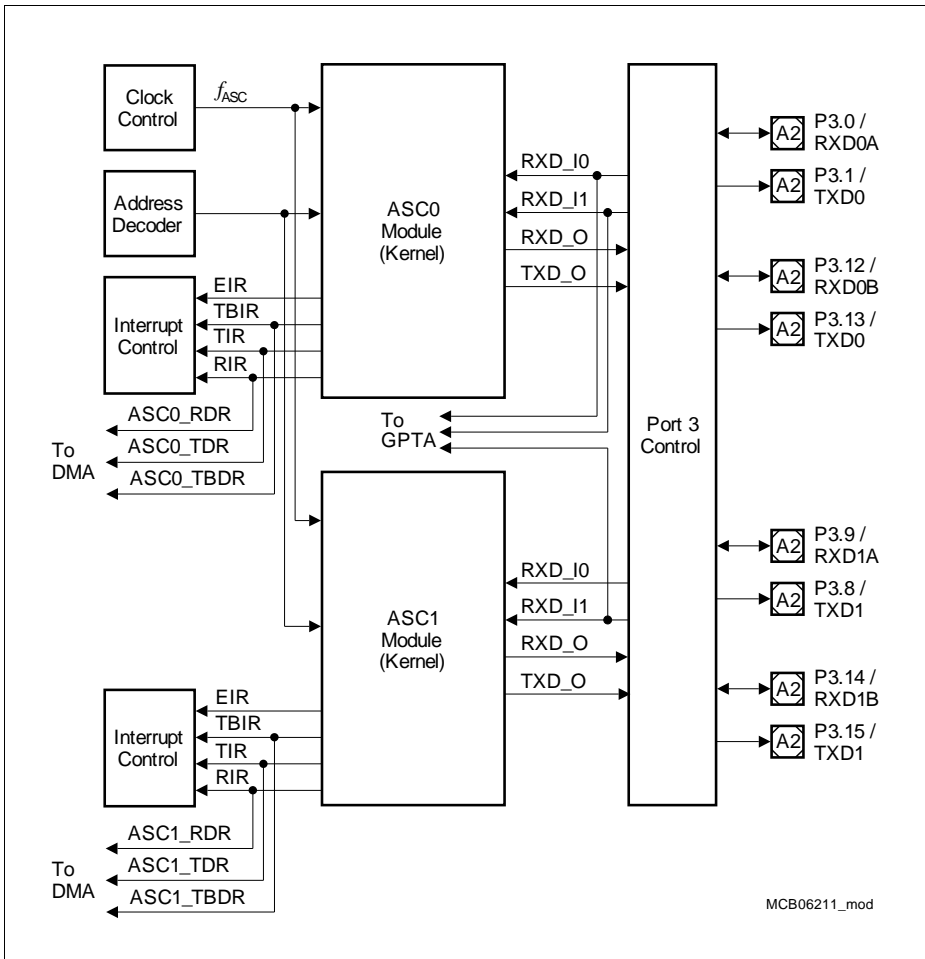


Figure 17-12 ASC0/ASC1 Module Implementation and Interconnections

Some of the receive inputs of the ASC0 and ASC1 are connected via a multiplexer to an LTC input of the GPTA module. Details are described in the SCU and the GPTA chapters.

Asynchronous/Synchronous Serial Interface (ASC)

17.3.2 ASC0/ASC1 Module Related External Registers

Figure 17-12 summarizes the module-related external registers which are required for ASC0/ASC1 programming (see also **Figure 17-11** for the module kernel-specific registers).

Control Registers	Port Registers	Interrupt Registers
ASC0_CLC	P3_IOCRO	ASC0_TSRC
ASC0_PISEL	P3_IOCRO8	ASC0_RSRC
ASC1_PISEL	P3_IOCRO12	ASC0_ESRC
	P3_PDR	ASC0_TB SRC
		ASC1_TSRC
		ASC1_RSRC
		ASC1_ESRC
		ASC1_TB SRC

MCA06212

Figure 17-13 ASC0/ASC1 Implementation-specific Special Function Registers

Asynchronous/Synchronous Serial Interface (ASC)

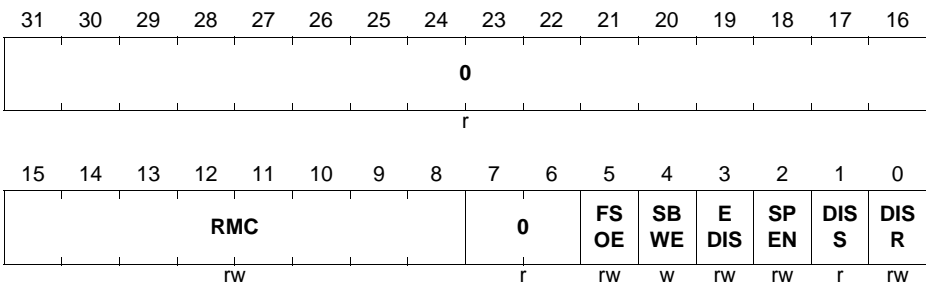
17.3.2.1 Clock Control Register

The Clock Control Register ASC0_CLC allows the programmer to adapt the functionality and power consumption of the ASC modules to the requirements of the application. The description below shows the clock control register functionality which is implemented for the ASC modules. Because ASC0 and ASC1 share one common clock control interface, ASC0_CLC controls the f_{ASC} module clock signal, sleep mode, suspend mode and fast shut-off mode for both modules.

ASC0_CLC

ASC0 Clock Control Register

(00_H)

Reset Value: 0000 0003_H


Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode.
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used to switch off fast clock in Suspend Mode.
RMC	[15:8]	rw	8-bit Clock Divider Value in RUN Mode
0	[7:6], [31:16]	r	Reserved Read as 0; should be written with 0.

Asynchronous/Synchronous Serial Interface (ASC)

Note: After a hardware reset operation, the two ASC modules are disabled.

Note: The number of module clock cycles (wait states) which are required for a "destructive read" access (means: flags/bits are set/reset by one read access) to ASC module register depends on the selected CLC clock frequency, which is selected via bit field RMC in the CLC register. Therefore, increasing ASC0_CLC.RMC may result in a longer FPI Bus read cycle access time.

Asynchronous/Synchronous Serial Interface (ASC)

17.3.2.2 Peripheral Input Select Register

The ASC0/ASC1 modules include a peripheral input select registers that are used to switch the RXD input lines of the ASC0/ASC1 module kernels between different pair of pins of Port 3 as shown in [Figure 17-14](#). Register ASC0_PISEL controls the RXD input selection for ASC0, and ASC1_PISEL controls the RXD input selection for ASC1.

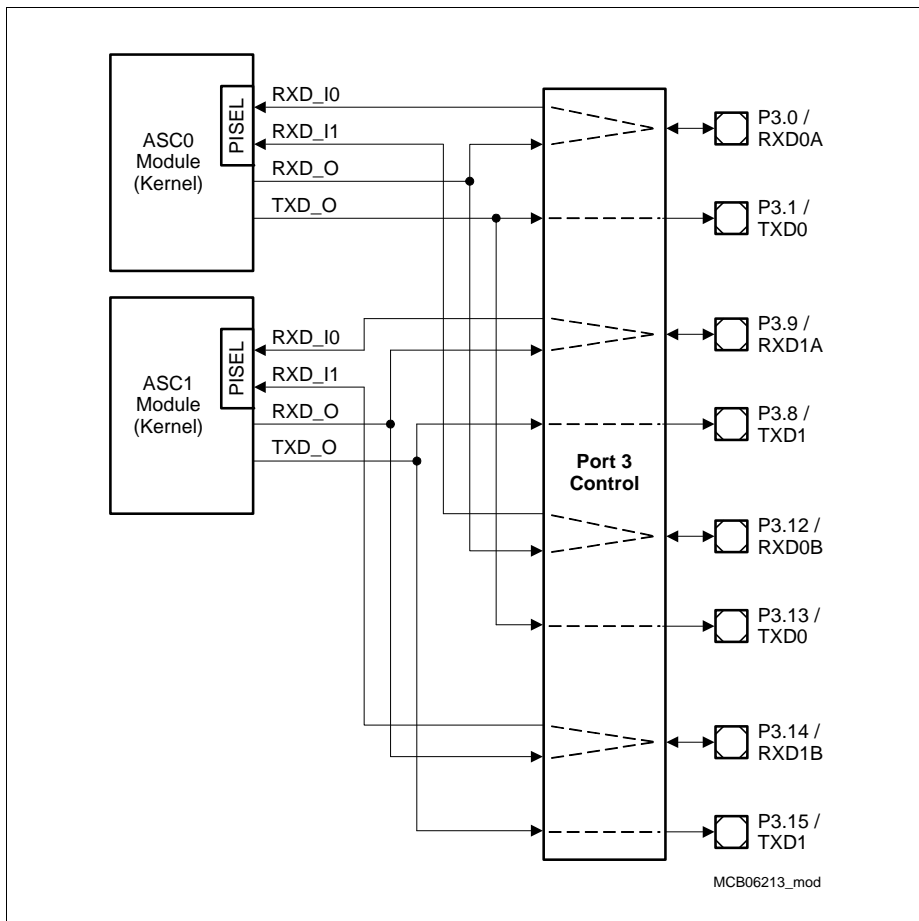


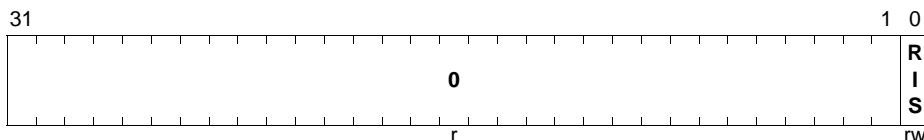
Figure 17-14 RXD Input Line Selection of the ASC Modules

Asynchronous/Synchronous Serial Interface (ASC)

ASC0_PISEL

ASC0 Peripheral Input Select Register

(04_H)

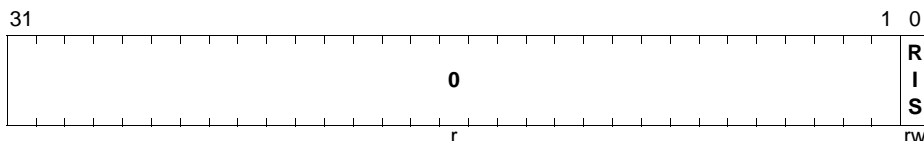
Reset Value: 0000 0000_H


Field	Bits	Type	Description
RIS	0	rw	Receive Input Select 0 _B ASC0 receiver input RXD0A (P3.0) selected 1 _B ASC0 receiver input RXD0B (P3.12) selected
0	[31:1]	0	Reserved Read as 0; should be written with 0.

ASC1_PISEL

ASC1 Peripheral Input Select Register

(04_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RIS	0	rw	Receive Input Select 0 _B ASC1 receiver input RXD1A (P3.9) selected 1 _B ASC1 receiver input RXD1B (P3.14) selected
0	[31:1]	0	Reserved Read as 0; should be written with 0.

Asynchronous/Synchronous Serial Interface (ASC)

17.3.2.3 Port Control Registers

As shown in [Figure 17-12](#), the I/O lines of the ASC modules are connected to Class A2 port pins of Port 3. Additionally to the PISEL register programming, the required ASC port lines must be programmed by software for the desired ASC input/output functionality. Two selections must be executed:

- Input/output function selection
(controlled by the port input/output control registers IOCR)
- Pad driver characteristics selection for the outputs
(controlled by the port pad driver mode register PDR)

Input/Output Function Selection

The port input/output control registers contain the 4-bit wide bit fields that select the digital output and input driver characteristics such as pull-up/down devices, port direction (input/output), open-drain, and alternate output selections individually for each pin. The I/O lines for the ASC modules are controlled by the port input/output control registers P3_IOCR0, P3_IOCR8 and P3_IOCR12.

[Table 17-8](#) shows how bits and bit fields must be programmed for the required I/O functionality of the ASC I/O lines. This table also shows the values of the peripheral input select registers.

Table 17-8 ASC0/ASC1 I/O Control Selection and Setup

Module	Port Lines	PISEL Register	Input/Output Control Register Bits	I/O
ASC0	P3.0/RXD0A	ASC0_PISEL.RIS = 0	P3_IOCR0.PC0 = 0XXX _B	Input
		—	P3_IOCR0.PC0 = 1X01 _B	Output ¹⁾
	P3.12/RXD0B	ASC0_PISEL.RIS = 1	P3_IOCR12.PC12 = 0XXX _B	Input
		—	P3_IOCR12.PC12 = 1X01 _B	Output ¹⁾
	P3.1/TXD0	—	P3_IOCR0.PC1 = 1X01 _B	Output
	P3.13/TXD0	—	P3_IOCR12.PC13 = 1X10 _B	Output
ASC1	P3.9/RXD1A	ASC1_PISEL.RIS = 0	P3_IOCR8.PC9 = 0XXX _B	Input
		—	P3_IOCR8.PC9 = 1X01 _B	Output ¹⁾
	P3.14/RXD1B	ASC1_PISEL.RIS = 1	P3_IOCR12.PC14 = 0XXX _B	Input
		—	P3_IOCR12.PC14 = 1X01 _B	Output ¹⁾
	P3.8/TXD1	—	P3_IOCR8.PC8 = 1X10 _B	Output
	P3.15/TXD1	—	P3_IOCR12.PC15 = 1X10 _B	Output

1) Applicable in Synchronous Mode only.

Asynchronous/Synchronous Serial Interface (ASC)

*Note: In synchronous operating mode of the ASC, the type of the selected RXD port pin (input or output) is **not** automatically controlled by the ASC but must be defined by a user program by writing the appropriate bit field in the IOCR registers.*

Asynchronous/Synchronous Serial Interface (ASC)

17.3.2.4 Interrupt Control Registers

The eight interrupts of the ASC0 and ASC1 modules are controlled by the following service request control registers:

- ASC0_TSRC, ASC1_TSRC: control the transmit interrupts
- ASC0_RSRC, ASC1_RSRC: control the receive interrupts
- ASC0_ESRC, ASC1_ESRC: control the error interrupts
- ASC0_TBSRC, ASC1_TBSRC: control the transmit buffer empty interrupts

TSRC

Transmit Interrupt Service Request Control Register

(F0_H)

Reset Value: 0000 0000_H

RSRC

Receive Interrupt Service Request Control Register

(F4_H)

Reset Value: 0000 0000_H

ESRC

Error Interrupt Service Request Control Register

(F8_H)

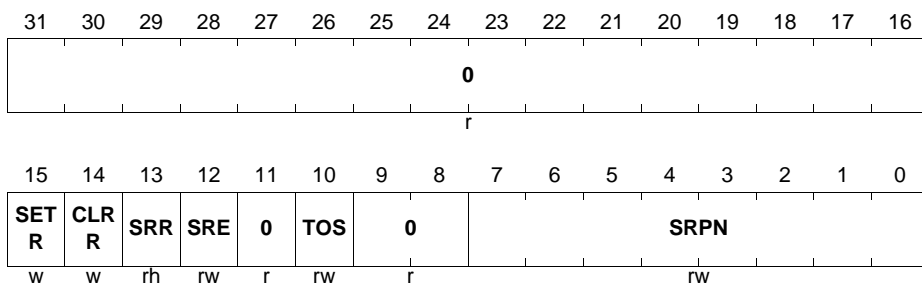
Reset Value: 0000 0000_H

TBSRC

Transmit Buffer Interrupt Service Request Control Register

(FC_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit

Asynchronous/Synchronous Serial Interface (ASC)

Field	Bits	Type	Description
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

17.3.3 DMA Requests

The DMA request output lines of the ASC0/ASC1 modules become active whenever the related ASC interrupt line becomes activated. The DMA request lines are connected to the DMA controller as shown in [Table 17-9](#).

Table 17-9 DMA Request Lines of ASC0/ASC1

Module	Related ASC Interrupt	DMA Request Line	Description
ASC0	RIR	ASC0_RDR	DMA Channel 00 Request Input 5
			DMA Channel 06 Request Input 5
	TIR	ASC0_TDR	DMA Channel 02 Request Input 5
			DMA Channel 04 Request Input 5
	TBIR	ASC0_TBDR	DMA Channel 02 Request Input 12
			DMA Channel 04 Request Input 12
ASC1	RIR	ASC1_RDR	DMA Channel 01 Request Input 5
			DMA Channel 07 Request Input 5
	TIR	ASC1_TDR	DMA Channel 03 Request Input 5
			DMA Channel 05 Request Input 5
	TBIR	ASC1_TBDR	DMA Channel 03 Request Input 12
			DMA Channel 05 Request Input 12

Note: Further details on DMA handling and processing are described in the chapter “DMA Controller” of the TC1728 System Units User’s Manual.

The reset values of the ASC0_ID and ASC1_ID module identification registers are 0000 4402_H.

Asynchronous/Synchronous Serial Interface (ASC)

17.3.4 Address Map

An absolute register address is given by the offset address of the register (given in [Table 17-7](#)) plus the module base address (given in [Table 17-6](#)).

Table 17-10 Address Map of ASC0/ASC1

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
Async./Sync. Serial Interface 0 (ASC0)					
ASC0_ CLC	ASC0 Clock Control Register	F000 0A00 _H	U, SV	SV, E	0000 0003 _H
ASC0_ PISEL	ASC0 Peripheral Input Select Register	F000 0A04 _H	U, SV	U, SV	0000 0000 _H
ASC0_ ID	ASC0 Module Identification Register	F000 0A08 _H	U, SV	BE	0000 44XX _H
–	Reserved	F000 0A0C _H	BE	BE	–
ASC0_ CON	ASC0 Control Register	F000 0A10 _H	U, SV	U, SV	0000 0000 _H
ASC0_ BG	ASC0 Baud Rate/Timer Reload Register	F000 0A14 _H	U, SV	U, SV	0000 0000 _H
ASC0_ FDV	ASC0 Fractional Divider Register	F000 0A18 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0A1C _H	BE	BE	–
ASC0_ TBUF	ASC0 Transmit Buffer Register	F000 0A20 _H	U, SV	U, SV	0000 0000 _H
ASC0_ RBUF	ASC0 Receive Buffer Register	F000 0A24 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0A28 _H - F000 0A4C _H	BE	BE	–
ASC0_ WHBCON	ASC0 Write Hardware Bits Control Register	F000 0A50 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0A54 _H - F000 0AEC _H	BE	BE	–
ASC0_ TSRC	ASC0 Transmit Interrupt Service Req. Control Reg.	F000 0AF0 _H	U, SV	U, SV	0000 0000 _H
ASC0_ RSRC	ASC0 Receive Interrupt Service Req. Control Reg.	F000 0AF4 _H	U, SV	U, SV	0000 0000 _H

Asynchronous/Synchronous Serial Interface (ASC)

Table 17-10 Address Map of ASC0/ASC1 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
ASC0_ ESRC	ASC0 Error Interrupt Service Req. Control Reg.	F000 0AF8 _H	U, SV	U, SV	0000 0000 _H
ASC0_ TBSRC	ASC0 Transmit Buffer Interrupt Service Req. Control Reg.	F000 0AFC _H	U, SV	U, SV	0000 0000 _H
Async./Sync. Serial Interface 1 (ASC1)					
–	Reserved	F000 0B00 _H	BE	BE	–
ASC1_ PISEL	ASC1 Peripheral Input Select Register	F000 0B04 _H	U, SV	U, SV	0000 0000 _H
ASC1_ ID	ASC1 Module Identification Register	F000 0B08 _H	U, SV	BE	0000 44XX _H
–	Reserved	F000 0B0C _H	BE	BE	–
ASC1_ CON	ASC1 Control Register	F000 0B10 _H	U, SV	U, SV	0000 0000 _H
ASC1_ BG	ASC1 Baud Rate/Timer Reload Register	F000 0B14 _H	U, SV	U, SV	0000 0000 _H
ASC1_ FDV	ASC1 Fractional Divider Register	F000 0B18 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0B1C _H	BE	BE	–
ASC1_ TBUF	ASC1 Transmit Buffer Register	F000 0B20 _H	U, SV	U, SV	0000 0000 _H
ASC1_ RBUF	ASC1 Receive Buffer Register	F000 0B24 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0B28 _H - F000 0B4C _H	BE	BE	–
ASC1_ WHBCON	ASC1 Write Hardware Bits Control Register	F000 0B50 _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0B54 _H - F000 0BEC _H	BE	BE	–
ASC1_ TSRC	ASC1 Transmit Interrupt Service Req. Control Reg.	F000 0BF0 _H	U, SV	U, SV	0000 0000 _H
ASC1_ RSRC	ASC1 Receive Interrupt Service Req. Control Reg.	F000 0BF4 _H	U, SV	U, SV	0000 0000 _H

Asynchronous/Synchronous Serial Interface (ASC)
Table 17-10 Address Map of ASC0/ASC1 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
ASC1_ ESRC	ASC1 Error Interrupt Service Req. Control Reg.	F000 0BF8 _H	U, SV	U, SV	0000 0000 _H
ASC1_ TBSRC	ASC1 Transmit Buffer Interrupt Service Req. Control Reg.	F000 0BFC _H	U, SV	U, SV	0000 0000 _H

Synchronous Serial Interface (SSC)

18 Synchronous Serial Interface (SSC)

This chapter describes the four SSC Synchronous Serial Interfaces SSC0, SSC1, SSC2 and SSC3 of the TC1728. It contains the following sections:

- Functional description of the SSC kernel, valid for SSC0, SSC1, SSC2 and SSC3 (see [Page 18-1](#)).
- SSC kernel register description, describes all SSC kernel specific registers (see [Page 18-27](#)).
- TC1728 implementation-specific details and registers of the SSC0/SSC1/SSC2 modules (port connections and control, interrupt control, address decoding, clock control, see [Page 18-43](#)).

Note: The SSC kernel register names described in [Section 18.2](#) are referenced in the TC1728 User's Manual by the module name prefix "SSC0_" for the SSC0 interface, by "SSC1_" for the SSC1 interface, and by "SSC2_" for the SSC2 interface.

18.1 SSC Kernel Description

[Figure 18-1](#) shows a global view of the SSC interface.

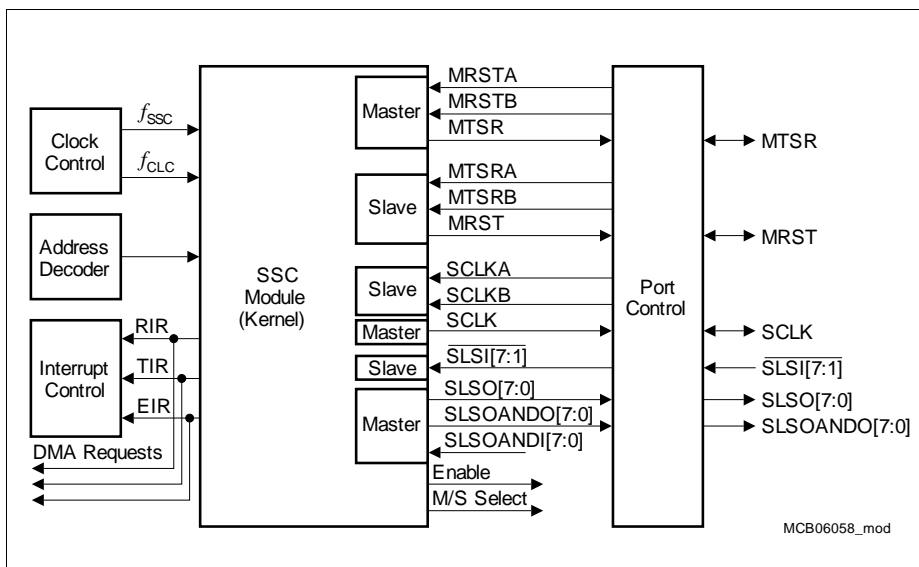


Figure 18-1 General Block Diagram of the SSC Interface

Synchronous Serial Interface (SSC)

18.1.1 Overview

The SSC supports full-duplex and half-duplex serial synchronous communication up to 55.0 Mbit/s (@ 110.0 MHz module clock, Master Mode). The serial clock signal can be generated by the SSC itself (Master Mode) or can be received from an external master (Slave Mode). Data width, shift direction, clock polarity and phase are programmable. This allows communication with SPI-compatible devices. Transmission and reception of data is double-buffered. A shift clock generator provides the SSC with a separate serial clock signal. Seven slave select inputs are available for Slave Mode operation. Eight programmable slave select outputs (chip selects) are supported in Master Mode.

Features:

- Master and Slave Mode operation
 - Full-duplex or half-duplex operation
 - Automatic pad control possible
- Flexible data format
 - Programmable number of data bits: 2 to 16 data bits (with parity: 1 to 15 data bits)
 - Programmable shift direction: LSB or MSB shift first
 - Programmable clock polarity: Idle low or idle high state for the shift clock
 - Programmable clock/data phase: Data shift with leading or trailing edge of the shift clock
- Baud rate generation
 - Master Mode: 55.0 Mbit/s to 839.3 bit/s (@ 110 MHz module clock)
 - Slave Mode: 27.5 Mbit/s to 839.3 bit/s (@ 110 MHz module clock)
- Interrupt generation
 - On a transmitter empty condition
 - On a receiver full condition
 - On an error condition (receive, phase, baud rate, transmit error, parity error)
- Queued SSC Mode supports control and data handling by the DMA controller
- Flexible SSC pin configuration
- Hardware supported parity mode
 - Individually selectable for transmit and receive frames
 - Even/odd parity selection
- Seven slave select inputs SLSI[7:1] in Slave Mode
- Eight programmable slave select outputs SLSO[7:0] in Master Mode
 - Automatic SLSO generation with programmable timing
 - Programmable active level and enable control
 - Combinable with SLSO output signals from other SSC modules

Synchronous Serial Interface (SSC)

18.1.2 General Operation

The SSC supports full-duplex and half-duplex synchronous communication up to 55.0 Mbit/s (@ 110.0 MHz module clock). The serial clock signal can be generated by the SSC itself (Master Mode) or be received from an external master (Slave Mode). Data width, shift direction, clock polarity and phase are programmable. This allows communication with SPI-compatible devices. Transmission and reception of data are double-buffered. A shift clock generator provides the SSC with a separate serial clock signal.

Configuration of the high-speed synchronous serial interface is very flexible, so it can work with other synchronous serial interfaces, can serve master/slave or multi-master interconnections, or can operate compatibly with the popular SPI interface. It can be used to communicate with shift registers (I/O expansion), peripherals (e.g. EEPROMs etc.), or other controllers (networking). The SSC supports half-duplex and full-duplex communication. Data is transmitted or received on pins MTSR (Master Transmit/Slave Receive) and MRST (Master Receive/Slave Transmit). The clock signal is output or input via pin SCLK (Serial Clock). These three pins are typically used for alternate output functions of port pins. If they are implemented as dedicated bi-directional pins, they can be directly controlled by the SSC. In Slave Mode, the SSC can be selected from a master via dedicated slave select input lines (SLSI). In Master Mode, automatic generation of slave select output lines (SLSO) is supported. In Master Mode, control and data handling of transfers can be also be controlled independently by the DMA controller (Queued SSC Mode).

Synchronous Serial Interface (SSC)

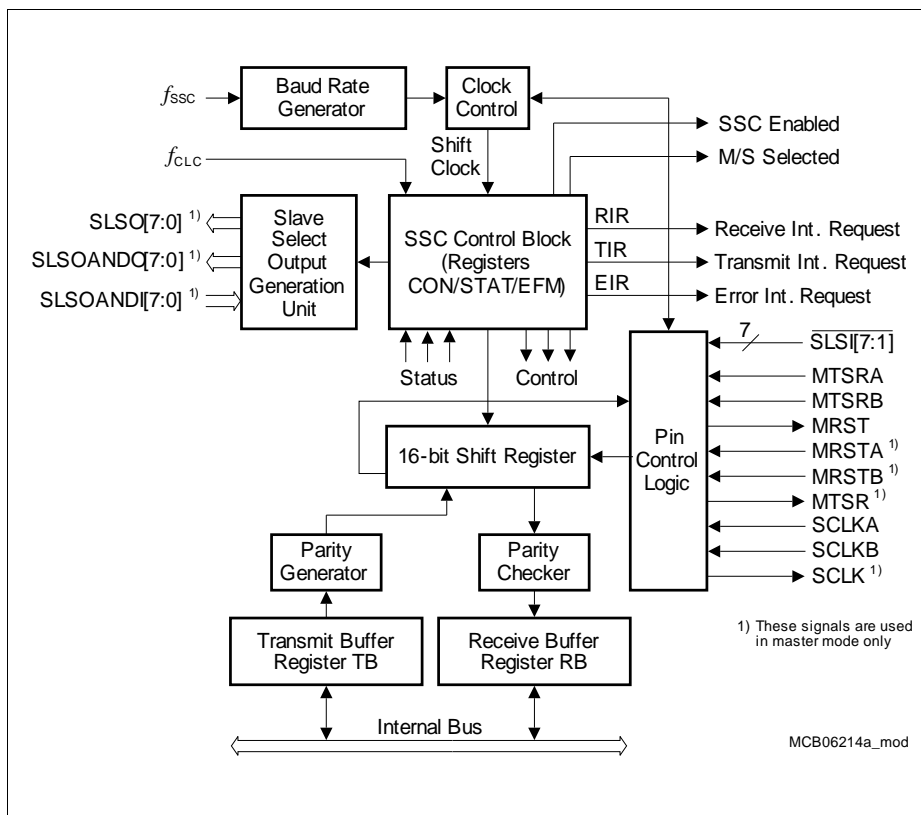


Figure 18-2 Synchronous Serial Channel SSC Block Diagram

Synchronous Serial Interface (SSC)

18.1.2.1 Operating Mode Selection

The operating mode of the serial channel SSC is controlled by its Control Register, CON. Status information is contained in its Status Register, STAT.

The shift register of the SSC is connected to both the transmit pin and the receive pin via the pin control logic (see block diagram in [Figure 18-2](#)). Transmission and reception of serial data are synchronized and take place at the same time, that is, the same number of transmitted bits is also received. Transmit data is written into the Transmit Buffer TB. It is moved to the shift register as soon as this is empty, including the generated parity bit for the transmit data if transmit parity mode is enabled (CON.PARTEN = 1). An SSC master (CON.MS = 1) immediately begins transmitting, while an SSC slave (CON.MS = 0) will wait for an active shift clock. When the transfer starts, the busy flag STAT.BSY is set, and the transmit interrupt request line (TIR) will be activated to indicate that the Transmit Buffer Register (TB) may be reloaded. When the number of bits as programmed in CON.BM have been received, the data bits of the shift register are moved to the Receive Buffer Register (RB) right-aligned, the receive parity bit (if enabled by CON.PARREN = 1) is loaded into STAT.PARRVAL, and the receive interrupt request line (RIR) will be activated. If no further transfer is to take place (TB is empty), STAT.BSY will be cleared at the same time. Software should not modify STAT.BSY, as this flag is hardware-controlled.

Note: Only one SSC can be master at a given time.

The following features of the serial data bit transfer can be programmed:

- The data width can be selected from 2 to 16 data bits (with parity: 1 to 15 data bits)
- A transfer may start with the LSB or the MSB of the data bits
- The shift clock may be idle low or idle high
- The data bits may be shifted with the leading or trailing edge of the clock signal
- The baud rate (shift clock) can be set from 839.3 bit/s up to 55.0Mbit/s (@ 110 MHz module clock)
- The shift clock can be generated (master) or received (slave)

These features allow the SSC to be adapted to a wide range of applications that require serial data transfer.

The Data Width Selection supports the transfer of frames of any data length from 2-bit “characters” up to 16-bit “characters”. If parity is enabled, the maximum number of data bits of a frame is 15-bit.

Starting the serial data bit transfer with the LSB (CON.HB = 0) allows communication with devices such as an SSC device in Synchronous Mode, or 8051-like serial interfaces. If parity mode is enabled, the parity bit preceeds the serial data bit transfer (see [Page 18-12](#)).

Starting with the MSB (CON.HB = 1) allows operation compatible with the SPI interface. If parity mode is enabled, the parity bit follows the serial data bit transfer (see [Page 18-12](#)).

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Regardless of the selected data width and whether the MSB or the LSB is transmitted first, the transfer data is always right-aligned in registers TB and RB, with the LSB of the transfer data in bit 0 of these registers. The data bits are rearranged for transfer by the internal shift register logic. The unselected bits of TB are ignored, and the unselected bits of RB will not be valid and should be ignored by the receiver service routine.

The Clock Control allows the adaptation of transmit and receive behavior of the SSC to a variety of serial interfaces. A specific clock edge (rising or falling) is used to shift out transmit data, while the other clock edge is used to latch in receive data. Bit CON.PH selects the leading edge or the trailing edge for each function. Bit CON.PO selects the level of the clock line in the idle state. For an idle-high clock, the leading edge is a falling one, a 1-to-0 transition (see [Figure 18-3](#)).

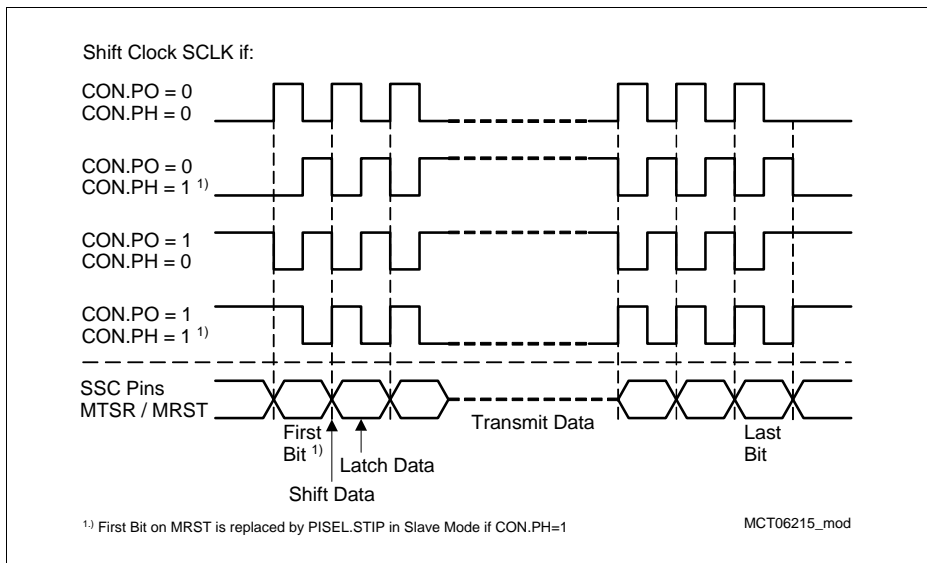


Figure 18-3 Serial Clock SCLK Phase and Polarity Options

18.1.2.2 Full-Duplex Operation

The description in this section assumes that the SSC is used with software controlled bi-directional GPIO port lines that have open-drain capability (see also [Section 18.1.2.6](#)).

The various devices are connected through three lines. The definition of these lines is always determined by the master. The line connected to the master's data output pin MTSR is the transmit line, the receive line is connected to its data input line MRST, and the clock line is connected to pin SCLK. Only the device selected for master operation generates and outputs the serial clock on pin SCLK. All slaves receive this clock, so their

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pin SCLK must be switched to input mode. The output of the master's shift register is connected to the external transmit line, which in turn is connected to the slaves' shift register input. The output of the slaves' shift register is connected to the external receive line in order to enable the master to receive the data shifted out of the slave. The external connections are hard-wired, with the function and direction of these pins determined by the master or slave operation of the individual device.

Note: The shift direction shown in [Figure 18-4](#) applies to both MSB-first and LSB-first operation.

When initializing the devices in this configuration, one device must be selected for master operation while all other devices must be programmed for slave operation. Initialization includes the operating mode of the device's SSC and also the function of the respective port lines.

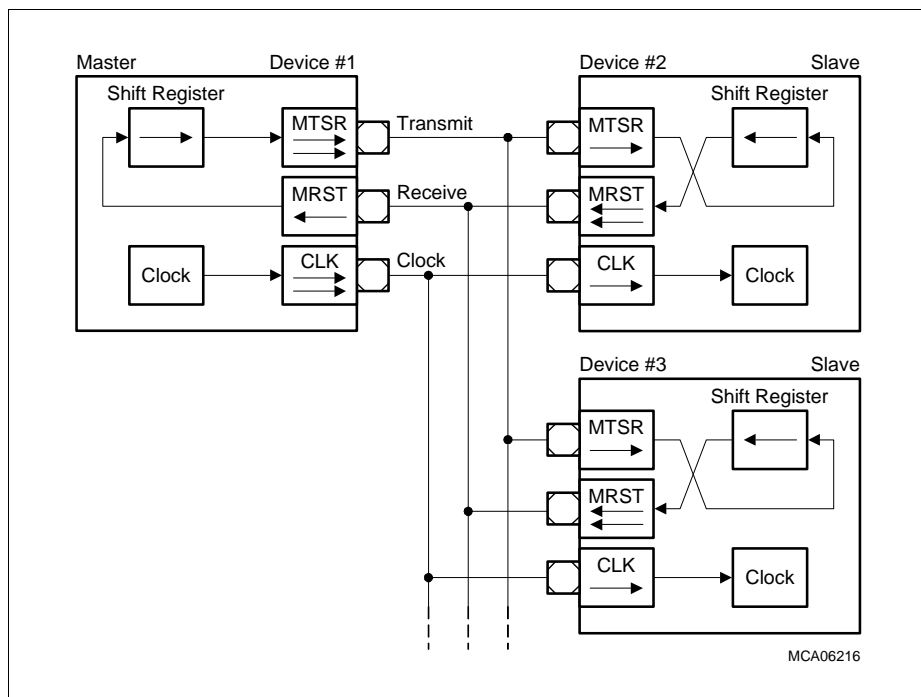


Figure 18-4 SSC Full-Duplex Configuration

The data output pins MRST of all slave devices are connected onto one receive line in this configuration. During a transfer, each slave shifts out data from its shift register. There are two ways to avoid collisions on the receive line due to different slave data:

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- **Only one slave drives the line** and enables the driver of its MRST pin. All the other slaves must program their MRST pins to input. Therefore, only one slave can put its data onto the master's receive line. Only reception of data from the master is possible. The master selects the slave device from which it expects data either by separate select lines, or by sending a special command to this slave. The selected slave then switches its MRST line to output until it gets a de-selection signal or command.
- **The slaves use open drain output on MRST.** This forms a wired-AND connection. The receive line needs an external pull-up in this case. Corruption of the data on the receive line sent by the selected slave is avoided when all slaves not selected for transmission to the master send only 1s. Since this high level is not actively driven onto the line, but is only held through the pull-up device, the selected slave can pull this line actively to a low level when transmitting a zero bit. The master selects the slave device from which it expects data either by separate select lines, or by sending a special command to this slave.

After performing all necessary initializations of the SSC, the serial interfaces can be enabled. For a master device, the alternate clock line will now go to its programmed polarity. The alternate data line will go to either 0 or 1, until the first transfer starts. After a transfer, the alternate data line will always remain at the logic level of the last transmitted data bit.

When the serial interfaces are enabled, the master device can initiate the first data transfer by writing the transmit data into register TB. This value is copied into the shift register (assumed to be empty at this time), and the selected first bit of the transmit data will be placed onto the MTSR line on the next clock from the shift clock generator (transmission only starts, if CON.EN = 1). Depending on the selected clock phase, a clock pulse is generated on the SCLK line. With the opposite clock edge, the master simultaneously latches and shifts in the data detected at its input line MRST. This "exchanges" the transmit data with the receive data. Because the clock line is connected to all slaves, their shift registers will be shifted synchronously with the master's shift register, shifting out the data contained in the registers, and shifting in the data detected at the input line. After the pre-programmed number of clock pulses (via the data width selection), the data transmitted by the master is contained in all slaves' shift registers, while the master's shift register holds the data of the selected slave. In the master and all slaves, the content of the shift register is copied into the Receive Buffer (RB) and the receive interrupt line (RIR) is activated.

A slave device will immediately output the selected first bit (MSB or LSB of the transfer data) at pin MRST when the contents of the transmit buffer are copied into the slave's shift register. Bit STAT.BSY is not set until the first clock edge at SCLK appears. The slave device will not wait for the next clock from the shift clock generator – as the master does – because the first clock edge generated by the master may be already used to clock in the first data bit, depending on the selected clock phase. So the slave's first data bit must already be valid at this time.

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*Note: On the SSC, a transmission **and** a reception always take place at the same time, regardless whether valid data has been transmitted or received.*

18.1.2.3 Half-Duplex Operation

The description in this section assumes that the SSC is used with software controlled bi-directional GPIO port lines that provide open-drain capability (see also [Section 18.1.2.6](#)).

In a half-duplex configuration, only one data line is necessary for both receiving **and** transmitting data. The data exchange line is connected to both pins MTSR and MRST of each device, and the clock line is connected to the SCLK pin.

The master device controls the data transfer by generating the shift clock, while the slave devices receive it. Due to the fact that all transmit and receive pins are connected to the one data exchange line, serial data may be moved between arbitrary stations.

As in full-duplex mode, there are two ways to avoid collisions on the data exchange line:

- Only the transmitting device may enable its transmit pin driver
- The non-transmitting devices use open-drain output and send only 1s

Because the data inputs and outputs are connected together, a transmitting device will clock in its own data at the input pin (MRST for a master device, MTSR for a slave). In this way, any corruption is detected on the common data exchange line when the received data is not equal to the transmitted data.

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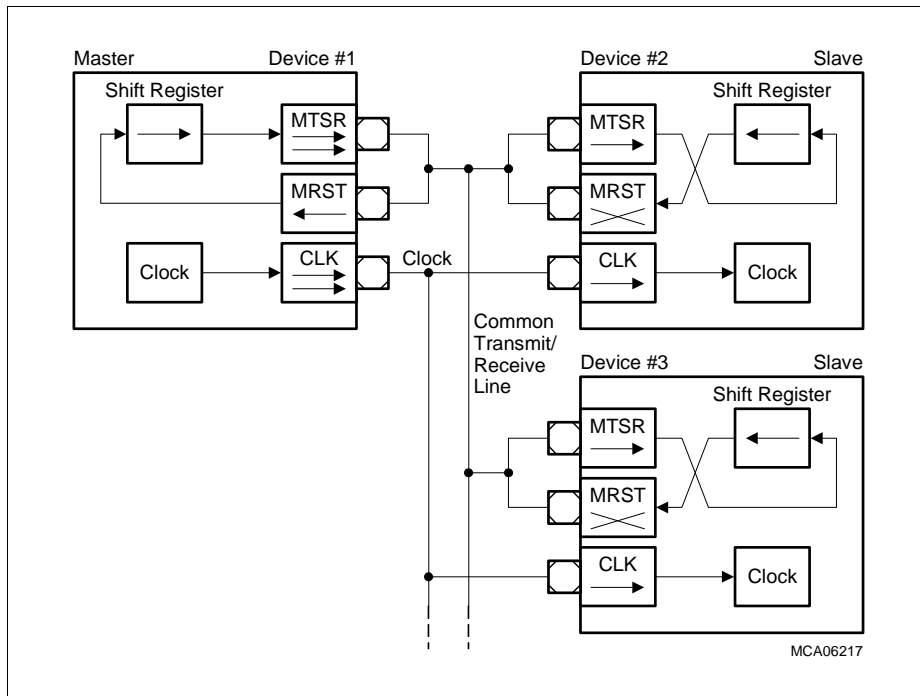


Figure 18-5 SSC Half-Duplex Configuration

18.1.2.4 Continuous Transfers

When the transmit interrupt request flag is set, it indicates that the Transmit Buffer (TB) is empty and is ready to be loaded with the next transmit data. If the TB has been reloaded by the time the current transmission is finished, the data is immediately transferred to the shift register and the next transmission can start without any additional delay (according to the selected SLSO timings). On the data line, there is no gap between the two successive frames if no delays are selected. For example, two byte transfers would look the same as one word transfer. This feature can be used to interface with devices that can operate with (or require more than) 16 data bits per transfer. It is just a matter for software how long a total data frame length can be. This option can also be used, e.g., to interface to byte-wide and word-wide devices on the same serial bus.

Note: This option can only happen in multiples of the selected basic data width, because it would require disabling/enabling of the SSC to reprogram the basic data width on-the-fly.

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Note: In Master Mode, the Transmit Buffer register TB is loaded with new data for the following transmission just at the end of the current transmission and a leading delay > 0 is selected (SSOTC.LEAD not equal 00_B), a slightly enlarged leading delay ($< \text{one SCLK shift clock period}$) is generated for the following transmission.

18.1.2.5 Parity Mode

The SSC allows to add a parity bit to a serial frame. The parity mode can be enabled individually for frame transmission (CON.PARTEN) and frame reception (CON.PARREN). The type of parity (even/odd parity) can be selected, valid for transmit and receive parity.

If transmit parity is enabled (CON.PARTEN = 1), the shift register is loaded for a frame transmission by the content of the Transmit Buffer TB, the parity bit becomes calculated and stored in STAT.PARTVAL. Depending on bit CON.HB, the parity bit preceeds or follows the transmitted data bits.

If receive parity is enabled (CON.PARREN = 1) and the last bit of a frame has been received, the received data of the frame is stored in RB and the received parity bit is stored in STAT.PARRVAL. The received and calculated parity bits are now compared. If this comparison fails, a parity error is detected and the error status flag STAT.PARE is set. If enabled by bit CON.PAREEN, a parity error activates the error interrupt request line EIR.

Figure 18-6 shows how a parity bit is added to the transmitted data bits of a frame. The number of the transmitted bits of a complete frame remains constant without or with parity, assuming that COM.BM is not changed. Therefore, the number of transmitted data bits is reduced by one bit when parity mode is enabled.

If the heading control bit CON.HB = 0 (LSB first), the parity bit preceeds the data bits in parity mode and is transmitted as the first bit of a frame. If the heading control bit CON.HB = 1 (MSB first), the parity bit follows the data bits in parity mode and is transmitted as the last bit of a frame.

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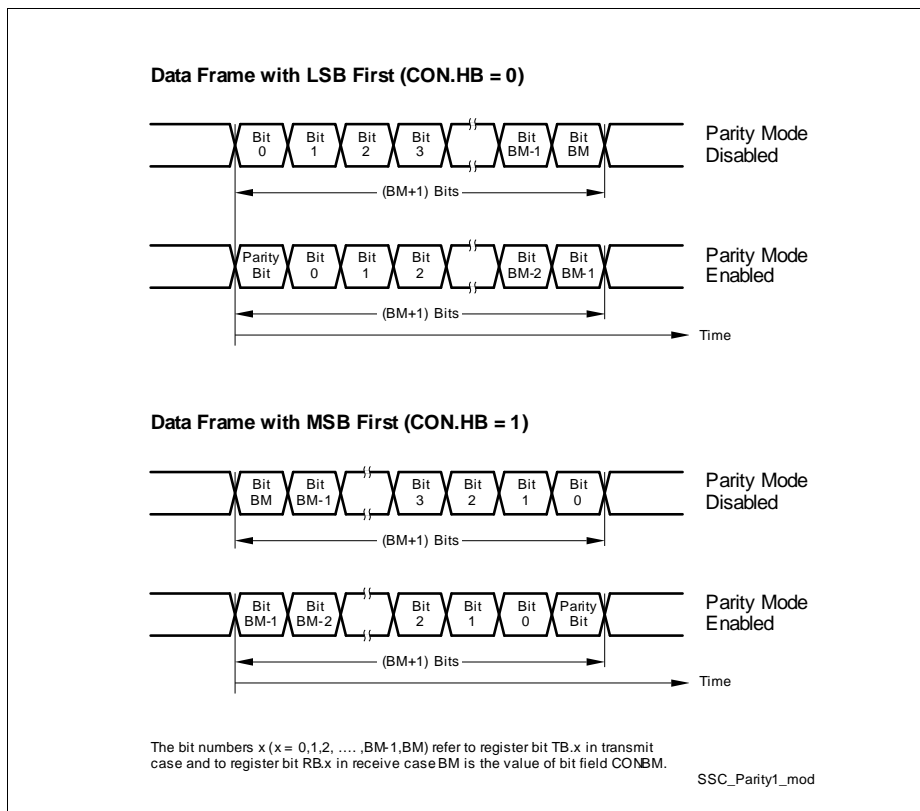


Figure 18-6 Data Frames without/with Parity

18.1.2.6 Port Control

The SSC uses three lines to communicate with the external world. Pin SCLK serves as the clock line, while pins MRST (Master Receive/Slave Transmit) and MTSR (Master Transmit/Slave Receive) serve as the serial data input/output lines. As shown in [Figure 18-1](#) these three lines (SCLK as input, Master Receive, Slave Receive) have two inputs each at the SSC Module kernel. Three bits in register PISEL determine which of the two kernel inputs (A or B) are connected. This feature allows for each of the three SSC communication lines to be connected to two inputs coming from different port pins.

Operation of the SSC I/O lines depends on the selected operating mode (master or slave). The direction of the port lines depends on the operating mode. The SSC will automatically use the correct kernel output or kernel input line of the ports when

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switching modes. Port pins assigned as SSC I/O lines can be controlled either by hardware or by software.

When the SSC I/O lines are connected to dedicated pins, hardware I/O control should typically be used. In this case, two output signals reflect the state of the CON.EN and CON.MS bits directly (the M/S select line is inverted to the CON.MS bit definition).

When the SSC I/O lines are connected with bi-directional lines of general purpose I/O ports, software I/O control should be typically used. In this case port registers must be programmed for alternate output and input selection. When switching between master and slave mode port registers must be reprogrammed.

Using the open-drain output feature of port lines helps to avoid bus contention problems and reduces the need for hard-wired hand-shaking or slave select lines. In open-drain output mode, it is not always necessary to switch the direction of a port pin. Note that in hardware-controlled I/O mode, the availability of open-drain outputs depends on the type of the dedicated output pins that are used. The SSC module itself does not provide any control capability for open-drain control.

Note: For details of SSC port connections and configuration, see [Page 18-53](#).

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18.1.2.7 Baud Rate Generation

The serial channel SSC has its own dedicated 16-bit baud rate generator with 16-bit reload capability, allowing baud rate generation independent of timers. In addition to [Figure 18-2](#), [Figure 18-7](#) shows the baud rate generator of the SSC in more detail.

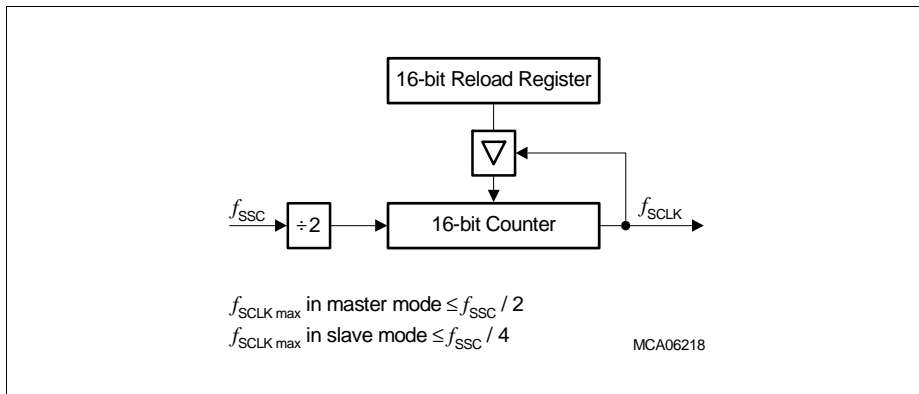


Figure 18-7 SSC Baud Rate Generator

The baud rate generator is clocked with f_{SSC} . The timer counts downwards. Register BR is the dual-function Baud Rate Generator/Reload register. Reading BR while the SSC is enabled returns the contents of the timer. Reading BR while the SSC is disabled returns the programmed reload value. In this mode, the desired reload value can be written to BR.

Note: Never write to BR while the SSC is enabled.

The formulas below calculate either the resulting baud rate for a given reload value, or the required reload value for a given baud rate:

$$\text{Baud rate}_{\text{SSC}} = \frac{f_{\text{SSC}}}{2 \times (\text{BR_VALUE} + 1)} \quad \text{BR_VALUE} = \frac{f_{\text{SSC}}}{2 \times \text{Baud rate}_{\text{SSC}}} - 1 \quad (18.1)$$

BR_VALUE represents the content of the reload register, taken as an unsigned 16-bit integer, while $\text{Baud rate}_{\text{SSC}}$ is equal to f_{SCLK} as shown in [Figure 18-7](#).

The maximum baud rate that can be achieved with $f_{\text{SSC}} = 110 \text{ MHz}$ is 55.0 Mbit/s in Master Mode (with $\text{BR_VALUE} = 0000_{\text{H}}$) and 275.0 Mbit/s in Slave Mode (with $\text{BR_VALUE} = 0001_{\text{H}}$).

[Table 18-1](#) lists some possible baud rates together with the required reload values and the resulting bit times, assuming a module clock f_{SSC} of 110 MHz.

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Table 18-1 Typical Asynchronous Baud Rates using Fixed Input Clock Dividers

Reload Value	Baud Rate ($= f_{\text{SCLK}}$)	Deviation
0000 _H	55 Mbit/s (only in Master Mode)	0.0%
0001 _H	27.5 Mbit/s	0.0%
0003 _H	13.75 Mbit/s	0.0%
0036 _H	1 Mbit/s	0.0%
006D _H	500 kbit/s	0.0%
0225 _H	100 kbit/s	0.0%
157B _H	10 kbit/s	0.0%
D6D7 _H	1 kbit/s	0.0%
FFFF _H	839.3 bit/s	0.0%

In the TC1728, the module clock f_{SSC} is generated outside the SSC module kernel. Therefore, for baud rate calculations the dependencies of f_{SSC} from f_{SYS} must be taken into account. on describes these dependencies in detail.

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18.1.2.8 Slave Select Input Operation

For systems with multiple slaves, the SSC module provides seven $\overline{\text{SLSI}}$ slave select input lines, that permit enabling or disabling of the SCLK, MTSR, and MRST signals in Slave Mode. Slave Mode is selected by $\text{CON.MS} = 0$. The $\overline{\text{SLSI}}$ input logic shown in **Figure 18-8** is controlled by register PISEL and CON.

Note: In the following description, only one of the seven $\overline{\text{SLSI}}$ input lines is mentioned. The remaining six $\overline{\text{SLSI}}$ input lines are connected to the other six inputs of the input multiplexer, which is controlled by PISEL.SLSIS .

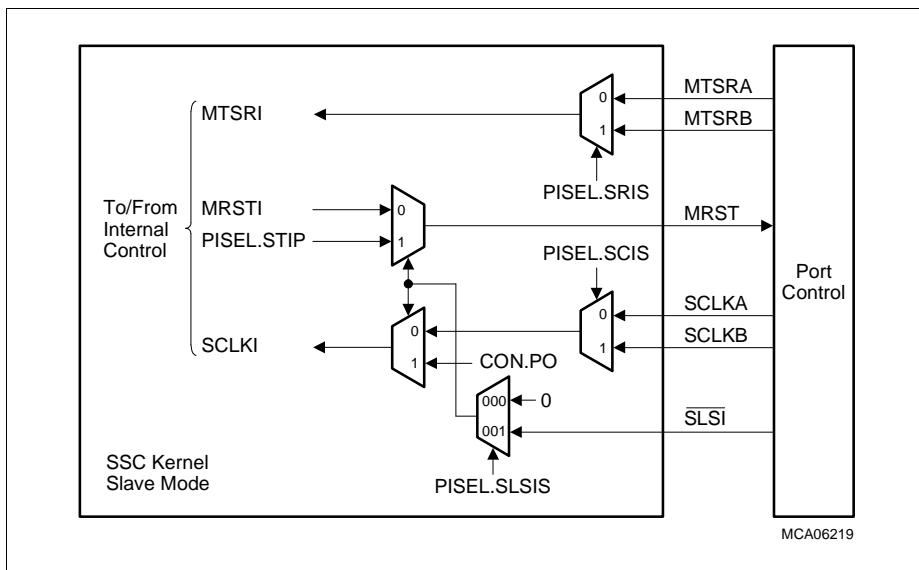


Figure 18-8 Slave Select Input Logic

With $\text{PISEL.SLSIS} = 000_{\text{B}}$ and Slave Mode selected, the $\overline{\text{SLSI}}$ input line does not control the SSC I/O lines. The slave receive input signal MTSRA or MTSRB (selected by PISEL.SRIS) and the slave clock input signal SCLKA or SCLKB (selected by PISEL.SCIS) are passed further as MTSRI and SCLKI to the internal SSC control logic. The slave transmit signal MRSTI from the internal SSC control logic MRSTI is passed directly to MRST.

With $\text{PISEL.SLSIS} = 001_{\text{B}}$, input signal $\overline{\text{SLSI}}$ controls the operation of the SSC I/O lines as a slave select signal as follows:

- $\overline{\text{SLSI}} = 1$: SSC slave is not selected.
 - The slave receive input signals, MTSRA or MTSRB are connected to MTSRI, depending on PISEL.SRIS (Slave Mode receive input select).

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- MRST is driven with the logic level of bit PISEL.STIP (slave transmit idle state).
- SCLKI is driven with the logic level of CON.PO (clock polarity control).
- $\overline{\text{SLSI}} = 0$: SSC is selected as slave.
 - The slave receive input signals MTSRA or MTSRB are connected to MTSRI, depending on PISEL.SRIS (Slave Mode receive input select).
 - MRST is directly driven with the slave transmit output signal MRSTI.
 - The slave clock input signals SCLKA or SCLKB are connected to SCLKI, depending on PISEL.SCIS (Slave Mode clock input select).

18.1.2.9 Slave Select Output Generation Unit

In Master Mode, the slave select output generation unit of the SSC automatically generates up to eight slave select output lines $\text{SLSO}[7:0]$ for serial transmit operations. The slave select output generation unit further makes it possible to adjust the chip select timing parameters. The active/inactive state of a slave select output as well as the enable/disable state can be controlled individually for each slave select output (see [Figure 18-10](#)). The basic slave select output timing is shown in [Figure 18-9](#), assuming a low active level of the SLSO_n lines.

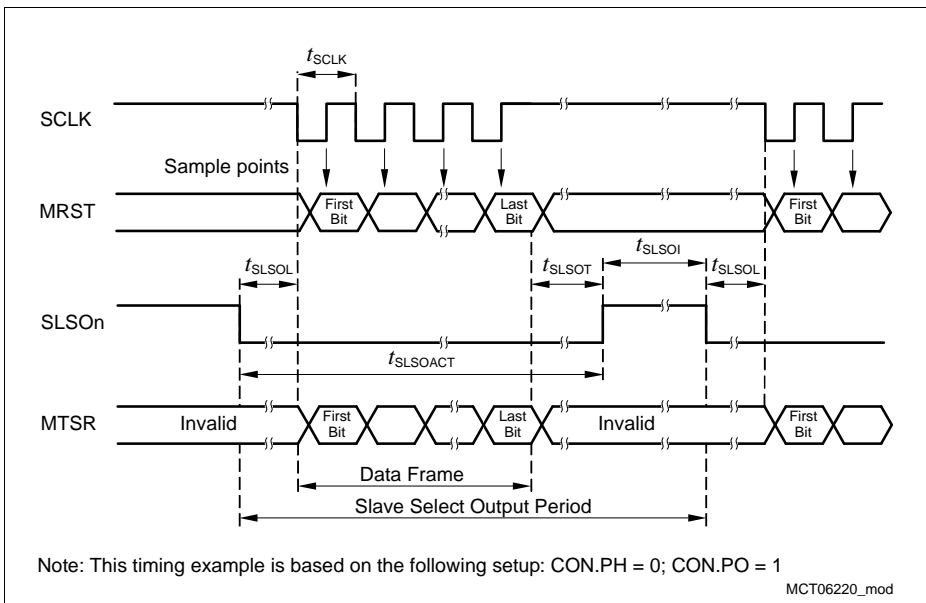


Figure 18-9 SSC Slave Select Output Timing

A slave select output period always starts after a write operation to register TB. With a TB write operation, all timing parameters stored in register SSOTC (LEAD, TRAIL,

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As a special feature, each SLSOn output signal can be combined (ANDed) by an external signal SLSOANDIn coming from another SSC to an output signal SLSANDOn. This AND gate can be used for example to combine two slave select output signals from two SSCs to one common SLSOn output signal. Note that this functionality only works for low active SLSOn signals (SSOC.AOLn = 0).

Slave Select Output 7 Delayed Mode

In the SLSO7 delayed mode (SSOTC.SLSO7MOD = 1), the timing of the slave select output SLSO7 as programmed by the three parameters in SSOTC (number of trailing, leading, and inactive delay clock cycles) is delayed by one shift clock period for the inactive-to-active edge. The active-to-inactive edge is not delayed. The timing of SLSO7 in the delayed mode is shown in [Figure 18-11](#). The bold lines show the timing of SLSO7 in normal operating mode, and the dotted lines show the timing of SLSO7 in delayed mode.

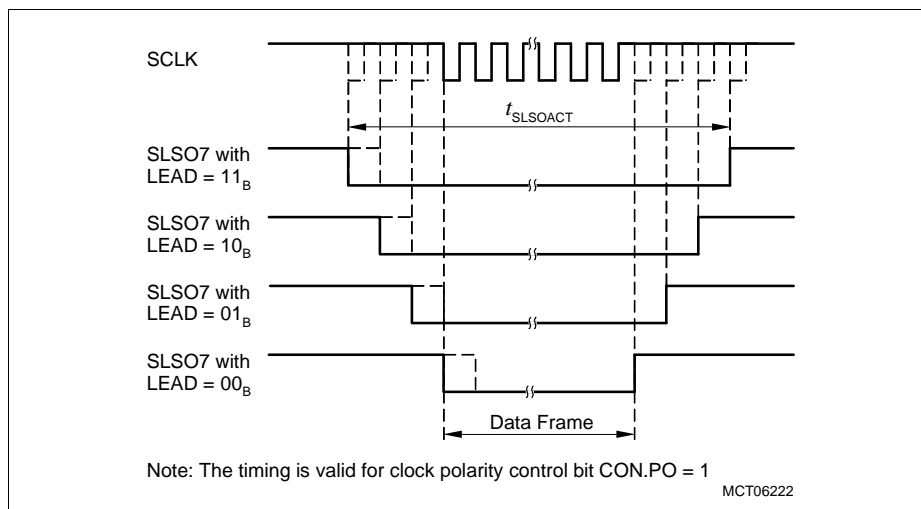


Figure 18-11 SLSO7 Delayed Mode

Slave Select Register Update

At the start of an internal transmit sequence (with the TB register write operation), the parameters in registers SSOC and SSOTC are latched. This means that they remain stable while a serial transmission is in progress. Therefore, it is always guaranteed that the data of one serial transmission is always transmitted with a constant slave select configuration setup. A configuration change by reprogramming SSOC or SSOTC during a serial transmission will first become valid with the start of the subsequent serial transmission.

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18.1.2.10 Error Detection Mechanisms

The SSC is able to detect four different error conditions. Receive Error and Phase Error are detected in all modes, while Transmit Error and Baud Rate Error apply to Slave Mode only. In case of a Transmit Error or Receive Error, the respective error flags are always set and the error interrupt requests will be generated by activating the EIR line only if the corresponding error enable bits have been set (see [Figure 18-12](#)). The error interrupt handler may then check the error flags to determine the cause of the error interrupt. The error flags are not cleared automatically, but must be cleared via register EFM after servicing. This allows servicing of some error conditions via interrupt, while others may be polled by software. The error status flags can be set and cleared by software via the error flag modification register EFM.

Note: The error interrupt handler must clear the associated (enabled) error flag(s) to prevent repeated interrupt requests. The setting of an error flag by software does not generate an interrupt request.

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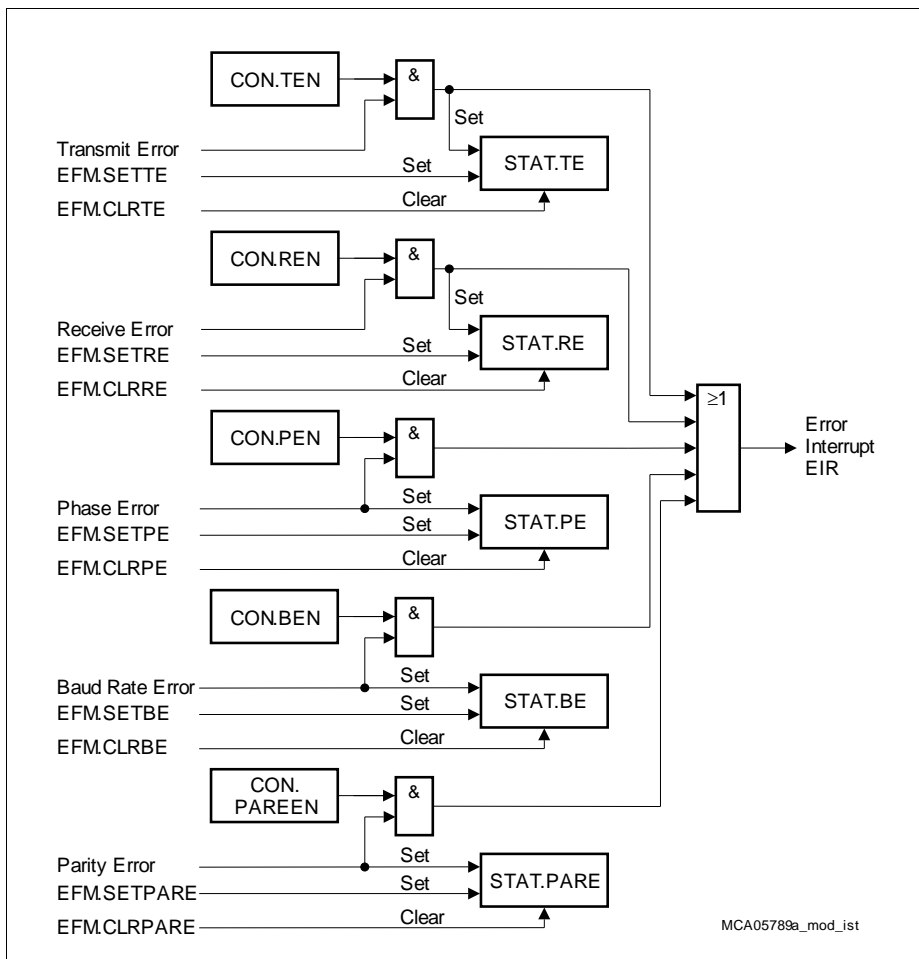


Figure 18-12 SSC Error Interrupt Control

A **Receive Error** (Master or Slave mode) is detected when a new data frame is completely received, but the previous data was not read out of the receive buffer register RB. If enabled via CON.REN, this condition sets the error flag STAT.RE and activates the error interrupt request line EIR. This condition sets the error flag STAT.RE and, if enabled via CON.REN, sets the error interrupt request line EIR. The old data in the receive buffer RB will be overwritten with the new value and is irretrievably lost.

A **Phase Error** (Master or Slave Mode) is detected when the incoming data at pin MRST (Master Mode) or MTSR (Slave Mode), sampled with the same frequency as the module

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clock, changes between one cycle before and two cycles after the latching edge of the shift clock signal SCLK. This condition sets the error status flag STAT.PE and, if enabled via CON.PEN, the error interrupt request line EIR.

Note: When CON.PH = 1, the data output signal may be disturbed shortly when the slave select input signal is changed after a serial transmission, resulting in a phase error.

A **Baud Rate Error** (Slave Mode) is detected when the incoming clock signal deviates from the programmed baud rate (shift clock) by more than 100%, meaning it is either more than double or less than half the expected baud rate. This condition sets the error status flag STAT.BE and, if enabled via CON.BEN, the EIR line. Using this error detection capability requires that the slave's shift clock generator is programmed to the same baud rate as the master device. This feature detects false additional pulses or missing pulses on the clock line (within a certain frame).

Note: If this error condition occurs and bit CON.AREN = 1, an automatic reset of the SSC will be performed. This is done to re-initialize the SSC, if too few or too many clock pulses have been detected.

Note: The baud rate error can occur in slave mode after any transfer if the communication is stopped by the master. This is the case due to the fact that SSC module supports back-to-back transfers for multiple transfers. In order to handle this the baud rate detection logic expects after a finished transfer immediately a next clock cycle for a new transfer.

If baud rate error is enabled and the transmit buffer of the slave SSC is loaded with a new value for the next data frame while the current data frame is not yet finished (while STAT.BSY = 1), the slave SSC expects continuation of the clock pulses for the next data frame transmission immediately after finishing the current data frame. Any write to TBUF of the slave SSC while STAT.BSY = 1 initiates or sustains a continuous transmission in the slave. Therefore, the master (shift) clock must be continued after the current frame transmission. Otherwise, the slave SSC will detect a baud rate error. Note that the master SSC does not necessarily send out a continuous shift clock in the case that its transmit buffer is not yet filled with new data or transmission delays occur. Further details on continuous transfers are described in [Section 18.1.2.4](#) on [Page 18-10](#).

A **Transmit Error** (Slave Mode) is detected when a transfer was initiated by the master (shift clock gets active), but the transmit buffer (TB) of the slave was not updated since the last transfer. If enabled via CON.TEN, this condition sets the error status flag STAT.TE and activates the EIR line. This condition sets the error status flag STAT.TE and, if enabled via CON.TEN, the EIR line. If a transfer starts while the transmit buffer is not updated, the slave will shift out the 'old' contents of the shift register, which is normally the data received during the last transfer. This may lead to the corruption of the data on the transmit/receive line in half-duplex mode (open drain configuration) if this slave is not selected for transmission. This mode requires that slaves not selected for

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transmission only shift out ones; thus, their transmit buffers must be loaded with $FFFF_H$ prior to any transfer.

A **Parity Error** (Master or Slave Mode) is detected when the data frame is completely received and the generated parity bit for the received data is not equal to the calculated parity bit. This condition sets the error status flag `STAT.PARE` and, if enabled via `CON.PAREEN`, the error interrupt request line `EIR`.

Note: A slave with push/pull output drivers not selected for transmission will normally have its output drivers switched off. However, to avoid possible conflicts or misinterpretations, it is recommended to always load the slave's transmit buffer prior to any transfer.

The cause of an error interrupt request (receive, phase, baud rate, transmit error) can be identified by the error status flags in control register `CON`.

Note: In contrast to the `EIR` line, the error status flags `STAT.TE`, `STAT.RE`, `STAT.PE`, and `STAT.BE`, are not automatically cleared upon entry into the error interrupt service routine, but must be cleared by software.

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18.1.2.11 Queued SSC Mode

In queued SSC mode, the enable/disable control of the SSC is possible by two bit locations, one control bit in register CON and one additional control bit in register SSOTC. This double-enable control capability allows control and data operations of the SSC to be completely handled by a DMA controller.

The bits for queued SSC mode are:

- Bit SSOTC.QSMEN: Queued SSC Mode Enable
- Bit SSOTC.EN: Enable SSC (functionality identical with bit CON.EN)

Table 18-2 Queued SSC Mode Control

Write SSOTC Register		SSC Module Enable/Disable Control	
Bit QSMEN	Bit EN		
0	X	Enable/disable control of SSC is only possible via bit CON.EN (queued SSC mode disabled).	
1	0	Enable/disable control of SSC is possible via bits SSOTC.EN <u>and</u> CON.EN (queued SSC mode enabled).	SSC is disabled
	1		SSC is enabled

Note: Both register bits, CON.EN and SSOTC.EN, control one common flip-flop for enable/disable control.

Figure 18-13 shows how the Queued SSC Mode control logic. Reading SSOTC returns the state of CON.EN for SSOTC.EN. Writing to SSOTC with QSMEN = 1, sets CON.EN if SSOTC.EN is written with 1 and clears CON.EN if SSOTC.EN is written with 0.

Compared to the timing parameters stored in register SSOTC (LEAD, TRAIL, INACT, and SLSO7MOD), the Queued SSC Mode control bits QSMEN and EN are not latched and directly control the receive/transmit functionality. But note that CON.EN should only be cleared by software (either by a CON or SSOTC write operation) while no transfer is in progress (STAT.BSY = 0).

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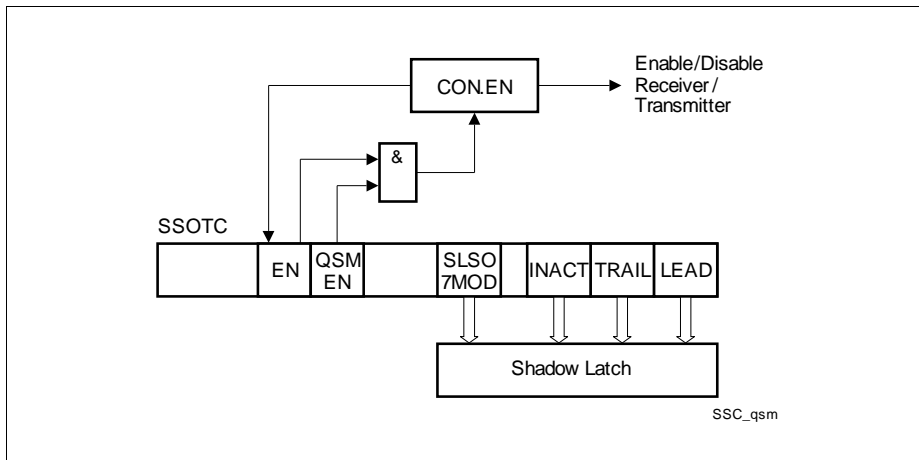


Figure 18-13 Queued SSC Mode Control

Application for Queued SSC Mode

Example: the SSC operates in master mode and controls multiple SSC slave devices with different frame settings and baud rates.

For controlling such an application task, that can be time critical when CPU is used for SSC control, the queued SSC mode is applicable. In this case, the control and data handling for an SSC slave is handled by three DMA channels.

- **DMA Channel 1**

One DMA transaction consists of four consecutive DMA write transfers, programming registers CON, BR, SSOC, and SSOTC. All these registers are on consecutive addresses with an offset of 4.

With the CON write operation, CON.EN is set to 0 (SSC disabled). The BR, SSOC, and SSOTC write operations program the SSC slave parameters such as baud rate, frame layout, and slave select output timing. The fourth write operation to SSOTC enables again the SSC by writing SSOTC.QSMEN = 1 and SSOTC.EN = 1. After DMA channel 1 has finished this 4-byte control setup transaction it can be programmed to start automatically data transactions via DMA channel 2 or 3 (depending on the application).

- **DMA Channel 2**

This DMA channel is setup to write the transmit buffer register TB.

- **DMA Channel 3**

This DMA channel is setup to read the receive buffer register RB.

Depending on the details of the application, the write or read DMA channel may be unnecessary.

Synchronous Serial Interface (SSC)

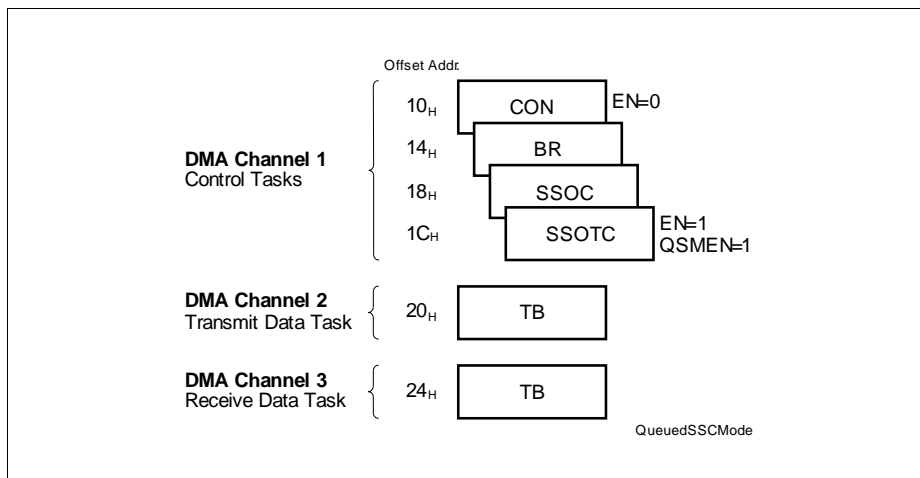


Figure 18-14 SSC Error Interrupt Control

Synchronous Serial Interface (SSC)

18.2 SSC Kernel Registers

This section describes the kernel registers of the SSC module. All SSC kernel register names described in this section will be referenced in other parts of the TC1728 User's Manual by the module name prefix "SSC0_" for the SSC0 interface and "SSC1_" for the SSC1 interface.

All registers in the SSC address spaces are reset with the application reset (definition see SCU section "Reset Operation").

SSC Kernel Register Overview

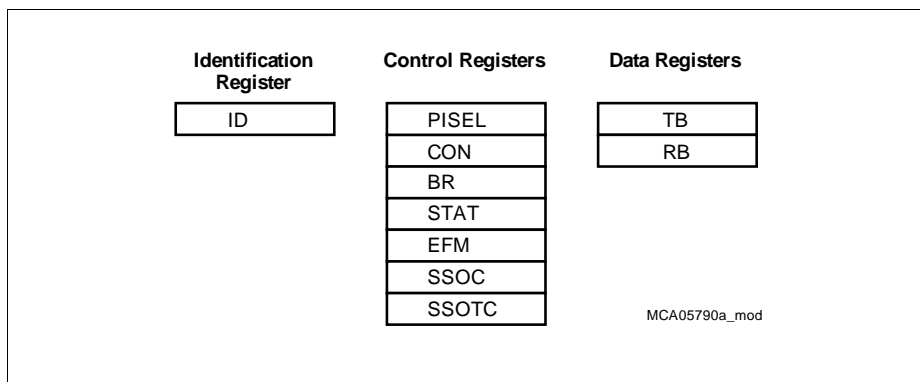


Figure 18-15 SSC Kernel Registers

The complete and detailed address map of the SSC modules is described at the end of this chapter.

Table 18-3 Registers Address Space - SSC Kernel Registers

Module	Base Address	End Address	Note
SSC0	F010 0100 _H	F010 01FF _H	—
SSC1	F010 0200 _H	F010 02FF _H	—
SSC2	F010 0300 _H	F010 03FF _H	—
SSC3	F010 0000 _H	F010 00FF _H	—

Synchronous Serial Interface (SSC)

Table 18-4 Registers Overview - SSC Kernel Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
PISEL	Port Input Select Register	04 _H	Page 18-29
ID	Module Identification Register	08 _H	Page 18-28
CON	Control Register	10 _H	Page 18-31
BR	Baud Rate Timer Reload Register	14 _H	Page 18-41
STAT	Status Register	28 _H	Page 18-34
EFM	Error Flag Modification Register	2C _H	Page 18-36
SSOC	Slave Select Output Control Register	18 _H	Page 18-38
SSOTC	Slave Select Output Timing Control Register	1C _H	Page 18-39
TB	Transmit Buffer Register	20 _H	Page 18-42
RB	Receive Buffer Register	24 _H	Page 18-42

1) The absolute register address is calculated as follows:

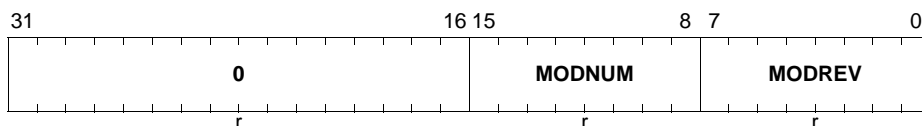
Module Base Address ([Table 18-3](#)) + Offset Address (shown in this column)

18.2.1 Module Identification Register

The SSC Module Identification Register ID contains read-only information about the module version.

ID

Module Identification Register (08_H) **Reset Value: 0000 45XX_H**



Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number MODREV defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MODNUM	[15:8]	r	Module Number Value This bit field defines the module identification number for the SSC: 45 _H

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0.

Note: Implementation specific details (e.g. reset value) see “[Module Identification Registers](#)” on [Page 18-43](#).

18.2.2 Control Registers

The PISEL register controls the input signal selection of the SSC module. Each input of the module kernel receive, transmit and clock signals has associated two input lines (marked by suffix A and B).

PISEL

Port Input Select Register

(04_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							STIP	0	SLSIS			SCIS	SRIS	MRI S	
r							rw	r	rw			rw	rw	rw	

Field	Bits	Type	Description
MRIS	0	rw	Master Mode Receive Input Select MRIS selects the receive input line in Master Mode. 0 _B Receive input line MRSTA is selected 1 _B Receive input line MRSTB is selected
SRIS	1	rw	Slave Mode Receive Input Select SRIS selects receive input line in Slave Mode. 0 _B Receive input line MTSRA is selected 1 _B Receive input line MTSRB is selected
SCIS	2	rw	Slave Mode Clock Input Select SCIS selects the module kernel SCLK input line that is used as clock input line in slave mode. 0 _B Slave Mode clock input line SCLKA is selected 1 _B Slave Mode clock input line SCLKB is selected

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
SLSIS	[5:3]	rw	Slave Mode Slave Select Input Selection 000 _B Slave select input lines are deselected; SSC is operating without slave select input functionality. 001 _B <u>SLSI</u> input line 1 is selected for operation. 010 _B <u>SLSI</u> input line 2 is selected for operation. 011 _B <u>SLSI</u> input line 3 is selected for operation. 100 _B <u>SLSI</u> input line 4 is selected for operation. 101 _B <u>SLSI</u> input line 5 is selected for operation. 110 _B <u>SLSI</u> input line 6 is selected for operation. 111 _B <u>SLSI</u> input line 7 is selected for operation. In the TC1728, other combinations of SLSIS except 000 _B and 001 _B are reserved and must not be used.
STIP	8	rw	Slave Transmit Idle State Polarity This bit determines the logic level of the Slave Mode transmit signal MRST when the SSC slave select input signals are inactive (PISEL.SLSIS ≠ 000 _B). 0 _B MRST = 0 when SSC is deselected in Slave Mode. 1 _B MRST = 1 when SSC is deselected in Slave Mode.
0	[7:6], [31:9]	r	Reserved Read as 0; should be written with 0.

Synchronous Serial Interface (SSC)

The operating modes of the SSC are controlled by the Control Register CON. This register contains control bits for mode and error check selection.

Note: Whenever operating mode parameters in the CON register are changed by software, no transfer should be in progress (STAT.BSY = 0) and the SSC should be disabled (CON.EN = 0) and afterwards enabled again (CON.EN = 1).

CON

Control Register

(10_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
												PAR EEN	PAR TYP	PAR REN	PAR TEN
												rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN	MS	0	A REN	BEN	PEN	REN	TEN	LB	PO	PH	HB				
rw	rw	r	rw	rw	rw	rw	rw	rw	rw	rw	rw			rw	

Field	Bits	Type	Description
BM	[3:0]	rw	Frame Width Selection BM determines the number of bits of the serial frame. <u>PAREN = 0, parity mode disabled:</u> 0000 _B Reserved; do not use this combination. 0001 _B Frame width is 2 bits (2 data bits). 0010 _B Frame width is 3 bits (3 data bits). ... _B ... 1110 _B Frame width is 15 bits (15 data bits). 1111 _B Frame width is 16 bits (16 data bits). <u>PAREN = 1, parity mode enabled:</u> 0000 _B Reserved; do not use this combination. 0001 _B Frame width is 2 bits (1 data bit + parity bit). 0010 _B Frame width is 3 bits (2 data bits + parity bit). ... _B ... 1110 _B Frame width is 15 bits (14 data bits + parity bit). 1111 _B Frame width is 16 bits (15 data bits + parity bit).

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
HB	4	rw	Heading Bit Control 0_B Transmit/Receive LSB First 1_B Transmit/Receive MSB First
PH	5	rw	Clock Phase Control 0_B Shift transmit data on the leading clock edge, latch on trailing edge 1_B Latch receive data on leading clock edge, shift on trailing edge
PO	6	rw	Clock Polarity Control 0_B Idle clock line is low, the leading clock edge is low-to-high transition 1_B Idle clock line is high, the leading clock edge is high-to-low transition
LB	7	rw	Loop-Back Control 0_B Normal output 1_B Receive input is connected to transmit output (Half-duplex Mode)
TEN	8	rw	Transmit Error Enable 0_B Ignore transmit errors 1_B Check transmit errors
REN	9	rw	Receive Error Enable 0_B Ignore receive errors 1_B Check receive errors
PEN	10	rw	Phase Error Enable 0_B Ignore phase errors 1_B Check phase errors
BEN	11	rw	Baud Rate Error Enable 0_B Ignore baud rate errors 1_B Check baud rate errors
AREN	12	rw	Automatic Reset Enable 0_B No additional action upon a baud rate error 1_B SSC is automatically reset on a baud rate error

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
MS	14	rw	Master Select 0_B Slave Mode. Operate on shift clock received via SCLK 1_B Master Mode. Generate shift clock and output it via SCLK The inverted state of this bit is available on module output line "M/S selected" (see Figure 18-2).
EN	15	rw	Enable Bit 0_B Transmission and reception are disabled. 1_B Transmission and reception are enabled. This bit is available as module output line "SSC enabled" (see Figure 18-2). Note that EN should only be cleared by software while no transfer is in progress (STAT.BSY = 0). Note that the transmission/reception enable can also be controlled in queued SSC mode by bit SSOTC.EN (see Page 18-24).
PARTEN	16	rw	Parity Transmit Enable Bit This bit enables the parity mode for the transmission of frames. 0_B Parity mode for transmission is disabled. 1_B Parity mode for transmission is enabled.
PARREN	17	rw	Parity Receive Enable Bit This bit enables the parity mode for the reception of frames. 0_B Parity mode for reception is disabled. 1_B Parity mode for reception is enabled.
PARTYP	18	rw	Parity Type Bit If PAREN = 1, this bit defines the type of parity to be generated or checked. 0_B Even parity is selected (parity bit = 1 on odd number of 1s in data, parity bit = 0 on even number of 1s in data). 1_B Odd parity selected (parity bit = 1 on even number of 1s in data, parity bit = 0 on odd number of 1s in data)
PAREEN	19	rw	Parity Error Enable 0_B Ignore receive parity errors 1_B Check receive parity errors

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
0	13, [31:20]	r	Reserved Read as 0; should be written with 0.

The Status Register STAT contains status flags for error identification, the busy flag, and a bit field that indicates the current shift counter status.

STAT

Status Register

(28_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0			BSY	BE	PE	RE	TE	0	PAR R VAL	PAR T VAL	PAR E	BC			
r			rh	rh	rh	rh	rh	r	rh	rh	rh	rh			

Field	Bits	Type	Description
BC	[3:0]	rh	Bit Count Status BC indicates the current status of the shift counter. The shift counter is updated with every shifted bit.
PAPE	4	rh	Parity Error Flag 0 _B No error 1 _B Received parity bit is wrong.
PARTVAL	5	rh	Parity Transmit Value If parity mode is enabled, this bit indicates the calculated parity bit for the transmission of the actual serial frame. PARTVAL is written with the transmit parity value when the shift register is loaded from TB. PARTVAL is reset when CON.PAREN is reset.
PARRVAL	6	rh	Parity Receive Value if parity mode is enabled, this bit PARRVAL is loaded when the received data is written into RB. PARRVAL is reset when CON.PAREN is reset.

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
TE	8	rh	Transmit Error Flag 0_B No error 1_B Transfer starts with the slave's transmit buffer not being updated
RE	9	rh	Receive Error Flag 0_B No error 1_B Reception completed before the receive buffer was read
PE	10	rh	Phase Error Flag 0_B No error 1_B Received data changes during the sampling clock edge
BE	11	rh	Baud Rate Error Flag 0_B No error 1_B There is more than factor 2 or less than factor 0.5 between the slave's actual and the expected baud rate.
BSY	12	rh	Busy Flag BSY is set while a transfer is in progress.
0	7, [31:13]	r	Reserved Read as 0; should be written with 0.

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
CLRBE	11	w	Clear Baud Rate Error Flag 0_B No effect 1_B Bit STAT.BE is cleared. Bit is always read as 0.
SETTE	12	w	Set Transmit Error Flag 0_B No effect 1_B Bit STAT.TE is set. Bit is always read as 0.
SETRE	13	w	Set Receive Error Flag 0_B No effect 1_B Bit STAT.RE is set. Bit is always read as 0.
SETPE	14	w	Set Phase Error Flag 0_B No effect 1_B Bit STAT.PE is set. Bit is always read as 0.
SETBE	15	w	Set Baud Rate Error Flag 0_B No effect 1_B Bit STAT.BE is set. Bit is always read as 0.
0	[3:1], [7:5], [31:16]	r	Reserved Read as 0; should be written with 0.

Note: When the set and clear bits for an error flag are set at the same time during an EFM write operation (e.g. SETPE = CLRPE = 1), the error flag in STAT is not affected.

Synchronous Serial Interface (SSC)

The Slave Select Output Control Register controls the operation of the Chip Select Output Generation Unit.

SSOC

Slave Select Output Control Register (18_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OEN	OEN	OEN	OEN	OEN	OEN	OEN	OEN	AOL	AOL	AOL	AOL	AOL	AOL	AOL	AOL
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
AOLn (n = 0-7)	n	rw	Active Output Level 0 _B SLSON is at low level during the chip select active time t_{SLSOACT} . The high level is the inactive level of SLSON. 1 _B SLSON line n is at high level during the chip select active time t_{SLSOACT} . The low level is the inactive level of SLSON.
OENn (n = 0-7)	8 + n	rw	Output n Enable Control 0 _B SLSON output is disabled; SLSON is always at inactive level as defined by AOLn. 1 _B SLSON output is enabled.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Note: The SSOC register content is latched by each TB register write operation and remains latched during the consecutive serial transmission.

Synchronous Serial Interface (SSC)

The Slave Select Output Timing Control Register controls the operation of the Slave Select Output Generation Unit.

SSOTC

Slave Select Output Timing Control Register

(1C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN	QSM EN	0					SLS O7 MOD	0	INACT		TRAIL		LEAD		
rw	w	r					rw	r	rw		rw		rw		

Field	Bits	Type	Description
LEAD	[1:0]	rw	Slave Output Select Leading Delay This bit field determines the number of leading delay clock cycles. A leading delay clock cycle is always a multiple of an SCLK shift clock period. 00 _B Zero leading delay clock cycle selected ¹⁾ 01 _B One leading delay clock cycle selected 10 _B Two leading delay clock cycles selected 11 _B Three leading delay clock cycles selected
TRAIL	[3:2]	rw	Slave Output Select Trailing Delay This bit field determines the number of trailing delay clock cycles. A trailing delay clock cycle is always a multiple of an SCLK shift clock period. 00 _B Zero trailing delay clock cycle selected ¹⁾ 01 _B One trailing delay clock cycle selected 10 _B Two trailing delay clock cycles selected 11 _B Three trailing delay clock cycles selected

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
INACT	[5:4]	rw	Slave Output Select Inactive Delay This bit field determines the number of inactive delay clock cycles. An inactive delay clock cycle is always a multiple of an SCLK shift clock period. 00 _B Zero inactive delay clock cycle selected ¹⁾ 01 _B One inactive delay clock cycle selected 10 _B Two inactive delay clock cycles selected 11 _B Three inactive delay clock cycles selected
SLSO7MOD	8	rw	SLSO7 Delayed Mode Selection This bit selects the delayed mode for the SLSO7 slave select output. 0 _B Normal mode selected for SLSO7 1 _B Delayed mode selected for SLSO7
QSMEN	14	w	Queued SSC Mode Enabled 0 _B When QSMEN is written with 0, the state of bit SSOTC.EN is don't care. In this case, the enable/disable of the SSC is controlled by bit CON.EN only. Note that EN should only be cleared by software while no transfer is in progress (STAT.BSY = 0). 1 _B When QSMEN is written with 1, queued SSC mode is enabled, and the state of bit SSOTC.EN is copied to CON.EN. QSMEN is always read as 0.
EN	15	rw	Enable Bit 0 _B Transmission and reception are disabled. 1 _B Transmission and reception are enabled. Note that the transmission/reception enable can also be controlled in queued SSC mode by bit CON.EN.
0	[7:6], [13:9], [31:16]	r	Reserved Read as 0; should be written with 0.

1) For getting a best case timing with no timing delays (see [Figure 18-9](#)), this bit field value should be set when the SLSOn outputs are disabled (SSOC.OENn bits set to 0).

Note: The SSOTC register timing parameters LEAD, TRAIL, INACT, and SLSO7MOD are latched by each TB register write operation and remain latched during a consecutive serial transmission. Bits QSMEN and EN of register SSOTC are not latched.

Synchronous Serial Interface (SSC)

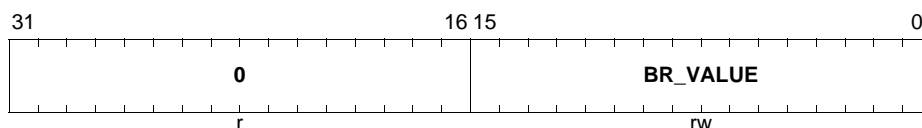
The Baud Rate Timer Reload Register BR contains the 16-bit reload value for the baud rate timer.

BR

Baud Rate Timer Reload Register

(14_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
BR_VALUE	[15:0]	rw	Baud Rate Timer/Reload Register Value Reading BR returns the 16-bit content of the baud rate timer. Writing BR loads the baud rate timer reload register with BR_VALUE.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Synchronous Serial Interface (SSC)

18.2.3 Data Registers

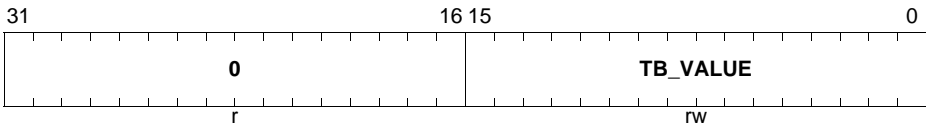
The Transmit Buffer Register TB contains the transmit data value. A TB write operation latches all timing parameters stored in register SSOTC.

TB

Transmit Buffer Register

(20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TB_VALUE	[15:0]	rw	Transmit Data Register Value Register TB stores the data value to be transmitted TB_VALUE. Unused bits of TB_VALUE (as defined by CON.BM) are ignored during transmission.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

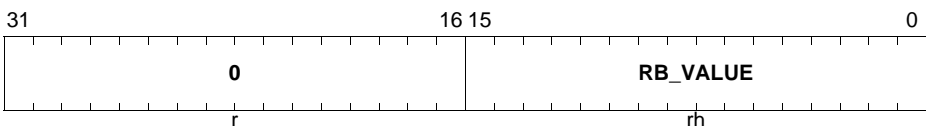
The Receive Buffer Register RB contains the receive data value.

RB

Receive Buffer Register

(24_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RB_VALUE	[15:0]	rh	Receive Data Register Value Register RB contains the received data value RB_VALUE (without the parity bit in parity mode) right aligned. Unused bits of RB_VALUE (as defined by CON.BM) will not be valid and should be ignored.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Synchronous Serial Interface (SSC)

18.3 SSC0/SSC1/SSC2/SSC3 Module Implementation

This section describes SSC0/SSC1/SSC2/SSC3 module interfaces with the clock control, port connections, interrupt control, and address decoding.

18.3.1 Module Identification Registers

The reset values of the SSCx_ID module identification registers are 0000 4512_H.

18.3.2 Interfaces of the SSC Modules

Figure 18-16 and **Figure 18-17** show the TC1798-specific implementation details and interconnections of the SSC0/SSC1/SSC2/SSC3 modules.

Each of the SSC modules is supplied with a separate clock control, interrupt control, and address decoding logic. Two interrupt outputs can be used to generate DMA requests. The SSC0/SSC1/SSC2/SSC3 I/O lines are connected to Port 1, Port 2, Port 3, Port 5, Port 8, and Port 10.

Synchronous Serial Interface (SSC)

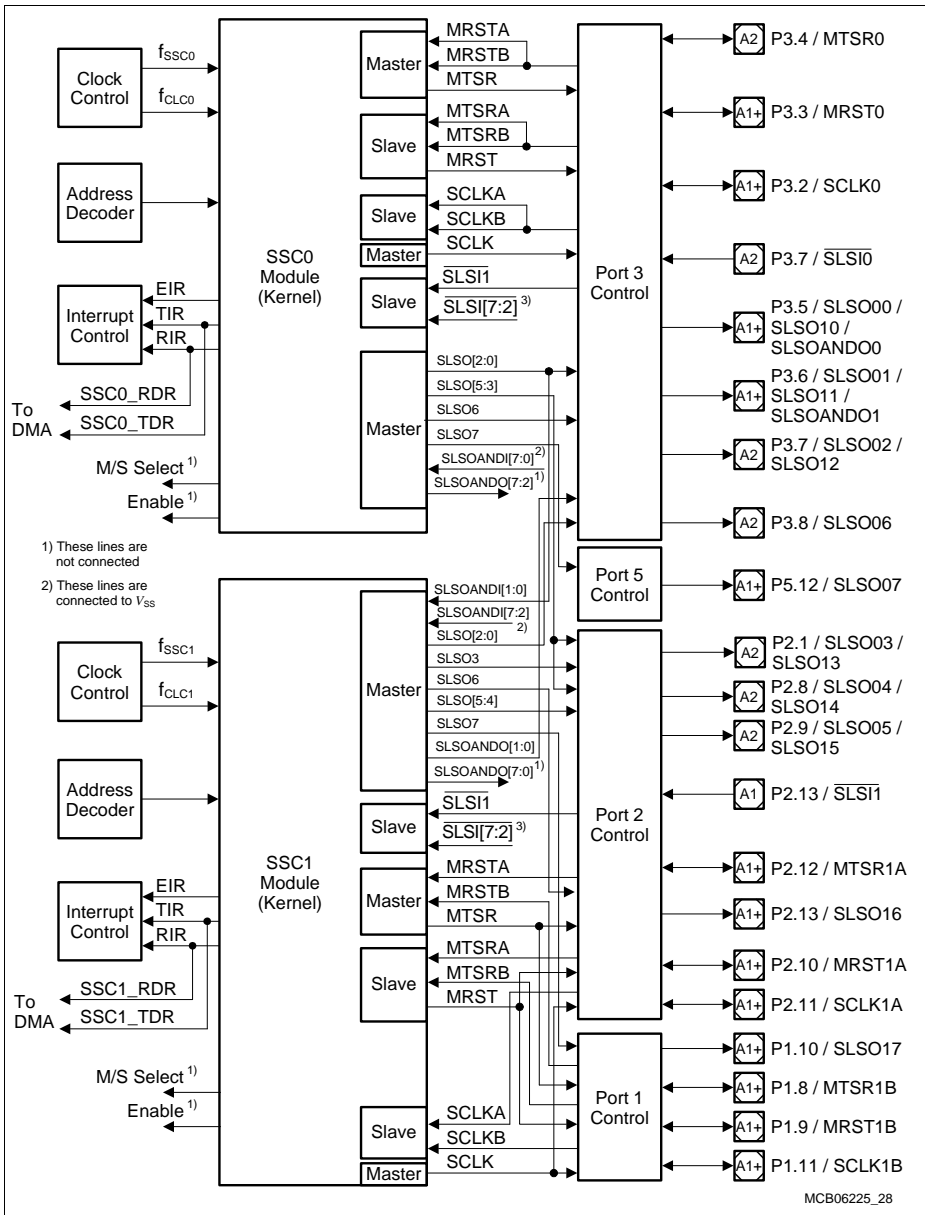


Figure 18-16 SSC0/SSC1 Module Implementation and Interconnections

Synchronous Serial Interface (SSC)

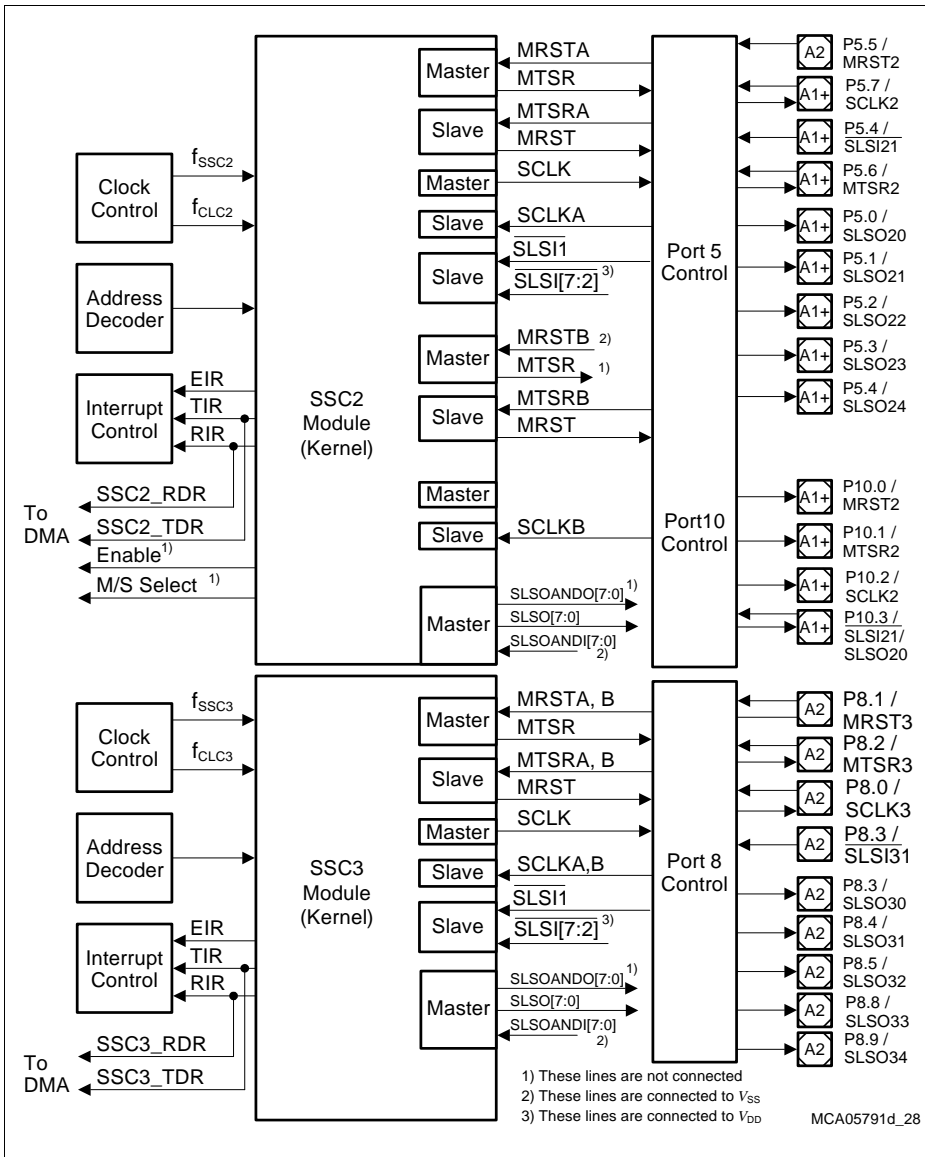


Figure 18-17 SSC2/SSC3 Module Implementation and Interconnections

Synchronous Serial Interface (SSC)

18.3.3 On-Chip Connections

This section describes the on-chip connections of the SSC0/SSC1/SSC2/SSC3 modules.

DMA Requests

The DMA request lines of the SSC0/SSC1/SSC2/SSC3 modules become active whenever the related interrupt line is activated. The DMA request lines are connected to the DMA controller as shown in [Table 18-5](#).

Table 18-5 DMA Request Lines of SSC0/SSC1/SSC2/SSC3

Module	SSC Interrupt Request Line	DMA Request Line	Description
SSC0	RIR	SSC0_RDR	DMA Channel 00 Request Input 4
			DMA Channel 06 Request Input 4
	TIR	SSC0_TDR	DMA Channel 02 Request Input 4
			DMA Channel 04 Request Input 4
SSC1	RIR	SSC1_RDR	DMA Channel 01 Request Input 4
			DMA Channel 07 Request Input 4
	TIR	SSC1_TDR	DMA Channel 03 Request Input 4
			DMA Channel 05 Request Input 4
SSC2	RIR	SSC2_RDR	DMA Channel 00 Request Input 13
	TIR	SSC2_TDR	DMA Channel 02 Request Input 13
SSC3	RIR	SSC2_RDR	DMA Channel 07 Request Input 12
	TIR	SSC2_TDR	DMA Channel 06 Request Input 12

18.3.4 SSC0/SSC1/SSC2/SSC3 Module Related External Registers

[Figure 18-18](#) summarizes the module-related external registers which are required for SSC0/SSC1/SSC2/SSC3 programming (see also [Figure 18-15](#) for the module kernel specific registers).

Synchronous Serial Interface (SSC)

Clock Control Registers	Port Registers	Interrupt Registers
SSC0_CLC	P1_IOC8	SSC0_TSRC
SSC1_CLC	P1_PDR	SSC0_RSRC
SSC2_CLC	P2_IOC0	SSC0_ESRC
SSC3_CLC	P2_IOC8	SSC1_TSRC
SSC0_FDR	P2_IOC12	SSC1_RSRC
SSC1_FDR	P2_PDR	SSC1_ESRC
SSC2_FDR	P3_IOC0	SSC2_TSRC
SSC3_FDR	P3_IOC4	SSC2_RSRC
	P3_IOC8	SSC2_ESRC
	P3_PDR	SSC3_TSRC
	P5_IOC0	SSC3_RSRC
	P5_IOC4	SSC3_ESRC
	P5_IOC12	
	P5_PDR	
	P8_IOC0	
	P8_IOC4	
	P8_IOC8	
	P8_PDR	
	P10_IOC0	
	P10_PDR	

MCA06226_28_mod

Figure 18-18 SSC0/SSC1/SSC2/SSC3 Implementation-specific Special Function Registers

18.3.4.1 Clock Control

Each SSC module has two clock signals ($x = 0-3$):

- f_{CLCx}
This is the module clock that is used inside the SSC kernel for control purposes such as clocking of control logic and register operations. The frequency of f_{CLCx} is always identical to the system clock frequency f_{SYS} ($= f_{FPI}$ in TC1784). The clock control registers `SSCx_CLC` make it possible to enable/disable f_{CLCx} under certain conditions.
- f_{SSCx}
This clock is the module clock that is used in the `SSCx` as input clock of the baud rate generator, which finally determines the baud rate of the serial data. The fractional divider registers `SSCx_FDR` control the frequency of f_{SSCx} and make it possible to enable/disable it independently of f_{CLCx} .
The Baud Rate Timer Reload Register `SSCx_BR` define serial data baud rate dependent from the frequency of f_{SSCx} .

Synchronous Serial Interface (SSC)

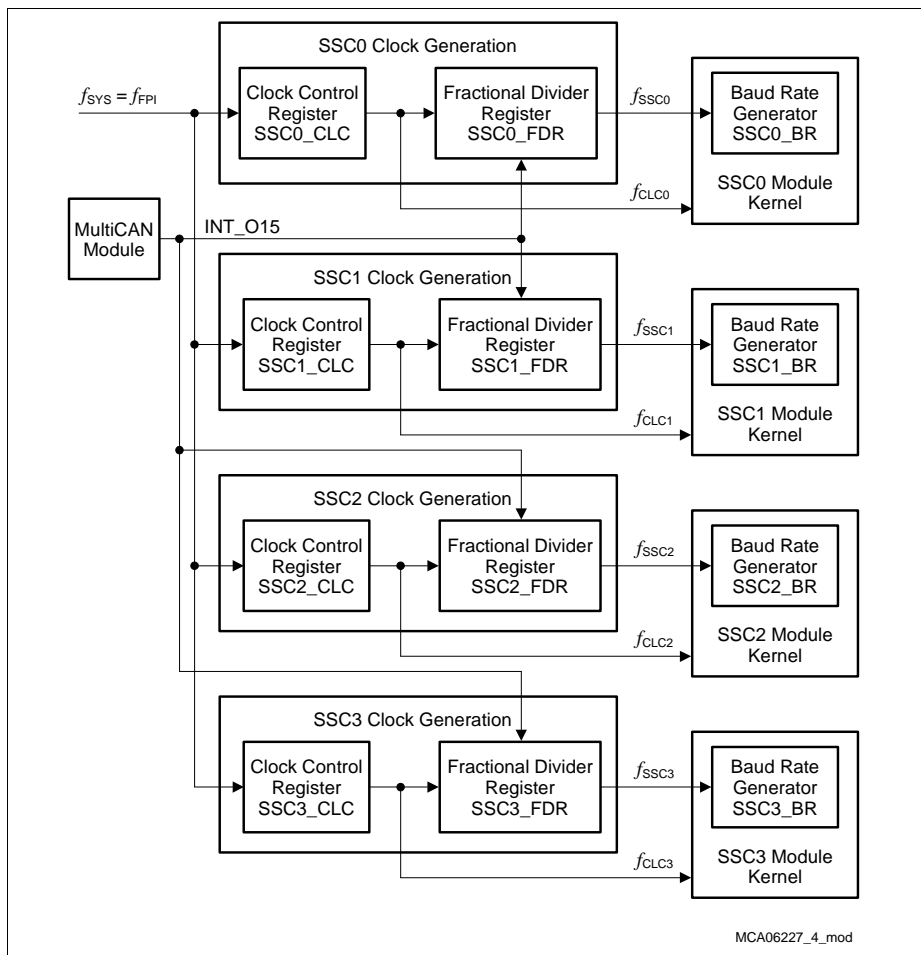


Figure 18-19 SSC Clock Generation

Output signal CAN_INT_O15 of the MultiCAN module can be used for external clock enable control of the fractional divider.

Synchronous Serial Interface (SSC)

The following formulas define the frequency of f_{SSCx} .

$$f_{SSCx} = f_{SYS} \times \frac{1}{n} \text{ with } n = 1024 - \text{FDR.STEP} \quad (18.2)$$

$$f_{SSCx} = f_{SYS} \times \frac{n}{1024} \text{ with } n = 0-1023 \quad (18.3)$$

Note: In SSC Master Mode, the maximum shift clock frequency is $f_{SSCx}/2$. In SSC Slave Mode, the maximum shift clock frequency is $f_{SSCx}/4$.

Combined with the formulas of the baud rate generator (see [Page 18-14](#)) and the fractional divider, the resulting serial data baud rate is defined by:

$$\text{Baud rate}_{SSC} = \frac{f_{SYS}}{2 \times (\text{BR.BR_VALUE} + 1) \times (1024 - \text{FDR.STEP})} \quad (18.4)$$

$$\text{Baud rate}_{SSC} = \frac{f_{SYS} \times \text{FDR.STEP}}{2 \times (\text{BR.BR_VALUE} + 1) \times 1024} \text{ with } \text{FDR.STEP} = 0-1023 \quad (18.5)$$

Note: [Equation \(18.2\)](#) and [Equation \(18.4\)](#) apply to normal divider mode of the fractional divider ($\text{FDR.DM} = 01_B$). [Equation \(18.3\)](#) and [Equation \(18.5\)](#) apply to fractional divider mode ($\text{FDR.DM} = 10_B$).

Synchronous Serial Interface (SSC)

Clock Control Register

Each SSC has its own clock control register. The Clock Control Registers SSCx_CLC make it possible to control (enable/disable) the clock signals f_{CLCx} under certain conditions.

SSC0_CLC

SSC0_Clock Control Register (00_H) **Reset Value: 0000 0003_H**

SSC1_CLC

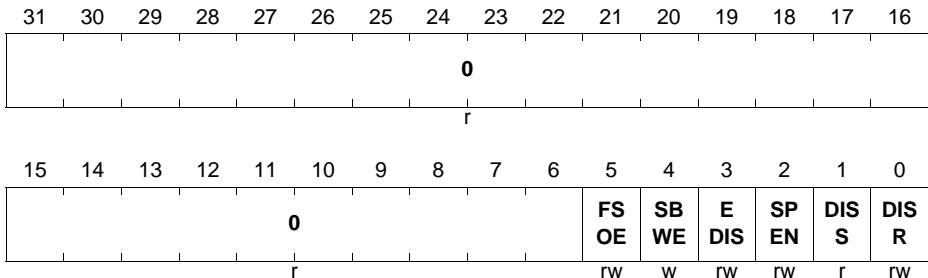
SSC1_Clock Control Register (00_H) **Reset Value: 0000 0003_H**

SSC2_CLC

SSC2_Clock Control Register (00_H) **Reset Value: 0000 0003_H**

SSC3_CLC

SSC3_Clock Control Register (00_H) **Reset Value: 0000 0003_H**



Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode.
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used to switch off fast clock in Suspend Mode.

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
0	[31:6]	r	Reserved Read as 0; should be written with 0.

Note: After a hardware reset operation, the f_{CLKx} clocks are disabled, and therefore also the SSC modules are disabled (DISS set).

Fractional Divider Register

Each SSC has its own fractional divider register. The Fractional Divider Registers SSCx_FDR control the clock rate of the shift clocks f_{SSCx} .

SSC0_FDR

SSC0 Fractional Divider Register (0C_H) **Reset Value: 1000 0000_H**

SSC1_FDR

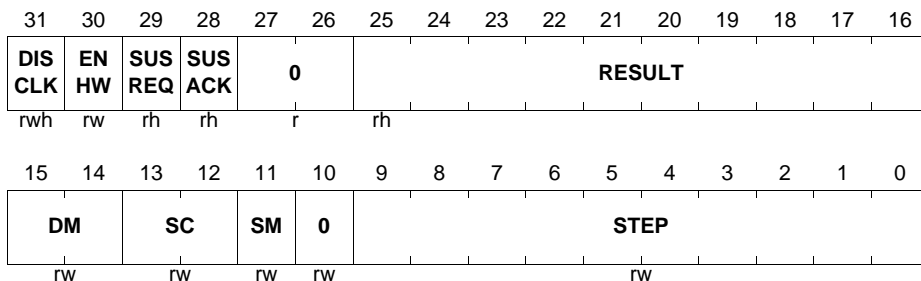
SSC1 Fractional Divider Register (0C_H) **Reset Value: 1000 0000_H**

SSC2_FDR

SSC2 Fractional Divider Register (0C_H) **Reset Value: 1000 0000_H**

SSC3_FDR

SSC3 Fractional Divider Register (0C_H) **Reset Value: 1000 0000_H**



Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value Reload or addition value for RESULT.
SM	11	rw	Suspend Mode SM selects between granted or immediate suspend mode.
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in suspend mode.

Synchronous Serial Interface (SSC)

Field	Bits	Type	Description
DM	[15:14]	rw	Divider Mode This bit field selects normal divider mode, fractional divider mode, and off-state.
RESULT	[25:16]	rh	Result Value Bit field for the addition result.
SUSACK	28	rh	Suspend Mode Acknowledge Indicates state of SPNDACK signal.
SUSREQ	29	rh	Suspend Mode Request Indicates state of SPND signal.
ENHW	30	rw	Enable Hardware Clock Control Controls operation of ECEN input and DISCLK bit.
DISCLK	31	rwh	Disable Clock Hardware-controlled disable for f_{OUT} signal.
0	10	rw	Reserved Read as 0; should be written with 0.
0	[27:26]	r	Reserved Read as 0; should be written with 0.

18.3.4.2 Port Control

Note: The SSCs in the TC1728 do not directly control the I/O functionality of pins. Therefore, control bits CON.EN and CON.MS have no functionality.

The interconnections between the SSC modules and the I/O lines/pins are controlled by software in the port logics. The SSC0/SSC1/SSC2/SSC3 I/O functionality must be selected by the following port control operations (additionally to the PISEL programming):

- Input/output function selection (IOCR registers)
- Pad driver characteristics selection for the outputs (PDR registers)

The SSC0/SSC1/SSC2/SSC3 port input/output control registers contain the bit fields that select the digital output and input driver characteristics such as pull-up/down devices, port direction (input/output), open-drain, and alternate output selections.

Synchronous Serial Interface (SSC)

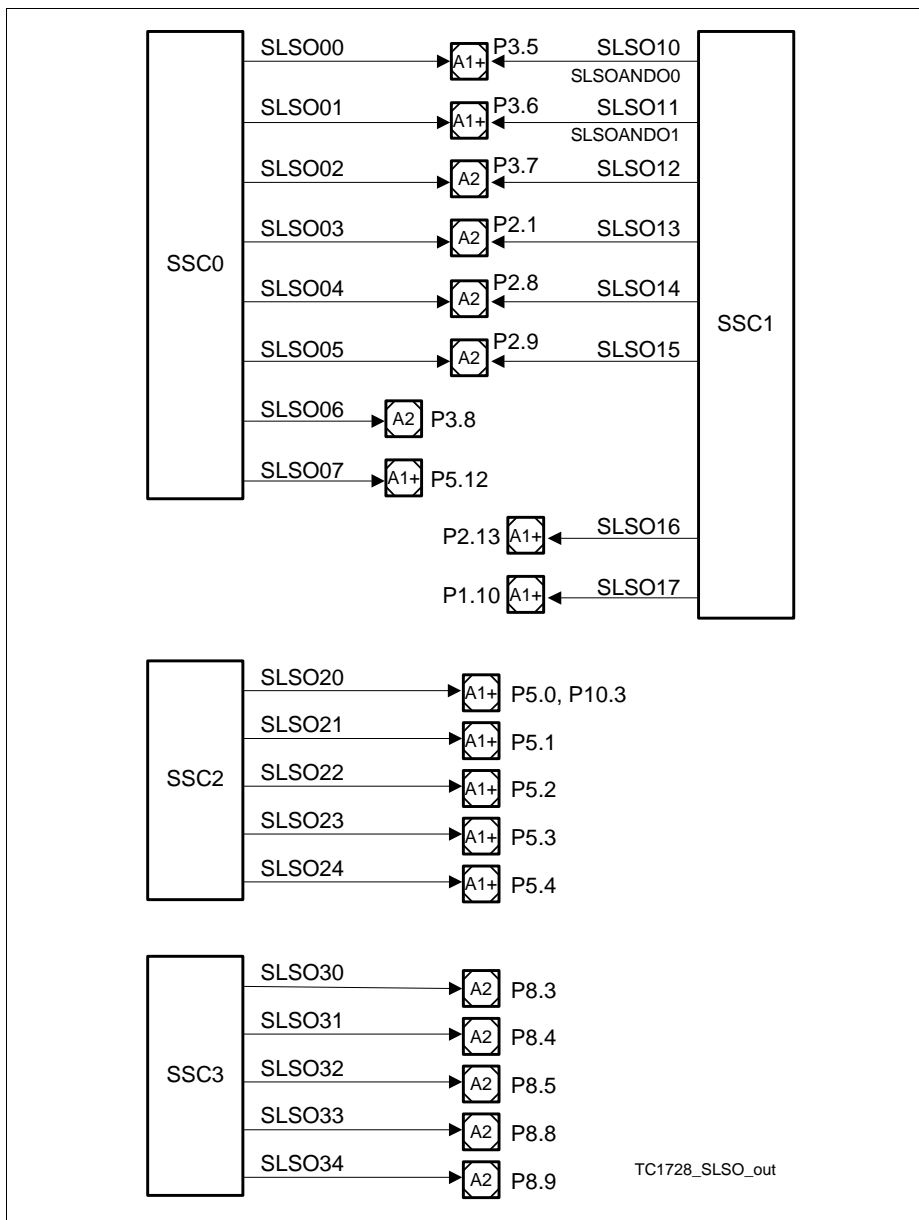


Figure 18-20 SLSI and SLSO Input/Output Connections

Synchronous Serial Interface (SSC)

Table 18-6 shows how bits and bit fields must be programmed for the required I/O functionality of the SSC I/O lines.

Table 18-6 SSC I/O Line Selection and Setup

Module	Port.Pin	Signal	Input/Output Control Register Bits	I/O
SSC0	P3.4	MTSR0A	P3_IOCR4.PC4 = 0XXX _B	Input
		MTSR0	P3_IOCR4.PC4 = 1X01 _B	Output
			P3_IOCR4.PC4 = 1X10 _B	
	P3.3	MRST0A	P3_IOCR0.PC3 = 0XXX _B	Input
		MRST0	P3_IOCR0.PC3 = 1X01 _B	Output
			P3_IOCR0.PC3 = 1X10 _B	
	P3.2	SCLK0A	P3_IOCR0.PC2 = 0XXX _B	Input
		SCLK0	P3_IOCR0.PC2 = 1X01 _B	Output
			P3_IOCR0.PC2 = 1X10 _B	
	P3.7	SLSI0	P3_IOCR4.PC7 = 0XXX _B	Input
SSC1	P2.12	MTSR1A	P2_IOCR12.PC12 = 0XXX _B	Input
		MTSR1	P2_IOCR12.PC12 = 1X01 _B	Output
	P2.10	MRST1A	P2_IOCR8.PC10 = 0XXX _B	Input
		MRST1	P2_IOCR8.PC10 = 1X01 _B	Output
	P2.11	SCLK1A	P2_IOCR8.PC11 = 0XXX _B	Input
		SCLK1	P2_IOCR8.PC11 = 1X01 _B	Output
	P1.8	MTSR1B	P1_IOCR8.PC8 = 0XXX _B	Input
		MTSR1	P1_IOCR8.PC8 = 1X11 _B	Output
	P1.9	MRST1B	P1_IOCR8.PC9 = 0XXX _B	Input
		MRST1	P1_IOCR8.PC9 = 1X11 _B	Output
	P1.11	SCLK1B	P1_IOCR8.PC11 = 0XXX _B	Input
		SCLK1	P1_IOCR8.PC11 = 1X11 _B	Output
	P2.13	SLSI1A	P2_IOCR12.PC13 = 0XXX _B	Input

Synchronous Serial Interface (SSC)

Table 18-6 SSC I/O Line Selection and Setup (cont'd)

Module	Port.Pin	Signal	Input/Output Control Register Bits	I/O
SSC2	P5.6	MTSR2A	P5_IOCR4.PC6 = 0XXX _B	Input
		MTSR2	P5_IOCR4.PC6 = 1X11 _B	Output
	P5.5	MRST2A	P5_IOCR0.PC5 = 0XXX _B	Input
		MRST2	P5_IOCR0.PC5 = 1X11 _B	Output
	P5.7	SCLK2A	P5_IOCR4.PC7 = 0XXX _B	Input
		SCLK2	P5_IOCR4.PC7 = 1X11 _B	Output
	P5.4	SLSI2A	P5_IOCR4.PC4 = 0XXX _B	Input
	P10.1	MTSR2B	P10_IOCR0.PC1 = 0XXX _B	Input
		MTSR2	P10_IOCR0.PC1 = 1X01 _B	Output
	P10.0	MRST2B	P10_IOCR0.PC0 = 0XXX _B	Input
		MRST2	P10_IOCR0.PC0 = 1X01 _B	Output
	P10.2	SCLK2B	P10_IOCR0.PC2 = 0XXX _B	Input
		SCLK2	P10_IOCR0.PC2 = 1X01 _B	Output
	P10.3	SLSI2B	P10_IOCR0.PC3 = 0XXX _B	Input
SSC3	P8.2	MTSR3A	P8_IOCR0.PC2 = 0XXX _B	Input
		MTSR3	P8_IOCR0.PC2 = 1X11 _B	Output
	P8.1	MRST3A	P8_IOCR0.PC1 = 0XXX _B	Input
		MRST3	P8_IOCR0.PC1 = 1X11 _B	Output
	P8.0	SCLK3A	P8_IOCR0.PC0 = 0XXX _B	Input
		SCLK3	P8_IOCR0.PC0 = 1X11 _B	Output
	P8.3	SLSI3A	P8_IOCR0.PC3 = 0XXX _B	Input
	Slave Select Outputs			
SSC0	P3.5	SLSO00	P3_IOCR4.PC5 = 1X01 _B	Output
	P3.6	SLSO01	P3_IOCR4.PC6 = 1X01 _B	Output
	P3.7	SLSO02	P3_IOCR4.PC7 = 1X01 _B	Output
	P2.1	SLSO03	P2_IOCR0.PC1 = 1X10 _B	Output
	P2.8	SLSO04	P2_IOCR8.PC8 = 1X01 _B	Output
	P2.9	SLSO05	P2_IOCR8.PC9 = 1X01 _B	Output
	P3.8	SLSO06	P3_IOCR8.PC8 = 1X01 _B	Output
	P5.12	SLSO07	P5_IOCR12.PC11 = 1X10 _B	Output

Synchronous Serial Interface (SSC)

Table 18-6 SSC I/O Line Selection and Setup (cont'd)

Module	Port.Pin	Signal	Input/Output Control Register Bits	I/O
SSC1	P3.5	SLSO10	P3_IOCR4.PC5 = 1X10 _B	Output
	P3.6	SLSO11	P3_IOCR4.PC6 = 1X10 _B	Output
	P3.7	SLSO12	P3_IOCR4.PC7 = 1X10 _B	Output
	P2.1	SLSO13	P2_IOCR0.PC1 = 1X11 _B	Output
	P2.8	SLSO14	P2_IOCR8.PC8 = 1X10 _B	Output
	P2.9	SLSO15	P2_IOCR8.PC9 = 1X10 _B	Output
	P2.13	SLSO16	P5_IOCR12.PC13 = 1X01 _B	Output
	P1.10	SLSO17	P1_IOCR8.PC10 = 1X11 _B	Output
SSC0 & SSC1	P3.5	SLSOANDO0	P3_IOCR4.PC5 = 1X11 _B	Output
	P3.6	SLSOANDO1	P3_IOCR4.PC6 = 1X11 _B	
SSC2	P5.0	SLSO20	P5_IOCR0.PC0 = 1X10 _B	Output
	P5.1	SLSO21	P5_IOCR0.PC1 = 1X10 _B	
	P5.2	SLSO22	P5_IOCR0.PC2 = 1X10 _B	
	P5.3	SLSO23	P5_IOCR0.PC3 = 1X10 _B	
	P5.4	SLSO24	P5_IOCR4.PC4 = 1X10 _B	
SSC3	P8.3	SLSO30	P8_IOCR0.PC3 = 1X11 _B	Output
	P8.4	SLSO31	P8_IOCR4.PC4 = 1X11 _B	
	P8.5	SLSO32	P8_IOCR4.PC5 = 1X11 _B	
	P8.8	SLSO33	P8_IOCR8.PC8 = 1X11 _B	
	P8.9	SLSO34	P8_IOCR8.PC9 = 1X11 _B	

Synchronous Serial Interface (SSC)

18.3.4.3 Interrupt Control Registers

The 3×3 interrupts of the SSC0/SSC1/SSC2 modules are controlled by the following service request control registers:

- SSCx_TSRC (x = 0-3) controls the transmit interrupts of the SSCx module
- SSCx_RSRC (x = 0-3) controls the receive interrupts of the SSCx module
- SSCx_ESRC (x = 0-3) controls the error interrupts of the SSCx module

TSRC

Transmit Interrupt Service Request Control Register

(F4_H)

Reset Value: 0000 0000_H

RSRC

Receive Interrupt Service Request Control Register

(F8_H)

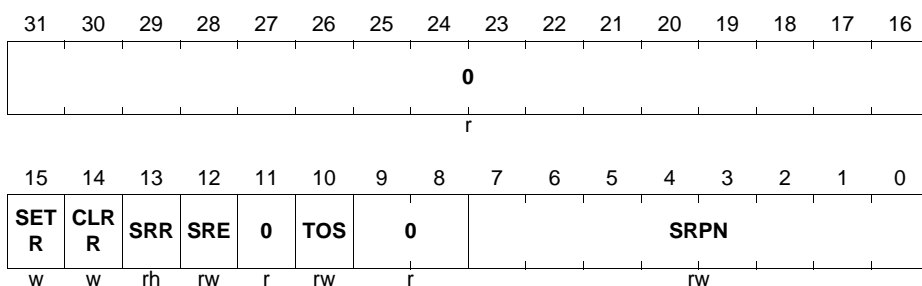
Reset Value: 0000 0000_H

ESRC

Error Interrupt Service Request Control Register

(FC_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Synchronous Serial Interface (SSC)

18.3.5 Address Map of the SSC Modules

An absolute register address is given by the offset address of the register (given in [Table 18-4](#)) plus the module base address (given in [Table 18-3](#)).

Table 18-7 Address Map of SSC0/SSC1/SSC2/SSC3

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
Synchronous Serial Interface 0 (SSC0)					
SSC0_ CLC	SSC0 Clock Control Register	F010 0100 _H	U, SV	SV, E	0000 0003 _H
SSC0_ PISEL	SSC0 Port Input Select Register	F010 0104 _H	U, SV	U, SV	0000 0000 _H
SSC0_ ID	SSC0 Module Identification Register	F010 0108 _H	U, SV	BE	0000 45XX _H
SSC0_ FDR	SSC0 Fractional Divider Register	F010 010C _H	U, SV	SV, E	1000 0000 _H
SSC0_CON	SSC0 Control Register	F010 0110 _H	U, SV	U, SV	0000 0000 _H
SSC0_ BR	SSC0 Baud Rate Timer Reload Register	F010 0114 _H	U, SV	U, SV	0000 0000 _H
SSC0_ SSOC	SSC0 Slave Select Output Control Register	F010 0118 _H	U, SV	U, SV	0000 0000 _H
SSC0_ SSOTC	SSC0 Slave Select Output Timing Control Register	F010 011C _H	U, SV	U, SV	0000 0000 _H
SSC0_ TB	SSC0 Transmit Buffer Register	F010 0120 _H	U, SV	U, SV	0000 0000 _H
SSC0_ RB	SSC0 Receive Buffer Register	F010 0124 _H	U, SV	U, SV	0000 0000 _H
SSC0_ STAT	SSC0 Status Register	F010 0128 _H	U, SV	U, SV	0000 0000 _H
SSC0_ EFM	SSC0 Error Flag Modification Register	F010 012C _H	U, SV	U, SV	0000 0000 _H
—	Reserved	F010 0130 _H - F010 01F0 _H	BE	BE	—
SSC0_ TSRC	SSC0 Transmit Interrupt Service Req. Control Reg.	F010 01F4 _H	U, SV	SV	0000 0000 _H

Synchronous Serial Interface (SSC)

Table 18-7 Address Map of SSC0/SSC1/SSC2/SSC3 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
SSC0_RSRC	SSC0 Receive Interrupt Service Req. Control Reg.	F010 01F8 _H	U, SV	SV	0000 0000 _H
SSC0_ESRC	SSC0 Error Interrupt Service Req. Control Reg.	F010 01FC _H	U, SV	SV	0000 0000 _H
Synchronous Serial Interface 1 (SSC1)					
SSC1_CLC	SSC1 Clock Control Register	F010 0200 _H	U, SV	SV, E	0000 0003 _H
SSC1_PISEL	SSC1 Port Input Select Register	F010 0204 _H	U, SV	U, SV	0000 0000 _H
SSC1_ID	SSC1 Module Identification Register	F010 0208 _H	U, SV	BE	0000 45XX _H
SSC1_FDR	SSC1 Fractional Divider Register	F010 020C _H	U, SV	SV, E	1000 0000 _H
SSC1_CON	SSC1 Control Register	F010 0210 _H	U, SV	U, SV	0000 0000 _H
SSC1_BR	SSC1 Baud Rate Timer Reload Register	F010 0214 _H	U, SV	U, SV	0000 0000 _H
SSC1_SSOC	SSC1 Slave Select Output Control Register	F010 0218 _H	U, SV	U, SV	0000 0000 _H
SSC1_SSOTC	SSC1 Slave Select Output Timing Control Register	F010 021C _H	U, SV	U, SV	0000 0000 _H
SSC1_TB	SSC1 Transmit Buffer Register	F010 0220 _H	U, SV	U, SV	0000 0000 _H
SSC1_RB	SSC1 Receive Buffer Register	F010 0224 _H	U, SV	U, SV	0000 0000 _H
SSC1_STAT	SSC1 Status Register	F010 0228 _H	U, SV	U, SV	0000 0000 _H
SSC1_EFM	SSC1 Error Flag Modification Register	F010 022C _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F010 0230 _H - F010 02F0 _H	BE	BE	–
SSC1_TSRC	SSC1 Transmit Interrupt Service Req. Control Reg.	F010 02F4 _H	U, SV	SV	0000 0000 _H
SSC1_RSRC	SSC1 Receive Interrupt Service Req. Control Reg.	F010 02F8 _H	U, SV	SV	0000 0000 _H

Synchronous Serial Interface (SSC)

Table 18-7 Address Map of SSC0/SSC1/SSC2/SSC3 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
SSC1_ ESRC	SSC1 Error Interrupt Service Req. Control Reg.	F010 02FC _H	U, SV	SV	0000 0000 _H
Synchronous Serial Interface 2 (SSC2)					
SSC2_CLC	SSC2 Clock Control Register	F010 0300 _H	U, SV	SV, E	0000 0003 _H
SSC2_ PISEL	SSC2 Port Input Select Register	F010 0304 _H	U, SV	U, SV	0000 0000 _H
SSC2_ ID	SSC2 Module Identification Register	F010 0308 _H	U, SV	BE	0000 45XX _H
SSC2_ FDR	SSC2 Fractional Divider Register	F010 030C _H	U, SV	SV, E	1000 0000 _H
SSC2_CON	SSC2 Control Register	F010 0310 _H	U, SV	U, SV	0000 0000 _H
SSC2_ BR	SSC2 Baud Rate Timer Reload Register	F010 0314 _H	U, SV	U, SV	0000 0000 _H
SSC2_ SSOC	SSC2 Slave Select Output Control Register	F010 0318 _H	U, SV	U, SV	0000 0000 _H
SSC2_ SSOTC	SSC2 Slave Select Output Timing Control Register	F010 031C _H	U, SV	U, SV	0000 0000 _H
SSC2_ TB	SSC2 Transmit Buffer Register	F010 0320 _H	U, SV	U, SV	0000 0000 _H
SSC2_ RB	SSC2 Receive Buffer Register	F010 0324 _H	U, SV	U, SV	0000 0000 _H
SSC2_STAT	SSC2 Status Register	F010 0328 _H	U, SV	U, SV	0000 0000 _H
SSC2_ EFM	SSC2 Error Flag Modification Register	F010 032C _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F010 0330 _H - F010 03F0 _H	BE	BE	–
SSC2_ TSRC	SSC2 Transmit Interrupt Service Req. Control Reg.	F010 03F4 _H	U, SV	SV	0000 0000 _H
SSC2_ RSRC	SSC2 Receive Interrupt Service Req. Control Reg.	F010 03F8 _H	U, SV	SV	0000 0000 _H
SSC2_ ESRC	SSC2 Error Interrupt Service Req. Control Reg.	F010 03FC _H	U, SV	SV	0000 0000 _H

Synchronous Serial Interface (SSC)

Table 18-7 Address Map of SSC0/SSC1/SSC2/SSC3 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
Synchronous Serial Interface 3 (SSC3)					
SSC3_CLC	SSC3 Clock Control Register	F010 0000 _H	U, SV	SV, E	0000 0003 _H
SSC3_PISEL	SSC3 Port Input Select Register	F010 0004 _H	U, SV	U, SV	0000 0000 _H
SSC3_ID	SSC3 Module Identification Register	F010 0008 _H	U, SV	BE	0000 45XX _H
SSC3_FDR	SSC3 Fractional Divider Register	F010 000C _H	U, SV	SV, E	1000 0000 _H
SSC3_CON	SSC3 Control Register	F010 0010 _H	U, SV	U, SV	0000 0000 _H
SSC3_BR	SSC3 Baud Rate Timer Reload Register	F010 0014 _H	U, SV	U, SV	0000 0000 _H
SSC3_SSOC	SSC3 Slave Select Output Control Register	F010 0018 _H	U, SV	U, SV	0000 0000 _H
SSC3_SSOTC	SSC3 Slave Select Output Timing Control Register	F010 001C _H	U, SV	U, SV	0000 0000 _H
SSC3_TB	SSC3 Transmit Buffer Register	F010 0020 _H	U, SV	U, SV	0000 0000 _H
SSC3_RB	SSC3 Receive Buffer Register	F010 0024 _H	U, SV	U, SV	0000 0000 _H
SSC3_STAT	SSC3 Status Register	F010 0028 _H	U, SV	U, SV	0000 0000 _H
SSC3_EFM	SSC3 Error Flag Modification Register	F010 002C _H	U, SV	U, SV	0000 0000 _H
—	Reserved	F010 0030 _H - F010 00F0 _H	BE	BE	—
SSC3_TSRC	SSC3 Transmit Interrupt Service Req. Control Reg.	F010 00F4 _H	U, SV	SV	0000 0000 _H
SSC3_RSRC	SSC3 Receive Interrupt Service Req. Control Reg.	F010 00F8 _H	U, SV	SV	0000 0000 _H
SSC3_ESRC	SSC3 Error Interrupt Service Req. Control Reg.	F010 00FC _H	U, SV	SV	0000 0000 _H

19 Micro Second Channel (MSC)

This chapter describes the Micro Second Channel Interface MSC0 of the TC1728. It contains the following sections:

- Functional description of the MSC kernel (see [Page 19-3](#))
- MSC kernel register descriptions (see [Page 19-36](#))
- TC1728 implementation-specific details and registers of the MSC module (port connections and control, interrupt control, address decoding, and clock control, see [Page 19-62](#))

Note: The MSC kernel register names described in [Section 19.2](#) are also referenced in the TC1728 User's Manual by the module name prefix "MSC0_" for the MSC0 module.

Micro Second Channel (MSC)

MSC Applications

The MSC is a serial interface that is especially designed to connect external power devices to the TC1728. The serial data transmission capability minimizes the number of pins required to connect such external power devices. Parallel data information (coming from the timer units) or command information is sent out to the power device via a high-speed synchronous serial data stream (downstream channel). The MSC receives data and status back from the power device via a low-speed asynchronous serial data stream (upstream channel).

Figure 19-1 shows a typical TC1728 application in which an MSC interface controls two power devices. Output data is provided by the GPTA module.

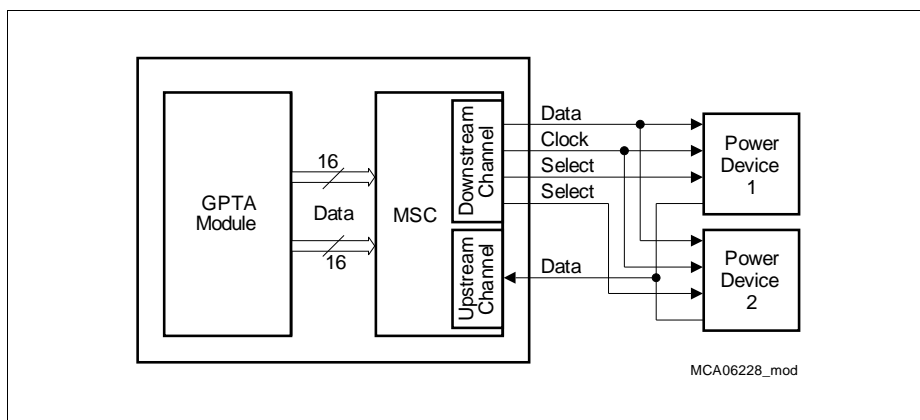


Figure 19-1 MSC to External Power Device Connection

Some applications are:

- Control of the external power switching unit via the downstream channel
- Receiving information back from power switching unit
- Serial connections of the TC1728 to other peripheral devices

Micro Second Channel (MSC)

19.1 MSC Kernel Description

This section describes the functionality of the MSC kernel.

19.1.1 Overview

The MSC interface provides a serial communication link typically used to connect power switches or other peripheral devices. The serial communication link includes a fast synchronous downstream channel and a slow asynchronous upstream channel.

Figure 19-2 shows a global view of the MSC interface signals.

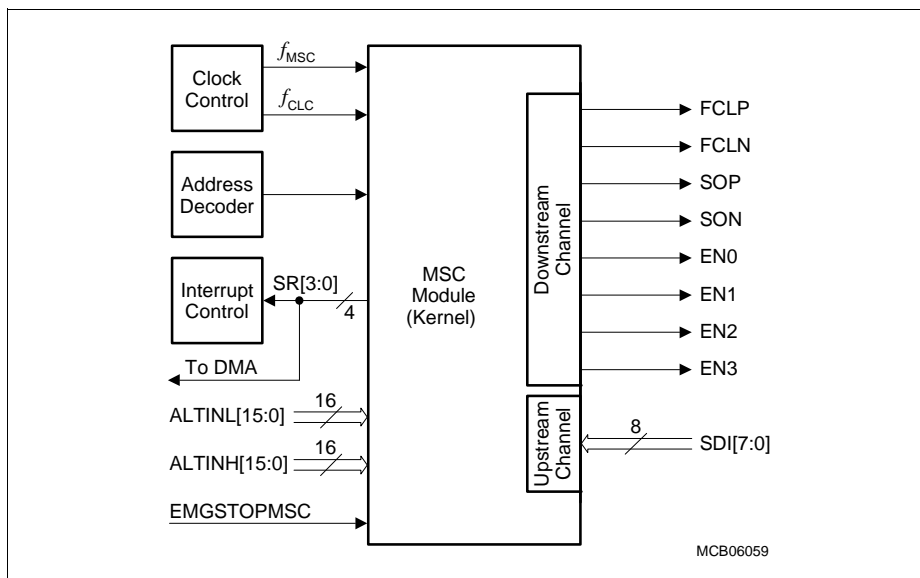


Figure 19-2 General Block Diagram of the MSC Interface

The downstream and upstream channels of the MSC module communicate with the external world via nine I/O lines. Eight output lines are required for the serial communication of the downstream channel (clock, data, and enable signals). One out of eight input lines $SDI[7:0]$ is used as serial data input signal for the upstream channel. The source of the serial data to be transmitted by the downstream channel can be MSC register contents or data that is provided at the $ALTINL/ALTINH$ input lines. These input lines are typically connected to other on-chip peripheral units (for example with a timer unit like the GPTA). An emergency stop input signal makes it possible to set bits of the serial data stream to dedicated values in emergency case.

Micro Second Channel (MSC)

Clock control, address decoding, and interrupt service request control are managed outside the MSC module kernel. Service request outputs are able to trigger an interrupt or a DMA request.

Features

- Fast synchronous serial interface to connect power switches in particular, or other peripheral devices via serial buses
- High-speed synchronous serial transmission on downstream channel
 - Serial output clock frequency: $f_{FCL} = f_{MSC}/2$ ($f_{MSCmax} = 110$ MHz)
 - Fractional clock divider for precise frequency control of serial clock f_{MSC}
 - Command, data, and passive frame types
 - Start of serial frame: Software-controlled, timer-controlled, or free-running
 - Transmission with or without SEL bit
 - Flexible chip select generation indicates status during serial frame transmission
 - Emergency stop without CPU intervention
- Low-speed asynchronous serial reception on upstream channel
 - Baud rate: f_{MSC} divided by 4, 8, 16, 32, 64, 128, or 256 ($f_{MSCmax} = 110$ MHz)
 - Standard asynchronous serial frames
 - Programmable upstream data frame length (16 or 12 bits)
 - Parity error checker
 - 8-to-1 input multiplexer for SDI lines
 - Built-in spike filter on SDI lines

Micro Second Channel (MSC)

19.1.2 Downstream Channel

The downstream channel performs a high-speed synchronous serial transmission of data to external devices. Its 32-bit shift register is divided into two 16-bit parts, SRL and SRH. Each bit of SRL and SRH can be selected to be delivered by the downstream data register DD, by the Downstream Command Register DC, or by two 16-bit wide input signal buses ALTINL and ALTINH.

Figure 19-3 is a diagram of the MSC downstream channel.

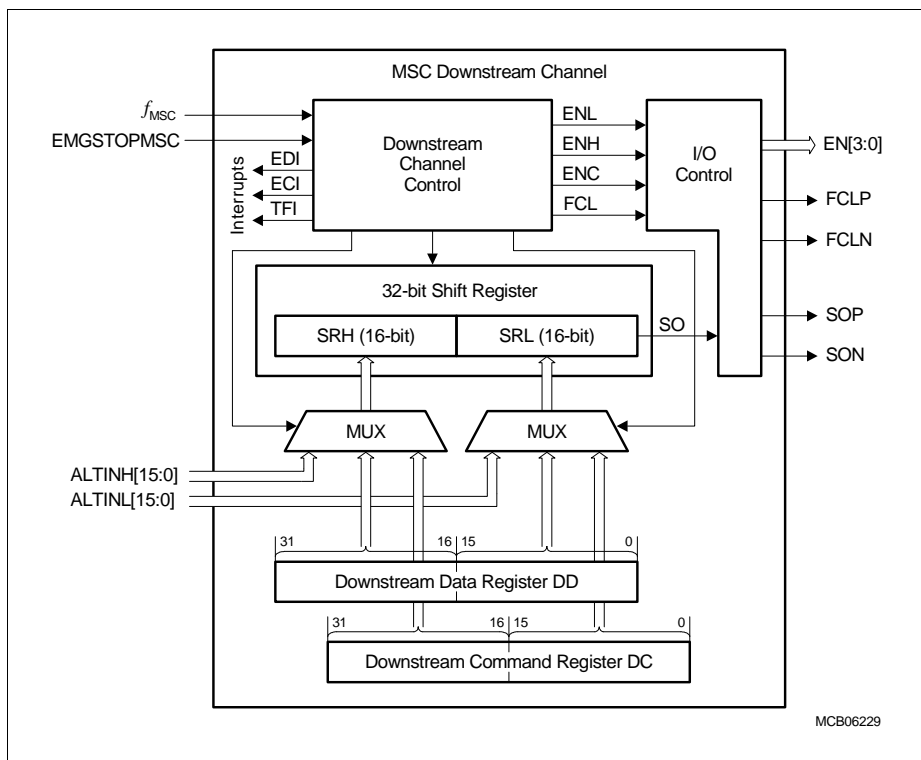


Figure 19-3 Downstream Channel Block Diagram

The enable signals ENL, ENH, and ENC indicate certain phases of the serial transmission in relation to the serial clock FCL. In the I/O control logic, these signals can be combined to four enable/select outputs EN[3:0]. For supporting differential output drivers, the serial clock output FCL and the serial data output SO are available in both polarities, indicated by the signal name suffix "P" and "N".

Micro Second Channel (MSC)

The emergency stop input line EMGSTOPMSC is used to indicate an emergency stop condition of a power device. In emergency case, shift register bits can be loaded bit-wise from the downstream data register instead from the ALTINL and ALTINH buses.

19.1.2.1 Frame Formats and Definitions

This section describes the frame formats and definitions of the MSC.

Basic Definitions

Figure 19-4 shows the layout and definitions of a downstream frame. A downstream frame is composed of an active phase and a passive phase. During the active phase, data transmission takes place and during the passive phase no data is transmitted at SO. The active phase is split into two parts: The SRL active phase in which the content of the shift register low part SRL is transmitted, and the SRH active phase in which the content of the shift register high part SRH is transmitted. At the beginning of the SRL and SRH active phase, a selection bit (SELL) can be optionally inserted into the serial data stream. In the frame shown in **Figure 19-4**, SELL is generated at the beginning of the SRL active phase (not for the SRH active phase). The least significant bits of SRL and SRH are sent out first. MCT06230

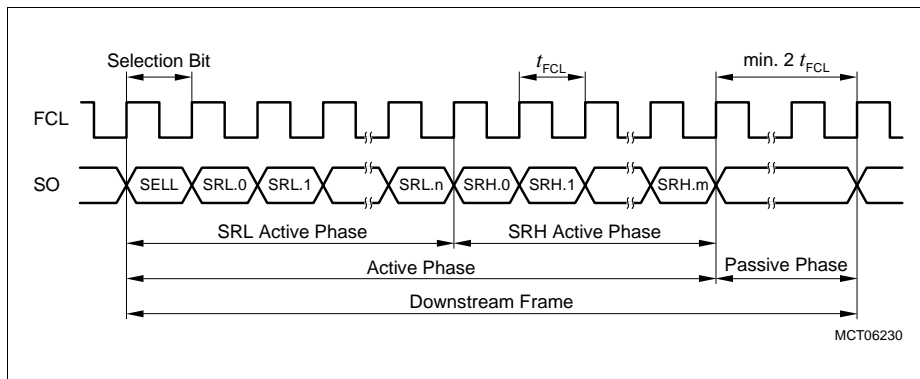


Figure 19-4 Downstream Channel Frame

The MSC downstream channel uses three types of frame formats for operation:

- Command frames, indicated by SELL = 1
- Data frames, indicated by SELL = 0 or SELL bit insertion disabled
- Passive time frame, indicated by ENL = ENH = 0

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Command Frames

A command frame has two active phase parts, SRL active phase and SRH active phase. The command frame always starts with a high-level selection bit, independently whether the selection bit insertion (as defined by bit DSC.ENSELL) is enabled or not. The number of the bits transmitted during SRL and SRH active phases (except the selection bit) is defined by bit field DSC.NBC. SRL and SRH are combined to a 32-bit value whose length can be selected from 0 up to 32 bits. In other words, whenever bits of SRH are transmitted, they are always preceded by the transmission of the complete SRL content.

During the active phase of a command frame, the enable output signal ENC becomes active. The enable output signals ENL and ENH remain inactive.

The passive phase of a command frame always has a fixed length of $2 \times t_{FCL}$. The diagram shown in [Figure 19-5](#) assumes that the FCL clock is only generated during the active phase of the command frame (OCR.CLKCTRL = 0).

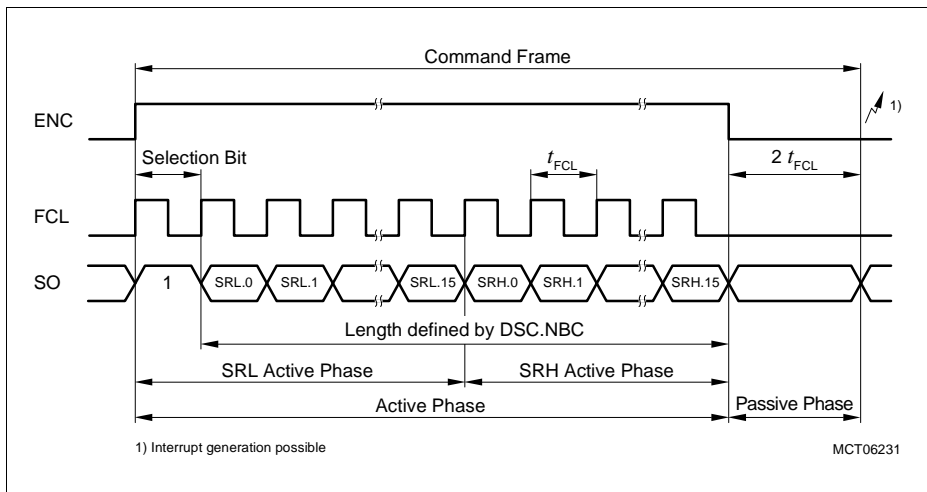


Figure 19-5 Command Frame Layout

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Table 19-1 shows the programming of the bits to be transmitted and the resulting length of the complete command frame.

Table 19-1 Command Frame Length

DSC.NBC	SRL/SRH Bits that are Transmitted in Active Phase	Command Frame Length in t_{FCL} Periods
000000 _B	No bit shifted out	$1 + 0 + 2 = 3$
000001 _B	SRL[0] shifted out	$1 + 1 + 2 = 4$
000010 _B	SRL[1:0] shifted out	$1 + 2 + 2 = 5$
000011 _B	SRL[2:0] shifted out	$1 + 3 + 2 = 6$
...
001111 _B	SRL[14:0] shifted out	$1 + 15 + 2 = 18$
010000 _B	SRL[15:0] shifted out	$1 + 16 + 2 = 19$
010001 _B	SRL[15:0] and SRH[0] shifted out	$1 + 17 + 2 = 20$
010010 _B	SRL[15:0] and SRH[1:0] shifted out	$1 + 18 + 2 = 21$
010011 _B	SRL[15:0] and SRH[2:0] shifted out	$1 + 19 + 2 = 22$
...
011111 _B	SRL[15:0] and SRH[14:0] shifted out	$1 + 31 + 2 = 34$
100000 _B	SRL[15:0] and SRH[15:0] shifted out	$1 + 32 + 2 = 35$
Other NBC combinations	Reserved; do not use these bit combinations.	

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Data Frames

A data frame has two active phase parts, SRL active phase and SRH active phase. The number of bits that are transmitted can be programmed separately for each of these two phases. Bit field DSC.NDBL determines the number of SRL bits that are transmitted during the SRL active phase and DSC.NDBH determines the number of SRH bits that are transmitted during the SRH active phase.

SRL and SRH active phases can start with a low-level selection bit when enabled by bits DSC.ENSELL or DSC.ENSELH.

During the SRL active phase of a data frame, the enable output signal ENL becomes active and during the SRH active phase of a data frame, the enable output signal ENH becomes active. The enable output signal ENC remains inactive.

The length of the data frame's passive phase is variable and is defined by bit field DSC.PPD. It can be within a range of $2 \times t_{FCL}$ up to $31 \times t_{FCL}$. The diagram shown in [Figure 19-6](#) assumes that the FCL clock is only generated during the active phase of the data frame (OCR.CLKCTRL = 0).

[Table 19-2](#), [Table 19-3](#), and [Table 19-4](#) show the definitions of the five data frame parameters that determine the layout of the data frame.

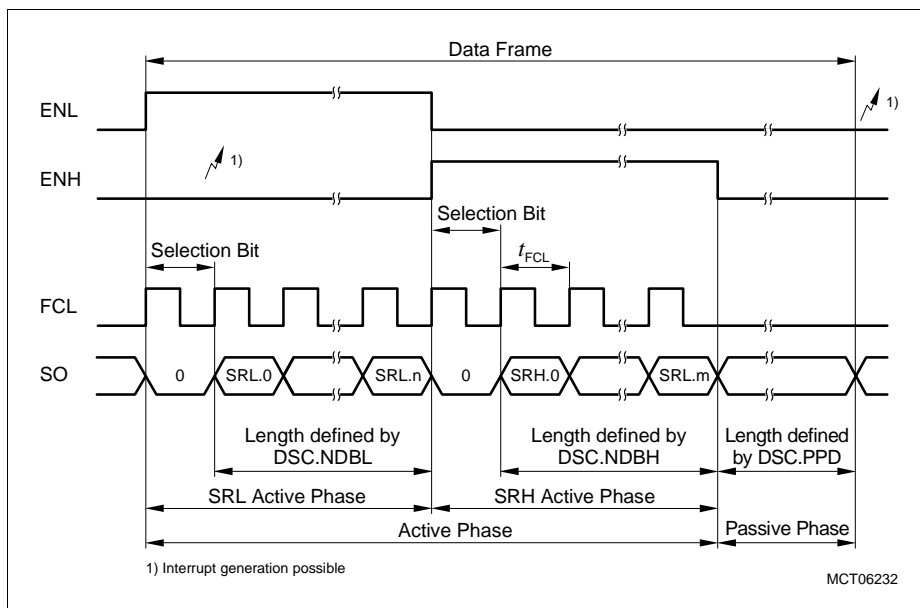


Figure 19-6 Data Frame Layout

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Table 19-2 Data Frame Selection Bit Parameters

DSC.ENSELL	Selection Bit	DSC.ENSELH	Selection Bit
0	No selection bit inserted at the beginning of the SRL active phase	0	No selection bit inserted at the beginning of the SRH active phase
1	A low level selection bit is inserted at the beginning of the SRL active phase	1	A low level selection bit is inserted at the beginning of the SRH active phase

Table 19-3 Data Frame SRL/SRH Length Parameters

DSC.NDBL	SRL Bits Transmitted in SRL Active Phase	DSC.NDBH	SRH Bits Transmitted in SRH Active Phase
00000 _B	No SRL bit transmitted	00000 _B	No SRH bit transmitted
00001 _B	SRL[0]	00001 _B	SRHL[0]
00010 _B	SRL[1:0]	00010 _B	SRH[1:0]
00011 _B	SRL[2:0]	00011 _B	SRH[2:0]
...
01111 _B	SRL[14:0]	01111 _B	SRH[14:0]
10000 _B	SRL[15:0]	10000 _B	SRH[15:0]
Other bit combinations	Reserved; do not use these bit combinations.	Other bit combinations	Reserved; do not use these bit combinations.

Table 19-4 Data Frame Passive Phase Length

DSC.PPD	Passive Phase Length
00000 _B	$2 \times t_{FCL}$
00001 _B	$2 \times t_{FCL}$
00010 _B	$2 \times t_{FCL}$
00011 _B	$3 \times t_{FCL}$
...	...
01110 _B	$30 \times t_{FCL}$
01111 _B	$31 \times t_{FCL}$

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The following formula determines the number of t_{FCL} cycles of a data frame: All parameters (bits and bit fields) are located in register DSC.

$$\text{Number of cycles} = \text{ENSELL} + \text{NDBL} + \text{ENSELH} + \text{NDBH} + \text{PPD} \quad (19.1)$$

Note that in the formula above, PPD must be set to 2 when $\text{DSC.PPD} \leq 00010_{\text{B}}$.

Passive Time Frames

A passive time frame has the length defined by the five data frame parameters according **Equation (19.1)**. They are generated only in Data Repetition Mode. Under special conditions (command frame insertion), passive time frames can be shortened (see **Figure 19-9**).

During passive time frames, the data output SO have to be considered as invalid at the receiving device and the clock output FCL may toggle or not (as selected by bit OCR.CLKCTRL). The ENL and ENH enable signals remain at low level during a passive time frame.

19.1.2.2 Shift Register Operation

This section describes the SRL and SRH shift register loading.

SRL Shift Register Loading

During the SRL/SRH shift register load operation at the beginning of each downstream frame transmission, several parameters determine which information is loaded into the bits of the shift register. **Figure 19-7** shows the logic that is implemented for the SRL shift register loading operation. The logic for the SRH shift register loading operation is equivalent to the one for the SRL register. Its differences in data sources and register controls are described later in this section.

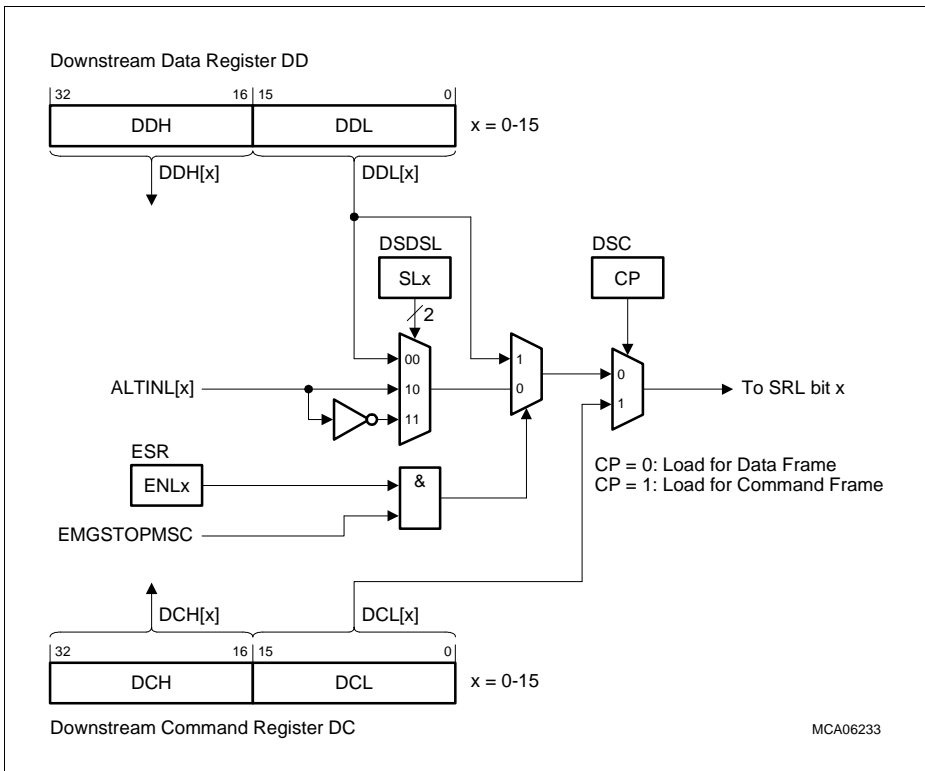


Figure 19-7 SRL Shift Register Data Loading Control

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Four data sources can be selected for each SRL bit by using several control bits and one control signal:

- ALTINL input line (non-inverted)
- ALTINL input line (inverted)
- Bit of DD.DDL (downstream data register)
- Bit of DC.DCL (downstream control register)

When SRL is loaded for data frame transmission ($DSC.CP = 0$), bit fields DSDSL.SLx determine bit-wise which data is loaded into SRL bit x. The data source selection as controlled by DSDSL.SLx will only be effective when EMGSTOPMSC is inactive (at low level). When $EMGSTOPMSC = 1$ (active) during the load operation, all $SRL[x]$ bits that are enabled for the emergency stop feature (bit $ESR.ENLx = 1$) are loaded directly with the corresponding bit $DDL[x]$ of the downstream data register DD.

When SRL is loaded for command frame transmission ($DSC.CP = 1$), always the lower 16-bit part DCL of the downstream control register is loaded completely into SRL.

Table 19-5 summarizes all SRL data source selection capabilities ($x = 0-15$).

Table 19-5 SRL Data Source Selection Capabilities

DSC.CP	DSDSL.SLx	ESR.ENLx	EMGSTOPMSC	Selection
0	00 _B	0	–	Bit DD.DDL[x] is loaded into SRL[x].
	01 _B			Reserved.
	10 _B			State of ALTINL[x] input is loaded into SRL[x].
	11 _B			Inverted state of ALTINL[x] input is loaded into SRL[x].
	XX _B	1	1	Bit DD.DDL[x] is loaded into SRL[x].
1	XX _B	X	X	Bit fields DCL and DCH are completely loaded into SRL and SRH, respectively.

SRH Shift Register Loading

The SRH shift register load operation is equivalent to the SRL shift register load operation. The following differences must be taken into account for SRH shift register loading:

- Input lines ALTINH are connected instead of ALTINL input lines.
- DSDSH register bits control data source selection instead of DSDSL register.
- Emergency stop is enabled by ESR.ENHx bits instead of ESR.ENLx bits.
- Bits of the downstream data register high part DDH are selected instead of DDL.
- Downstream control register high part DCH is selected instead of DCL.

19.1.2.3 Transmission Modes

The downstream channel of the MSC makes it possible to select between two transmission modes:

- Triggered Mode, selected by DSC.TM = 0, or
- Data Repetition Mode, selected by DSC.TM = 1

Triggered Mode

In Triggered Mode, command frames or data frames are sent out as a result of a software event. When a frame transmission has been finished and no further frame transmission has been requested, the downstream channel returns to idle state and waits for the next frame transmission to be triggered by software.

When the Downstream Command Register DC is written, the command pending bit DSC.CP becomes set and a command frame will be immediately started and sent out if the downstream channel is idle. If a data or command frame is currently processed and output, the command frame transmission is delayed, and started when the active downstream frame has been finished. The command pending bit DSC.CP becomes cleared by hardware when the first bit of the command frame is sent out.

If the downstream channel is idle and the data pending bit DSC.DP is set by writing bit ISC.SDP with 1, a data frame will be immediately started and sent out if the downstream channel is idle. If a data frame or a command frame is currently processed and output, the data frame transmission is delayed and started when the active downstream frame has been finished. The data pending bit DSC.DP becomes cleared by hardware when the first bit of the data frame is sent out.

A command frame always has priority over the data frame. This means that if both frame pending bits are set (DSC.DP = DSC.CP = 1), the command frame will always be sent first. Therefore, a pending data frame transmission will be delayed as long as no further command frame transmission is running or requested.

Figure 19-8 is a flow diagram of the Triggered Mode. This diagram especially shows the behavior of the data and command pending bits DSC.DP and DSC.CP. If both frame pending bits are set (DSC.DP = DSC.CP = 1), the command frame will always be sent first, followed by the data frame (assuming no further command frame has been requested).

The type of the active frame that is currently processed and output is indicated by two status flags: DSS.DFA is set during a data frame transmission and DSS.CFA is set during a command frame transmission. Further, the downstream counter DSS.DC indicates the number of shift clock periods that have been elapsed since the start of the current frame.

In Triggered Mode, the shift register loading event as described in [Section 19.1.2.2](#) occurs just before a command or data frame transmission is started.

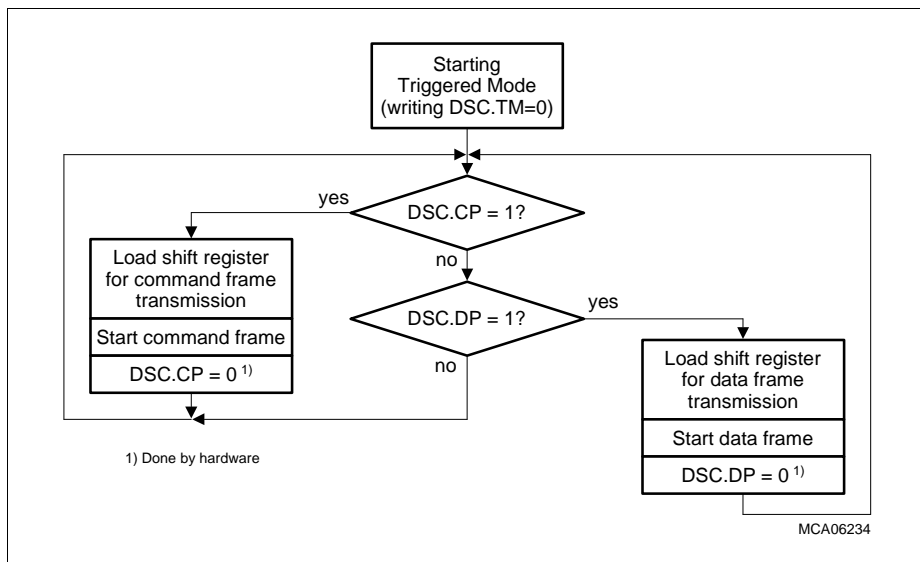


Figure 19-8 Triggered Mode Flow Diagram

Data Repetition Mode

In Data Repetition Mode, data frames are sent out continuously without any software interaction. In the time gap between two consecutive data frames, passive time frames can be inserted. The number of passive time frames to be inserted (0 to 15) is defined by bit field DSS.NPTF. The duration of data frame (t_{DF}) and passive time frames (t_{PTF}) is determined by the five data frame parameters (see [Equation \(19.1\)](#)). These parameters determine time reference points (TRP) at which a data or passive time frames is started (see diagram A in [Figure 19-9](#)).

The automatic data frame generation is controlled by the data pending bit DSC.DP. This bit is set near the end of the last transmitted passive time frame. At the next TRP, a data frame is started (if no command frame has been requested) and DSC.DP is cleared again by hardware after the data frame has been started. Data Frames are always aligned to time reference points. This means they always start at a TRP. Passive time frames can be shortened. This is especially the case when command frames are inserted.

Continuous data frame transmission can be interrupted by insertion of command frames. Command frames are initiated by software. When the downstream control register DSC is written, the command pending bit DSC.CP is set by hardware. CP = 1 indicates that the MSC starts a command frame at the next TRP, independently of whether a data

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frame (indicated by DSC.DP = 1) or passive time frame should be started with the next TRP. This means also that command frames are always aligned to time reference points.

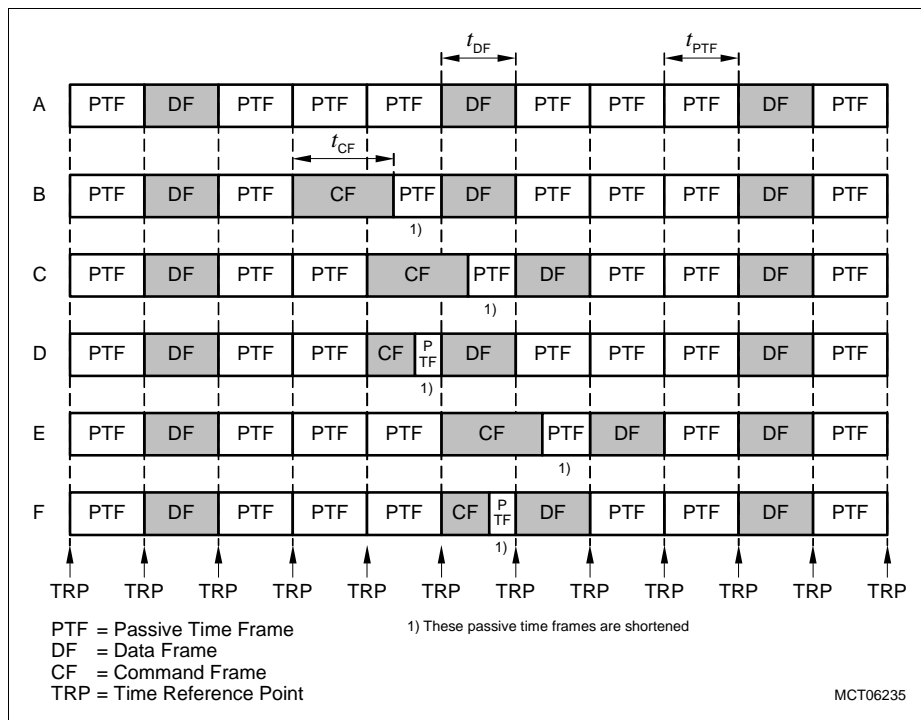


Figure 19-9 Data Repetition Mode Frame Examples with DSS.NPTF = 0011_B

Diagrams B to F in [Figure 19-9](#) show the command frame insertion in Data Repetition Mode.

In diagram B, a command frame has been requested during the first passive time frame after the data frame, and is inserted at the next TRP. In diagrams C and D, a command frame has been requested during the second passive time frame, and is inserted at the time reference point of the last nominal passive time frame.

When the command frame and data frame is not of the same length (this is the case in diagram B to F), a shortened passive time frame is inserted until the next TRP is reached. This ensures that the next data or normal passive time frame is again aligned to a TRP.

[Figure 19-10](#) is a flow diagram of the Data Repetition Mode. This diagram especially shows the behavior of the data and command pending bits DSC.DP and DSC.CP. If both frame pending bits are set (DSC.DP = DSC.CP = 1), the command frame will always be

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sent first, followed by the data frame when the next TRP is reached (assuming no further command frame has been requested).

When the last passive frame is transmitted, DSC.DP becomes set by hardware. This triggers the start of a data frame when the next TRP is reached.

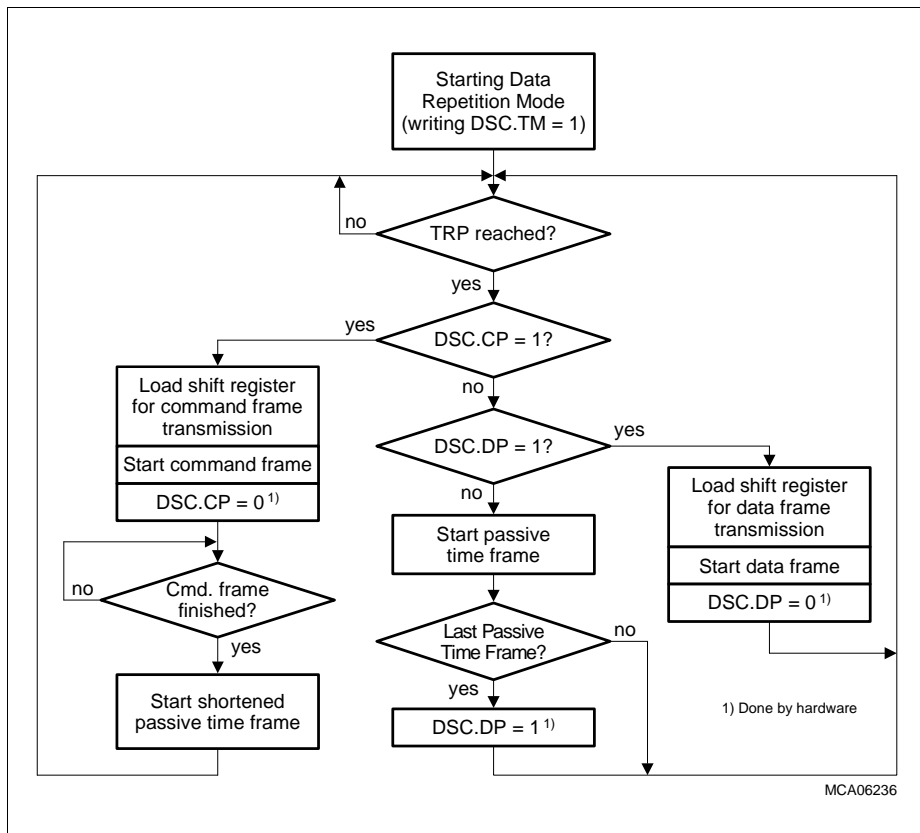


Figure 19-10 Data Repetition Mode Flow Diagram

The type of the active frame (data or command frame) that is currently processed and output is indicated by two status flags: DSS.DFA is set during a data frame transmission and DSS.CFA is set during a command frame transmission. Further, the downstream counter DSS.DC indicates the number of shift clock periods that have been elapsed since the start of the current data, command, or passive time frame.

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As in Triggered Mode, the shift register loading event as described in [Section 19.1.2.2](#) occurs in Data Repetition Mode just before a TRP, this means shortly before a command or data frame transmission is started.

Passive Frame Counter in Data Repetition Mode

In Data Repetition Mode, a passive time frame counter DSS.PFC indicates how many time frames have been already transmitted after the last regular data frame occurrence. The passive time frame counter counts up from 0000_B to the value which has been written into bit field DSS.NPTF (number of passive time frames). $DSS.PFC = 0000_B$ indicates that a data frame is requested for transmission.

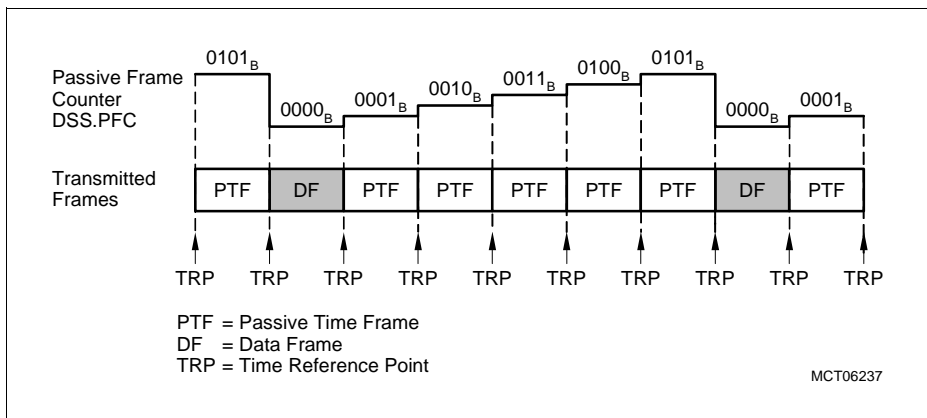


Figure 19-11 Passive Frame Counter Operation (with DSS.NPTF = 0101_B)

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19.1.2.4 Downstream Counter and Enable Signals

During downstream channel operation, a 7-bit downstream counter DSS.DC is counting FCL shift clock periods. With the loading of the shift register, the downstream counter is reset to 00_H and started for counting up to the end of the downstream frame (end of passive phase).

In Triggered Mode, the downstream counter stops counting at the end of the passive phase and waits until a new downstream frame is started.

In Repetition Mode, the downstream counter does not stop at the end of the passive phase but is reset and starts counting up again with the next frame, independently whether a data frame, command frame, or passive time frame is started as next frame.

Figure 19-12 shows an example of downstream channel data frame transmission. In this example, the selection bit for the SRL active frame is enabled (ENSELL = 1), and the selection bit for the SRH active frame is disabled (ENSELH = 0). With loading of the shift register SRL/SRH, the downstream counter is reset and then starts counting up with each FCL clock until the end of the passive phase. ENL is set to high level at the beginning of the SRL active frame selection bit.

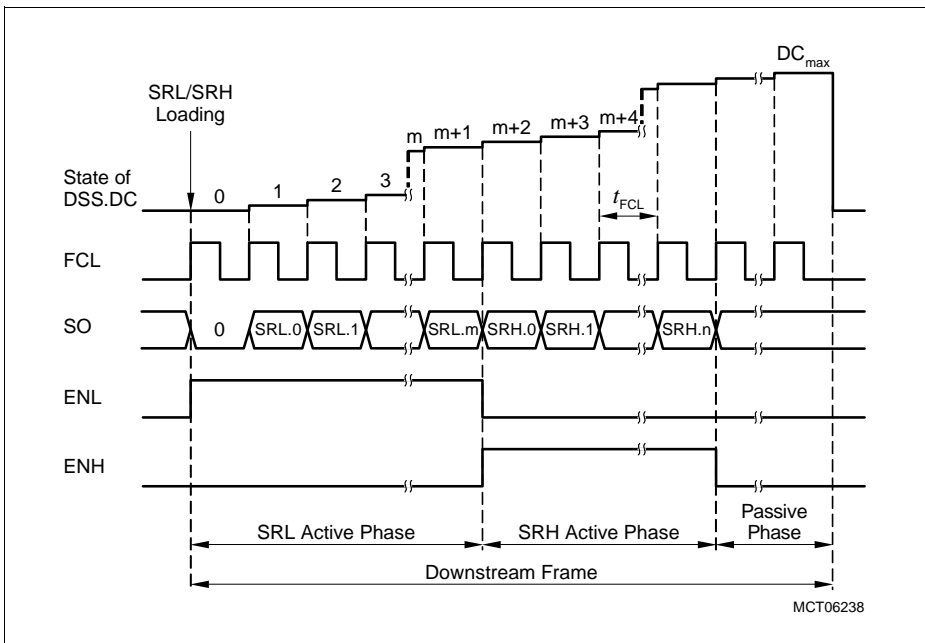


Figure 19-12 Shift Clock Counting: Data Frame with ENSELL = 1 and ENSELH = 0

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When the selection bit for the SRL active frame is disabled (ENSELL = 0, see [Figure 19-13](#)), the loading of the shift register SRL/SRH (and reset of the downstream counter) occurs one FCL clock cycle before the first data bit SRL.0 is output. ENL is set to high level with the beginning of the first data bit SRL.0.

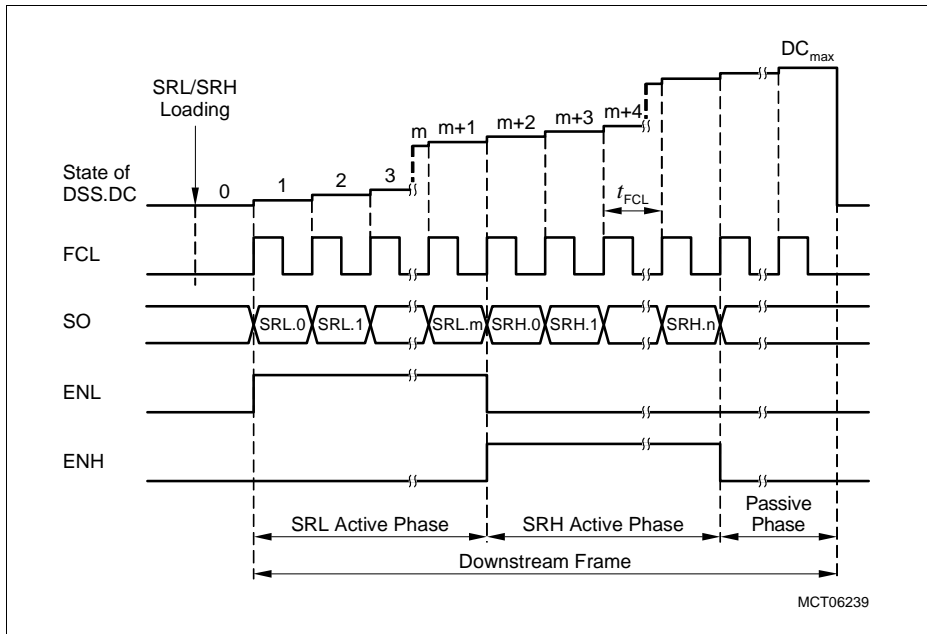


Figure 19-13 Shift Clock Counting: Data Frame with ENSELL = 0 and ENSELH = 0

19.1.2.5 Baud Rate

The baud rate of the downstream channel's serial transmission is defined by the frequency of the serial clock FCL, and is always $f_{MSC}/2$. The f_{MSC} generation is device specific and depends on the implementation of the MSC module. The TC1728 specific clock generation is described on [Page 19-65](#).

19.1.2.6 Abort of Frames

Only a reset condition of the device can abort a current transmission. The MSC module does not start a new frame transmission when the downstream channel becomes disabled, the suspend mode is requested, or the sleep mode is entered. If one of these three conditions becomes active during a running frame transmission, the frame transmission is completely finished before the requested abort state is entered. Note that in this case no time frame finished interrupt is generated any more.

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19.1.3 Upstream Channel

The MSC upstream channel is an asynchronous serial receiver based on the standard asynchronous data transfer protocol. It is dedicated to receive a serial data stream from a peripheral device via its serial data input SDI, using two specific data frame formats.

Figure 19-14 is a block diagram of the MSC upstream channel.

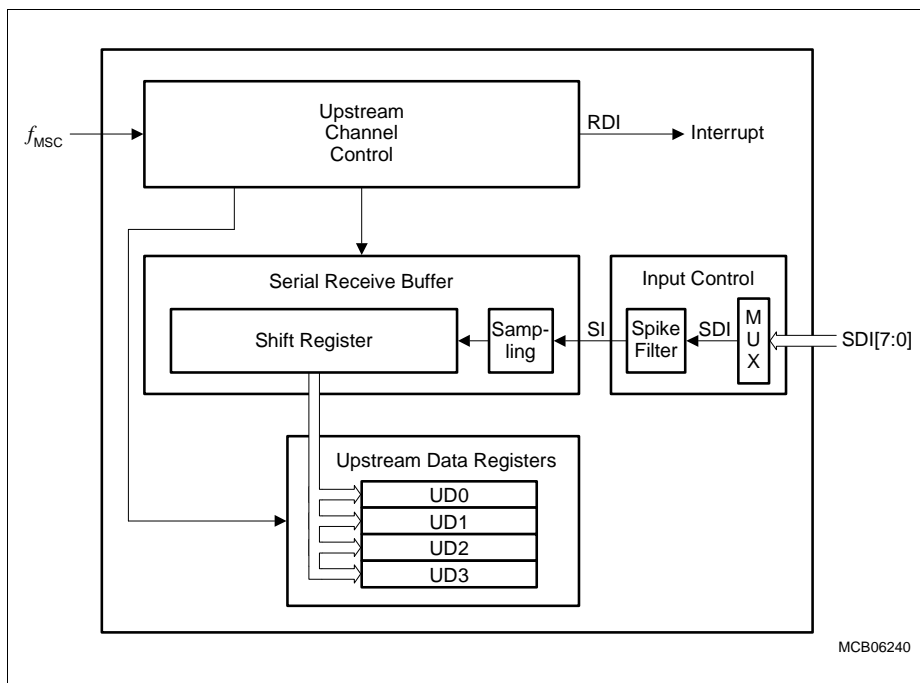


Figure 19-14 Upstream Channel Block Diagram

The incoming data at SI is sampled after it has been filtered for spikes. The detected logic states of the serial input are clocked into a shift register. After the complete reception of the serial data frame, the content of the shift register is transferred into one of the four data registers, and an interrupt can be generated optionally.

The reception baud rate is directly coupled to the module clock f_{MSC} , and can be within a range of $f_{MSC}/4$ up to $f_{MSC}/256$.

19.1.3.1 Data Frames

The asynchronous data frames used by the upstream channel include four basic parts:

1. One start bit, always at low level
2. An 8-bit data field $D[7:0]$ with LSB first
3. An optional 4-bit address field $A[3:0]$ with LSB first
4. One parity bit and two stop bits, that are always at high level

As shown in [Figure 19-15](#), the 16-bit upstream data frame includes an additional 4-bit address field. The upstream frame type is selected by bit USR.UFT.

- USR.UFT = 0: 12-bit upstream data frame selected
- USR.UFT = 1: 16-bit upstream data frame with 4-bit address field selected

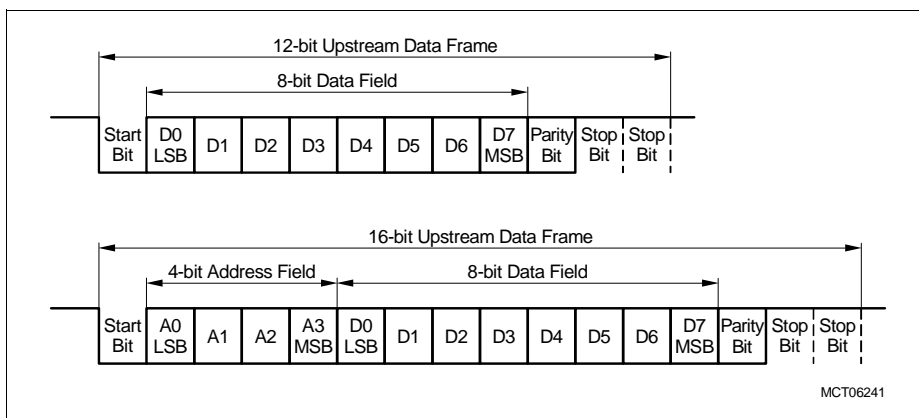


Figure 19-15 Upstream Channel Frame Types

19.1.3.2 Parity Checking

The incoming parity bit of the data frames can be checked by the upstream channel. When a parity error is detected, the parity error flag PERR in the related Upstream Data Register UDx is set. Note that a setting of the parity error flag PERR does not generate an interrupt. The PERR bits must be checked by software. The UDx registers also store the parity bit of the incoming data frame (UDx.P) and the parity bit that is generated internally (UDx.IPF).

Bit USR.PCTR determines the parity mode, even or odd, that is selected for parity checking. With USR.PCTR = 0, even parity mode is selected. Even parity means that the parity bit is set on an odd number of 1s in the data field (12-bit upstream data frame) or in the address plus data field (16-bit upstream data frame). With USR.PCTR = 1, odd parity mode is selected. In odd parity mode, the parity bit is set on an even number of 1s of the related data.

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The parity checking logic in the upstream channel also controls whether start bit and the two stop bits of the upstream data frame are at correct logic level. If the start bit is not at low level and the two stop bits are not at high level at the end of the frame reception, the parity error flag UDx.PERR is set, too.

19.1.3.3 Data Reception

The reception of the upstream frame is started with a falling edge (1-to-0 transition) on the SI line. When the start bit is detected, serial reception is enabled and the receive circuit begins to sample the incoming serial data and to buffer it in the receive buffer. After the second stop bit has been detected, the content of the receive buffer is transferred to one of four upstream data registers UDx. The receive circuit then waits for the next start bit (1-to-0 transition) at the SI line. When the content of the receive buffer has been transferred to UDx, the valid bit UDx.V is set by hardware, and a receive interrupt can be generated.

Note: The SI input line is the filtered non-inverted (OCR.ILP = 0) or inverted (OCR.ILP = 1) SDI input signal. The SI input signal selection is described on [Page 19-30](#).

Frame Reception with Address Field

Frame reception for a 16-bit data frame (see [Figure 19-16](#)) is selected by USR.UFT = 1. When the content of the receive buffer has been received completely, it is transferred to one of the four UDx registers. The two most significant address bits A[3:2] of the received 4-bit address field select the number x of register UDx in which the received frame content is stored. Register UDx is loaded with the two least significant address bits A0 and A1 (UDx.LABF), the 8-bit data (UDx.DATA), the received parity bit (UDx.P), the calculated parity bit (UDx.IPF), and the parity checking result (UDx.PERR). Finally, the valid bit UDx.V is set to indicate that the UDx register contains valid data.

The current state of the frame reception is indicated by the content of an upstream counter that is readable via bit field USR.UC. The upstream counter is a 5-bit counter that counts the upstream frame bits during reception. As shown in [Figure 19-16](#), the upstream counter is loaded with 10000_B at the detection of a start bit. It counts down and is again at 00000_B when the second stop bit has been detected and the frame reception is finished.

The state of the serial input data line SI is sampled in the middle of a bit cell and shifted into the receive buffer at the end of the bit cell. The frequency of the shift clock f_{SHIFT} depends the selected baud rate (see [Page 19-25](#)).

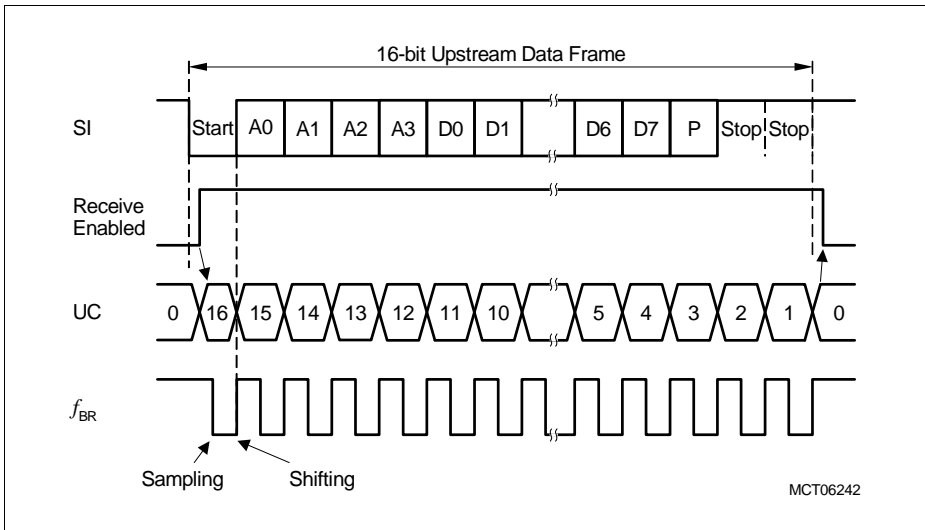


Figure 19-16 16-bit Upstream Reception

Data Reception without Address Field

Frame reception for a 12-bit data frame is selected by $USR.UFT = 0$. The reception scheme is comparable with that of the 16-bit data frame reception but there are a few differences:

- The upstream counter is initially loaded with 01100_B .
- The received frame content is always stored in register UD0.
- Bit field UD0.LABF is always loaded with 00_B when the frame is stored.

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19.1.3.4 Baud Rate

The baud rate of the upstream channel is derived from the MSC module clock f_{MSC} . **Figure 19-17** shows the configuration of the upstream channel clock circuitry.

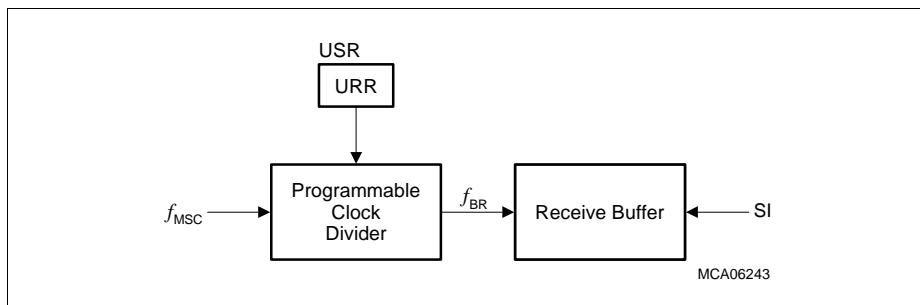


Figure 19-17 Upstream Channel Clock Circuitry

The serial data input SI is evaluated with the baud rate clock f_{BR} in the middle of each bit cell, and latched in case of a data bit. The baud rate clock f_{BR} is derived from f_{MSC} by a programmable clock divider. The frequency of f_{BR} determines the width of a received bit cell and therefore the baud rate for the received data. The content of bit field USR.URR selects the baud rate according **Table 19-6**. The resulting baud rate formula is:

$$\text{Baud rate}_{\text{MSC Upstream Channel}} = \frac{f_{MSC}}{DF} \quad (19.2)$$

Table 19-6 Upstream Channel Divide Factor DF Selection & Baud Rate

USR.URR	Divide Factor DF	Baud Rate
000 _B	reception disabled	—
001 _B	4	$f_{MSC}/4$
010 _B	8	$f_{MSC}/8$
011 _B	16	$f_{MSC}/16$
100 _B	32	$f_{MSC}/32$
101 _B	64	$f_{MSC}/64$
110 _B	128	$f_{MSC}/128$
111 _B	256	$f_{MSC}/256$

Note: With the USR.URR = 000_B the upstream channel is disabled and data reception is not possible.

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The content of bit field USR.URR determines the operation of an internal sampling reload counter that is clocked with f_{MSC} . **Figure 19-18** shows the operation of the sampling counter at the beginning of an upstream frame with a divide factor DF of 8 (USR.URR = 010_B is equal to DF = 8) which means eight sampling clocks per each frame bit cell.

When the upstream channel is in idle state, it waits for a falling edge (1-to-0 transition) at SI. Therefore, the sample counter starts counting up and is reset when the selected divide factor DF as shown in **Table 19-6** is reached. In the middle of the sampling counter's count range, the logic state at SI is evaluated and, in case of a data bit, latched in the receive buffer's shift register. With the reload of the sampling counter, the shift register is shifted by one bit position.

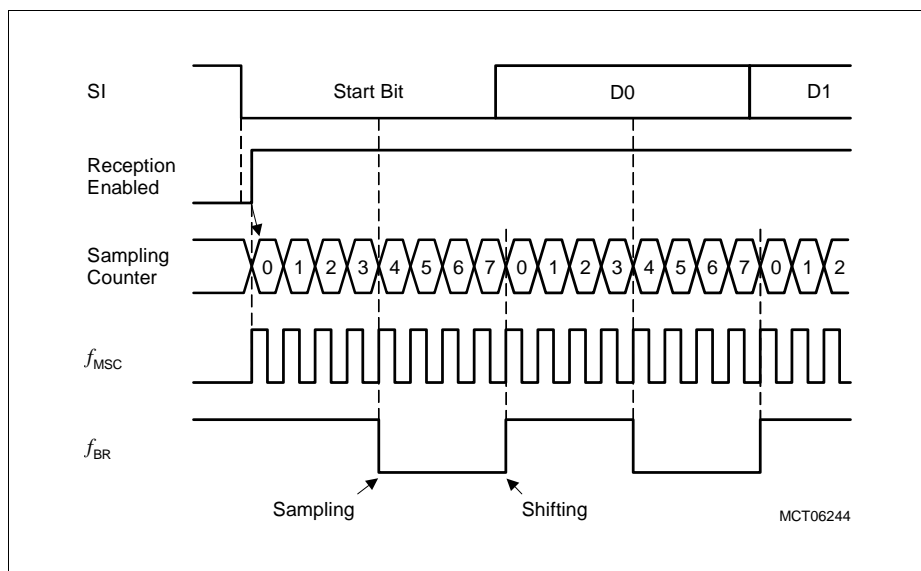


Figure 19-18 Upstream Channel Sampling with URR = 010_B

19.1.3.5 Spike Filter

The upstream channel input line SDI is sampled using a built-in spike filter with synchronization stage, both clocked with f_{MSC} . The spike filter is a chain of flip-flops with a majority decision logic (2 out of 3). A sampled value that is found at least twice in three samples is taken as data input value for SI.

Micro Second Channel (MSC)

19.1.4 I/O Control

The types of I/O control logic for the MSC module I/O lines are shown in [Figure 19-19](#). The downstream channel generates five output signals that control eight MSC module outputs, split into four chip select outputs, two clock outputs, and two serial data outputs. The upstream channel has one input signal.

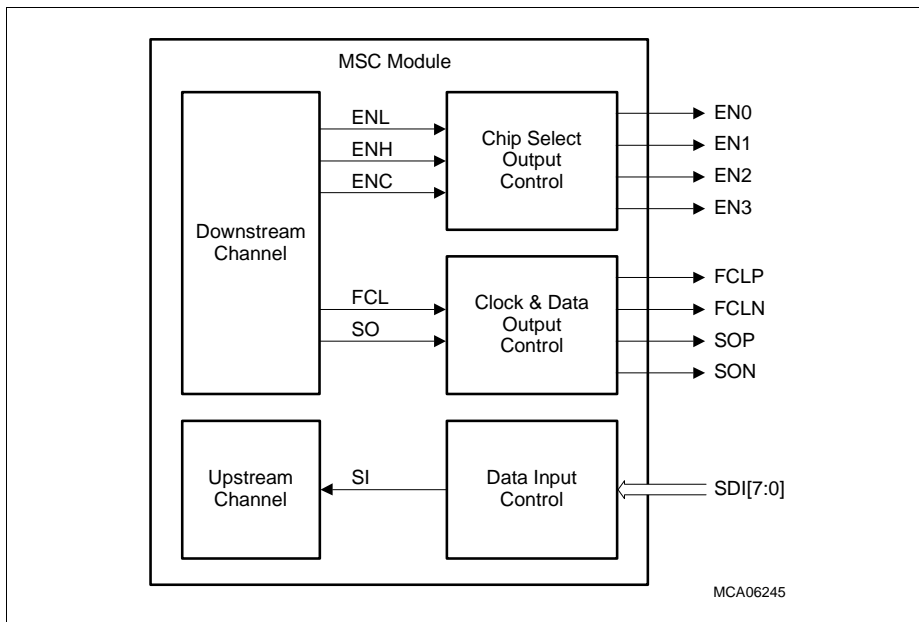


Figure 19-19 I/O Control

The MSC module I/O signals is controlled by bit fields that are located in the Output Control Register OCR.

19.1.4.1 Downstream Channel Output Control

As shown in [Figure 19-5](#) and [Figure 19-6](#), the active phases during downstream channel operation are indicated by three enable signals:

- ENL indicates the SRL active phase of a data frame
- ENH indicates the SRH active phase of a data frame
- ENC indicates the active phase of a command frame

The chip select output control logic of the MSC uses a signal compressing scheme (similar to the interrupt request compressing scheme in [Figure 19-27](#)) that allows each of the three enable signals to be directed via a 2-bit selector to one of the four chip enable

Micro Second Channel (MSC)

outputs EN[3:0]. This also makes it possible to connect more than one internal enable signal (ENL, ENH, ENC) to one chip enable output ENx. Three bit fields in register OCR (CSL, CSH, and CSC) determine which chip enable output becomes active on a valid internal enable signal.

In the MSC, enable signals are high-level active signals. If required in a specific application, all chip enable outputs ENx can be assigned for low-level active polarity by setting bit OCR.CSLP.

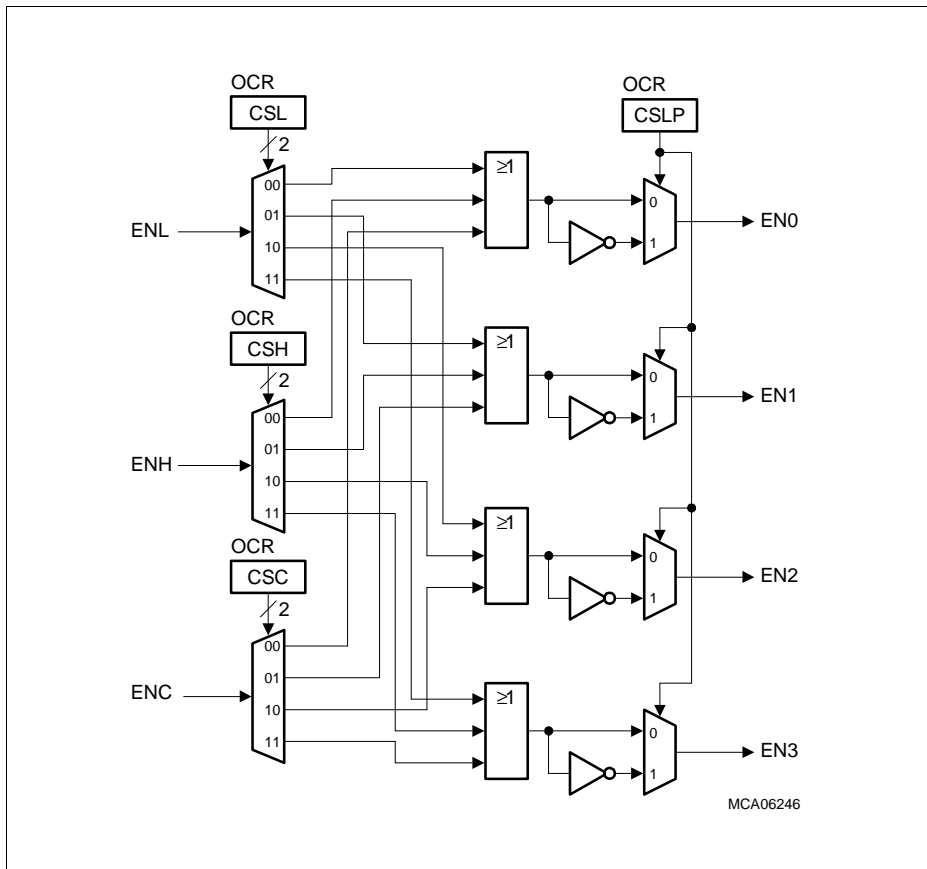


Figure 19-20 Downstream Channel: Chip Enable Output Control

Micro Second Channel (MSC)

At the MSC downstream channel, the internal serial clock output FCL and data output line SO are available outside the MSC module as two signal pairs with inverted signal polarity, FCLP/FCLN and SOP/SON. Both, clock and data outputs, are generated from the module internal signals FCL and SO according to [Figure 19-21](#).

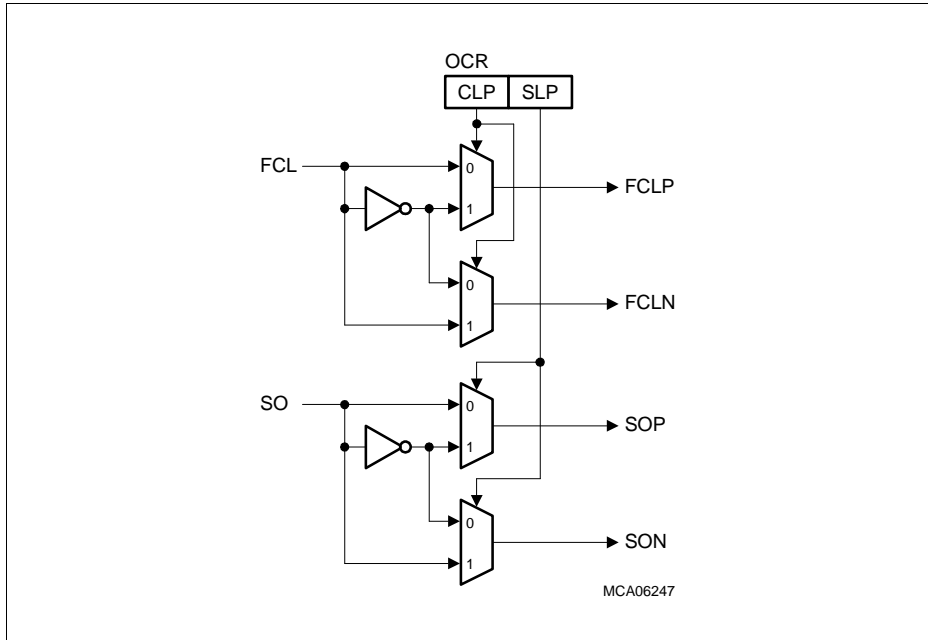


Figure 19-21 Downstream Channel: Clock and Data Output Control

With $OCR.CLP = 0$, FCLP has identical and FCLN has inverted polarity compared to FCL. Setting $OCR.CLP$, exchanges the signal polarities of FCLP and FCLN. An equivalent control capability is available for the SOP and SON data outputs (controlled by $OCR.SLP$).

One additional control capability not shown in [Figure 19-21](#) is available for the FCL signal. With $OCR.CLKCTRL = 1$, the FCL clock signal will always be generated, independently whether a downstream frame is currently transmitted or not. If $OCR.CLKCTRL = 0$, FCL becomes only active during the active phases of data or command frames (not during passive time frames).

Micro Second Channel (MSC)

19.1.4.2 Upstream Channel

As shown in [Figure 19-22](#), the MSC upstream channel can be connected to up to eight SDI[7:0] serial inputs. Bit field OCR.SDISEL selects one out of these input lines (input signal SDI). If OCR.ILP = 0, SDI is directly connected to the serial receive buffer input SI. If OCR.ILP = 1, SDI is connected to input SI via an inverter.

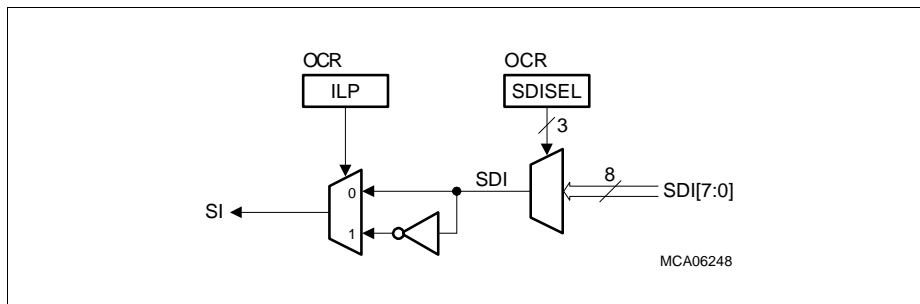


Figure 19-22 Upstream Channel Serial Data Input Control

Micro Second Channel (MSC)

19.1.5 MSC Interrupts

The MSC module has four interrupt sources and four service request outputs. A service request output is able to generate interrupts (controlled by a service request control register) or DMA requests. The service request output assignment, interrupt or DMA request, is specific for each microcontroller that is using the MSC. In this section, the term “interrupt request” has the meaning of “service request” that is able to handle interrupt or DMA requests.

Each interrupt source is provided with a status flag, enable bit(s) with software set/clear capability, and an interrupt node pointer. An interrupt event, internally generated as a request pulse, is always stored in an interrupt status flag that is located in the Interrupt Status Register ISR. All interrupt status flag can be set or cleared individually by software via the interrupt Set Clear Register ISC. Software-controlled interrupt generation can be initiated by setting the interrupt status flag of the corresponding interrupt. Each interrupt source can be enabled or disabled individually. When an interrupt event is enabled, a 2-bit interrupt node pointer determines which of the service request outputs will be activated.

Table 19-7 shows the four MSC interrupt sources.

Table 19-7 MSC Interrupts

Interrupt Type	Generated by
Data frame interrupt	Downstream Channel
Command frame interrupt	
Time frame finished interrupt	
Receive data interrupt	Upstream Channel

Micro Second Channel (MSC)

19.1.5.1 Data Frame Interrupt

A data frame interrupt can be generated when either the first or the last data bit of the downstream channel is shifted out and becomes available at the SO output line (see also [Figure 19-6](#)). Bit ICR.EDIE selects which case is selected.

Note: If $ICR.EDIE = 10_B$, an interrupt at the first data bit is only generated if $DSC.NDBL$ is not equal 00000_B . This means, at least one SRL bit must be shifted out for the first data bit shifted interrupt to become active.

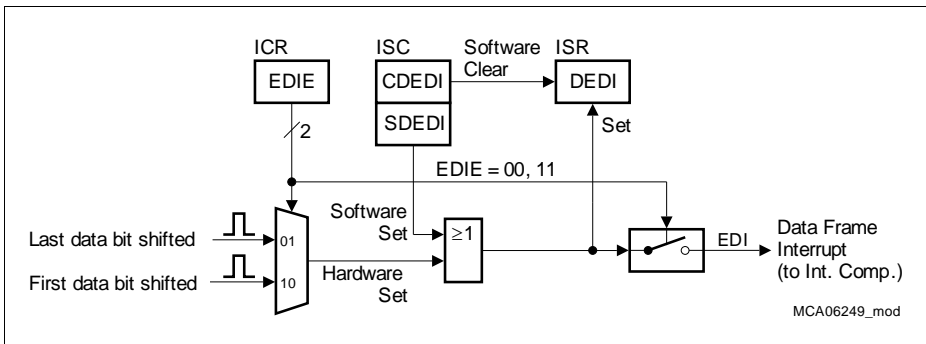


Figure 19-23 Data Frame Interrupt Control

19.1.5.2 Command Frame Interrupt

A command frame interrupt can be generated at the end of a downstream channel command frame (see also [Figure 19-5](#)).

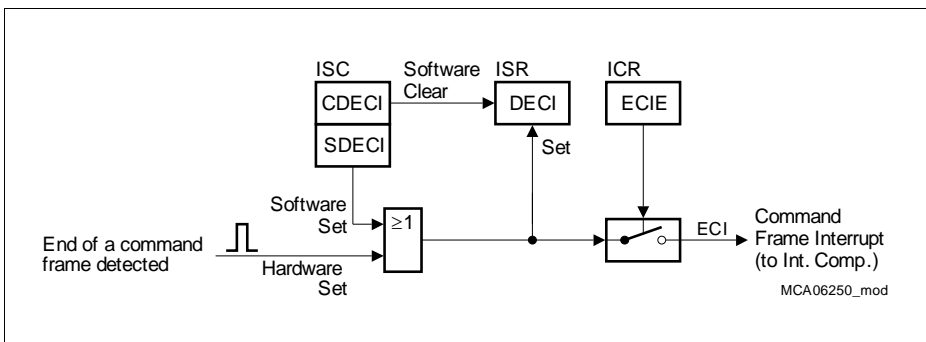


Figure 19-24 Command Frame Interrupt Control

Micro Second Channel (MSC)

19.1.5.3 Time Frame Finished Interrupt

A time frame finished interrupt can be generated at the end of a downstream channel passive time phase.

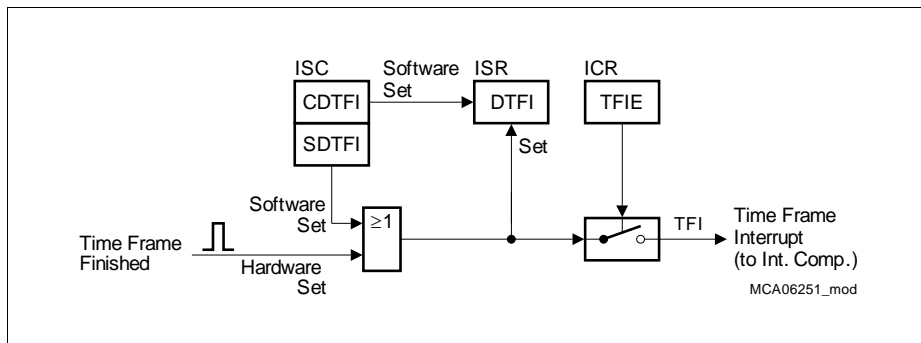


Figure 19-25 Time Frame Interrupt Control

Micro Second Channel (MSC)

19.1.5.4 Receive Data Interrupt

Whenever the upstream channel receives data in registers UD_x (x = 0-3), the MSC is able to generate an interrupt. Three interrupt generation conditions can be selected for the receive data interrupt:

- Each update of UD_x (x = 0-3) generates a receive data interrupt.
- Each update of UD_x (x = 0-3) generates a receive data interrupt when the updated value is not equal 00_H.
- Only an update of register UD₃ generates a receive data interrupt.

The selection of the interrupt generation condition is controlled by bit field ICR.RDIE. Setting ICR.RDIE = 0 disables the receive data interrupt in general. ISR.URDI is the interrupt status flag that can be set or clear when writing bits ISC.CURDI or ISC.SURDI with a 1.

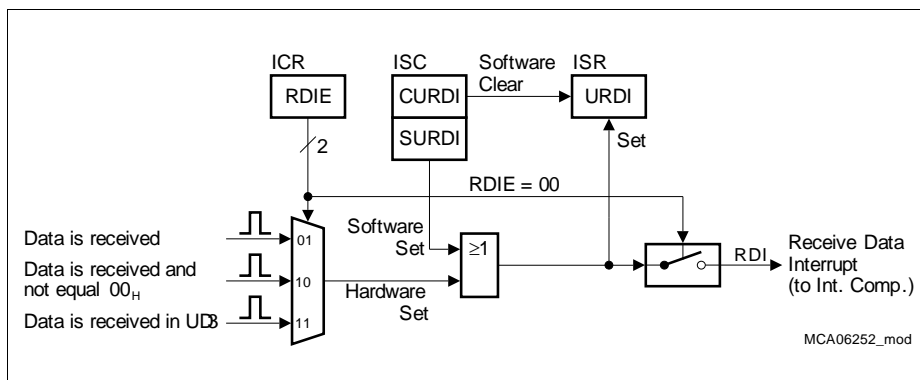


Figure 19-26 Receive Data Interrupt Control

19.1.5.5 Interrupt Request Compressor

The interrupt control logic of the MSC uses an interrupt compressing scheme that allows high flexibility in interrupt processing. Each of the four interrupt sources can be directed via a 2-bit interrupt node pointer to one of the four service request outputs SR[3:0]. This also makes it possible to connect more than one interrupt source to one interrupt output SRx.

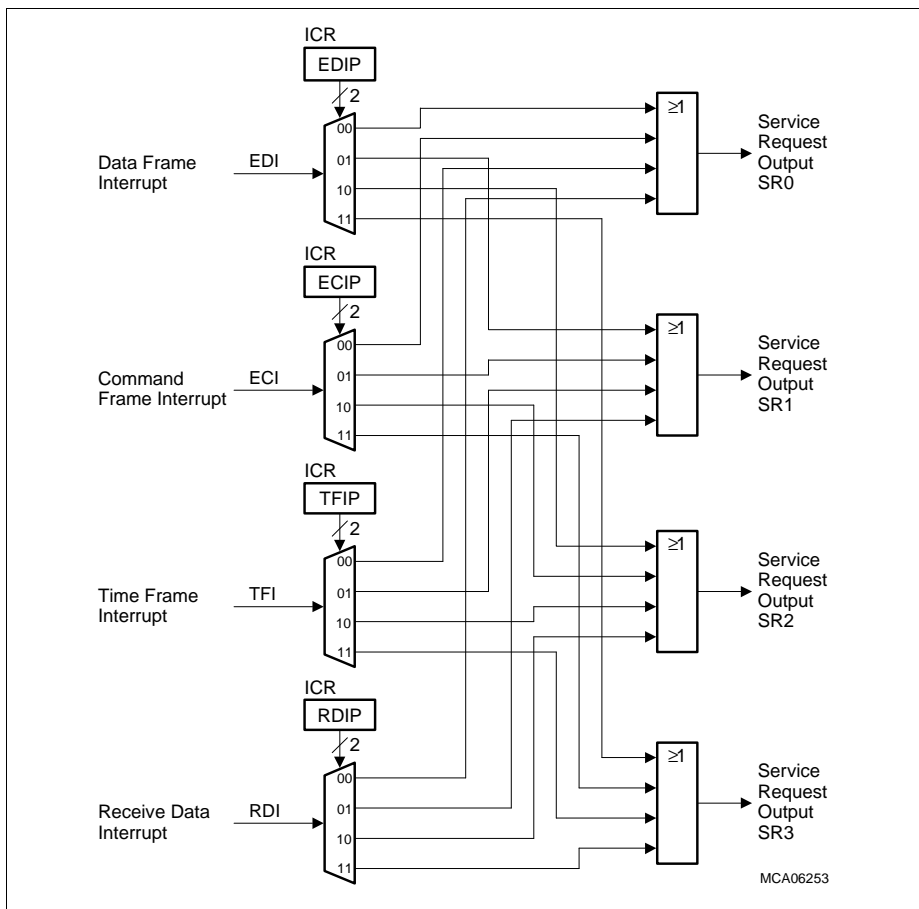


Figure 19-27 MSC Interrupt Request Compressor

Note: The number of available MSC interrupt outputs depends on the implementation of the MSC module(s) in the specific product (see [Page 19-72](#) for TC1728 details).

Micro Second Channel (MSC)

19.2 MSC Kernel Registers

This section describes the kernel registers of the MSC module. All MSC kernel register names described in this section will be referenced in other parts of the TC1728 User's Manual by the module name prefix "MSC0_" for the MSC0 interface.

All registers in the MSC address spaces are reset with the application reset (definition see SCU section "Reset Operation").

MSC Kernel Register Overview

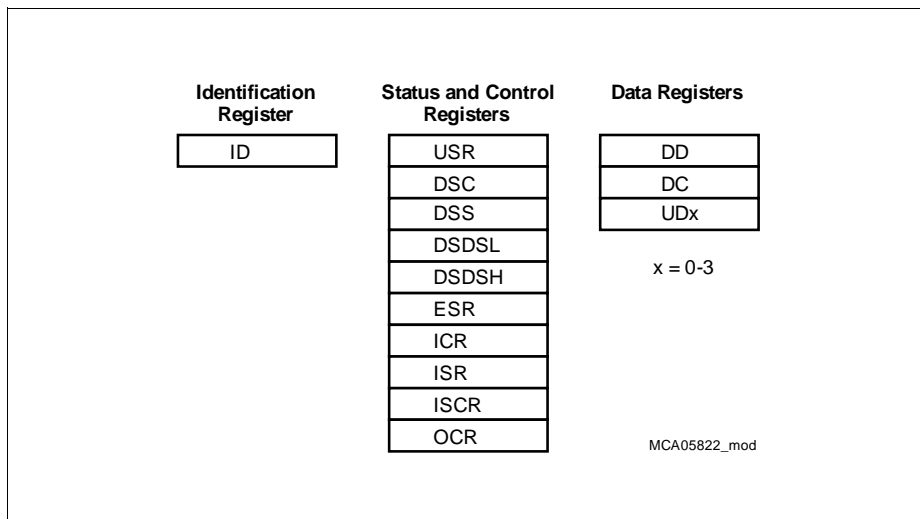


Figure 19-28 MSC Kernel Registers

The complete and detailed address map of the MSC0 module is described in [Table 19-12](#) on [Page 19-73](#).

Table 19-8 Registers Address Space - MSC0 Kernel Registers

Module	Base Address	End Address	Note
MSC0	F000 0800 _H	F000 08FF _H	—

Micro Second Channel (MSC)

Table 19-9 Registers Overview - MSC Kernel Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
ID	Module Identification Register	08 _H	Page 19-38
USR	Upstream Status Register	10 _H	Page 19-39
DSC	Downstream Control Register	14 _H	Page 19-41
DSS	Downstream Status Register	18 _H	Page 19-44
DD	Downstream Data Register	1C _H	Page 19-59
DC	Downstream Command Register	20 _H	Page 19-59
DSDSL	Downstream Select Data Source Low Register	24 _H	Page 19-46
DSDSH	Downstream Select Data Source High Register	28 _H	Page 19-47
ESR	Emergency Stop Register	2C _H	Page 19-48
UD0	Upstream Data Register 0	30 _H	Page 19-60
UD1	Upstream Data Register 1	34 _H	
UD2	Upstream Data Register 2	38 _H	
UD3	Upstream Data Register 3	3C _H	
ICR	Interrupt Control Register	40 _H	Page 19-49
ISR	Interrupt Status Register	44 _H	Page 19-52
ISC	Interrupt Set Clear Register	48 _H	Page 19-54
OCR	Output Control Register	4C _H	Page 19-56

1) The absolute register address is calculated as follows:

Module Base Address ([Table 19-8](#)) + Offset Address (shown in this column)

Micro Second Channel (MSC)

19.2.1 Module Identification Register

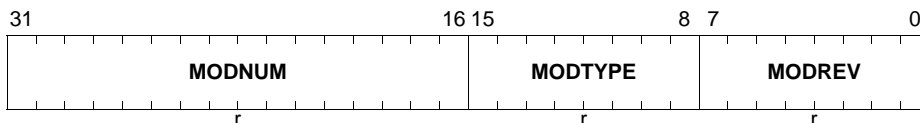
The MSC Module Identification Register ID contains read-only information about the module version.

ID

Module Identification Register

(08_H)

Reset Value: 0028 C0XX_H



Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MODTYPE	[15:8]	r	Module Type This bit field defines the module as a 32-bit module: C0 _H
MODNUM	[31:16]	r	Module Number Value This bit field defines the module identification number for the MSC: 0028 _H

Micro Second Channel (MSC)

19.2.2 Status and Control Registers

The Upstream Status Register is used to configure the upstream channel data format, baud rate, and parity type. It also provides the status information of the upstream counter (UC).

USR

Upstream Status Register

(10_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0											UC				
r											rh				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0											P CTR	URR		UFT	
r											rw	rw		rw	

Field	Bits	Type	Description
UFT	0	rw	Upstream Channel Frame Type This bit determines the frame type used by the upstream channel for data reception. 0 _B 12-bit upstream frame selected 1 _B 16-bit upstream frame selected (with 4-bit address field)
URR	[3:1]	rw	Upstream Channel Receiving Rate This bit field determines the baud rate for the upstream channel. 000 _B Upstream channel disabled; no reception is possible 001 _B Baud rate = $f_{MSC}/4$ 010 _B Baud rate = $f_{MSC}/8$ 011 _B Baud rate = $f_{MSC}/16$ 100 _B Baud rate = $f_{MSC}/32$ 101 _B Baud rate = $f_{MSC}/64$ 110 _B Baud rate = $f_{MSC}/128$ 111 _B Baud rate = $f_{MSC}/256$

Micro Second Channel (MSC)

Field	Bits	Type	Description
PCTR	4	rw	Parity Control This bit determines the parity mode used by the upstream channel for data reception. 0_B Even parity mode is selected. A parity bit is set on an odd number of 1s in the serial address/data stream. 1_B Odd parity mode is selected. A parity bit is set on an even number of 1s in the serial address/data stream.
UC	[20:16]	rh	Upstream Counter This bit field indicates the content of the upstream counter that counts the bits during upstream channel reception.
0	[15:5], [31:21]	r	Reserved Read as 0; should be written with 0.

Micro Second Channel (MSC)

The Downstream Control Register is used to control the operation mode and frame layout of the downstream channel transmission. It also contains the two pending status bits.

DSC

Downstream Control Register

(14_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0			PPD					0	NBC						
r			rw					r	rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DS DIS	EN SEL H	EN SEL L	NDBH					NDBL					DP	CP	TM
rh	rw	rw	rw					rw					rh	rh	rw

Field	Bits	Type	Description
TM	0	rw	Transmission Mode This bit selects the transmission mode of the downstream channel. 0 _B Triggered Mode selected 1 _B Data Repetition Mode selected
CP	1	rh	Command Pending This bit is set when the downstream command register DC is written. CP is cleared when the first bit of the related command frame is sent out.
DP	2	rh	Data Pending In Triggered Mode, this bit is set when the set data pending bit ISC.SDP is set by software. In Data Repetition Mode, this bit is set by hardware at the last passive time frame. At the start of the data frame, DP is cleared by hardware.

Micro Second Channel (MSC)

Field	Bits	Type	Description
NDBL	[7:3]	rw	Number of SRL Bits Shifted at Data Frames NDBL determines the number of shift register low part (SRL) bits that are shifted out on SO during a data frame. 00000 _B No SRL bit shifted 00001 _B SRL[0] shifted 00010 _B SRL[1:0] shifted ... _B ... 01111 _B SRL[14:0] shifted 10000 _B SRL[15:0] shifted Other bit combinations are reserved; do not use these bit combinations.
NDBH	[12:8]	rw	Number of SRH Bits Shifted at Data Frames NDBH determines the number of shift register high part (SRH) bits that are shifted out on SO during a data frame. 00000 _B No SRH bit shifted; no selection bit is generated, the SRH active phase is completely skipped. 00001 _B SRH[0] shifted 00010 _B SRH[1:0] shifted ... _B ... 01111 _B SRH[14:0] shifted 10000 _B SRH[15:0] shifted Other bit combinations are reserved; do not use these bit combinations.
ENSELL	13	rw	Enable SRL Active Phase Selection Bit This bit determines whether a low level selection bit is inserted at the beginning of a data frame's SRL active phase. 0 _B No selection bit inserted. 1 _B Low level selection bit inserted.
ENSELH	14	rw	Enable SRH Active Phase Selection Bit This bit determines whether a low level selection bit is inserted at the beginning of a data frame's SRH active phase. 0 _B No selection bit inserted. 1 _B Low level selection bit inserted.

Micro Second Channel (MSC)

Field	Bits	Type	Description
DSDIS	15	rh	Downstream Disable This bit indicates the state of the downstream channel operation. 0 _B The downstream channel is enabled. A frame transmission can take place (Triggered Mode) or takes place (Data Repetition Mode). 1 _B Downstream Counter becomes disabled. No new frame transmission is started. A running frame transmission is always completed.
NBC	[21:16]	rw	Number of Bits Shifted at Command Frames This bit field determines how many bits of the SRL/SRH shift registers are shifted out during transmission of a command frame. 000000 _B No bit shifted 000001 _B SRL[0] shifted 000010 _B SRL[1:0] shifted 000011 _B SRL[2:0] shifted ... _B ... 010000 _B SRL[15:0] shifted 010001 _B SRL[15:0] and SRH[0] shifted 010010 _B SRL[15:0] and SRH[1:0] shifted ... _B ... 011111 _B SRL[15:0] and SRH[14:0] shifted 100000 _B SRL[15:0] and SRH[15:0] shifted Other bit combinations are reserved; do not use these bit combinations
PPD	[28:24]	rw	Passive Phase Length at Data Frames This bit field determines the length of the passive phase of a data frame. 00000 _B Passive phase length is $2 \times t_{FCL}$ 00001 _B Passive phase length is $2 \times t_{FCL}$ 00010 _B Passive phase length is $2 \times t_{FCL}$ 00011 _B Passive phase length is $3 \times t_{FCL}$... _B ... 11111 _B Passive phase length is $31 \times t_{FCL}$
0	[23:22], [31:29]	r	Reserved Read as 0; should be written with 0.

Note: The "rw" bits in the DSC register are buffered in a shadow buffer at the start of a corresponding frame transmission.

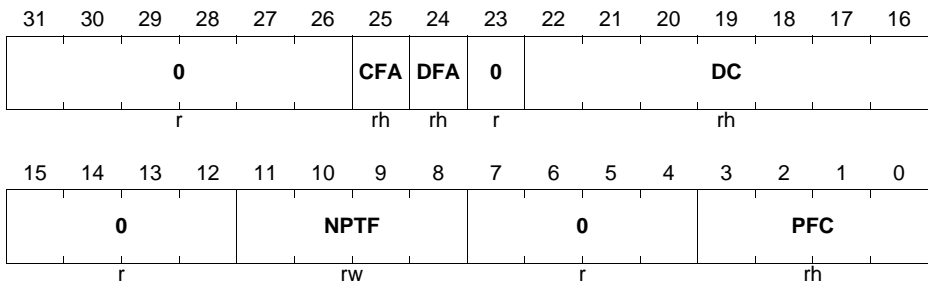
Micro Second Channel (MSC)

The Downstream Status Register DSS contains counter bit fields, status bits, and indicates the number of passive time frames.

DSS

Downstream Status Register

(18_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
PFC	[3:0]	rh	Passive Time Frame Counter In Data Repetition Mode, this bit field indicates the count of passive time frames that are currently transmitted. In Triggered Mode PFC remains at 0000 _B . 0000 _B Data frame is transmitted. 0001 _B First passive time frame is transmitted. 0010 _B Second passive time frame is transmitted. ... _B ... 1111 _B Fifteenth passive time frame is transmitted.
NPTF	[11:8]	rw	Number Of Passive Time Frames This bit field indicates the number of passive time frames that are inserted in Data Repetition Mode between two data frames. 0000 _B No passive time frame inserted. 0001 _B One passive time frame inserted. 0010 _B Two passive time frames inserted. ... _B ... 1111 _B Fifteen passive time frames inserted. <i>Note: NPTF is buffered in a shadow buffer at the start of each data frame.</i>

Micro Second Channel (MSC)

Field	Bits	Type	Description
DC	[22:16]	rh	Downstream Counter This bit field indicates the number of downstream shift clock periods that have been elapsed since the start of the current frame. 00 _H No shift clock elapsed (after counter reset). 01 _H 1 shift clock elapsed. ... _H ... 7F _H 127 shift clocks elapsed. DC is reset at the end of a downstream frame.
DFA	24	rh	Data Frame Active This bit indicates if a data frame is currently sent out. 0 _B No data frame is currently sent out. 1 _B A data frame is currently sent out.
CFA	25	rh	Command Frame Active This bit indicates if a command frame is currently sent out. 0 _B No command frame is currently sent out. 1 _B A command frame is currently sent out.
0	[7:4], [15:12], 23, [31:26]	r	Reserved Read as 0; should be written with 0.

Micro Second Channel (MSC)

The bit fields of the Downstream Select Data Low Register DSDSL determine the data source for each bit in shift register SRL.

DSDSL

Downstream Select Data Source Low Register

(24_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SL15	SL14	SL13	SL12	SL11	SL10	SL9	SL8								
rw	rw	rw	rw	rw	rw	rw	rw								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SL7	SL6	SL5	SL4	SL3	SL2	SL1	SL0								
rw	rw	rw	rw	rw	rw	rw	rw								

Field	Bits	Type	Description
SLx (x = 0-15)	[2*x+1: 2*x]	rw	Select Source for SRL SLx determines which data source is used for the shift register bit SRL[x] during data frame transmission. 00 _B SRL[x] is taken from data register DD.DDL[x]. 01 _B Reserved. 10 _B SRL[x] is taken from the ALTINL input line x. 11 _B SRL[x] is taken from the ALTINL input line x in inverted state.

Micro Second Channel (MSC)

The bit fields of the Downstream Select Data Source High Register DSDSH determine the data source for each bit in shift register SRH.

DSDSH

Downstream Select Data Source High Register

(28_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SH15		SH14		SH13		SH12		SH11		SH10		SH9		SH8	
rw		rw		rw		rw		rw		rw		rw		rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SH7		SH6		SH5		SH4		SH3		SH2		SH1		SH0	
rw		rw		rw		rw		rw		rw		rw		rw	

Field	Bits	Type	Description
SHx (x = 0-15)	[2*x+1: 2*x]	rw	Select Source for SRH SHx determines which data source is used for the shift register bit SRH[x] during data frame transmission. 00 _B SRH[x] is taken from data register DD.DDH[x]. 01 _B Reserved. 10 _B SRH[x] is taken from the ALTINH input line x. 11 _B SRH[x] is taken from the ALTINH input line x in inverted state.

Micro Second Channel (MSC)

The Emergency Stop Register ESR determines which bits of SRL and SRH are enabled for emergency operation.

ESR

Emergency Stop Register

(2C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH	ENH
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL	ENL
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ENLx (x = 0-15)	x	rw	Emergency Stop Enable for Bit x in SRL This bit enables the emergency stop feature selectively for each SRL bit. If the emergency stop condition is met and enabled (ENLx = 1), the SRL[x] bit is of the data register DD.DDL[x] is used for the shift register load operation. 0 _B Emergency stop feature for bit SRL[x] is disabled. 1 _B The emergency stop feature for bit SRL[x] is enabled.
ENHx (x = 0-15)	x+16	rw	Emergency Stop Enable for Bit x in SRH This bit enables the emergency stop feature selectively for each SRH bit. If the emergency stop condition is met and enabled (ENHx = 1), the SRH[x] bit of the data register DD.DDH[x] is used for the shift register load operation. 0 _B Emergency stop feature for bit SRH[x] is disabled. 1 _B The emergency stop feature for bit SRH[x] is enabled.

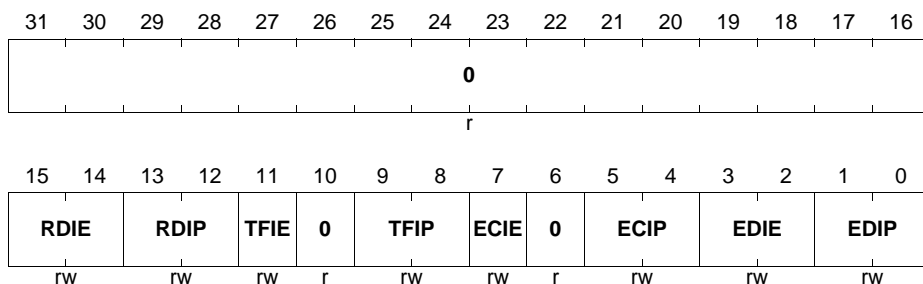
Micro Second Channel (MSC)

The Interrupt Control Register ICR holds the interrupt enable bits and interrupt pointers of all four MSC interrupts.

ICR

Interrupt Control Register

(40_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
EDIP	[1:0]	rw	Data Frame Interrupt Node Pointer EDIP selects the service request output line SR _n (n = 0-3) for the data frame interrupt. 00 _B Service request output SR0 selected 01 _B Service request output SR1 selected 10 _B Service request output SR2 selected 11 _B Service request output SR3 selected
EDIE	[3:2]	rw	Data Frame Interrupt Enable This bit field determines the enable conditions for the data frame interrupt. 00 _B Interrupt generation disabled 01 _B An interrupt is generated when the last data bit has been shifted out. 10 _B An interrupt is generated when the first data bit has been shifted out, but only if DSC.NDBL is not equal 00000 _B . This means, at least one SRL bit must be shifted out for the first data bit shifted interrupt to become active. 11 _B Interrupt generation disabled

Micro Second Channel (MSC)

Field	Bits	Type	Description
ECIP	[5:4]	rw	Command Frame Interrupt Node Pointer ECIP selects the service request output line SR _n (n = 0-3) for the command frame interrupt. 00 _B Service request output SR0 selected 01 _B Service request output SR1 selected 10 _B Service request output SR2 selected 11 _B Service request output SR3 selected
ECIE	7	rw	Command Frame Interrupt Enable This bit enables the command frame interrupt. 0 _B Interrupt generation disabled. 1 _B Interrupt generation enabled.
TFIP	[9:8]	rw	Time Frame Interrupt Pointer TFIP selects the service request output line SR _n (n = 3-0) for the time frame interrupt. 00 _B Service request output SR0 selected 01 _B Service request output SR1 selected 10 _B Service request output SR2 selected 11 _B Service request output SR3 selected
TFIE	11	rw	Time Frame Interrupt Enable This bit enables the time frame interrupt. 0 _B Interrupt generation disabled. 1 _B Interrupt generation enabled.
RDIP	[13:12]	rw	Receive Data Interrupt Pointer RDIP selects the service request output line SR _n (n = 3-0) for the receive data interrupt. 00 _B Service request output SR0 selected 01 _B Service request output SR1 selected 10 _B Service request output SR2 selected 11 _B Service request output SR3 selected

Micro Second Channel (MSC)

Field	Bits	Type	Description
RDIE	[15:14]	rw	Receive Data Interrupt Enable This bit field determines the enable conditions for the receive data interrupt. 00 _B Interrupt generation disabled. 01 _B An interrupt is generated when data is received and written into the upstream data registers UD _x (x = 0-3). 10 _B An interrupt is generated as with RDIE = 01 _B but only if the received data is not equal to 00 _H . 11 _B An interrupt is generated when data is received and written into register UD3.
0	6, 10, [31:16]	r	Reserved Read as 0; should be written with 0.

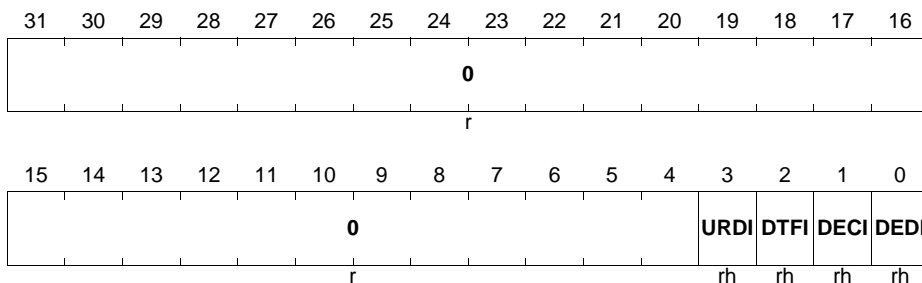
Micro Second Channel (MSC)

The Interrupt Status Register ISR holds the interrupt status flags that indicate an interrupt occurrence in downstream and upstream channels.

ISR

Interrupt Status Register

(44_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
DEDI	0	rh	Data Frame Interrupt Flag This flag is always set by hardware when a downstream channel data frame interrupt is generated. DEDI can be set or cleared by software when writing to register ISC with the appropriate bits ISC.SDEDI or ISC.CDEDI set.
DECI	1	rh	Command Frame Interrupt Flag This flag is always set by hardware when a downstream channel command frame interrupt is generated, whether or not it is enabled. DECI can be set or cleared by software when writing to register ISC with the appropriate bits SDECI or CDECI set.
DTFI	2	rh	Time Frame Interrupt Flag This flag is always set by hardware when a downstream channel time frame interrupt is generated, whether or not it is enabled. DTFI can be set or cleared by software when writing to register ISC with the appropriate bits SDTFI or CDTFI set.

Micro Second Channel (MSC)

Field	Bits	Type	Description
URDI	3	rh	Receive Data Interrupt Flag This flag is always set by hardware when an upstream channel receive data interrupt is generated, whether or not it is enabled. URDI can be set or cleared by software when writing to register ISC with the appropriate bits SURDI or CURDI set.
0	[31:4]	r	Reserved Read as 0; should be written with 0.

Micro Second Channel (MSC)

The Interrupt Set Clear Register ISC is used to set or clear the MSC interrupt flags located in the Interrupt Status Register ISR. Reading ISC always returns 0000 0000_H.

ISC

Interrupt Set Clear Register

(48_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0									S	S	S	S	S	S	S
									DDIS	CP	DP	URDI	DTFI	DECI	DEDI
r									w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0									C	C	C	C	C	C	C
									DDIS	CP	DP	URDI	DTFI	DECI	DEDI
r									w	w	w	w	w	w	w

Field	Bits	Type	Description
CDEDI	0	w	Clear DEDI Flag 0 _B No operation 1 _B Bit ISR.DEDI is cleared.
CDECI	1	w	Clear DECI Flag 0 _B No operation 1 _B Bit ISR.DECI is cleared.
CDTFI	2	w	Clear DTFI Flag 0 _B No operation 1 _B Bit ISR.DTFI is cleared.
CURDI	3	w	Clear URDI Flag 0 _B No operation 1 _B Bit ISR.URDI is cleared.
CDP	4	w	Clear DP Flag 0 _B No operation 1 _B Bit DSC.DP is cleared.
CCP	5	w	Clear CP Flag 0 _B No operation 1 _B Bit DSC.CP is cleared.
CDDIS	6	w	Clear DSDIS Flag 0 _B No operation 1 _B Bit DSC.DSDIS is cleared.

Micro Second Channel (MSC)

Field	Bits	Type	Description
SDEDI	16	w	Set DEDI Flag 0 _B No operation 1 _B Bit ISR.DEDI is set.
SDECI	17	w	Set DECI Flag 0 _B No operation 1 _B Bit ISR.DECI is set.
SDTFI	18	w	Set DTFI Flag 0 _B No operation 1 _B Bit ISR.DTFI is set.
SURDI	19	w	Set URDI Flag 0 _B No operation 1 _B Bit ISR.URDI is set.
SDP	20	w	Set DP Bit 0 _B No effect 1 _B Bit DSC.DP is set.
SCP	21	w	Set CP Flag 0 _B No operation 1 _B Bit DSC.CP is set.
SDDIS	22	w	Set DSDIS Flag 0 _B No operation 1 _B Bit DSC.DSDIS is set.
0	[15:7], [31:23]	r	Reserved Read as 0; should be written with 0.

Note: When the ISC register is written with both bits (set and reset bit) for a specific interrupt flag, the clear operation takes place and the set operation is ignored.

Micro Second Channel (MSC)

The Output Control Register OCR determines the MSC input/output signal polarities, the chip select output signal assignment, and the serial output clock generation.

OCR

Output Control Register

(4C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													SDISEL		
r													rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CSC		CSH		CSL		CLK CTR L	0				ILP	CS LP	SLP	CLP
r	rw		rw		rw		rw	r				rw	rw	rw	rw

Field	Bits	Type	Description
CLP	0	rw	FCLP Line Polarity 0 _B FCLP and FCL signal polarity is identical. FCLN signal has inverted FCL signal polarity. 1 _B FCLP signal has inverted FCL signal polarity. FCLN and FCL signal polarities are identical.
SLP	1	rw	SOP Line Polarity 0 _B SOP and SO signal polarity is identical. SON signal has inverted SO signal polarity. 1 _B SOP signal has inverted SO signal polarity. SON and SO signal polarities are identical.
CSLP	2	rw	Chip Selection Lines Polarity 0 _B EN[3:0] and ENL, ENH, ENC signal polarities are identical (high active). 1 _B EN[3:0] signal polarities are inverted (low active) to the ENL, ENH, ENC signal polarities. Bit CSLP is buffered during a frame transmission. This means that any change of CSLP becomes valid first with the start of the next frame transmission.
ILP	3	rw	SDI Line Polarity 0 _B SDI and SI signal polarities are identical. 1 _B SDI and SI signal polarities are inverted.

Micro Second Channel (MSC)

Field	Bits	Type	Description
CLKCTRL	8	rw	Clock Control This bit determines the activation of clock output FCL. 0 _B FCL is activated only during the active phases of data or command frames (not during passive time frames). 1 _B FCL is always active whether or not a downstream frame is currently transmitted.
CSL	[10:9]	rw	Chip Enable Selection for ENL This bit field selects the chip enable output ENx that becomes active during the SRL active phase (ENL = 1) of a data frame. The active level of ENx is defined by bit CSLP. 00 _B EN0 line is selected for ENL. 01 _B EN1 line is selected for ENL. 10 _B EN2 line is selected for ENL. 11 _B EN3 line is selected for ENL.
CSH	[12:11]	rw	Chip Enable Selection for ENH This bit field selects the chip enable output ENx that becomes active during the SRH active phase (ENH = 1) of a data frame. The active level of ENx is defined by bit CSLP. 00 _B EN0 line is selected for ENH. 01 _B EN1 line is selected for ENH. 10 _B EN2 line is selected for ENH. 11 _B EN3 line is selected for ENH.
CSC	[14:13]	rw	Chip Enable Selection for ENC This bit field selects the chip enable output ENx that becomes active during the active phase (ENC = 1) of a command frame. The active level of ENx is defined by bit CSLP. 00 _B EN0 line is selected for ENC. 01 _B EN1 line is selected for ENC. 10 _B EN2 line is selected for ENC. 11 _B EN3 line is selected for ENC.

Micro Second Channel (MSC)

Field	Bits	Type	Description
SDISEL	[18:16]	rw	Serial Data Input Selection This bit field selects the source for the serial data input SDI of the upstream channel. 000 _B SDI0 input is selected for SDI. 001 _B SDI1 input is selected for SDI. 010 _B SDI2 input is selected for SDI. 011 _B SDI3 input is selected for SDI. 100 _B SDI4 input is selected for SDI. 101 _B SDI5 input is selected for SDI. 110 _B SDI6 input is selected for SDI. 111 _B SDI7 input is selected for SDI.
0	[7:4], 15, [31:19]	r	Reserved Read as 0; should be written with 0.

Micro Second Channel (MSC)

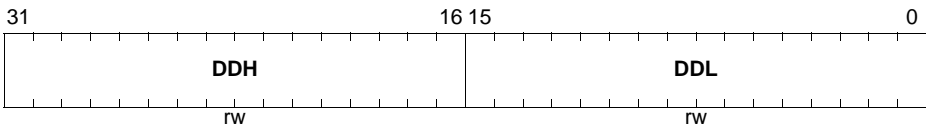
19.2.3 Data Registers

The Downstream Data Register DD contains data to be transmitted during data frames.

DD

Downstream Data Register

(1C_H)

Reset Value: 0000 0000_H


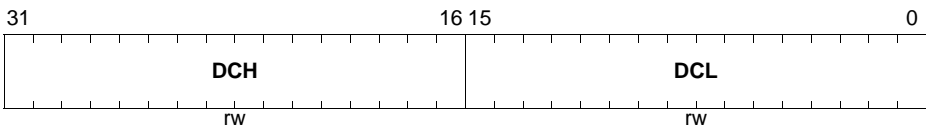
Field	Bits	Type	Description
DDL	[15:0]	rw	Downstream Data for SRL Shift Register Contains the data bits to be transmitted during the SRL active phase of a data frame.
DDH	[31:16]	rw	Downstream Data for SRH Shift Register Contains the data bits to be transmitted during the SRH active phase of a data frame.

The Downstream Command Register DC contains command information to be transmitted during command frames.

DC

Downstream Command Register

(20_H)

Reset Value: 0000 0000_H


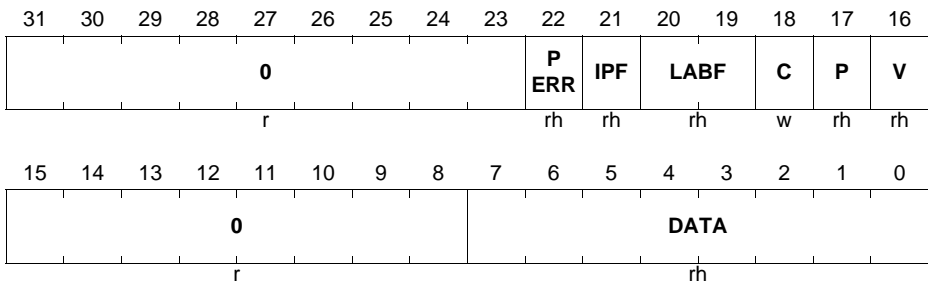
Field	Bits	Type	Description
DCL	[15:0]	rw	Downstream Command for SRL Shift Register Contains the data bits to be transmitted during the SRL active phase of a command frame.
DCH	[31:16]	rw	Downstream Command for SRH Shift Register Contains the data bits to be transmitted during the SRH active phase of a command frame.

Micro Second Channel (MSC)

The four Upstream Data Registers UDx store the content (data, addresses, received and calculated parity bit, parity error bit) of a received upstream channel data frame.

UDx (x = 0-3)

Upstream Data Register x (30_H+x*4_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
DATA	[7:0]	rh	Received Data This bit field contains the 8-bit receive data.
V	16	rh	Valid Bit This bit is set by hardware when the received data is written to UDx. Writing bit C = 1 clears V. If hardware setting and software clearing of the valid bit occur simultaneously, bit V will be cleared.
P	17	rh	Parity Bit This flag contains the parity bit that has been received with the data frame.
C	18	w	Clear Bit 0 _B No operation. 1 _B Bit V is cleared. C is always read as 0.
LABF	[20:19]	rh	Lower Address Bit Field This bit field contains the two address bits A[1:0] of the 4-bit address field (16-bit data frame). If 12-bit data frame is selected, LABF is always set to 00 _B .
IPF	21	rh	Internal Parity Flag This bit contains the parity bit that has been calculated in the MSC during data frame reception.

Micro Second Channel (MSC)

Field	Bits	Type	Description
PERR	22	rh	Parity Error This bit indicates if a start bit error, parity error, or stop bit error occurred during frame reception. 0 _B No error detected. 1 _B Error detected.
0	[15:8], [31:23]	r	Reserved Read as 0; should be written with 0.

19.3 MSC Module Implementation

This section describes the MSC module interface as it is implemented in the TC1728. It especially covers clock control, port and on-chip connections, interrupt control, and address decoding.

19.3.1 Interface Connections of the MSC Module

Figure 19-29 shows the TC172x-specific implementation details and interconnections of the MSC0 module.

The MSC0 module is supplied with a separate clock control, address decoding, and interrupt control logic. Two of the four modules' service request outputs are connected with interrupt nodes, and two with the DMA controller. Outputs of the GPTA module are connected to the alternate input buses ALTINL/ALTINH. The emergency stop output from the SCU controls the corresponding inputs of MSC0 module.

The serial data and clock outputs of the downstream channels of the MSC0 module and the device select outputs (EN0x) are connected to GPIO lines of Port 2. One Port 2 input line is connected to the upstream channel serial data input.

Micro Second Channel (MSC)

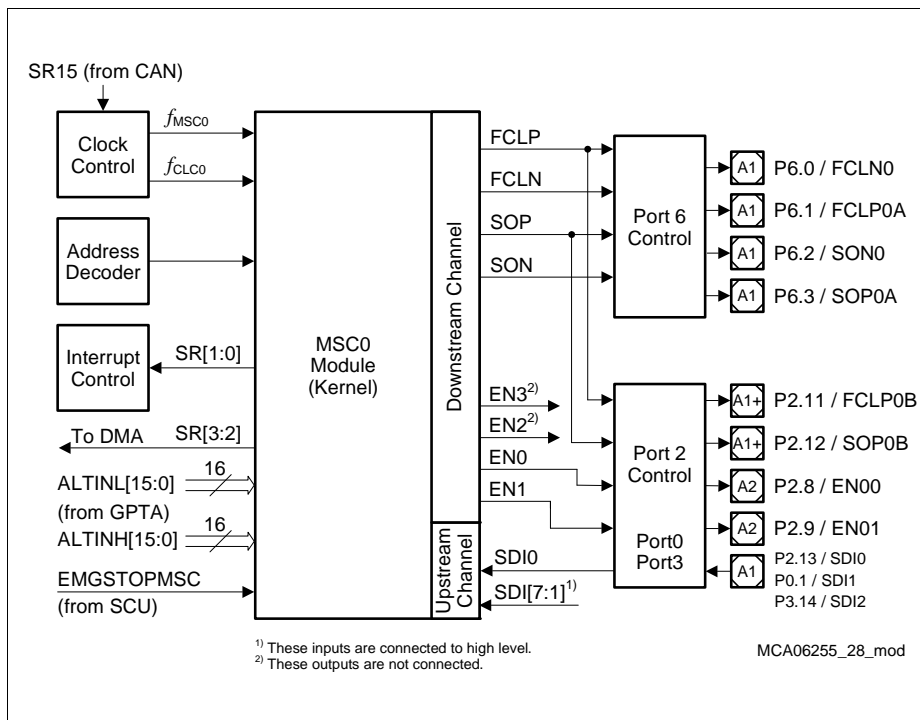


Figure 19-29 MSC0 Module Implementation and Interconnections

Micro Second Channel (MSC)

19.3.2 MSC0 Module-Related External Registers

Figure 19-30 summarizes the module-related external registers which are required for MSC programming (see also **Figure 19-28** for the module kernel specific registers). These registers are described in the following sections.

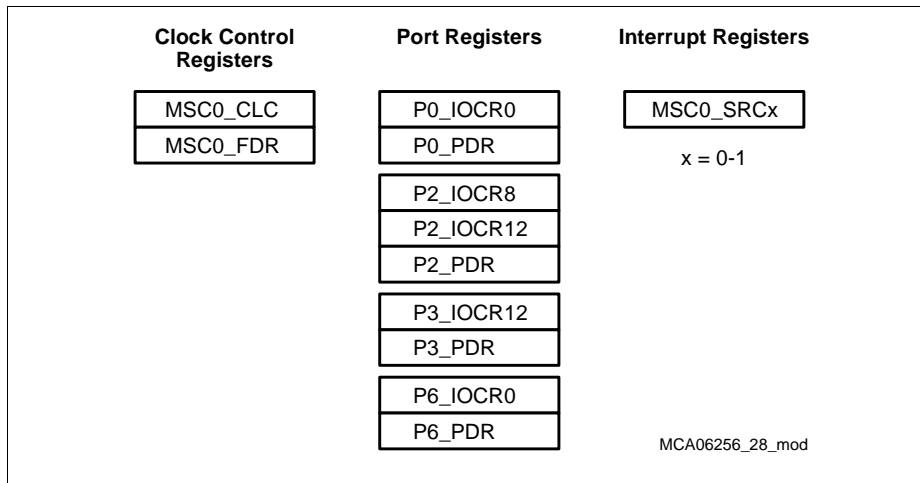


Figure 19-30 MSC Implementation-specific Special Function Registers

Micro Second Channel (MSC)

19.3.3 Clock Control

The MSC0 module is provided with two independent clock signals (**Figure 19-31**):

- f_{CLC0}
This is the module clock that is used inside the MSC kernel for control purposes such as clocking of control logic and register operations. The frequency of f_{CLC0} is always identical to the system clock frequency f_{SYS} . The clock control register MSC0_CLC makes it possible to enable/disable f_{CLC0} under certain conditions.
- f_{MSC0}
This clock is the module clock that is used inside the MSC for baud rate generation of the serial upstream and downstream channel. The fractional divider register MSC0_FDR controls the frequency of f_{MSC0} and makes it possible to enable/disable it independent of f_{CLC0} .

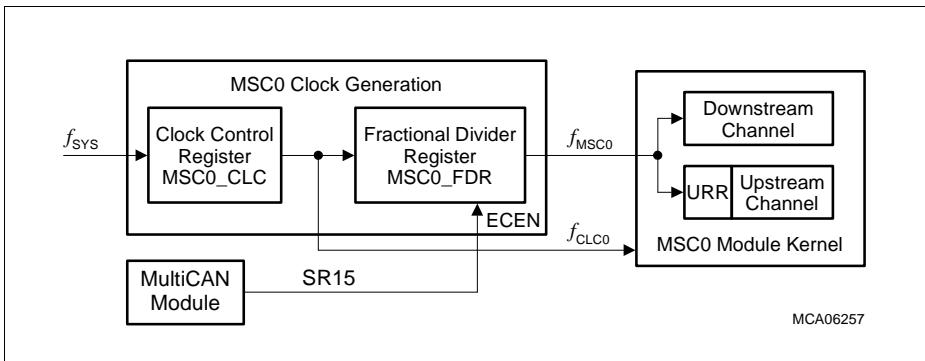


Figure 19-31 MSC0 Module Clock Generation

The following two formulas define the frequency of f_{MSC0} :

$$f_{MSC0} = f_{SYS} \times \frac{1}{n} \quad \text{with } n = 1024 - \text{MSC0_FDR.STEP} \quad (19.3)$$

$$f_{MSC0} = f_{SYS} \times \frac{n}{1024} \quad \text{with } n = 0-1023 \quad (19.4)$$

Micro Second Channel (MSC)

Downstream Channel Baud Rate

As the clock signal FCL of the synchronous downstream channel is always half the frequency of f_{MSC0} , the resulting downstream channel baud rate is defined by:

$$\text{Baud rate}_{\text{MSC0}} = f_{\text{SYS}} \times \frac{1}{2 \times (1024 - \text{MSC0_FDR.STEP})} \quad (19.5)$$

$$\text{Baud rate}_{\text{MSC0}} = f_{\text{SYS}} \times \frac{\text{MSC0_FDR.STEP}}{2 \times 1024} \quad (19.6)$$

Upstream Channel Baud Rate

The baud rate of the asynchronous upstream channel is derived from the module clock f_{MSC0} by a programmable clock divider selected by bit field MSC0_USR.URR (see also [Equation \(19.2\)](#) on [Page 19-25](#)). The divide factor DF can be at minimum 4 and at maximum 256.

$$\text{Baud rate}_{\text{MSC0}} = f_{\text{SYS}} \times \frac{1}{\text{DF} \times (1024 - \text{MSC0_FDR.STEP})} \quad (19.7)$$

$$\text{Baud rate}_{\text{MSC0}} = f_{\text{SYS}} \times \frac{\text{MSC0_FDR.STEP}}{\text{DF} \times 1024} \quad (19.8)$$

[Equation \(19.3\)](#), [Equation \(19.5\)](#), and [Equation \(19.7\)](#) are valid for normal divider mode (MSC0.FDR.DM = 01_B). [Equation \(19.4\)](#), [Equation \(19.6\)](#), and [Equation \(19.8\)](#) are valid for fractional divider mode (MSC0.FDR.DM = 10_B).

Micro Second Channel (MSC)

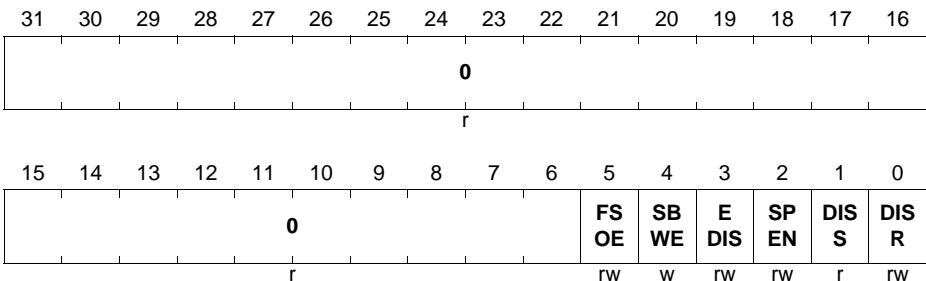
19.3.3.1 Clock Control Register

The Clock Control Register allows the programmer to control (enable/disable) the clock signals to the MSC0 module under certain conditions. The diagram below shows the clock control register functionality as is implemented for the MSC0 module.

MSC0_CLC

MSC0 Clock Control Register

(00_H)

Reset Value: 0000 0003_H


Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used to switch off fast clock in Suspend Mode.
0	[31:6]	r	Reserved Read as 0; should be written with 0.

Note: After a hardware reset operation, the f_{CLC0} and f_{MSC0} clocks are switched off and the MSC0 module is disabled (DISS set).

Micro Second Channel (MSC)

19.3.3.2 Fractional Divider Register

The Fractional Divider Register controls the clock rate of the shift clock f_{MSC0} .

MSC0_FDR

MSC0 Fractional Divider Register (0C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS	EN	SUS	SUS	0		RESULT									
rw	rw	rh	rh	r		rh									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM		SC		SM	FDIS	STEP									
rw		rw		rw	rw	rw									

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value Reload or addition value for RESULT.
FDIS	10	rw	Freeze Disable This bit controls the freeze function for this module. 0 _B Module operates on corrected clock, with reduced modulation jitter. 1 _B Module operates on uncorrected clock, with full modulation jitter.
SM	11	rw	Suspend Mode SM selects between granted or immediate suspend mode.
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in suspend mode.
DM	[15:14]	rw	Divider Mode DM selects normal or fractional divider mode.
RESULT	[25:16]	rh	Result Value Bit field for the addition result.
SUSACK	28	rh	Suspend Mode Acknowledge Indicates state of SPNDACK signal.

Micro Second Channel (MSC)

Field	Bits	Type	Description
SUSREQ	29	rh	Suspend Mode Request Indicates state of SPND signal.
ENHW	30	rw	Enable Hardware Clock Control Controls operation of ECEN input and DISCLK bit.
DISCLK	31	rwh	Disable Clock Hardware controlled disable for f_{OUT} signal.
0	[27:26]	r	Reserved Read as 0; should be written with 0.

19.3.4 Port Control

MSC0 clock and data output lines are connected to dedicated differential output drivers. Some of the MSC0 module I/O lines are connected to I/O ports and therefore controlled in the port logic (see also [Figure 19-29](#)). The following port control operations selections must be executed for these I/O lines:

- Input/output function selection (IOCR registers)
- Pad driver characteristics selection for the outputs (PDR registers)

19.3.4.1 Input/Output Function Selection

The port input/output control registers contain the bit fields that select the digital output and input driver characteristics such as port direction (input/output) with alternate output selection, pull-up/down devices, and open-drain selections. The I/O lines for the MSC0 module are controlled by the Port 2 input/output control registers.

[Table 19-10](#) shows in an overview how bits and bit fields must be programmed for the required I/O functionality of the MSC0 I/O lines.

Micro Second Channel (MSC)

Table 19-10 MSC0 I/O Line Selection and Setup

Module	Port Lines	Input/Output Control Register Bits	I/O
MSC0x	P0.1 / SDI1	P0_IOC0.PC1 = 0XXX _B	CMOS Input
	P2.8 / EN00	P2_IOC8.PC8 = 1X11 _B	CMOS Output
	P2.9 / EN01	P2_IOC8.PC9 = 1X11 _B	CMOS Output
	P2.11 / FCLP0B	P2_IOC8.PC11 = 1X11 _B	CMOS Output
	P2.12 / SOP0B	P2_IOC12.PC12 = 1X11 _B	CMOS Output
	P2.13 / SDI0 ¹⁾	P2_IOC12.PC13 = 0XXX _B	CMOS Input
	P3.14 / SDI2	P3_IOC12.PC14 = 0XXX _B	CMOS Input
	P6.0 / FCLN0	P6_IOC0.PC0 = 1X01 _B	CMOS Output
	P6.1 / FCLP0A	P6_IOC0.PC1 = 1X01 _B	CMOS Output
	P6.2 / SON0	P6_IOC0.PC2 = 1X01 _B	CMOS Output
	P6.3 / SOP0A	P6_IOC0.PC3 = 1X01 _B	CMOS Output

1) For the upstream channel serial data inputs, additionally bit fields MSC0_OCR.SDISEL must be set to 000_B.

Micro Second Channel (MSC)

19.3.5 On-Chip Connections

This section describes the on-chip connections of the MSC0 module.

19.3.5.1 EMGSTOPMSC Signal (from SCU)

The emergency stop input signal EMGSTOPMSC of the MSC0 module is connected to the output signal of the emergency stop input control logic. This logic is located in the SCU. Its functionality is controlled by the SCU emergency stop register.

19.3.5.2 DMA Controller Service Requests

Two service request outputs (SR[3:2]) of the MSC0 module are connected as DMA request input to the DMA controller. The DMA request lines are connected to the DMA controller as shown in [Table 19-11](#).

Table 19-11 Service Request Lines of MSC0

Module	Service Request Line	Connected to	Description
MSC0	SR0	MSC0_SRC0	MSC0 Service Request Node 0
	SR1	MSC0_SRC1	MSC0 Service Request Node 1
	SR2	CH02_REQI6	DMA Channel 02 Request Input 6
		CH04_REQI6	DMA Channel 04 Request Input 6
	SR3	CH03_REQI6	DMA Channel 03 Request Input 6
		CH05_REQI6	DMA Channel 05 Request Input 6

Micro Second Channel (MSC)

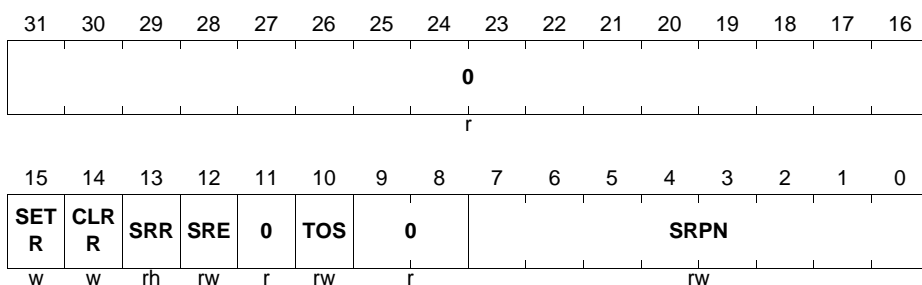
19.3.6 Interrupt Control Registers

In the TC172x, the two service request outputs SR[1:0] of the MSC0 module are connected to one interrupt node. The upper two service request outputs SR[3:2] of the MSC0 module are not connected to interrupt nodes, but can be used as DMA requests (see [Table 19-11](#)).

MSC0_SRCx (x = 0-1)

MSC0 Service Request Control Register x

 $(FC_H - x * 4_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Micro Second Channel (MSC)

19.3.7 MSC0 Address Map

An absolute register address is given by the offset address of the register (given in [Table 19-9](#)) plus the module base address (given in [Table 19-8](#)).

Table 19-12 Address Map of MSC0

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
MicroSecond Bus Controller 0 (MSC0)					
MSC0_ CLC	MSC0 Clock Control Register	F000 0800 _H	U, SV	SV, E	0000 0003 _H
–	Reserved	F000 0804 _H	BE	BE	–
MSC0_ ID	MSC0 Module Identification Register	F000 0808 _H	U, SV	BE	0028 C0XX _H
MSC0_ FDR	MSC0 Fractional Divider Register	F000 080C _H	U, SV	SV, E	0000 0000 _H
MSC0_ USR	MSC0 Upstream Status Register	F000 0810 _H	U, SV	U, SV	0000 0000 _H
MSC0_ DSC	MSC0 Downstream Control Register	F000 0814 _H	U, SV	U, SV	0000 0000 _H
MSC0_ DSS	MSC0 Downstream Status Register	F000 0818 _H	U, SV	U, SV	0000 0000 _H
MSC0_ DD	MSC0 Downstream Data Register	F000 081C _H	U, SV	U, SV	0000 0000 _H
MSC0_ DC	MSC0 Downstream Command Register	F000 0820 _H	U, SV	U, SV	0000 0000 _H
MSC0_ DSDSL	MSC0 Downstream Select Data Source Low Register	F000 0824 _H	U, SV	U, SV	0000 0000 _H
MSC0_ DSDSH	MSC0 Downstream Select Data Source High Register	F000 0828 _H	U, SV	U, SV	0000 0000 _H
MSC0_ ESR	MSC0 Emergency Stop Register	F000 082C _H	U, SV	U, SV	0000 0000 _H
MSC0_ UD0	MSC0 Upstream Data Register 0	F000 0830 _H	U, SV	U, SV	0000 0000 _H
MSC0_ UD1	MSC0 Upstream Data Register 1	F000 0834 _H	U, SV	U, SV	0000 0000 _H

Micro Second Channel (MSC)

Table 19-12 Address Map of MSC0 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
MSC0_UD2	MSC0 Upstream Data Register 2	F000 0838 _H	U, SV	U, SV	0000 0000 _H
MSC0_UD3	MSC0 Upstream Data Register 3	F000 083C _H	U, SV	U, SV	0000 0000 _H
MSC0_ICR	MSC0 Interrupt Control Register	F000 0840 _H	U, SV	U, SV	0000 0000 _H
MSC0_ISR	MSC0 Interrupt Status Register	F000 0844 _H	U, SV	U, SV	0000 0000 _H
MSC0_ISC	MSC0 Interrupt Set Clear Register	F000 0848 _H	U, SV	U, SV	0000 0000 _H
MSC0_OCR	MSC0 Output Control Register	F000 084C _H	U, SV	U, SV	0000 0000 _H
–	Reserved	F000 0850 _H - F000 0854 _H	nBE	nBE	–
		F000 0858 _H - F000 08F4 _H	BE	BE	–
MSC0_SRC1	MSC0 Service Request Control Register 1	F000 08F8 _H	U, SV	U, SV	0000 0000 _H
MSC0_SRC0	MSC0 Service Request Control Register 0	F000 08FC _H	U, SV	U, SV	0000 0000 _H

20 Controller Area Network Controller (MultiCAN)

This chapter describes the MultiCAN controller of the TC1728. It contains the following sections:

- CAN basics (see [Page 20-2](#))
- Overview of the CAN Module in the TC1728 (see [Page 20-11](#))
- Functional description of the MultiCAN Kernel (see [Page 20-14](#))
- MultiCAN Kernel register description (see [Page 20-56](#))
- TC1728 implementation-specific details (port connections and control, interrupt control, address decoding, clock control, see [Page 20-113](#)).

Note: The MultiCAN register names described in this chapter are referenced in the TC1728 User's Manual by the module name prefix "CAN_".

Table 20-1 Fixed Module Constants

Constant	Description
n_objects	Number of Message Objects available.
n_interrupts	Number of Interrupt Output Lines available.
n_pendings n_pendingregs	Number of Message Pending Bits available. There are n_pendings/32 message pending registers.
n_lists	Number of Lists available for allocation of Message Objects.
n_nodes	Number of CAN Nodes available As each CAN node has it's own list in addition to the list of un-allocated elements, the relation n_nodes < n_lists is true.

Controller Area Network Controller (MultiCAN)**20.1 CAN Basics**

CAN is an asynchronous serial bus system with one logical bus line. It has an open, linear bus structure with equal bus participants called nodes. A CAN bus consists of two or more nodes.

The bus logic corresponds to a “wired-AND” mechanism. Recessive bits (equivalent to the logic 1 level) are overwritten by dominant bits (logic 0 level). As long as no bus node is sending a dominant bit, the bus is in the recessive state. In this state, a dominant bit from any bus node generates a dominant bus state. The maximum CAN bus speed is, by definition, 1 Mbit/s. This speed limits the CAN bus to a length of up to 40 m. For bus lengths longer than 40 m, the bus speed must be reduced.

The binary data of a CAN frame is coded in NRZ code (Non-Return-to-Zero). To ensure re-synchronization of all bus nodes, bit stuffing is used. This means that during the transmission of a message, a maximum of five consecutive bits can have the same polarity. Whenever five consecutive bits of the same polarity have been transmitted, the transmitter will insert one additional bit (stuff bit) of the opposite polarity into the bit stream before transmitting further bits. The receiver also checks the number of bits with the same polarity and removes the stuff bits from the bit stream (= destuffing).

20.1.1 Addressing and Bus Arbitration

In the CAN protocol, address information is defined in the identifier field of a message. The identifier indicates the contents of the message and its priority. The lower the binary value of the identifier, the higher is the priority of the message.

For bus arbitration, CSMA/CD with NDA (Carrier Sense Multiple Access/Collision Detection with Non-Destructive Arbitration) is used. If bus node A attempts to transmit a message across the network, it first checks that the bus is in the idle state (“Carrier Sense”) i.e. no node is currently transmitting. If this is the case (and no other node wishes to start a transmission at the same moment), node A becomes the bus master and sends its message. All other nodes switch to receive mode during the first transmitted bit (Start-Of-Frame bit). After correct reception of the message (acknowledged by each node), each bus node checks the message identifier and stores the message, if required. Otherwise, the message is discarded.

If two or more bus nodes start their transmission at the same time (“Multiple Access”), bus collision of the messages is avoided by bit-wise arbitration (“Collision Detection / Non-Destructive Arbitration” together with the “Wired-AND” mechanism, dominant bits override recessive bits). Each node that sends also reads back the bus level. When a recessive bit is sent but a dominant one is read back, bus arbitration is lost and the transmitting node switches to receive mode. This condition occurs for example when the message identifier of a competing node has a lower binary value and therefore sends a message with a higher priority. In this way, the bus node with the highest priority message wins arbitration without losing time by having to repeat the message. Other nodes that lost arbitration will automatically try to repeat their transmission once the bus

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returns to idle state. Therefore, the same identifier can be sent in a Data Frame only by one node in the system. There must not be more than one node programmed to send Data Frames with the same identifier.

Standard message identifier has a length of 11 bits. CAN specification 2.0B extends the message identifier lengths to 29 bits, i.e. the extended identifier.

20.1.2 CAN Frame Formats

There are three types of CAN frames:

- Data Frames
- Remote Frames
- Error Frames

A Data Frame contains a Data Field of 0 to 8 bytes in length. A Remote Frame contains no Data Field and is typically generated as a request for data (e.g. from a sensor). Data and Remote Frames can use an 11-bit “Standard” identifier or a 29-bit “Extended” identifier. An Error Frame can be generated by any node that detects a CAN bus error.

20.1.2.1 Data Frames

There are two types of Data Frames defined (see [Figure 20-1](#)):

- Standard Data Frame
- Extended Data Frame

Standard Data Frame

A Data Frame begins with the Start-Of-Frame bit (SOF = dominant level) for hard synchronization of all nodes. The SOF is followed by the Arbitration Field consisting of 12 bits, the 11-bit identifier (reflecting the contents and priority of the message), and the RTR (Remote Transmission Request) bit. With RTR at dominant level, the frame is marked as Data Frame. With RTR at recessive level, the frame is defined as a Remote Frame.

The next field is the Control Field consisting of 6 bits. The first bit of this field is the IDE (Identifier Extension) bit and is at dominant level for the Standard Data Frame. The following bit is reserved and defined as a dominant bit. The remaining 4 bits of the Control Field are the Data Length Code (DLC) that specifies the number of bytes in the Data Field. The Data Field can be 0 to 8 bytes wide. The Cyclic Redundancy (CRC) Field that follows the data bytes is used to detect possible transmission errors. It consists of a 15-bit CRC sequence, completed by a recessive CRC delimiter bit.

The final field is the Acknowledge Field. During the ACK Slot, the transmitting node sends out a recessive bit. Any node that has received an error free frame acknowledges the correct reception of the frame by sending back a dominant bit, regardless of whether or not the node is configured to accept that specific message. This behavior assigns the

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CAN protocol to the “in-bit-response” group of protocols. The recessive ACK delimiter bit, which must not be overwritten by a dominant bit, completes the Acknowledge Field. Seven recessive End-of-Frame (EOF) bits finish the Data Frame. Between any two consecutive frames, the bus must remain in the recessive state for at least 3 bit times (called Inter Frame Space). If after the Inter Frame Space, no other nodes attempt to transmit the bus remains in idle state with a recessive level.

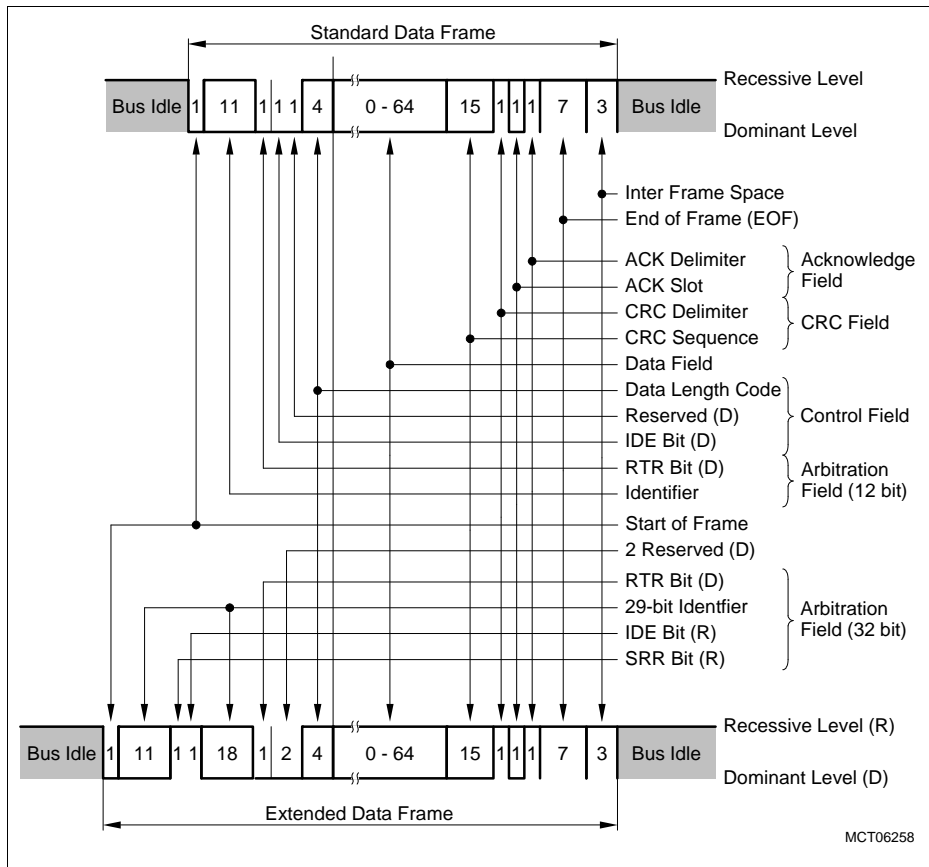


Figure 20-1 CAN Data Frame

Extended Data Frame

In the Extended CAN Data Frame, the message identifier of the standard frame has been extended to 29-bit. A split of the extended identifier into two parts, an 11-bit least

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significant section (as in standard CAN frame) and an 18-bit most significant section, ensures that the Identifier Extension bit (IDE) can remain at the same bit position in both standard and extended frames.

In the Extended CAN Data Frame, the SOF bit is followed by the 32-bit Arbitration Field. The first 11 bits are the least significant bits of the 29-bit Identifier ("Base-ID"). These 11 bits are followed by the recessive Substitute Remote Request (SRR) bit. The SRR is further followed by the recessive IDE bit, which indicates the frame to be an Extended CAN frame. If arbitration remains unresolved after transmission of the first 11 bits of the identifier, and if one of the nodes involved in arbitration is sending a Standard CAN frame, then the Standard CAN frame will win arbitration due to the assertion of its dominant IDE bit. Therefore, the SRR bit in an Extended CAN frame is recessive to allow the assertion of a dominant RTR bit by a node that is sending a Standard CAN Remote Frame. The SRR and IDE bits are followed by the remaining 18 bits of the extended identifier and the RTR bit.

Control field and frame termination is identical to the Standard Data Frame.

20.1.2.2 Remote Frames

Normally, data transmission is performed on an autonomous basis with the data source node (e.g. a sensor) sending out a Data Frame. It is also possible, however, for a destination node (or nodes) to request the data from the source. For this purpose, the destination node sends a Remote Frame with an identifier that matches the identifier of the required Data Frame. The appropriate data source node will then send a Data Frame as a response to this remote request.

There are 2 differences between a Remote Frame and a Data Frame.

- The RTR bit is in the recessive state in a Remote Frame.
- There is no Data Field in a Remote Frame.

If a Data Frame and a Remote Frame with the same identifier are transmitted at the same time, the Data Frame wins arbitration due to the dominant RTR bit following the identifier. In this way, the node that transmitted the Remote Frame receives the requested data immediately. The format of a Standard and Extended Remote Frames is shown in [Figure 20-2](#).

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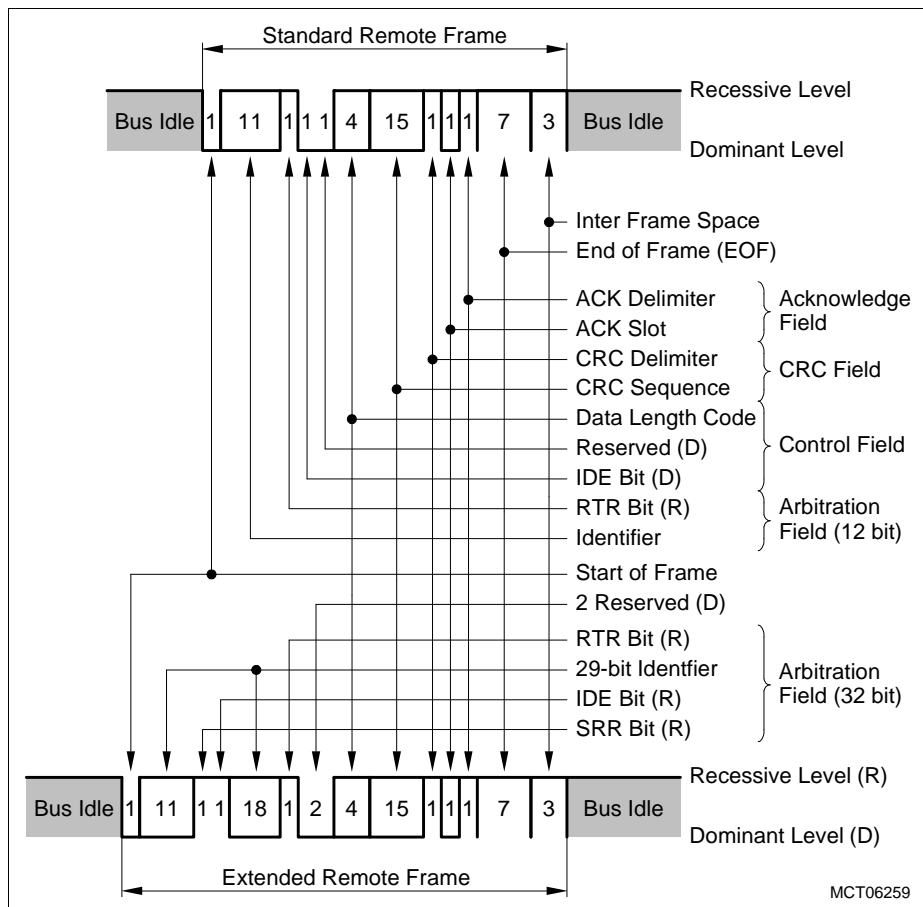


Figure 20-2 CAN Remote Frame

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20.1.2.3 Error Frames

An Error Frame is generated by any node that detects a bus error. An Error Frame consists of two fields, an Error Flag field followed by an Error Delimiter field. The Error Delimiter Field consists of 8 recessive bits and allows the bus nodes to restart bus communications after an error. There are, however, two forms of Error Flag fields. The form of the Error Flag field depends on the error status of the node that detects the error.

When an error-active node detects a bus error, the node generates an Error Frame with an active-error flag. The error-active flag is composed of six consecutive dominant bits that actively violate the bit-stuffing rule. All other stations recognize a bit-stuffing error and generate Error Frames themselves. The resulting Error Flag field on the CAN bus therefore consists of six to twelve consecutive dominant bits (generated by one or more nodes). The Error Delimiter field completes the Error Frame. After completion of the Error Frame, bus activity returns to normal and the interrupted node attempts to re-send the aborted message.

If an error-passive node detects a bus error, the node transmits an error-passive flag followed, again, by the Error Delimiter field. The error-passive flag consists of six consecutive recessive bits, and therefore the Error Frame (for an error-passive node) consists of 14 recessive bits (i.e. no dominant bits). Therefore, the transmission of an Error Frame by an error-passive node will not affect any other node on the network, unless the bus error is detected by the node that is actually transmitting (i.e. the bus master). If the bus master node generates an error-passive flag, this may cause other nodes to generate Error Frames due to the resulting bit-stuffing violation. After transmission of an Error Frame an error-passive node must wait for 6 consecutive recessive bits on the bus before attempting to rejoin bus communications.

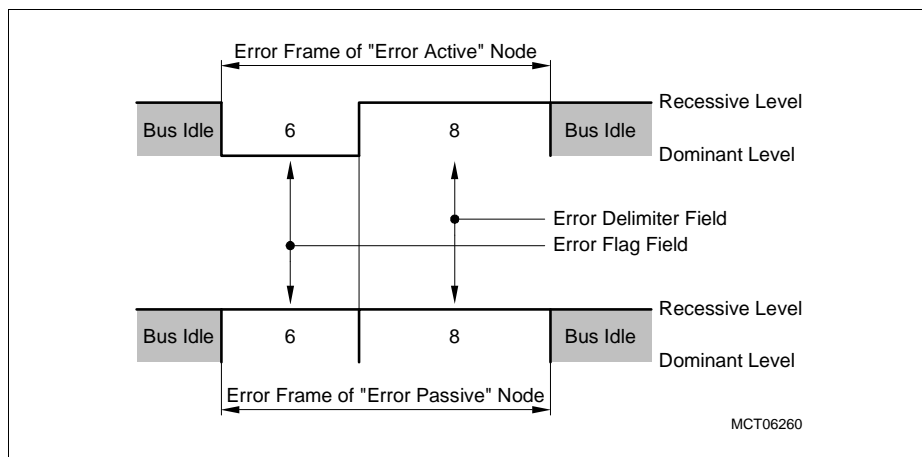


Figure 20-3 CAN Error Frames

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20.1.3 The Nominal Bit Time

One bit cell (this means one high or low pulse of the NRZ code) is composed by four segments. Each segment is an integer multiple of Time Quanta t_Q . The Time Quanta is the smallest discrete timing resolution used by a CAN node. The nominal bit time definition with its segments is shown in [Figure 20-4](#).

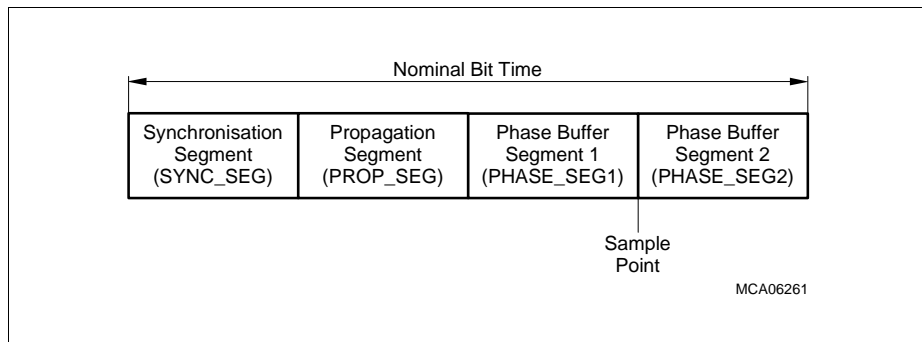


Figure 20-4 Partition of Nominal Bit Time

The Synchronization Segment (SYNC_SEG) is used to synchronize the various bus nodes. If there is a bit state change between the previous bit and the current bit, then the bus state change is expected to occur within this segment. The length of this segment is always $1 t_Q$.

The Propagation Segment (PROP_SEG) is used to compensate for signal delays across the network. These delays are caused by signal propagation delay on the bus line and through the electronic interface circuits of the bus nodes.

The Phase Segments 1 and 2 (PHASE_SEG1, PHASE_SEG2) are used to compensate for edge phase errors. These segments can be lengthened or shortened by re-synchronization. PHASE_SEG2 is reserved for calculation of the subsequent bit level, and is $\geq 2 t_Q$. At the sample point, the bus level is read and interpreted as the value of the bit cell. It occurs at the end of PHASE_SEG1.

The total number of t_Q in a bit time is between 8 and 25.

As a result of re-synchronization, PHASE_SEG1 can be lengthened or PHASE_SEG2 can be shortened. The amount of lengthening or shortening the phase buffer segments has an upper limit given by the re-synchronization jump width. The re-synchronization jump width may be between 1 and $4 t_Q$, but it may not be longer than PHASE_SEG1.

20.1.4 Error Detection and Error Handling

The CAN protocol has sophisticated error detection mechanisms. The following errors can be detected:

- **Cyclic Redundancy Check (CRC) Error**

With the Cyclic Redundancy Check, the transmitter calculates special check bits for the bit sequence from the start of a frame until the end of the Data Field. This CRC sequence is transmitted in the CRC Field. The receiving node also calculates the CRC sequence using the same formula, and performs a comparison to the received sequence. If a mismatch is detected, a CRC error has occurred and an Error Frame is generated. The message is repeated.

- **Acknowledge Error**

In the Acknowledge Field of a message, the transmitter checks whether a dominant bit is read during the Acknowledge Slot (that is sent out as a recessive bit). If not, no other node has received the frame correctly, an Acknowledge Error has occurred, and the message must be repeated. No Error Frame is generated.

- **Form Error**

If a transmitter detects a dominant bit in one of the four segments End of Frame, Interframe Space, Acknowledge Delimiter, or CRC Delimiter, a Form Error has occurred, and an Error Frame is generated. The message is repeated.

- **Bit Error**

A Bit Error occurs if a) a transmitter sends a dominant bit and detects a recessive bit or b) if the transmitter sends a recessive bit and detects a dominant bit when monitoring the actual bus level and comparing it to the just transmitted bit. In case b), no error occurs during the Arbitration Field (ID, RTR, IDE) and the Acknowledge Slot.

- **Stuff Error**

If between Start of Frame and CRC Delimiter, six consecutive bits with the same polarity are detected, the bit-stuffing rule has been violated. A stuff error occurs and an Error Frame is generated. The message is repeated.

Detected errors are made public to all other nodes via Error Frames (except Acknowledge Errors). The transmission of the erroneous message is aborted and the frame is repeated as soon as possible. Furthermore, each CAN node is in one of the three error states (error-active, error-passive or bus-off) according to the value of the internal error counters. The error-active state is the usual state where the bus node can transmit messages and active-error frames (made of dominant bits) without any restrictions. In the error-passive state, messages and passive-error frames (made of recessive bits) may be transmitted. The bus-off state makes it temporarily impossible for the node to participate in the bus communication. During this state, messages can be neither received nor transmitted.

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Basic CAN, Full CAN

There is one more CAN characteristic that is related to the interface of a CAN module (controller) and the host CPU: Basic-CAN and Full-CAN functionality.

In Basic-CAN devices, only basic functions of the protocol are implemented in hardware, such as the generation and the check of the bit stream. The decision, whether a received message has to be stored or not (acceptance filtering), and the complete message management must be done by software. Normally, the CAN device also provides only one transmit buffer and one or two receive buffers. Therefore, the host CPU load is quite high when using Basic-CAN modules. The main advantage of Basic-CAN is a reduced chip size leading to low costs of these devices.

Full-CAN devices (this is the case for the MultiCAN controller as implemented in TC1728) manage the whole bus protocol in hardware, including the acceptance filtering and message management. Full-CAN devices contain message objects that handle autonomously the identifier, the data, the direction (receive or transmit) and the information of Standard CAN/Extended CAN operation. During the initialization of the device, the host CPU determines which messages are to be sent and which are to be received. The host CPU is informed by interrupt if the identifier of a received message matches with one of the programmed (receive-) message objects. The CPU load of Full-CAN devices is greatly reduced. When using Full-CAN devices, high baud rates and high bus loads with many messages can be handled.

Controller Area Network Controller (MultiCAN)

20.2 Overview

This section describes the serial communication module called MultiCAN (CAN = Controller Area Network) of the TC1728. A MultiCAN module can contain between two and eight independent CAN nodes, depending on the device, each representing one serial communication interface.

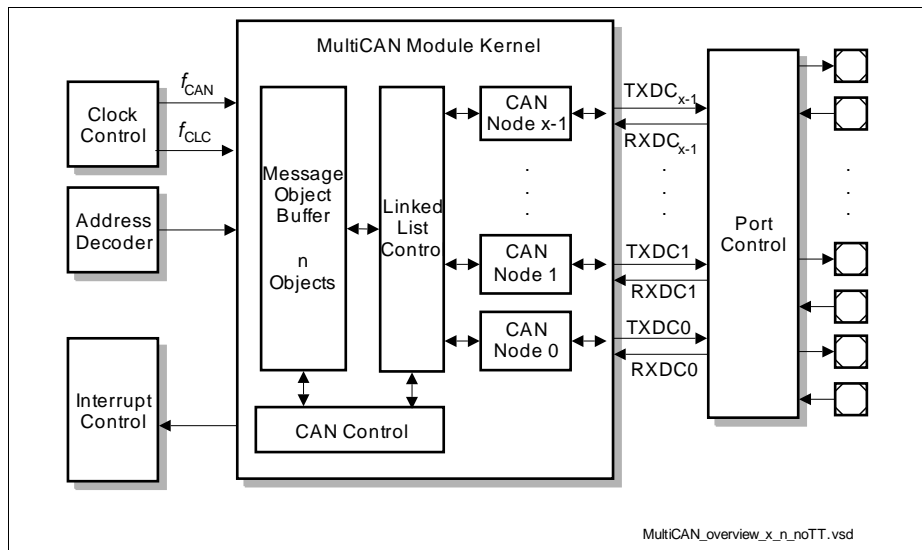


Figure 20-5 Overview of the MultiCAN Module

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20.2.1 MultiCAN Module

The MultiCAN module contains independently operating CAN nodes with Full-CAN functionality that are able to exchange Data and Remote Frames via a gateway function. Transmission and reception of CAN frames is handled in accordance with CAN specification V2.0 B (active). Each CAN node can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers.

Both CAN nodes share a common set of message objects. Each message object can be individually allocated to one of the CAN nodes. Besides serving as a storage container for incoming and outgoing frames, message objects can be combined to build gateways between the CAN nodes or to setup a FIFO buffer.

The message objects are organized in double-chained linked lists, where each CAN node has its own list of message objects. A CAN node stores frames only into message objects that are allocated to the message object list of the CAN node, and it transmits only messages belonging to this message object list. A powerful, command-driven list controller performs all message object list operations.

The bit timings for the CAN nodes are derived from the module timer clock (f_{CAN}), and are programmable up to a data rate of 1 Mbit/s. External bus transceivers are connected to a CAN node via a pair of receive and transmit pins.

Features

- Compliant with ISO 11898
- CAN functionality according to CAN specification V2.0 B active
- Dedicated control registers for each CAN node
- Data transfer rates up to 1 Mbit/s
- Support for ceramic resonator by providing separate frequency domain and input
- Flexible and powerful message transfer control and error handling capabilities
- Advanced CAN bus bit timing analysis and baud rate detection for each CAN node via a frame counter
- Full-CAN functionality: A set of message objects can be individually
 - Allocated (assigned) to any CAN node
 - Configured as transmit or receive object
 - Set up to handle frames with 11-bit or 29-bit identifier
 - Identified by a timestamp via a frame counter
 - Configured to remote monitoring mode
- Advanced acceptance filtering
 - Each message object provides an individual acceptance mask to filter incoming frames
 - A message object can be configured to accept standard or extended frames or to accept both standard and extended frames
 - Message objects can be grouped into four priority classes for transmission and reception

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- The selection of the message to be transmitted first can be based on frame identifier, IDE bit and RTR bit according to CAN arbitration rules, or according to its order in the list
- Advanced message object functionality
 - Message objects can be combined to build FIFO message buffers of arbitrary size, limited only by the total number of message objects
 - Message objects can be linked to form a gateway that automatically transfers frames between two different CAN buses. A single gateway can link any two CAN nodes. An arbitrary number of gateways can be defined.
- Advanced data management
 - The message objects are organized in double-chained lists
 - List reorganizations can be performed at any time, even during full operation of the CAN nodes
 - A powerful, command-driven list controller manages the organization of the list structure and ensures consistency of the list
 - Message FIFOs are based on the list structure and can easily be scaled in size during CAN operation
 - Static allocation commands offer compatibility with TwinCAN applications that are not list-based
- Advanced interrupt handling
 - Up to 16 interrupt output lines are available. Interrupt requests can be routed individually to one of the 16 interrupt output lines
 - Message post-processing notifications can be mapped flexibly using dedicated registers consisting of notification bits

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20.3 MultiCAN Kernel Functional Description

This section describes the functionality of the MultiCAN module.

20.3.1 Module Structure

Figure 20-6 shows the general structure of the MultiCAN module.

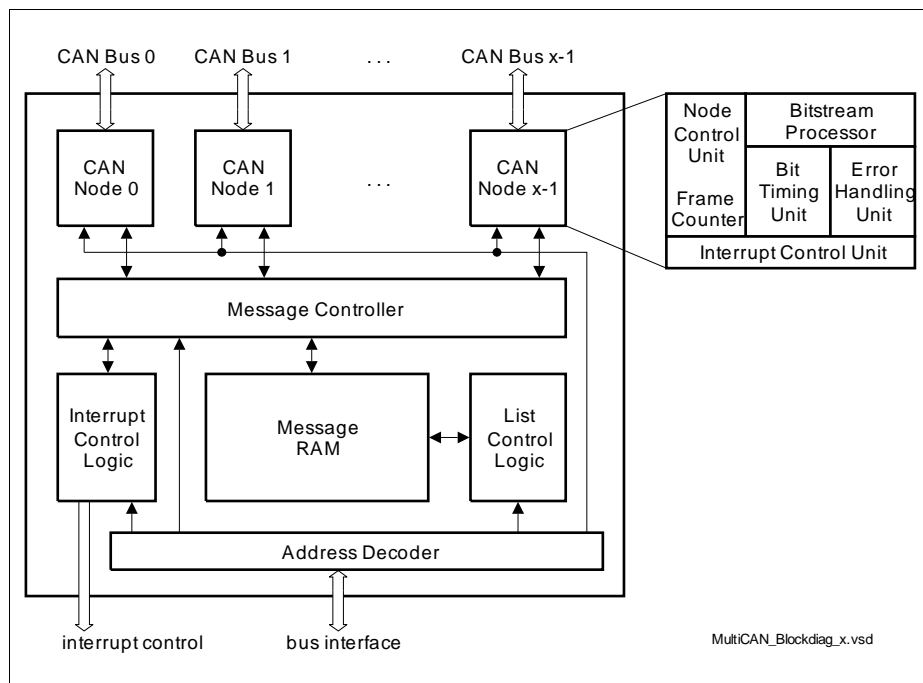


Figure 20-6 MultiCAN Block Diagram

CAN Nodes

Each CAN node consists of several sub-units.

- **Bitstream Processor**

The Bitstream Processor performs data, remote, error and overload frame processing according to the ISO 11898 standard. This includes conversion between the serial data stream and the input/output registers.

- **Bit Timing Unit**

The Bit Timing Unit determines the length of a bit time and the location of the sample point according to the user settings, taking into account propagation delays and phase shift errors. The Bit Timing Unit also performs resynchronization.

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- **Error Handling Unit**

The Error Handling Unit manages the receive and transmit error counter. Depending on the contents of both counters, the CAN node is set into an error-active, error passive or bus-off state.

- **Node Control Unit**

The Node Control Unit coordinates the operation of the CAN node:

- Enable/disable CAN transfer of the node
- Enable/disable and generate node-specific events that lead to an interrupt request (CAN bus errors, successful frame transfers etc.)
- Administration of the Frame Counter

- **Interrupt Control Unit**

The Interrupt Control Unit in the CAN node controls the interrupt generation for the different conditions that can occur in the CAN node.

Message Controller

The Message Controller handles the exchange of CAN frames between the CAN nodes and the message objects that are stored in the Message RAM. The Message Controller performs several functions:

- Receive acceptance filtering to determine the correct message object for storing of a received CAN frame
- Transmit acceptance filtering to determine the message object to be transmitted first, individually for each CAN node
- Transfer contents between message objects and the CAN nodes, taking into account the status/control bits of the message objects
- Handling of the FIFO buffering and gateway functionality
- Aggregation of message-pending notification bits

List Controller

The List Controller performs all operations that lead to a modification of the double-chained message object lists. Only the list controller is allowed to modify the list structure. The allocation/deallocation or reallocation of a message object can be requested via a user command interface (command panel). The list controller state machine then performs the requested command autonomously.

Interrupt Control

The general interrupt structure is shown in [Figure 20-8](#). The interrupt event can trigger the interrupt generation. The interrupt pulse is generated independently of the interrupt flag in the interrupt status register. The interrupt flag can be reset by software by writing a 0 to it.

If enabled by the related interrupt enable bit in the interrupt enable register, an interrupt pulse can be generated at one of the 16 interrupt output lines INT_Om of the MultiCAN

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module. If more than one interrupt source is connected to the same interrupt node pointer (in the interrupt node pointer register), the requests are combined to one common line.

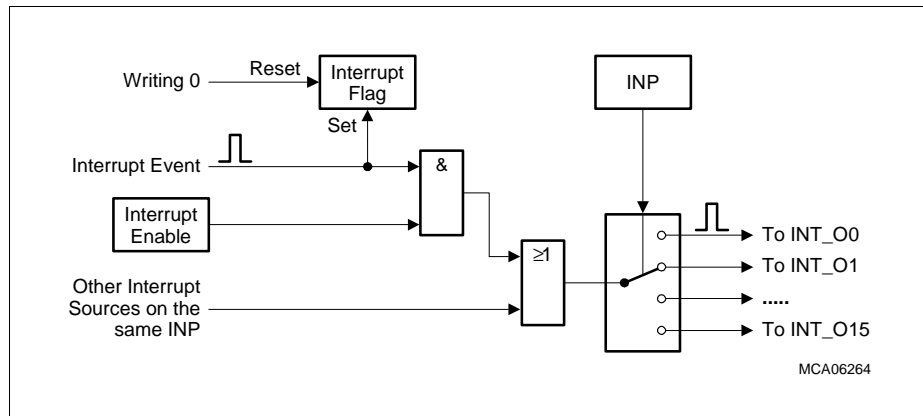


Figure 20-7 General Interrupt Structure

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20.3.2 Clock Control

The CAN module timer clock f_{CAN} of the functional blocks of the MultiCAN module is derived from the asynchronous, higher precision clock f_A . The Fractional Divider is used to generate f_{CAN} used for bit timing calculation. The frequency of f_{CAN} is identical for all CAN nodes. The register file operate with the module control clock f_{CLC} . See also [“Module Clock Generation” on Page 20-115](#).

The output clock f_{CAN} of the Fractional Divider is based on the clock f_A , but only every n -th clock pulse is taken. The suspend signal (coming as acknowledge from the MultiCAN module in response to a OCDS suspend request) freezes or resets the Fractional Divider.

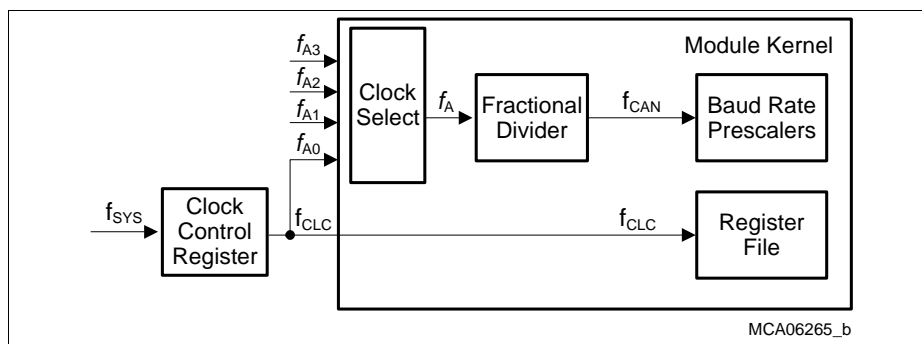


Figure 20-8 MultiCAN Clock Generation

[Table 20-2](#) indicates the minimum operating frequencies in MHz for f_A that are required for a baud rate of 1 Mbit/s for the active CAN nodes. If a lower baud rate is desired, the values can be scaled linearly (e.g. for a maximum of 500 kbit/s, 50% of the indicated value are required).

The values imply that the CPU (or DMA) executes maximum accesses to the MultiCAN module. The values may contain rounding effects.

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Table 20-2 Minimum Operating Frequencies [MHz]¹⁾

Number of allocated message objects MO ²⁾ , without TTCAN functionality	1 CAN node active	2 CAN nodes active	3 CAN nodes active	4 CAN nodes active	5 CAN nodes active
16 MO, without TTCAN	12	19	26	33	40
32 MO, without TTCAN	15	23	30	37	44
64 MO, without TTCAN	21	28	37	46	53
128 MO, without TTCAN	40	45	50	55	61

1) In the case of 15 time quanta, the minimum operating frequency required is 15MHz.

2) Only those message objects have to be taken into account that are allocated to a CAN node. The unallocated message objects have no influence on the minimum operating frequency.

The baud rate generation of the MultiCAN being based on f_A , this frequency has to be chosen carefully to allow correct CAN bit timing. The required value of f_A is given by an integer multiple (n) of the CAN baud rate multiplied by the number of time quanta per CAN bit time. For example, to reach 1 Mbit/s with 20 tq per bit time, possible values of f_A are given by formula $[n \times 20]$ MHz, with n being an integer value, starting at 1.

In order to minimize jitter, it is not recommended to use the fractional divider mode for high baud rates.

Additionally, for correct operation of the MultiCAN, the following conditions have to be fulfilled,

$$\text{Baudrate}_{\max} = [(8 \times T_{\text{CAN}}) + (8 \times T_{\text{CLC}}) + (4 \times \text{No. of active CAN nodes} \times T_{\text{CLC}})] \quad (20.1)$$

also

$$\text{NBTR.SJW} < \text{NBTR.TSEG1}$$

As an example, when $f_{\text{CAN}} = f_{\text{CLC}} = 20\text{MHz}$, No of active CAN nodes =1,

$$\text{Baudrate}_{\max} = [(8 \times 50\text{ns}) + (8 \times 50\text{ns}) + (4 \times 1 \times 50\text{ns})] = 1000\text{ns} = 1\text{MBaud}$$

Table 20-3 below illustrates the minimum CAN module timer clock f_{CAN} and Module Control Clock f_{CLC} that's required to support a Baurate Generation of 500KBaud. If a higher baudrate is desired, the values need to be calculated as per [Equation \(20.1\)](#).

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Table 20-3 Minimum Operating Frequencies [MHz] required for 500KBaud

No. of active CAN nodes	$f_{CAN} = f_{CLC}$ (MHz)	$f_{CAN} \neq f_{CLC}$ (MHz)	
		f_{CAN}	f_{CLC}
1	10	16	8
		20	8
		24	8
		80	7
2	12	16	11
		20	10
		24	10
		80	9
3	14	16	14
		20	13
		24	12
		80	11
4	16	16	16
		20	15
		24	15
		80	13
5	18	16	19
		20	18
		24	17
		80	15

20.3.3 Port Input Control

It is possible to select the input lines for the RXDCANx inputs for the CAN nodes. The selected input is connected to the CAN node and is also available to wake-up the system. More details are defined in [Section 20.5.4.2](#) on [Page 20-119](#).

20.3.4 Suspend Mode

The Suspend Mode can be triggered by the OCDS in order to freeze the state of the module and to permit access to the registers (at least for read actions). The MultiCAN module provides two types of Suspend Modes:

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- All actions are immediately stopped (Hard Suspend Mode):
The module clocks f_{CLC} and f_{CAN} are switched off as soon as the suspend request becomes active. Read and write operations to the module are no longer possible. This means that the CAN registers cannot be accessed anymore. In this mode, there is a very high probability that the communication with other CAN devices is made impossible, and that the CAN bus is blocked (e.g. if the suspended CAN module just sends a dominant level). A reset operation must be executed to leave Hard Suspend Mode.
- The current action is finished (Soft Suspend Mode):
The module clock f_{CLC} keeps running. Module functions are stopped automatically after internal actions have been finished (for example, after a CAN frame has been sent out). The end of the internal actions is indicated to the fractional divider by a suspend mode acknowledged signal. Due to this behavior, the communication network is not blocked. Furthermore, all registers are accessible for read and write actions. As a result, the debugger can stop the module actions and modify registers. These modifications are taken into account after the Suspend Mode is left.

The Hard Suspend Mode can be enabled/disabled only for the complete MultiCAN module. The Soft Suspend Mode can be individually enabled for each CAN node.

The fractional divider disables module clock f_{CAN} only if all CAN nodes signal that they can be suspended. A CAN node that is not active can always be suspended.

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20.3.5 CAN Node Control

Each CAN node may be configured and run independently of the other CAN node. Each CAN node is equipped with its own node control logic to configure the global behavior and to provide status information.

Note: In the following descriptions, index “x” stands for the node number and index “n” represents the message object number.

Configuration Mode is activated when bit NCRx.CCE is set to 1. This mode allows CAN bit timing parameters and the error counter registers to be modified.

CAN Analyze Mode is activated when bit NCRx.CALM is set to 1. In this operation mode, Data And Remote Frames are monitored without active participation in any CAN transfer (CAN transmit pin is held on recessive level). Incoming Remote Frames are stored in a corresponding transmit message object, while arriving data frames are saved in a matching receive message object.

In CAN Analyze Mode, the entire configuration information of the received frame is stored in the corresponding message object, and can be evaluated by the CPU to determine their identifier, XTD bit information and data length code (ID and DLC optionally if the Remote Monitoring Mode is active, bit MOFCRn.RMM = 1). Incoming frames are not acknowledged, and no Error Frames are generated. If CAN Analyze Mode is enabled, Remote Frames are not responded to by the corresponding Data Frame, and Data Frames cannot be transmitted by setting the transmit request bit MOSTATn.TXRQ. Receive interrupts are generated in CAN Analyze Mode (if enabled) for all error free received frames.

The node-specific interrupt configuration is also defined by the Node Control Logic via the NCRx register bits TRIE, ALIE and LECIE:

- If control bit TRIE is set to 1, a transfer interrupt is generated when the NSRx register has been updated (after each successfully completed message transfer).
- If control bit ALIE is set to 1, an error interrupt is generated when a “bus-off” condition has been recognized or the Error Warning Level has been exceeded or under-run. Additionally, list or object errors lead to this type of interrupt.
- If control bit LECIE is set to 1, a last error code interrupt is generated when an error code > 0 is written into bit field NSRx.LEC by hardware.

The Node x Status Register NSRx provides an overview about the current state of the respective CAN node x, comprising information about CAN transfers, CAN node status, and error conditions.

The CAN frame counter can be used to check the transfer sequence of message objects or to obtain information about the instant a frame has been transmitted or received from the associated CAN bus. CAN frame counting is performed by a 16-bit counter, controlled by register NFCRx. Bit fields NFCRx.CFMODE and NFCRx.CFSEL determine the operation mode and the trigger event incrementing the frame counter.

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20.3.5.1 Bit Timing Unit

According to the ISO 11898 standard, a CAN bit time is subdivided into different segments (Figure 20-9). Each segment consists of multiples of a time quantum t_q . The magnitude of t_q is adjusted by Node x Bit Timing Register bit fields NBTRx.BRP and NBTRx.DIV8, both controlling the baud rate prescaler (register NBTRx is described on Page 20-85). The baud rate prescaler is driven by the module timer clock f_{CAN} (generation and control of f_{CAN} is described on Page 20-115).

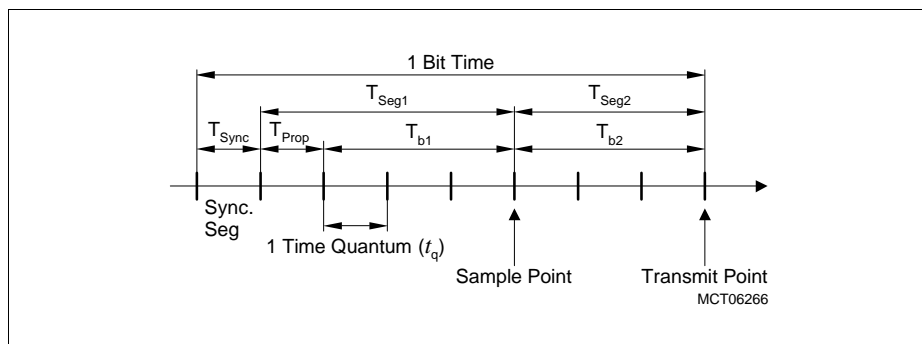


Figure 20-9 CAN Bus Bit Timing Standard

The Synchronization Segment (T_{Sync}) allows a phase synchronization between transmitter and receiver time base. The Synchronization Segment length is always one t_q . The Propagation Time Segment (T_{Prop}) takes into account the physical propagation delay in the transmitter output driver on the CAN bus line and in the transceiver circuit. For a working collision detection mechanism, T_{Prop} must be two times the sum of all propagation delay quantities rounded up to a multiple of t_q . The phase buffer segments 1 and 2 (T_{b1} , T_{b2}) before and after the signal sample point are used to compensate for a mismatch between transmitter and receiver clock phases detected in the synchronization segment.

The maximum number of time quanta allowed for re-synchronization is defined by bit field NBTRx.SJW. The Propagation Time Segment and the Phase Buffer Segment 1 are combined to parameter T_{Seg1} , which is defined by the value NBTRx.TSEG1. A minimum of 3 time quanta is demanded by the ISO standard. Parameter T_{Seg2} , which is defined by the value of NBTRx.TSEG2, covers the Phase Buffer Segment 2. A minimum of 2 time quanta is demanded by the ISO standard. According to ISO standard, a CAN bit time, calculated as the sum of T_{Sync} , T_{Seg1} and T_{Seg2} , must not fall below 8 time quanta.

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Calculation of the bit time:

$$\begin{aligned}
 t_q &= (\text{BRP} + 1) / f_{\text{CAN}} && \text{if DIV8} = 0 \\
 &= 8 \times (\text{BRP} + 1) / f_{\text{CAN}} && \text{if DIV8} = 1 \\
 T_{\text{Sync}} &= 1 \times t_q \\
 T_{\text{Seg1}} &= (\text{TSEG1} + 1) \times t_q && (\text{min. } 3 \ t_q) \\
 T_{\text{Seg2}} &= (\text{TSEG2} + 1) \times t_q && (\text{min. } 2 \ t_q) \\
 \text{bit time} &= T_{\text{Sync}} + T_{\text{Seg1}} + T_{\text{Seg2}} && (\text{min. } 8 \ t_q)
 \end{aligned}$$

To compensate phase shifts between clocks of different CAN controllers, the CAN controller must synchronize on any edge from the recessive to the dominant bus level. If the hard synchronization is enabled (at the start of frame), the bit time is restarted at the synchronization segment. Otherwise, the re-synchronization jump width T_{SJW} defines the maximum number of time quanta, a bit time may be shortened or lengthened by one re-synchronization. The value of SJW is defined by bit field NBTRx.SJW.

$$\begin{aligned}
 T_{\text{SJW}} &= (\text{SJW} + 1) \times t_q \\
 T_{\text{Seg1}} &\geq T_{\text{SJW}} + T_{\text{prop}} \\
 T_{\text{Seg2}} &\geq T_{\text{SJW}}
 \end{aligned}$$

The maximum relative tolerance for f_{CAN} depends on the Phase Buffer Segments and the re-synchronization jump width.

$$\begin{aligned}
 df_{\text{CAN}} &\leq \min(T_{b1}, T_{b2}) / 2 \times (13 \times \text{bit time} - T_{b2}) \quad \text{AND} \\
 df_{\text{CAN}} &\leq T_{\text{SJW}} / 20 \times \text{bit time}
 \end{aligned}$$

A valid CAN bit timing must be written to the CAN Node Bit Timing Register NBTR before resetting the INIT bit in the Node Control Register, i.e. before enabling the operation of the CAN node.

The Node Bit Timing Register may be written only if bit CCE (Configuration Change Enable) is set in the corresponding Node Control Register.

20.3.5.2 Bitstream Processor

Based on the message objects in the message buffer, the Bitstream Processor generates the remote and Data Frames to be transmitted via the CAN bus. It controls the CRC generator and adds the checksum information to the new remote or Data Frame. After including the SOF bit and the EOF field, the Bitstream Processor starts the CAN

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bus arbitration procedure and continues with the frame transmission when the bus was found in idle state. While the data transmission is running, the Bitstream Processor continuously monitors the I/O line. If (outside the CAN bus arbitration phase or the acknowledge slot) a mismatch is detected between the voltage level on the I/O line and the logic state of the bit currently sent out by the transmit shift register, a CAN error interrupt request is generated, and the error code is indicated by the Node x Status Register bit field NSRx.LEC.

The data consistency of an incoming frame is verified by checking the associated CRC field. When an error has been detected, a CAN error interrupt request is generated and the associated error code is presented in the Node x Status Register NSRx. Furthermore, an Error Frame is generated and transmitted on the CAN bus. After decomposing a faultless frame into identifier and data portion, the received information is transferred to the message buffer executing remote and Data Frame handling, interrupt generation and status processing.

20.3.5.3 Error Handling Unit

The Error Handling Unit of a CAN node x is responsible for the fault confinement of the CAN device. Its two counters, the Receive Error Counter REC and the Transmit Error Counter TEC (bit fields of the Node x Error Counter Register NECNTx, see [Page 20-87](#)) are incremented and decremented by commands from the Bitstream Processor. If the Bitstream Processor itself detects an error while a transmit operation is running, the Transmit Error Counter is incremented by 8. An increment of 1 is used when the error condition was reported by an external CAN node via an Error Frame generation. For error analysis, the transfer direction of the disturbed message and the node that recognizes the transfer error are indicated for the respective CAN node x in register NECNTx. Depending on the values of the error counters, the CAN node is set into error-active, error-passive, or bus-off state.

The CAN node is in error-active state if both error counters are below the error-passive limit of 128. The CAN node is in error-passive state, if at least one of the error counters is equal to or greater than 128.

The bus-off state is activated if the Transmit Error Counter is equal to or greater than the bus-off limit of 256. This state is reported for CAN node x by the Node x Status Register flag NSRx.BOFF. The device remains in this state, until the "bus-off" recovery sequence is finished. Additionally, Node x Status Register flag NSRx.EWRN is set when at least one of the error counters is equal to or greater than the error warning limit defined by the Node x Error Count Register bit field NECNTx.EWRNLVL. Bit NSRx.EWRN is reset if both error counters fall below the error warning limit again (see [Page 20-75](#)).

20.3.5.4 CAN Frame Counter

Each CAN node is equipped with a frame counter that counts transmitted/received CAN frames or obtains information about the time when a frame has been started to transmit or be received by the CAN node. CAN frame counting/bit time counting is performed by a 16-bit counter that is controlled by Node x Frame Counter Register NFCRx (see [Page 20-88](#)). Bit field NFCRx.CFSEL determines the operation mode of the frame counter:

- **Frame Count Mode:**
After the successful transmission and/or reception of a CAN frame, the frame counter is copied into the CFCVAL bit field of the MOIPRn register of the message object involved in the transfer. Afterwards, the frame counter is incremented.
- **Time Stamp Mode:**
The frame counter is incremented with the beginning of a new bit time. When the transmission/reception of a frame starts, the value of the frame counter is captured and stored to the CFC bit field of the NFCRx register. After the successful transfer of the frame the captured value is copied to the CFCVAL bit field of the MOIPRn register of the message object involved in the transfer.
- **Bit Timing Mode:**
Used for baud rate detection and analysis of the bit timing ([Chapter 20.3.7.3](#)).

20.3.5.5 CAN Node Interrupts

Each CAN node has four hardware triggered interrupt request types that are able to generate an interrupt request upon:

- The successful transmission or reception of a frame
- A CAN protocol error with a last error code
- An alert condition: Transmit/receive error counters reach the warning limit, bus-off state changes, a List Length Error occurs, or a List Object Error occurs
- An overflow of the frame counter

Besides the hardware generated interrupts, software initiated interrupts can be generated using the Module Interrupt Trigger Register MITR. Writing a 1 to bit n of bit field MITR.IT generates an interrupt request signal on the corresponding interrupt output line INT_On. When writing MITR.IT more than one bit can be set resulting in activation of multiple INT_On interrupt output lines at the same time. See also [“Interrupt Control” on Page 20-123](#) for further processing of the CAN node interrupts.

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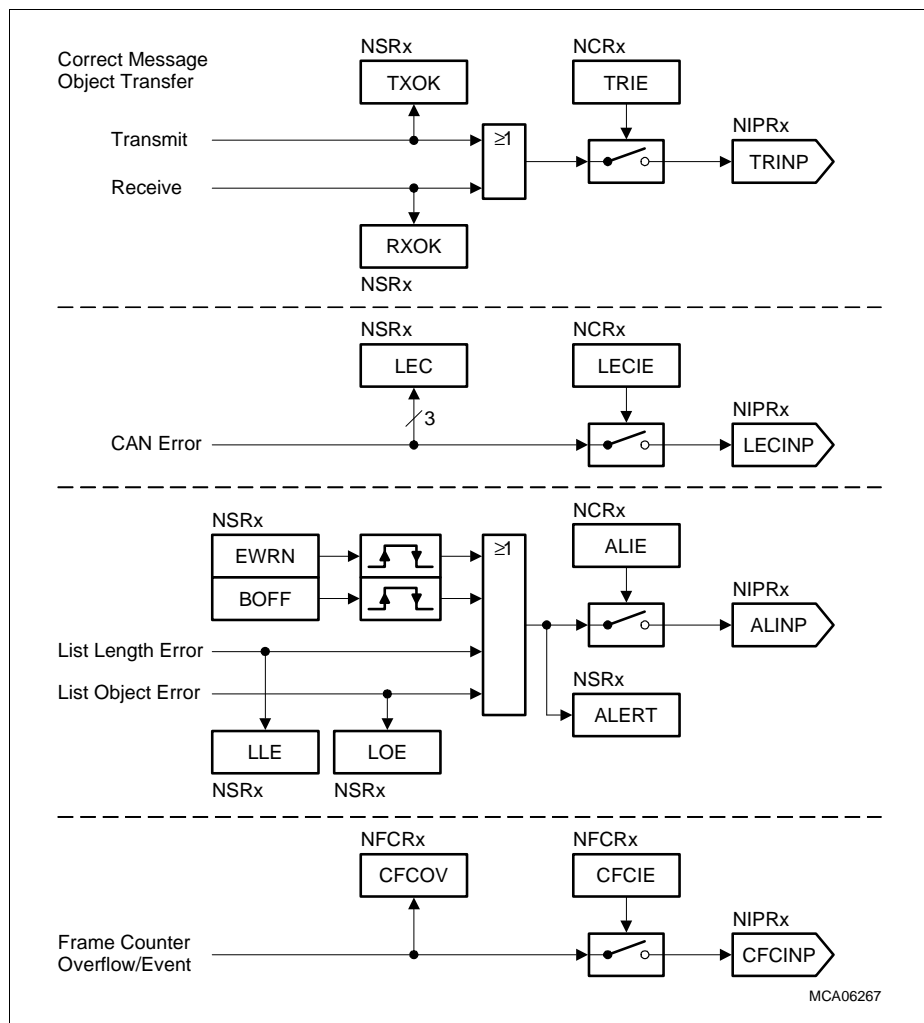


Figure 20-10 CAN Node Interrupts

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20.3.6 Message Object List Structure

This section describes the structure of the message object lists in the MultiCAN module.

20.3.6.1 Basics

The message objects of the MultiCAN module are organized in double-chained lists, where each message object has a pointer to the previous message object in the list as well as a pointer to the next message object in the list. The MultiCAN module provides eight lists. Each message object is allocated to one of these lists. In the example in [Figure 20-11](#), the three message objects (3, 5, and 16) are allocated to the list with index 2 (List Register LIST2).

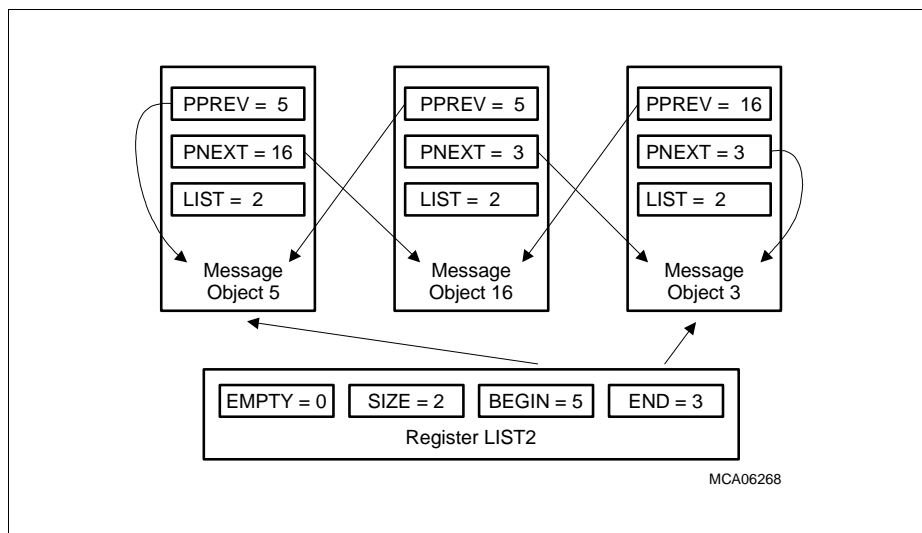


Figure 20-11 Example Allocation of Message Objects to a List

Bit field BEGIN in the List Register (for definition, see [Page 20-69](#)) points to the first element in the list (object 5 in the example), and bit field END points to the last element in the list (object 3 in the example). The number of elements in the list is indicated by bit field SIZE of the List Register (SIZE = number of list elements - 1, thus SIZE = 2 for the 3 elements in the example). The EMPTY bit of the List Register indicates whether or not a list is empty (EMPTY = 0 in the example, because list 2 is not empty).

Each message object n has a pointer PNEXT in its Message Object n Control Register MOCTR n (see [Page 20-92](#)) that points to the next message object in the list, and a pointer PPREV that points to the previous message object in the list. PPREV of the first message object points to the message object itself because the first message object has no predecessor (in the example message object 5 is the first message object in the list,

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indicated by $PPREV = 5$). $PNEXT$ of the last message object also points to the message object itself because the last message object has no successor (in the example, object 3 is the last message object in the list, indicated by $PNEXT = 3$).

Bit field $MOCTRn.LIST$ indicates the list index number to which the message object is currently allocated. The message object of the example are allocated to list 2. Therefore, all $LIST$ bit fields for the message objects assigned to list 2 are set to $LIST = 2$.

20.3.6.2 List of Unallocated Elements

The list with list index 0 has a special meaning: it is the list of all unallocated elements. An element is called unallocated if it belongs to list 0 ($MOCTRn.LIST = 0$). It is called allocated if it belongs to a list with an index not equal to 0 ($MOCTRn.LIST > 0$).

After reset, all message objects are unallocated. This means that they are assigned to the list of unallocated elements with $MOCTRn.LIST = 0$. After this initial allocation of the message objects caused by reset, the list of all unallocated message objects is ordered by message number (predecessor of message object n is object $n-1$, successor of object n is object $n+1$).

20.3.6.3 Connection to the CAN Nodes

Each CAN node is linked to one unique list of message objects. A CAN node performs message transfer only with the message objects that are allocated to the list of the CAN node. This is illustrated in [Figure 20-12](#). Frames that are received on a CAN node may only be stored in one of the message objects that belongs to the CAN node; frames to be transmitted on a CAN node are selected only from the message objects that are allocated to that node, as indicated by the vertical arrows.

There are more lists (eight) than CAN nodes (two). This means that some lists are not linked to one of the CAN nodes. A message object that is allocated to one of these unlinked lists cannot receive messages directly from a CAN node and it may not transmit messages.

FIFO and gateway mechanisms refer to message numbers and not directly to a specific list. The user must take care that the message objects targeted by FIFO/gateway belong to the desired list. The mechanisms make it possible to work with lists that do not belong to the CAN node.

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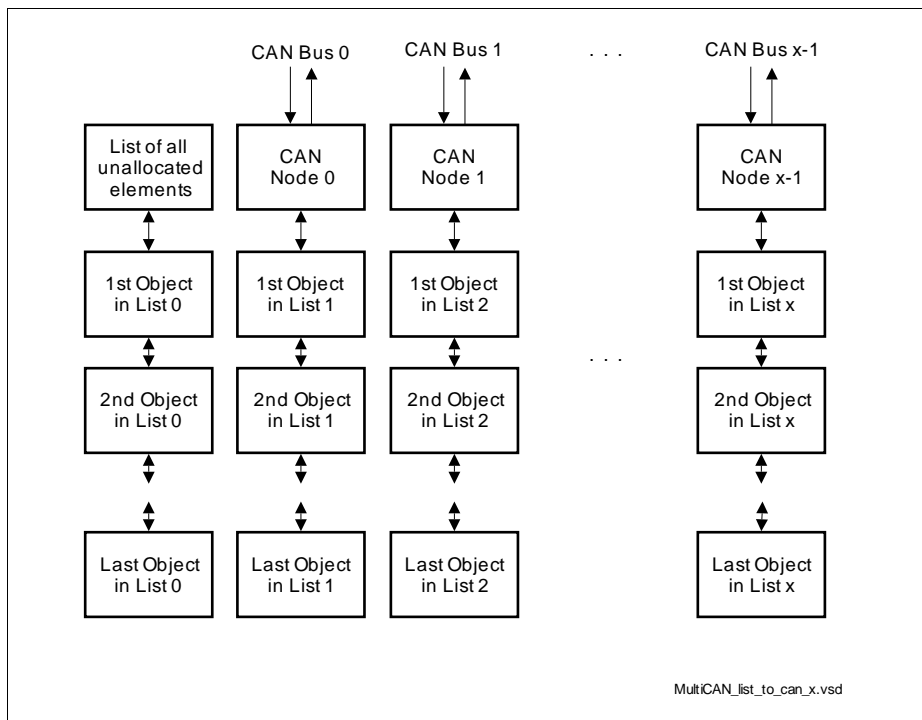


Figure 20-12 Message Objects Linked to CAN Nodes

20.3.6.4 List Command Panel

The list structure cannot be modified directly by write accesses to the LIST registers and the PPREV, PNEXT and LIST bit fields in the Message Object Control Registers, as they are read only. The list structure is managed by and limited to the list controller inside the MultiCAN module. The list controller is controlled via a command panel allowing the user to issue list allocation commands to the list controller. The list controller has two main purposes:

1. Ensure that all operations that modify the list structure result in a consistent list structure.
2. Present maximum ease of use and flexibility to the user.

The list controller and the associated command panel allows the programmer to concentrate on the final properties of the list, which are characterized by the allocation of message objects to a CAN node, and the ordering relation between objects that are allocated to the same list. The process of list (re-)building is done in the list controller.

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Table 20-4 gives an overview on the available panel commands while **Table 20-8** on **Page 20-63** describes the panel commands in more detail.

Table 20-4 Panel Commands Overview

Command Name	Description
No Operation	No new command is started.
Initialize Lists	Run the initialization sequence to reset the CTRL and LIST field of all message objects.
Static Allocate	Allocate message object to a list.
Dynamic Allocate	Allocate the first message object of the list of unallocated objects to the selected list.
Static Insert Before	Remove a message object (source object) from the list that it currently belongs to, and insert it before a given destination object into the list structure of the destination object.
Dynamic Insert Before	Insert a new message object before a given destination object.
Static Insert Behind	Remove a message object (source object) from the list that it currently belongs to, and insert it behind a given destination object into the list structure of the destination object.
Dynamic Insert Behind	Insert a new message object behind a given destination object.

A panel command is started by writing the respective command code into the Panel Control Register bit field PANCTR.PANCMD (see **Page 20-62**). The corresponding command arguments must be written into bit fields PANCTR.PANAR1 and PANCTR.PANAR2 before writing the command code, or latest along with the command code in a single 32-bit write access to the Panel Control Register.

With the write operation of a valid command code, the PANCTR.BUSY flag is set and further write accesses to the Panel Control Register are ignored. The BUSY flag remains active and the control panel remains locked until the execution of the requested command has been completed. After a reset, the list controller builds up list 0. During this operation, BUSY is set and other accesses to the CAN RAM are forbidden. The CAN RAM can be accessed again when BUSY becomes inactive.

Note: The CAN RAM is automatically initialized after reset by the list controller in order to ensure correct list pointers in each message object. The end of this CAN RAM initialization is indicated by bit PANCTR.BUSY becoming inactive.

In case of a dynamic allocation command that takes an element from the list of unallocated objects, the PANCTR.RBUSY bit is also set along with the BUSY bit

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(RBUSY = BUSY = 1). This indicates that bit fields PANAR1 and PANAR2 are going to be updated by the list controller in the following way:

1. The message number of the message object taken from the list of unallocated elements is written to PANAR1.
2. If ERR (bit 7 of PANAR2) is set to 1, the list of unallocated elements was empty and the command is aborted. If ERR is 0, the list was not empty and the command will be performed successfully.

The results of a dynamic allocation command are written before the list controller starts the actual allocation process. As soon as the results are available, RBUSY becomes inactive (RBUSY = 0) again, while BUSY still remains active until completion of the command. This allows the user to set up the new message object while it is still in the process of list allocation. The access to message objects is not limited during ongoing list operations. However, any access to a register resource located inside the RAM delays the ongoing allocation process by one access cycle.

As soon as the command is finished, the BUSY flag becomes inactive (BUSY = 0) and write accesses to the Panel Control Register are enabled again. Also, the "No Operation" command code is automatically written to the PANCTR.PANCMD field. A new command may be started any time when BUSY = 0.

All fields of the Panel Control Register PANCTR except BUSY and RBUSY may be written by the user. This makes it possible to save and restore the Panel Control Register if the Command Panel is used within independent (mutually interruptible) interrupt service routines. If this is the case, any task that uses the Command Panel and that may interrupt another task that also uses the Command Panel should poll the BUSY flag until it becomes inactive and save the whole PANCTR register to a memory location before issuing a command. At the end of the interrupt service routine, the task should restore PANCTR from the memory location.

Before a message object that is allocated to the list of an active CAN node shall be moved to another list or to another position within the same list, bit MOCTRn.MSGVAL ("Message Valid") of message object n must be cleared.

20.3.7 CAN Node Analysis Features

The chapter describes the CAN node analysis capabilities of the MultiCAN module.

20.3.7.1 Analyze Mode

The CAN Analyze Mode makes it possible to monitor the CAN traffic for each CAN node individually without affecting the logical state of the CAN bus. The CAN Analyze Mode for CAN node x is selected by setting Node x Control Register bit NCRx.CALM.

In CAN Analyze Mode, the transmit pin of a CAN node is held at a recessive level permanently. The CAN node may receive frames (Data, Remote, and Error Frames) but is not allowed to transmit. Received Data/Remote Frames are not acknowledged (i.e. acknowledge slot is sent recessive) but will be received and stored in matching message objects as long as there is any other node that acknowledges the frame. The complete message object functionality is available, but no transmit request will be executed.

20.3.7.2 Loop-Back Mode

The MultiCAN module provides a Loop-Back Mode to enable an in-system test of the MultiCAN module as well as the development of CAN driver software without access to an external CAN bus.

The loop-back feature consists of an internal CAN bus (inside the MultiCAN module) and a bus select switch for each CAN node (see [Figure 20-13](#)). With the switch, each CAN node can be connected either to the internal CAN bus (Loop-Back Mode activated) or the external CAN bus, respectively to transmit and receive pins (normal operation). The CAN bus that is not currently selected is driven recessive; this means the transmit pin is held at 1, and the receive pin is ignored by the CAN nodes that are in Loop-Back Mode.

The Loop-Back Mode is selected for CAN node x by setting the Node x Port Control Register bit NPCRx.LBM. All CAN nodes that are in Loop-Back Mode may communicate together via the internal CAN bus without affecting the normal operation of the other CAN nodes that are not in Loop-Back Mode.

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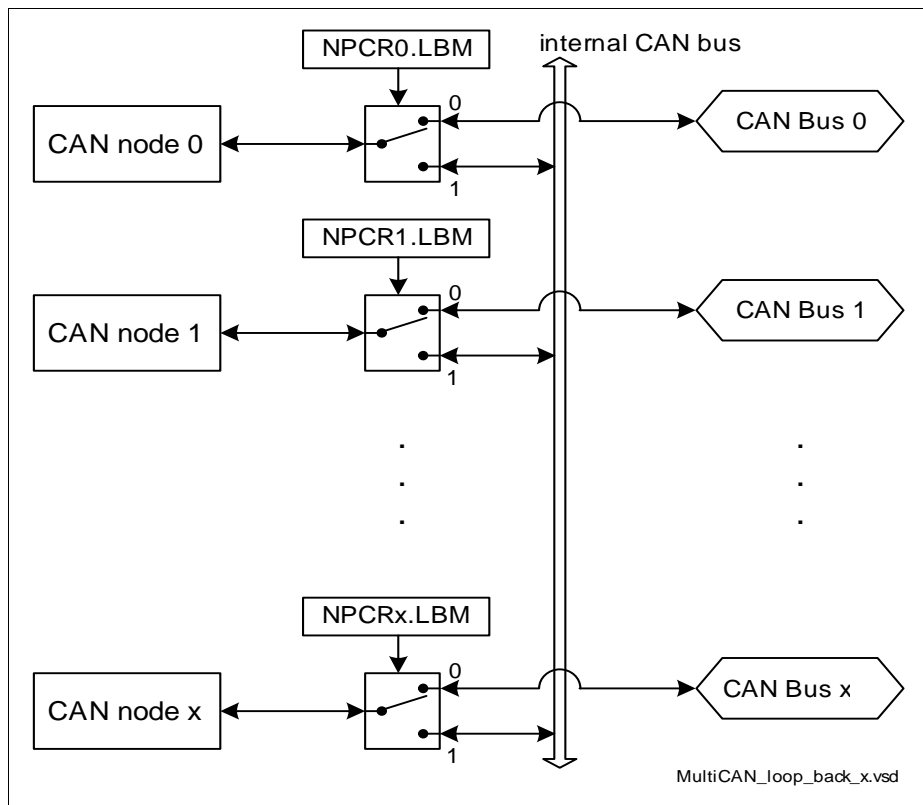


Figure 20-13 Loop-Back Mode

20.3.7.3 Bit Timing Analysis

Detailed analysis of the bit timing can be performed for each CAN node using the analysis modes of the CAN frame counter. The bit timing analysis functionality of the frame counter may be used for automatic detection of the CAN baud rate, as well as to analyze the timing of the CAN network.

Bit timing analysis for CAN node x is selected when bit field $\text{NFCRx.CFMODE} = 10_{\text{B}}$. Bit timing analysis does not affect the operation of the CAN node.

The bit timing measurement results are written into the NFCRx.CFC bit field. Whenever NFCRx.CFC is updated in bit timing analysis mode, bit NFCRx.CFCOV is also set to indicate the CFC update event. If NFCRx.CFCIE is set, an interrupt request can be generated (see [Figure 20-10](#)).

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Automatic Baud Rate Detection

For automatic baud rate detection, the time between the observation of subsequent dominant edges on the CAN bus must be measured. This measurement is automatically performed if bit field $\text{NFCRx.CFSEL} = 000_{\text{B}}$. With each dominant edge monitored on the CAN receive input line, the time (measured in f_{CAN} clock cycles) between this edge and the most recent dominant edge is stored in the NFCRx.CFC bit field.

Synchronization Analysis

The bit time synchronization is monitored if $\text{NFCRx.CFSEL} = 010_{\text{B}}$. The time between the first dominant edge and the sample point is measured and stored in the NFCRx.CFC bit field. The bit timing synchronization offset may be derived from this time as the first edge after the sample point triggers synchronization and there is only one synchronization between consecutive sample points.

Synchronization analysis can be used, for example, for fine tuning of the baud rate during reception of the first CAN frame with the measured baud rate.

Driver Delay Measurement

The delay between a transmitted edge and the corresponding received edge is measured when $\text{NFCRx.CFSEL} = 011_{\text{B}}$ (dominant to dominant) and $\text{NFCRx.CFSEL} = 100_{\text{B}}$ (recessive to recessive). These delays indicate the time needed to represent a new bit value on the physical implementation of the CAN bus.

20.3.8 Message Acceptance Filtering

The chapter describes the Message Acceptance Filtering capabilities of the MultiCAN module.

20.3.8.1 Receive Acceptance Filtering

When a CAN frame is received by a CAN node, a unique message object is determined in which the received frame is stored after successful frame reception. A message object is qualified for reception of a frame if the following six conditions are met.

- The message object is allocated to the message object list of the CAN node by which the frame is received.
- Bit MOSTATn.MSGVAL in the Message Status Register (see [Page 20-95](#)) is set.
- Bit MOSTATn.RXEN is set.
- Bit MOSTATn.DIR is equal to bit RTR of the received frame.
If bit MOSTATn.DIR = 1 (transmit object), the message object accepts only Remote Frames. If bit MOSTATn.DIR = 0 (receive object), the message object accepts only Data Frames.
- If bit MOAMRn.MIDE = 1, the IDE bit of the received frame becomes evaluated in the following way: If MOARn.IDE = 1, the IDE bit of the received frame must be set (indicates extended identifier). If MOARn.IDE = 0, the IDE bit of the received frame must be cleared (indicates standard identifier).
If bit MOAMRn.MIDE = 0, the IDE bit of the received frame is “don't care”. In this case, message objects with standard and extended frames are accepted.
- The identifier of the received frame matches the identifier stored in the Arbitration Register of the message object as qualified by the acceptance mask in the MOAMRn register. This means that each bit of the received message object identifier is equal to the bit field MOARn.ID, except those bits for which the corresponding acceptance mask bits in bit field MOAMRn.AM are cleared. These identifier bits are “don't care” for reception. [Figure 20-14](#) illustrates this receive message identifier check.

Among all messages that fulfill all six qualifying criteria the message object with the highest receive priority wins receive acceptance filtering and becomes selected to store the received frame. All other message objects lose receive acceptance filtering.

The following priority scheme is defined for the message objects:

A message object a (MOa) has higher receive priority than a message object b (MOb) if the following two conditions are fulfilled (see [Page 20-109](#)):

1. MOa has a higher priority class than MOb. This means, the 2-bit priority bit field MOARa.PRI must be equal or less than bit field MOARb.PRI.
2. If both message objects have the same priority class (MOARa.PRI = MOARb.PRI), MOb is a list successor of MOa. This means that MOb can be reached by means of successively stepping forward in the list, starting from a.

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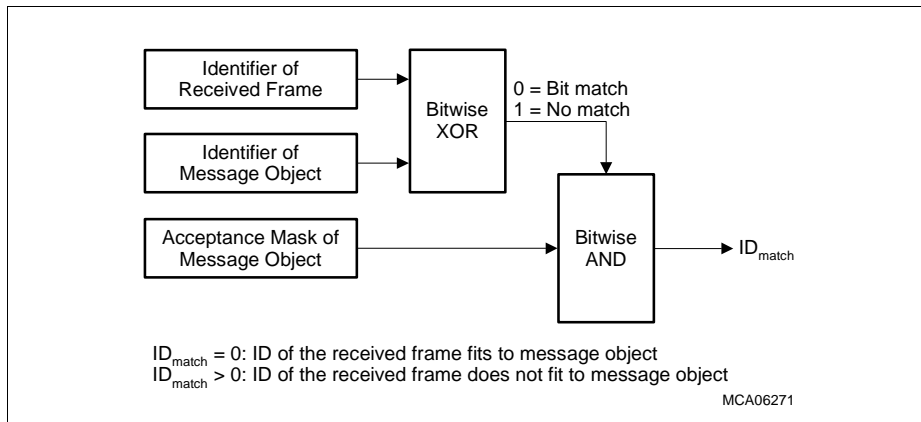


Figure 20-14 Received Message Identifier Acceptance Check

20.3.8.2 Transmit Acceptance Filtering

A message is requested for transmission by setting a transmit request in the message object that holds the message. If more than one message object have a valid transmit request for the same CAN node, one of these message objects is chosen for transmission, because only a single message object can be transmitted at one time on a CAN bus.

A message object is qualified for transmission on a CAN node if the following four conditions are met (see also [Figure 20-15](#)).

1. The message object is allocated to the message object list of the CAN node.
2. Bit MOSTATn.MSGVAL is set.
3. Bit MOSTATn.TXRQ is set.
4. Bit MOSTATn.TXEN0 and MOSTATn.TXEN1 are set.

A priority scheme determines which one of all qualifying message objects is transmitted first. It is assumed that message object a (MOa) and message object b (MOb) are two message objects qualified for transmission. MOb is a list successor of MOa. For both message objects, CAN messages CANa and CANb are defined (identifier, IDE, and RTR are taken from the message-specific bit fields and bits MOARn.ID, MOARn.IDE and MOCTRn.DIR).

If both message objects belong to the same priority class (identical PRI bit field in register MOARn), MOa has a higher transmit priority than MOb if one of the following conditions is fulfilled.

- PRI = 10_B and CAN message MOa has higher or equal priority than CAN message MOb with respect to CAN arbitration rules (see [Table 20-14](#) on [Page 20-110](#)).
- PRI = 01_B or PRI = 11_B (priority by list order).

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The message object that is qualified for transmission and has highest transmit priority wins the transmit acceptance filtering, and will be transmitted first. All other message objects lose the current transmit acceptance filtering round. They get a new chance in subsequent acceptance filtering rounds.

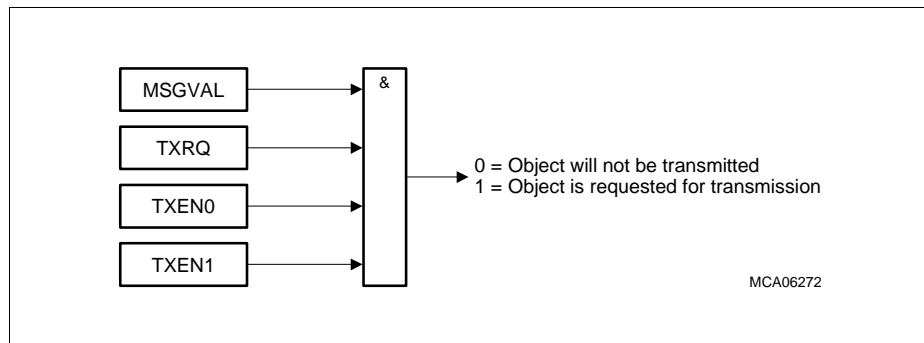


Figure 20-15 Effective Transmit Request of Message Object

20.3.9 Message Postprocessing

After a message object has successfully received or transmitted a frame, the CPU can be notified to perform a postprocessing on the message object. The postprocessing of the MultiCAN module consists of two elements:

1. Message interrupts to trigger postprocessing.
2. Message pending registers to collect pending message interrupts into a common structure for postprocessing.

20.3.9.1 Message Object Interrupts

When the storage of a received frame into a message object or the successful transmission of a frame is completed, a message interrupt can be issued. For each message object, a transmit and a receive interrupt can be generated and routed to one of the sixteen CAN interrupt output lines (see [Figure 20-16](#)). A receive interrupt occurs also after a frame storage event that has been induced by a FIFO or a gateway action. The status bits TXPND and RXPND in the Message Object n Status Register are always set after a successful transmission/reception, whether or not the respective message interrupt is enabled.

A third FIFO full interrupt condition of a message object is provided. If bit field MOFCRn.OVIE (Overflow Interrupt Enable) is set, the FIFO full interrupt will be activated depending on the actual message object type.

In case of a Receive FIFO Base Object (MOFCRn.MMC = 0001_B), the FIFO full interrupt is routed to the interrupt output line INT_Om as defined by the transmit interrupt node pointer MOIPRn.TXINP.

In case of a Transmit FIFO Base Object (MOFCRn.MMC = 0010_B), the FIFO full interrupt becomes routed to the interrupt output line INT_Om as defined by the receive interrupt node pointer MOIPRn.RXINP.

See also [“Interrupt Control” on Page 20-123](#) for further processing of the message object interrupts.

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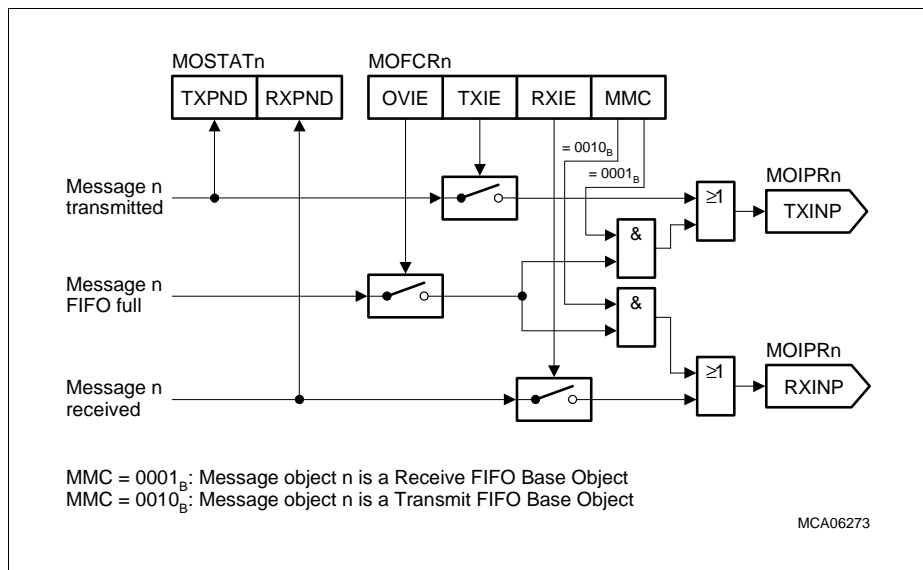


Figure 20-16 Message Interrupt Request Routing

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The location of a pending bit is defined by two demultiplexers selecting the number k of the MSPND k registers (3-bit demux), and the bit location within the corresponding MSPND k register (5-bit demux).

Allocation Case 1

In this allocation case, bit field MCR.MPSEL = 0000_B (see [Page 20-66](#)). The location selection consists of 2 parts:

- The upper three bits of MOIPR n .MPN (MPN[7:5]) select the number k of a Message Pending Register MSPND k in which the pending bit will be set.
- The lower five bits of MOIPR n .MPN (MPN[4:0]) select the bit position (0-31) in MSPND k for the pending bit to be set.

Allocation Case 2

In this allocation case, bit field MCR.MPSEL is taken into account for pending bit allocation. Bit field MCR.MPSEL makes it possible to include the interrupt request node pointer for reception (MOIPR n .RXINP) or transmission (MOIPR n .TXINP) for pending bit allocation in such a way that different target locations for the pending bits are used in receive and transmit case. If MPSEL = 1111_B, the location selection operates in the following way:

- At a transmit event, the upper 3 bits of TXINP determine the number k of a Message Pending Register MSPND k in which the pending bit will be set. At a receive event, the upper 3 bits of RXINP determine the number k .
- The bit position (0-31) in MSPND k for the pending bit to be set is selected by the lowest bit of TXINP or RXINP (selects between low and high half-word of MSPND k) and the four least significant bits of MPN.

General Hints

The Message Pending Registers MSPND k can be written by software. Bits that are written with 1 are left unchanged, and bits which are written with 0 are cleared. This makes it possible to clear individual MSPND k bits with a single register write access. Therefore, access conflicts are avoided when the MultiCAN module (hardware) sets another pending bit at the same time when software writes to the register.

Each Message Pending Register MSPND k is associated with a Message Index Register MSID k (see [Page 20-72](#)) which indicates the lowest bit position of all set (1) bits in Message Pending Register k . The MSID k register is a read-only register that is updated immediately when a value in the corresponding Message Pending Register k is changed by software or hardware.

20.3.10 Message Object Data Handling

This chapter describes the handling capabilities for the Message Object Data of the MultiCAN module.

20.3.10.1 Frame Reception

After the reception of a message, it is stored in a message object according to the scheme shown in [Figure 20-18](#). The MultiCAN module not only copies the received data into the message object, and it provides advanced features to enable consistent data exchange between MultiCAN and CPU.

MSGVAL

Bit MSGVAL (Message Valid) in the Message Object n Status Register MOSTATn is the main switch of the message object. During the frame reception, information is stored in the message object only when MSGVAL = 1. If bit MSGVAL is reset by the CPU, the MultiCAN module stops all ongoing write accesses to the message object. Now the message object can be re-configured by the CPU with subsequent write accesses to it without being disturbed by the MultiCAN.

RTSEL

When the CPU re-configures a message object during CAN operation (for example, clears MSGVAL, modifies the message object and sets MSGVAL again), the following scenario can occur:

1. The message object wins receive acceptance filtering.
2. The CPU clears MSGVAL to re-configure the message object.
3. The CPU sets MSGVAL again after re-configuration.
4. The end of the received frame is reached. As MSGVAL is set, the received data is stored in the message object, a message interrupt request is generated, gateway and FIFO actions are processed, etc.

After the re-configuration of the message object (after step 3 above) the storage of further received data may be undesirable. This can be achieved through bit MOCTRn.RTSEL (Receive/Transmit Selected) that makes it possible to disconnect a message object from an ongoing frame reception.

When a message object wins the receive acceptance filtering, its RTSEL bit is set by the MultiCAN module to indicate an upcoming frame delivery. The MultiCAN module checks RTSEL whether it is set on successful frame reception to verify that the object is still ready for receiving the frame. The received frame is then stored in the message object (along with all subsequent actions such as message interrupts, FIFO & gateway actions, flag updates) only if RTSEL = 1.

When a message object is invalidated during CAN operation (resetting bit MSGVAL), RTSEL should be cleared before setting MSGVAL again (latest with the same write

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access that sets MSGVAL) to prevent the storage of a frame that belongs to the old context of the message object. Therefore, a message object re-configuration should consist of the following steps:

1. Clear MSGVAL bit
2. Re-configure the message object while MSGVAL = 0
3. Clear RTSEL bit and set MSGVAL again

RXEN

Bit MOSTATn.RXEN enables a message object for frame reception. A message object can receive CAN messages from the CAN bus only if RXEN = 1. The MultiCAN module evaluates RXEN only during receive acceptance filtering. After receive acceptance filtering, RXEN is ignored and has no further influence on the actual storage of a received message in a message object.

Bit RXEN enables the “soft phase out” of a message object: after clearing RXEN, a currently received CAN message for which the message object has won acceptance filtering is still stored in the message object but for subsequent messages the message object no longer wins receive acceptance filtering.

RXUPD, NEWDAT and MSGLST

An ongoing frame storage process is indicated by the RXUPD (Receive Updating) flag in the MOSTATn register. RXUPD is set with the start and cleared with the end of a message object update, which consists of frame storage as well as flag updates.

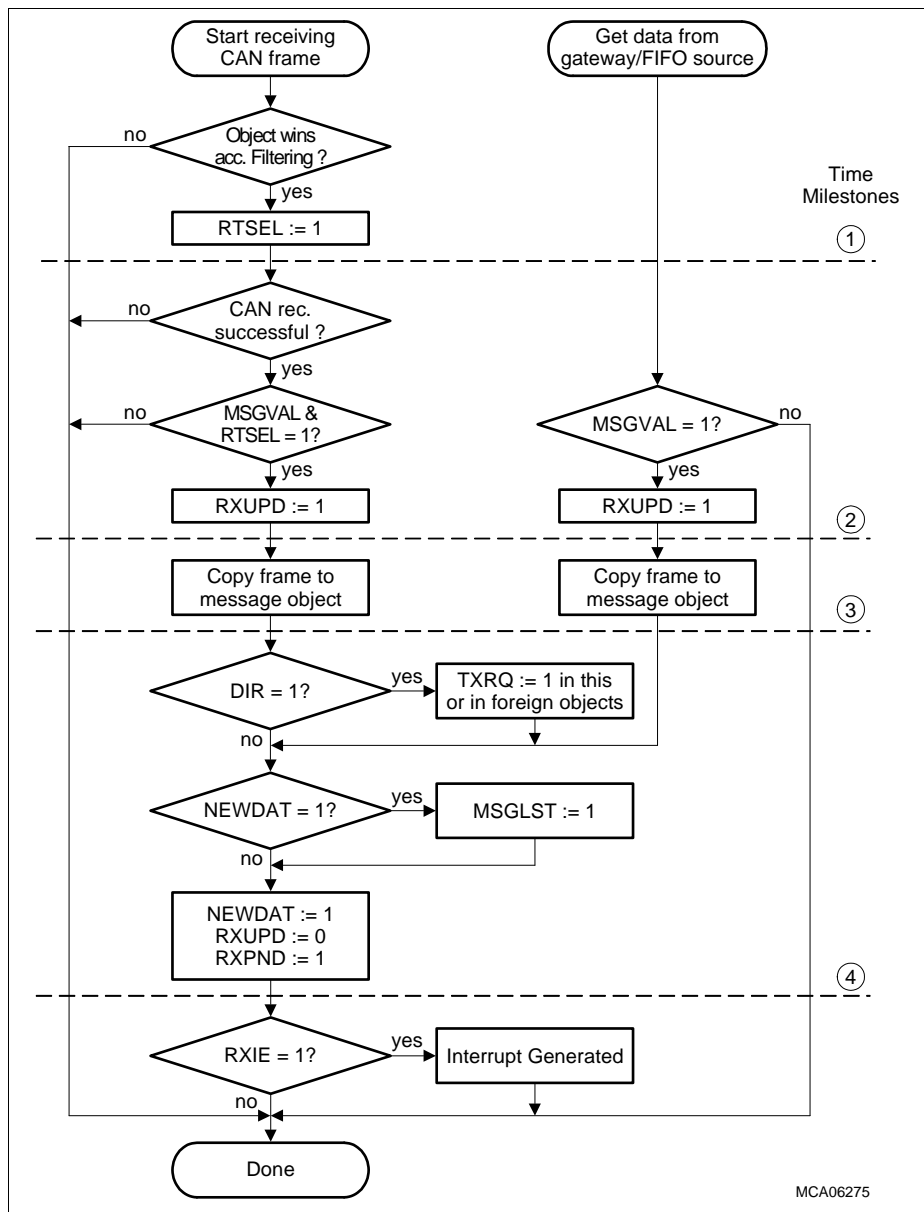
After storing the received frame (identifier, IDE bit, DLC; including the Data Field for Data Frames), the NEWDAT (New Data) bit of the message object is set. If NEWDAT was already set before it becomes set again, bit MSGLST (Message Lost) is set to indicate a data loss condition.

The RXUPD and NEWDAT flags can help to read consistent frame data from the message object during an ongoing CAN operation. The following steps are recommended to be executed:

1. Clear NEWDAT bit.
2. Read message content (identifier, data etc.) from the message object.
3. Check that both, NEWDAT and RXUPD, are cleared. If this is not the case, go back to step 1.
4. When step 3 was successful, the message object contents are consistent and has not been updated by the MultiCAN module while reading.

Bits RXUPD, NEWDAT and MSGLST have the same behavior for the reception of Data as well as Remote Frames.

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MCA06275

Figure 20-18 Reception of a Message Object

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20.3.10.2 Frame Transmission

The process of a message object transmission is shown in [Figure 20-19](#). Along with the copy of the message object content to be transmitted (identifier, IDE bit, RTR = DIR bit, DLC, including the Data Field for Data Frames) into the internal transmit buffer of the assigned CAN node, several status flags are also served and monitored to control consistent data handling.

The transmission process of a message object starting after the transmit acceptance filtering is identical for Remote and Data Frames.

MSGVAL, TXRQ, TXEN0, TXEN1

A message can only be transmitted if all four bits in registers MOSTATn, MSGVAL (Message Valid), TXRQ (Transmit Request), TXEN0 (Transmit Enable 0), TXEN1 (Transmit Enable 1) are set as shown in [Figure 20-15](#). Although these bits are equivalent with respect to the transmission process, they have different semantics:

Table 20-5 Message Transmission Bit Definitions

Bit	Description
MSGVAL	Message Valid This is the main switch bit of the message object.
TXRQ	Transmit Request This is the standard transmit request bit. This bit must be set whenever a message object should be transmitted. TXRQ is cleared by hardware at the end of a successful transmission, except when there is new data (indicated by NEWDAT = 1) to be transmitted. When bit MOFCRn.STT ("Single Transmit Trial") is set, TXRQ becomes already cleared when the contents of the message object are copied into the transmit frame buffer of the CAN node. A received remote request (after a Remote Frame reception) sets bit TXRQ to request the transmission of the requested data frame.
TXEN0	Transmit Enable 0 This bit can be temporarily cleared by software to suppress the transmission of this message object when it writes new content to the Data Field. This avoids transmission of inconsistent frames that consist of a mixture of old and new data. Remote requests are still accepted when TXEN0 = 0, but transmission of the Data Frame is suspended until transmission is re-enabled by software (setting TXEN0).

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Table 20-5 Message Transmission Bit Definitions (cont'd)

Bit	Description
TXEN1	Transmit Enable 1 This bit is used in transmit FIFOs to select the message object that is transmit active within the FIFO structure. For message objects that are not transmit FIFO elements, TXEN1 can either be set permanently to 1 or can be used as a second independent transmission enable bit.

RTSEL

When a message object has been identified to be transmitted next after transmission acceptance filtering, bit MOCTRn.RTSEL (Receive/Transmit Selected) is set.

When the message object is copied into the internal transmit buffer, bit RTSEL is checked, and the message is transmitted only if RTSEL = 1. After the successful transmission of the message, bit RTSEL is checked again and the message postprocessing is only executed if RTSEL = 1.

For a complete re-configuration of a valid message object, the following steps should be executed:

1. Clear MSGVAL bit
2. Re-configure the message object while MSGVAL = 0
3. Clear RTSEL and set MSGVAL

Clearing of RTSEL ensures that the message object is disconnected from an ongoing/scheduled transmission and no message object processing (copying message to transmit buffer including clearing NEWDAT, clearing TXRQ, time stamp update, message interrupt, etc.) within the old context of the object can occur after the message object becomes valid again, but within a new context.

NEWDAT

When the contents of a message object have been transferred to the internal transmit buffer of the CAN node, bit MOSTATn.NEWDAT (New Data) is cleared by hardware to indicate that the transmit message object data is no longer new.

When the transmission of the frame is successful and NEWDAT is still cleared (if no new data has been copied into the message object meanwhile), TXRQ (Transmit Request) is cleared automatically by hardware.

If, however, the NEWDAT bit has been set again by the software (because a new frame should be transmitted), TXRQ is not cleared to enable the transmission of the new data.

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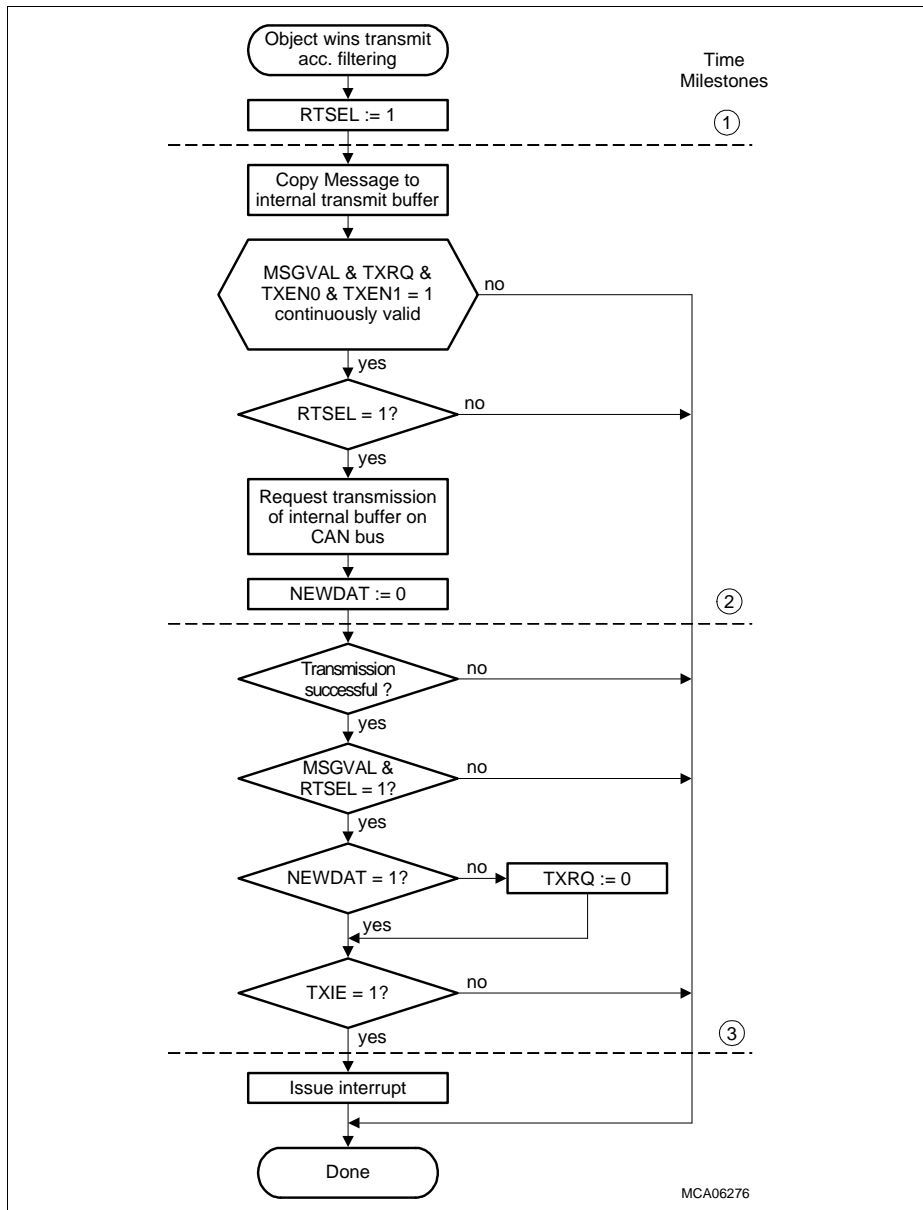


Figure 20-19 Transmission of a Message Object

20.3.11 Message Object Functionality

This chapter describes the functionality of the Message Objects in the MultiCAN module.

20.3.11.1 Standard Message Object

A message object is selected as standard message object when bit field MOFCRn.MMC = 0000_B (see [Page 20-88](#)). The standard message object can transmit and receive CAN frames according to the basic rules described in the previous sections. Additional services such as Single Data Transfer Mode or Single Transmit Trial (see following sections) are available and can be individually selected.

20.3.11.2 Single Data Transfer Mode

Single Data Transfer Mode is a useful feature in order to broadcast data over the CAN bus without unintended duplication of information. Single Data Transfer Mode is selected via bit MOFCRn.SDT.

Message Reception

When a received message stored in a message object is overwritten by a new received message, the contents of the first message are lost and replaced with the contents of the new received message (indicated by MSGLST = 1).

If SDT is set (Single Data Transfer Mode activated), bit MSGVAL of the message object is automatically cleared by hardware after the storage of a received Data Frame. This prevents the reception of further messages.

After the reception of a Remote Frame, bit MSGVAL is not automatically cleared.

Message Transmission

When a message object receives a series of multiple remote requests, it transmits several Data Frames in response to the remote requests. If the data within the message object has not been updated in the time between the transmissions, the same data can be sent more than once on the CAN bus.

In Single Data Transfer Mode (SDT = 1), this is avoided because MSGVAL is automatically cleared after the successful transmission of a Data Frame.

After the transmission of a Remote Frame, bit MSGVAL is not automatically cleared.

20.3.11.3 Single Transmit Trial

If the bit STT in the message object function register is set (STT = 1), the transmission request is cleared (TXRQ = 0) when the frame contents of the message object have been copied to the internal transmit buffer of the CAN node. Thus, the transmission of the message object is not tried again when it fails due to CAN bus errors.

20.3.11.4 Message Object FIFO Structure

In case of high CPU load it may be difficult to process a series of CAN frames in time. This may happen if multiple messages are received or must be transmitted in short time. Therefore, a FIFO buffer structure is available to avoid loss of incoming messages and to minimize the setup time for outgoing messages. The FIFO structure can also be used to automate the reception or transmission of a series of CAN messages and to generate a single message interrupt when the whole CAN frame series is done.

There can be several FIFOs in parallel. The number of FIFOs and their size are limited only by the number of available message objects. A FIFO can be installed, resized and de-installed at any time, even during CAN operation.

The basic structure of a FIFO is shown in [Figure 20-20](#). A FIFO consists of one base object and n slave objects. The slave objects are chained together in a list structure (similar as in message object lists). The base object may be allocated to any list. Although [Figure 20-20](#) shows the base object as a separate part beside the slave objects, it is also possible to integrate the base object at any place into the chain of slave objects. This means that the base object is slave object, too (not possible for gateways). The absolute object numbers of the message objects have no impact on the operation of the FIFO.

The base object does not need to be allocated to the same list as the slave objects. Only the slave object must be allocated to a common list (as they are chained together). Several pointers (BOT, CUR and TOP) that are located in the Message Object n FIFO/Gateway Pointer Register MOFGPR n link the base object to the slave objects, regardless whether the base object is allocated to the same or to another **list** than the slave objects.

The smallest FIFO would be a single message object which is both, FIFO base and FIFO slave (not very useful). The biggest possible FIFO structure would include all message objects of the MultiCAN module. Any FIFO sizes between these limits are possible.

In the FIFO base object, the FIFO boundaries are defined. Bit field MOFGPR n .BOT of the base object points to (includes the number of) the bottom slave object in the FIFO structure. The MOFGPR n .TOP bit field points to (includes the number of) the top slave object in the FIFO structure. The MOFGPR n .CUR bit field points to (includes the number of) the slave object that is actually selected by the MultiCAN module for message transfer. When a message transfer takes place with this object, CUR is set to the next message object in the list structure of the slave objects (CUR = PNEXT of current object). If CUR was equal to TOP (top of the FIFO reached), the next update of CUR will result in CUR = BOT (wrap-around from the top to the bottom of the FIFO). This scheme represents a circular FIFO structure where the bit fields BOT and TOP establish the link from the last to the first element.

Bit field MOFGPR n .SEL of the base object can be used for monitoring purposes. It makes it possible to define a slave object within the list at which a message interrupt is

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generated whenever the CUR pointer reaches the value of the SEL pointer. Thus SEL makes it possible to detect the end of a predefined message transfer series or to issue a warning interrupt when the FIFO becomes full.

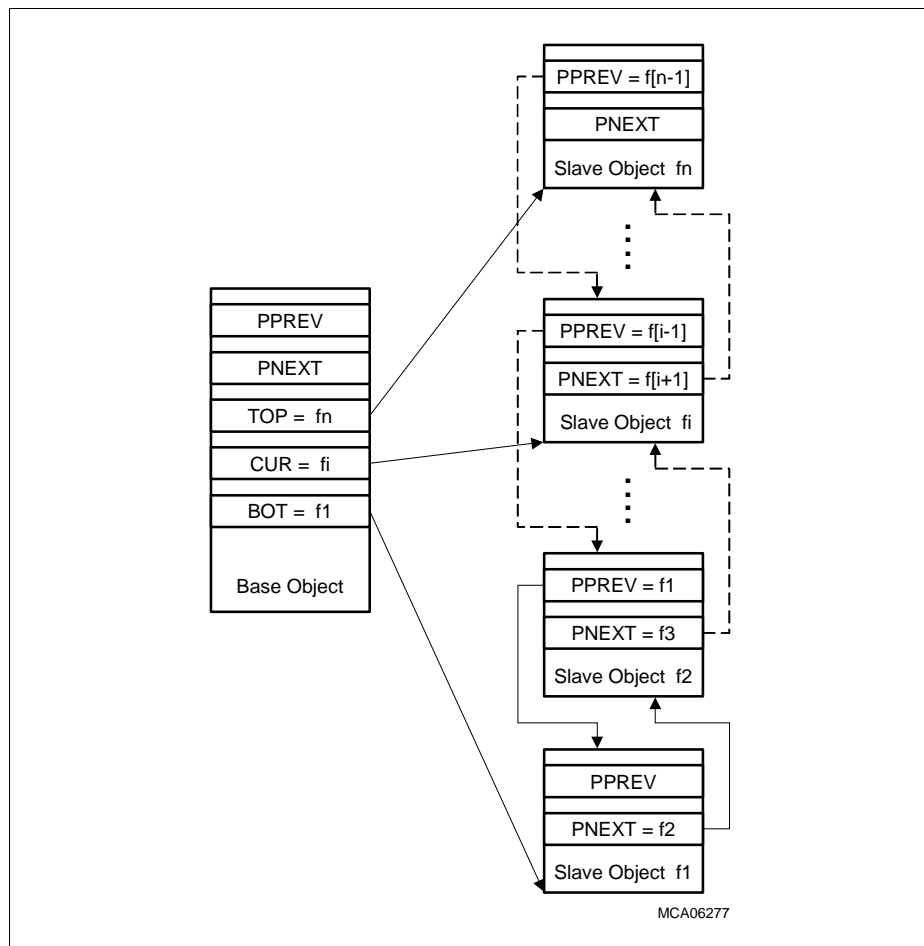


Figure 20-20 FIFO Structure with FIFO Base Object and n FIFO Slave Objects

20.3.11.5 Receive FIFO

The Receive FIFO structure is used to buffer incoming (received) Remote or Data Frames.

A Receive FIFO is selected by setting MOFCRn.MMC = 0001_B in the FIFO base object. This MMC code automatically designates a message object as FIFO base object. The message modes of the FIFO slave objects are not relevant for the operation of the Receive FIFO.

When the FIFO base object receives a frame from the CAN node it belongs to, the frame is not stored in the base object itself but in the message object that is selected by the base object's MOFGPRn.CUR pointer. This message object receives the CAN message as if it is the direct receiver of the message. However, MOFCRn.MMC = 0000_B is implicitly assumed for the FIFO slave object, and a standard message delivery is performed. The actual message mode (MMC setting) of the FIFO slave object is ignored. For the slave object, no acceptance filtering takes place that checks the received frame for a match with the identifier, IDE bit, and DIR bit.

With the reception of a CAN frame, the current pointer CUR of the base object is set to the number of the next message object in the FIFO structure. This message object will then be used to store the next incoming message.

If bit field MOFCRn.OVIE ("Overflow Interrupt Enable") of the FIFO base object is set and the current pointer MOFGPRn.CUR becomes equal to MOFGPRn.SEL, a FIFO overflow interrupt request is generated. This interrupt request is generated on interrupt node TXINP of the base object immediately after the storage of the received frame in the slave object. Transmit interrupts are still generated if TXIE is set.

A CAN message is stored in FIFO base and slave object only if MSGVAL = 1.

In order to avoid direct reception of a message by a slave message object, as if it was an independent message object and not a part of a FIFO, the bit RXEN of each slave object must be cleared. The setting of the bit RXEN is "don't care" only if the slave object is located in a list not assigned to a CAN node.

20.3.11.6 Transmit FIFO

The Transmit FIFO structure is used to buffer a series of Data or Remote Frames that must be transmitted. A transmit FIFO consists of one base message object and one or more slave message objects.

A Transmit FIFO is selected by setting $\text{MOFCRn.MMC} = 0010_{\text{B}}$ in the FIFO base object. Unlike the Receive FIFO, slave objects assigned to the Transmit FIFO must explicitly set their bit fields $\text{MOFCRn.MMC} = 0011_{\text{B}}$. The CUR pointer in all slave objects must point back to the Transmit FIFO Base Object (to be initialized by software).

The MOSTATn.TXEN1 bits (Transmit Enable 1) of all message objects except the one which is selected by the CUR pointer of the base object must be cleared by software. TXEN1 of the message (slave) object selected by CUR must be set. CUR (of the base object) may be initialized to any FIFO slave object.

When tagging the message objects of the FIFO as valid to start the operation of the FIFO, then the base object must be tagged valid ($\text{MSGVAL} = 1$) first.

Before a Transmit FIFO becomes de-installed during operation, its slave objects must be tagged invalid ($\text{MSGVAL} = 0$).

The Transmit FIFO uses the TXEN1 bit in the Message Object Control Register of all FIFO elements to select the actual message for transmission. Transmit acceptance filtering evaluates TXEN1 for each message object and a message object can win transmit acceptance filtering only if its TXEN1 bit is set. When a FIFO object has transmitted a message, the hardware clears its TXEN1 bit in addition to standard transmit postprocessing (clear TXRQ, transmit interrupt etc.), and moves the CUR pointer in the next FIFO base object to be transmitted. TXEN1 is set automatically (by hardware) in the next message object. Thus, TXEN1 moves along the Transmit FIFO structure as a token that selects the active element.

If bit field MOFCRn.OVIE ("Overflow Interrupt Enable") of the FIFO base object is set and the current pointer CUR becomes equal to MOFGPRn.SEL , a FIFO overflow interrupt request is generated. The interrupt request is generated on interrupt node RXINP of the base object after postprocessing of the received frame. Receive interrupts are still generated for the Transmit FIFO base object if bit RXIE is set.

20.3.11.7 Gateway Mode

The Gateway Mode makes it possible to establish an automatic information transfer between two independent CAN buses without CPU interaction.

The Gateway Mode operates on message object level. In Gateway mode, information is transferred between two message objects, resulting in an information transfer between the two CAN nodes to which the message objects are allocated. A gateway may be established with any pair of CAN nodes, and there can be as many gateways as there are message objects available to build the gateway structure.

Gateway Mode is selected by setting MOFCRs.MMC = 0100_B for the gateway source object *s*. The gateway destination object *d* is selected by the MOFGPRd.CUR pointer of the source object. The gateway destination object only needs to be valid (its MSGVAL = 1). All other settings are not relevant for the information transfer from the source object to the destination object.

Gateway source object behaves as a standard message object with the difference that some additional actions are performed by the MultiCAN module when a CAN frame has been received and stored in the source object (see [Figure 20-21](#)):

1. If bit MOFCRs.DLCC is set, the data length code MOFCRs.DLC is copied from the gateway source object to the gateway destination object.
2. If bit MOFCRs.IDC is set, the identifier MOARs.ID and the identifier extension MOARs.IDE are copied from the gateway source object to the gateway destination object.
3. If bit MOFCRs.DATC is set, the data bytes stored in the two data registers MODATALs and MODATAHs are copied from the gateway source object to the gateway destination object. All 8 data bytes are copied, even if MOFCRs.DLC indicates less than 8 data bytes.
4. If bit MOFCRs.GDFS is set, the transmit request flag MOSTATd.TXRQ is set in the gateway destination object.
5. The receive pending bit MOSTATd.RXPND and the new data bit MOSTATd.NEWDAT are set in the gateway destination object.
6. A message interrupt request is generated for the gateway destination object if its MOSTATd.RXIE is set.
7. The current object pointer MOFGPRs.CUR of the gateway source object is moved to the next destination object according to the FIFO rules as described on [Page 20-49](#).
A gateway with a single (static) destination object is obtained by setting MOFGPRs.TOP = MOFGPRs.BOT = MOFGPRs.CUR = destination object.

The link from the gateway source object to the gateway destination object works in the same way as the link from a FIFO base to a FIFO slave. This means that a gateway with an integrated destination FIFO may be created; in [Figure 20-20](#), the object on the left is the gateway source object and the message object on the right side is the gateway destination objects.

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The gateway operates equivalent for the reception of data frames (source object is receive object, i.e. DIR = 0) as well as for the reception of Remote Frames (source object is transmit object).

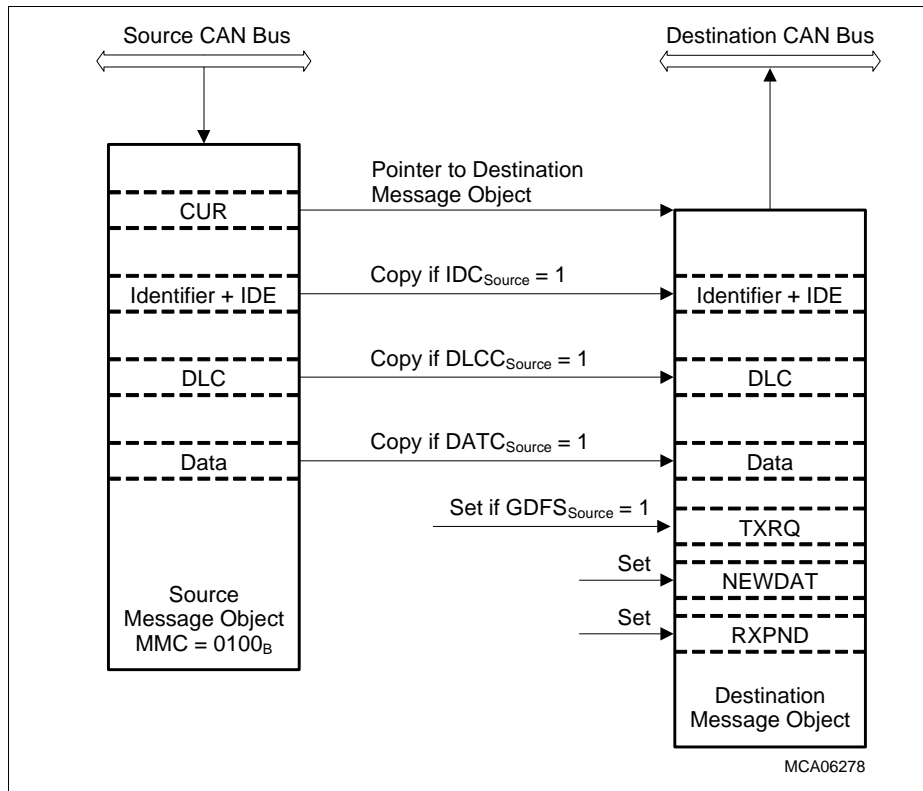


Figure 20-21 Gateway Transfer from Source to Destination

20.3.11.8 Foreign Remote Requests

When a Remote Frame has been received on a CAN node and is stored in a message object, a transmit request is set to trigger the answer (transmission of a Data Frame) to the request or to automatically issue a secondary request. If the Foreign Remote Request Enable bit MOFCRn.FRREN is cleared in the message object in which the remote request is stored, MOSTATn.TXRQ is set in the same message object.

If bit FRREN is set (FRREN = 1: foreign remote request enabled), TXRQ is set in the message object that is referenced by pointer MOFGPRn.CUR. The value of CUR is, however, not changed by this feature.

Although the foreign remote request feature works independently of the selected message mode, it is especially useful for gateways to issue a remote request on the source bus of a gateway after the reception of a remote request on the gateway destination bus. According to the setting of FRREN in the gateway destination object, there are two capabilities to handle remote requests that appear on the destination side (assuming that the source object is a receive object and the destination is a transmit object, i.e. $DIR_{source} = 0$ and $DIR_{destination} = 1$):

FRREN = 0 in the Gateway Destination Object

1. A Remote Frame is received by gateway destination object.
2. TXRQ is set automatically in the gateway destination object.
3. A Data Frame with the current data stored in the destination object is transmitted on the destination bus.

FRREN = 1 in the Gateway Destination Object

1. A Remote Frame is received by gateway destination object.
2. TXRQ is set automatically in the gateway source object (must be referenced by CUR pointer of the destination object).
3. A remote request is transmitted by the source object (which is a receive object) on the source CAN bus.
4. The receiver of the remote request responds with a Data Frame on the source bus.
5. The Data Frame is stored in the source object.
6. The Data Frame is copied to the destination object (gateway action).
7. TXRQ is set in the destination object (assuming $GDFS_{source} = 1$).
8. The new data stored in the destination object is transmitted on the destination bus, in response to the initial remote request on the destination bus.

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20.4 MultiCAN Kernel Registers

This section describes the kernel registers of the MultiCAN module. All MultiCAN kernel register names described in this section are also referenced in other parts of the TC1728 User's Manual by the module name prefix "CAN_".

MultiCAN Kernel Register Overview

The MultiCAN Kernel include three blocks of registers:

- Global Module Registers
- Node Registers, for each CAN node x
- Message Object Registers, for each message object n

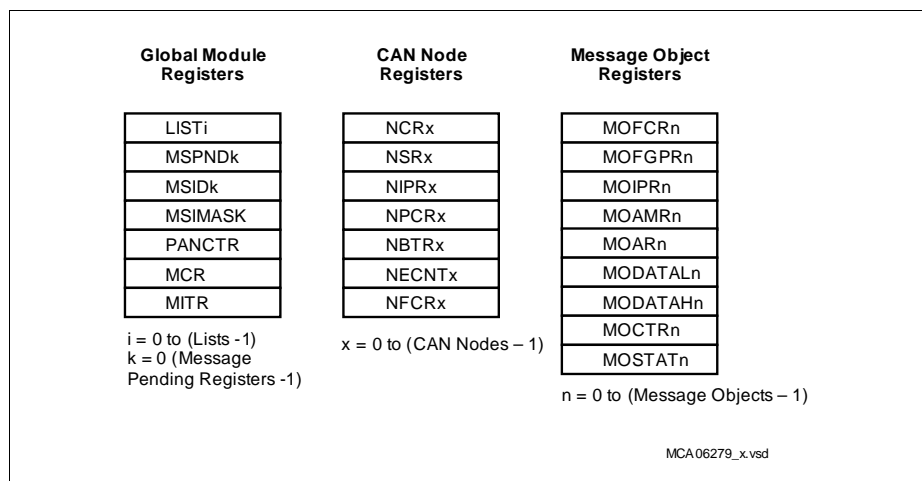


Figure 20-22 MultiCAN Kernel Registers

The registers of the MultiCAN module kernel are listed below.

Table 20-6 Registers Address Space - MultiCAN Kernel Registers

Module	Base Address	End Address	Note
CAN	F000 4000 _H	F000 7FFF _H	-

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Table 20-7 Registers Overview - MultiCAN Kernel Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
LISTi	List Register i	$0100_H + i \times 4_H$	Page 20-69
MSPNDk	Message Pending Register k	$0140_H + k \times 4_H$	Page 20-71
MSIDk	Message Index Register k	$0180_H + k \times 4_H$	Page 20-72
MSIMASK	Message Index Mask Register	$01C0_H$	Page 20-73
ID	Module Identification Register	008_H	Page 20-60
EDCR	Error Detection and Correction Test Register	080_H	Page 20-61
PANCTR	Panel Control Register	$01C4_H$	Page 20-62
MCR	Module Control Register	$01C8_H$	Page 20-66
MITR	Module Interrupt Trigger Reg.	$01CC_H$	Page 20-68
NCRx	Node x Control Register	$0200_H + x \times 100_H$	Page 20-74
NSRx	Node x Status Register	$0204_H + x \times 100_H$	Page 20-78
NIPRx	Node x Interrupt Pointer Reg.	$0208_H + x \times 100_H$	Page 20-82
NPCRx	Node x Port Control Register	$020C_H + x \times 100_H$	Page 20-84
NBTRx	Node x Bit Timing Register	$0210_H + x \times 100_H$	Page 20-85
NECNTx	Node x Error Counter Register	$0214_H + x \times 100_H$	Page 20-87
NFCRx	Node x Frame Counter Register	$0218_H + x \times 100_H$	Page 20-88
MOFCRn	Message Object n Function Control Register	$1000_H + n \times 20_H$	Page 20-102
MOFGPRn	Message Object n FIFO/Gateway Pointer Register	$1004_H + n \times 20_H$	Page 20-106
MOIPRn	Message Object n Interrupt Pointer Register	$1008_H + n \times 20_H$	Page 20-100
MOAMRn	Message Object n Acceptance Mask Register	$100C_H + n \times 20_H$	Page 20-107
MODATALn	Message Object n Data Register Low	$1010_H + n \times 20_H$	Page 20-111
MODATAHn	Message Object n Data Register High	$1014_H + n \times 20_H$	Page 20-112

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Table 20-7 Registers Overview - MultiCAN Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
MOARn	Message Object n Arbitration Register	$1018_H + n \times 20_H$	Page 20-108
MOCTRn	Message Object n Control Reg.	$101C_H + n \times 20_H$	Page 20-92
MOSTATn	Message Object n Status Reg.		Page 20-95

1) The absolute register address is calculated as follows:

Module Base Address ([Table 20-6](#)) + Offset Address (shown in this column)

Further, the following ranges for parameters i, k, x, and n are valid: i = 0-7, k = 0-7, x = 0-2, n = 0-63.

[Figure 20-23](#) shows the MultiCAN register address map.

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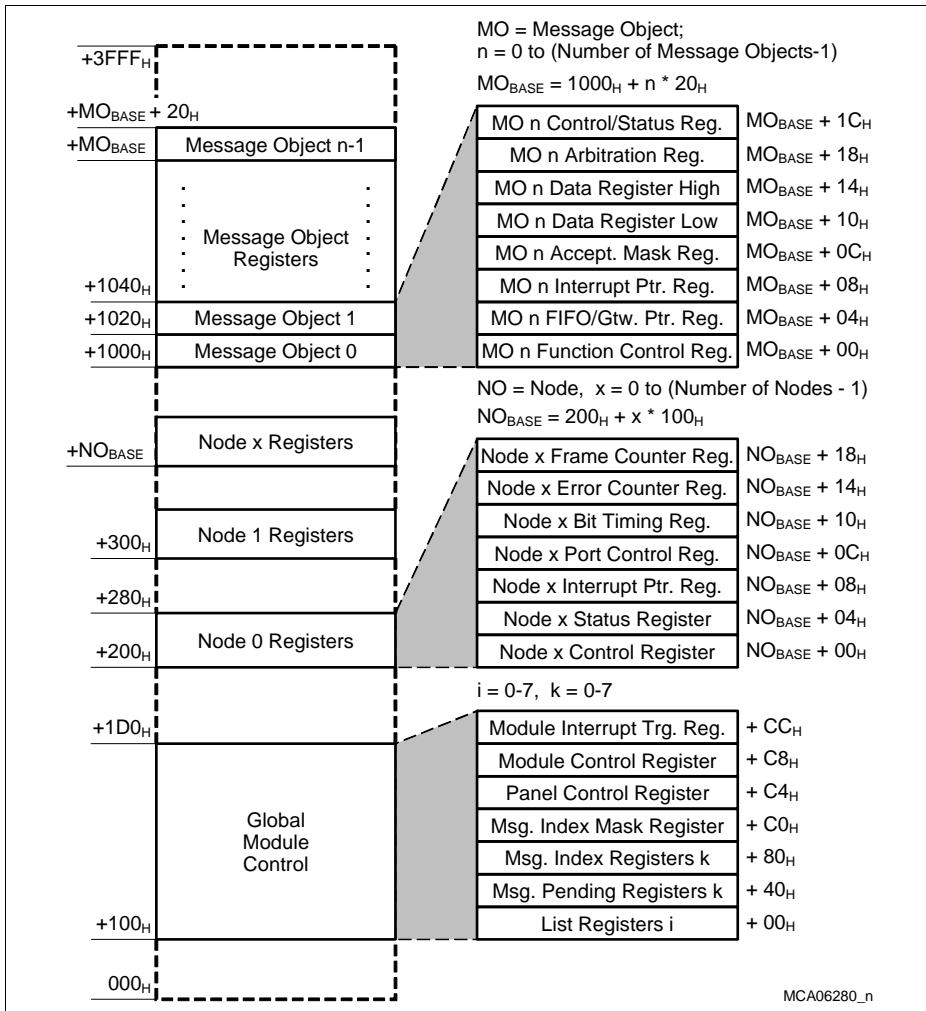


Figure 20-23 MultiCAN Register Address Map

20.4.1 Global Module Registers

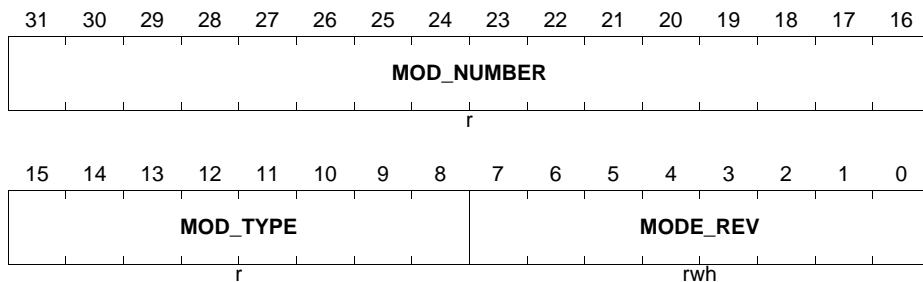
All list operations such as allocation, de-allocation and relocation of message objects within the list structure are performed via the Command Panel. It is not possible to modify the list structure directly by software by writing to the message objects and the LIST registers.

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Module Identification Register .

ID

Module Identification Register (008_H) **Reset Value: 002B C0XX_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type C0 _H Define the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines the MultiCAN module identification number (=002BH)

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The Error Detection and Correction Register ECDR is a test register which is only writable when the direct RAM access test mode is enabled for the CAN module (SCU_MEMTEST.MCANDRA = 1).

EDCR

Error Detection and Correction Test Register(080_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						DB ERR	SB ERR	0	ECCR						
r						rh	rh	r	rh						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						EDC DIS		0	ECCW						
r						rw		r	rw						

Field	Bits	Type	Description
ECCW	[6:0]	rw	ECC Write Data This data is used as ECC for bus write access to RAM when the error detection and correction is disabled (EDCDIS = 1).
EDCDIS	8	rw	Error Detection and Correction Disable 0 _B Error detection and correction enabled. 1 _B Error detection and correction disabled.
ECCR	[22:16]	rh	ECC Read Data of last RAM Bus Read Access
SBERR	24	rh	Single Bit Error Flag This bit indicates whether a single bit error has occurred with the last RAM read access.
DBERR	25	rh	Double Bit Error Flag This bit indicates whether a double bit error has occurred with the last RAM read access.
0	7, 23, [15:9], [31:26]	r	Reserved read as 0, should be written with 0.

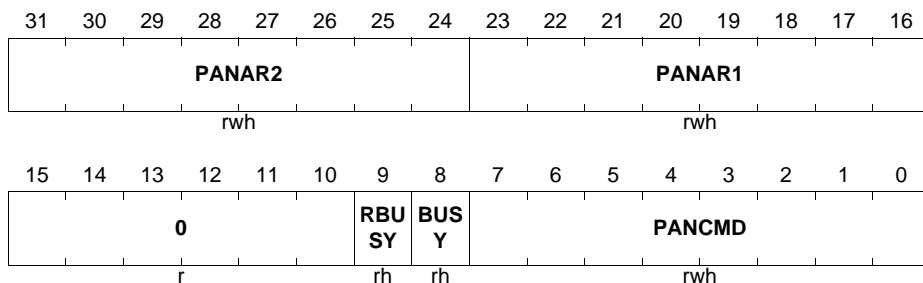
Controller Area Network Controller (MultiCAN)

The Panel Control Register PANCTR is used to start a new command by writing the command arguments and the command code into its bit fields.

PANCTR

Panel Control Register

(1C4_H)

Reset Value: 0000 0301_H


Field	Bits	Type	Description
PANCMD	[7:0]	rwh	Panel Command This bit field is used to start a new command by writing a panel command code into it. At the end of a panel command, the NOP (no operation) command code is automatically written into PANCMD. The coding of PANCMD is defined in Table 20-8 .
BUSY	8	rh	Panel Busy Flag 0 _B Panel has finished command and is ready to accept a new command. 1 _B Panel operation is in progress.
RBUSY	9	rh	Result Busy Flag 0 _B No update of PANAR1 and PANAR2 is scheduled by the list controller. 1 _B A list command is running (BUSY = 1) that will write results to PANAR1 and PANAR2, but the results are not yet available.
PANAR1	[23:16]	rwh	Panel Argument 1 See Table 20-8 .
PANAR2	[31:24]	rwh	Panel Argument 2 See Table 20-8 .
0	[15:10]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

Panel Commands

A panel operation consists of a command code (PANCMD) and up to two panel arguments (PANAR1, PANAR2). Commands that have a return value deliver it to the PANAR1 bit field. Commands that return an error flag deliver it to bit 31 of the Panel Control Register, this means bit 7 of PANAR2.

Table 20-8 Panel Commands

PANCMD	PANAR2	PANAR1	Command Description
00 _H	–	–	No Operation Writing 00 _H to PANCMD has no effect. No new command is started.
01 _H	Result: Bit 7: ERR Bit 6-0: undefined	–	Initialize Lists Run the initialization sequence to reset the CTRL and LIST fields of all message objects. List registers LIST[7:0] are set to their reset values. This results in the deallocation of all message objects. The initialization command requires that bits NCRx.INIT and NCRx.CCE are set for all CAN nodes. Bit 7 of PANAR2 (ERR) reports the success of the operation: 0 _B Initialization was successful 1 _B Not all NCRx.INIT and NCRx.CCE bits are set. Therefore, no initialization is performed. The initialize lists command is automatically performed with each reset of the MultiCAN module, but with the exception that all message object registers are reset, too.
02 _H	Argument: List Index	Argument: Message Object Number	Static Allocate Allocate message object to a list. The message object is removed from the list that it currently belongs to, and appended to the end of the list, given by PANAR2. This command is also used to deallocate a message object. In this case, the target list is the list of unallocated elements (PANAR2 = 0).

Controller Area Network Controller (MultiCAN)

Table 20-8 Panel Commands (cont'd)

PANCMD	PANAR2	PANAR1	Command Description
03 _H	Argument: List Index Result: Bit 7: ERR Bit 6-0: undefined	Result: Message Object Number	Dynamic Allocate Allocate the first message object of the list of unallocated objects to the selected list. The message object is appended to the end of the list. The message number of the message object is returned in PANAR1. An ERR bit (bit 7 of PANAR2) reports the success of the operation: 0 _B Success. 1 _B The operation has not been performed because the list of unallocated elements was empty.
04 _H	Argument: Destination Object Number	Argument: Source Object Number	Static Insert Before Remove a message object (source object) from the list that it currently belongs to, and insert it before a given destination object into the list structure of the destination object. The source object thus becomes the predecessor of the destination object.
05 _H	Argument: Destination Object Number Result: Bit 7: ERR Bit 6-0: undefined	Result: Object Number of inserted object	Dynamic Insert Before Insert a new message object before a given destination object. The new object is taken from the list of unallocated elements (the first element is chosen). The number of the new object is delivered as a result to PANAR1. An ERR bit (bit 7 of PANAR2) reports the success of the operation: 0 _B Success. 1 _B The operation has not been performed because the list of unallocated elements was empty.

Controller Area Network Controller (MultiCAN)

Table 20-8 Panel Commands (cont'd)

PANCMD	PANAR2	PANAR1	Command Description
06 _H	Argument: Destination Object Number	Argument: Source Object Number	Static Insert Behind Remove a message object (source object) from the list that it currently belongs to, and insert it behind a given destination object into the list structure of the destination object. The source object thus becomes the successor of the destination object.
07 _H	Argument: Destination Object Number Result: Bit 7: ERR Bit 6-0: undefined	Result: Object Number of inserted object	Dynamic Insert Behind Insert a new message object behind a given destination object. The new object is taken from the list of unallocated elements (the first element is chosen). The number of the new object is delivered as result to PANAR1. An ERR bit (bit 7 of PANAR2) reports the success of the operation: 0 _B Success. 1 _B The operation has not been performed because the list of unallocated elements was empty.
08 _H - FF _H	—	—	Reserved

Controller Area Network Controller (MultiCAN)

The Module Control Register MCR contains basic settings that determine the operation of the MultiCAN module.

The write access to the lowest byte of the MCR register is possible only if the CCE bits of all CAN nodes are set (NCRx.CCE bits). The NCRx.INIT bits will be automatically set when the lowest byte of the MCR register is written, independent of the setting of the CCE bits. The INIT bits have to be reset by software in order to activate the CAN nodes.

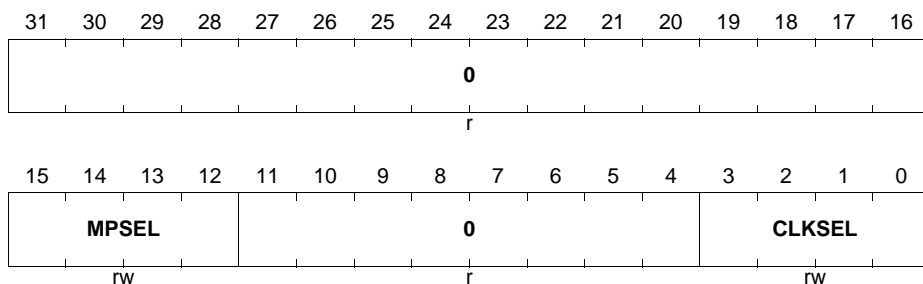
The reconfiguration of the clock source has to be done by using two writes: first a write of zero to the CLKSEL bitfield, and then a second write defining the new clock source. Between the first and the second write a delay of minimum $4 * (1/f_A) + 2 * (1/f_{CLC})$ must be inserted by software, where f_A is the frequency being switched off with the first write. Exception: in case that the f_{CLC} is selected as a baud rate and bit timing logic clock (MCR.CLKSEL = 1), no delay cycles between the writes are necessary. In both cases, simply using one write defining the new clock source is not allowed.

Note: If the baud rate logic is supplied from an unstable clock source, or no clock at all, the CAN functionality is not guaranteed.

MCR

Module Control Register

(1C8_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CLKSEL	[3:0]	rw	Baud Rate Logic Clock Select 0000 _B No clock supplied 0001 _B f_{CLC} 0010 _B Oscillator Clock 0100 _B E-Ray PLL clock 1000 _B hard wired to 0 ... _B not allowed

Controller Area Network Controller (MultiCAN)

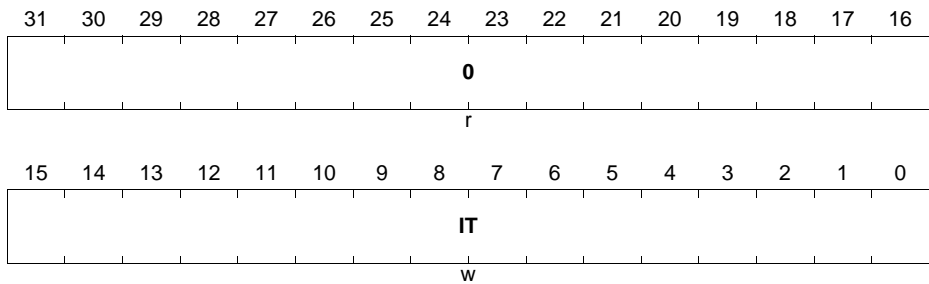
Field	Bits	Type	Description
MPSEL	[15:12]	rw	Message Pending Selector Bit field MPSEL makes it possible to select the bit position of the message pending bit after a message reception/transmission by a mixture of the MOIPRn register bit fields RXINP, TXINP, and MPN. Selection details are given in Figure 20-17 on Page 20-40 .
0	[31:16], [11:4]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

The Interrupt Trigger Register ITR is used to trigger interrupt requests on each interrupt output line by software.

MITR

Module Interrupt Trigger Register (1CC_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
IT	[15:0]	w	Interrupt Trigger Writing a 1 to IT[n] (n = 0-15) generates an interrupt request on interrupt output line INT_O[n]. Writing a 0 to IT[n] has no effect. Bit field IT is always read as 0. Multiple interrupt requests can be generated with a single write operation to MITR by writing a 1 to several bit positions of IT.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

List Pointer and List Register

Each CAN node has a list that determines the allocated message objects. Additionally, a list of all unallocated objects is available. Furthermore, general purpose lists are available which are not associated to a CAN node. The List Registers are assigned in the following way:

- LIST0 provides the list of all unallocated objects
- LIST1 provides the list for CAN node 0
- LIST2 provides the list for CAN node 1
- LIST3 provides the list for CAN node 2
- LIST[7:4] are not associated to a CAN node (free lists)

LIST0

List Register 0

(100_H)

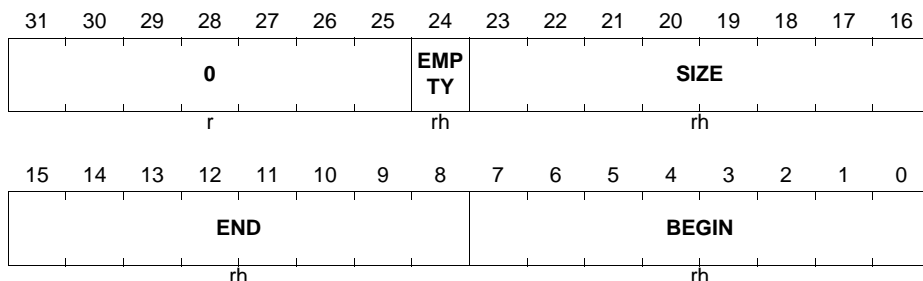
Reset Value: 003F 3F00_H

LISTx (x = 1-7)

List Register x

(100_H+x*4_H)

Reset Value: 0100 0000_H



Field	Bits	Type	Description
BEGIN	[7:0]	rh	List Begin BEGIN indicates the number of the first message object in list i.
END	[15:8]	rh	List End END indicates the number of the last message object in list i.
SIZE	[23:16]	rh	List Size SIZE indicates the number of elements in the list i. SIZE = number of list elements - 1 SIZE = 0 indicates that list x is empty.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
EMPTY	24	rh	List Empty Indication 0_B At least one message object is allocated to list i. 1_B No message object is allocated to the list x. List x is empty.
0	[31:25]	r	Reserved Read as 0.

Controller Area Network Controller (MultiCAN)

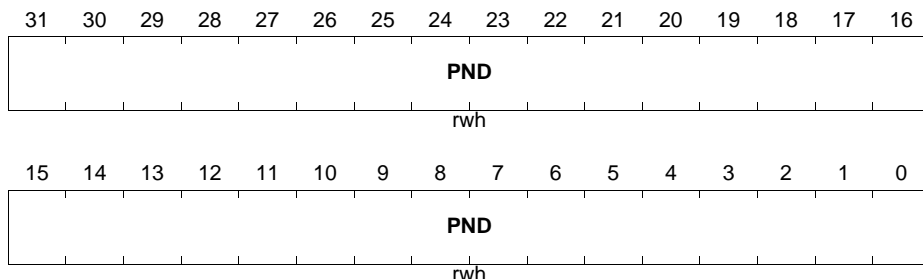
Message Notifications

When a message object n generates an interrupt request upon the transmission or reception of a message, then the request is routed to the interrupt output line selected by the bit field $MOIPRn.TXINP$ or $MOIPRn.RXINP$ of the message object n . As there are more message objects than interrupt output lines, an interrupt routine typically processes requests from more than one message object. Therefore, a priority selection mechanism is implemented in the MultiCAN module to select the highest priority object within a collection of message objects.

The Message Pending Register $MSPNDk$ contains the pending interrupt notification of list i .

$MSPNDk$ ($k = 0-7$)

Message Pending Register k **($140_H + k \cdot 4_H$)** **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
PND	[31:0]	rwh	Message Pending When a message interrupt occurs, the message object sets a bit in one of the MSPND register, where the bit position is given by the $MPN[4:0]$ field of the IPR register of the message object. The register selection n is given by the higher bits of MPN. The register bits can be cleared by software (write 0). Writing a 1 has no effect.

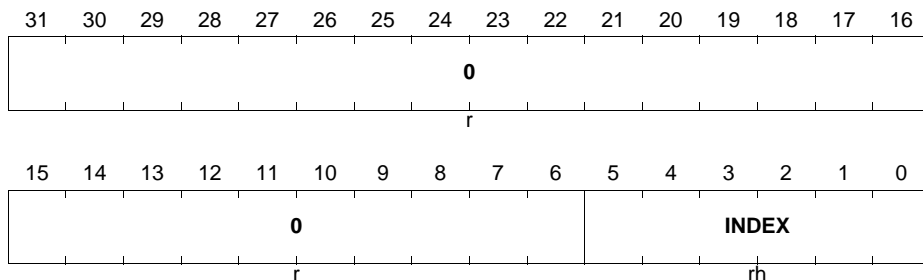
Controller Area Network Controller (MultiCAN)

Each Message Pending Register has a Message Index Register MSIDk associated with it. The Message Index Register shows the active (set) pending bit with lowest bit position within groups of pending bits.

MSIDk (k = 0-7)

Message Index Register k

 $(180_H + k \cdot 4_H)$

Reset Value: 0000 0020_H


Field	Bits	Type	Description
INDEX	[5:0]	rh	Message Pending Index The value of INDEX is given by the bit position i of the pending bit of MSPNDk with the following properties: <ol style="list-style-type: none"> MSPNDk[i] & IM[i] = 1 i = 0 or MSPNDk[i-1:0] & IM[i-1:0] = 0 If no bit of MSPNDk satisfies these conditions then INDEX reads 100000 _B . Thus INDEX shows the position of the first pending bit of MSPNDk, in which only those bits of MSPNDk that are selected in the Message Index Mask Register are taken into account.
0	[31:6]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

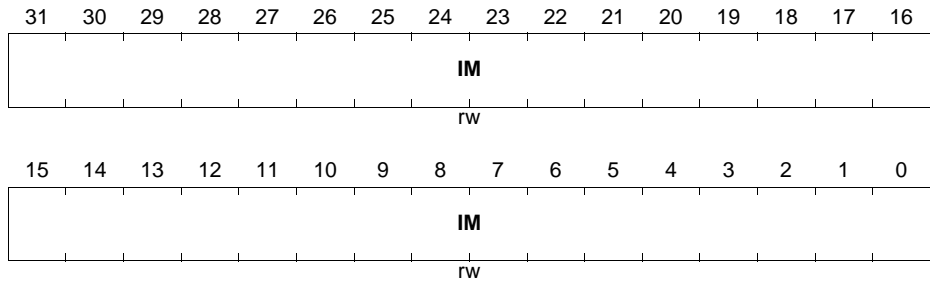
The Message Index Mask Register MSIMASK selects individual bits for the calculation of the Message Pending Index. The Message Index Mask Register is used commonly for all Message Pending registers and their associated Message Index registers.

MSIMASK

Message Index Mask Register

(1C0_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
IM	[31:0]	rw	Message Index Mask Only those bits in MSPNDk for which the corresponding Index Mask bits are set contribute to the calculation of the Message Index.

Controller Area Network Controller (MultiCAN)

20.4.2 CAN Node Registers

The CAN node registers are built in for each CAN node of the MultiCAN module. They contain information that is directly related to the operation of the CAN nodes and are shared among the nodes.

The Node Control Register contains basic settings that determine the operation of the CAN node.

NCRx (x = 0-2)

Node x Control Register (200_H+x*100_H) **Reset Value: 0000 0041_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							SUS EN	CAL M	CCE	0	CAN DIS	ALIE	LECI E	TRIE	INIT
r							rw	rw	rw	r	rw	rw	rw	rw	rwh

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
INIT	0	rwh	<p>Node Initialization</p> <p>0_B Resetting bit INIT enables the participation of the node in the CAN traffic.</p> <p>If the CAN node is in the bus-off state, the ongoing bus-off recovery (which does not depend on the INIT bit) is continued. With the end of the bus-off recovery sequence the CAN node is allowed to take part in the CAN traffic.</p> <p>If the CAN node is not in the bus-off state, a sequence of 11 consecutive recessive bits must be detected before the node is allowed to take part in the CAN traffic.</p> <p>1_B Setting this bit terminates the participation of this node in the CAN traffic. Any ongoing frame transfer is cancelled and the transmit line goes recessive. If the CAN node is in the bus-off state, then the running bus-off recovery sequence is continued. If the INIT bit is still set after the successful completion of the bus-off recovery sequence, i.e. after detecting 128 sequences of 11 consecutive recessive bits (11 × 1), then the CAN node leaves the bus-off state but remains inactive as long as INIT remains set.</p> <p>Bit INIT is automatically set when the CAN node enters the bus-off state (see Page 20-24).</p>
TRIE	1	rw	<p>Transfer Interrupt Enable</p> <p>TRIE enables the transfer interrupt of CAN node x. This interrupt is generated after the successful reception or transmission of a CAN frame in node x.</p> <p>0_B Transfer interrupt is disabled.</p> <p>1_B Transfer interrupt is enabled.</p> <p>Bit field NIPRx.TRINP selects the interrupt output line which becomes activated at this type of interrupt.</p>

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
LECIE	2	rw	LEC Indicated Error Interrupt Enable LECIE enables the last error code interrupt of CAN node x. This interrupt is generated with each update of bit field NSRx.LEC with LEC > 0 (CAN protocol error). 0 _B Last error code interrupt is disabled. 1 _B Last error code interrupt is enabled. Bit field NIPRx.LECINP selects the interrupt output line which becomes activated at this type of interrupt.
ALIE	3	rw	Alert Interrupt Enable ALIE enables the alert interrupt of CAN node x. This interrupt is generated by any one of the following events: <ul style="list-style-type: none"> • A change of bit NSRx.BOFF • A change of bit NSRx.EWRN • A List Length Error, which also sets bit NSRx.LLE • A List Object Error, which also sets bit NSRx.LOE • A Bit INIT is set by hardware 0 _B Alert interrupt is disabled. 1 _B Alert interrupt is enabled. Bit field NIPRx.ALINP selects the interrupt output line which becomes activated at this type of interrupt.
CANDIS	4	rw	CAN Disable Setting this bit disables the CAN node. The CAN node first waits until it is bus-idle or bus-off. Then bit INIT is automatically set, and an alert interrupt is generated if bit ALIE is set.
CCE	6	rw	Configuration Change Enable 0 _B The Bit Timing Register, the Port Control Register, and the Error Counter Register may only be read. All attempts to modify them are ignored. 1 _B The Bit Timing Register, the Port Control Register, and the Error Counter Register may be read and written.
CALM	7	rw	CAN Analyze Mode If this bit is set, then the CAN node operates in Analyze Mode. This means that messages may be received, but not transmitted. No acknowledge is sent on the CAN bus upon frame reception. Active-error flags are sent recessive instead of dominant. The transmit line is continuously held at recessive (1) level. Bit CALM can be written only while bit INIT is set.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
SUSEN	8	rw	Suspend Enable This bit makes it possible to set the CAN node into Suspend Mode via OCDS (on chip debug support): 0 _B An OCDS suspend trigger is ignored by the CAN node. 1 _B An OCDS suspend trigger disables the CAN node: As soon as the CAN node becomes bus-idle or bus-off, bit INIT is internally forced to 1 to disable the CAN node. The actual value of bit INIT remains unchanged. Bit SUSEN is reset via OCDS Reset.
0	[31:9], 5	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

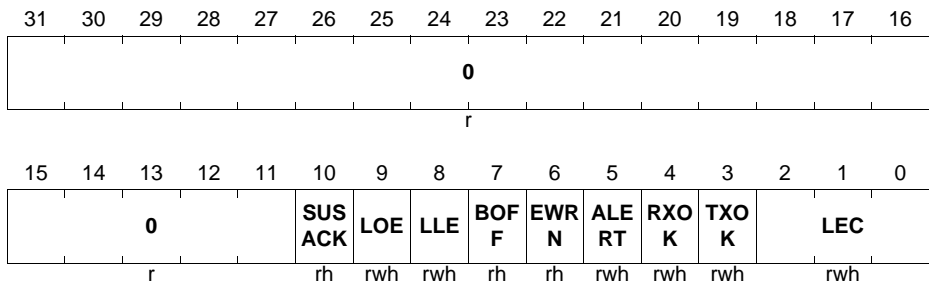
The Node Status Register NSRx reports errors as well as successfully transferred CAN frames.

NSRx (x = 0-2)

Node x Status Register

(204_H+x*100_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
LEC	[2:0]	rwh	Last Error Code This bit field indicates the type of the last (most recent) CAN error. The encoding of this bit field is described in Table 20-9 .
TXOK	3	rwh	Message Transmitted Successfully 0 _B No successful transmission since last (most recent) flag reset. 1 _B A message has been transmitted successfully (error-free and acknowledged by at least another node). TXOK must be reset by software (write 0). Writing 1 has no effect.
RXOK	4	rwh	Message Received Successfully 0 _B No successful reception since last (most recent) flag reset. 1 _B A message has been received successfully. RXOK must be reset by software (write 0). Writing 1 has no effect.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
ALERT	5	rwh	Alert Warning The ALERT bit is set upon the occurrence of one of the following events (the same events which also trigger an alert interrupt if ALIE is set): <ul style="list-style-type: none"> • A change of bit NSRx.BOFF • A change of bit NSRx.EWRN • A List Length Error, which also sets bit NSRx.LLE • A List Object Error, which also sets bit NSRx.LOE • Bit INIT has been set by hardware ALERT must be reset by software (write 0). Writing 1 has no effect.
EWRN	6	rh	Error Warning Status 0 _B No warning limit exceeded. 1 _B One of the error counters REC or TEC reached the warning limit EWRNLVL.
BOFF	7	rh	Bus-off Status 0 _B CAN controller is not in the bus-off state. 1 _B CAN controller is in the bus-off state.
LLE	8	rwh	List Length Error 0 _B No List Length Error since last (most recent) flag reset. 1 _B A List Length Error has been detected during message acceptance filtering. The number of elements in the list that belongs to this CAN node differs from the list SIZE given in the list termination pointer. LLE must be reset by software (write 0). Writing 1 has no effect.
LOE	9	rwh	List Object Error 0 _B No List Object Error since last (most recent) flag reset. 1 _B A List Object Error has been detected during message acceptance filtering. A message object with wrong LIST index entry in the Message Object Control Register has been detected. LOE must be reset by software (write 0). Writing 1 has no effect.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
SUSACK	10	rh	Suspend Acknowledge 0_B The CAN node is not in Suspend Mode or a suspend request is pending, but the CAN node has not yet reached bus-idle or bus-off. 1_B The CAN node is in Suspend Mode: The CAN node is inactive (bit NCR.INIT internally forced to 1) due to an OCDS suspend request.
0	[31:11]	r	Reserved Read as 0; should be written with 0.

Encoding of the LEC Bit Field

Table 20-9 Encoding of the LEC Bit Field

LEC Value	Signification
000_B	No Error: No error was detected for the last (most recent) message on the CAN bus.
001_B	Stuff Error: More than 5 equal bits in a sequence have occurred in a part of a received message where this is not allowed.
010_B	Form Error: A fixed format part of a received frame has the wrong format.
011_B	Ack Error: The transmitted message was not acknowledged by another node.
100_B	Bit1 Error: During a message transmission, the CAN node tried to send a recessive level (1) outside the arbitration field and the acknowledge slot, but the monitored bus value was dominant.
101_B	Bit0 Error: Two different conditions are signaled by this code: <ol style="list-style-type: none"> During transmission of a message (or acknowledge bit, active-error flag, overload flag), the CAN node tried to send a dominant level (0), but the monitored bus value was recessive. During bus-off recovery, this code is set each time a sequence of 11 recessive bits has been monitored. The CPU may use this code as indication that the bus is not continuously disturbed.

Controller Area Network Controller (MultiCAN)

Table 20-9 Encoding of the LEC Bit Field (cont'd)

LEC Value	Signification
110 _B	CRC Error: The CRC checksum of the received message was incorrect.
111 _B	CPU write to LEC: Whenever the the CPU writes the value 111 to LEC, it takes the value 111. Whenever the CPU writes another value to LEC, the written LEC value is ignored.

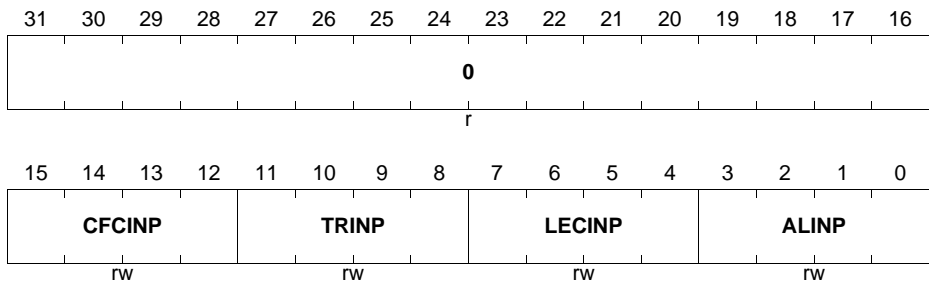
Controller Area Network Controller (MultiCAN)

The four interrupt pointers in the Node Interrupt Pointer Register NIPRx select one out of the sixteen interrupt outputs individually for each type of CAN node interrupt. See also [Page 20-25](#) for more CAN node interrupt details.

NIPRx (x = 0-2)

Node x Interrupt Pointer Register

 $(208_H + x \cdot 100_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ALINP	[3:0]	rw	Alert Interrupt Node Pointer ALINP selects the interrupt output line INT_Om (m = 0-15) for an alert interrupt of CAN Node x. 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.
LECINP	[7:4]	rw	Last Error Code Interrupt Node Pointer LECINP selects the interrupt output line INT_Om (m = 0-15) for an LEC interrupt of CAN Node x. 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.

Controller Area Network Controller (MultiCAN)

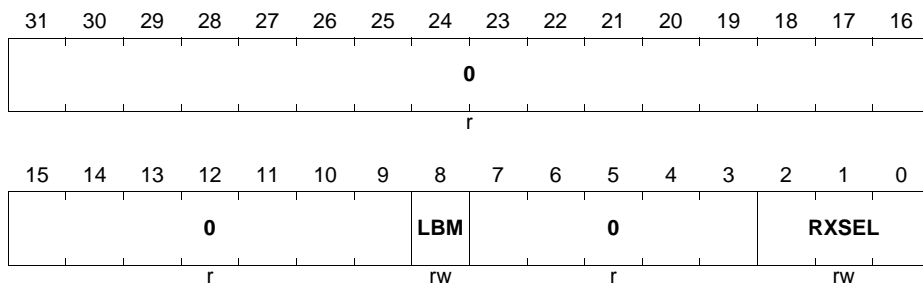
Field	Bits	Type	Description
TRINP	[11:8]	rw	Transfer OK Interrupt Node Pointer TRINP selects the interrupt output line INT_Om (m = 0-15) for a transfer OK interrupt of CAN Node x. 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.
CFCINP	[15:12]	rw	Frame Counter Interrupt Node Pointer CFCINP selects the interrupt output line INT_Om (m = 0-15) for a frame counter overflow interrupt of CAN Node x. 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

The Node Port Control Register NPCRx configures the CAN bus transmit/receive ports. NPCRx can be written only if bit NCRx.CCE is set.

NPCRx (x = 0-2)

Node x Port Control Register (20C_H+x*100_H) **Reset Value: 0000 0000_H**



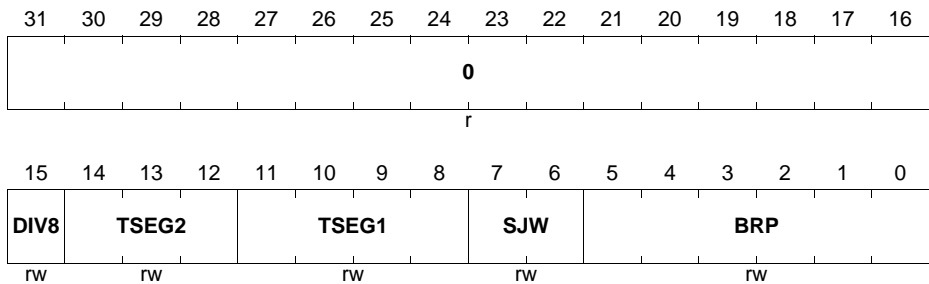
Field	Bits	Type	Description
RXSEL	[2:0]	rw	Receive Select RXSEL selects one out of 8 possible receive inputs. The CAN receive signal is performed only through the selected input. <i>Note: In TC1728, only specific combinations of RXSEL are available (see also “Receive Input Selection” on Page 20-120).</i>
LBM	8	rw	Loop-Back Mode 0 _B Loop-Back Mode is disabled. 1 _B Loop-Back Mode is enabled. This node is connected to an internal (virtual) loop-back CAN bus. All CAN nodes which are in Loop-Back Mode are connected to this virtual CAN bus so that they can communicate with each other internally. The external transmit line is forced recessive in Loop-Back Mode.
0	[7:3], [31:9]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

The Node Bit Timing Register NBTRx contains all parameters to set up the bit timing for the CAN transfer. NBTRx can be written only if bit NCRx.CCE is set.

NBTRx (x = 0-2)

Node x Bit Timing Register (210_H+x*100_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
BRP	[5:0]	rw	Baud Rate Prescaler The duration of one time quantum is given by (BRP + 1) clock cycles if DIV8 = 0. The duration of one time quantum is given by 8 × (BRP + 1) clock cycles if DIV8 = 1.
SJW	[7:6]	rw	(Re) Synchronization Jump Width (SJW + 1) time quanta are allowed for re-synchronization.
TSEG1	[11:8]	rw	Time Segment Before Sample Point (TSEG1 + 1) time quanta is the user-defined nominal time between the end of the synchronization segment and the sample point. It includes the propagation segment, which takes into account signal propagation delays. The time segment may be lengthened due to re-synchronization. Valid values for TSEG1 are 2 to 15.
TSEG2	[14:12]	rw	Time Segment After Sample Point (TSEG2 + 1) time quanta is the user-defined nominal time between the sample point and the start of the next synchronization segment. It may be shortened due to re-synchronization. Valid values for TSEG2 are 1 to 7.

Controller Area Network Controller (MultiCAN)

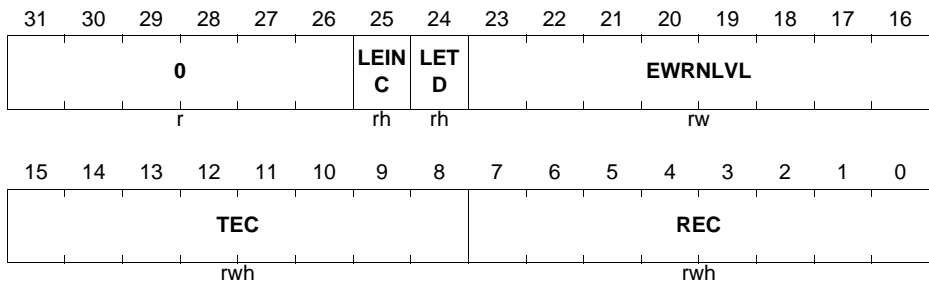
Field	Bits	Type	Description
DIV8	15	rw	Divide Prescaler Clock by 8 0_B A time quantum lasts (BRP+1) clock cycles. 1_B A time quantum lasts $8 \times (\text{BRP}+1)$ clock cycles.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

The Node Error Counter Register NECNTx contains the CAN receive and transmit error counter as well as some additional bits to ease error analysis. NECNTx can be written only if bit NCRx.CCE is set.

NECNTx (x = 0-2)

Node x Error Counter Register ($214_H + x \cdot 100_H$) **Reset Value: 0060 0000_H**



Field	Bits	Type	Description
REC	[7:0]	rwh	Receive Error Counter Bit field REC contains the value of the receive error counter of CAN node x.
TEC	[15:8]	rwh	Transmit Error Counter Bit field TEC contains the value of the transmit error counter of CAN node x.
EWRNLVL	[23:16]	rw	Error Warning Level Bit field EWRNLVL determines the threshold value (warning level, default 96) to be reached in order to set the corresponding error warning bit EWRN.
LETD	24	rh	Last Error Transfer Direction 0 _B The last error occurred while the CAN node x was receiver (REC has been incremented). 1 _B The last error occurred while the CAN node x was transmitter (TEC has been incremented).
LEINC	25	rh	Last Error Increment 0 _B The last error led to an error counter increment of 1. 1 _B The last error led to an error counter increment of 8.

Controller Area Network Controller (MultiCAN)

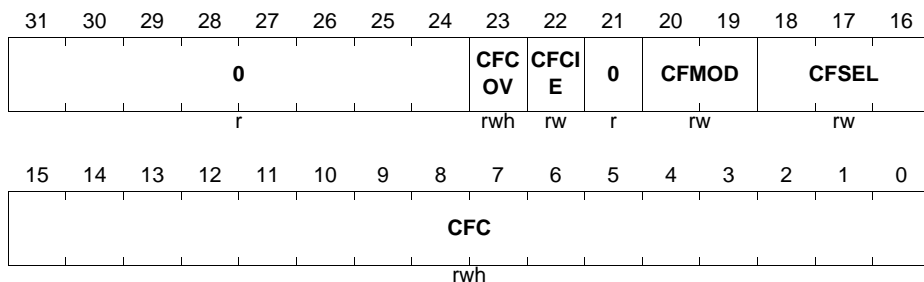
Field	Bits	Type	Description
0	[31:26]	r	Reserved Read as 0; should be written with 0.

The Node Frame Counter Register NFCRx contains the actual value of the frame counter as well as control and status bits of the frame counter.

NFCRx (x = 0-2)

Node x Frame Counter Register ($218_H + x \cdot 100_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CFC	[15:0]	rwh	CAN Frame Counter In Frame Count Mode (CFMOD = 00 _B), this bit field contains the frame count value. In Time Stamp Mode (CFMOD = 01 _B), this bit field contains the captured bit time count value, captured with the start of a new frame. In all Bit Timing Analysis Modes (CFMOD = 10 _B), CFC always displays the number of f_{CLC} clock cycles (measurement result) minus 1. Example: a CFC value of 34 in measurement mode CFSEL = 000 _B means that 35 f_{CLC} clock cycles have been elapsed between the most recent two dominant edges on the receive input.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
CFSEL	[18:16]	rw	<p>CAN Frame Count Selection</p> <p>This bit field selects the function of the frame counter for the chosen frame count mode.</p> <p>Frame Count Mode</p> <p>Bit 0</p> <p>If Bit 0 of CFSEL is set, then CFC is incremented each time a foreign frame (i.e. a frame not matching to a message object) has been received on the CAN bus.</p> <p>Bit 1</p> <p>If Bit 1 of CFSEL is set, then CFC is incremented each time a frame matching to a message object has been received on the CAN bus.</p> <p>Bit 2</p> <p>If Bit 2 of CFSEL is set, then CFC is incremented each time a frame has been transmitted successfully by the node.</p> <p>Time Stamp Mode</p> <p>000_B The frame counter is incremented (internally) at the beginning of a new bit time. The value is sampled during the SOF bit of a new frame. The sampled value is visible in the CFC field.</p> <p>Bit Timing Mode</p> <p>The available bit timing measurement modes are shown in Table 20-10. If CFCIE is set, then an interrupt on request node x (where x is the CAN node number) is generated with a CFC update.</p>
CFMOD	[20:19]	rw	<p>CAN Frame Counter Mode</p> <p>This bit field determines the operation mode of the frame counter.</p> <p>00_B Frame Count Mode: The frame counter is incremented upon the reception and transmission of frames.</p> <p>01_B Time Stamp Mode: The frame counter is used to count bit times.</p> <p>10_B Bit Timing Mode: The frame counter is used for analysis of the bit timing.</p>

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
CFCIE	22	rw	CAN Frame Count Interrupt Enable CFCIE enables the CAN frame counter overflow interrupt of CAN node x. 0 _B CAN frame counter overflow interrupt is disabled. 1 _B CAN frame counter overflow interrupt is enabled. Bit field NIPRx.CFCINP selects the interrupt output line that is activated at this type of interrupt.
CFCOV	23	rwh	CAN Frame Counter Overflow Flag Flag CFCOV is set upon a frame counter overflow (transition from FFFF _H to 0000 _H). In bit timing analysis mode, CFCOV is set upon an update of CFC. An interrupt request is generated if CFCIE = 1. 0 _B No overflow has occurred since last flag reset. 1 _B An overflow has occurred since last flag reset. CFCOV must be reset by software.
0	21, [31:24]	r	Reserved Read as 0; should be written with 0.

Bit Timing Analysis Modes

Table 20-10 Bit Timing Analysis Modes (CFMOD = 10)

CFSEL	Measurement
000 _B	Whenever a dominant edge (transition from 1 to 0) is monitored on the receive input, the time (measured in clock cycles) between this edge and the most recent dominant edge is stored in CFC.
001 _B	Whenever a recessive edge (transition from 0 to 1) is monitored on the receive input the time (measured in clock cycles) between this edge and the most recent dominant edge is stored in CFC.
010 _B	Whenever a dominant edge is received as a result of a transmitted dominant edge, the time (clock cycles) between both edges is stored in CFC.
011 _B	Whenever a recessive edge is received as a result of a transmitted recessive edge, the time (clock cycles) between both edges is stored in CFC.
100 _B	Whenever a dominant edge that qualifies for synchronization is monitored on the receive input, the time (measured in clock cycles) between this edge and the most recent sample point is stored in CFC.

Controller Area Network Controller (MultiCAN)

Table 20-10 Bit Timing Analysis Modes (CFMOD = 10) (cont'd)

CFSEL	Measurement
101 _B	<p>With each sample point, the time (measured in clock cycles) between the start of the new bit time and the start of the previous bit time is stored in CFC[11:0].</p> <p>Additional information is written to CFC[15:12] at each sample point:</p> <p>CFC[15]: Transmit value of actual bit time</p> <p>CFC[14]: Receive sample value of actual bit time</p> <p>CFC[13:12]: CAN bus information (see Table 20-11)</p>
110 _B	Reserved, do not use this combination.
111 _B	Reserved, do not use this combination.

Table 20-11 CAN Bus State Information

CFC[13:12]	CAN Bus State
00 _B	<p>NoBit</p> <p>The CAN bus is idle, performs bit (de-) stuffing or is in one of the following frame segments:</p> <p>SOF, SRR, CRC, delimiters, first 6 EOF bits, IFS.</p>
01 _B	<p>NewBit</p> <p>This code represents the first bit of a new frame segment.</p> <p>The current bit is the first bit in one of the following frame segments:</p> <p>Bit 10 (MSB) of standard ID (transmit only), RTR, reserved bits, IDE, DLC(MSB), bit 7 (MSB) in each data byte and the first bit of the ID extension.</p>
10 _B	<p>Bit</p> <p>This code represents a bit inside a frame segment with a length of more than one bit (not the first bit of those frame segments that is indicated by NewBit).</p> <p>The current bit is processed within one of the following frame segments:</p> <p>ID bits (except first bit of standard ID for transmission and first bit of ID extension), DLC (3 LSB) and bits 6-0 in each data byte.</p>
11 _B	<p>Done</p> <p>The current bit is in one of the following frame segments:</p> <p>Acknowledge slot, last bit of EOF, active/passive-error frame, overload frame.</p> <p>Two or more directly consecutive Done codes signal an Error Frame.</p>

Controller Area Network Controller (MultiCAN)

20.4.3 Message Object Registers

The Message Object Control Register MOCTR_n and the Message Object Status Register MOSTAT_n are located at the same address offset within a message object address block (offset address 1C_H). The MOCTR_n is a write-only register that makes it possible to set/reset CAN transfer related control bits through software.

MOCTR0

Message Object 0 Control Register (101C_H)

Reset Value: 0100 0000_H

MOCTR63

Message Object 63 Control Register (17FC_H)

Reset Value: 3F3E 0000_H

MOCTR_n (n = 1-62)

Message Object n Control Register

(101C_H+n*20_H)

Reset Value: ((n+1)*01000000_H)+((n-1)*00010000_H)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				SET DIR	SET TXE N1	SET TXE N0	SET TXR Q	SET RXE N	SET RTS EL	SET MSG VAL	SET MSG LST	SET NEW DAT	SET RXU PD	SET TXP ND	SET RXP ND
W				W	W	W	W	W	W	W	W	W	W	W	W

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				RES DIR	RES TXE N1	RES TXE N0	RES TXR Q	RES RXE N	RES RTS EL	RES MSG VAL	RES MSG LST	RES NEW DAT	RES RXU PD	RES TXP ND	RES RXP ND
W				W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
RESRXPND, SETRXPND	0, 16	w	Reset/Set Receive Pending These bits control the set/reset condition for RXPND (see Table 20-12).
RESTXPND, SETTXPND	1, 17	w	Reset/Set Transmit Pending These bits control the set/reset condition for TXPND (see Table 20-12).
RESRXUPD, SETRXUPD	2, 18	w	Reset/Set Receive Updating These bits control the set/reset condition for RXUPD (see Table 20-12).
RESNEWDAT, SETNEWDAT	3, 19	w	Reset/Set New Data These bits control the set/reset condition for NEWDAT (see Table 20-12).

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
RESMSGSLST, SETMSGSLST	4, 20	w	Reset/Set Message Lost These bits control the set/reset condition for MSGSLST (see Table 20-12).
RESMSGVAL, SETMSGVAL	5, 21	w	Reset/Set Message Valid These bits control the set/reset condition for MSGVAL (see Table 20-12).
RESRTSEL, SETRTSEL	6, 22	w	Reset/Set Receive/Transmit Selected These bits control the set/reset condition for RTSEL (see Table 20-12).
RESRXEN, SETRXEN	7, 23	w	Reset/Set Receive Enable These bits control the set/reset condition for RXEN (see Table 20-12).
RESTXRQ, SETTXRQ	8, 24	w	Reset/Set Transmit Request These bits control the set/reset condition for TXRQ (see Table 20-12).
RESTXEN0, SETTXEN0	9, 25	w	Reset/Set Transmit Enable 0 These bits control the set/reset condition for TXEN0 (see Table 20-12).
RESTXEN1, SETTXEN1	10, 26	w	Reset/Set Transmit Enable 1 These bits control the set/reset condition for TXEN1 (see Table 20-12).
RESDIR, SETDIR	11, 27	w	Reset/Set Message Direction These bits control the set/reset condition for DIR (see Table 20-12).
0	[15:12], [31:28]	w	Reserved Should be written with 0.

Table 20-12 Reset/Set Conditions for Bits in Register MOCTRn

RESy Bit ¹⁾	SETy Bit	Action on Write
Write 0	Write 0	Leave element unchanged
	No write	
No write	Write 0	
Write 1	Write 1	

Controller Area Network Controller (MultiCAN)

Table 20-12 Reset/Set Conditions for Bits in Register MOCTRn (cont'd)

RESy Bit ¹⁾	SETy Bit	Action on Write
Write 1	Write 0	Reset element
	No write	
Write 0	Write 1	Set element
No write		

1) The parameter "y" stands for the second part of the bit name ("RXPND", "TXPND", ... up to "DIR").

Controller Area Network Controller (MultiCAN)

The MOSTATn is a read-only register that indicates message object list status information such as the number of the current message object predecessor and successor message object, as well as the list number to which the message object is assigned.

MOSTAT0

Message Object 0 Status Register (101C_H)

Reset Value: 0100 0000_H

MOSTAT63

Message Object 63 Status Register (17FC_H)

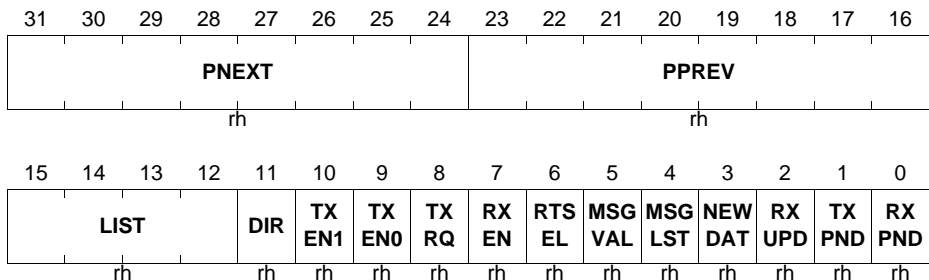
Reset Value: 3F3E 0000_H

MOSTATn (n = 1-62)

Message Object n Status Register

(101C_H+n*20_H)

Reset Value: ((n+1)*01000000_H)+((n-1)*00010000_H)



Field	Bits	Type	Description
RXPND	0	rh	Receive Pending 0 _B No CAN message has been received. 1 _B A CAN message has been received by the message object n, either directly or via gateway copy action. RXPND is set by hardware and must be reset by software.
TXPND	1	rh	Transmit Pending 0 _B No CAN message has been transmitted. 1 _B A CAN message from message object n has been transmitted successfully over the CAN bus. TXPND is set by hardware and must be reset by software.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
RXUPD	2	rh	Receive Updating 0_B No receive update ongoing. 1_B Message identifier, DLC, and data of the message object are currently updated.
NEWDAT	3	rh	New Data 0_B No update of the message object n since last flag reset. 1_B Message object n has been updated. NEWDAT is set by hardware after a received CAN frame has been stored in message object n. NEWDAT is cleared by hardware when a CAN transmission of message object n has been started. NEWDAT should be set by software after the new transmit data has been stored in message object n to prevent the automatic reset of TXRQ at the end of an ongoing transmission.
MSGLST	4	rh	Message Lost 0_B No CAN message is lost. 1_B A CAN message is lost because NEWDAT has become set again when it has already been set.
MSGVAL	5	rh	Message Valid 0_B Message object n is not valid. 1_B Message object n is valid. Only a valid message object takes part in CAN transfers.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
RTSEL	6	rh	<p>Receive/Transmit Selected</p> <p>0_B Message object n is not selected for receive or transmit operation.</p> <p>1_B Message object n is selected for receive or transmit operation.</p> <p>Frame Reception: RTSEL is set by hardware when message object n has been identified for storage of a CAN frame that is currently received. Before a received frame becomes finally stored in message object n, a check is performed to determine if RTSEL is set. Thus the CPU can suppress a scheduled frame delivery to this message object n by clearing RTSEL by software.</p> <p>Frame Transmission: RTSEL is set by hardware when message object n has been identified to be transmitted next. A check is performed to determine if RTSEL is still set before message object n is actually set up for transmission and bit NEWDAT is cleared. It is also checked that RTSEL is still set before its message object n is verified due to the successful transmission of a frame. RTSEL needs to be checked only when the context of message object n changes, and a conflict with an ongoing frame transfer shall be avoided. In all other cases, RTSEL can be ignored. RTSEL has no impact on message acceptance filtering. RTSEL is not cleared by hardware.</p>
RXEN	7	rh	<p>Receive Enable</p> <p>0_B Message object n is not enabled for frame reception.</p> <p>1_B Message object n is enabled for frame reception.</p> <p>RXEN is evaluated for receive acceptance filtering only.</p>

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
TXRQ	8	rh	Transmit Request 0_B No transmission of message object n is requested. 1_B Transmission of message object n on the CAN bus is requested. The transmit request becomes valid only if TXRQ, TXEN0, TXEN1 and MSGVAL are set. TXRQ is set by hardware if a matching Remote Frame has been received correctly. TXRQ is reset by hardware if message object n has been transmitted successfully and NEWDAT is not set again by software.
TXEN0	9	rh	Transmit Enable 0 0_B Message object n is not enabled for frame transmission. 1_B Message object n is enabled for frame transmission. Message object n can be transmitted only if both bits, TXEN0 and TXEN1, are set. The user may clear TXEN0 in order to inhibit the transmission of a message that is currently updated, or to disable automatic response of Remote Frames.
TXEN1	10	rh	Transmit Enable 1 0_B Message object n is not enabled for frame transmission. 1_B Message object n is enabled for frame transmission. Message object n can be transmitted only if both bits, TXEN0 and TXEN1, are set. TXEN1 is used by the MultiCAN module for selecting the active message object in the Transmit FIFOs.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
DIR	11	rh	Message Direction 0_B Receive Object selected: With TXRQ = 1, a Remote Frame with the identifier of message object n is scheduled for transmission. On reception of a Data Frame with matching identifier, the message is stored in message object n. 1_B Transmit Object selected: If TXRQ = 1, message object n is scheduled for transmission of a Data Frame. On reception of a Remote Frame with matching identifier, bit TXRQ is set.
LIST	[15:12]	rh	List Allocation LIST indicates the number of the message list to which message object n is allocated. LIST is updated by hardware when the list allocation of the object is modified by a panel command.
PPREV	[23:16]	rh	Pointer to Previous Message Object PPREV holds the message object number of the previous message object in a message list structure.
PNEXT	[31:24]	rh	Pointer to Next Message Object PNEXT holds the message object number of the next message object in a message list structure.

Table 20-13 MOSTATn Reset Values

Message Object	PNEXT	PPREV	Reset Value
0	1	0	0100 0000 _H
1	2	0	0200 0000 _H
2	3	1	0301 0000 _H
3	4	2	0402 0000 _H
...
60	61	59	3D3B 0000 _H
61	62	60	3E3C 0000 _H
62	63	61	3F3D 0000 _H
63	63	62	3F3E 0000 _H

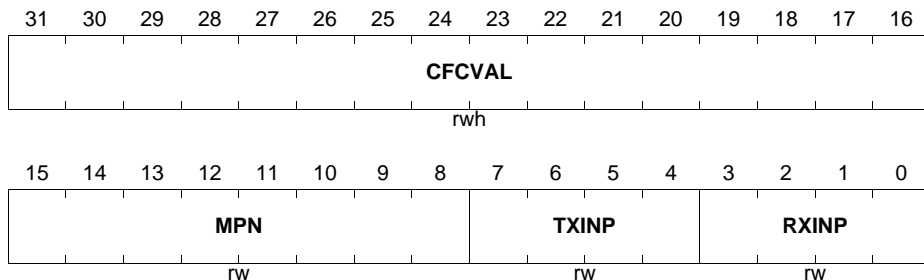
Controller Area Network Controller (MultiCAN)

The Message Object Interrupt Pointer Register MOIPR_n holds the message interrupt pointers, the message pending number, and the frame counter value of message object n.

MOIPR_n (n = 0-63)

Message Object n Interrupt Pointer Register

 $(1008_H + n \cdot 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RXINP	[3:0]	rw	Receive Interrupt Node Pointer RXINP selects the interrupt output line INT_O _m (m = 0-15) for a receive interrupt event of message object n. RXINP can also be taken for message pending bit selection (see Page 20-40). 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.
TXINP	[7:4]	rw	Transmit Interrupt Node Pointer TXINP selects the interrupt output line INT_O _m (m = 0-15) for a transmit interrupt event of message object n. TXINP can also be taken for message pending bit selection (see Page 20-40). 0000 _B Interrupt output line INT_O0 is selected. 0001 _B Interrupt output line INT_O1 is selected. ... 1110 _B Interrupt output line INT_O14 is selected. 1111 _B Interrupt output line INT_O15 is selected.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
MPN	[15:8]	rw	Message Pending Number This bit field selects the bit position of the bit in the Message Pending Register that is set upon a message object n receive/transmit interrupt.
CFCVAL	[31:16]	rwh	CAN Frame Counter Value When a message is stored in message object n or message object n has been successfully transmitted, the CAN frame counter value NFCRx.CFC is then copied to CFCVAL.

Controller Area Network Controller (MultiCAN)

The Message Object Function Control Register MOFCR_n contains bits that select and configure the function of the message object. It also holds the CAN data length code.

MOFCR_n (n = 0-63)

Message Object n Function Control Register

(1000_H+n*20_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				DLC				STT	SDT	RMM	FRR EN	0	OVIE	TXIE	RXIE
rw				rwh				rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				DAT C	DLC C	IDC	GDF S	0				MMC			
rw				rw	rw	rw	rw	rw				rw			

Field	Bits	Type	Description
MMC	[3:0]	rw	Message Mode Control MMC controls the message mode of message object n. 0000 _B Standard Message Object 0001 _B Receive FIFO Base Object 0010 _B Transmit FIFO Base Object 0011 _B Transmit FIFO Slave Object 0100 _B Gateway Source Object ... _B Reserved
GDFS	8	rw	Gateway Data Frame Send 0 _B TXRQ is unchanged in the destination object. 1 _B TXRQ is set in the gateway destination object after the internal transfer from the gateway source to the gateway destination object. Applicable only to a gateway source object; ignored in other nodes.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
IDC	9	rw	Identifier Copy 0_B The identifier of the gateway source object is not copied. 1_B The identifier of the gateway source object (after storing the received frame in the source) is copied to the gateway destination object. Applicable only to a gateway source object; ignored in other nodes.
DLCC	10	rw	Data Length Code Copy 0_B Data length code is not copied. 1_B Data length code of the gateway source object (after storing the received frame in the source) is copied to the gateway destination object. Applicable only to a gateway source object; ignored in other nodes.
DATC	11	rw	Data Copy 0_B Data fields are not copied. 1_B Data fields in registers MODATALn and MODATAHn of the gateway source object (after storing the received frame in the source) are copied to the gateway destination. Applicable only to a gateway source object; ignored in other nodes.
RXIE	16	rw	Receive Interrupt Enable RXIE enables the message receive interrupt of message object n. This interrupt is generated after reception of a CAN message (independent of whether the CAN message is received directly or indirectly via a gateway action). 0_B Message receive interrupt is disabled. 1_B Message receive interrupt is enabled. Bit field MOIPRn.RXINP selects the interrupt output line which becomes activated at this type of interrupt.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
TXIE	17	rw	Transmit Interrupt Enable TXIE enables the message transmit interrupt of message object n. This interrupt is generated after the transmission of a CAN message. 0 _B Message transmit interrupt is disabled. 1 _B Message transmit interrupt is enabled. Bit field MOIPRn.TXINP selects the interrupt output line which becomes activated at this type of interrupt.
OVIE	18	rw	Overflow Interrupt Enable OVIE enables the FIFO full interrupt of message object n. This interrupt is generated when the pointer to the current message object (CUR) reaches the value of SEL in the FIFO/Gateway Pointer Register. 0 _B FIFO full interrupt is disabled. 1 _B FIFO full interrupt is enabled. If message object n is a Receive FIFO base object, bit field MOIPRn.TXINP selects the interrupt output line which becomes activated at this type of interrupt. If message object n is a Transmit FIFO base object, bit field MOIPRn.RXINP selects the interrupt output line which becomes activated at this type of interrupt. For all other message object modes, bit OVIE has no effect.
FRREN	20	rw	Foreign Remote Request Enable Specifies whether the TXRQ bit is set in message object n or in a foreign message object referenced by the pointer CUR. 0 _B TXRQ of message object n is set on reception of a matching Remote Frame. 1 _B TXRQ of the message object referenced by the pointer CUR is set on reception of a matching Remote Frame.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
RMM	21	rw	Transmit Object Remote Monitoring 0 _B Remote monitoring is disabled: Identifier, IDE bit, and DLC of message object n remain unchanged upon the reception of a matching Remote Frame. 1 _B Remote monitoring is enabled: Identifier, IDE bit, and DLC of a matching Remote Frame are copied to transmit object n in order to monitor incoming Remote Frames. Bit RMM applies only to transmit objects and has no effect on receive objects.
SDT	22	rw	Single Data Transfer If SDT = 1 and message object n is not a FIFO base object, then MSGVAL is reset when this object has taken part in a successful data transfer (receive or transmit). If SDT = 1 and message object n is a FIFO base object, then MSGVAL is reset when the pointer to the current object CUR reaches the value of SEL in the FIFO/Gateway Pointer Register. With SDT = 0, bit MSGVAL is not affected.
STT	23	rw	Single Transmit Trial If this bit is set, then TXRQ is cleared on transmission start of message object n. Thus, no transmission retry is performed in case of transmission failure.
DLC	[27:24]	rwh	Data Length Code Bit field determines the number of data bytes for message object n. Valid values for DLC are 0 to 8. A value of DLC > 8 results in a data length of 8 data bytes. If a frame with DLC > 8 is received, the received value is stored in the message object.
0	[7:4], [15:12], 19	rw	Reserved Read as 0 after reset; value last written is read back; should be written with 0.

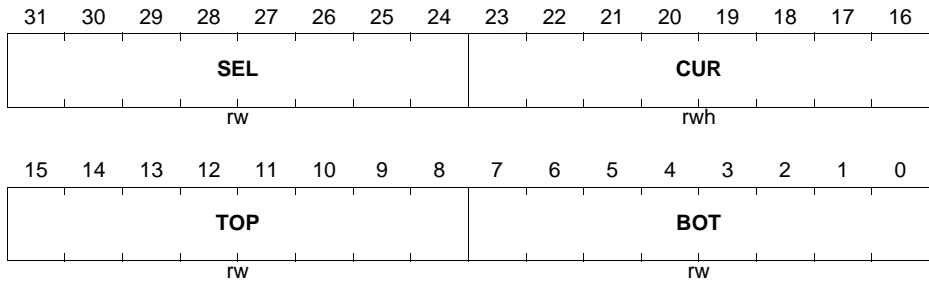
Controller Area Network Controller (MultiCAN)

The Message Object FIFO/Gateway Pointer register MOFGPRn contains a set of message object link pointers that are used for FIFO and gateway operations.

MOFGPRn (n = 0-63)

Message Object n FIFO/Gateway Pointer Register

 $(1004_H + n * 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
BOT	[7:0]	rw	Bottom Pointer Bit field BOT points to the first element in a FIFO structure.
TOP	[15:8]	rw	Top Pointer Bit field TOP points to the last element in a FIFO structure.
CUR	[23:16]	rwh	Current Object Pointer Bit field CUR points to the actual target object within a FIFO/Gateway structure. After a FIFO/gateway operation CUR is updated with the message number of the next message object in the list structure (given by PNEXT of the message control register) until it reaches the FIFO top element (given by TOP) when it is reset to the bottom element (given by BOT).
SEL	[31:24]	rw	Object Select Pointer Bit field SEL is the second (software) pointer to complement the hardware pointer CUR in the FIFO structure. SEL is used for monitoring purposes (FIFO interrupt generation).

Controller Area Network Controller (MultiCAN)

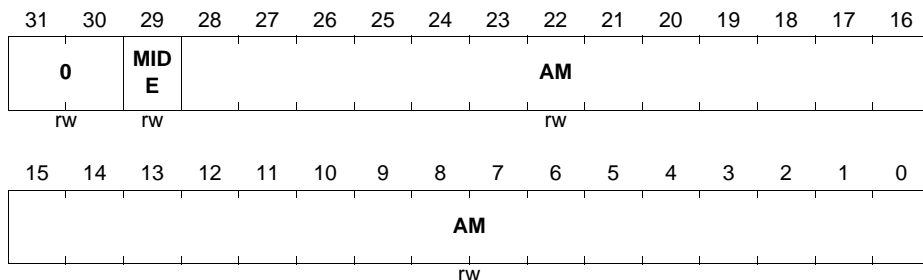
Message Object n Acceptance Mask Register MOAMRn contains the mask bits for the acceptance filtering of the message object n.

MOAMRn (n = 0-63)

Message Object n Acceptance Mask Register

(100C_H+n*20_H)

Reset Value: 3FFF FFFF_H



Field	Bits	Type	Description
AM	[28:0]	rw	Acceptance Mask for Message Identifier Bit field AM is the 29-bit mask for filtering incoming messages with standard identifiers (AM[28:18]) or extended identifiers (AM[28:0]). For standard identifiers, bits AM[17:0] are "don't care".
MIDE	29	rw	Acceptance Mask Bit for Message IDE Bit 0 _B Message object n accepts the reception of both, standard and extended frames. 1 _B Message object n receives frames only with matching IDE bit.
0	[31:30]	rw	Reserved Read as 0 after reset; value last written is read back; should be written with 0.

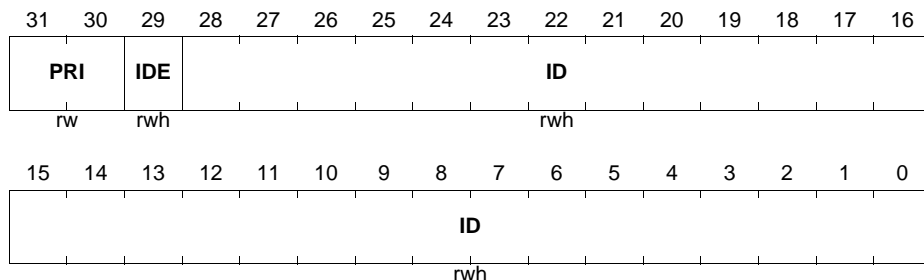
Controller Area Network Controller (MultiCAN)

Message Object n Arbitration Register MOARn contains the CAN identifier of the message object.

MOARn (n = 0-63)

Message Object n Arbitration Register

 $(1018_H + n \cdot 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ID	[28:0]	rwh	CAN Identifier of Message Object n Identifier of a standard message (ID[28:18]) or an extended message (ID[28:0]). For standard identifiers, bits ID[17:0] are “don’t care”.
IDE	29	rwh	Identifier Extension Bit of Message Object n 0 _B Message object n handles standard frames with 11-bit identifier. 1 _B Message object n handles extended frames with 29-bit identifier.

Controller Area Network Controller (MultiCAN)

Field	Bits	Type	Description
PRI	[31:30]	rw	<p>Priority Class</p> <p>PRI assigns one of the four priority classes 0, 1, 2, 3 to message object n. A lower PRI number defines a higher priority. Message objects with lower PRI value always win acceptance filtering for frame reception and transmission over message objects with higher PRI value. Acceptance filtering based on identifier/mask and list position is performed only between message objects of the same priority class. PRI also determines the acceptance filtering method for transmission:</p> <p>00_B Reserved.</p> <p>01_B Transmit acceptance filtering is based on the list order. This means that message object n is considered for transmission only if there is no other message object with valid transmit request (MSGVAL & TXEN0 & TXEN1 = 1) somewhere before this object in the list.</p> <p>10_B Transmit acceptance filtering is based on the CAN identifier. This means, message object n is considered for transmission only if there is no other message object with higher priority identifier + IDE + DIR (with respect to CAN arbitration rules) somewhere in the list (see Table 20-14).</p> <p>11_B Transmit acceptance filtering is based on the list order (as PRI = 01_B).</p>

Controller Area Network Controller (MultiCAN)

Transmit Priority of Msg. Objects based on CAN Arbitration Rules

Table 20-14 Transmit Priority of Msg. Objects Based on CAN Arbitration Rules

Settings of Arbitrarily Chosen Message Objects A and B, (A has higher transmit priority than B)	Comment
A.MOAR[28:18] < B.MOAR[28:18] (11-bit standard identifier of A less than 11-bit standard identifier of B)	Messages with lower standard identifier have higher priority than messages with higher standard identifier. MOAR[28] is the most significant bit (MSB) of the standard identifier. MOAR[18] is the least significant bit of the standard identifier.
A.MOAR[28:18] = B.MOAR[28:18] A.MOAR.IDE = 0 (send Standard Frame) B.MOAR.IDE = 1 (send Extended Frame)	Standard Frames have higher transmit priority than Extended Frames with equal standard identifier.
A.MOAR[28:18] = B.MOAR[28:18] A.MOAR.IDE = B.MOAR.IDE = 0 A.MOCTR.DIR = 1 (send Data Frame) B.MOCTR.DIR = 0 (send Remote Fame)	Standard Data Frames have higher transmit priority than standard Remote Frames with equal identifier.
A.MOAR[28:0] = B.MOAR[28:0] A.MOAR.IDE = B.MOAR.IDE = 1 A.MOCTR.DIR = 1 (send Data Frame) B.MOCTR.DIR = 0 (send Remote Frame)	Extended Data Frames have higher transmit priority than Extended Remote Frames with equal identifier.
A.MOAR[28:0] < B.MOAR[28:0] A.MOAR.IDE = B.MOAR.IDE = 1 (29-bit identifier)	Extended Frames with lower identifier have higher transmit priority than Extended Frames with higher identifier. MOAR[28] is the most significant bit (MSB) of the overall identifier (standard identifier MOAR[28:18] and identifier extension MOAR[17:0]). MOAR[0] is the least significant bit (LSB) of the overall identifier.

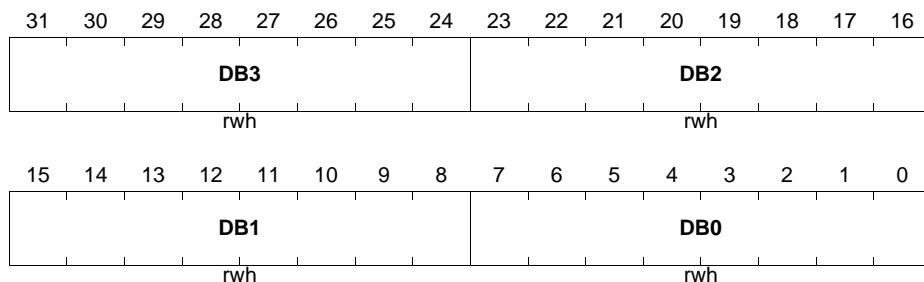
Controller Area Network Controller (MultiCAN)

Message Object n Data Register Low MODATALn contains the lowest four data bytes of message object n. Unused data bytes are set to zero upon reception and ignored for transmission.

MODATALn (n = 0-63)

Message Object n Data Register Low

 $(1010_H + n * 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
DB0	[7:0]	rwh	Data Byte 0 of Message Object n
DB1	[15:8]	rwh	Data Byte 1 of Message Object n
DB2	[23:16]	rwh	Data Byte 2 of Message Object n
DB3	[31:24]	rwh	Data Byte 3 of Message Object n

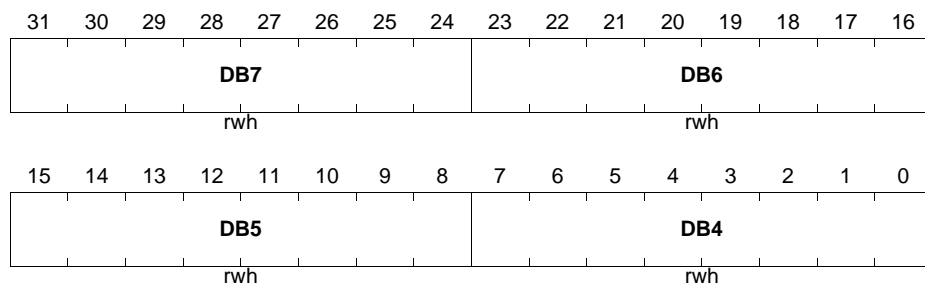
Controller Area Network Controller (MultiCAN)

Message Object n Data Register High MODATAH contains the highest four data bytes of message object n. Unused data bytes are set to zero upon reception and ignored for transmission.

MODATAHn (n = 0-63)

Message Object n Data Register High

 $(1014_H + n * 20_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
DB4	[7:0]	rwh	Data Byte 4 of Message Object n
DB5	[15:8]	rwh	Data Byte 5 of Message Object n
DB6	[23:16]	rwh	Data Byte 6 of Message Object n
DB7	[31:24]	rwh	Data Byte 7 of Message Object n

Controller Area Network Controller (MultiCAN)

20.5 MultiCAN Module Implementation

This section describes CAN module interfaces with the clock control, port connections, interrupt control, and address decoding.

20.5.1 Interfaces of the MultiCAN Module

Figure 20-24 shows the TC1728 specific implementation details and interconnections of the MultiCAN module. The four I/O lines of the MultiCAN module (two I/O lines of each CAN node) are connected to I/O lines of Port 3. The MultiCAN module is also supplied by clock control, interrupt control, and address decoding logic. MultiCAN interrupts can be directed to the DMA controller and the GPTA modules. CAN interrupts are able to trigger DMA transfers and GPTA operations.

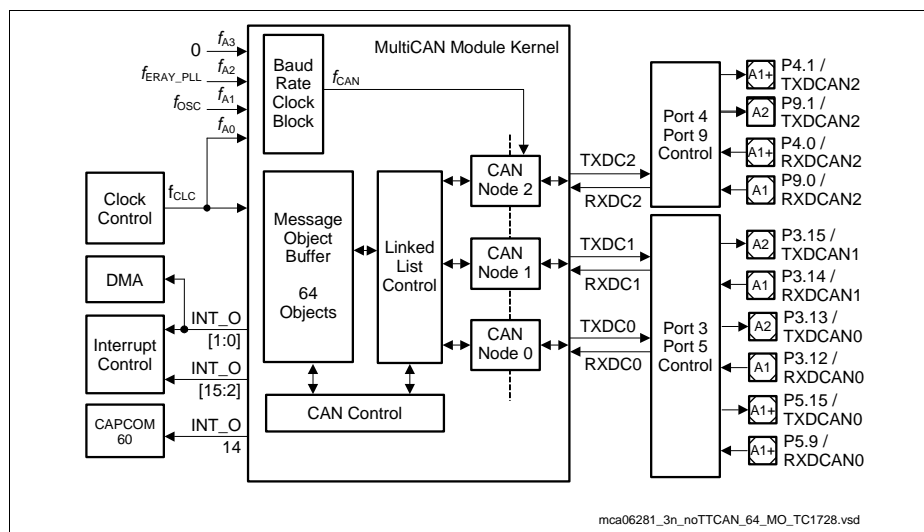


Figure 20-24 CAN Module Implementation and Interconnections

Controller Area Network Controller (MultiCAN)

20.5.2 MultiCAN Module External Registers

The registers listed in [Figure 20-25](#) are not included in the MultiCAN module kernel but must be programmed for proper operation of the MultiCAN module.

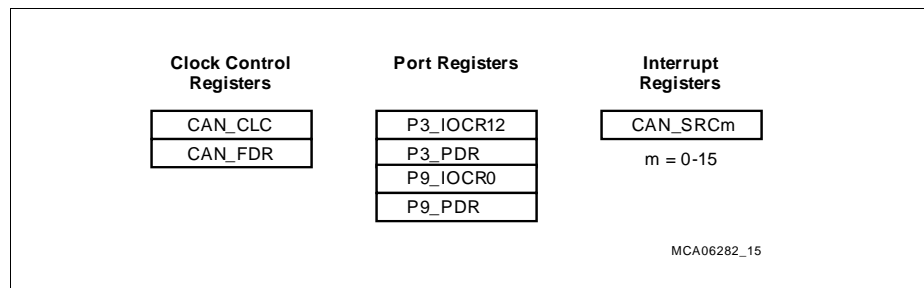


Figure 20-25 CAN Implementation-specific Special Function Registers

Controller Area Network Controller (MultiCAN)

20.5.3 Module Clock Generation

20.5.3.1 Clock Selection

The bit timing machine and the rest of the MultiCAN module are separate frequency domains and can be driven by separate independent frequencies. The bit timing unit can be driven by the FPI bus clock or with the direct oscillator clock, and the rest of the chip is driven only by the FPI bus clock.

The purpose of supplying the bit timing unit with a direct oscillator clock is to avoid the clock jitter added by the PLL, necessary when the chip is driven by a low cost ceramic resonator instead of by high precision quartz crystal.

Selecting the clock source for the bit timing unit is done by programming the bit-field MCR.CLKSEL.

Enabling and disabling the clock of the module by using CLC.DISR affects always both frequency domains, so that when f_{CLC} is switched off, f_A is also switched off.

20.5.3.2 Fractional Divider

As shown in [Figure 20-26](#), the clock signals for the MultiCAN module are generated and controlled by a clock control unit. This clock generation unit is responsible for the enable/disable control, the clock frequency adjustment, and the debug clock control. This unit includes two registers:

- CAN_CLC: generation of the module control clock f_{CLC}
- CAN_FDR: frequency control of the module timer clock f_{CAN}

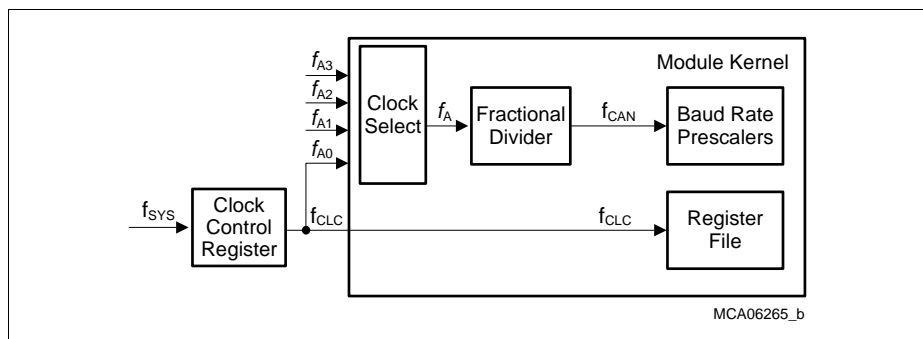


Figure 20-26 MultiCAN Module Clock Generation

The module control clock f_{CLC} is used inside the MultiCAN module for control purposes such as clocking of control logic and register operations. The frequency of f_{CLC} is

Controller Area Network Controller (MultiCAN)

identical to the system clock frequency f_{SYS} . The clock control register CAN_CLC makes it possible to enable/disable f_{CLC} under certain conditions.

The module timer clock f_{CAN} is used inside the MultiCAN module as input clock for all timing relevant operations (e.g. bit timing). The settings in the CAN_FDR register determine the frequency of the module timer clock f_{CAN} according the following two formulas:

$$f_{\text{CAN}} = f_{\text{A}} \times \frac{1}{n} \quad \text{with } n = 1024 - \text{CAN_FDR.STEP} \quad (20.2)$$

$$f_{\text{CAN}} = f_{\text{A}} \times \frac{n}{1024} \quad \text{with } n = 0-1023 \quad (20.3)$$

Equation (20.2) applies to normal divider mode (CAN_FDR.DM = 01_B) of the fractional divider. **Equation (20.3)** applies to fractional divider mode (CAN_FDR.DM = 10_B).

Note: The CAN module is disabled after reset. In general, after reset, the module control clock f_{CLC} must be switched on (writing to register CAN_CLC) before the frequency of the module timer clock f_{CAN} is defined (writing to register CAN_FDR).

Controller Area Network Controller (MultiCAN)

CAN Clock Control Register

The clock control registers makes it possible to control (enable/disable) the module control clock f_{CLC} .

CAN_CLC

CAN Clock Control Register

(000_H)

Reset Value: 0000 0003_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
r										rw	w	rw	rw	r	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode.
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE ¹⁾	5	rw	Fast Switch Off Enable Used to switch off fast clock in Suspend Mode.
0	[31:6]	r	Reserved Read as 0; should be written with 0.

1) In Secure shut off mode (FSOE=1), the transmit is brought to recessive state and does not continue an ongoing CAN frame.

Note: In disabled state, no registers of CAN module can be read or written except the CAN_CLC register.

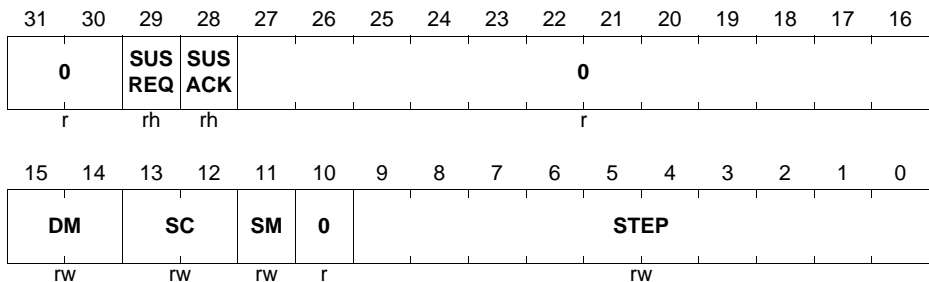
Controller Area Network Controller (MultiCAN)

The fractional divider register allows the programmer to control the clock rate of the module timer clock f_{CAN} .

CAN_FDR

CAN Fractional Divider Register

(00C_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value Reload or addition value for the result.
SM	11	rw	Suspend Mode SM selects between granted or immediate Suspend Mode.
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in Suspend Mode.
DM	[15:14]	rw	Divider Mode This bit field selects normal divider mode, fractional divider mode, and off-state.
SUSACK	28	rh	Suspend Mode Acknowledge Indicates state of SPNDACK signal.
SUSREQ	29	rh	Suspend Mode Request Indicates state of SPND signal.
0	10	rw	Reserved Read as 0; should be written with 0.
0	[27:16], [31:30]	r	Reserved Read as 0; should be written with 0.

Controller Area Network Controller (MultiCAN)

20.5.4 Port and I/O Line Control

The interconnections between the MultiCAN module and the port I/O lines are controlled in the port logic. Additionally to the port input selection, the following port control operations must be executed:

- Input/output function selection (IOCR registers)
- Pad driver characteristics selection for the outputs (PDR registers)

20.5.4.1 Input/Output Function Selection in Ports

The port input/output control registers contain the bit fields that select the digital output and input driver characteristics such as pull-up/down devices, port direction (input/output), open-drain, and alternate output selections. The I/O lines for the MultiCAN module are controlled by the port input/output control registers P3_IOCR12 and P9_IOCR0.

Table 20-15 shows how bits and bit fields must be programmed for the required I/O functionality of the CAN I/O lines.

Table 20-15 MultiCAN I/O Control Selection and Setup

Module	Port Lines	Input/Output Control Register Bits	I/O
CAN	P3.12 / RXDCAN0	P3_IOCR12.PC12 = 0XXX _B	Input
	P3.13 / TXDCAN0	P3_IOCR12.PC13 = 1X01 _B	Output
	P5.9 / RXDCAN0	P5_IOCR8.PC9 = 0XXX _B	Input
	P5.15 / TXDCAN0	P5_IOCR12.PC15 = 1X11 _B	Output
	P3.14 / RXDCAN1	P3_IOCR12.PC14 = 0XXX _B	Input
	P3.15 / TXDCAN1	P3_IOCR12.PC15 = 1X01 _B	Output
	P9.0 / RXDCAN2	P9_IOCR0.PC0 = 0XXX _B	Input
	P9.1 / TXDCAN2	P9_IOCR0.PC1 = 1X01 _B	Output
	P4.0 / RXDCAN2	P4_IOCR0.PC0 = 0XXX _B	Input
	P4.1 / TXDCAN2	P4_IOCR0.PC1 = 1X11 _B	Output

20.5.4.2 Node Receive Input Selection

Additionally to the I/O control selection, as defined in **Table 20-15**, the selection of a CAN node's receive input line requires that bit field RXSEL in its node port control register NPCRx must be set according to **Table 20-16**. Values for NPCRx.RXSEL other than those of **Table 20-16** result in a recessive receive input for node x.

Controller Area Network Controller (MultiCAN)

This feature allows, for example, a CAN node which operates in analyzer mode to monitor the receive operations of its neighbor CAN node. The default setting after reset of a node's NPCRx.RXSEL bit field connect node x with RXDCANx I/O line (x = 0-2).

Table 20-16 Receive Input Selection

Receive Input of	Connected to	Selected by
CAN Node 0	P3.12 / RXDCAN0	NPCR0.RXSEL = 000 _B
	P3.14 / RXDCAN1	NPCR0.RXSEL = 001 _B
	P5.9 / RXDCAN0	NPCR0.RXSEL = 010 _B
CAN Node 1	P3.14 / RXDCAN1	NPCR1.RXSEL = 000 _B
	P3.12 / RXDCAN0	NPCR1.RXSEL = 001 _B
	P9.0 / RXDCAN2	NPCR1.RXSEL = 010 _B
	P5.9 / RXDCAN0	NPCR1.RXSEL = 011 _B
	P4.0 / RXDCAN2	NPCR1.RXSEL = 100 _B
CAN Node 2	P9.0 / RXDCAN2	NPCR2.RXSEL = 000 _B
	P3.12 / RXDCAN0	NPCR2.RXSEL = 001 _B
	P4.0 / RXDCAN2	NPCR2.RXSEL = 010 _B
	P5.9 / RXDCAN0	NPCR2.RXSEL = 011 _B

Controller Area Network Controller (MultiCAN)

20.5.4.3 External CAN Time Trigger Inputs

The external CAN time trigger inputs ECTT[7:1] can be used as a transmit trigger for a reference message. In the TC1728, these input lines are connected as shown in [Table 20-17](#).

Table 20-17 External CAN Time Trigger Inputs

Receive Input	Connected to	From / to Module
ECTT1	P3.8 / REQ14	Port 3 / External Request Unit (SCU)
ECTT2	P0.11 / REQ9	Port 0 / External Request Unit (SCU)
ECTT3	Output OUT5	GPTA0
ECTT4	Output IOUT2	External Request Unit (SCU)
ECTT5	Output IOUT3	External Request Unit (SCU)
ECTT6	-	-
ECTT7	-	-

20.5.4.4 DMA Request Outputs

The interrupt output lines INT_O0 to INT_O1 of the MultiCAN module can be used as a DMA requestor and are able to trigger DMA transfers. INT_O[1:0] are connected to the DMA controller as shown in [Table 20-18](#).

Table 20-18 CAN-to-DMA Request Connections

DMA Channel	Connected to CAN Interrupt Output	Selected in DMA Controller by programming
06	INT_O0	CHCR06.PRSEL = 011 _B
07	INT_O1	CHCR07.PRSEL = 010 _B

20.5.4.5 Connectons to GPTA0 Inputs

The interrupt output line INT_O15 is connected to the GPTA module, see [Table 20-19](#).

Table 20-19 CAN-to-GPTA0 Request Connections

GPTA Input	Connected to CAN Interrupt Output
INT0	INT_O15

Controller Area Network Controller (MultiCAN)**20.5.4.6 Connectons to CAPCOM6 Inputs**

The interrupt output line INT_O14 is connected to the CAPCOM60 module, see [Table 20-20](#).

Table 20-20 CAN-to-CAPCOM60 Connections

CAPCOM6 Input	Connected to CAN Interrupt Output
CCU60_CC61IND	INT_O14

20.5.5 Interrupt Control

The interrupt control logic in the MultiCAN module uses an interrupt compressing scheme that allows high flexibility in interrupt processing. There are 140 hardware interrupt sources and one software interrupt source available:

- CAN node interrupts:
 - Four different interrupt sources for each of the three CAN nodes = 12 interrupt sources
- Message object interrupts:
 - Two interrupt source for each message object = 128 interrupt sources
- One software initiated interrupt (register MITR)

Each of the 140 hardware initiated interrupt sources is controlled by a 4-bit interrupt pointer that directs the interrupt source to one of the sixteen interrupt outputs INT_Om (m = 0-15). This makes it possible to connect more than one interrupt source (between one and all) to one interrupt output line. The interrupt wiring matrix shown in **Figure 20-27** is built up according to the following rules:

- Each output of the 4-bit interrupt pointer demultiplexer is connected to exactly one OR-gate input of the INT_Om line. The number “m” of the corresponding selected INT_Om interrupt output line is defined by the interrupt pointer value.
- Each INT_Om output line has an input OR gate which is connected to all interrupt pointer demultiplexer outputs which are selected by an identical 4-bit pointer value.

Controller Area Network Controller (MultiCAN)

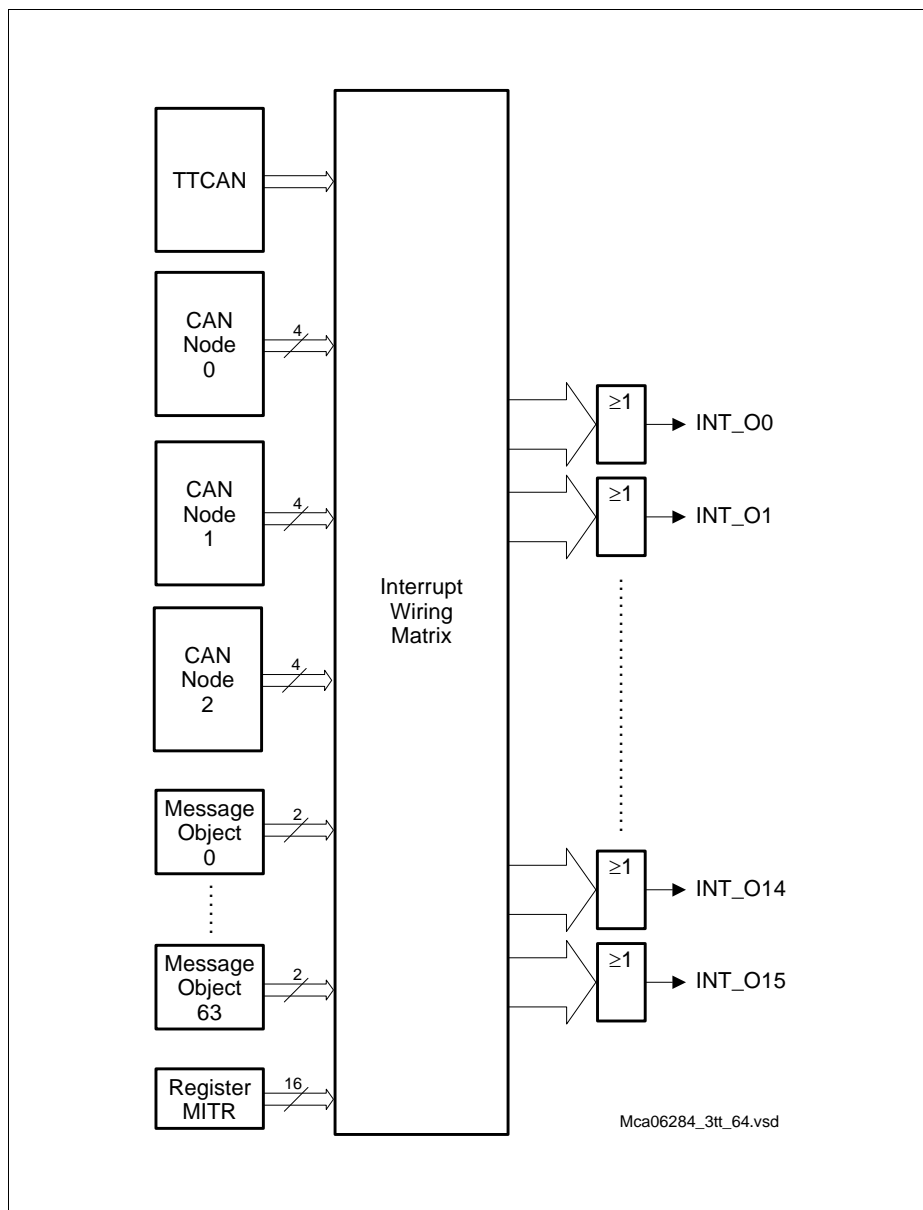


Figure 20-27 Interrupt Compressor

Controller Area Network Controller (MultiCAN)

20.5.5.1 CAN Service Request Control Register

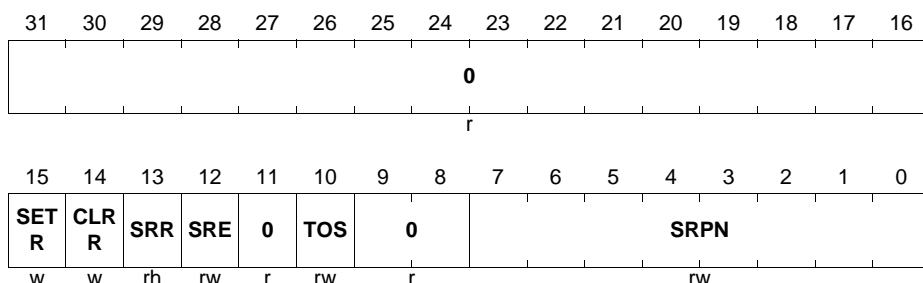
Each of the sixteen interrupt outputs INT_Om of the MultiCAN module is controlled by its service request control registers.

CAN_SRCm (m = 0-15)

CAN Service Request Control Register m

(0FC_H-m*4_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Note: Additional details on service request nodes and the service request control registers are described in section “Service Request Nodes” of the TC1728 System Units part.

Some of the sixteen interrupt outputs of the MultiCAN module can be used to trigger operations in the DMA controller.

20.5.6 MultiCAN Module Register Address Map

In addition to the MultiCAN register address map from [Page 20-59](#), the complete MultiCAN module register address map of [Figure 20-28](#) also shows the general implementation-specific registers for clock control, module identification, and interrupt service request control and adds the absolute address information. [The address map of TTCAN registers only is shown in Figure 0-16.](#)

Controller Area Network Controller (MultiCAN)

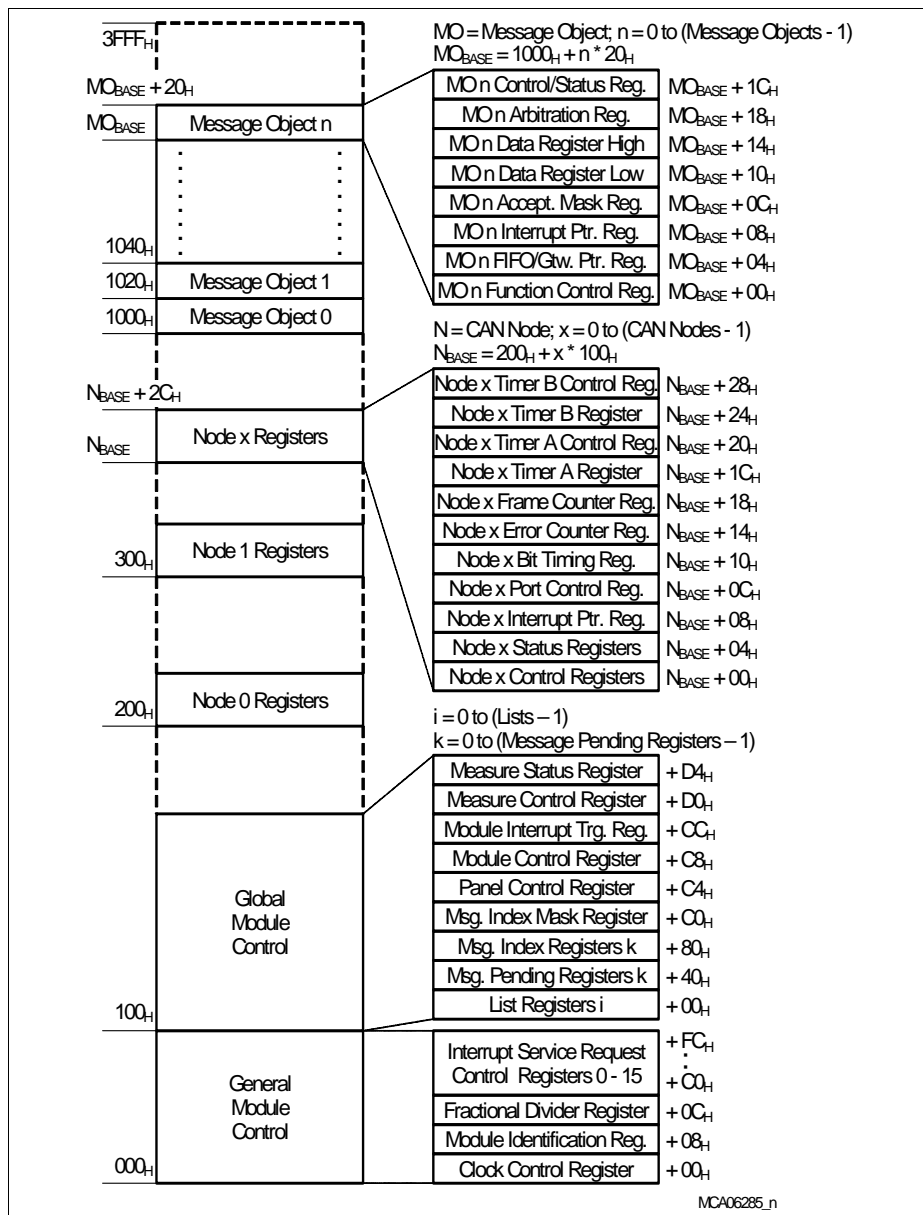


Figure 20-28 MultiCAN Module Register Map, without TTCAN registers

FlexRay™ Protocol Controller (E-Ray)

21 FlexRay™ Protocol Controller (E-Ray)

The E-Ray IP-module performs communication according to the FlexRay™ ¹⁾ protocol specification v2.1. With maximum specified clock the bitrate can be programmed to values up to 10 Mbit/s. Additional bus driver (BD) hardware is required for connection to the physical layer.

21.1 E-Ray Kernel Description

Figure 21.1 shows a global view of the E-Ray interface.

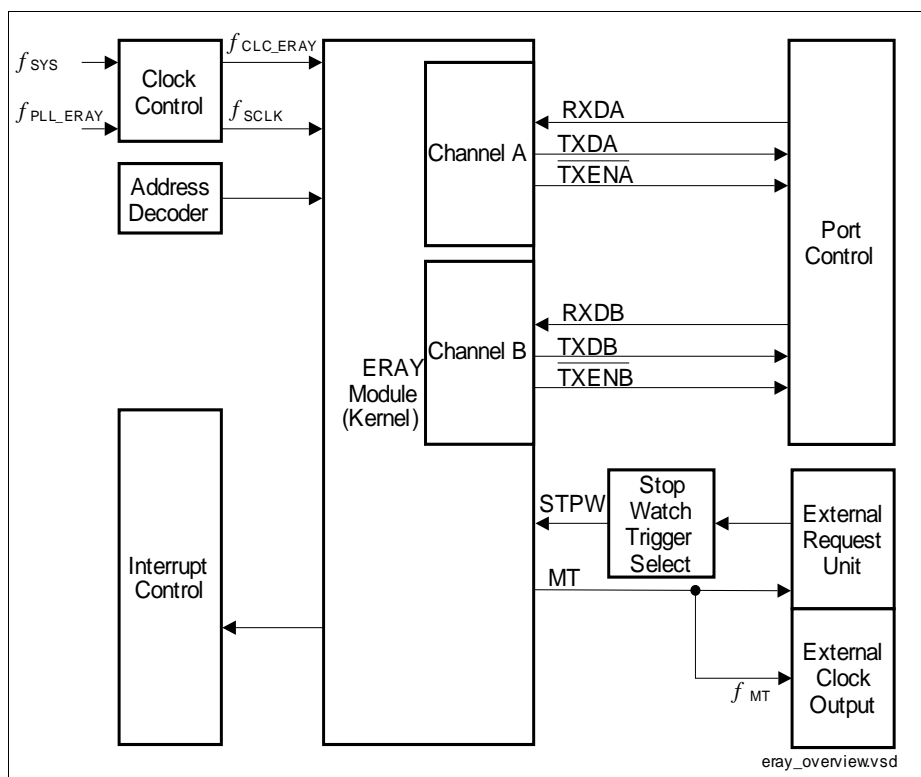


Figure 11 General Block Diagram of the E-Ray Interface

1) Infineon®, Infineon Technologies®, are trademarks of Infineon Technologies AG. FlexRay™ is a trademark of FlexRay Consortium.

FlexRay™ Protocol Controller (E-Ray)

The E-Ray module communicates with the external world via three I/O lines each channel. The RXDAx and RXDBx lines are the receive data input signals, TXDA and TXDB lines are the transmit output signals, TXENA and TXENB the transmit enable signals.

Clock control, address decoding, and service request control are managed outside the E-Ray module kernel.

21.2 Overview

For communication on a FlexRay™ network, individual Message Buffers with up to 254 data byte are configurable. The message storage consists of a single-ported Message RAM that holds up to 128 Message Buffers. All functions concerning the handling of messages are implemented in the Message Handler. Those functions are the acceptance filtering, the transfer of messages between the two FlexRay™ Channel Protocol Controllers and the Message RAM, maintaining the transmission schedule as well as providing message status information.

The register set of the E-Ray IP-module can be accessed directly by an external Host via the module's Host interface. These registers are used to control/configure/monitor the FlexRay™ Channel Protocol Controllers, Message Handler, Global Time Unit, System Universal Control, Frame and Symbol Processing, Network Management, Service Request Control, and to access the Message RAM via Input / Output Buffer.

The E-Ray IP-module supports the following features:

- Conformance with FlexRay™ protocol specification v2.1
- Data rates of up to 10 Mbit/s on each channel
- Up to 128 Message Buffers configurable
- 8 Kbyte of Message RAM for storage of e.g. 128 Message Buffers with max. 48 byte data field or up to 30 Message Buffers with 254 byte Data Sections
- Configuration of Message Buffers with different payload lengths possible
- One configurable receive FIFO
- Each Message Buffer can be configured as receive buffer, as transmit buffer or as part of the receive FIFO
- Host access to Message Buffers via Input and Output Buffer.
Input Buffer: Holds message to be transferred to the Message RAM
Output Buffer: Holds message read from the Message RAM
- Filtering for slot counter, cycle counter, and channel
- Maskable module service requests
- Network Management supported
- Four service request lines
- Automatic delayed read access to Output Command Request Register (OBCR) if a data transfer from Message RAM to Output Shadow Buffer (initiated by a previous write access to the OBCR) is ongoing.

FlexRay™ Protocol Controller (E-Ray)

- Automatic delayed read access to Input Command Request Register (IBCR) if a data transfer from Input Shadow Buffer to Message RAM to (initiated by a previous write access to the IBCR) is ongoing.
- Four Input Buffer for building up transmission Frames in parallel.
- Flag indicating which Input Buffer is currently accessible by the host.

21.3 Definitions

FlexRay™ Frame: Header Segment + Payload Segment

Message Buffer: Header Section + Data Section

Message RAM: Header Partition + Data Partition

Data Frame: FlexRay™ Frame that is not a NULL Frame

21.4 Block Diagram

The E-Ray is built up by the following main submodules:

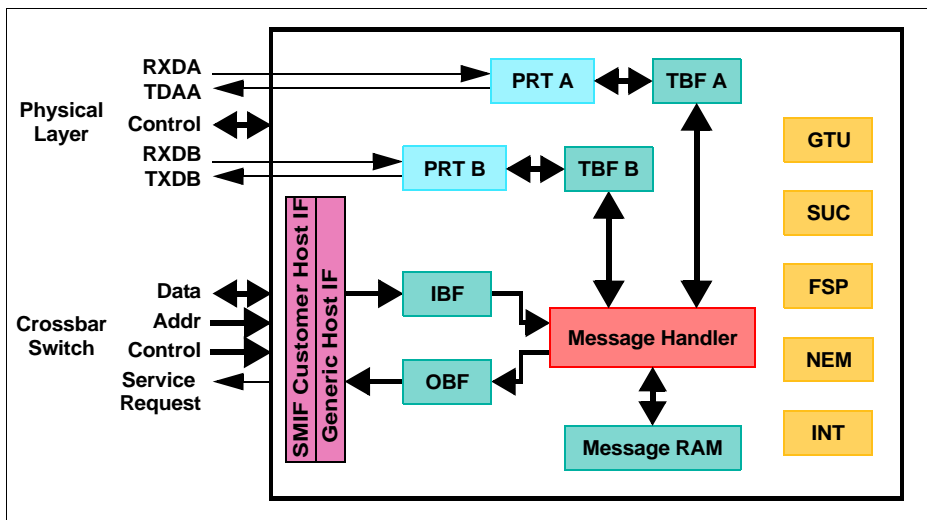


Figure 12 E-Ray Block Diagram

Customer Host Interface (CIF)

Connects the FPI Bus to the E-Ray IP-module via the Generic Host Interface.

FlexRay™ Protocol Controller (E-Ray)**Generic Host Interface (GIF)**

The E-Ray IP-module is provided with an 8/16/32-bit Generic Host Interface prepared for the connection to a wide range of customer-specific Hosts. Configuration registers, status registers, and service request registers are attached to the respective blocks and can be accessed via the Generic Host Interface.

Input Buffer (IBF)

For write access to the Message Buffers configured in the Message RAM, the Host can write the Header and Data Section for a specific Message Buffer to the Input Buffer. The Message Handler then transfers the data from the Input Buffer to the selected Message Buffer in the Message RAM.

Because the Input Buffer (IBF) Scheme does only allow to write the entire Message Frame, not only parts of it, the number of IBF has been increased from originally 2 to 4. This enables to fill the buffer partly and at the end request transfer into Message RAM. Therefore 2 extra bits allow to switch between the two banks of IBF and one status bit signals the IBF currently active for Host writes.

Output Buffer (OBF)

For read access to a Message Buffer configured in the Message RAM the Message Handler transfers the selected Message Buffer to the Output Buffer. After the transfer has completed, the Host can read the Header and Data Section of the transferred Message Buffer from the Output Buffer.

Message Handler (MHD)

The E-Ray Message Handler controls data transfers between the following components:

- Input / Output Buffer and Message RAM
- Transient Buffer RAMs of the two FlexRay™ Protocol Controllers and Message RAM

Message RAM (MRAM)

The Message RAM consists of a single-port RAM that stores up to 128 FlexRay™ Message Buffers together with the related configuration data (Header and Data Partition).

Transient Buffer RAM (TBF 1/2)

Stores the Data Section of two complete messages.

FlexRay™ Protocol Controller (E-Ray)

FlexRay™ Channel Protocol Controller (PRT A/B)

The FlexRay™ Channel Protocol Controllers consist of shift register and FlexRay™ protocol FSM. They are connected to the Transient Buffer RAMs for intermediate message storage and to the physical layer via bus driver BD.

They perform the following functionality:

- Control and check of bit timing
- Reception and transmission of FlexRay™ Frames and symbols
- Check of Header CRC
- Generation / check of Frame CRC
- Interfacing to bus driver

The FlexRay™ Channel Protocol Controllers have interfaces to:

- Physical Layer (bus driver)
- Transient Buffer RAM
- Message Handler
- Global Time Unit
- System Universal Control
- Frame and Symbol Processing
- Network Management
- Service Request Control

Global Time Unit (GTU)

The Global Time Unit performs the following functions:

- Generation of Microtick
- Generation of Macrotick
- Fault tolerant clock synchronization by FTM algorithm
 - Rate correction
 - Offset correction
- Cycle counter
- Timing control of static segment
- Timing control of dynamic segment (minislotting)
- Support of external clock correction

System Universal Control (SUC)

The System Universal Control controls the following functions:

- Configuration
- Wakeup
- Startup
- Normal Operation
- Passive Operation
- Monitor Mode

Frame and Symbol Processing (FSP)

The Frame and Symbol Processing controls the following functions:

- Checks the correct timing of Frames and symbols
- Tests the syntactical and semantical correctness of received Frames
- Sets the slot status flags

Network Management (NEM)

Handles of the Network Management vector

Service Request Control (INT)

The Service Request Controller performs the following functions:

- Provides error and status service request flags
- Enables and disables service request sources
- Assignment of service request sources to one of the two module service request lines
- Enables and disables module service request lines
- Manages the two service request timers
- Stop watch time capturing

21.5 Programmer's Model

The programmer's model of the E-Ray module follows the principle of memory mapped peripheral. Some portion of the memory follows the principle of segmented/paged memory organization.

21.5.1 Register Map

The E-Ray module allocates an address space of 4 Kbyte (000_H to FFFF_H). The registers are organized as 32-bit registers. 8/16-bit accesses are also supported. Host access to the Message RAM is done via the Input and Output Buffers. They buffer data to be transferred to and from the Message RAM under control of the Message Handler, avoiding conflicts between Host accesses and message reception / transmission. Addresses 0004_H - 000F_H, 03C8_H - 03EC_H and 0800_H - 0FFF_H are reserved for customer specific purposes. All functions related to these addresses are located in the Customer Host Interface. The test registers located on address 0010_H and 0014_H are writeable only under the conditions described in **“Special Registers” on Page 24**.

The assignment of the Message Buffers is done according to the scheme shown in **Table 42** below. The number N of available Message Buffers depends on the payload length of the configured Message Buffers. The maximum number of Message Buffers is 128. The maximum payload length supported is 254 byte.

The Message Buffers are separated into three consecutive groups:

- Static Buffers: Transmit / Receive Buffers assigned to static segment

FlexRay™ Protocol Controller (E-Ray)

- Static and Dynamic Buffers: Transmit / Receive Buffers assigned to static or dynamic segment
- FIFO- Receive FIFO

The Message Buffer separation configuration can be changed only in “DEFAULT_CONFIG” or “CONFIG” state only by programming the Message RAM Configuration register (MRC).

The first group starts with Message Buffer 0 and consists of static Message Buffers only. Message Buffer 0 is dedicated to hold the startup / SYNC Frame or the single slot Frame, if node transmit one, as configured by SUCC1.TXST, SUCC1.TXSY, and SUCC1.TSM in the SUC Configuration Register 1 (SUCC1). In addition, Message Buffer 1 may be used for SYNC Frame transmission in case that SYNC Frames or single-slot Frames should have different payloads on the two channels. In this case bit MRC.SPLM has to be programmed to 1 and Message Buffers 0 and 1 have to be configured with the key slot ID and can be (re)configured in “DEFAULT_CONFIG” or “CONFIG” state only.

The second group consists of Message Buffers assigned to the static or to the dynamic segment. Message Buffers belonging to this group may be reconfigured during run time from dynamic to static or vice versa depending on the state of MRC.SEC.

The Message Buffers belonging to the third group are concatenated to a single receive FIFO.

Table 42 Assignment of Message Buffers

Message Buffer 0	⇓ Static Buffers	
Message Buffer 1		
...		
	⇓ Static + Dynamic Buffers	⇐ FDB
	⇓ FIFO	⇐ FFB
Message Buffer N-1		
Message Buffer N		⇐ LCB

21.5.2 E-Ray Kernel Registers

This chapter describes all registers of the E-Ray kernel.

Table 43 Registers Address Space E-Ray Kernel Register Address Space

Module	Base Address	End Address	Note
ERAY	F0010000 _H	F0010FFF _H	4Kbyte

Table 44 Registers OverviewE-Ray Kernel Registers

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		

Customer Registers

CLC	E-Ray Clock Control Register	0000 _H	SV,U	SV,E	3	Page 270
CUST1	Busy and Input Buffer Control Register	0004 _H	SV,U	SV,U	3	Page 18
ID	Module Identification Register	0008 _H	SV,U	SV,U	3	Page 17
CUST3	Customer Interface Timeout Counter	000C _H	SV,U	SV,U	3	Page 21

Special Registers

TEST1	Test Register 1	0010 _H	SV,U	SV,U	3	Page 24
TEST2	Test Register 2	0014 _H	SV,U	SV,U	3	Page 29
-	Reserved	0018 _H	nBE	nBE	-	-
LCK	Lock Register	001C _H	SV,U	SV,U	3	Page 40

Service Request Registers

EIR	Error Service Request Register	0020 _H	SV,U	SV,U	3	Page 42
SIR	Status Service Request Register	0024 _H	SV,U	SV,U	3	Page 48
EILS	Error Service Request Line Select	0028 _H	SV,U	SV,U	3	Page 53
SILS	Status Service Request Line Select	002C _H	SV,U	SV,U	3	Page 57

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Table 44 **Registers OverviewE-Ray Kernel Registers (cont'd)**

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
EIES	Error Service Request Enable Set	0030 _H	SV,U	SV,U	3	Page 61
EIER	Error Service Request Enable Reset	0034 _H	SV,U	SV,U	3	Page 66
SIES	Status Service Request Enable Set	0038 _H	SV,U	SV,U	3	Page 71
SIER	Status Service Request Enable Reset	003C _H	SV,U	SV,U	3	Page 76
ILE	Service Request Line Enable	0040 _H	SV,U	SV,U	3	Page 81
T0C	Timer 0 Configuration	0044 _H	SV,U	SV,U	3	Page 82
T1C	Timer 1 Configuration	0048 _H	SV,U	SV,U	3	Page 84
STPW1	Stop Watch Register 1	004C _H	SV,U	SV,U	3	Page 86
STPW2	Stop Watch Register 2	0050 _H	SV,U	SV,U	3	Page 88
-	Reserved	0054 _H - 007C _H	nBE	nBE	-	-

Communication Controller Control Registers

SUCC1	SUC Configuration Register 1	0080 _H	SV,U	SV,U	3	Page 89
SUCC2	SUC Configuration Register 2	0084 _H	SV,U	SV,U	3	Page 97
SUCC3	SUC Configuration Register 3	0088 _H	SV,U	SV,U	3	Page 98
NEMC	NEM Configuration Register	008C _H	SV,U	SV,U	3	Page 99
PRTC1	PRT Configuration Register 1	0090 _H	SV,U	SV,U	3	Page 100
PRTC2	PRT Configuration Register 2	0094 _H	SV,U	SV,U	3	Page 102
MHDC	MHD Configuration Register	0098 _H	SV,U	SV,U	3	Page 103
-	Reserved	009C _H	nBE	nBE	-	-

FlexRay™ Protocol Controller (E-Ray)

Table 44 **Registers OverviewE-Ray Kernel Registers** (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
GTUC01	GTU Configuration Register 1	00A0 _H	SV,U	SV,U		Page 104
GTUC02	GTU Configuration Register 2	00A4 _H	SV,U	SV,U	3	Page 105
GTUC03	GTU Configuration Register 3	00A8 _H	SV,U	SV,U	3	Page 106
GTUC04	GTU Configuration Register 4	00AC _H	SV,U	SV,U	3	Page 107
GTUC05	GTU Configuration Register 5	00B0 _H	SV,U	SV,U	3	Page 108
GTUC06	GTU Configuration Register 6	00B4 _H	SV,U	SV,U	3	Page 109
GTUC07	GTU Configuration Register 7	00B8 _H	SV,U	SV,U	3	Page 110
GTUC08	GTU Configuration Register 8	00BC _H	SV,U	SV,U	3	Page 111
GTUC09	GTU Configuration Register 9	00C0 _H	SV,U	SV,U	3	Page 112
GTUC10	GTU Configuration Register 10	00C4 _H	SV,U	SV,U	3	Page 113
GTUC11	GTU Configuration Register 11	00C8 _H	SV,U	SV,U	3	Page 114
-	Reserved	00CC _H - 00FC _H	nBE	nBE	-	-

Communication Controller Status Registers

CCSV	Communication Controller Status Vector	0100 _H	SV,U	nBE	3	Page 116
CCEV	Communication Controller Error Vector	0104 _H	SV,U	nBE	3	Page 121
-	Reserved	0108 _H	nBE	nBE	-	-
-	Reserved	010C _H	nBE	nBE	-	-
SCV	Slot Counter Value	0110 _H	SV,U	nBE	3	Page 122

FlexRay™ Protocol Controller (E-Ray)

Table 44 **Registers OverviewE-Ray Kernel Registers** (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
MTCCV	Macrotick and Cycle Counter Value	0114 _H	SV,U	nBE	3	Page 123
RCV	Rate Correction Value	0118 _H	SV,U	nBE	3	Page 124
OCV	Offset Correction Value	011C _H	SV,U	nBE	3	Page 125
SFS	SYNC Frame Status	0120 _H	SV,U	nBE	3	Page 126
SWNIT	Symbol Window and Network Idle Time Status	0124 _H	SV,U	nBE	3	Page 128
ACS	Aggregated Channel Status	0128 _H	SV,U	SV,U	3	Page 131
-	Reserved	012C _H	nBE	nBE	-	-
ESIDnn	Even Sync ID Symbol Window nn	0130 _H - 0168 _H	SV,U	nBE	3	Page 134
-	Reserved	016C _H	SV,U	nBE	-	-
OSIDnn	Odd Sync ID Symbol Window nn	0170 _H - 01A8 _H	SV,U	nBE	3	Page 136
-	Reserved	01AC _H	SV,U	nBE	-	-
NMVx	Network Management Vector [1...3]	01B0 _H - 01B8 _H	SV,U	nBE	3	Page 138
-	Reserved	01BC _H - 02FC _H	nBE	nBE	-	-

Message Buffer Control Registers

MRC	Message RAM Configuration	0300 _H	SV,U	SV,U	3	Page 139
FRF	FIFO Rejection Filter	0304 _H	SV,U	SV,U	3	Page 142
FRFM	FIFO Rejection Filter Mask	0308 _H	SV,U	SV,U	3	Page 144
FCL	FIFO Critical Level	030C _H	SV,U	SV,U	3	Page 145

Message Buffer Status Registers

MHDS	Message Handler Status	0310 _H	SV,U	SV,U	3	Page 146
LDS	Last Dynamic Transmit Slot	0314 _H	SV,U	SV,U	3	Page 149

FlexRay™ Protocol Controller (E-Ray)

Table 44 **Registers OverviewE-Ray Kernel Registers** (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
FSR	FIFO Status Register	0318 _H	SV,U	SV,U	3	Page 150
MHDF	Message Handler Constraints Flags	031C _H	SV,U	nBE	3	Page 152
TXRQ1	Transmission Request Register 1	0320 _H	SV,U	nBE	3	Page 155
TXRQ2	Transmission Request Register 2	0324 _H	SV,U	nBE	3	Page 156
TXRQ3	Transmission Request Register 3	0328 _H	SV,U	nBE	3	Page 157
TXRQ4	Transmission Request Register 4	032C _H	SV,U	nBE	3	Page 158
NDAT1	New Data Register 1	0330 _H	SV,U	nBE	3	Page 159
NDAT2	New Data Register 2	0334 _H	SV,U	nBE	3	Page 160
NDAT3	New Data Register 3	0338 _H	SV,U	nBE	3	Page 161
NDAT4	New Data Register 4	033C _H	SV,U	nBE	3	Page 162
MBSC1	Message Buffer Status Changed 1	0340 _H	SV,U	nBE	3	Page 163
MBSC2	Message Buffer Status Changed 2	0344 _H	SV,U	nBE	3	Page 164
MBSC3	Message Buffer Status Changed 3	0348 _H	SV,U	nBE	3	Page 165
MBSC4	Message Buffer Status Changed 4	034C _H	SV,U	nBE	3	Page 166
-	Reserved	0350 _H - 03A4 _H	nBE	nBE	-	-
NDIC1	New Data Interrupt Control 1	03A8 _H	SV,U	SV,U	3	Page 273
NDIC2	New Data Interrupt Control 2	03AC _H	SV,U	SV,U	3	Page 274
NDIC3	New Data Interrupt Control 3	03B0 _H	SV,U	SV,U	3	Page 275

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Table 44 **Registers OverviewE-Ray Kernel Registers (cont'd)**

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
NDIC4	New Data Interrupt Control 4	03B4 _H	SV,U	SV,U	3	Page 276
MSIC1	Message Buffer Status Changed Interrupt Control 1	03B8 _H	SV,U	SV,U	3	Page 277
MSIC2	Message Buffer Status Changed Interrupt Control 2	03BC _H	SV,U	SV,U	3	Page 278
MSIC3	Message Buffer Status Changed Interrupt Control 3	03C0 _H	SV,U	SV,U	3	Page 279
MSIC4	Message Buffer Status Changed Interrupt Control 4	03C4 _H	SV,U	SV,U	3	Page 276
IBUSYSRC	Input Buffer Busy Service Request Control Register	03C8 _H	SV,U	SV,U	3	Page 282
OBUSYSRC	Output Buffer Busy Service Request Control Register	03CC _H	SV,U	SV,U	3	Page 282
MBSC1SRC	Message Buffer Status Changed 1 Service Request Control Register	03D0 _H	SV,U	SV,U	3	Page 282
MBSC0SRC	Message Buffer Status Changed 0 Service Request Control Register	03D4 _H	SV,U	SV,U	3	Page 282
NDAT1SRC	New Data 1 Service Request Control Register	03D8 _H	SV,U	SV,U	3	Page 282
NDAT0SRC	New Data 0 Service Request Control Register	03DC _H	SV,U	SV,U	3	Page 282
TINT1SRC	Timer Interrupt 1 Service Request Control Register	03E0 _H	SV,U	SV,U	3	Page 282
TINT0SRC	Timer Interrupt 0 Service Request Control Register	03E4 _H	SV,U	SV,U	3	Page 282

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Table 44 **Registers OverviewE-Ray Kernel Registers** (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
INT1SRC	Interrupt 1 Service Request Control Register	03E8 _H	SV,U	SV,U	3	Page 282
INT0SRC	Interrupt 0 Service Request Control Register	03EC _H	SV,U	SV,U	3	Page 282

Identification Registers

CREL	Core Release Registers	03F0 _H	SV,U	nBE	3	Page 167
ENDN	Endian Register	03F4 _H	SV,U	nBE	3	Page 169
-	Reserved	03F6 _H - 03FC _H	nBE	nBE	-	-

Input Buffer

WRDSn	Write Data Section [1...64]	0400 _H - 04FC _H	SV,U	SV,U	3	Page 170
WRHS1	Write Header Section 1	0500 _H	SV,U	SV,U	3	Page 171
WRHS2	Write Header Section 2	0504 _H	SV,U	SV,U	3	Page 174
WRHS3	Write Header Section 3	0508 _H	SV,U	SV,U	3	Page 175
	Reserved	050C _H	nBE	nBE	-	
IBCM	Input Buffer Command Mask	0510 _H	SV,U	SV,U	3	Page 176
IBCR	Input Buffer Command Request	0514 _H	SV,U	SV,U	3	Page 178
	Reserved	0518 _H - 05FC _H	nBE	nBE	-	

Output Buffer

RDDS _n	Read Data Section [1...64]	0600 _H - 06FC _H	SV,U	nBE	3	Page 180
RDHS1	Read Header Section 1	0700 _H	SV,U	nBE	3	Page 181
RDHS2	Read Header Section 2	0704 _H	SV,U	nBE	3	Page 183
RDHS3	Read Header Section 3	0708 _H	SV,U	nBE	3	Page 185
MBS	Message Buffer Status	070C _H	SV,U	nBE	3	Page 187
OBCM	Output Buffer Command Mask	0710 _H	SV,U	SV,U	3	Page 192

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Table 44 **Registers OverviewE-Ray Kernel Registers** (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
OBCR	Output Buffer Command Request	0714 _H	SV,U	SV,U	3	Page 195
	Reserved	0718 _H - 07FC _H	nBE	nBE	-	-
ECC Control						
SECCON	Single Bit Error Correction Control	0800 _H	SV,U	SV,E	3	Page 32
SEDCON	Single Bit Error Detection Control	0804 _H	SV,U	SV,E	3	Page 34
DEDCON	Double Bit Error Correction Control	0808 _H	SV,U	SV,E	3	Page 36
ECCR	ECC Data Read	080C _H	SV,U	SV,U	3	Page 38
ECCW	ECC Data Write	0810 _H	SV,U	SV,U	3	Page 39
	Reserved	0814 _H - 0FFF _H	nBE	nBE	-	-

- 1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

21.5.2.1 Customer Registers

The addresses 0004_H - $000F_H$, $03C8_H$ - $03EC_H$ and 0800_H - $0FFF_H$ are reserved for customer-specific registers.

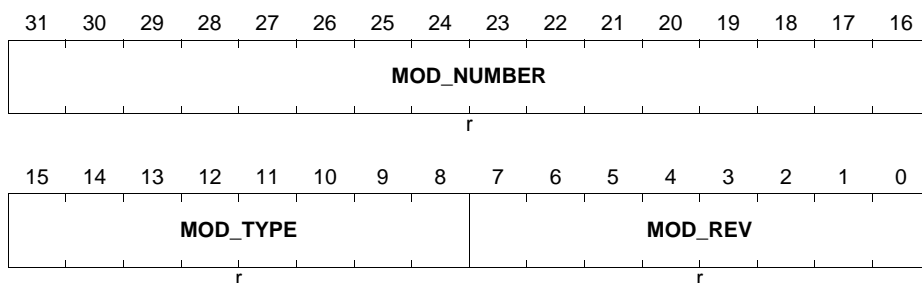
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Module Identification Register (ID)

This register contains bit fields identifying the E-Ray module in Infineons Module portfolio and is read only.

ID

Module Identification Register (0008_H) **Reset Value: 0044 C0XX_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type The value of this bit field is C0 _H . It defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines a module identification number. For the E-Ray module the module identification number is 44 _H .

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Busy Control Register (CUST1)

The Busy Control Register enables the automatic delay scheme. Furthermore it signals a timeout service request for the automatic delay scheme.

CUST1

Busy and Input Buffer Control Register

(0004_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STPWTS		RISB		RISA		0		IBF2 PAG	0		IBF1 PAG	IBFS	IEN	OEN	INT0
rw		rw		rw		r		rw	r		rw	rh	rw	rw	rwh

Field	Bits	Type	Description
INT0	0	rwh	CIF Timeout Service Request Status INT0 will be set if a timeout has occurred during the auto delay scheme and must be reset by writing zero to INT0. <i>Note: In case hardware sets INT0 and at the same point of time software clears INT0, INT0 is cleared.</i>
OEN	1	rw	Enable auto delay scheme for Output Buffer Control Register (OBCR) This control bit controls the delay scheme for Output Buffer Control Register (OBCR) read accesses. 0 _B Disable auto delay scheme for Output Buffer Control Register (OBCR) 1 _B Enable auto delay scheme for Output Buffer Control Register (OBCR)
IEN	2	rw	Enable auto delay scheme for Input Buffer Control Register (IBCR) This control bit controls the auto delay scheme for Input Buffer Control Register (IBCR) read accesses. 0 _B Disable auto delay scheme for Input Buffer Control Register (IBCR) 1 _B Enable auto delay scheme for Input Buffer Control Register (IBCR)

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Field	Bits	Type	Description
IBFS	3	rh	<p>Input Buffer Status Register</p> <p>This status bit indicates which of the two Input Buffer RAMs (IBF) is accessible by the host (via CIF) as Input Buffer. The other non accessible buffer RAM is currently used as shadow buffer RAM by the ERAY message handler and therefore not accessible by the host.</p> <p>0_B Input Buffer RAM 2 (IBF2) is accessible as Input Buffer by the host (CIF)</p> <p>1_B Input Buffer RAM 1 (IBF1) is accessible as Input Buffer by the host (CIF)</p>
IBF1PAG	4	rw	<p>Input Buffer 1 Page Select Register</p> <p>This control bit selects if the upper page or lower page of Input Buffer 1 (IBF1) currently active.</p> <p>Read:</p> <p>0_B Lower Page (256 Bytes) of Input Buffer RAM 1 selected</p> <p>1_B Upper Page (256 Bytes) of Input Buffer RAM 1 selected</p> <p>Write:</p> <p>0_B Select Lower Page (256 Bytes) of Input Buffer RAM 1</p> <p>1_B Select Upper Page (256 Bytes) of Input Buffer RAM 1</p> <p><i>Note: Write is only possible, if Input Buffer RAM 1 is currently accessible by the host (via CIF) and therefore IBFS set.</i></p>
IBF2PAG	7	rw	<p>Input Buffer 2 Page Select Register</p> <p>This control bit selects if the upper page or lower page of Input Buffer 2 (IBF2) currently active.</p> <p>Read:</p> <p>0_B Lower Page (256 Bytes) of Input Buffer RAM 2 selected</p> <p>1_B Upper Page (256 Bytes) of Input Buffer RAM 2 selected</p> <p>Write:</p> <p>0_B Select Lower Page (256 Bytes) of Input Buffer RAM 2</p> <p>1_B Select Upper Page (256 Byte) of Input Buffer RAM 2</p> <p><i>Note: Write is only possible, if Input Buffer RAM 2 is currently accessible by the host (via CIF) and therefore IBFS cleared.</i></p>

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Field	Bits	Type	Description
RISA	[11:10]	rw	Receive Input Select Channel A 00 _B Channel A receiver input RXDA0 selected 01 _B Channel A receiver input RXDA1 selected 10 _B Channel A receiver input RXDA2 selected 11 _B Channel A receiver input RXDA3 selected
RISB	[13:12]	rw	Receive Input Select Channel B 00 _B Channel B receiver input RXDB0 selected 01 _B Channel B receiver input RXDB1 selected 10 _B Channel B receiver input RXDB2 selected 11 _B Channel B receiver input RXDB3 selected
STPWTS	[15:14]	rw	Stop Watch Trigger Input Select 00 _B Stop Watch Trigger input STPWT0 selected 01 _B Stop Watch Trigger input STPWT1 selected 10 _B Stop Watch Trigger input STPWT2 selected 11 _B Stop Watch Trigger input STPWT3 selected
0	[6:5], [9:8], [31:16]	r	Reserved Returns 0 if read; should be written with 0.

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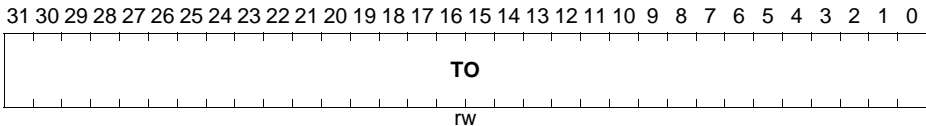
Customer Interface Timeout Counter Register (CUST3)

The Timeout Counter Register is realizing the timeout counter reload (startup) value for the automatic delay scheme (not the timeout down counter itself).

CUST3

Customer Interface Timeout Counter (000C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TO	[31:0]	rw	CIF Timeout Reload Value The 32-bit down counter reload (start-up) value must be setup for the automatic delay scheme.

Automatic Delayed Write Access to OBCR and IBCR

Write and read accesses to the Output Buffer Control Register (OBCR) can be automatically stalled due to a ongoing transfer from the Message Buffer to the Output Buffer. Also write and read accesses to the Input Buffer Control Register (IBCR) may be automatically delayed due to a ongoing transfer from the Input Buffer to the Message Buffer.

This delay scheme can be controlled (enabled or disabled) by CUST1.IEN and CUST1.OEN. The maximum time to stall a write or read access is determined by a single timeout counter preloaded with the 32-bit value specified in the bit field CUST3.TO. If the timeout counter counts down to zero before the transfer to/from the Message Buffer is completed, the access (read or write) will be canceled and a service request will be generated. A canceled read access provides a 0 value. A canceled write access does not modify any bits in the OBCR or IBCR. In addition the bit CUST1.INT0 of the service request status register will be set and must be reset by the host to disable the service request line.

The read and write access to the Output Buffer Control Register (OBCR) may be configured without automatic delay by clearing CUST1.OEN. Setting OBCR.REQ and immediately afterwards reading or writing OBCR, e.g. to set OBCR.VIEW will lead to a canceled read or write operation, e.g. OBCR.VIEW remains cleared, and an error is signalled by a set EIR.IOBA. Besides canceling the erroneous read or write operation, and setting the error bit, no further state change happens. So full operation is granted. OBCR remains read and write inaccessible until the transfer of data from the Message Buffer to the Output Buffer (MBF⇒OBF) is completed. During this time span all read and

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write accesses to the Output Buffer Control Register (OBCR) are canceled. The transfer is completed when OBCR.OBSYS is cleared. Additionally signal TOBC may be used, e.g. for service request triggering, DMA triggering, or driving a pin, to communicate the access status.

The read and write access to the Output Buffer Control Register (OBCR) may be configured to be automatic delayed by setting CUST1.OEN and configuring CUST3.TO to the maximum stall time acceptable to the system. If setting OBCR.REQ and immediately afterwards reading or writing to OBCR, e.g. to set the OBCR.VIEW bit, this read or write will be stalled until either the maximum delay time elapsed (in this case the read or write operation is cancelled after the stall time, e.g. OBCR.VIEW remains cleared, and an error is signalled by setting EIR.IOBA) or the read or write completes normally, e.g. set OBCR.VIEW after the transfer of data from the Message Buffer to the Output Buffer (MBF⇒OBF) is finalized. During this time the bus is locked and no further access to the E-Ray module is possible due to the ongoing stalled read or write operation. Because no access is possible to the E-Ray module, read or write stall may only be detected through the signal TOBC or due to other not processed read or write accesses to the E-Ray module.

The read and write access to the Input Buffer Control Register (IBCR) may also be configured without automatic delay by clearing CUST1.IEN. By writing to IBCR.IBRH the Input Buffers are swapped (shadow IBF changes to host IBF and host IBF to shadow IBF), the content of the shadow IBF is copied into the MBF (IBF⇒MBF), and IBCR.IBSYS is set. Writing to IBCR.IBRH a second time while IBCR.IBSYS remained set (previously initiated copy process IBF⇒MBF ongoing) will correctly update IBCR.IBRH and set IBCR.IBSYH. This will set the signal IBUSY. A third access, read or write, to IBCR while IBCR.IBSYH remains set will cancel this third access and an error is signalled by setting EIR.IIBA. Besides canceling this last access to IBCR and setting the error bit, no further state change happens. So full operation is granted. IBCR remains read and write inaccessible until the transfer of data from the Input Shadow Buffer to the Message Buffer (IBF⇒MBF) is completed and once more the Input Buffers are swapped (shadow IBF changes to host IBF and host IBF to shadow IBF). During this time span all read and write accesses to the Input Buffer Control Register (IBCR) are canceled. The transfer is completed when IBCR.IBSYH is cleared. Additionally signal TIBC may be used, e.g. for service request triggering, DMA triggering, or driving a pin, to communicate the access status.

The read and write access to the Input Buffer Control Register (IBCR) may be configured for being automatically delayed by setting CUST1.IEN and configuring CUST3.TO to the maximum stall time acceptable to the system. By writing to IBCR.IBRH the Input Buffers are swapped (shadow IBF changes to host IBF and host IBF to shadow IBF), the content of the shadow IBF copied into the MBF, and IBCR.IBSYS is set. Writing to IBCR.IBRH a second time while IBCR.IBSYS remains set (previously initiated copy process ongoing) will correctly update IBCR.IBRH and set IBCR.IBSYH. A third access to IBCR while IBCR.IBSYH remains set will stall this read or write until either the maximum delay

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time elapsed (in this case the read or write operation is cancelled after the stall time and an error is signalled by setting EIR.IOBA) or the read or write completes normally, after the transfer of data from the Input Shadow Buffer to the Message Buffer (IBF⇒MBF) is finalized and once more the Input Buffers are swapped (shadow IBF changes to host IBF and host IBF to shadow IBF). During this time the bus is locked and no further access to E-Ray module is possible due to the ongoing stalled read or write operation. Because no access is possible to the E-Ray module, read or write stall may only be detected through the signal TIBC or due to other not processed read or write accesses to the E-Ray module.

So setting CUST3.TO = FFFFFFFF_H, CUST1.IEN = 1, and CUST1.OEN = 1 will always grant a consistent data access of the host to the Output and Input Buffers without the need of reading and taking into account the status of OBCR.OBSYS or IBCR.IBSYH. But this simplified access may cause system latencies and system performance loss.

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21.5.2.2 Special Registers

Test Register 1 (TEST1)

The Test Register 1 holds the control bits to configure the test modes of the E-Ray module. Write access to these bits is only possible if bit TEST1.WRTEN is set.

The Test Register 1 bits therefore can be used to test the interface to the physical layer (connectivity test) by driving / reading the respective pins.

When the E-Ray IP is operated in one of its test modes that requires TEST1.WRTEN to be set (RAM Test Mode, I/O Test Mode, Asynchronous Transmit Mode, and Loop Back Mode) only the selected test mode functionality is available.

The test functions are not available in addition to the normal operational mode functions, they change the functions of parts of the E-Ray module. Therefore normal operation as specified outside this chapter and as required by the FlexRay™ protocol specification and the FlexRay™ conformance test is not possible. Test mode functions may not be combined with each other or with FlexRay™ protocol functions.

The test mode features are intended for hardware testing or for FlexRay™ bus analyzer tools. They are not intended to be used in FlexRay™ applications

TEST1

Test Register 1

(0010_H)

Reset Value: 0000 0300_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CERB				CERA				0	TXE NB	TXE NA	TXB	TXA	RXB	RXA	
rh				rh				r	rwh	rwh	rwh	rwh	rh	rh	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				AOB		AOA	0	TMC			0	ELB E	WRT EN		
r				rh		rh	r	rw			r	rw	rw		

Field	Bits	Type	Description
WRTEN	0	rw	Write Test Register Enable Enables write access to the test registers. To set the bit from 0 to 1 the test mode key has to be written as defined on “Lock Register (LCK)” on Page 40 . The unlock sequence is not required when TEST1.WRTEN is kept at 1 while other bits of the register are changed. The bit can be reset to 0 at any time. 0 _B Write access to test registers disabled. 1 _B Write access to test registers enabled.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
ELBE	1	rw	External Loop Back Enable There are two possibilities to perform a loop back test. External loop back via physical layer or internal loop back for in-system self-test (default). In case of an internal loop back pins TXENA and TXENB are in their inactive state, pins TXDA and TXDB are set to HIGH, pins RXDA and RXDB are not evaluated. Bit ELBE is evaluated only when POC is in loop back mode and test multiplexer control is in non multiplexed mode TMC = 00. 0 _B Internal loop back (default) 1 _B External loop back
TMC	[5:4]	rw	Test Multiplexer Control 00 _B Normal signal path (default). 01 _B RAM Test Mode: Internal busses are multiplexed to make all RAM blocks of the E-Ray module directly accessible by the Host. This mode is intended to enable testing of the embedded RAM blocks during production testing. 10 _B I/O Test Mode: Output pins are driven to the values defined by bits TXA, TXB, TXENA, TXENB. The values applied to the input pins can be read from register bits RXA and RXB. 11 _B Reserved; should not be used.
AOA	8	rh	Activity on A The channel idle condition is specified in the FlexRay™ protocol spec v2.1, chapter 3, BITSTRB process (zChannelIdle). 0 _B No activity detected, channel A idle 1 _B Activity detected, channel A not idle
AOB	9	rh	Activity on B The channel idle condition is specified in the FlexRay™ protocol spec v2.1, chapter 3, BITSTRB process (zChannelIdle). 0 _B No activity detected, channel B idle 1 _B Activity detected, channel B not idle
RXA	16	rh	Read Channel A Receive Pin 0 _B RXDA = 0 1 _B RXDA = 1

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
RXB	17	rh	Read Channel B Receive Pin 0_B RXDB = 0 1_B RXDB = 1
TXA	18	rwh	Read or Write to Channel A Transmit Pin 0_B TXDA = 0 1_B TXDA = 1
TXB	19	rwh	Read or Write to Channel B Transmit Pin 0_B TXDB = 0 1_B TXDB = 1
TXENA	20	rwh	Read or Write to Channel A Transmit Enable Pin 0_B $\overline{\text{TXENA}}$ = 0 1_B $\overline{\text{TXENA}}$ = 1
TXENB	21	rwh	Read or Write to Channel B Transmit Enable Pin 0_B $\overline{\text{TXENB}}$ = 0 1_B $\overline{\text{TXENB}}$ = 1
CERA	[27:24]	rh	Coding Error Report Channel A¹⁾ Set when a coding error is detected on channel A. Reset to zero when register TEST1 is read or written. Once the CERA is set it will remain unchanged until the Host accesses the TEST1 register. 0000_B No coding error detected 0001_B Header CRC error detected 0010_B Frame CRC error detected 0011_B Frame Start Sequence FSS too long 0100_B First bit of Byte Start Sequence BSS seen LOW 0101_B Second bit of Byte Start Sequence BSS seen HIGH 0110_B First bit of Frame End Sequence FES seen HIGH 0111_B Second bit of Frame End Sequence FES seen LOW 1000_B CAS / MTS symbol seen too short 1001_B CAS / MTS symbol seen too long Other combinations are reserved.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
CERB	[31:28]	rh	Coding Error Report Channel B¹⁾ Set when a coding error is detected on channel B. Reset to zero when register TEST1 is read or written. Once the CERB is set it will remain unchanged until the Host accesses the TEST1 register. 0000 _B No coding error detected 0001 _B Header CRC error detected 0010 _B Frame CRC error detected 0011 _B Frame Start Sequence FSS too long 0100 _B First bit of Byte Start Sequence BSS seen LOW 0101 _B Second bit of Byte Start Sequence BSS seen HIGH 0110 _B First bit of Frame End Sequence FES seen HIGH 0111 _B Second bit of Frame End Sequence FES seen LOW 1000 _B CAS / MTS symbol seen too short 1001 _B CAS / MTS symbol seen too long Other combinations are reserved.
0	[3:2], [7:6], [15:10], [23:22]	r	Reserved Returns 0 if read; should be written with 0.

1) Coding errors are also signalled when the Communication Controller is in "MONITOR_MODE". The error codes regarding CAS / MTS symbols concern only the monitored bit pattern, irrelevant whether those bit patterns are seen in the symbol window or elsewhere.

Asynchronous Transmit Mode (ATM)

The asynchronous transmit mode is entered by writing 1110_B to the CHI Command Vector SUCC1.CMD in the SUC Configuration Register 1 (CHI command: ATM) while the Communication Controller is in "CONFIG" state and bit TEST1.WRTEN in the Test Register 1 is set. This write operation has to be directly preceded by two consecutive write accesses to the Configuration Lock Key (unlock sequence). When called in any other state or when bit TEST1.WRTEN is not set, SUCC1.CMD will be reset to 0000_B = "COMMAND_NOT_ACCEPTED". CCSV.POCS in the Communication Controller Status Vector will return 1110_B while the E-Ray module is in ATM mode. Asynchronous Transmit mode can be left by writing 0001_B (CHI command: "CONFIG") to the CHI Command Vector SUCC1.CMD in the SUC Configuration Register 1.

In ATM mode transmission of a FlexRay™ Frame is triggered by writing the number of the respective Message Buffer to the Input Buffer Command Request register (IBCR.IBRH) while bit IBCM.STXRS in the Input Buffer Command Mask register is set to 1. In this mode wakeup, startup, and clock synchronization are bypassed. The CHI command SEND_MTS results in the immediate transmission of an MTS symbol.

FlexRay™ Protocol Controller (E-Ray)

The cycle counter value of Frames send in ATM mode can be programmed via MTCCV.CCV (writeable in ATM and loop back mode only).

Loop Back Mode

The loop back mode is entered by writing 1111_B to the CHI Command Vector SUCC1.CMD in the SUC Configuration Register 1 (CHI command: LOOP_BACK) while the Communication Controller is in "CONFIG" state and bit TEST1.WRTEN in the Test Register 1 is set. This write operation has to be directly preceded by two consecutive write accesses to the Configuration Lock Key (unlock sequence). When called in any other state or when bit TEST1.WRTEN is not set, SUCC1.CMD will be reset to 0000_B = "COMMAND_NOT_ACCEPTED". CCSV.POCS in the Communication Controller Status Vector will show $0000\ 1101_H$ while the E-Ray module is in loop back mode.

Loop Back mode can be left by writing 0001_B (CHI command: "CONFIG") to the CHI Command Vector SUCC1.CMD in the SUC Configuration Register 1.

The loop back test mode is intended to check the module's internal data paths. Normal, time triggered operation is not possible in loop back mode.

There are two possibilities to perform a loop back test. External loop back via physical layer (TEST1.ELBE = 1) or internal loop back for in-system self-test (TEST1.ELBE = 0). In case of an internal loop back pins TXENA, TXENB are in their inactive state, pins TXDA and TXDB are set to HIGH, pins RXDAn and RXDBn are not evaluated.

When the Communication Controller is in loop back mode, a loop back test is started by the Host writing a message to the Input Buffer and requesting the transmission by writing to the Input Buffer Command Request register IBCR. The Message Handler will transfer the message into the Message RAM and then into the Transient Buffer of the selected channel. The Channel Protocol Controller (PRT) will read (in 32-bit words) the message from the transmit part of the Transient Buffer and load it into its Rx / Tx shift register. The serial transmission is looped back into the shift register; its content is written into the receive part of the channels's Transient Buffer before the next word is loaded.

The PRT and the Message Handler will then treat this transmitted message like a received message, perform an acceptance filtering on Frame ID and receive channel, and store the message into the Message RAM if it passed acceptance filtering. The loop back test ends with the Host requesting this received message from the Message RAM and then checking the contents of the Output Buffer.

Each FlexRay™ channel is tested separately. The E-Ray cannot receive messages from the FlexRay™ bus while it is in the loop back mode.

The cycle counter value of Frames used in loop back mode can be programmed via MTCCV.CCV (writeable in ATM and loop back mode only).

Note that in case of an odd payload the last two bytes of the looped-back payload will be shifted by 16 bits to the right inside the last 32-bit data word.

FlexRay™ Protocol Controller (E-Ray)

Test Register 2 (TEST2)

The Test Register 2 holds all bits required for the RAM test of the seven embedded RAM blocks of the E-Ray module. Write access to this register is only possible when TEST1.WRTEN in the Test Register 1 is set to 1.

TEST2

Test Register 2

(0014_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	WR ECC					0				SSEL		0		RS	
r	rw					r				rw		r		rw	

Field	Bits	Type	Description
RS	[2:0]	rw	RAM Select In RAM Test mode the RAM blocks selected by RS are mapped to module address 0000 0400 _H to 0000 07FF _H (1024 byte addresses). 000 _B Input Buffer RAM 1 (IBF1) 001 _B Input Buffer RAM 2 (IBF2) 010 _B Output Buffer RAM 1 (OBF1) 011 _B Output Buffer RAM 2 (OBF2) 100 _B Transient Buffer RAM A (TBF1) 101 _B Transient Buffer RAM B (TBF2) 110 _B Message RAM (MBF) 111 _B Reserved; should not be used.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SSEL	[6:4]	rw	Segment Select To enable access to the complete Message RAM (8192 byte addresses) the Message RAM is segmented. 000 _B access to RAM byte 0000 _H to 03FF _H enabled 001 _B access to RAM byte 0400 _H to 07FF _H enabled 010 _B access to RAM byte 0800 _H to 0BFF _H enabled 011 _B access to RAM byte 0C00 _H to 0FFF _H enabled 100 _B access to RAM byte 1000 _H to 11FF _H enabled 101 _B access to RAM byte 1400 _H to 17FF _H enabled 110 _B access to RAM byte 1800 _H to 1BFF _H enabled 111 _B access to RAM byte 1C00 _H to 1FFF _H enabled
WR ECC	14	rw	Write ECC Data Enable Content of ECCW is transferred to the RAM: 0 _B disabled 1 _B enabled <i>Note: Test mode must be entered. See “Test Register 1 (TEST1)” on Page 24</i>
0	3, [13:7], 15, [31:16]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

RAM Test Mode

In RAM test mode (TEST1.TMC = 1), one of the seven RAM blocks can be selected for direct RD/WR access by programming TEST2.RS.

For external access the selected RAM block is mapped to address space 400_H to 7FF_H (1024 byte addresses or 256 word addresses).

Because the length of the Message RAM exceeds the available address space, the Message RAM is segmented into segments of 1024 byte. The segments can be selected by programming TEST2.SSEL in the Test Register 2.

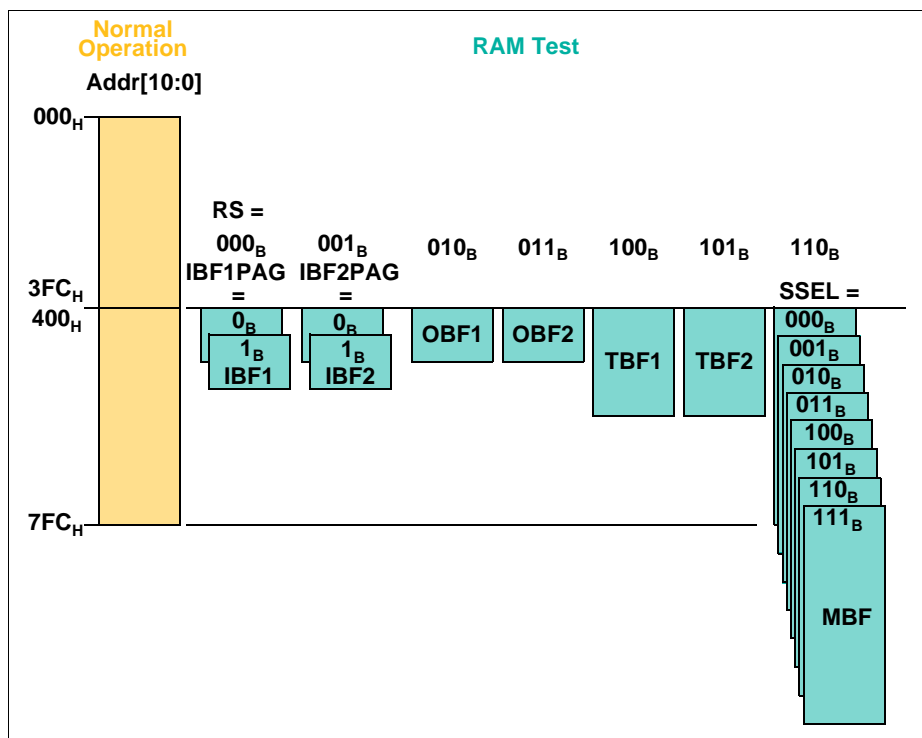


Figure 13 RAM test mode Access to E-Ray RAM Blocks

FlexRay™ Protocol Controller (E-Ray)

SECCON

The Single Bit Error Correction Control Register holds the bits required for enabling the single bit error correction for each respective RAM block of the E-Ray module. It can only be written if PRDCFG2.SENAV is set. It is supervisor and endinit protected.

SECCON

SEC Control (0800_H) Reset Value: 0000 007F_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0									SEC I2 EN	SEC I1 EN	SEC O2 EN	SEC O1 EN	SEC T2 EN	SEC T1 EN	SEC M EN
r									rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
SEC M EN	0	rw	Single Bit Error Correction for Message Buffer (MBF) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SEC T1 EN	1	rw	Single Bit Error Correction for Transfer Buffer 1 (TBF1) RAMs Enable/Test Disable 0 _B OFF 1 _B ON
SEC T2 EN	2	rw	Single Bit Error Correction for Transfer Buffer 2 (TBF2) RAMs Enable/Test Disable 0 _B OFF 1 _B ON
SEC O1 EN	3	rw	Single Bit Error Correction for Output Buffer 1 (OBF1) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SEC O2 EN	4	rw	Single Bit Error Correction for Output Buffer 2 (OBF2) RAM Enable/Test Disable 0 _B OFF 1 _B ON

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SEC I1 EN	5	rw	Single Bit Error Correction for Input Buffer 1 (IBF1) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SEC I2 EN	6	rw	Single Bit Error Correction for Input Buffer 2 (IBF2) RAM Enable/Test Disable 0 _B OFF 1 _B ON
0	[31:7]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

SEDCON

The Single Bit Error Detection Control Register holds the bits required for enabling the single bit error detection for each respective RAM block of the E-Ray module. It can only be written if PRDCFG2.SENAV is set. The Register is supervisor and endinit protected.

SEDCON

SED Control (0804_H) Reset Value: 0000 007F_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
										SED I2 EN	SED I1 EN	SED O2 EN	SED O1 EN	SED T2 EN	SED T1 EN
										rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
SED M EN	0	rw	Single Bit Error Detection for Message Buffer (MBF) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SED T1 EN	1	rw	Single Bit Error Detection for Transfer Buffer 1 (TBF1) RAMs Enable/Test Disable 0 _B OFF 1 _B ON
SED T2 EN	2	rw	Single Bit Error Detection for Transfer Buffer 2 (TBF2) RAMs Enable/Test Disable 0 _B OFF 1 _B ON
SED O1 EN	3	rw	Single Bit Error Detection for Output Buffer 1 (OBF1) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SED O2 EN	4	rw	Single Bit Error Detection for Output Buffer 2(OBF2) RAM Enable/Test Disable 0 _B OFF 1 _B ON

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SED I1 EN	5	rw	Single Bit Error Detection for Input Buffer 1 (IBF1) RAM Enable/Test Disable 0 _B OFF 1 _B ON
SED I2 EN	6	rw	Single Bit Error Detection for Input Buffer 2 (IBF2) RAM Enable/Test Disable 0 _B OFF 1 _B ON
0	[31:7]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
DED I1 EN	5	rw	Double Bit Error Detection for Input Buffer 1 (IBF1) RAM Enable/Test Disable 0 _B OFF 1 _B ON
DED I2 EN	6	rw	Double Bit Error Detection for Input Buffer 2 (IBF2) RAM Enable/Test Disable 0 _B OFF 1 _B ON
0	[31:7]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

ECCR

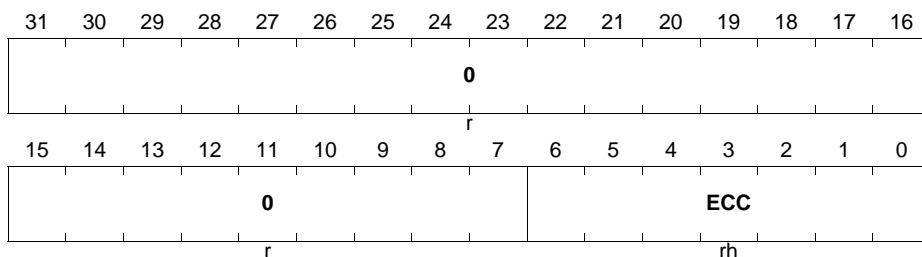
The ECC Data Read Register always holds the ECC bits referring to the last accessed RAM address. In normal operation RAM can not be accessed by the CPU. For dedicated RAM access to selected addresses by the CPU, Test mode must be entered. See [“Test Register 2 \(TEST2\)” on Page 29](#)

ECCR

ECC Data Read Register

(080C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
ECC	[6:0]	rh	Error Correction Data of the last accessed RAM address
0	[31:7]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

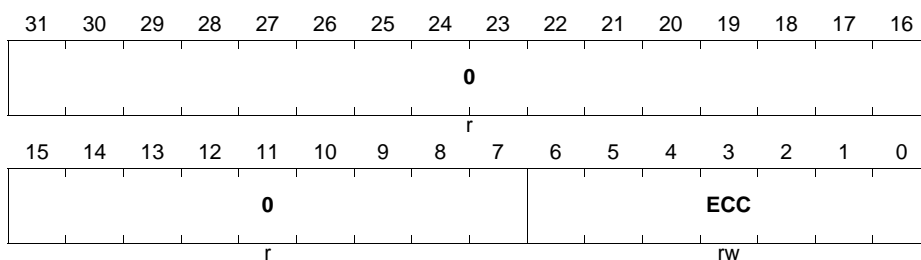
ECCW

The ECC Data Write Register holds the ECC bits to be written together with the next RAM access. These bits are written to the ECC bit field referring to the RAM address accessed next. In normal operation E-Ray RAM can not be accessed by the CPU. The content of ECCW is not transferred to the RAM ECC data field in normal operation. For ECCW to become effective (and for dedicated RAM access to selected addresses by the CPU), Test mode must be entered. See [“Test Register 1 \(TEST1\)” on Page 24](#). The referring RAM must be selected. See [“Test Register 2 \(TEST2\)” on Page 29](#).

Note: Content of ECCW is transferred to the RAM only if TEST2.WRECC is set!

ECCW

ECC Data Write Register (0810_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
ECC	[6:0]	rw	Error Correction Data written with next RAM address written next
0	[31:7]	r	Reserved Returns 0 if read; should be written with 0.

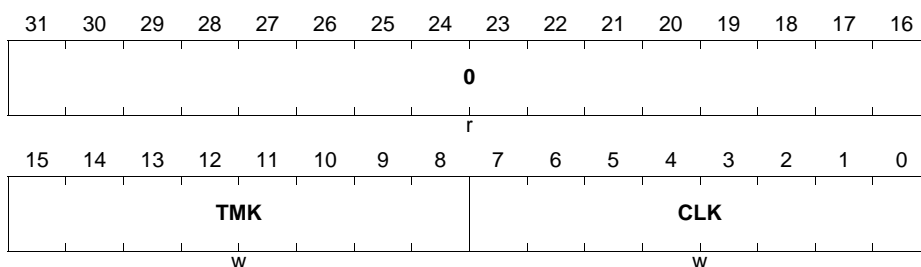
FlexRay™ Protocol Controller (E-Ray)

Lock Register (LCK)

The Lock Register is write-only. Reading the register will return 0000 0000_H.

LCK

Lock Register (001C_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
CLK	[7:0]	w	Configuration Lock Key To leave "CONFIG" state by writing to SUCC1.CMD commands READY, MONITOR_MODE, ATM, LOOP_BACK) in the SUC Configuration Register 1, the write operation has to be directly preceded by two consecutive write accesses to the Configuration Lock Key (unlock sequence). If the write sequence below is interrupted by other write accesses between the second write to the Configuration Lock Key and the write access to the SUCC1 register, the Communication Controller remains in "CONFIG" state and the sequence has to be repeated. First write: LCK.CLK = CE _H = 1100 1110 _B Second write: LCK.CLK = 31 _H = 0011 0001 _B Third write: SUCC1.CMD Returns 0 if read

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TMK	[15:8]	w	Test Mode Key To set bit TEST1.WRTEN the write operation has to be directly preceded by two consecutive write accesses to the Test Mode Key. If the write sequence is interrupted by other write accesses between the second write to the Test Mode Key and the write access to the Test1 register, bit TEST1.WRTEN is not set to 1 and the sequence has to be repeated. First write: LCK.TMK = 75 _H = 0111 0101 _B Second write: LCK.TMK = 8A _H = 1000 1010 _B Second write: TEST1.WRTEN = 1 Returns 0 if read
0	[31:16]	r	Reserved Returns 0 if read; should be written with 0.

Note: In case the Host uses 8/16-bit accesses to write the listed bit fields, the programmer has to ensure that no “dummy accesses” e.g. to the remaining register bytes / words are inserted by the compiler.

To exit “CONFIG” state by writing to SUCC1.CMD in the SUC Configuration Register 1, the write operation has to be directly preceded by two consecutive write accesses to the Configuration Lock Key. If this write sequence is service requested by read accesses or write accesses to other locations, the Communication Controller remains in “CONFIG” state and the sequence has to be repeated.

First write: LCK.CLK = CE_H = 1100 1110_B

Second write: LCK.CLK = 31_H = 0011 0001_B

21.5.2.3 Service Request Registers

The address space from 0020_H to 007F_H is reserved for service request registers.

Error Service Request Select (EIR)

The flags are set when the Communication Controller detects one of the listed error conditions. They remain set until the Host clears them. A flag is cleared by writing a 1 to the corresponding bit position. Writing a 0 has no effect on the flag. An application reset will also clear the register.

EIR

Error Service Request Register (0020_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0					TAB B	LTV B	EDB	0					TAB A	LTV A	EDA
r					rwh	rwh	rwh	r					rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0					MHF	IO BA	II BA	EFA	RFO	EER R	CCL	CCF	SFO	SFB M	PEM C
r					rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
PEMC	0	rwh	POC Error Mode Changed This flag is set whenever the error mode signalled by CCEV.ERRM in the Communication Controller Error Vector register has changed. 0 _B Error mode has not changed 1 _B Error mode has changed This flag is cleared by writing a 1.
CNA	1	rwh	Command Not Accepted The flag signals that the write access to the CHI command vector SUCC1.CMD in the SUC Configuration Register 1 was not successful because the requested command was not valid in the actual POC state, or because the CHI command was locked (CCL = 1). 0 _B CHI command accepted 1 _B CHI command not accepted This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SFBM	2	rwh	<p>SYNC Frames Below Minimum</p> <p>This flag signals that the number of SYNC Frames received during the last communication cycle was below the limit required by the FlexRay™ protocol. May be set during startup and therefore should be cleared by the Host after the Communication Controller entered “NORMAL_ACTIVE” state.</p> <p>0_B Sync node: 1 or more SYNC Frames received Non-sync node: 2 or more SYNC Frames received</p> <p>1_B Less than the required minimum of SYNC Frames received</p> <p>This flag is cleared by writing a 1.</p>
SFO	3	rwh	<p>SYNC Frame Overflow</p> <p>Set when either the number of SYNC Frames received during the last communication cycle or the total number of SYNC Frames received during the last double cycle exceeds the maximum number of SYNC Frames as defined by GTUC02.SNM in the GTU Configuration Register 2.</p> <p>0_B Number of received SYNC Frames ≤ GTUC02.SNM</p> <p>1_B More SYNC Frames received than configured by GTUC02.SNM</p> <p>This flag is cleared by writing a 1.</p>
CCF	4	rwh	<p>Clock Correction Failure</p> <p>This flag is set at the end of the cycle whenever one of the following errors occurred:</p> <ul style="list-style-type: none"> Missing offset and / or rate correction Clock Correction limit reached <p>The clock correction status is monitored in registers CCEV and SFS. A failure may occur during startup, therefore bit CCF should be cleared by the Host after the Communication Controller entered “NORMAL_ACTIVE” state.</p> <p>0_B Clock correction successful so far</p> <p>1_B Clock correction failed</p> <p>This flag is cleared by writing a 1.</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
CCL	5	rwh	CHI Command Locked The flag signals that the write access to the CHI command vector SUCC1.CMD was not successful because the execution of the previous CHI command has not yet completed. In this case bit EIR.CNA is also set to 1. 0 _B CHI command accepted 1 _B CHI command not accepted This flag is cleared by writing a 1.
EERR	6	rh	ECC Error The flag signals an ECC error to the Host. It is set whenever one of the flags MHDS.EIBF, MHDS.EOBF, MHDS.EMR, MHDS.ETBF1, MHDS.ETBF2 changes from 0 to 1. See also “Message Handler Status (MHDS)” on Page 146 . 0 _B No error detected 1 _B Error detected
RFO	7	rh	Receive FIFO Overrun The flag is set by the Communication Controller when a receive FIFO overrun is detected. When a receive FIFO overrun occurs, the oldest message is overwritten with the actual received message. The actual state of the FIFO is monitored in register FSR. 0 _B No receive FIFO overrun detected 1 _B A receive FIFO overrun has been detected
EFA	8	rwh	Empty FIFO Access This flag is set by the Communication Controller when the Host requests the transfer of a message from the receive FIFO via Output Buffer while the receive FIFO is empty. 0 _B No Host access to empty FIFO occurred 1 _B Host access to empty FIFO occurred

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
IIBA	9	rwh	<p>Illegal Input Buffer Access</p> <p>This flag is set by the Communication Controller when the Host wants to modify a Message Buffer via Input Buffer while the Communication Controller is not in “CONFIG” or “DEFAULT_CONFIG” state and one of the following conditions applies:</p> <ol style="list-style-type: none"> The Host writes to the Input Buffer Command Request register to modify the: <ol style="list-style-type: none"> Header Section of Message Buffer 0, 1 if configured for transmission in key slot Header Section of static Message Buffers with buffer number < MRC.FDB while MRC.SEC = 01_B Header Section of any static or dynamic Message Buffer while MRC.SEC = 1x_B Header and / or Data Section of any message buffer belonging to the receive FIFO The Host writes to any register of the Input Buffer while IBCR.IBSYS is set. <p>0_B No illegal Host access to Input Buffer occurred 1_B Illegal Host access to Input Buffer occurred</p>
IOBA	10	rwh	<p>Illegal Output Buffer Access</p> <p>This flag is set by the Communication Controller when the Host requests the transfer of a Message Buffer from the Message RAM to the Output Buffer while OBCR.OBSYS is set to 1.</p> <p>0_B No illegal Host access to Output Buffer occurred 1_B Illegal Host access to Output Buffer occurred</p>
MHF	11	rwh	<p>Message Handler Constraints Flag</p> <p>The flag signals a Message Handler constraints violation condition. It is set whenever one of the flags MHDF.SNUA, MHDF.SNUB, MHDF.FNFA, MHDF.FNFB, MHDF.TBFA, MHDF.TBFB, MHDF.TNSA, MHDF.TNSB, MHDF.WAHP changes from 0 to 1.</p> <p>0_B No Message Handler failure detected 1_B Message Handler failure detected</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
EDA	16	rwh	Error Detected on Channel A This bit is set whenever one of the flags ACS.SEDA, ACS.CEDA, ACS.CIA, ACS.SBVA changes from 0 to 1. 0_B No error detected on channel A 1_B Error detected on channel A This flag is cleared by writing a 1.
LTVA	17	rwh	Latest Transmit Violation Channel A The flag signals a latest transmit violation on channel A to the Host. 0_B No latest transmit violation detected on channel A 1_B Latest transmit violation detected on channel A This flag is cleared by writing a 1.
TABA	18	rwh	Transmission Across Boundary Channel A The flag signals to the Host that a transmission across a slot boundary occurred for channel A. 0_B No transmission across slot boundary detected on channel A 1_B Transmission across slot boundary detected on channel A This flag is cleared by writing a 1.
EDB	24	rwh	Error Detected on Channel B This bit is set whenever one of the flags ACS.SEDB, ACS.CEDB, ACS.CIB, ACS.SBVB changes from 0 to 1. 0_B No error detected on channel B 1_B Error detected on channel B This flag is cleared by writing a 1.
LTVB	25	rwh	Latest Transmit Violation Channel B The flag signals a latest transmit violation on channel B to the Host. 0_B No latest transmit violation detected on channel B 1_B Latest transmit violation detected on channel B This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TABB	26	rwh	Transmission Across Boundary Channel B The flag signals to the Host that a transmission across a slot boundary occurred for channel B. 0 _B No transmission across slot boundary detected on channel B 1 _B Transmission across slot boundary detected on channel B This flag is cleared by writing a 1.
0	[15:12], [23:19], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Status Service Request Register (SIR)

The flags are set whenever the Communication Controller detects one of the listed events. The flags remain set until the Host clears them. A flag is cleared by writing a 1 to the corresponding bit position. Writing a 0 has no effect on the flag. An application reset will also clear the register.

SIR

Status Service Request Register (0024_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						MTS B	WUP B	0						MTS A	WUP A
r						rwh	rwh	r						rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDS	MBS I	SUC S	SWE	TOB C	TIBC	TI1	TI0	NMV C	RF CL	RF NE	RXI	TXI	CYC S	CAS	WST
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rh	rh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
WST	0	rwh	Wakeup Status This flag is set when the wakeup status vector CCSV.WSV in the Communication Controller Status Vector register changes to a value other than UNDEFINED. 0 _B Wakeup status unmodified 1 _B Wakeup status modified (and not UNDEFINED) This flag is cleared by writing a 1.
CAS	1	rwh	Collision Avoidance Symbol This flag is set by the Communication Controller during STARTUP state when a CAS or potential CAS was received. 0 _B No bit pattern matching the CAS symbol received 1 _B Bit pattern matching the CAS symbol received This flag is cleared by writing a 1.
CYCS	2	rwh	Cycle Start Service Request This flag is set by the Communication Controller when a communication cycle starts 0 _B No communication cycle started 1 _B Communication cycle started This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TXI	3	rwh	Transmit Service Request This flag is set by the Communication Controller at the end of Frame transmission if bit WRHS1.MBI in the respective Message Buffer is set (see Table 65). 0 _B No Frame transmitted from a transmit buffer with WRHS1.MBI = 1 1 _B At least one Frame was transmitted from a transmit buffer with WRHS1.MBI = 1 This flag is cleared by writing a 1.
RXI	4	rwh	Receive Service Request This flag is set by the Communication Controller whenever the set condition of a Message Buffer ND flag is fulfilled and if bit WRHS1.MBI of that Message Buffer is set to 1 (see Table 65). 0 _B No ND flag of a receive buffer with WRHS1.MBI = 1 has been set to 1 1 _B At least one ND flag of a receive buffer with WRHS1.MBI = 1 has been set to 1 This flag is cleared by writing a 1.
RFNE	5	rh	Receive FIFO Not Empty This flag is set by the Communication Controller when a received valid Frame was stored into the empty receive FIFO.m The actual state of the receive FIFO is monitored in register FSR 0 _B Receive FIFO is empty 1 _B Receive FIFO is not empty
RFCL	6	rh	Receive FIFO Critical Level This flag is set when a valid receive FIFO fill level FSR.RFFL is equal or greater than the critical level as configured by FCL.CL. 0 _B Receive FIFO below critical level 1 _B Receive FIFO critical level reached
NMVC	7	rwh	Network Management Vector Changed This service request flag signals a change in the Network Management Vector visible to the Host. 0 _B No change in the Network Management vector 1 _B Network Management vector changed This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TIO	8	rwh	Timer Service Request 0 This flag is set whenever timer 0 matches the conditions configured in the Timer Service Request 0 Configuration Register T0C. A Timer Service Request 0 is also signalled by TINT0SRC. 0 _B No Timer Service Request 0 1 _B Timer Service Request 0 occurred This flag is cleared by writing a 1.
TI1	9	rwh	Timer Service Request 1 This flag is set whenever the conditions programmed in the Timer Service Request 1 Configuration Register T1C are met. A Timer Service Request 1 is also signalled by TINT1SRC. 0 _B No Timer Service Request 1 1 _B Timer Service Request 1 occurred This flag is cleared by writing a 1.
TIBC	10	rwh	Transfer Input Buffer Completed This flag is set whenever a transfer from Input Buffer to the Message RAM has completed and bit IBCR.IBSYS in the Input Buffer Command Request register has been reset by the Message Handler. 0 _B No transfer completed 1 _B Transfer between Input Buffer and Message RAM completed This flag is cleared by writing a 1.
TOBC	11	rwh	Transfer Output Buffer Completed This flag is set whenever a transfer from Message RAM to the Output Buffer has completed and bit OBCR.OBSYS in the Output Buffer Command Request register has been reset by the Message Handler. 0 _B No transfer completed 1 _B Transfer between Message RAM and the Output Buffer completed This flag is cleared by writing a 1.
SWE	12	rwh	Stop Watch Event This flag is set after a stop watch activation when the current cycle counter and Macrotick value are stored in the Stop Watch Register 1 (STPW1). 0 _B No Stop Watch Event 1 _B Stop Watch Event occurred This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SUCS	13	rwh	Startup Completed Successfully This flag is set whenever a startup completed successfully and the Communication Controller entered "NORMAL_ACTIVE" state. 0 _B No startup completed successfully 1 _B Startup completed successfully This flag is cleared by writing a 1.
MBSI	14	rwh	Message Buffer Status Service Request This flag is set by the Communication Controller when the Message Buffer status MBS has changed and if bit RDHS1.MBI of that Message Buffer is set (see Table 65). 0 _B No Message Buffer status change of Message Buffer with RDHS1.MBI= 1 has changed 1 _B Message Buffer status of at least one Message Buffer with RDHS1.MBI= 1 has changed This flag is cleared by writing a 1.
SDS	15	rwh	Start of Dynamic Segment This flag is set by the Communication Controller when the dynamic segment starts. 0 _B Dynamic segment not yet started 1 _B Dynamic segment started
WUPA	16	rwh	Wakeup Pattern Channel A This flag is set by the Communication Controller when a wakeup pattern was received on channel A. Only set when the Communication Controller is in "WAKEUP", "READY", or "STARTUP" state, or when in Monitor mode. 0 _B No wakeup pattern received on channel A 1 _B Wakeup pattern received on channel A This flag is cleared by writing a 1.
MTSA	17	rwh	MTS Received on Channel A (vSS!ValidMTSA) Media Access Test symbol received on channel A during the proceeding symbol window. Updated by the Communication Controller for each channel at the end of the symbol window. 0 _B No MTS symbol received on channel A 1 _B MTS symbol received on channel A This flag is cleared by writing a 1.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
WUPB	24	rwh	Wakeup Pattern Channel B This flag is set by the Communication Controller when a wakeup pattern was received on channel B. Only set when the Communication Controller is in “WAKEUP”, “READY”, or “STARTUP” state, or when in Monitor mode. 0 _B No wakeup pattern received on channel B 1 _B Wakeup pattern received on channel B This flag is cleared by writing a 1.
MTSB	25	rwh	MTS Received on Channel B (vSSI!ValidMTSB) Media Access Test symbol received on channel B during the proceeding symbol window. Updated by the Communication Controller for each channel at the end of the symbol window. 0 _B No MTS symbol received on channel B 1 _B MTS symbol received on channel B This flag is cleared by writing a 1.
0	[23:18], [31:26]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SFOL	3	rw	SYNC Frame Overflow Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
CCFL	4	rw	Clock Correction Failure Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
CCLL	5	rw	CHI Command Locked Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
EERRL	6	rw	ECC Error Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
RFOL	7	rw	Receive FIFO Overrun Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
EFAL	8	rw	Empty FIFO Access Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC
IIBAL	9	rw	Illegal Input Buffer Access Service Request Line 0_B Service Request assigned to service request line INT0SRC 1_B Service Request assigned to service request line INT1SRC

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
IOBAL	10	rw	Illegal Output Buffer Access Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
MHFL	11	rw	Message Handler Constrains Flag Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
EDAL	16	rw	Error Detected on Channel A Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
LTVAL	17	rw	Latest Transmit Violation Channel A Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
TABAL	18	rw	Transmission Across Boundary Channel A Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
EDBL	24	rw	Error Detected on Channel B Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
LTVBL	25	rw	Latest Transmit Violation Channel B Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TABBL	26	rw	Transmission Across Boundary Channel A Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
0	[15:12], [23:19], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Status Service Request Line Select (SILS)

The Status Service Request Line Select register assign an service request generated by a specific status service request flag from register SIR to one of the two module service request lines INT0SRC or INT1SRC:

0 = Interrupt assigned to interrupt line INT0SRC

1 = Interrupt assigned to interrupt line INT1SRC

SILS

Status Service Request Line Select (002C_H)

Reset Value: 0303 FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						MTS BL	WUP BL	0						MTS AL	WUP AL
r						rw	rw	r						rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDS L	MBS IL	SUC SL	SWE L	TOB CL	TIBC L	TI1L	TI0L	NMV CL	RFC LL	RFN EL	RXIL	TXIL	CYC SL	CAS L	WST L
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
WSTL	0	rw	Wakeup Status Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
CASL	1	rw	Collision Avoidance Symbol Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
CYCSL	2	rw	Cycle Start Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TXIL	3	rw	Transmit Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
RXIL	4	rw	Receive Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
RFNEL	5	rw	Receive FIFO Not Empty Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
RFCLL	6	rw	Receive FIFO Critical Level Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
NMVCL	7	rw	Network Management Vector Changed Service Request Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
TI0L	8	rw	Timer Service Request 0 Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC
TI1L	9	rw	Timer Service Request 1 Line
			0 _B Service Request assigned to service request line INT0SRC
			1 _B Service Request assigned to service request line INT1SRC

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TIBCL	10	rw	Transfer Input Buffer Completed Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
TOBCL	11	rw	Transfer Output Buffer Completed Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
SWEL	12	rw	Stop Watch Event Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
SUCSL	13	rw	Startup Completed Successfully Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
MBSIL	14	rw	Message Buffer Status Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
SDSL	15	rw	Start of Dynamic Segment Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
WUPAL	16	rw	Wakeup Pattern Channel A Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
MTSAL	17	rw	Media Access Test Symbol Channel A Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
WUPBL	24	rw	Wakeup Pattern Channel B Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
MTSBL	25	rw	Media Access Test Symbol Channel B Service Request Line 0 _B Service Request assigned to service request line INT0SRC 1 _B Service Request assigned to service request line INT1SRC
0	[23:18], [31:26]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Error Service Request Enable Set (EIES)

The settings in the Error Service Request Enable register determine which status changes in the Error Service Request Register will result in a service request. The enable bits are set by writing to EIES and reset by writing to EIER. Writing a 1 sets the specific enable bit, a 0 has no effect.

EIES

Error Service Request Enable Set (0030_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
					TAB BE	LTV BE	EDB E						TAB AE	LTV AE	EDA E
					rwh	rwh	rwh						rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
					MHF E	IOB AE	IIBA E	EFA E	RFO E	EER RE	CCL E	CCF E	SFO E	SFB ME	CNA E
					rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
PEMCE	0	rwh	POC Error Mode Changed Service Request Enable Read: 0 _B Protocol Error Mode Changed Service Request disabled 1 _B Protocol Error Mode Changed Service Request enabled Write: 0 _B Unchanged 1 _B Enable Protocol Error Mode Changed Service Request
CNAE	1	rwh	Command Not Accepted Service Request Enable Read: 0 _B Command Not Valid Service Request disabled 1 _B Command Not Valid Service Request enabled Write: 0 _B Unchanged 1 _B Enable Command Not Valid Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SFBME	2	rwh	SYNC Frames Below Minimum Service Request Enable Read: 0 _B SYNC Frames Below Minimum Service Request disabled 1 _B SYNC Frames Below Minimum Service Request enabled Write: 0 _B Unchanged 1 _B Enable SYNC Frames Below Minimum Service Request
SFOE	3	rwh	SYNC Frame Overflow Service Request Enable Read: 0 _B SYNC Frame Overflow Service Request disabled 1 _B SYNC Frame Overflow Service Request enabled Write: 0 _B Unchanged 1 _B Enable Protocol Error Mode Changed Service Request
CCFE	4	rwh	Clock Correction Failure Service Request Enable Read: 0 _B Clock Correction Failure Service Request disabled 1 _B Clock Correction Failure Service Request enabled Write: 0 _B Unchanged 1 _B Enable Clock Correction Failure Service Request
CCLE	5	rwh	CHI Command Locked Service Request Enable Read: 0 _B CHI Command Locked Service Request disabled 1 _B CHI Command Locked Service Request enabled Write: 0 _B Unchanged 1 _B Enable CHI Command Locked Service Request
EERRE	6	rwh	ECC Error Service Request Enable Read: 0 _B ECC Error Service Request disabled 1 _B ECC Error Service Request enabled Write: 0 _B Unchanged 1 _B Enable ECC Error Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
RFOE	7	rwh	Receive FIFO Overrun Service Request Enable Read: 0 _B Receive FIFO Overrun Service Request disabled 1 _B Receive FIFO Overrun Service Request enabled Write: 0 _B Unchanged 1 _B Enable Receive FIFO Overrun Service Request
EFAE	8	rwh	Empty FIFO Access Service Request Enable Read: 0 _B Empty FIFO Access Service Request disabled 1 _B Empty FIFO Access Service Request enabled Write: 0 _B Unchanged 1 _B Enable Empty FIFO Access Service Request
IIBAE	9	rwh	Illegal Input Buffer Access Service Request Enable Read: 0 _B Illegal Input Buffer Access Service Request disabled 1 _B Illegal Input Buffer Access Service Request enabled Write: 0 _B Unchanged 1 _B Enable Illegal Input Buffer Access Service Request
IOBAE	10	rwh	Illegal Output Buffer Access Service Request Enable Read: 0 _B Illegal Output Buffer Access Service Request disabled 1 _B Illegal Output Buffer Access Service Request enabled Write: 0 _B Unchanged 1 _B Enable Illegal Output Buffer Access Service Request
MHFE	11	rwh	Message Handler Constraints Flag Service Request Enable Read: 0 _B Message Handler Constraints Flag Service Request disabled 1 _B Message Handler Constraints Flag Service Request enabled Write: 0 _B Unchanged 1 _B Enable Message Handler Constraints Flag Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
EDAE	16	rwh	Error Detected on Channel A Service Request Enable Read: 0 _B Error Detected on Channel A Service Request disabled 1 _B Error Detected on Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Error Detected on Channel A Service Request
LTVAE	17	rwh	Latest Transmit Violation Channel A Service Request Enable Read: 0 _B Latest Transmit Violation Channel A Service Request disabled 1 _B Latest Transmit Violation Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Latest Transmit Violation Channel A Service Request
TABAE	18	rwh	Transmission Across Boundary Channel A Service Request Enable Read: 0 _B Transmission Across Boundary Channel A Service Request disabled 1 _B Transmission Across Boundary Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Transmission Across Boundary Channel A Service Request
EDBE	24	rwh	Error Detected on Channel B Service Request Enable Read: 0 _B Error Detected on Channel B Service Request disabled 1 _B Error Detected on Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Enable Error Detected on Channel B Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
LTVBE	25	rwh	Latest Transmit Violation Channel B Service Request Enable Read: 0 _B Latest Transmit Violation Channel B Service Request disabled 1 _B Latest Transmit Violation Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Enable Latest Transmit Violation Channel B Service Request
TABBE	26	rwh	Transmission Across Boundary Channel B Service Request Enable Read: 0 _B Transmission Across Boundary Channel B Service Request disabled 1 _B Transmission Across Boundary Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Enable Transmission Across Boundary Channel B Service Request
0	[15:12], [23:19], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Error Service Request Enable Reset (EIER)

The settings in the Error Service Request Enable register determine which status changes in the Error Service Request Register will result in a service request. The enable bits are set by writing to EIES and reset by writing to EIER. Writing a 1 resets the specific enable bit, a 0 has no effect.

EIER

Error Service Request Enable Reset (0034_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0					TAB BE	LTV BE	EDB E	0					TAB AE	LTV AE	EDA E
r					rwh	rwh	rwh	r					rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				MHF E	IOB AE	IIBA E	EFA E	RFO E	EER RE	CCL E	CCF E	SFO E	SFB ME	CNA E	PEM CE
r				rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
PEMCE	0	rwh	POC Error Mode Changed Service Request Enable Read: 0 _B Protocol Error Mode Changed Service Request disabled 1 _B Protocol Error Mode Changed Service Request enabled Write: 0 _B Unchanged 1 _B Disable Protocol Error Mode Changed Service Request
CNAE	1	rwh	Command Not Accepted Service Request Enable Read: 0 _B Command Not Accepted Service Request disabled 1 _B Command Not Accepted Service Request enabled Write: 0 _B Unchanged 1 _B Disable Command Not Accepted Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SFBME	2	rwh	SYNC Frames Below Minimum Service Request Enable Read: 0 _B SYNC Frames Below Minimum Service Request disabled 1 _B SYNC Frames Below Minimum Service Request enabled Write: 0 _B Unchanged 1 _B Disable SYNC Frames Below Minimum Service Request
SFOE	3	rwh	SYNC Frame Overflow Service Request Enable Read: 0 _B SYNC Frame Overflow Service Request disabled 1 _B SYNC Frame Overflow Service Request enabled Write: 0 _B Unchanged 1 _B Disable Protocol Error Mode Changed Service Request
CCFE	4	rwh	Clock Correction Failure Service Request Enable Read: 0 _B Clock Correction Failure Service Request disabled 1 _B Clock Correction Failure Service Request enabled Write: 0 _B Unchanged 1 _B Disable Clock Correction Failure Service Request
CCLE	5	rwh	CHI Command Locked Service Request Enable Read: 0 _B CHI Command Locked Service Request disabled 1 _B CHI Command Locked Service Request enabled Write: 0 _B Unchanged 1 _B Disable CHI Command Locked Service Request
EERRE	6	rwh	ECC Error Service Request Enable Read: 0 _B ECC Error Service Request disabled 1 _B ECC Error Service Request enabled Write: 0 _B Unchanged 1 _B Disable ECC Error Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
RFOE	7	rwh	Receive FIFO Overrun Service Request Enable Read: 0 _B Receive FIFO Overrun Service Request disabled 1 _B Receive FIFO Overrun Service Request enabled Write: 0 _B Unchanged 1 _B Disable Receive FIFO Overrun Service Request
EFAE	8	rwh	Empty FIFO Access Service Request Enable Read: 0 _B Empty FIFO Access Service Request disabled 1 _B Empty FIFO Access Service Request enabled Write: 0 _B Unchanged 1 _B Disable Empty FIFO Access Service Request
IIBAE	9	rwh	Illegal Input Buffer Access Service Request Enable Read: 0 _B Illegal Input Buffer Access Service Request disabled 1 _B Illegal Input Buffer Access Service Request enabled Write: 0 _B Unchanged 1 _B Disable Illegal Input Buffer Access Service Request
IOBAE	10	rwh	Illegal Output Buffer Access Service Request Enable Read: 0 _B Illegal Output Buffer Access Service Request disabled 1 _B Illegal Output Buffer Access Service Request enabled Write: 0 _B Unchanged 1 _B Disable Illegal Output Buffer Access Service Request
MHFE	11	rwh	Message Handler Constraints Flag Service Request Enable Read: 0 _B Message Handler Constraints Flag Service Request disabled 1 _B Message Handler Constraints Flag Service Request enabled Write: 0 _B Unchanged 1 _B Disable Message Handler Constraints Flag Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
EDAE	16	rwh	Error Detected on Channel A Service Request Enable Read: 0 _B Error Detected on Channel A Service Request disabled 1 _B Error Detected on Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Disable Error Detected on Channel A Service Request
LTVAE	17	rwh	Latest Transmit Violation Channel A Service Request Enable Read: 0 _B Latest Transmit Violation Channel A Service Request disabled 1 _B Latest Transmit Violation Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Disable Latest Transmit Violation Channel A Service Request
TABAE	18	rwh	Transmission Across Boundary Channel A Service Request Enable Read: 0 _B Transmission Across Boundary Channel A Service Request disabled 1 _B Transmission Across Boundary Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Transmission Across Boundary Channel A Service Request
EDBE	24	rwh	Error Detected on Channel B Service Request Enable Read: 0 _B Error Detected on Channel B Service Request disabled 1 _B Error Detected on Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Disable Error Detected on Channel B Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
LTVBE	25	rwh	Latest Transmit Violation Channel B Service Request Enable Read: 0 _B Latest Transmit Violation Channel B Service Request disabled 1 _B Latest Transmit Violation Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Disable Latest Transmit Violation Channel B Service Request
TABBE	26	rwh	Transmission Across Boundary Channel B Service Request Enable Read: 0 _B Transmission Across Boundary Channel B Service Request disabled 1 _B Transmission Across Boundary Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Disable Transmission Across Boundary Channel B Service Request
0	[15:12], [23:19], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Status Service Request Enable Set (SIES)

The settings in the Status Service Request Enable Set register determine which status changes in the Status Service Request Register will result in a service request. The enable bits are set by writing to SIES and reset by writing to SIER. Writing a 1 sets the specific enable bit, a 0 has no effect.

SIES

Status Service Request Enable Set (0038_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
			0			MTS BE	WUP BE				0			MTS AE	WUP AE
			r			rwh	rwh				r			rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDS E	MBS IE	SUC SE	SWE E	TOB CE	TIBC E	T1IE	TIOE	NMV CE	RFC LE	RFN EE	RXIE	TXIE	CYC SE	CAS E	WST E
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
WSTE	0	rwh	Wakeup Status Service Request Enable Read: 0 _B Wakeup Status Service Request disabled 1 _B Wakeup Status Service Request enabled Write: 0 _B Unchanged 1 _B Enable Wakeup Status Service Request
CASE	1	rwh	Collision Avoidance Symbol Service Request Enable Read: 0 _B Collision Avoidance Symbol Service Request disabled 1 _B Collision Avoidance Symbol Service Request enabled Write: 0 _B Unchanged 1 _B Enable Collision Avoidance Symbol Service Request
CYCSE	2	rwh	Cycle Start Service Request Enable Read: 0 _B Cycle Start Service Request disabled 1 _B Cycle Start Service Request enabled Write: 0 _B Unchanged 1 _B Enable Cycle Start Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TXIE	3	rwh	Transmit Service Request Enable Read: 0 _B Transmit Service Request disabled 1 _B Transmit Service Request enabled Write: 0 _B Unchanged 1 _B Enable Transmit Service Request
RXIE	4	rwh	Receive Service Request Enable Read: 0 _B Receive Service Request disabled 1 _B Receive Service Request enabled Write: 0 _B Unchanged 1 _B Enable Receive Service Request
RFNEE	5	rwh	Receive FIFO Not Empty Service Request Enable Read: 0 _B Receive FIFO Not Empty Service Request disabled 1 _B Receive FIFO Not Empty Service Request enabled Write: 0 _B Unchanged 1 _B Enable Receive FIFO Not Empty Service Request
RFCLE	6	rwh	Receive FIFO Critical Level Service Request Enable Read: 0 _B Receive FIFO Critical Level Service Request disabled 1 _B Receive FIFO Critical Level Service Request enabled Write: 0 _B Unchanged 1 _B Enable Receive FIFO Critical Level Service Request
NMVCE	7	rwh	Network Management Vector Changed Service Request Enable Read: 0 _B Network Management Vector Changed Service Request disabled 1 _B Network Management Vector Changed Service Request enabled Write: 0 _B Unchanged 1 _B Enable Network Management Vector Changed Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TI0E	8	rwh	Timer Service Request 0 Enable Read: 0 _B Timer Service Request 0 disabled 1 _B Timer Service Request 0 enabled Write: 0 _B Unchanged 1 _B Enable Timer Service Request 0
TI1E	9	rwh	Timer Service Request 1 Enable Read: 0 _B Timer Service Request 1 disabled 1 _B Timer Service Request 1 enabled Write: 0 _B Unchanged 1 _B Enable Timer Service Request 1
TIBCE	10	rwh	Transfer Input Buffer Completed Service Request Enable Read: 0 _B Wakeup Status Service Request disabled 1 _B Wakeup Status Service Request enabled Write: 0 _B Unchanged 1 _B Enable Wakeup Status Service Request
TOBCE	11	rwh	Transfer Output Buffer Completed Service Request Enable Read: 0 _B Transfer Input Buffer Completed Service Request disabled 1 _B Transfer Input Buffer Completed Service Request enabled Write: 0 _B Unchanged 1 _B Enable Transfer Input Buffer Completed Service Request
SWEE	12	rwh	Stop Watch Event Service Request Enable Read: 0 _B Stop Watch Event Service Request disabled 1 _B Stop Watch Event Service Request enabled Write: 0 _B Unchanged 1 _B Enable Stop Watch Event Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SUCSE	13	rwh	Startup Completed Successfully Service Request Enable Read: 0 _B Startup Completed Successfully Service Request disabled 1 _B Startup Completed Successfully Service Request enabled Write: 0 _B Unchanged 1 _B Enable Startup Completed Successfully Service Request
MBSIE	14	rwh	Message Buffer Status Service Request Enable Read: 0 _B Message Buffer Status Service Request disabled 1 _B Message Buffer Status Service Request enabled Write: 0 _B Unchanged 1 _B Enable Message Buffer Status Service Request
SDSE	15	rwh	Start of Dynamic Segment Service Request Enable Read: 0 _B Start of Dynamic Service Request disabled 1 _B Start of Dynamic Service Request enabled Write: 0 _B Unchanged 1 _B Enable Start of Dynamic Service Request
WUPAE	16	rwh	Wakeup Pattern Channel A Service Request Enable Read: 0 _B Wakeup Pattern Channel A Service Request disabled 1 _B Wakeup Pattern Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Wakeup Pattern Channel A Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
MTSAE	17	rwh	Media Access Test Symbol Channel A Service Request Enable Read: 0 _B Media Access Test Symbol Channel A Service Request disabled 1 _B Media Access Test Symbol Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Enable Media Access Test Symbol Channel A Service Request
WUPBE	24	rwh	Wakeup Pattern Channel B Service Request Enable Read: 0 _B Wakeup Pattern Channel B Service Request disabled 1 _B Wakeup Pattern Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Enable Wakeup Pattern Channel A Service Request
MTSBE	25	rwh	Media Access Test Symbol Channel B Service Request Enable Read: 0 _B Media Access Test Symbol Channel B Service Request disabled 1 _B Media Access Test Symbol Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Enable Media Access Test Symbol Channel B Service Request
0	[23:18], [31:26]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Status Service Request Enable Reset (SIER)

The settings in the Status Service Request Enable Reset register determine which status changes in the Status Service Request Register will result in a service request. The enable bits are set by writing to SIES and reset by writing to SIER. Writing a 1 resets the specific enable bit, a 0 has no effect.

SIER

Status Service Request Enable Reset(003C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						MTS BE	WUP BE	0						MTS AE	WUP AE
r						rwh	rwh	r						rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SDS E	MBS IE	SUC SE	SWE E	TOB CE	TIBC E	TI1E	TI0E	NMV CE	RFC LE	RFN EE	RXIE	TXIE	CYC SE	CAS E	WST E
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
WSTE	0	rwh	Wakeup Status Service Request Enable Read: 0 _B Wakeup Status Service Request disabled 1 _B Wakeup Status Service Request enabled Write: 0 _B Unchanged 1 _B Disable Wakeup Status Service Request
CASE	1	rwh	Collision Avoidance Symbol Service Request Enable Read: 0 _B Collision Avoidance Symbol Service Request disabled 1 _B Collision Avoidance Symbol Service Request enabled Write: 0 _B Unchanged 1 _B Disable Collision Avoidance Symbol Service Request
CYCSE	2	rwh	Cycle Start Service Request Enable Read: 0 _B Cycle Start Service Request disabled 1 _B Cycle Start Service Request enabled Write: 0 _B Unchanged 1 _B Disable Cycle Start Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TXIE	3	rwh	Transmit Service Request Enable Read: 0 _B Transmit Service Request disabled 1 _B Transmit Service Request enabled Write: 0 _B Unchanged 1 _B Disable Transmit Service Request
RXIE	4	rwh	Receive Service Request Enable Read: 0 _B Receive Service Request disabled 1 _B Receive Service Request enabled Write: 0 _B Unchanged 1 _B Disable Receive Service Request
RFNEE	5	rwh	Receive FIFO Not Empty Service Request Enable Read: 0 _B Receive FIFO Not Empty Service Request disabled 1 _B Receive FIFO Not Empty Service Request enabled Write: 0 _B Unchanged 1 _B Disable Receive FIFO Not Empty Service Request
RFCLE	6	rwh	Receive FIFO Critical Level Service Request Enable Read: 0 _B Service Request disabled 1 _B Receive FIFO Critical Level Service Request enabled Write: 0 _B Unchanged 1 _B Disable Receive FIFO Critical Level Service Request
NMVCE	7	rwh	Network Management Vector Changed Service Request Enable Read: 0 _B Network Management Vector Changed Service Request disabled 1 _B Network Management Vector Changed Service Request enabled Write: 0 _B Unchanged 1 _B Disable Network Management Vector Changed Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TI0E	8	rwh	Timer Service Request 0 Enable Read: 0 _B Timer Service Request 0 disabled 1 _B Timer Service Request 0 enabled Write: 0 _B Unchanged 1 _B Disable Service Request 0
TI1E	9	rwh	Timer Service Request 1 Enable Read: 0 _B Timer Service Request 1 disabled 1 _B Timer Service Request 1 enabled Write: 0 _B Unchanged 1 _B Disable Timer Service Request 1
TIBCE	10	rwh	Transfer Input Buffer Completed Service Request Enable Read: 0 _B Wakeup Status Service Request disabled 1 _B Wakeup Status Service Request enabled Write: 0 _B Unchanged 1 _B Disable Wakeup Status Service Request
TOBCE	11	rwh	Transfer Output Buffer Completed Service Request Enable Read: 0 _B Transfer Input Buffer Completed Service Request disabled 1 _B Transfer Input Buffer Completed Service Request enabled Write: 0 _B Unchanged 1 _B Disable Transfer Input Buffer Completed Service Request
SWEE	12	rwh	Stop Watch Event Service Request Enable Read: 0 _B Stop Watch Event Service Request disabled 1 _B Stop Watch Event Service Request enabled Write: 0 _B Unchanged 1 _B Disable Stop Watch Event Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SUCSE	13	rwh	Startup Completed Successfully Service Request Enable Read: 0 _B Startup Completed Successfully Service Request disabled 1 _B Startup Completed Successfully Service Request enabled Write: 0 _B Unchanged 1 _B Disable Startup Completed Successfully Service Request
MBSIE	14	rwh	Message Buffer Status Service Request Enable Read: 0 _B Message Buffer Status Service Request disabled 1 _B Message Buffer Status Service Request enabled Write: 0 _B Unchanged 1 _B Disable Message Buffer Status Service Request
SDSE	15	rwh	Start of Dynamic Segment Service Request Enable Read: 0 _B Start of Dynamic Service Request disabled 1 _B Start of Dynamic Service Request enabled Write: 0 _B Unchanged 1 _B Disable Start of Dynamic Service Request
WUPAE	16	rwh	Wakeup Pattern Channel A Service Request Enable Read: 0 _B Wakeup Pattern Channel A Service Request disabled 1 _B Wakeup Pattern Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Disable Wakeup Pattern Channel A Service Request

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
MTSAE	17	rwh	Media Access Test Symbol Channel A Service Request Enable Read: 0 _B Media Access Test Symbol Channel A Service Request disabled 1 _B Media Access Test Symbol Channel A Service Request enabled Write: 0 _B Unchanged 1 _B Disable Media Access Test Symbol Channel A Service Request
WUPBE	24	rwh	Wakeup Pattern Channel B Service Request Enable Read: 0 _B Wakeup Pattern Channel B Service Request disabled 1 _B Wakeup Pattern Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Disable Wakeup Pattern Channel A Service Request
MTSBE	25	rwh	Media Access Test Symbol Channel B Service Request Enable Read: 0 _B Media Access Test Symbol Channel B Service Request disabled 1 _B Media Access Test Symbol Channel B Service Request enabled Write: 0 _B Unchanged 1 _B Disable Media Access Test Symbol Channel B Service Request
0	[23:18], [31:26]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Service Request Line Enable (ILE)

Each of the two service request lines to the Host INT0SRC, INT1SRC can be enabled / disabled separately by programming bit EINT0 and EINT1.

ILE

Service Request Line Enable (0040_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0														EINT 1	EINT 0
r														rw	rw

Field	Bits	Type	Description
EINT0	0	rw	Enable Service Request Line 0 (INT0SRC) 0 _B Service Request line disabled 1 _B Service Request line enabled
EINT1	1	rw	Enable Service Request Line 1 (INT1SRC) 0 _B Service Request line disabled 1 _B Service Request line enabled
0	[31:2]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Timer 0 Configuration (T0C)

Absolute timer. Specifies in terms of cycle count and Macrotick the point in time when the timer 0 service request occurs. When the timer 0 service request is asserted, output signal TINT0SR is set to 1 for the duration of one Macrotick and SIR.TI0 is set to 1.

Timer 0 can be activated as long as the POC is either in “NORMAL_ACTIVE” state or in “NORMAL_PASSIVE” state. Timer 0 is deactivated when leaving “NORMAL_ACTIVE” state or “NORMAL_PASSIVE” state except for transitions between the two states.

Before reconfiguration of the timer, the timer has to be halted first by writing 0 to bit T0RC.

T0C

Timer 0 Configuration

(0044_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		T0MO													
r		rw													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	T0CC							0					T0MS	T0RC	
r	rw							r					rw	rwh	

Field	Bits	Type	Description
T0RC	0	rwh	Timer 0 Run Control 0 _B Timer 0 halted 1 _B Timer 0 running
T0MS	1	rw	Timer 0 Mode Select 0 _B Single-shot mode 1 _B Continuous mode
T0CC	[14:8]	rw	Timer 0 Cycle Code The 7-bit timer 0 cycle code determines the cycle set used for generation of the timer 0 service request. For details about the configuration of the cycle code see “Cycle Counter Filtering” on Page 225 .
T0MO	[29:16]	rw	Timer 0 Macrotick Offset Configures the Macrotick offset from the beginning of the cycle where the service request is to occur. The Timer 0 Service Request occurs at this offset for each cycle of the cycle set.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	[7:2], 15, [31:30]	r	Reserved Returns 0 if read; should be written with 0.

Note: The configuration of timer 0 is compared against the Macrotick counter value, there is no separate counter for timer 0. In case the Communication Controller leaves "NORMAL_ACTIVE" or "NORMAL_PASSIVE" state, or if timer 0 is halted by Host command, output signal TINT0SR is reset to 0 immediately.

FlexRay™ Protocol Controller (E-Ray)

Timer 1 Configuration (T1C)

Relative timer. After the specified number of MacroTicks has expired, the timer 1 service request is asserted, output signal TINT1SR is set to 1 for the duration of one MacroTick and SIR.TI1 is set to 1.

Timer 1 can be activated as long as the POC is either in "NORMAL_ACTIVE" state or in "NORMAL_PASSIVE" state. Timer 1 is deactivated when leaving "NORMAL_ACTIVE" state or "NORMAL_PASSIVE" state except for transitions between the two states.

Before reconfiguration of the timer, the timer has to be halted first by resetting bit T1RC to 0.

T1C

Timer 1 Configuration (0048_H) Reset Value: 0002 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		T1MC													
r		rw													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0													T1M	T1R	
r													rw	rw	rw

Field	Bits	Type	Description
T1RC	0	rw	Timer 1 Run Control 0 _B Timer 1 halted 1 _B Timer 1 running
T1MS	1	rw	Timer 1 Mode Select 0 _B Single-shot mode 1 _B Continuous mode
T1MC	[29:16]	rw	Timer 1 MacroTick Count When the configured MacroTick count is reached the timer 1 service request is generated. Valid values are: 2 _H ... 3FFF _H MacroTicks in continuous mode 1 _H ... 3FFF _H MacroTicks in single-shot mode
0	[15:2], [31:30]	r	Reserved Returns 0 if read; should be written with 0.

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Note: In case the Communication Controller leaves "NORMAL_ACTIVE" or "NORMAL_PASSIVE" state, or if timer 1 is halted by Host command, output signal TINT1SR is reset to 0 immediately.

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Stop Watch Register 1 (STPW1)

The stop watch is activated by a rising or falling edge on signal STPW, by a service request 0 or 1 event (rising edge on signal INT0SR or INT1SR) or by the Host by writing bit STPW1.SSWT to 1. With the Macro-tick counter increment following next to the stop watch activation the actual cycle counter and Macro-tick value are captured in the Stop Watch Register 1 STPW1 while the slot counter values for channel A and B are captured in the Stop Watch Register 2 STPW2.

STPW1

Stop Watch Register 1

(004C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		SMTV													
r		rh													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		SCCV						0	EINT	EINT	EET	SSW	EDG	SWM	ESW
r		rh						r	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ESWT	0	rwh	Enable Stop Watch Trigger If enabled an edge on input STPW or a service request 0 or 1 event (rising edge on signal INT0SR or INT1SR) activates the stop watch. In single-shot mode this bit is reset to 0 after the actual cycle counter and Macro-tick value are stored in the Stop Watch register. 0 _B Stop watch trigger disabled 1 _B Stop watch trigger enabled
SWMS	1	rw	Stop Watch Mode Select It is not possible to change the Stop Watch Mode during enabled stop watch trigger (STPW1.ESWT) 0 _B Single-shot mode 1 _B Continuous mode
EDGE	2	rw	Stop Watch Trigger Edge Select 0 _B Falling Edge 1 _B Rising Edge

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Field	Bits	Type	Description
SSWT	3	rwh	Software Stop Watch Trigger When the Host writes this bit to 1 the stop watch is activated. After the actual cycle counter and Macrotick value are stored in the Stop Watch register this bit is reset to 0. The bit is only writeable while ESWT = 0. 0 _B Software trigger reset 1 _B Stop watch activated by software trigger
EETP	4	rw	Enable External Trigger Pin Enables stop watch trigger event via signal STPW if ESWT = 1. 0 _B Stop watch trigger via signal STPW disabled 1 _B Edge on signal STPW triggers stop watch
EINT0	5	rw	Enable Service Request 0 Trigger Enables stop watch trigger by service request 0 event if ESWT = 1. 0 _B Stop watch trigger by service request 0 disabled 1 _B Service Request 0 event triggers stop watch
EINT1	6	rw	Enable Service Request 1 Trigger Enables stop watch trigger by service request 1 event if ESWT = 1. 0 _B Stop watch trigger by service request 1 disabled 1 _B Service Request 1 event triggers stop watch
SCCV	[13:8]	rh	Stopped Cycle Counter Value State of the cycle counter when the stop watch event occurred. Valid values are: 0...3F _H Valid Values
SMTV	[29:16]	rh	Stopped Macrotick Value State of the Macrotick counter when the stop watch event occurred. Valid values are: 0...3F _H Valid Values
0	7, [15:14], [31:30]	r	Reserved Returns 0 if read; should be written with 0.

Note: Bits ESWT and SSWT cannot be set to 1 simultaneously. In this case the write access is ignored, and both bits keep their previous values. Therefore either the external stop watch triggers or the software stop watch trigger may be used.

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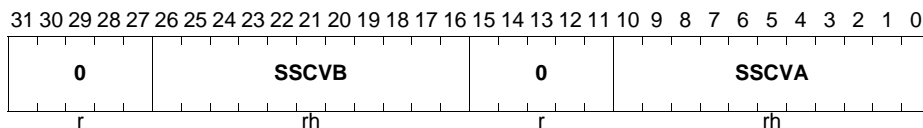
Stop Watch Register 2 (STPW2)

STPW2

Stop Watch Register 2

(0050_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SSCVA	[10:0]	rh	Stop Watch Captured Slot Counter Value Channel A State of the slot counter for channel A when the stop watch event occurred. Valid values are 0 to 2047 (0 _H to 7FF _H).
SSCVB	[26:16]	rh	Stop Watch Captured Slot Counter Value Channel B State of the slot counter for channel B when the stop watch event occurred. Valid values are 0 to 2047 (0 _H to 7FF _H).
0	[15:11], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

21.5.2.4 Communication Controller Control Registers

This section describes the registers provided by the Communication Controller to allow the Host to control the operation of the Communication Controller. The FlexRay™ protocol specification requires the Host to write application configuration data in “CONFIG” state only. Please consider that the configuration registers are not locked for writing in “DEFAULT_CONFIG” state.

The configuration data is reset when “DEFAULT_CONFIG” state is entered from application reset. To change POC state from “DEFAULT_CONFIG” to “CONFIG” state the Host has to apply CHI command “CONFIG”. If the Host wants the Communication Controller to leave “CONFIG” state, the Host has to proceed as described on [“Lock Register \(LCK\)” on Page 40](#).

SUC Configuration Register 1 (SUCC1)

SUCC1

SUC Configuration Register 1

(0080_H)

Reset Value: 0C40 1080_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				CCH B	CCH A	MTS B	MTS A	HCS E	TSM	WUC S	PTA				
r				rw	rw	rw	rw	rw	rw	rw	rw				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CSA					0	TXS Y	TXS T	P BSY	0			CMD			
rw					r	rw	rw	rh	r			rwh			

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Field	Bits	Type	Description
CMD	[3:0]	rwh	<p>CHI Command Vector</p> <p>The host may write any CHI command at any time, but certain commands are only enabled in specific POC states. A disabled command will not be executed, the CHI command vector CMD will be reset to 0000_B = "COMMAND_NOT_ACCEPTED", and flag EIR.CNA in the Error Service Request register will be set to 1. In case the previous CHI command has not yet completed, EIR.CCL is set to 1 together with EIR.CNA; the CHI command needs to be repeated. Except for HALT state, POC state change command applied while the Communication Controller is already in the requested POC state will be ignored.</p> <p>0000_B COMMAND_NOT_ACCEPTED"</p> <p>0001_B CONFIG</p> <p>0010_B READY</p> <p>0011_B WAKEUP</p> <p>0100_B RUN</p> <p>0101_B ALL_SLOTS</p> <p>0110_B HALT</p> <p>0111_B FREEZE</p> <p>1000_B SEND_MTS</p> <p>1001_B ALLOW_COLDSTART</p> <p>1010_B RESET_STATUS_INDICATORS</p> <p>1011_B MONITOR_MODE</p> <p>1100_B CLEAR_RAMs</p> <p>1101_B Reserved</p> <p>1110_B Reserved</p> <p>1111_B Reserved</p> <p>Reading SUCC1.CMD shows whether the last CHI command was accepted. CCSV.POCS monitors the actual POC state. The reserved CHI commands code hardware test functions.</p>
PBSY	7	rh	<p>POC Busy</p> <p>Signals that the POC is busy and cannot accept a command from the Host. SUCC1.CMD is locked against write accesses. Set to 1 after hard reset during initialization of internal RAM blocks.</p> <p>0_B POC not busy, SUCC1.CMD writeable</p> <p>1_B POC is busy, SUCC1.CMD locked</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TXST	8	rw	Transmit Startup Frame in Key Slot^{1) 2)} (pKeySlotUsedForStartup) Defines whether the key slot is used to transmit startup Frames. The bit can be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 0 _B No Startup Frame transmission in key slot, node is non-coldstarter 1 _B Key slot used to transmit startup Frame, node is leading or following coldstarter
TXSY	9	rw	Transmit SYNC Frame in Key Slot^{1) 2)} (pKeySlotUsedForSync) Defines whether the key slot is used to transmit SYNC Frames. The bit can be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 0 _B No SYNC Frame transmission in key slot, node is neither sync nor coldstart node 1 _B Key slot used to transmit SYNC Frames, node is sync node
CSA	[15:11]	rw	Cold Start Attempts¹⁾ (gColdStartAttempts) Configures the maximum number of attempts that a cold starting node is permitted to try to start up the network without receiving any valid response from another node. It can be modified in “DEFAULT_CONFIG” or “CONFIG” state only. Must be identical in all nodes of a cluster. Valid values are 2 to 31.
PTA	[20:16]	rw	Passive to Active¹⁾ (pAllowPassiveToActive) Defines the number of consecutive even / odd cycle pairs that must have valid clock correction terms before the Communication Controller is allowed to transit from “NORMAL_PASSIVE” to “NORMAL_ACTIVE” state. If set to 00000 _B the Communication Controller is not allowed to transit from “NORMAL_PASSIVE” to “NORMAL_ACTIVE” state. It can be modified in “DEFAULT_CONFIG” or “CONFIG” state only. Valid values are 0 to 31 even / odd cycle pairs.

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Field	Bits	Type	Description
WUCS	21	rw	<p>Wakeup Channel Select¹⁾ (pWakeupChannel)</p> <p>With this bit the Host selects the channel on which the Communication Controller sends the Wakeup pattern. The Communication Controller ignores any attempt to change the status of this bit when not in “DEFAULT_CONFIG” or “CONFIG” state.</p> <p>0_B Send wakeup pattern on channel A</p> <p>1_B Send wakeup pattern on channel B</p>
TSM	22	rw	<p>Transmission Slot Mode¹⁾ (pSingleSlotEnabled)</p> <p>Selects the initial transmission slot mode. In SINGLE slot mode the Communication Controller may only transmit in the preconfigured key slot. The key slot ID is configured in the Header Section of Message Buffer 0 respectively Message Buffers 0 and 1 depending on bit MRC.SPLM. In case SUCC1.TSM = 1, Message Buffer 0 respectively Message Buffers 0,1 can be (re)configured in “DEFAULT_CONFIG” or “CONFIG” state only. In ALL slot mode the Communication Controller may transmit in all slots. The bit can be written in “DEFAULT_CONFIG” or “CONFIG” state only. The communication controller changes to ALL slot mode when the Host successfully applied the ALL_SLOTS command by writing SUCC1.CMD = 0101_B in POC states “NORMAL_ACTIVE” or “NORMAL_PASSIVE”. The actual slot mode is monitored by CCSV.SLM.</p> <p>0_B ALL Slot Mode</p> <p>1_B SINGLE Slot Mode (default after application reset)</p>
HCSE	23	rw	<p>Halt due to Clock Sync Error¹⁾ (pAllowHaltDueToClock)</p> <p>Controls the transition to “HALT” state due to a clock synchronization error. The bit can be modified in “DEFAULT_CONFIG” or “CONFIG” state only.</p> <p>0_B Communication Controller will enter / remain in “NORMAL_PASSIVE”</p> <p>1_B Communication Controller will enter “HALT” state</p>
MTSA	24	rw	<p>Select Channel A for MTS Transmission^{1) 3)}</p> <p>The bit selects channel A for MTS symbol transmission. The flag is reset by default and may be modified only in “DEFAULT_CONFIG” or “CONFIG” state.</p> <p>0_B Channel A disabled for MTS transmission</p> <p>1_B Channel A selected for MTS transmission</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
MTSB	25	rw	Select Channel B for MTS Transmission^{1) 3)} The bit selects channel B for MTS symbol transmission. The flag is reset by default and may be modified only in "DEFAULT_CONFIG" or "CONFIG" state. 0 _B Channel B disabled for MTS transmission 1 _B Channel B selected for MTS transmission
CCHA	26	rw	Connected to Channel A¹⁾ (pChannels) Configures whether the node is connected to channel A. 0 _B Not connected to channel A 1 _B Node connected to channel A (default after application reset)
CCHB	27	rw	Connected to Channel B¹⁾ (pChannels) Configures whether the node is connected to channel B. 0 _B Not connected to channel B 1 _B Node connected to channel B (default after application reset)
0	[6:4], 10, [31:28]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

2) The protocol requires that both bits TXST and TXY are set for coldstart nodes.

3) MTSA and MTSB may also be changed outside "DEFAULT_CONFIG" or "CONFIG" state when the write to SUCC1 register is directly preceded by the unlock sequence as described in Lock Register (LCK). This may be combined with CHI command "SEND_MTS". If both bits MTSA and MTSB are set to 1 an MTS symbol will be transmitted on both channels when requested by writing SUCC1.CMD = 1000_B.

COMMAND_NOT_ACCEPTED

SUCC1.CMD is reset to 0000_B due to one of the following conditions:

- Illegal command applied by the Host
- Host writes command_not_accepted
- Host applied new command while execution of the previous Host command has not completed

When SUCC1.CMD is reset to 0000_B, bit EIR.CNA in the Error Service Request register is set, and - if enabled - an service request is generated. Commands which are not accepted are not executed.

CONFIG

Go to POC state "CONFIG" when called in POC states "DEFAULT_CONFIG", "READY", or in "MONITOR_MODE". When called in "HALT" state transits to POC state

FlexRay™ Protocol Controller (E-Ray)

“DEFAULT_CONFIG“. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

READY

Go to POC state “READY” when called in POC states “CONFIG”, “NORMAL_ACTIVE”, “NORMAL_PASSIVE”, “STARTUP”, or “WAKEUP”. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

WAKEUP

Go to POC state WAKEUP when called in POC state “READY”. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

RUN

Go to POC state “STARTUP” when called in POC state “READY”. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

ALL_SLOTS

Leave SINGLE slot mode after successful startup / integration at the next end of cycle when called in POC states “NORMAL_ACTIVE” or “NORMAL_PASSIVE”. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

HALT

Set the halt request CCSV.HRQ bit in the Communication Controller Status Vector register and go to POC state “HALT” at the next end of cycle when called in POC states “NORMAL_ACTIVE” or “NORMAL_PASSIVE“. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

FREEZE

Set the freeze status indicator CCSV.FSI and go to POC state “HALT” immediately. Can be called from any state.

SEND_MTS

Send single MTS symbol during the next following symbol window on the channel configured by SUCC1.MTSA, SUCC1.MTSB, when called in POC state “NORMAL_ACTIVE”. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

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ALLOW_COLDSTART

The command resets bit CCSV.CSI to enable the node to become cold starter. When called in states “DEFAULT_CONFIG”, “CONFIG”, “HALT”, or “MONITOR_MODE”. SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”. To become leading coldstarter it is also required that both TXST and TXSY are set.

RESET_STATUS_INDICATORS

Resets status flags CCSV.CSNI, CCSV.CSAI, CCSV.WSV to their default values. May be called in POC state READY. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”.

MONITOR_MODE

Enter MONITOR_MODE when called in POC state CONFIG. In this mode the Communication Controller is able to receive FlexRay™ Frames and wakeup pattern. It is also able to detect coding errors. The temporal integrity of received Frames is not checked. This mode can be used for debugging purposes, e.g. in case that the startup of a FlexRay™ network fails. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”. For details see [“MONITOR_MODE” on Page 209](#).

CLEAR_RAMs

Sets bit MHDS.CRAM in the Message Handler Status register when called in “DEFAULT_CONFIG” or “CONFIG” state. When called in any other state, SUCC1.CMD will be reset to 0000_B = “COMMAND_NOT_ACCEPTED”. MHDS.CRAM is also set when the Communication Controller leaves application reset. By setting MHDS.CRAM all internal RAM blocks are initialized to zero. Note that only the currently active IBF bank is cleared. To clear the 2nd bank as well, CUST1.IBF1PAG and CUST1.IBF2PAG need to be set and command CLEAR_RAMs need to be issued again. This is required in particular after an application reset. If the 2nd bank of IBF is left unused, this procedure is not required. During the initialization of the RAMs, SUCC1.PBSY will show POC busy. Access to the configuration and status registers is possible during execution of CHI command CLEAR_RAMs.

The initialization of the E-Ray internal RAM blocks requires $2048 f_{CLC_ERAY}$ cycles. There should be no Host access to IBF or OBF during initialization of the internal RAM blocks after application reset or after assertion of CHI command CLEAR_RAMs. Before asserting CHI command CLEAR_RAMs the Host should make sure that no transfer between Message RAM and IBF / OBF or the Transient Buffer RAMs is ongoing. This command also resets the Message Buffer Status registers MHDS, LDTS, FSR, MHDF, TXRQ1, TXRQ2, TXRQ3, TXRQ4, NDAT1, NDAT2, NDAT3, NDAT4, MBSC1, MBSC2, MBSC3, and MBSC4.

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Note: All accepted commands with exception of CLEAR_RAMs and SEND_MTS will cause a change of register CCSV after at most 8 cycles of the slower of the two clocks f_{CLC_ERAY} and f_{SCLK} , assumed that POC was not busy when the command was applied and that no POC state change was forced by bus activity in that time Frame. Reading register CCSV will show data that is delayed by synchronization from f_{SCLK} to f_{CLC_ERAY} domain and by the Host-specific CPU interface.

Table 45 below references the CHI commands from the FlexRay™ Protocol Specification v2.1 (section 2.2.1.1, Table 2-2) to the E-Ray CHI command vector CMD.]

Table 45 Reference to CHI Host command summary from FlexRay™ protocol specification

CHI Command	Where processed (POC State)	CHI Command Vector CMD
ALL_SLOT	POC:NORMAL_ACTIVE, POC:NORMAL_PASSIVE	ALL_SLOTS
ALLOW_COLDSTART	All except POC:DEFAULT_CONFIG, POC:CONFIG, POC:HALT	ALLOW_COLDSTART
CONFIG	POC:DEFAULT_CONFIG, POC:READY	CONFIG
CONFIG_COMPLETE	POC:CONFIG	Unlock sequence & READY
DEFAULT_CONFIG	POC:HALT	CONFIG
FREEZE	All	FREEZE
HALT	POC:NORMAL_ACTIVE, POC:NORMAL_PASSIVE	HALT
READY	All except POC:DEFAULT_CONFIG, POC:CONFIG, POC:READY, POC:HALT	READY
RUN	POC:READY	RUN
WAKEUP	POC:READY	WAKEUP

FlexRay™ Protocol Controller (E-Ray)

SUC Configuration Register 2 (SUCC2)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

SUCC2

SUC Configuration Register 2 (0084_H) **Reset Value: 0100 0504_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				LTN				0				LT																			
r				rw				r				rw																			

Field	Bits	Type	Description
LT	[20:0]	rw	Listen Timeout¹⁾ (pdListenTimeout) Configures wakeup / startup listen timeout in Microticks. The range for wakeup / startup listen timeout (pdListenTimeout) is 1284 to 1283846 (504 _H to 139706 _H) Microticks
LTN	[27:24]	rw	Listen Timeout Noise¹⁾ (gListenNoise - 1) Configures the upper limit for startup and wakeup listen timeout in the presence of noise expressed as a multiple of the cluster constant pdListenTimeout. The range of pdListenTimeout 2 to 16. LTN must be configured identical in all nodes of a cluster. 1 _H Listen Timeout Noise is equal 2 2 _H Listen Timeout Noise is equal 3 ... _H ... F _H Listen Timeout Noise is equal 16
0	[23:21], [31:28]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

Note: The wakeup / startup noise timeout is calculated as follows:

$$\begin{aligned} \text{The wakeup / startup noise timeout} &= \text{pdListenTimeout} \cdot \text{gListenNoise} \\ &= \text{LT} \cdot (\text{LTN} + 1) \end{aligned}$$

FlexRay™ Protocol Controller (E-Ray)

SUC Configuration Register 3 (SUCC3)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

SUCC3

SUC Configuration Register 3

(0088_H)

Reset Value: 0000 0011_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0																								WCF			WCP				
r																								rw			rw				

Field	Bits	Type	Description
WCP	[3:0]	rw	Maximum Without Clock Correction Passive¹⁾ (gMaxWithoutClockCorrectionPassive) Defines the number of consecutive even / odd cycle pairs with missing clock correction terms that will cause a transition from "NORMAL_ACTIVE" to "NORMAL_PASSIVE" state. Must be identical in all nodes of a cluster. Valid values are 1 to 15 (1 _H to F _H) cycle pairs.
WCF	[7:4]	rw	Maximum Without Clock Correction Fatal¹⁾ (gMaxWithoutClockCorrectionFatal) Defines the number of consecutive even / odd cycle pairs with missing clock correction terms that will cause a transition from "NORMAL_ACTIVE" or "NORMAL_PASSIVE" to "HALT" state. Must be identical in all nodes of a cluster. Valid values are 1 to 15 (1 _H to F _H) cycle pairs.
0	[31:8]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

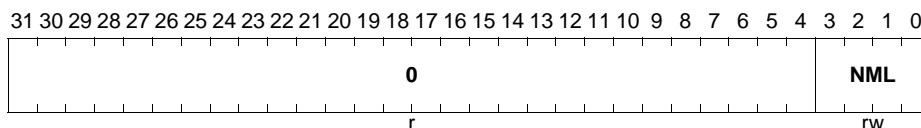
NEM Configuration Register (NEMC)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

NEMC

NEM Configuration Register

(008C_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
NML	[3:0]	rw	Network Management Vector Length¹⁾ (gNetworkManagementVectorLength) These bits configure the length of the NM Vector. The configured length must be identical in all nodes of a cluster. Valid values are 0 to 12 (0 _H to C _H) bytes.
0	[31:4]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

PRT Configuration Register 1 (PRTC1)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

PRTC1

PRT Configuration Register 1 (0090_H) **Reset Value: 084C 0633_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RWP						0	RXW								BRP		SPP		0	1	CASM					TSST					
rw						r	rw								rw		rw		r	r	rw					rw					

Field	Bits	Type	Description
TSST	[3:0]	rw	Transmission Start Sequence Transmitter¹⁾ (gdTSSTransmitter) Configures the duration of the Transmission Start Sequence (TSS) in terms of Bit Times (1 bit time = 4 Microticks = 100ns at 10Mbps). Must be identical in all nodes of a cluster. Valid values are 3 to 15 (3 _H to F _H) Bit Times.
CASM	[10:4]	rw	Collision Avoidance Symbol Maximum¹⁾ (gdCASRxLowMax) Configures the upper limit of the acceptance window for a collision avoidance symbol (CAS). Valid values are 67 to 99 (43 _H to 63 _H). Most significant bit of CASM is hard wired to 1 and can not be modified.
SPP	[13:12]	rw	Strobe Point Position¹⁾ Defines the sample count value for strobing. The strobed bit value is set to the voted value when the sample count is incremented to the value configured by SPP. 00 _B Sample 5 (default) 01 _B Sample 4 10 _B Sample 6 11 _B Reserved; should not be used. <i>Note: The current revision 2.1 of the FlexRay™ protocol requires that SPP = 00_B. The alternate strobe point positions could be used to compensate for asymmetries in the physical layer.</i>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
BRP	[15:14]	rw	<p>Baud Rate Prescaler¹⁾ (gdSampleClockPeriod, pSamplePerMicrotick)</p> <p>The baud rate prescaler configures the baud rate on the FlexRay™ bus. The baud rates listed below are valid with a sample clock $f_{SCLK} = 80$ MHz. One bit time always consists of 8 samples independent of the configured baud rate.</p> <p>00_B 10 Mbit/s (1 Microtick= 25 ns; twice sampled with f_{SCLK}) gdSampleClockPeriod = 12.5 ns = $1 / f_{SCLK}$ pSamplesPerMicrotick = 2</p> <p>01_B 5 Mbit/s (1 Microtick= 25ns; single sampled with $f_{SCLK} / 2$) gdSampleClockPeriod = 25 ns = $2 / f_{SCLK}$ pSamplesPerMicrotick = 1</p> <p>10_B 2.5 Mbit/s (1 Microtick = 50ns; single sampled with $f_{SCLK} / 4$) gdSampleClockPeriod = 50 ns = $4 / f_{SCLK}$ pSamplesPerMicrotick = 1</p> <p>11_B Reserved; should not be used (2.5 Mbit/s (1 Microtick = 50 ns; single sampled with $f_{SCLK} / 4$) gdSampleClockPeriod = 50 ns = $4 / f_{SCLK}$ pSamplesPerMicrotick = 1</p>
RXW	[24:16]	rw	<p>Wakeup Symbol Receive Window Length¹⁾ (gdWakeupSymbolRxWindow)</p> <p>Configures the number of Bit Times used by the node to test the duration of the received wakeup pattern. Must be identical in all nodes of a cluster. Valid values are 76 to 301 ($4C_H$ to $12D_H$) Bit Times.</p>
RWP	[31:26]	rw	<p>Repetitions of Tx Wakeup Pattern¹⁾ (pWakeupPattern)</p> <p>Configures the number of repetitions (sequences) of the Tx wakeup symbol. Valid values are 2 to 63 (2_H to $3F_H$).</p>
0	11, 25	r	<p>Reserved</p> <p>Returns 0 if read; should be written with 0.</p>

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

PRT Configuration Register 2 (PRTC2)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

PRTC2

PRT Configuration Register 2

(0094_H)

Reset Value: 0F2D 0A0E_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		TXL								TXI				0		RXL				0		RXI									
r		rw								rw				r		rw				r		rw									

Field	Bits	Type	Description
RXI	[5:0]	rw	Wakeup Symbol Receive Idle¹⁾ (gdWakeupSymbolRxIdle) Configures the number of Bit Times used by the node to test the duration of the idle phase of the received wakeup symbol. Must be identical in all nodes of a cluster. Valid values are 14 to 59 (E _H to 3B _H) Bit Times.
RXL	[13:8]	rw	Wakeup Symbol Receive Low¹⁾ (gdWakeupSymbolRxLow) Configures the number of Bit Times used by the node to test the duration of the low phase of the received wakeup symbol. Must be identical in all nodes of a cluster. Valid values are 10 to 55 (A _H to 37 _H) Bit Times.
TXI	[23:16]	rw	Wakeup Symbol Transmit Idle¹⁾ (gdWakeupSymbolTxIdle) Configures the number of Bit Times used by the node to transmit the idle phase of the wakeup symbol. Must be identical in all nodes of a cluster. Valid values are 45 to 180 (2D _H to B4 _H) Bit Times.
TXL	[29:24]	rw	Wakeup Symbol Transmit Low¹⁾ (gdWakeupSymbolTxLow) Configures the number of Bit Times used by the node to transmit the low phase of the wakeup symbol. Must be identical in all nodes of a cluster. Valid values are 15 to 60 (F _H to 3C _H) Bit Times.
0	[7:6], [15:14], [31:30]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

MHD Configuration Register (MHDC)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

MHDC

MHD Configuration Register

(0098_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		SLT														0						SFDL									
r		rw														r						rw									

Field	Bits	Type	Description
SFDL	[6:0]	rw	Static Frame Data Length (gPayloadLengthStatic) ¹⁾ Configures the cluster-wide payload length for all Frames sent in the static segment in double byte. The payload length must be identical in all nodes of a cluster. Valid values are 0 to 127 (0 to 7F _H).
SLT	[28:16]	rw	Start of Latest Transmit (pLatestTx) ¹⁾ Configures the maximum minislot value allowed before inhibiting Frame transmission in the dynamic segment of the cycle. There is no transmission dynamic segment if SLT is reset to zero. Valid values are 0 to 7981 (0 to 1F2D _H) minislots.
0	[15:7], [31:29]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

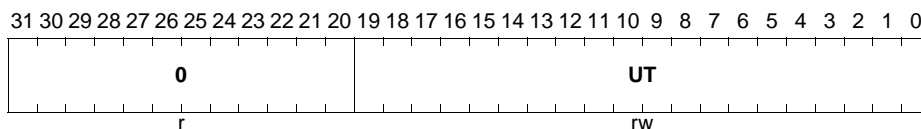
GTU Configuration Register 1 (GTUC01)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC01

GTU Configuration Register 1

(00A0_H)

Reset Value: 0000 0280_H


Field	Bits	Type	Description
UT	[19:0]	rw	Microtick per Cycle (pMicroPerCycle) ¹⁾ Configures the duration of the communication cycle in Microticks. Valid values are 640 to 640000 (280 _H to 9C400 _H) Microticks.
0	[31:20]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 2 (GTUC02)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC02

GTU Configuration Register 2 (00A4_H) **Reset Value: 0002 000A_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												SNM			0		MPC														
r												rw			r		rw														

Field	Bits	Type	Description
MPC	[13:0]	rw	Macro tick Per Cycle (gMacroPerCycle) ¹⁾ Configures the duration of one communication cycle in Macro ticks. The cycle length must be identical in all nodes of a cluster. Valid values are 10 to 16000 (A _H to 3E80 _H) Macro ticks.
SNM	[19:16]	rw	Sync Node Max (gSyncNodeMax) ¹⁾ Maximum number of Frames within a cluster with SYNC Frame indicator bit SYN set to 1. Must be identical in all nodes of a cluster. Valid values are 2 to 15 (2 _H to F _H).
0	[15:14], [31:20]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 3 (GTUC03)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC03

GTU Configuration Register 3 (00A8_H) **Reset Value: 0202 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				MIOB				0				MIOA				UIOB								UIOA							
r				rw				r				rw				rw								rw							

Field	Bits	Type	Description
UIOA	[7:0]	rw	Microtick Initial Offset Channel A¹⁾ (pMicroInitialOffset[A]) Configures the number of Microticks between the actual time reference point on channel A and the subsequent Macrotick boundary of the secondary time reference point. The parameter depends on pDelayCompensation[A] and therefore has to be set for each channel independently. Valid values are 0 to 240 (0 _H to F0 _H) Microticks.
UIOB	[15:8]	rw	Microtick Initial Offset Channel B¹⁾ (pMicroInitialOffset[B]) Configures the number of Microticks between the actual time reference point on channel B and the subsequent Macrotick boundary of the secondary time reference point. The parameter depends on pDelayCompensation[B] and therefore has to be set for each channel independently. Valid values are 0 to 240 (0 _H to F0 _H) Microticks.
MIOA	[22:16]	rw	Macrotick Initial Offset Channel A (gMacroInitialOffset[A]) ¹⁾ Configures the number of Macroticks between the static slot boundary and the subsequent Macrotick boundary of the secondary time reference point based on the nominal Macrotick duration. Must be identical in all nodes of a cluster. Valid values are 2 to 72 (2 _H to 48 _H) Macroticks.
MIOB	[30:24]	rw	Macrotick Initial Offset Channel B (gMacroInitialOffset[B]) ¹⁾ Configures the number of Macroticks between the static slot boundary and the subsequent Macrotick boundary of the secondary time reference point based on the nominal Macrotick duration. Must be identical in all nodes of a cluster. Valid values are 2 to 72 (2 _H to 48 _H) Macroticks.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	23, 31	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

GTU Configuration Register 4 (GTUC04)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only. For details about configuration of NIT and OCS see ["Configuration of Network Idle Time \(NIT\) Start and Offset Correction Start" on Page 198](#).

GTUC04

GTU Configuration Register 4 (00AC_H) **Reset Value: 0008 0007_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		OCS														0		NIT													
r		rw														r		rw													

Field	Bits	Type	Description
NIT	[13:0]	rw	Network Idle Time Start ¹⁾ (gMacroPerCycle - gdNIT - 1) Configures the starting point of the Network Idle Time (NIT) at the end of the communication cycle expressed in terms of MacroTicks from the beginning of the cycle. The start of network idle time (NIT) is recognized if MacroTICK = gMacroPerCycle - gdNIT - 1 and the increment pulse of MacroTICK is set. Must be identical in all nodes of a cluster. Valid values are 7 to 15997 (7 _H to 3E7D _H) MacroTICKs.
OCS	[29:16]	rw	Offset Correction Start ¹⁾ (gOffsetCorrectionStart - 1) Determines the start of the offset correction within the network idle time (NIT) phase, calculated from start of cycle. Must be identical in all nodes of a cluster. For cluster consisting of E-Ray implementations only, it is sufficient to program OCS = NIT + 1. Valid values are 8 to 15998 (8 _H to 3E7E _H) MacroTICKs.
0	[15:14], [31:30]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 5 (GTUC05)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC05

GTU Configuration Register 5 (00B0_H)

Reset Value: 0E00 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DEC								0		CDD				DCB								DCA									
rw								r		rw				rw								rw									

Field	Bits	Type	Description
DCA	[7:0]	rw	Delay Compensation Channel A¹⁾ (pDelayCompensation[A]) Used to compensate for reception delays on channel A. This covers assumed propagation delay up to cPropagationDelayMax for Microticks in the range of 0.0125μs to 0.05μs. In practice, the minimum of the propagation delays of all sync nodes should be applied. Valid values are 0 to 200 (0 _H to C8 _H) Microticks.
DCB	[15:8]	rw	Delay Compensation Channel B¹⁾ (pDelayCompensation[B]) Used to compensate for reception delays on channel B. This covers assumed propagation delay up to cPropagationDelayMax for Microticks in the range of 0.0125 to 0.05μs. In practice, the minimum of the propagation delays of all sync nodes should be applied. Valid values are 0 to 200 (0 _H to C8 _H) Microticks.
CDD	[20:16]	rw	Cluster Drift Damping (pClusterDriftDamping) ¹⁾ Configures the cluster drift damping value used in clock synchronization to minimize accumulation of rounding errors. Valid values are 0 to 20 (0 _H to 14 _H) Microticks.
DEC	[31:24]	rw	Decoding Correction (pDecodingCorrection) ¹⁾ Configures the decoding correction value used to determine the primary time reference point. Valid values are 14 to 143 (E _H to 8F _H) Microticks.
0	[23:21]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 6 (GTUC06)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC06

GTU Configuration Register 6 (00B4_H) **Reset Value: 0002 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				MOD												0				ASR											
r				rw												r				rw											

Field	Bits	Type	Description
ASR	[10:0]	rw	Accepted Startup Range ¹⁾ (pdAcceptedStartupRange) Number of Microticks constituting the expanded range of measured deviation for startup Frames during integration. Valid values are 0 to 1875 (0 _H to 753 _H) Microticks.
MOD	[26:16]	rw	Maximum Oscillator Drift (pdMaxDrift) ¹⁾ Maximum drift offset between two nodes that operate with unsynchronized clocks over one communication cycle in Microticks. Valid values are 2 to 1923 (2 _H to 783 _H) Microticks.
0	[15:11], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 7 (GTUC07)

The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

GTUC07

GTU Configuration Register 7 (00B8_H) **Reset Value: 0002 0004_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				NSS												0				SSL											
r				rw												r				rw											

Field	Bits	Type	Description
SSL	[9:0]	rw	Static Slot Length (gdStaticSlot) ¹⁾ Configures the duration of a static slot in Macroticks. The static slot length must be identical in all nodes of a cluster. Valid values are 4 to 659 (4 _H to 293 _H) Macroticks.
NSS	[25:16]	rw	Number of Static Slots (gNumberOfStaticSlots) ¹⁾ Configures the number of static slots in a cycle. At least 2 coldstart nodes must be configured to startup a FlexRay™ network. The number of static slots must be identical in all nodes of a cluster. Valid values are 2 to 1023 (2 _H to 3FF _H).
0	[15:10], [31:26]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in “DEFAULT_CONFIG” or “CONFIG” state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 8 (GTUC08)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

GTUC08

GTU Configuration Register 8 (00BC_H) **Reset Value: 0000 0002_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		NMS														0										MSL					
r		rw														r										rw					

Field	Bits	Type	Description
MSL	[5:0]	rw	Minislot Length (gdMinislot) ¹⁾ Configures the duration of a minislot in Macroticks. The minislot length must be identical in all nodes of a cluster. Valid values are 2 to 63 (2 _H to 3F _H) Macroticks.
NMS	[28:16]	rw	Number of Minislots (gNumberOfMinislots) ¹⁾ Configures the number of minislots within the dynamic segment of a cycle. The number of minislots must be identical in all nodes of a cluster. Valid values are 0 to 7986 (0 _H to 1F32 _H).
0	[15:6], [31:29]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 9 (GTUC09)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

GTUC09

GTU Configuration Register 9 (00C0_H) **Reset Value: 0000 0101_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0														DSI	0	MAPO				0	APO										
r														rw	r	rw				r	rw										

Field	Bits	Type	Description
APO	[5:0]	rw	Action Point Offset (gdActionPointOffset) ¹⁾ Configures the action point offset in Macroticks within static slots and symbol window. Must be identical in all nodes of a cluster. Valid values are 1 to 63 (1 _H to 3F _H) Macroticks.
MAPO	[12:8]	rw	Minislot Action Point Offset ¹⁾ (gdMinislotActionPointOffset) Configures the action point offset in Macroticks within the minislots of the dynamic segment. Must be identical in all nodes of a cluster. Valid values are 1 to 31 (1 _H to 1F _H) Macroticks.
DSI	[17:16]	rw	Dynamic Slot Idle Phase ¹⁾ (gdDynamicSlotIdlePhase) The duration of the dynamic slot idle phase has to be greater or equal than the idle detection time. Must be identical in all nodes of a cluster. Valid values are 0 to 2 Minislot.
0	[7:6], [15:13], [31:18]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 10 (GTUC10)

The Communication Controller accepts modifications of the register in "DEFAULT_CONFIG" or "CONFIG" state only.

GTUC10

GTU Configuration Register 10 (00C4_H) **Reset Value: 0002 0005_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				MRC												0				MOC											
r				rw												r				rw											

Field	Bits	Type	Description
MOC	[13:0]	rw	Maximum Offset Correction¹⁾ (pOffsetCorrectionOut) Holds the maximum permitted offset correction value to be applied by the internal clock synchronization algorithm (absolute value). The Communication Controller checks only the internal offset correction value against the maximum offset correction value. Valid values are 5 to 15266 (5 _H to 3BA2 _H) Microticks.
MRC	[26:16]	rw	Maximum Rate Correction¹⁾ (pRateCorrectionOut) Holds the maximum permitted rate correction value to be applied by the internal clock synchronization algorithm. The communication controller checks only the internal rate correction value against the maximum rate correction value (absolute value). Valid values are 2 to 1923 (2 _H to 783 _H) Microticks.
0	[15:14], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

GTU Configuration Register 11 (GTUC11)

GTUC11

GTU Configuration Register 11 (00C8_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				ERC				0				EOC				0				ERC C				0				EOC C			
r				rw				r				rw				r				rw				rw				rw			

Field	Bits	Type	Description
EOCC	[1:0]	rw	External Offset Correction Control (pExternOffsetControl) By writing to EOCC the external offset correction is enabled as specified below. Should be modified only outside network idle time (NIT). 00 _B No external clock correction 01 _B No external clock correction 10 _B External offset correction value subtracted from calculated offset correction value 11 _B External offset correction value added to calculated offset correction value
ERCC	[9:8]	rw	External Rate Correction Control (pExternRateControl) By writing to ERCC the external rate correction is enabled as specified below. Should be modified only outside network idle time (NIT). 00 _B No external rate correction 01 _B No external rate correction 10 _B External rate correction value subtracted from calculated rate correction value 11 _B External rate correction value added to calculated rate correction value
EOC	[18:16]	rw	External Offset Correction¹⁾ (pExternOffsetCorrection) Holds the external clock offset correction value in Microticks to be applied by the internal synchronization algorithm. The value is subtracted / added from / to the calculated offset correction value. The value is applied during network idle time (NIT). May be modified in "DEFAULT_CONFIG" or "CONFIG" state only. Valid values are 0 to 7 Microticks.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
ERC	[26:24]	rw	External Rate Correction¹⁾ (pExternRateCorrection) Holds the external rate correction value in Microticks to be applied by the internal clock synchronization algorithm. The value is subtracted / added from / to the calculated rate correction value. The value is applied during network idle time (NIT). May be modified in "DEFAULT_CONFIG" or "CONFIG" state only. Valid values are 0 to 7 Microticks.
0	[7:2], [15:10], [23:19], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

1) This bit can be updated in "DEFAULT_CONFIG" or "CONFIG" state only!

FlexRay™ Protocol Controller (E-Ray)

21.5.2.5 Communication Controller Status Registers

During 8/16-bit accesses to status variables coded with more than 8/16-bit, the variable might be updated by the Communication Controller between two accesses (non-atomic read accesses). The status vector may change faster than the Host can poll the status vector, depending on f_{CLC_ERAY} frequency.

Communication Controller Status Vector (CCSV)

CCSV

Communication Controller Status Vector(0100_H)

Reset Value: 0010 4000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		PSL						RCA				WSV			
r		rh						rh				rh			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CSI	CSAI	CSNI	0	SLM	HRQ	FSI	POCS							
r	rh	rh	rh	r	rh	rh	rh	rh							

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
POCS	[5:0]	rh	<p>Protocol Operation Control Status</p> <p>Indicates the actual state of operation of the Communication Controller Protocol Operation Control</p> <p>000000_B "DEFAULT_CONFIG" state 000001_B "READY" state 000010_B "NORMAL_ACTIVE" state 000011_B "NORMAL_PASSIVE" state 000100_B "HALT" state 000101_B "MONITOR_MODE" state 000110_B ... 001110_B are reserved. 001111_B "CONFIG" state</p> <p>Indicates the actual state of operation of the POC in the wakeup path</p> <p>010000_B WAKEUP_STANDBY state 010001_B "WAKEUP_LISTEN" state 010010_B "WAKEUP_SEND" state 010011_B "WAKEUP_DETECT" state 010100_B ... 011111_B are reserved.</p> <p>Indicates the actual state of operation of the POC in the startup path</p> <p>100000_B "STARTUP_PREPARE" state 100001_B "COLDSTART_LISTEN" state 100010_B "COLDSTART_COLLISION_RESOLUTION" state 100011_B "COLDSTART_CONSISTENCY_CHECK" state 100100_B "COLDSTART_GAP" state 100101_B "COLDSTART_JOIN" State 100110_B "INTEGRATION_COLDSTART_CHECK" state 100111_B "INTEGRATION_LISTEN" state 101000_B "INTEGRATION_CONSISTENCY_CHECK" state 101001_B "INITIALIZE_SCHEDULE" state 101010_B "ABORT_STARTUP" state 101011_B "STARTUP_SUCCESS" state 101100_B ... 111111_B are reserved.</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
FSI	6	rh	Freeze Status Indicator (vPOC!Freeze) Indicates that the POC has entered the “HALT” state due to CHI command “FREEZE” or due to an error condition requiring an immediate POC halt. Reset by transition from “HALT” to “DEFAULT_CONFIG” state.
HRQ	7	rh	Halt Request (vPOC!CHIHaltRequest) Indicates that a request from the Host has been received to halt the POC at the end of the communication cycle. Reset by transition from “HALT” to “DEFAULT_CONFIG” state or when entering “READY” state.
SLM	[9:8]	rh	Slot Mode (vPOC!SlotMode) Indicates the actual slot mode of the POC in states READY, WAKEUP, STARTUP, NORMAL_ACTIVE, and NORMAL_PASSIVE. Default is “SINGLE”. Changes to “ALL”, depending on configuration bit SUCC1.TSM. In “NORMAL_ACTIVE” or “NORMAL_PASSIVE” state the CHI command “ALL_SLOTS” will change the slot mode from “SINGLE” over “ALL_PENDING” to “ALL”. Set to SINGLE in all other states. 00 _B SINGLE 01 _B Reserved 10 _B ALL_PENDING 11 _B ALL
CSNI	12	rh	Coldstart Noise Indicator (vPOC!ColdstartNoise) Indicates that the cold start procedure occurred under noisy conditions. Reset by CHI command “RESET_STATUS_INDICATORS” or by transition from “HALT” to “DEFAULT_CONFIG” state or from “READY” to “STARTUP” state.
CSAI	13	rh	Coldstart Abort Indicator Coldstart aborted. Reset by CHI command “RESET_STATUS_INDICATORS” or by transition from “HALT” to “DEFAULT_CONFIG” state or from “READY” to “STARTUP” state.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
CSI	14	rh	<p>Cold Start Inhibit (vColdStartInhibit)</p> <p>Indicates that the node is disabled from cold starting. The flag is set whenever the POC enters “READY” state due to CHI command “READY”. The flag has to be reset under control of the Host by CHI command “ALLOW_COLDSTART” (SUCC1.CMD = 1001_B).</p> <p>0_B Cold starting of node enabled</p> <p>1_B Cold starting of node disabled</p>
WSV	[18:16]	rh	<p>Wakeup Status (vPOC!WakeupStatus)</p> <p>Indicates the status of the current wakeup attempt. Reset by CHI command “RESET_STATUS_INDICATORS” or by transition from “HALT” to “DEFAULT_CONFIG” state.</p> <p>000_B UNDEFINED. Wakeup not yet executed by the Communication Controller.</p> <p>001_B RECEIVED_HEADER. Set when the Communication Controller finishes wakeup due to the reception of a Frame Header without coding violation on either channel in “WAKEUP_LISTEN” state.</p> <p>010_B RECEIVED_WUP. Set when the Communication Controller finishes wakeup due to the reception of a valid wakeup pattern on the configured wakeup channel in “WAKEUP_LISTEN” state.</p> <p>011_B COLLISION_HEADER. Set when the Communication Controller stops wakeup due to a detected collision during wakeup pattern transmission by receiving a valid Header on either channel.</p> <p>100_B COLLISION_WUP. Set when the Communication Controller stops wakeup due to a detected collision during wakeup pattern transmission by receiving a valid wakeup pattern on the configured wakeup channel.</p> <p>101_B COLLISION_UNKNOWN. Set when the Communication Controller stops wakeup by leaving “WAKEUP_DETECT” state after expiration of the wakeup timer without receiving a valid wakeup pattern or a valid Frame Header.</p> <p>110_B TRANSMITTED. Set when the Communication Controller has successfully completed the transmission of the wakeup pattern.</p> <p>111_B Reserved</p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
RCA	[23:19]	rh	Remaining Coldstart Attempts (vRemainingColdstartAttempts) Indicates the number of remaining coldstart attempts. The RUN command resets this counter to the maximum number of coldstart attempts as configured by SUCC1.CSA.
PSL	[29:24]	rh	POC Status Log Status of CCSV.POCS immediately before entering “HALT” state. Set when entering “HALT” state. Set to “HALT” when FREEZE command is applied during “HALT” state. Reset to 000000 _B when leaving “HALT” state.
0	[11:10], 15, [31:30]	rh	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

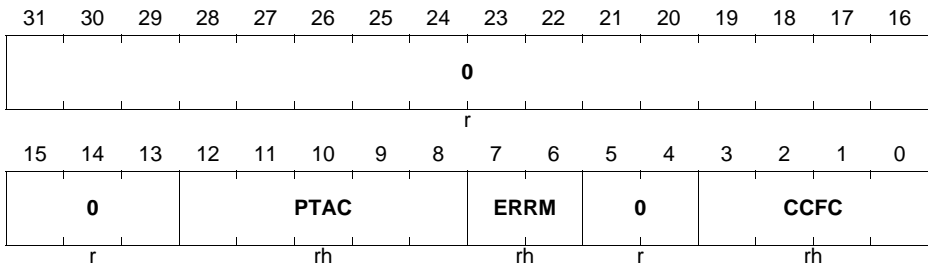
Communication Controller Error Vector (CCEV)

Reset by transition from “HALT” to “DEFAULT_CONFIG” state or when entering “READY” state.

CCEV

Communication Controller Error Vector (0104_H)

Reset Value: 0000 0000_H



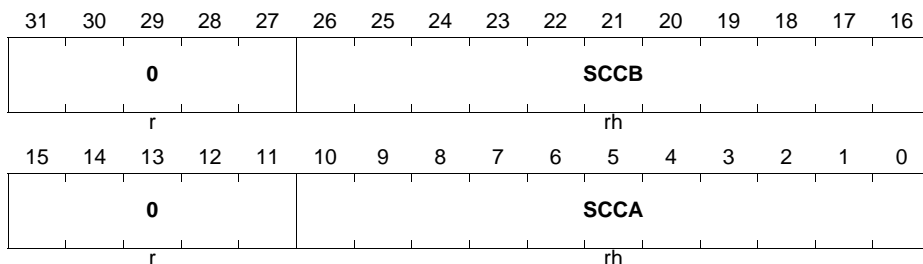
Field	Bits	Type	Description
CCFC	[3:0]	rh	Clock Correction Failed Counter (vClockCorrectionFailed) The Clock Correction Failed Counter is incremented by one at the end of any odd communication cycle where either the missing offset correction error or missing rate correction error are active. The Clock Correction Failed Counter is reset to 0 at the end of an odd communication cycle if neither the offset correction failed nor the rate correction failed errors are active. The Clock Correction Failed Counter stops at 15.
ERRM	[7:6]	rh	Error Mode (vPOC!ErrorMode) Indicates the actual error mode of the POC. 00 _B “ACTIVE” (green) 01 _B “PASSIVE” (yellow) 10 _B “COMM_HALT” (red) 11 _B Reserved
PTAC	[12:8]	rh	Passive to Active Count (vAllowPassiveToActive) Indicates the number of consecutive even / odd cycle pairs that have passed with valid rate and offset correction terms, while the node is waiting to transit from “NORMAL_PASSIVE” state to “NORMAL_ACTIVE” state. The transition takes place when PTAC equals SUCC1.PTA.
0	[5:4], [31:13]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Slot Counter Value (SCV)

SCV

Slot Counter Value (0110_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
SCCA	[10:0]	rh	Slot Counter Channel A (vSlotCounter[A]) Current slot counter value on channel A. The value is incremented by the Communication Controller and reset at the start of a communication cycle. Valid values are 0 to 2047 (0 _H to 7FD _H).
SCCB	[26:16]	rh	Slot Counter Channel B (vSlotCounter[B]) Current slot counter value on channel B. The value is incremented by the Communication Controller and reset at the start of a communication cycle. Valid values are 0 to 2047 (0 _H to 7FD _H).
0	[15:11], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

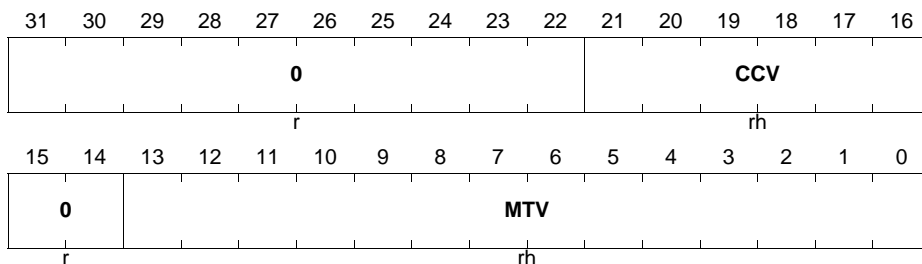
FlexRay™ Protocol Controller (E-Ray)

Macrotick and Cycle Counter Value (MTCCV)

MTCCV

Macrotick and Cycle Counter Value (0114_H)

Reset Value: 0000 0000_H



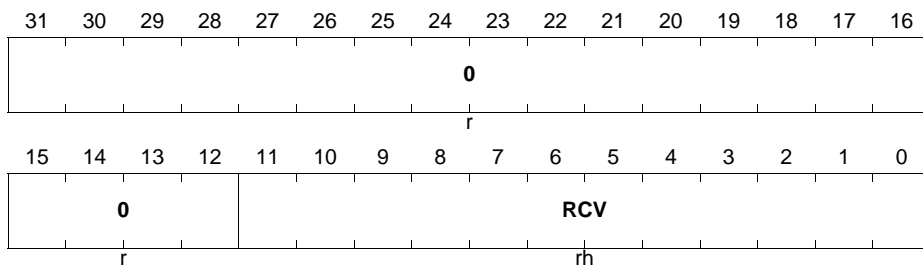
Field	Bits	Type	Description
MTV	[13:0]	rh	Macrotick Value (vMacrotick) Current Macrotick value. The value is incremented by the Communication Controller and reset at the start of a communication cycle. Valid values are 0 to 16000 (0 _H to 3E80 _H).
CCV	[21:16]	rh	Cycle Counter Value (vCycleCounter) Current cycle counter value. The value is incremented by the Communication Controller at the start of a communication cycle. Valid values are 0 to 63 (0 _H to 3F _H).
0	[15:14], [31:22]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Rate Correction Value (RCV)

RCV

Rate Correction Value (0118_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
RCV	[11:0]	rh	Rate Correction Value (vRateCorrection) Rate correction value (two's complement). Calculated internal rate correction value before limitation. If the RCV value exceeds the limits defined by GTUC10.MRC, flag SFS.RCLR is set to 1.
0	[31:12]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

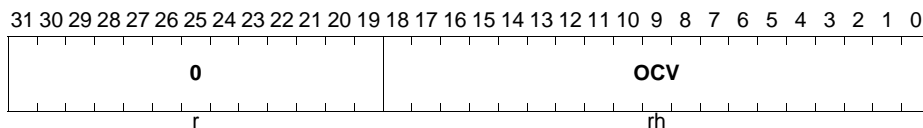
Offset Correction Value (OCV)

OCV

Offset Correction Value

(011C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
OCV	[18:0]	rh	Offset Correction Value (vOffsetCorrection) Offset correction value (two's complement). Calculated internal offset correction value before limitation. If the OCV value exceeds the limits defined by GTUC10.MOC flag SFS.OCLR is set to 1.
0	[31:19]	r	Reserved Returns 0 if read; should be written with 0.

Note: The external rate / offset correction value is added to the limited rate / offset correction value.

FlexRay™ Protocol Controller (E-Ray)

SYNC Frame Status (SFS)

The maximum number of valid SYNC Frames in a communication cycle is 15.

SFS

SYNC Frame Status (0120_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												RC LR	MR CS	OC LR	MO CS
r												rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VSBO				VSBE				VSAO				VSAE			
rh				rh				rh				rh			

Field	Bits	Type	Description
VSAE	[3:0]	rh	Valid SYNC Frames Channel A, even communication cycle Holds the number of valid SYNC Frames received on channel A in the even communication cycle. If transmission of SYNC Frames is enabled by SUCC1.TXSY the value is incremented by one. The value is updated during the network idle time (NIT) of each even communication cycle. This bit field is only valid if the channel A is assigned to the Communication Controller by SUCC1.CCHA.
VSAO	[7:4]	rh	Valid SYNC Frames Channel A, odd communication cycle Holds the number of valid SYNC Frames received on channel A in the odd communication cycle. If transmission of SYNC Frames is enabled by SUCC1.TXSY the value is incremented by one. The value is updated during the network idle time (NIT) of each odd communication cycle. This bit field is only valid if the channel A is assigned to the Communication Controller by SUCC1.CCHA.
VSBE	[11:8]	rh	Valid SYNC Frames Channel B, even communication cycle Holds the number of valid SYNC Frames received on channel B in the even communication cycle. If transmission of SYNC Frames is enabled by SUCC1.TXSY the value is incremented by one. The value is updated during the network idle time (NIT) of each even communication cycle. This bit field is only valid if the channel B is assigned to the Communication Controller by SUCC1.CCHB.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
VSBO	[15:12]	rh	Valid SYNC Frames Channel B, odd communication cycle Holds the number of valid SYNC Frames received on channel B in the odd communication cycle. If transmission of SYNC Frames is enabled by SUCC1.TXSY the value is incremented by one. The value is updated during the network idle time (NIT) of each odd communication cycle. This bit field is only valid if the channel B is assigned to the Communication Controller by SUCC1.CCHB.
MOCS	16	rh	Missing Offset Correction Signal The Missing Offset Correction flag signals to the Host, that no offset correction calculation can be performed because no SYNC Frames were received. The flag is updated by the Communication Controller at start of offset correction phase. 0 _B Offset correction signal valid 1 _B Missing offset correction signal
OCLR	17	rh	Offset Correction Limit Reached The Offset Correction Limit Reached flag signals to the Host, that the offset correction value has exceeded its limit as defined by GTUC10.MOC. The flag is updated by the Communication Controller at start of offset correction phase. 0 _B Offset correction below limit 1 _B Offset correction limit reached
MRCS	18	rh	Missing Rate Correction Signal The Missing Rate Correction Flag signals to the Host, that no rate correction calculation can be performed because no pairs of even / odd SYNC Frames were received. The flag is updated by the Communication Controller at start of offset correction phase. 0 _B Rate correction signal valid 1 _B Missing rate correction signal
RCLR	19	rh	Rate Correction Limit Reached The Rate Correction Limit Reached flag signals to the Host, that the rate correction value has exceeded its limit.as defined by GTUC10.MRC. The flag is updated by the Communication Controller at start of offset correction phase. 0 _B Rate correction below limit 1 _B Rate correction limit reached
0	[31:20]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Symbol Window and network idle time (NIT) Status (SWNIT)

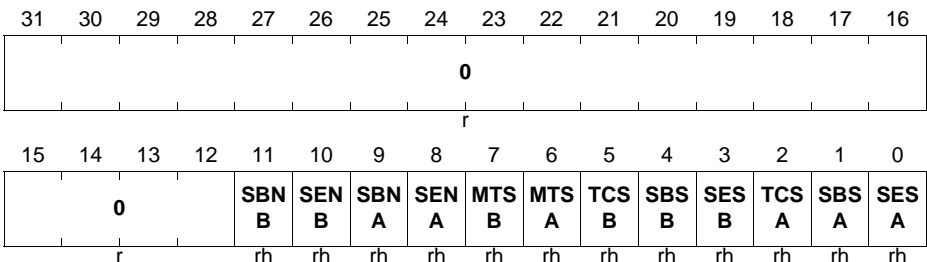
Symbol window related status information. Updated by the Communication Controller at the end of the symbol window for each channel. During startup the status data is not updated.

Note: MTSA and MTSB may be changed outside “DEFAULT_CONFIG” or “CONFIG” state when the write to SUC Configuration Register 1 (SUCC1) register is directly preceded by the unlock sequence as described in “Lock Register (LCK)” on Page 40. This may be combined with CHI command SEND_MTS. If both bits MTSA and MTSB are set to 1 an MTS symbol will be transmitted on both channels when requested by writing SUCC1.CMD = 1000_B

SWNIT

Symbol Window and Network Idle Time Status

(0124_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
SESA	0	rh	Syntax Error in Symbol Window Channel A (vSSISyntaxErrorA) 0 _B No syntax error detected 1 _B Syntax error during symbol window detected on channel A
SBSA	1	rh	Slot Boundary Violation in Symbol Window Channel A (vSSIBViolationA) 0 _B No slot boundary violation detected 1 _B Slot boundary violation during symbol window detected on channel A

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TCSA	2	rh	Transmission Conflict in Symbol Window Channel A (vSS!TxConflictA) 0 _B No transmission conflict detected 1 _B Transmission conflict in symbol window detected on channel A
SESB	3	rh	Syntax Error in Symbol Window Channel B (vSS!SyntaxErrorB) 0 _B No syntax error detected 1 _B Syntax error during symbol window detected on channel B
SBSB	4	rh	Slot Boundary Violation in Symbol Window Channel B (vSS!BViolationB) 0 _B No slot boundary violation detected 1 _B Slot boundary violation during symbol window detected on channel B
TCSB	5	rh	Transmission Conflict in Symbol Window Channel B (vSS!TxConflictB) 0 _B No transmission conflict detected 1 _B Transmission conflict in symbol window detected on channel B
MTSA	6	rh	MTS Received on Channel A (vSS!ValidMTSA) ¹⁾ Media Access Test symbol received on channel A during the proceeding symbol window. Updated by the Communication Controller for each channel at the end of the symbol window. When this bit is set to 1, also interrupt flag SIR.MTSA is set to 1. 0 _B No MTS symbol received on channel A 1 _B MTS symbol received on channel A
MTSB	7	rh	MTS Received on Channel B (vSS!ValidMTSB) ¹⁾ Media Access Test symbol received on channel B during the proceeding symbol window. Updated by the Communication Controller for each channel at the end of the symbol window. When this bit is set to 1, also interrupt flag SIR.MTSB is set to 1. 0 _B No MTS symbol received on channel B 1 _B MTS symbol received on channel B

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SENA	8	rh	Syntax Error during network idle time (NIT) Channel A (vSSI!SyntaxErrorA) Updated by the Communication Controller channel A at the end of the NIT. 0 _B No syntax error detected 1 _B Syntax error during network idle time (NIT) detected on channel A
SBNA	9	rh	Slot Boundary Violation during network idle time (NIT) Channel A (vSSI!BViolationA) Updated by the Communication Controller channel A at the end of the NIT. 0 _B No slot boundary violation detected 1 _B Slot boundary violation during network idle time (NIT) detected on channel A
SENB	10	rh	Syntax Error during network idle time (NIT) Channel B (vSSI!SyntaxErrorB) Updated by the Communication Controller channel B at the end of the NIT. 0 _B No syntax error detected 1 _B Syntax error during network idle time (NIT) detected on channel B
SBNB	11	rh	Slot Boundary Violation during network idle time (NIT) Channel B (vSSI!BViolationB) Updated by the Communication Controller channel B at the end of the NIT. 0 _B No slot boundary violation detected 1 _B Slot boundary violation during network idle time (NIT) detected on channel B
0	[31:12]	r	Reserved Returns 0 if read; should be written with 0.

- 1) MTSA and MTSB may also be changed outside "DEFAULT_CONFIG" or "CONFIG" state when the write to SUCC1 register is directly preceded by the unlock sequence as described in "Lock Register (LCK)". This may be combined with CHI command SEND_MTS. If both bits MTSA and MTSB are set to 1 an MTS symbol will be transmitted on both channels when requested by writing SUCC1.CMD = 1000_B.

FlexRay™ Protocol Controller (E-Ray)

Aggregated Channel Status (ACS)

The aggregated channel status provides the Host with an accrued status of channel activity for all communication slots regardless of whether they are assigned for transmission or subscribed for reception. The aggregated channel status also includes status data from the symbol window and the network idle time. The status data is updated (set) after each slot and aggregated until it is reset by the Host. During startup the status data is not updated. A flag is cleared by writing a 1 to the corresponding bit position. Writing a 0 has no effect on the flag. An application reset will also clear the register.

ACS

Aggregated Channel Status (0128_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		SBV B	CIB	CED B	SED B	VFR B	0		SBV A	CIA	CED A	SED A	VFR A		
r		rwh	rwh	rwh	rwh	rwh	r		rwh	rwh	rwh	rwh	rwh	rwh	

Field	Bits	Type	Description
VFRA	0	rwh	Valid Frame Received on Channel A (vSSI!ValidFrameA) One or more valid Frames were received on channel A in any static or dynamic slot during the observation period. 0 _B No valid Frame received 1 _B Valid Frame(s) received on channel A
SEDA	1	rwh	Syntax Error Detected on Channel A (vSSI!SyntaxErrorA) One or more syntax errors in static or dynamic slots, symbol window, and network idle time (NIT) were observed on channel A. 0 _B No syntax error observed 1 _B Syntax error(s) observed on channel A
CEDA	2	rwh	Content Error Detected on Channel A (vSSI!ContentErrorA) One or more Frames with a content error were received on channel A in any static or dynamic slot during the observation period. 0 _B No Frame with content error received 1 _B Frame(s) with content error received on channel A

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
CIA	3	rwh	Communication Indicator Channel A One or more valid Frames were received on channel A in slots that also contained any additional communication during the observation period, i.e. one or more slots received a valid Frame AND had any combination of either syntax error OR content error OR slot boundary violation. 0 _B No valid Frame(s) received in slots containing any additional communication 1 _B Valid Frame(s) received on channel A in slots containing any additional communication
SBVA	4	rwh	Slot Boundary Violation on Channel A (vSS!BViolationA) One or more slot boundary violations were observed on channel A at any time during the observation period (static or dynamic slots, symbol window, and network idle time NIT). 0 _B No slot boundary violation observed 1 _B Slot boundary violation(s) observed on channel A
VFRB	8	rwh	Valid Frame Received on Channel B (vSS!ValidFrameB) One or more valid Frames were received on channel B in any static or dynamic slot during the observation period. 0 _B No valid Frame received 1 _B Valid Frame(s) received on channel B
SEDB	9	rwh	Syntax Error Detected on Channel B (vSS!SyntaxErrorB) One or more syntax errors in static or dynamic slots, symbol window, and network idle time (NIT) were observed on channel B. 0 _B No syntax error observed 1 _B Syntax error(s) observed on channel B
CEDB	10	rwh	Content Error Detected on Channel B (vSS!ContentErrorB) One or more Frames with a content error were received on channel B in any static or dynamic slot during the observation period. 0 _B No Frame with content error received 1 _B Frame(s) with content error received on channel B

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Field	Bits	Type	Description
CIB	11	rwh	Communication Indicator Channel B One or more valid Frames were received on channel B in slots that also contained any additional communication during the observation period, i.e. one or more slots received a valid Frame AND had any combination of either syntax error OR content error OR slot boundary violation. 0_B No valid Frame(s) received in slots containing any additional communication 1_B Valid Frame(s) received on channel B in slots containing any additional communication
SBVB	12	rwh	Slot Boundary Violation on Channel B (vSS!BViolationB) One or more slot boundary violations were observed on channel B at any time during the observation period (static or dynamic slots, symbol window, and network idle time NIT). 0_B No slot boundary violation observed 1_B Slot boundary violation(s) observed on channel B
0	[7:5], [31:13]	r	Reserved Returns 0 if read; should be written with 0.

Note: The set condition of flags CIA and CIB is also fulfilled if there is only one single Frame in the slot and the slot boundary at the end of the slot is reached during the Frames channel idle recognition phase. When one of the flags SEDB, CEDB, CIB, SBVB changes from 0 to 1, service request flag EIR.EDB is set to 1. When one of the flags SEDA, CEDA, CIA, SBVA changes from 0 to 1, service request flag EIR.EDA is set to 1.

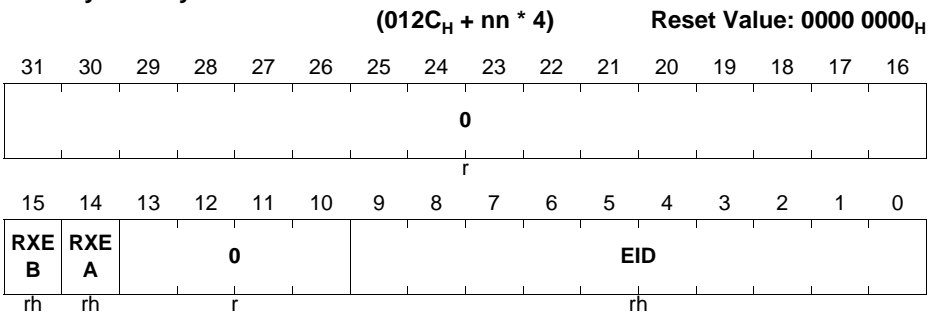
FlexRay™ Protocol Controller (E-Ray)

Even Sync ID [01...15] (ESIDnn)

Registers Even Sync ID nn (ESIDnn, nn=01-15) hold the Frame IDs of the SYNC Frames received in **even** communication cycles, sorted in ascending order, with register ESID01 holding the lowest received SYNC Frame ID. If the node itself transmits a SYNC Frame in an even communication cycle, register ESID01 holds the respective SYNC Frame ID as configured in Message Buffer 0 and the flags RXEA, RXEB are set. The value is updated during the network idle time (NIT) of each even communication cycle.

ESIDnn (nn = 01-15)

Even Sync ID Symbol Window nn



Field	Bits	Type	Description
EID	[9:0]	rh	Even Sync ID (vsSyncIDListA,B even) SYNC Frame ID even communication cycle.
RXEA	14	rh	Received/Configured Even Sync ID on Channel A Signals that a SYNC Frame corresponding to the stored even sync ID was received on channel A or that the node is configured to be a sync node with key slot = EID (ESID1 only). <div style="margin-left: 20px;"> 0_B SYNC Frame not received on channel A / node configured to transmit SYNC Frames 1_B SYNC Frame received on channel A / node not configured to transmit SYNC Frames </div>
RXEB	15	rh	Received/Configured Even Sync ID on Channel B Signals that a SYNC Frame corresponding to the stored even sync ID was received on channel B or that the node is configured to be a sync node with key slot = EID (ESID1 only). <div style="margin-left: 20px;"> 0_B SYNC Frame not received on channel B / node configured to transmit SYNC Frames 1_B SYNC Frame received on channel B / node not configured to transmit SYNC Frames </div>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	[13:10], [31:16]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

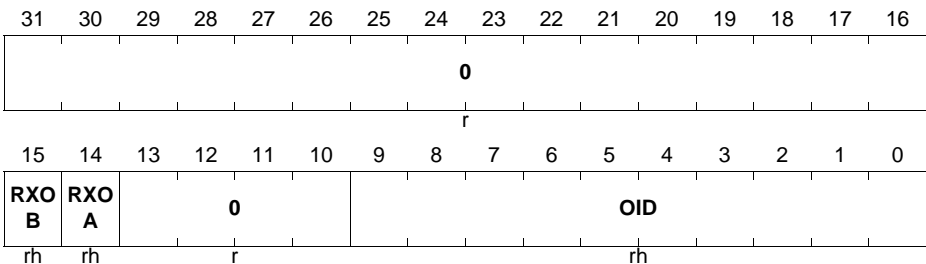
Odd Sync ID [01...15] (OSIDnn)

he Odd Sync ID nn (OSIDnn, nn=01-15) hold the Frame IDs of the SYNC Frames received in **odd** communication cycles, sorted in ascending order, with register OSID01 holding the lowest received SYNC Frame ID. If the node itself transmits a SYNC Frame in an odd communication cycle, register OSID01 holds the respective SYNC Frame ID as configured in Message Buffer 0 and flags RXOA, RXOB are set. The value is updated during the network idle time (NIT) of each odd communication cycle.

OSIDnn (nn = 01-15)

Odd Sync ID Symbol Window nn(016C_H + nn * 4)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
OID	[9:0]	rh	Odd Sync ID (vsSyncIDListA,B odd) SYNC Frame ID even communication cycle.
RXOA	14	rh	Received Odd Sync ID on Channel A Signals that a SYNC Frame corresponding to the stored odd sync ID was received on channel A or that the node is configured to be a sync node with key slot = OID (OSID1 only). 0 _B SYNC Frame not received on channel A/ node configured to transmit SYNC Frames 1 _B SYNC Frame received on channel A/ node not configured to transmit SYNC Frames
RXOB	15	rh	Received Odd Sync ID on Channel B Signals that a SYNC Frame corresponding to the stored odd sync ID was received on channel B or that the node is configured to be a sync node with key slot = OID (OSID1 only) 0 _B SYNC Frame not received on channel B/ node configured to transmit SYNC Frames 1 _B SYNC Frame received on channel B/ node not configured to transmit SYNC Frames

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	[13:10], [31:16]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

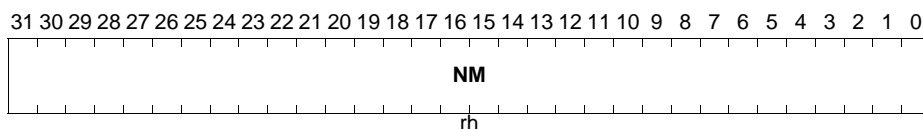
Network Management Vector [1...3] (NMVx)

The three Network Management Vectors n (NMVx, x=1-3) registers hold the accrued Network Management (NM) vector (configurable 0 to 12 byte). The accrued Network Management (NM) vector is generated by the Communication Controller by bit-wise ORing each Network Management (NM) vector received (valid static Frames with PPI = 1) on each channel (see “[Network Management” on Page 223](#)). The Communication Controller updates the Network Management (NM) vector at the end of each communication cycle as long as the Communication Controller is either in “NORMAL_ACTIVE” or “NORMAL_PASSIVE” state. NMVx-bytes exceeding the configured Network Management (NM) vector length are not valid.

NMVx (x = 1-3)

Network Management Vector x

$$(01AC_H + x * 4)$$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
NM	[31:0]	rh	Network Management Vector

Table 46 below shows the assignment of the received payload's data byte to the Network Management vector.

Table 46 Assignment of Data Byte to Network Management Vector

Bit	3	3	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	9	8	7	6	5	4	3	2	1	0	
Word	1	0	9	8	7	6	5	4	3	2	1	0	9	8	7	6	5	4	3	2	1	0										
NM1	Data3								Data2								Data1								Data0							
NM2	Data7								Data6								Data5								Data4							
NM3	Data11								Data10								Data9								Data8							

21.5.2.6 Message Buffer Control Registers

Message RAM Configuration (MRC)

The Message RAM Configuration register defines the number of Message Buffers assigned to the static segment, dynamic segment, and FIFO. The register can be written during “DEFAULT_CONFIG” or “CONFIG” state only.

MRC

Message RAM Configuration (0300_H) **Reset Value: 0180 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0					SP LM	SEC		LCB								
r					rw		rw		rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
FFB								FDB								
rw								rw								

Field	Bits	Type	Description
FDB	[7:0]	rw	First Dynamic Buffer May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 00 _H No group of Message Buffers exclusively for the static segment configured 01 _H ...7F _H Message Buffers 0 to FDB-1 reserved for static segment 80 _H ...FF _H No dynamic Message Buffers configured
FFB	[15:8]	rw	First Buffer of FIFO May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 00 _H ...7E _H Message Buffers from FFB to LCB assigned to the FIFO 7F _H All Message Buffers assigned to the FIFO 80 _H ...FF _H No Message Buffers assigned to the FIFO

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
LCB	[23:16]	rw	Last Configured Buffer May be only modified in “DEFAULT_CONFIG” or “CONFIG” state. 01 _H ...7F _H Number of Message Buffers is LCB + 1 80 _H ...FF _H No Message Buffer configured
SEC	[25:24]	rw	Secure Buffers Not evaluated when the Communication Controller is in “DEFAULT_CONFIG” or “CONFIG” state. For temporary unlocking see “Host Handling of Errors” on Page 258 . 00 _B Reconfiguration of Message Buffers enabled with numbers < FFB enabled. <i>Note: In nodes configured for SYNC Frame transmission or for single slot mode operation Message Buffer 0 (and if SPLM = 1, also Message Buffer 1) Reconfiguration of all Message Buffers is always locked</i> 01 _B Reconfiguration of Message Buffers with numbers < FDB and with numbers ≥ FFB locked and transmission of Message Buffers for static segment with numbers ≥ FDB disabled 10 _B Reconfiguration of all Message Buffers locked 11 _B Reconfiguration of all Message Buffers locked and transmission of Message Buffers for static segment with numbers ≥ FDB disabled
SPLM	26	rw	SYNC Frame Payload Multiplex This bit is only evaluated if the node is configured as sync node (SUCC1.TXSY = 1) or for single slot mode operation (SUCC1.TSM = 1). When this bit is set to 1 Message Buffers 0 and 1 are dedicated for SYNC Frame transmission with different payload data on channel A and B. When this bit is reset to 0, SYNC Frames are transmitted from Message Buffer 0 with the same payload data on both channels. Note that the channel filter configuration for Message Buffer 0 resp. Message Buffer 1 has to be chosen accordingly. 0 _B Only Message Buffer 0 locked against reconfiguration 1 _B Both Message Buffers 0 and 1 are locked against reconfiguration

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	[31:27]	r	Reserved Returns 0 if read; should be written with 0.

Note: In case the node is configured as sync node (SUCC1.TXSY = 1) or for single slot mode operation (SUCC1.TSM = 1), Message Buffer 0 resp. 1 is reserved for SYNC Frames or single slot Frames and have to be configured with the node-specific key slot ID. In case the node is neither configured as sync node nor for single slot operation Message Buffer 0 resp. 1 is treated like all other Message Buffers.

Table 47 Usage of the three Message Buffer Pointer

Message Buffer 0	↓ Static Buffers	
Message Buffer 1		
	↓ Static + Dynamic Buffers	← FDB
...		FIFO configured: FFB > FDB
	↓ FIFO	← FFB No FIFO configured: FFB ≥ 128
Message Buffer N-1		LCB ≥ FDB, LCB ≥ FFB
Message Buffer N		← LCB

The programmer has to ensure that the configuration defined by FDB, FFB, and LCB is valid. **The Communication Controller does not check for erroneous configurations!**

Note: The maximum number of Header Sections is 128. This means a maximum of 128 Message Buffer can be configured. The maximum length of a Data Section is 254 byte. The length of the Data Section may be configured differently for each Message Buffer. For details see [“Message RAM” on Page 249](#).

In case two or more Message Buffers are assigned to slot 1 by use of cycle filtering, all of them must be located either in the “Static Buffers” or at the beginning of the “Static + Dynamic Buffers” section.

The payload length configured and the length of the Data Section need to be configured identically for all Message Buffers belonging to the FIFO via WRHS2.PLC and WRHS3.DP. When the Communication Controller is not in “DEFAULT_CONFIG” or “CONFIG” state reconfiguration of Message Buffers belonging to the FIFO is locked.

FlexRay™ Protocol Controller (E-Ray)

FIFO Rejection Filter (FRF)

The FIFO Rejection Filter defines a user specified sequence of bits to which channel, Frame ID, and cycle count of the incoming Frames are compared. Together with the FIFO Rejection Filter Mask this register determines whether a message is rejected by the FIFO. The FRF register can be written during “DEFAULT_CONFIG” or “CONFIG” state only.

FRF

FIFO Rejection Filter (0304_H) **Reset Value: 0180 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							RNF	RSS	CYF						
r							rw	rw	rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0			FID												CH
r			rw												rw

Field	Bits	Type	Description
CH	[1:0]	rw	Channel Filter May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 00 _B receive on both channels ¹⁾ 01 _B receive only on channel B 10 _B receive only on channel A 11 _B no reception
FID	[12:2]	rw	Frame ID Filter Determines the Frame ID to be rejected by the FIFO. With the additional configuration of register FRFM, the corresponding Frame ID filter bits are ignored, which results in further rejected Frame IDs. When FRFM.MFID is zero, a Frame ID filter value of zero means that no Frame ID is rejected. 000 _H ... 7FF _H Frame ID filter values

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
CYF	[22:16]	rw	Cycle Counter Filter The 7-bit cycle counter filter determines the cycle set to which Frame ID and channel rejection filter are applied. In cycles not belonging to the cycle set specified by CYF, all Frames are rejected. For details about the configuration of the cycle counter filter see “Cycle Counter Filtering” on Page 225 . May be modified in “DEFAULT_CONFIG” or “CONFIG” state only.
RSS	23	rw	Reject in Static Segment If this bit is set, the FIFO is used only be used in dynamic segment. May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 0 _B FIFO also used in static segment 1 _B Reject messages for static segment
RNF	24	rw	Reject NULL Frames If this bit is set, received NULL Frames are not stored in the FIFO. May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 0 _B NULL Frames are stored in the FIFO 1 _B Reject all NULL Frames
0	[15:13], [31:25]	r	Reserved Returns 0 if read; should be written with 0.

- 1) If reception on both channels is configured, also in static segment always both Frames (from channel A and B) are stored in the FIFO, even if they are identical.

FlexRay™ Protocol Controller (E-Ray)

FIFO Rejection Filter Mask (FRFM)

The FIFO Rejection Filter Mask specifies which of the corresponding Frame ID filter bits are relevant for rejection filtering. If a bit is set, it indicates that the corresponding bit in the FRF register will not be considered for rejection filtering. The FRFM register can be written during “DEFAULT_CONFIG” or “CONFIG” state only.

FRFM

FIFO Rejection Filter Mask

(0308_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0																MFID											0				
r																rw											r				

Field	Bits	Type	Description
MFID	[12:2]	rw	Mask Frame ID Filter May be modified in “DEFAULT_CONFIG” or “CONFIG” state only. 0 _B Corresponding Frame ID filter bit is used for rejection filtering. 1 _B Ignore corresponding Frame ID filter bit.
0	[1:0], [31:13]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

FIFO Critical Level (FCL)

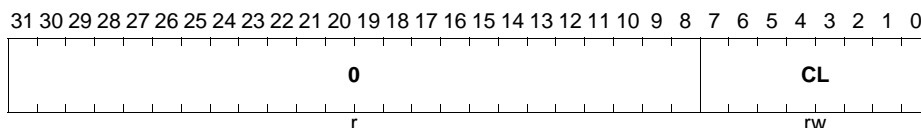
The Communication Controller accepts modifications of the register in “DEFAULT_CONFIG” or “CONFIG” state only.

FCL

FIFO Critical Level

(030C_H)

Reset Value: 0000 0080_H



Field	Bits	Type	Description
CL	[7:0]	rw	Critical Level When the receive FIFO fill level FSR.RFFL is equal or greater than the critical level configured by CL, the receive FIFO critical level flag FSR.RFCL is set. If CL is programmed to values > 128, bit FSR.RFCL is never set. When FSR.RFCL changes from 0 to 1 bit SIR.RFCL is set to 1, and if enabled, a service request is generated.
0	[31:8]	r	Reserved Returns 0 if read; should be written with 0.

21.5.2.7 Message Buffer Status Registers

Message Handler Status (MHDS)

The Message Handler Status register gives the Host access to the current state of the Message Handler. A flag is cleared by writing a 1 to the corresponding bit position. Writing a 0 has no effect on the flag. An application reset will also clear the register. If one of the flags MHDS.EIBF, MHDS.EOBF, MHDS.EMR, MHDS.ETBF1, MHDS.ETBF2 changes from 0 to 1 EIR.EERR is set.

MHDS

Message Handler Status

(0310_H)

Reset Value: 0000 0080_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								0							
MBU								MBT							
r				rh				r				rh			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								CRA M	MFM B	FMB D	ETB F2	ETB F1	EMR	EOB F	EIBF
r				rh				rh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
EIBF	0	rwh	ECC Error Input Buffer RAM 1,2 0 _B No error 1 _B Error occurred when reading Input Buffer RAM 1 or Input Buffer RAM 2
EOBF	1	rwh	ECC Error Output Buffer RAM 1,2 0 _B No error 1 _B Error occurred when reading Output Buffer RAM 1 or Output Buffer RAM 2
EMR	2	rwh	ECC Error Message RAM 0 _B No error 1 _B Error occurred when reading the Message RAM
ETBF1	3	rwh	ECC Error Transient Buffer RAM A 0 _B No error 1 _B Error occurred when reading Transient Buffer RAM A
ETBF2	4	rwh	ECC Error Transient Buffer RAM B 0 _B No error 1 _B Error occurred when reading Transient Buffer RAM B

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
FMBD	5	rwh	Faulty Message Buffer Detected 0_B No faulty Message Buffer 1_B Message Buffer referenced by MHDS.FMB holds faulty data due to a ECC error
MFMB	6	rwh	Multiple Faulty Message Buffers detected 0_B No additional faulty Message Buffer 1_B Another faulty Message Buffer was detected while flag MHDS.FMBD is set
GRAM	7	rh	Clear all internal RAM's Signals that execution of the CHI command CLEAR_RAMs is ongoing (all bits of all internal RAM blocks are written to 0). The bit is set by application reset or by CHI command CLEAR_RAMs. 0_B No execution of the CHI command CLEAR_RAMs 1_B Execution of the CHI command CLEAR_RAMs ongoing
FMB	[14:8]	rh	Faulty Message Buffer ECC error occurred when reading from the Message Buffer or when transferring data from Input Buffer or Transient Buffer A or Transient Buffer B to the Message Buffer referenced by MHDS.FMB. Value only valid when one of the flags MHDS.EIBF, MHDS.EMR, MHDS.ETBF1, MHDS.ETBF2, and flag MHDS.FMBD is set. Updated only after the Host has reset flag MHDS.FMBD.
MBT	[22:16]	rh	Message Buffer Transmitted Number of last successfully transmitted Message Buffer. If the Message Buffer is configured for single-shot mode, the respective TXR flag in the Transmission Request Registers TXRQ1 to TXRQ4 was reset. MBT is reset when the Communication Controller leaves "CONFIG" state or enters "STARTUP" state.
MBU	[30:24]	rh	Message Buffer Updated Number of Message Buffer that was updated last. For this Message Buffer the respective NDn (n = 0-31) to NDn (n = 96-127) and / or MBCn (n = 0-31) to MBCn (n = 96-127) flag in the New Data Registers NDAT1 to NDAT4 and the Message Buffer Status Changed MBSC1 to MBSC4 registers are also set. MBU is reset when the Communication Controller leaves "CONFIG" state or enters "STARTUP" state.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
0	15, 23, 31	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Last Dynamic Transmit Slot (LDTs)

The Last Dynamic Transmit Slot Register stores the Slot Counter value at the time of the last Frame transmission in the dynamic segment. This register is reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

LDTs

Last Dynamic Transmit Slot (0314_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		LDTB														0		LDTA													
r		rh														r		rh													

Field	Bits	Type	Description
LDTA	[10:0]	rh	Last Dynamic Transmission Channel A Value of (vSlotCounter[A]) at the time of the last Frame transmission on channel A in the dynamic segment of this node. It is updated at the end of the dynamic segment and is reset to zero if no Frame was transmitted during the dynamic segment.
LDTB	[26:16]	rh	Last Dynamic Transmission Channel B Value of (vSlotCounter[B]) at the time of the last Frame transmission on channel B in the dynamic segment of this node. It is updated at the end of the dynamic segment and is reset to zero if no Frame was transmitted during the dynamic segment.
0	[15:11], [31:27]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

FIFO Status Register (FSR)

The register is reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

FSR

FIFO Status Register (0318_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RFFL								0				RFO	RFC L	RFN E	
rh								r				rh		rh	rh

Field	Bits	Type	Description
RFNE	0	rh	Receive FIFO Not Empty This flag is set by the Communication Controller when a received valid Frame (data or NULL Frame depending on rejection mask) was stored in the FIFO. In addition, service request flag SIR.RFNE is set. The bit is reset after the Host has read all message from the FIFO. 0 _B Receive FIFO is empty 1 _B Receive FIFO is not empty
RFCL	1	rh	Receive FIFO Critical Level This flag is set when the receive FIFO fill level RFFL is equal or greater than the critical level as configured by FCL.CL. The flag is cleared by the Communication Controller as soon as RFFL drops below FCL.CL. When RFCL changes from 0 to 1 bit SIR.RFCL is set to 1, and if enabled, an service request is generated. 0 _B Receive FIFO below critical level 1 _B Receive FIFO critical level reached

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
RFO	2	rh	Receive FIFO Overflow The flag is set by the Communication Controller when a receive FIFO overflow is detected. When a receive FIFO overflow occurs, the oldest message is overwritten with the actual received message. In addition, service request flag EIR.RFO is set. The flag is cleared by the next FIFO read access issued by the Host. 0 _B No receive FIFO overflow detected 1 _B A receive FIFO overflow has been detected
RFFL	[15:8]	rh	Receive FIFO Fill Level Number of FIFO buffers filled up with new data not yet read by the Host. Maximum value is 128.
0	[7:3], [31:16]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Message Handler Constraints Flags (MHDF)

Some constraints exist for the Message Handler regarding $f_{\text{CLC_ERAY}}$ frequency, Message RAM configuration, and FlexRay™ bus traffic. To simplify software development, constraints violations are reported by setting flags in the MHDF. The register is reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state. A flag is cleared by setting the corresponding bit position. Clearing has no effect on the flag. If any flag in MHDFL is set, interrupt flag EIR.MHF is set.

MHDF

Message Handler Constraints Flags (031C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								WAH	TNS	TNS	TBF	TBF	FNF	FNF	SNU
r								P	B	A	B	A	B	A	A
								rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
SNUA	0	rwh	Status Not Updated Channel A This flag is set by the Communication Controller when the Message Handler, due to overload condition, was not able to update a Message Buffer's status MBS with respect to channel A. 0 _B No overload condition occurred when updating MBS for channel A 1 _B MBS for channel A not updated
SNUB	1	rwh	Status Not Updated Channel B This flag is set by the Communication Controller when the Message Handler, due to overload condition, was not able to update a Message Buffer's status MBS with respect to channel B. 0 _B No overload condition occurred when updating MBS for channel B 1 _B MBS for channel B not updated

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
FNFA	2	rwh	Find Sequence Not Finished Channel A This flag is set by the Communication Controller when the Message Handler, due to overload condition, was not able to finish a find sequence (scan of Message RAM for matching Message Buffer) with respect to channel A. 0 _B No find sequence not finished for channel A 1 _B Find sequence not finished for channel A
FNFB	3	rwh	Find Sequence Not Finished Channel B This flag is set by the Communication Controller when the Message Handler, due to overload condition, was not able to finish a find sequence (scan of Message RAM for matching Message Buffer) with respect to channel B. 0 _B No find sequence not finished for channel B 1 _B Find sequence not finished for channel B
TBFA	4	rwh	Transient Buffer Access Failure A This flag is set by the Communication Controller when a read or write access to Transient Buffer A requested by PRT A could not complete within the available time. 0 _B No TBF A access failure 1 _B TBF A access failure
TBFB	5	rwh	Transient Buffer Access Failure B This flag is set by the Communication Controller when a read or write access to Transient Buffer B requested by PRT B could not complete within the available time. 0 _B No Transient Buffer B access failure 1 _B Transient Buffer B access failure
TNSA	6	rwh	Transmission Not Started Channel A This flag is set by the CC when the Message Handler was not ready to start a scheduled transmission on channel A at the action point of the configured slot. 0 _B No transmission not started on channel A 1 _B Transmission not started on channel A
TNSB	7	rwh	Transmission Not Started Channel B This flag is set by the CC when the Message Handler was not ready to start a scheduled transmission on channel B at the action point of the configured slot. 0 _B No transmission not started on channel B 1 _B Transmission not started on channel B

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
WAHP	8	rwh	Write Attempt to Header Partition Outside “DEFAULT_CONFIG” and “CONFIG” state this flag is set by the Communication Controller when the message handler tries to write message data into the Header Partition of the Message RAM due to faulty configuration of a Message Buffer. The write attempt is not executed, to protect the Header Partition from unintended write accesses. 0 _B No write attempt to Header Partition 1 _B Write attempt to Header Partition
0	[31:9]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Transmission Request 1 (TXRQ1)

This register reflect the state of the TXR flags of the configured Message Buffers 0 to 31. The flags are evaluated for transmit buffers only. If the number of configured Message Buffers is less than 31, the remaining TXRn flags have no meaning and are read as 0.

TXRQ1

Transmission Request Register 1 (0320_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TXR 31	TXR 30	TXR 29	TXR 28	TXR 27	TXR 26	TXR 25	TXR 24	TXR 23	TXR 22	TXR 21	TXR 20	TXR 19	TXR 18	TXR 17	TXR 16
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TXR 15	TXR 14	TXR 13	TXR 12	TXR 11	TXR 10	TXR 9	TXR 8	TXR 7	TXR 6	TXR 5	TXR 4	TXR 3	TXR 2	TXR 1	TXR 0
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
TXRn (n = 0-31)	n	rh	Transmission Request n (n = 0-31) If the flag is set, the respective Message Buffer 0 to 31 is ready for transmission respectively transmission of this Message Buffer is in progress. In single-shot mode the flags are reset after transmission has completed.

FlexRay™ Protocol Controller (E-Ray)

Transmission Request Register 2 (TXRQ2)

This register reflect the state of the TXR flags of the configured Message Buffers 31 to 63. The flags are evaluated for transmit buffers only. If the number of configured Message Buffers is less than 63, the remaining TXRn flags have no meaning and are read as 0.

TXRQ2

Transmission Request Register 2 (0324_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TXR 63	TXR 62	TXR 61	TXR 60	TXR 59	TXR 58	TXR 57	TXR 56	TXR 55	TXR 54	TXR 53	TXR 52	TXR 51	TXR 50	TXR 49	TXR 48
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TXR 47	TXR 46	TXR 45	TXR 44	TXR 43	TXR 42	TXR 41	TXR 40	TXR 39	TXR 38	TXR 37	TXR 36	TXR 35	TXR 34	TXR 33	TXR 32
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
TXRn (n = 32-63)	n - 32	rh	Transmission Request n (n = 32-63) If the flag is set, the respective Message Buffer 32 to 63 is ready for transmission respectively transmission of this Message Buffer is in progress. In single-shot mode the flags are reset after transmission has completed.

FlexRay™ Protocol Controller (E-Ray)

Transmission Request Register 3 (TXRQ3)

This register reflect the state of the TXR flags of the configured Message Buffers 64 to 95. The flags are evaluated for transmit buffers only. If the number of configured Message Buffers is less than 95, the remaining TXRn flags have no meaning and are read as 0.

TXRQ3

Transmission Request Register 3 (0328_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TXR 95	TXR 94	TXR 93	TXR 92	TXR 91	TXR 90	TXR 89	TXR 88	TXR 87	TXR 86	TXR 85	TXR 84	TXR 83	TXR 82	TXR 81	TXR 80
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TXR 79	TXR 78	TXR 77	TXR 76	TXR 75	TXR 74	TXR 73	TXR 72	TXR 71	TXR 70	TXR 69	TXR 68	TXR 67	TXR 66	TXR 65	TXR 64
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
TXRn (n = 64-95)	n - 64	rh	Transmission Request n (n = 64-95) If the flag is set, the respective Message Buffer 64 to 95 is ready for transmission respectively transmission of this Message Buffer is in progress. In single-shot mode the flags are reset after transmission has completed.

FlexRay™ Protocol Controller (E-Ray)

Transmission Request Register 4 (TXRQ4)

This register reflect the state of the TXR flags of the configured Message Buffers 96 to 127. The flags are evaluated for transmit buffers only. If the number of configured Message Buffers is less than 127, the remaining TXRn flags have no meaning and are read as 0.

TXRQ4

Transmission Request Register 4 (032C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TXR 127	TXR 126	TXR 125	TXR 124	TXR 123	TXR 122	TXR 121	TXR 120	TXR 119	TXR 118	TXR 117	TXR 116	TXR 115	TXR 114	TXR 113	TXR 112
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TXR 111	TXR 110	TXR 109	TXR 108	TXR 107	TXR 106	TXR 105	TXR 104	TXR 103	TXR 102	TXR 101	TXR 100	TXR 99	TXR 98	TXR 97	TXR 96
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
TXRn (n = 96-127)	n - 96	rh	Transmission Request n (n = 96-127) If the flag is set, the respective Message Buffer 96 to 127 is ready for transmission respectively transmission of this Message Buffer is in progress. In single-shot mode the flags are reset after transmission has completed.

FlexRay™ Protocol Controller (E-Ray)

New Data Register 1 (NDAT1)

This register reflect the state of the ND flags of all configured Message Buffers 0 to 31. ND flags assigned to transmit buffers are meaningless. If the number of configured Message Buffers is less than 31, the remaining NDn flags have no meaning. The registers are reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

NDAT1

New Data Register 1

(0330_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ND 31	ND 30	ND 29	ND 28	ND 27	ND 26	ND 25	ND 24	ND 23	ND 22	ND 21	ND 20	ND 19	ND 18	ND 17	ND 16
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ND 15	ND 14	ND 13	ND 12	ND 11	ND 10	ND9	ND8	ND7	ND6	ND5	ND4	ND3	ND2	ND1	ND0
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
NDn (n = 0-31)	n	rh	New Data n (n = 0-31) The flags are set when a valid received Data Frame matches the Message Buffer's filter configuration, independent of the payload length received or the payload length configured for that Message Buffer. The flags are not set after reception of NULL Frames except for Message Buffers belonging to the receive FIFO. An ND flag is reset when the Header Section of the corresponding Message Buffer is reconfigured or when the Data Section has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

New Data Register 2 (NDAT2)

This register reflect the state of the ND flags of all configured Message Buffers 32 to 63. ND flags assigned to transmit buffers are meaningless. If the number of configured Message Buffers is less than 63, the remaining NDn flags have no meaning. The registers are reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

NDAT2

New Data Register 2

(0334_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ND 63	ND 62	ND 61	ND 60	ND 59	ND 58	ND 57	ND 56	ND 55	ND 54	ND 53	ND 52	ND 51	ND 50	ND 49	ND 48
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ND 47	ND 46	ND 45	ND 44	ND 43	ND 42	ND 41	ND 40	ND 39	ND 38	ND 37	ND 36	ND 35	ND 34	ND 33	ND 32
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
NDn (n = 32-63)	n - 32	rh	New Data n (n = 32-63) The flags are set when a valid received Data Frame matches the Message Buffer's filter configuration, independent of the payload length received or the payload length configured for that Message Buffer. The flags are not set after reception of NULL Frames except for Message Buffers belonging to the receive FIFO. An ND flag is reset when the Header Section of the corresponding Message Buffer is reconfigured or when the Data Section has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

New Data Register 3 (NDAT3)

This register reflect the state of the ND flags of all configured Message Buffers 64 to 95. ND flags assigned to transmit buffers are meaningless. If the number of configured Message Buffers is less than 95, the remaining NDn flags have no meaning. The registers are reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

NDAT3

New Data Register 3

(0338_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ND 95	ND 94	ND 93	ND 92	ND 91	ND 90	ND 89	ND 88	ND 87	ND 86	ND 85	ND 84	ND 83	ND 82	ND 81	ND 80
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ND 79	ND 78	ND 77	ND 76	ND 75	ND 74	ND 73	ND 72	ND 71	ND 70	ND 69	ND 68	ND 67	ND 66	ND 65	ND 64
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
NDn (n = 64-95)	n - 64	rh	New Data n (n = 64-95) The flags are set when a valid received Data Frame matches the Message Buffer's filter configuration, independent of the payload length received or the payload length configured for that Message Buffer. The flags are not set after reception of NULL Frames except for Message Buffers belonging to the receive FIFO. An ND flag is reset when the Header Section of the corresponding Message Buffer is reconfigured or when the Data Section has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

New Data Register 4 (NDAT4)

This register reflect the state of the ND flags of all configured Message Buffers 96 to 127. ND flags assigned to transmit buffers are meaningless. If the number of configured Message Buffers is less than 127, the remaining NDn flags have no meaning. The registers are reset when the Communication Controller leaves “CONFIG” state or enters “STARTUP” state.

NDAT4

New Data Register 4

(033C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ND 127	ND 126	ND 125	ND 124	ND 123	ND 122	ND 121	ND 120	ND 119	ND 118	ND 117	ND 116	ND 115	ND 114	ND 113	ND 112
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ND 111	ND 110	ND 109	ND 108	ND 107	ND 106	ND 105	ND 104	ND 103	ND 102	ND 101	ND 100	ND 99	ND 98	ND 97	ND 96
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
NDn (n = 96-127)	n - 96	rh	New Data n (n = 96-127) The flags are set when a valid received Data Frame matches the Message Buffer's filter configuration, independent of the payload length received or the payload length configured for that Message Buffer. The flags are not set after reception of NULL Frames except for Message Buffers belonging to the receive FIFO. An ND flag is reset when the Header Section of the corresponding Message Buffer is reconfigured or when the Data Section has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status Changed 1 (MBSC1)

This register reflect the state of the MBC flags of all configured Message Buffers. If the number of configured Message Buffers is less than 31, the remaining MBCn flags have no meaning. The register is reset when the communication controller leaves “CONFIG” state or enters “STARTUP” state.

MBSC1

Message Buffer Status Changed 1 (0340_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MBC 31	MBC 30	MBC 29	MBC 28	MBC 27	MBC 26	MBC 25	MBC 24	MBC 23	MBC 22	MBC 21	MBC 20	MBC 19	MBC 18	MBC 17	MBC 16
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MBC 15	MBC 14	MBC 13	MBC 12	MBC 11	MBC 10	MBC 9	MBC 8	MBC 7	MBC 6	MBC 5	MBC 4	MBC 3	MBC 2	MBC 1	MBC 0
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
MBCn (n = 0-31)	n	rh	Message Buffer Status Changed n (n = 0-31) An MBC flags is set whenever the Message Handler changes on of the status flags VFRA, VFRB, SEOA, SEOB, CEOA, CEOB, SVOA, SVOB, TCIA, TCIB, ESA, ESB, MLST, FTA, FTB in the Header Section (see “Message Buffer Status (MBS)” on Page 187) of the respective Message Buffer 0 to Message Buffer 31. The flags are reset when the Header Section of the Message Buffer is reconfigured or when it has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status Changed 2 (MBSC2)

This register reflect the state of the MBC flags of all configured Message Buffers. If the number of configured Message Buffers is less than 63, the remaining MBCn flags have no meaning. The register is reset when the communication controller leaves “CONFIG” state or enters “STARTUP” state.

MBSC2

Message Buffer Status Changed 2 (0344_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MBC 63	MBC 62	MBC 61	MBC 60	MBC 59	MBC 58	MBC 57	MBC 56	MBC 55	MBC 54	MBC 53	MBC 52	MBC 51	MBC 50	MBC 49	MBC 48
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MBC 47	MBC 46	MBC 45	MBC 44	MBC 43	MBC 42	MBC 41	MBC 40	MBC 39	MBC 38	MBC 37	MBC 36	MBC 35	MBC 34	MBC 33	MBC 32
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
MBCn (n = 32-63)	n - 32	rh	Message Buffer Status Changed n (n = 32-63) An MBC flags is set whenever the Message Handler changes on of the status flags VFRA, VFRB, SEOA, SEOB, CEOA, CEOB, SVOA, SVOB, TCIA, TCIB, ESA, ESB, MLST, FTA, FTB in the Header Section (see “Message Buffer Status (MBS)” on Page 187) of the respective Message Buffer 32 to Message Buffer 63. The flags are reset when the Header Section of the Message Buffer is reconfigured or when it has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status Changed 3 (MBSC3)

This register reflect the state of the MBC flags of all configured Message Buffers. If the number of configured Message Buffers is less than 95, the remaining MBCn flags have no meaning. The register is reset when the communication controller leaves “CONFIG” state or enters “STARTUP” state.

MBSC3

Message Buffer Status Changed 3 (0348_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MBC 95	MBC 94	MBC 93	MBC 92	MBC 91	MBC 90	MBC 89	MBC 88	MBC 87	MBC 86	MBC 85	MBC 84	MBC 83	MBC 82	MBC 81	MBC 80
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MBC 79	MBC 78	MBC 77	MBC 76	MBC 75	MBC 74	MBC 73	MBC 72	MBC 71	MBC 70	MBC 69	MBC 68	MBC 67	MBC 66	MBC 65	MBC 64
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
MBCn (n = 64-95)	n - 64	rh	Message Buffer Status Changed n (n = 64-95) An MBC flags is set whenever the Message Handler changes on of the status flags VFRA, VFRB, SEOA, SEOB, CEOA, CEOB, SVOA, SVOB, TCIA, TCIB, ESA, ESB, MLST, FTA, FTB in the Header Section (see “Message Buffer Status (MBS)” on Page 187) of the respective Message Buffer 64 to Message Buffer 95. The flags are reset when the Header Section of the Message Buffer is reconfigured or when it has been transferred to the Output Buffer.

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status Changed 4 (MBSC4)

This register reflect the state of the MBC flags of all configured Message Buffers. If the number of configured Message Buffers is less than 127, the remaining MBCn flags have no meaning. The register is reset when the communication controller leaves “CONFIG” state or enters “STARTUP” state.

MBSC4

Message Buffer Status Changed 4 (034C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MBC 127	MBC 126	MBC 125	MBC 124	MBC 123	MBC 122	MBC 121	MBC 120	MBC 119	MBC 118	MBC 117	MBC 116	MBC 115	MBC 114	MBC 113	MBC 112
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MBC 111	MBC 110	MBC 109	MBC 108	MBC 107	MBC 106	MBC 105	MBC 104	MBC 103	MBC 102	MBC 101	MBC 100	MBC 99	MBC 98	MBC 97	MBC 96
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
MBCn (n = 96-127)	n - 96	rh	Message Buffer Status Changed n (n = 96-127) An MBC flags is set whenever the Message Handler changes on of the status flags VFRA, VFRB, SEOA, SEOB, CEOA, CEOB, SVOA, SVOB, TCIA, TCIB, ESA, ESB, MLST, FTA, FTB in the Header Section (see “Message Buffer Status (MBS)” on Page 187) of the respective Message Buffer 96 to Message Buffer 127. The flags are reset when the Header Section of the Message Buffer is reconfigured or when it has been transferred to the Output Buffer.

21.5.2.8 Identification Registers

Core Release Register (CREL)

This register contains bit fields about the ERAY module identification. It is read only.

CREL

Core Release Register

(03F0_H)

Reset Value: XXXX XXXX_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REL				STEP				SUB STEP				YEAR				MON				DAY											
r				r				r				r				r															

Field	Bits	Type	Description
DAY	[7:0]	r	Design Time Stamp, Day Two digits, BCD-coded.
MON	[15:8]	r	Design Time Stamp, Month Two digits, BCD-coded.
YEAR	[19:16]	r	Design Time Stamp, Year One digit, BCD-coded.
SUBSTEP	[27:24]	r	Sub-Step of Core Release One digits, BCD-coded. 0 _H Alpha, pre-Beta, pre-Beta-update, pre-Beta2, pre-Beta2-update, Beta, Beta2, Revision 1.0.0 1 _H Beta_ct, Beta-ct-fix1, Revision 1.0.1 2 _H Revision1.0RC1,Beta-ct-fix2, REVISION 1.0RC1
STEP	[27:24]	r	Step of Core Release One digits, BCD-coded. 0 _H Revision 1.0.0 1 _H Alpha 2 _H pre-Beta 3 _H pre-Beta-update 4 _H pre-Beta2 5 _H pre-Beta2-update 6 _H Beta 7 _H Beta2

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
REL	[31:28]	r	Core Release One digit, BCD-coded. 0 _B alpha...beta2ct 1 _B Revision 1.0

Table 48 Coding of releases

Release	Step	Sub-Step	Name	Release Date
0	1	0	Alpha	
0	2	0	pre-Beta	
0	3	0	pre-Beta-update	
0	4	0	pre-Beta2	
0	5	0	pre-Beta2-update	
0	6	0	Beta	
0	6	1	Beta-ct-fix1	14.10.2005
0	6	2	Beta-ct-fix2	14.12.2005
0	7	0	Beta2	03.02.2006
0	7	1	Beta2ct	24.03.2006
0	7	2	Revision 1.0RC1	07.04.2006
1	0	0	Release 1.0.0	19.05.2006
1	0	1	Release 1.0.1	2006
1	0	2	Release 1.0.2	31.10.2007

FlexRay™ Protocol Controller (E-Ray)

Endian Register (ENDN)

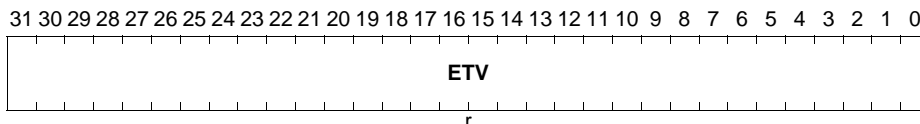
This register may be used to check, if the data of the E-Ray is handled by a host with the correct endian format. It is read only.

ENDN

Endian Register

(003F4_H)

Reset Value: 8765 4321_H



Field	Bits	Type	Description
ETV	[31:0]	r	Endianness Test Value The endianness test value.

21.5.2.9 Input Buffer

Double buffer structure consisting of Input Buffer Host and Input Buffer Shadow. While the Host can write to Input Buffer Host, the transfer to the Message RAM is done from Input Buffer Shadow. The Input Buffer holds the Header and Data Sections to be transferred to the selected Message Buffer in the Message RAM. It is used to configure the Message Buffers in the Message RAM and to update the Data Sections of transmit buffers.

When updating the Header Section of a Message Buffer in the Message RAM from the Input Buffer, the Message Buffer Status as described in [“Message Buffer Status \(MBS\)” on Page 187](#) is automatically reset to zero.

The Header Sections of Message Buffers belonging to the receive FIFO can only be (re)configured when the Communication Controller is in “DEFAULT_CONFIG” or “CONFIG” state. For those Message Buffers only the payload length configured and the data pointer need to be configured via WRHS2.PLC and WRHS2.DP. All information required for acceptance filtering is taken from the FIFO rejection filter and the FIFO rejection filter mask.

The data transfer between Input Buffer (IBF) and Message RAM is described in detail in [“Data Transfer from Input Buffer to Message RAM” on Page 234](#).

FlexRay™ Protocol Controller (E-Ray)

Write Data Section [01 - 64] (WRDSnn (nn = 01-64))

The Write Data Section (WRDSnn, nn = 01-64) holds the data words to be transferred to the Data Section of the addressed Message Buffer. The data words (DW_n) are written to the Message RAM in transmission order from DW_1 (byte0, byte1) to DW_{PL} (PL = number of data words as defined by the payload length configured by WRHS2.PLC).

WRDSnn (nn = 01-64)

Write Data Section nn $(03FC_H + nn * 4)$ Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MDWBnn3								MDWBnn2								MDWBnn1								MDWBnn0							
rw								rw								rw								rw							

Field	Bits	Type	Description
MDWB0	[7:0]	rw	32-Bit Word nn, Byte 0
MDWB1	[15:8]	rw	32-Bit Word nn, Byte 1
MDWB2	[23:16]	rw	32-Bit Word nn, Byte 2
MDWB3	[31:24]	rw	32-Bit Word nn, Byte 3

Note: 16-bit Word 127 is located on WRDS64.MDW. In this case WRDS64.MDW is unused (no valid data). The Input Buffer RAMs are initialized to zero when leaving application reset or by CHI command CLEAR_RAMs.

Note: When writing to the WRDSnn (nn = 01-64), each 32-bit word has to be filled up by one 32-bit access OR two consecutive 16-bit accesses OR four consecutive 8-bit accesses before the transfer from the Input Buffer to the Message RAM is started by writing the number of the target Message Buffer in the Message RAM to the Input Buffer Command Request register. If a 32-bit word of the Input Buffer has been filled with less than two consecutive 16-bit accesses OR four consecutive 8-bit accesses (less than 32-bit), random data is transferred into the Input buffer for every not written 16-bit or 8-bit of a 32-bit word.

FlexRay™ Protocol Controller (E-Ray)

Write Header Section 1 (WRHS1)

WRHS1

Write Header Section 1

(0500_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	MBI	TXM	PPIT	CFG	CHB	CHA	0	CYC							
r	rw		rw	rw	rw	rw	rw	r	rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0					FID										
r					rw										

Field	Bits	Type	Description
FID	[10:0]	rw	Frame ID Frame ID of the selected Message Buffer. The Frame ID defines the slot number for transmission / reception of the respective message. Message Buffers with Frame ID = 0 are considered as not valid.
CYC	[22:16]	rw	Cycle Code The 7-bit cycle code determines the cycle set used for cycle counter filtering. For details about the configuration of the cycle code see Section 21.6.7.3 .
CHA	24	rw	Channel Filter Control A The channel filtering field A associated with the buffer serves of channel A as a filter for receive buffers, and as a control field for transmit buffers
CHB	25	rw	Channel Filter Control B The channel filtering field B associated with the buffer serves of channel B as a filter for receive buffers, and as a control field for transmit buffers
CFG	26	rw	Message Buffer Direction Configuration Bit This bit is used to configure the corresponding buffer as a transmit buffer or as a receive buffer. For Message Buffers belonging to the receive FIFO the bit is not evaluated. 0 _B The corresponding buffer is configured as Receive Buffer 1 _B The corresponding buffer is configured as Transmit Buffer

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
PPIT	27	rw	Payload Preamble Indicator Transmit This bit is used to control the state of the Payload Preamble Indicator in transmit Frames. If the bit is set in a static Message Buffer, the respective Message Buffer holds Network Management information. If the bit is set in a dynamic Message Buffer the first two byte of the Payload Segment may be used for message ID filtering by the receiver. Message ID filtering of received FlexRay™ Frames is not supported by the E-Ray module, but can be done by the Host. 0 _B Payload Preamble Indicator not set 1 _B Payload Preamble Indicator set
TXM	28	rw	Transmission Mode This bit is used to select the transmission mode (see “Transmit Buffers” on Page 227). 0 _B Continuous mode 1 _B Single-shot mode
MBI	29	rw	Message Buffer Service Request This bit enables the receive / transmit service request for the corresponding Message Buffer. After a dedicated receive buffer has been updated by the Message Handler, flag SIR.RXI and /or SIR.MBSI in the Status Service Request register are set. After a transmission has completed flag SIR.TXI is set. 0 _B The corresponding Message Buffer service request is disabled 1 _B The corresponding Message Buffer service request is enabled
0	[15:11], 23, [31:30]	r	Reserved Returns 0 if read; should be written with 0.

Note: The Input Buffer RAMs are initialized to zero when leaving application reset or by CHI command CLEAR_RAMs. Note that only the currently active IBF bank is cleared. To clear the 2nd bank as well, CUST1.IBF1PAG and CUST1.IBF2PAG need to be set and command CLEAR_RAMs need to be issued again. This is required in particular after an application reset. If the 2nd bank of IBF is left unused, this procedure is not required.

Table 49 Channel Filter Control Bits

CHA	CHB	Transmit Buffer transmit Frame on	Receive Buffer store Frame received from
1 ¹⁾	1 ¹⁾	Both Channels (static segment only)	Channel A or B (store first semantically valid Frame, static segment only)
1	0	Channel A	Channel A
0	1	Channel B	Channel B
0	0	No Transmission	Ignore Frame

1) If a Message Buffer is configured for the dynamic segment and both bits of the channel filtering field are set to 1, no Frames are transmitted resp. received Frames are ignored (same function as CHA = CHB = 0)

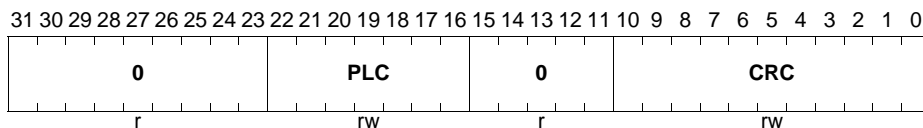
FlexRay™ Protocol Controller (E-Ray)

Write Header Section 2 (WRHS2)

WRHS2

Write Header Section 2

(0504_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CRC	[10:0]	rw	Header CRC (vRF!Header!HeaderCRC) Receive Buffer: Configuration not required Transmit Buffer: Header CRC calculated and configured by the Host. For calculation of the Header CRC the payload length of the Frame send on the bus has to be considered. In static segment the payload length of all Frames is configured by MHDC.SFDL.
PLC	[22:16]	rw	Payload Length Configured Length of Data Section (number of 2-byte words) as configured by the Host. During static segment the static Frame payload length as configured by MHDC.SFDL in the MHD Configuration Register defines the payload length for all static Frames. If the payload length configured by PLC is shorter than this value padding byte are inserted to ensure that Frames have proper physical length. The padding pattern is logical zero.
0	[15:11], [31:23]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

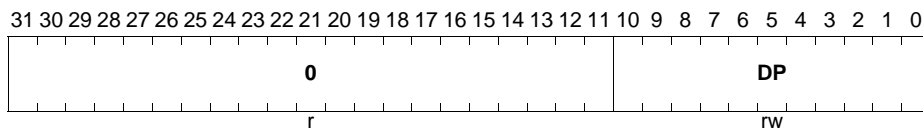
Write Header Section 3 (WRHS3)

WRHS3

Write Header Section 3

(0508_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DP	[10:0]	rw	Data Pointer Pointer to the first 32-bit word of the Data Section of the addressed Message Buffer in the Message RAM.
0	[31:11]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Input Buffer Command Mask (IBCM)

Configures how the Message Buffer in the Message RAM selected by the Input Buffer Command Request register IBCR is updated. If IBF Host and IBF Shadow are swapped, also masked bits IBCM.LHSH, IBCM.LDSH, and IBCM.STXRH are swapped with bits IBCM.LHSS, IBCM.LDSS, and IBCM.STXRS to keep them attached to the respective Input Buffer transfer.

IBCM

Input Buffer Command Mask (0510_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													STX RS	LD SS	LH SS
r													rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0													STX RH	LD SH	LH SH
r													rwh	rwh	rwh

Field	Bits	Type	Description
LHSH	0	rwh	Load Header Section Host 0 _B Header Section is not updated 1 _B Header Section selected for transfer from Input Buffer to the Message RAM
LDSH	1	rwh	Load Data Section Host 0 _B Data Section is not updated 1 _B Data Section selected for transfer from Input Buffer to the Message RAM
STXRH	2	rwh	Set Transmission Request Host If this bit is set to 1, the Transmission Request flag TXRQ1.TXRn (n = 0-31) to TXRQ4.TXRn (n = 0-31) for the selected Message Buffer is set in the Transmission Request Registers to release the Message Buffer for transmission. In single-shot mode the flag is cleared by the Communication Controller after transmission has completed. TXRQ1.TXRn (n = 0-31) to TXRQ4.TXRn (n = 0-31) are evaluated for transmit buffer only. 0 _B Reset Transmission Request flag 1 _B Set Transmission Request flag, transmit buffer released for transmission

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
LHSS	16	rh	Load Header Section Shadow 0_B Header Section is not updated 1_B Header Section selected for transfer from Input Buffer to the Message RAM (transfer is ongoing of finalized)
LDSS	17	rh	Load Data Section Shadow 0_B Data Section is not updated 1_B Data Section selected for transfer from Input Buffer to the Message RAM (transfer is ongoing of finalized)
STXRS	18	rh	Transmission Request Shadow If this bit is set to 1, the Transmission Request flag TXRQ1.TXRn (n = 0-31) to TXRQ4.TXRn (n = 0-31) for the selected Message Buffer is set in the Transmission Request Registers to release the Message Buffer for transmission. In single-shot mode the flag is cleared by the Communication Controller after transmission has completed. TXRQ1.TXRn (n = 0-31) to TXRQ4.TXRn (n = 0-31) are evaluated for transmit buffer only. 0_B Reset Transmission Request flag 1_B Set Transmission Request flag, transmit buffer released for transmission (operation is ongoing of finalized)
0	[15:3], [31:19]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Input Buffer Command Request (IBCR)

When the Host writes the number of the target Message Buffer in the Message RAM to IBRH in the Input Buffer Command Request register, IBF Host and IBF Shadow are swapped. In addition the Message Buffer numbers stored under IBRH and IBRS are also swapped (see also [“Data Transfer from Input Buffer to Message RAM” on Page 234](#)).

With this write operation the IBSYS bit in the Input Buffer Command Request register is set to 1. The Message Handler then starts to transfer the contents of IBF Shadow to the Message Buffer in the Message RAM selected by IBRS.

While the Message Handler transfers the data from IBF Shadow to the target Message Buffer in the Message RAM, the Host may write the next message into the IBF Host. After the transfer between IBF Shadow and the Message RAM has completed, the IBSYS bit is set back to 0 and the next transfer to the Message RAM may be started by the Host by writing the respective target Message Buffer number to IBRH.

If a write access to IBRH occurs while IBSYS is 1, IBSYH is set to 1. After completion of the ongoing data transfer from IBF Shadow to the Message RAM, IBF Host and IBF Shadow are swapped, IBSYH is reset to 0. IBSYS remains set to 1, and the next transfer to the Message RAM is started. In addition the Message Buffer numbers stored under IBRH and IBRS are also swapped. Any write access to an Input Buffer register while both IBSYS and IBSYH are set will cause the error flag EIR.IIBA to be set. In this case the Input Buffer will not be changed.

IBCR

Input Buffer Command Request (0514_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IB SYS	0								IBRS						
	r								rh						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IB SYH	0								IBRH						
	r								rwh						

Field	Bits	Type	Description
IBRH	[6:0]	rwh	Input Buffer Request Host Selects the target Message Buffer in the Message RAM for data transfer from Input Buffer. Valid values are 00 _H to 7F _H (0...127).

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
IBSYH	15	rh	Input Buffer Busy Host Set to 1 by writing IBRH while IBSYS is still 1. After the ongoing transfer between IBF Shadow and the Message RAM has completed, the IBSYH is set back to 0. 0 _B No request pending 1 _B Request while transfer between IBF Shadow and Message RAM in progress
IBRS	[22:16]	rh	Input Buffer Request Shadow Number of the target Message Buffer actually updated/lately updated. Valid values are 00 _H to 7F _H (0...127).
IBSYS	31	rh	Input Buffer Busy Shadow Set to 1 after writing IBRH. When the transfer between IBF Shadow and the Message RAM has completed, IBSYS is set back to 0. 0 _B Transfer between IBF Shadow and Message RAM completed 1 _B Transfer between IBF Shadow and Message RAM in progress
0	[14:7], [30:23]	r	Reserved Returns 0 if read; should be written with 0.

21.5.2.10 Output Buffer

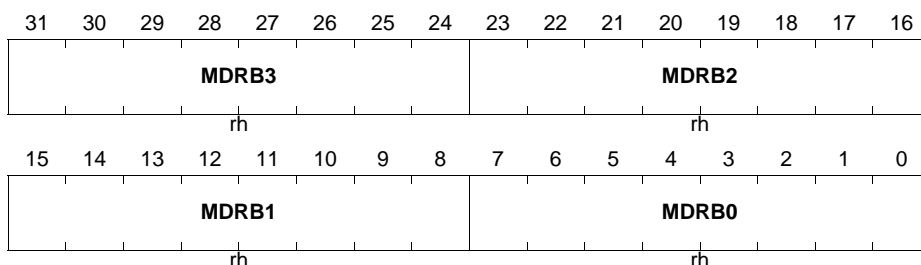
Double buffer structure consisting of Output Buffer Host and Output Buffer Shadow. Used to read out Message Buffers from the Message RAM. While the Host can read from Output Buffer Host, the Message Handler transfers the selected Message Buffer from Message RAM to the respective Output Buffer Shadow. The data transfer between Message RAM and Output Buffer (OBF) is described in [“Data Transfer from Message RAM to Output Buffer” on Page 236](#).

Read Data Section [1...64] (RDDSnn)

The Read Data Section nn (RDDSnn, nn = 01-64) holds the data words read from the Data Section of the addressed Message Buffer. The data words are read from the Message RAM in reception order from DW1 (byte0, byte1) to DW_{PL} (PL = number of data words as defined by the Payload Length).

RDDSnn (nn = 01-64)

Read Data Section nn $(05FC_H + nn * 4)$ Reset Value: 0000 0000_H



Field	Bits	Type	Description
MDRB0	[7:0]	rh	32-Bit Word nn, Byte 0
MDRB1	[15:8]	rh	32-Bit Word nn, Byte 1
MDRB2	[23:16]	rh	32-Bit Word nn, Byte 2
MDRB3	[31:24]	rh	32-Bit Word nn, Byte 3

Note: DW127 is located on RDDS64.MDW. In this case RDDS64.MDW is unused (no valid data). The Output Buffer RAMs are initialized to zero when leaving application reset or by CHI command CLEAR_RAMs.

FlexRay™ Protocol Controller (E-Ray)

Read Header Section 1 (RDHS1)

Values as configured by the Host via WRHS1 Register:

RDHS1

Read Header Section 1

(0700_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	MBI	TXM	PPIT	CFG	CHB	CHA	0	CYC							
r	rh	rh	rh	rh	rh	rh	r	rh							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						FID									
r						rh									

Field	Bits	Type	Description
FID	[10:0]	rh	Frame ID
CYC	[22:16]	rh	Cycle Code
CHA	24	rh	Channel Filter Control A
CHB	25	rh	Channel Filter Control B
CFG	26	rh	Message Buffer Direction Configuration Bit
PPIT	27	rh	Payload Preamble Indicator Transmit
TXM	28	rh	Transmission Mode
MBI	29	rh	Message Buffer Service Request
0	[15:11], 23, [31:30]	r	Reserved Returns 0 if read; should be written with 0.

Note: In case that the Message Buffer read from the Message RAM belongs to the receive FIFO, FID holds the received Frame ID, while CYC, CHA, CHB, CFG, PPIT, TXM, and MBI are reset to zero.

Table 50 Channel Filter Control Bits

CHA	CHB	Transmit Buffer transmit Frame on	Receive Buffer store Frame received from
1 ¹⁾	1 ¹⁾	Both Channels (static segment only)	Channel A or B (store first semantically valid Frame, static segment only)
1	0	Channel A	Channel A
0	1	Channel B	Channel B
0	0	No Transmission	Ignore Frame

1) If a Message Buffer is configured for the dynamic segment and both bits of the channel filtering field are set to 1, no Frames are transmitted resp. received Frames are ignored (same function as CHA = CHB = 0)

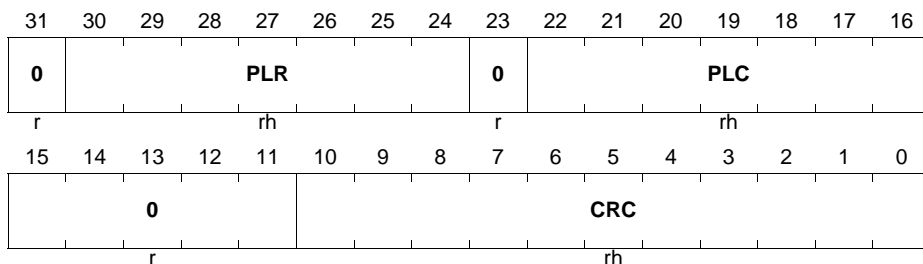
FlexRay™ Protocol Controller (E-Ray)

Read Header Section 2 (RDHS2)

RDHS2

Read Header Section 2

(0704_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CRC	[10:0]	rh	Header CRC (vRF!Header!HeaderCRC) Receive Buffer: Configuration not required. Header CRC updated from receive Data Frames. Transmit Buffer: Header CRC calculated and configured by the Host
PLC	[22:16]	rh	Payload Length Configured Length of Data Section (number of 2-byte words) as configured by the Host.

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
PLR	[30:24]	rh	Payload Length Received (vRF!Header!Length) Payload length value updated from received Data Frame (exception: if Message Buffer belongs to the receive FIFO PLR is also updated from received NULL Frames). When a message is stored into a Message Buffer the following behavior with respect to payload length received and payload length configured is implemented: <ul style="list-style-type: none"> • PLR > PLC: The payload data stored in the Message Buffer is truncated to the payload length configured for even PLC or else truncated to PLC + 1. • PLR ≤ PLC: The received payload data is stored into the Message Buffers Data Section. The remaining data bytes of the Data Section as configured by PLC are filled with undefined data. • PLR = 0: The Message Buffer's Data Section is filled with undefined data. • PLC = 0: Message Buffer has no Data Section configured. No data is stored into the Message Buffer's Data Section.
0	[15:11], 23, 31	r	Reserved Returns 0 if read; should be written with 0.

Note: The Message RAM is organized in 4-byte words. When received data is stored into a Message Buffer's Data Section, the number of 2-byte data words written into the Message Buffer is PLC rounded to the next even value. PLC should be configured identical for all Message Buffers belonging to the receive FIFO. Header 2 is updated from Data Frames only.

Read Header Section 3 (RDHS3)

Read Header Section 3

(0708_H)

Reset Value: 0000 0000_H

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
PPI	28	rh	Payload Preamble Indicator (vRF!Header!PPIndicator) The payload preamble indicator defines whether a Network Management vector or message ID is contained within the Payload Segment of the received Frame. 0 _B The Payload Segment of the received Frame does not contain a Network Management vector nor a message ID 1 _B Static segment: Network Management vector in the first part of the payload Dynamic segment: Message ID in the first part of the payload
RES	29	rh	Reserved Bit (vRF!Header!Reserved) Reflects the state of the received reserved bit. The reserved bit is transmitted as 0.
0	[15:11], [23:22], [31:30]	r	Reserved Returns 0 if read; should be written with 0.

Note: Header 3 is updated from Data Frames only.

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status (MBS)

The Message Buffer status is updated by the Communication Controller with respect to the assigned channel(s) latest at the end of the slot following the slot assigned to the Message Buffer. The flags are updated only when the Communication Controller is in “NORMAL_ACTIVE” or “NORMAL_PASSIVE” state. If only one channel (A or B) is assigned to a Message Buffer, the channel-specific status flags of the other channel are written to zero. If both channels are assigned to a Message Buffer, the channel-specific status flags of both channels are updated. The Message Buffer status is updated only when the slot counter reached the configured Frame ID and when the cycle counter filter matched. When the Host updates a Message Buffer via Input Buffer, all MBS flags are reset to zero independent of which IBCM bits are set or not. For details about receive / transmit filtering see [“Filtering and Masking” on Page 223](#), [“Transmit Process” on Page 227](#), and [“Receive Process” on Page 230](#).

Whenever the Message Handler changes one of the flags VFRA, VFRB, SEOA, SEOB, CEOA, CEOB, SVOA, SVOB, TCIA, TCIB, ESA, ESB, MLST, FTA, FTB the respective Message Buffer's MBC flag in registers MBSC1 to MBSC4 is set

MBS

Message Buffer Status (070C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	RES S	PPIS	NFIS	SYN S	SFIS	RCIS	0	CCS							
r	rh	rh	rh	rh	rh	rh	r	rh							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FTB	FTA	0	ML ST	ESB	ESA	TCIB	TCIA	SV OB	SV OA	CE OB	CE OA	SE OB	SE OA	VR FB	VR FA
rh	rh	r	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
VFRA	0	rh	Valid Frame Received on Channel A (vSS!ValidFrameA) A valid Frame indication is set if a valid Frame was received on channel A. 0 _B No valid Frame received on channel A 1 _B Valid Frame received on channel A
VFRB	1	rh	Valid Frame Received on Channel B (vSS!ValidFrameB) A valid Frame indication is set if a valid Frame was received on channel B. 0 _B No valid Frame received on channel B 1 _B Valid Frame received on channel B

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
SEOA	2	rh	Syntax Error Observed on Channel A (vSS!SyntaxErrorA) A syntax error was observed in the assigned slot on channel A. 0 _B No syntax error observed on channel A 1 _B Syntax error observed on channel A
SEOB	3	rh	Syntax Error Observed on Channel B (vSS!SyntaxErrorB) A syntax error was observed in the assigned slot on channel B. 0 _B No syntax error observed on channel B 1 _B Syntax error observed on channel B
CEOA	4	rh	Content Error Observed on Channel A (vSS!ContentErrorA) A content error was observed in the assigned slot on channel A. 0 _B No content error observed on channel A 1 _B Content error observed on channel A
CEOB	5	rh	Content Error Observed on Channel B (vSS!ContentErrorB) A content error was observed in the assigned slot on channel B. 0 _B No content error observed on channel B 1 _B Content error observed on channel B
SVOA	6	rh	Slot Boundary Violation Observed on Channel A (vSS!BViolationA) A slot boundary violation (channel active at the start or at the end of the assigned slot) was observed on channel A. 0 _B No slot boundary violation observed on channel A 1 _B Slot boundary violation observed on channel A
SVOB	7	rh	Slot Boundary Violation Observed on Channel B (vSS!BViolationB) A slot boundary violation (channel active at the start or at the end of the assigned slot) was observed on channel B. 0 _B No slot boundary violation observed on channel B 1 _B Slot boundary violation observed on channel B
TCIA	8	rh	Transmission Conflict Indication Channel A (vSS!TxConflictA) A transmission conflict indication is set if a transmission conflict has occurred on channel A. 0 _B No transmission conflict occurred on channel A 1 _B Transmission conflict occurred on channel A

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
TCIB	9	rh	Transmission Conflict Indication Channel B (vSS!TxConflictB) A transmission conflict indication is set if a transmission conflict has occurred on channel B. 0 _B No transmission conflict occurred on channel B 1 _B Transmission conflict occurred on channel B
ESA	10	rh	Empty Slot Channel A In an empty slot there is no activity detected on the bus. The condition is checked in static and dynamic slots. 0 _B Bus activity detected in the assigned slot on channel A 1 _B No bus activity detected in the assigned slot on channel A
ESB	11	rh	Empty Slot Channel B In an empty slot there is no activity detected on the bus. The condition is checked in static and dynamic slots. 0 _B Bus activity detected in the assigned slot on channel B 1 _B No bus activity detected in the assigned slot on channel B
MLST	12	rh	Message Lost The flag is set in case the Host did not read the message before the Message Buffer was updated from a received Data Frame. Not affected by reception of NULL Frames except for Message Buffers belonging to the receive FIFO. The flag is reset by a Host write to the Message Buffer via IBF or when a new message is stored into the Message Buffer after the Message Buffers ND flag was reset by reading out the Message Buffer via OBF. 0 _B No message lost 1 _B Unprocessed message was overwritten
FTA	14	rh	Frame Transmitted on Channel A Indicates that this node has transmitted a Data Frame in the assigned slot on channel A. 0 _B No transmission transmitted on channel A 1 _B Data Frame transmitted on channel A in cycle defined by CCS bit field <i>Note: The FlexRay™ protocol specification requires that FTA can only be reset by the Host. Therefore the Cycle Count Status CCS for these bits is only valid for the cycle where the bits are set to 1</i>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
FTB	15	rh	<p>Frame Transmitted on Channel B</p> <p>Indicates that this node has transmitted a Data Frame in the assigned slot on channel B.</p> <p>0_B No transmission transmitted on channel B</p> <p>1_B Data Frame transmitted on channel B in cycle defined by CCS bit field</p> <p><i>Note: The FlexRay™ protocol specification requires that FTB can only be reset by the Host. Therefore the Cycle Count Status CCS for these bits is only valid for the cycle where the bits are set to 1</i></p>
CCS	[21:16]	rh	<p>Cycle Count Status</p> <p>Cycle Count when status (MBS register) has been updated.</p>
RCIS	24	rh	<p>Received on Channel Indicator Status (vSS!Channel)</p> <p>Indicates the channel on which the Frame was received.</p> <p>0_B Frame received on channel B</p> <p>1_B Frame received on channel A</p> <p><i>Note: For receive buffers (CFG = 0) the RCIS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>
SFIS	25	rh	<p>Startup Frame Indicator Status (vRF!Header!SuFIndicator)</p> <p>A Startup Frame is marked by the Startup Frame indicator.</p> <p>0_B No Startup Frame received</p> <p>1_B The received Frame is a startup Frame</p> <p><i>Note: For receive buffers (CFG = 0) the SFIS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>
SYNS	26	rh	<p>SYNC Frame Indicator Status (vRF!Header!SyFIndicator)</p> <p>A Startup Frame is marked by the Startup Frame indicator.</p> <p>0_B No SYNC Frame received</p> <p>1_B The received Frame is a SYNC Frame</p> <p><i>Note: For receive buffers (CFG = 0) the SYNS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>

FlexRay™ Protocol Controller (E-Ray)

Field	Bits	Type	Description
NFIS	27	rh	<p>NULL Frame Indicator Status (vRF!Header!NFIndicator)</p> <p>If reset to 0 the Payload Segment of the received Frame contains no usable data.</p> <p>0_B Received Frame is a NULL Frame</p> <p>1_B Received Frame is not a NULL Frame</p> <p><i>Note: For receive buffers (CFG = 0) the NFIS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>
PPIS	28	rh	<p>Payload Preamble Indicator Status (vRF!Header!PPIndicator)</p> <p>The payload preamble indicator defines whether a Network Management vector or message ID is contained within the Payload Segment of the received Frame.</p> <p>Static Segment:</p> <p>0_B The Payload Segment of the received Frame does not contain a Network Management vector or a message ID</p> <p>1_B Network Management vector at the beginning of the payload</p> <p>Dynamic Segment:</p> <p>0_B The Payload Segment of the received Frame does not contain a Network Management vector or a message ID</p> <p>1_B Message ID at the beginning of the payload</p> <p><i>Note: For receive buffers (CFG = 0) the PPIS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>
RESS	29	rh	<p>Reserved Bit Status (vRF!Header!Reserved)</p> <p>Reflects the state of the received reserved bit. The reserved bit is transmitted as 0.</p> <p><i>Note: For receive buffers (CFG = 0) the RESS is updated from both valid data and NULL Frames. If no valid Frame was received, the previous value is maintained. For transmit buffers the flags have no meaning and should be ignored.</i></p>
0	13, [23:22], [31:30]	r	<p>Reserved</p> <p>Returns 0 if read; should be written with 0.</p>

FlexRay™ Protocol Controller (E-Ray)

Output Buffer Command Mask (OBCM)

Configures how the Output Buffer is updated from the Message Buffer in the Message RAM selected by the Output Buffer Command Request register. If OBF Host and OBF Shadow are swapped, also mask bits OBCM.RDSH and OBCM.RHSH are swapped with bits OBCM.RDSS and OBCM.RHSS to keep them attached to the respective Output Buffer transfer.

OBCM

Output Buffer Command Mask (0710_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0														RD SH	RH SH
														rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0														RD SS	RH SS
														rwh	rwh

Field	Bits	Type	Description
RHSS	0	rwh	Read Header Section Shadow 0 _B Header Section is not read 1 _B Header Section selected for transfer from Message RAM to Output Buffer
RDSS	1	rwh	Read Data Section Shadow 0 _B Data Section is not read 1 _B Data Section selected for transfer from Message RAM to Output Buffer
RHSH	16	rh	Read Header Section Host 0 _B Header Section is not read 1 _B Header Section selected for transfer from Message RAM to Output Buffer
RDSH	17	rh	Read Data Section Host 0 _B Data Section is not read 1 _B Data Section selected for transfer from Message RAM to Output Buffer
0	[15:2], [31:18]	r	Reserved Returns 0 if read; should be written with 0.

FlexRay™ Protocol Controller (E-Ray)

Note: After the transfer of the Header Section from the Message RAM to OBF Shadow has completed, the Message Buffer status changed flag MBCn ($n = 0-31$) to MBCn ($n = 96-127$) of the selected Message Buffer in the Message Buffer Changed MBSC1 to MBSC4 registers is cleared. After the transfer of the Data Section from the Message RAM to OBF Shadow has completed, the New Data flag NDn ($n = 0-31$) to NDn ($n = 96-127$) of the selected Message Buffer in the New Data NDAT1 to NDAT4 registers is cleared.

Output Buffer Command Request (OBCR)

The Message Buffer selected by OBCR.OBRS is transferred from the Message RAM to the Output Buffer as soon as the Host has set OBCR.REQ. Bit OBCR.REQ can only be set while OBCR.OBSYS is 0 (see also [“Data Transfer from Message RAM to Output Buffer” on Page 236](#)).

After setting OBCR.REQ, OBCR.OBSYS is automatically set, and the transfer of the Message Buffer selected by OBCR.OBRS from the Message RAM to Output Buffer Shadow is started. When the transfer between the Message RAM and OBF Shadow has completed, this is signalled by clearing OBCR.OBSYS. By setting OBCR.VIEW while OBCR.OBSYS is 0, OBF Host and OBF Shadow are swapped. When Output Buffer Host and Output Buffer Shadow are swapped, also mask bits OBCM.RDSH and OBCM.RHSH are swapped with bits OBCM.RDSS and OBCM.RHSS to keep them attached to the respective Output Buffer transfer. Now the Host can read the transferred Message Buffer from OBF Host. In parallel the Message Handler may transfer the next message from the Message RAM to OBF Shadow if OBCR.VIEW and OBCR.REQ are set at the same time.

Any write access to an Output Buffer register while OBCR.OBSYS is set will cause the error flag EIR.IOBA to be set. In this case the Output Buffer will not be changed.

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OBCR

Output Buffer Command Request (0714_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0										OBRH					
r										rh					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OBSYS	0					REQ	VIEW	0	OBRH						
rh	r					rw	rw	r	rwh						

Field	Bits	Type	Description
OBRH	[6:0]	rw	Output Buffer Request Shadow Number of source Message Buffer to be transferred from the Message RAM to OBF Shadow. Valid values are 00 _H to 7F _H (0 to 127). If the number of the first Message Buffer of the receive FIFO is written to this register the Message Handler transfers the Message Buffer addressed by the GET Index Register (GIDX, “FIFO Function” on Page 231) to OBF Shadow.
VIEW	8	rw	View Shadow Buffer Toggles between OBF Shadow and OBF Host. Only writeable while OBCR.OBSYS = 0. 0 _B No action 1 _B Swap OBF Shadow and OBF Host
REQ	9	rw	Request Message RAM Transfer Requests transfer of Message Buffer addressed by OBCR.OBRH from Message RAM to OBF Shadow. Only writeable while OBCR.OBSYS = 0. 0 _B No request 1 _B Transfer to OBF Shadow requested
OBSYS	15	rh	Output Buffer Busy Shadow Set to 1 after setting bit OBCR.REQ. When the transfer between the Message RAM and OBF Shadow has completed, OBCR.OBSYS is cleared again. 0 _B No transfer in progress 1 _B Transfer between Message RAM and OBF Shadow in progress

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Field	Bits	Type	Description
OBRH	[22:16]	rh	Output Buffer Request Host Number of Message Buffer currently accessible by the Host via RDHS1 to RDHS3, MBS, and RDDSnn (nn = 01-64). By setting OBCR.VIEW OBF Shadow and OBF Host are swapped and the transferred Message Buffer is accessible by the Host. Valid values are 00 _H to 7F _H (01 to 27).
0	7, [14:10], [31:23]	r	Reserved Returns 0 if read; should be written with 0.

21.6 Functional Description

This chapter describes the E-Ray implementation together with the related FlexRay™ protocol features. More information about the FlexRay™ protocol itself can be found in the FlexRay™ protocol specification v2.1.

Communication on FlexRay™ networks is based on Frames and symbols. The wakeup symbol (WUS) and the collision avoidance symbol (CAS) are transmitted outside the communication cycle to setup the time schedule. Frames and media access test symbols (MTS) are transmitted inside the communication cycle.

21.6.1 Communication Cycle

A communication cycle in FlexRay™ consists of the following elements:

- Static Segment
- Dynamic Segment
- Symbol Window
- Network Idle Time (NIT)

Static segment, dynamic segment, and symbol window form the Network Communication Time (NCT). For each communication channel the slot counter starts at 1 and counts up until the end of the dynamic segment is reached. Both channels share the same arbitration grid which means that they use the same synchronized Macrotick.

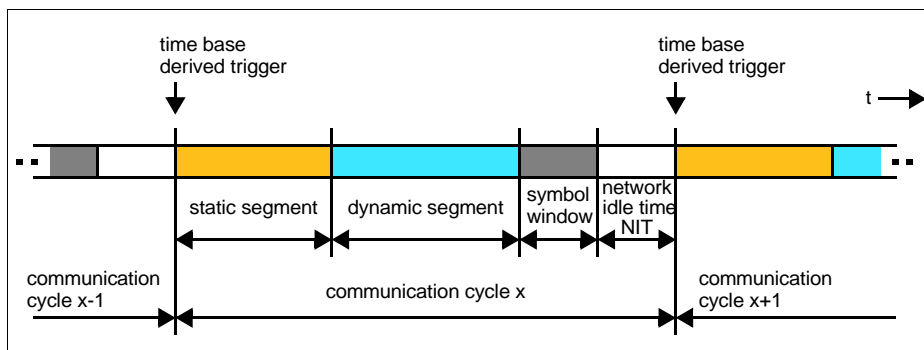


Figure 14 Structure of Communication Cycle

21.6.1.1 Static Segment

The Static Segment is characterized by the following features:

- Time slots of fixed length (optionally protected by bus guardian)
- Start of Frame transmission at action point of the respective static slot
- Payload length same for all Frames on both channel

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Parameters: Number of Static Slots [GTUC07.NSS](#), Static Slot Length [GTUC07.SSL](#), Payload Length Static [MHDC.SFDL](#), Action Point Offset [GTUC09.APO](#).

21.6.1.2 Dynamic Segment

The Dynamic Segment is characterized by the following features:

- All controllers have bus access (no bus guardian protection possible)
- Variable payload length and duration of slots, different for both channels
- Start of transmission at minislot action point

Parameters: Number of Minislots [GTUC08.NMS](#), Minislot Length [GTUC08.MSL](#), Minislot Action Point Offset [GTUC09.MAPO](#), Start of Latest Transmit (last minislot) [MHDC.SLT](#).

21.6.1.3 Symbol Window

During the symbol window only one media access test symbol (MTS) may be transmitted per channel. MTS symbols are send in "NORMAL_ACTIVE" state to test the bus guardian.

The symbol window is characterized by the following features:

- Send single symbol
- Transmission of the MTS symbol starts at the symbol windows action point

Parameters: Symbol Window Action Point Offset [GTUC09.APO](#) (same as for static slots), Network Idle Time Start [GTUC04.NIT](#).

21.6.1.4 Network Idle Time (NIT)

During network idle time the Communication Controller has to perform the following tasks:

- Calculate clock correction terms (offset and rate)
- Distribute offset correction over multiple MacroTicks
- Perform cluster cycle related tasks

Parameters: Network Idle Time Start [GTUC04.NIT](#), Offset Correction Start [GTUC04.OCs](#).

21.6.1.5 Configuration of Network Idle Time (NIT) Start and Offset Correction Start

The number of MacroTicks per cycle (gMacroPerCycle) is assumed to be m. It is configured by programming [GTUC02.MPC](#) = m.

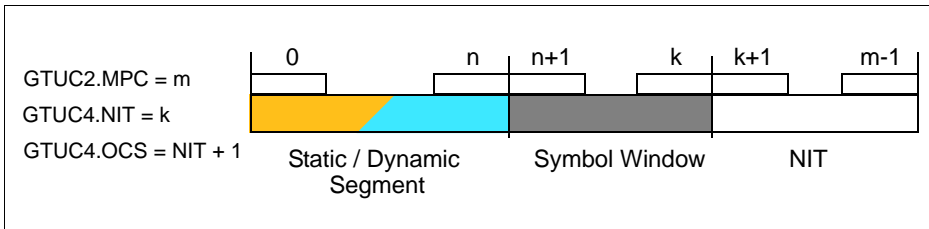


Figure 15 Configuration of network idle time (NIT) start and offset correction start

The static / dynamic segment starts with Macrotock 0 and ends with Macrotock n:

$n = \text{static segment length} + \text{dynamic segment offset} + \text{dynamic segment length} - 1 \text{ Macrotock}$

$n = g\text{NumberOfStaticSlots} \cdot g\text{dStaticSlot} + \text{dynamic segment offset} + g\text{NumberOfMinislots} \cdot g\text{dMinislot} - 1 \text{ Macroticks}$

The static segment length is configured by [GTUC07.SSL](#) and [GTUC07.NSS](#).

The dynamic segment length is configured by [GTUC08.MSL](#) and [GTUC08.NMS](#).

The dynamic segment offset is:

If $g\text{dActionPointOffset} \leq g\text{dMinislotActionPointOffset}$:

dynamic segment offset = 0 MT

Else if $g\text{dActionPointOffset} > g\text{dMinislotActionPointOffset}$:

dynamic segment offset = $g\text{dActionPointOffset} - g\text{dMinislotActionPointOffset}$

The network idle time (NIT) starts with Macrotock k+1 and ends with the last Macrotock of cycle m-1. It has to be configured by setting [GTUC04.NIT](#) = k.

For the E-Ray the offset correction start is required to be

[GTUC04.OCS](#) \geq [GTUC04.NIT](#) + 1 = k+1.

The length of symbol window results from the number of Macroticks between the end of the static / dynamic segment and the beginning of the NIT. It can be calculated by $k - n$.

21.6.2 Communication Modes

The FlexRay™ Protocol Specification v2.1 defines the Time-Triggered Distributed (TT-D) mode.

Time-triggered Distributed (TT-D)

In TT-D mode the following configurations are possible:

- **Pure static:** minimum 2 static slots + symbol window (optional)
- **Mixed static/dynamic:** minimum 2 static slots + dynamic segment + symbol window (optional)

A minimum of two coldstart nodes need to be configured for distributed time-triggered operation. Two fault-free coldstart nodes are necessary for the cluster startup. Each Startup Frame must be a SYNC Frame, therefore all coldstart nodes are sync nodes.

21.6.3 Clock Synchronization

In TT-D mode a distributed clock synchronization is used. Each node individually synchronizes itself to the cluster by observing the timing of received SYNC Frames from other nodes.

21.6.3.1 Global Time

Activities in a FlexRay™ node, including communication, are based on the concept of a global time, even though each individual node maintains its own view of it. It is the clock synchronization mechanism that differentiates the FlexRay™ cluster from other node collections with independent clock mechanisms. The global time is a vector of two values; the cycle (cycle counter) and the cycle time (Macro-tick counter).

Cluster specific:

- Macro-tick = basic unit of time measurement in a FlexRay™ network, a Macro-tick consists of an integer number of Micro-ticks
- Cycle length = duration of a communication cycle in units of Macro-ticks

21.6.3.2 Local Time

Internally, nodes time their behavior with Micro-tick resolution. Micro-ticks are time units derived from the oscillator clock tick of the specific node. Therefore Micro-ticks are controller-specific units. They may have different duration in different controllers. The precision of a node's local time difference measurements is a Micro-tick.

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Node specific:

- Oscillator clock → prescaler → Microtick
- Microtick = basic unit of time measurement in a Communication Controller, clock correction is done in units of Microticks
- Cycle counter + Macrotick counter = nodes local view of the global time

21.6.3.3 Synchronization Process

Clock synchronization is performed by means of SYNC Frames. Only preconfigured nodes (sync nodes) are allowed to send SYNC Frames. In a two-channel cluster a sync node has to send its SYNC Frame on both channels.

For synchronization in FlexRay™ the following constraints have to be considered:

- Max. one SYNC Frame per node in one communication cycle
- Max. 15 SYNC Frames per cluster in one communication cycle
- Every node has to use all available SYNC Frames for clock synchronization
- Minimum of two sync nodes required for clock synchronization and startup

For clock synchronization the time difference between expected and observed arrival time of SYNC Frames received during the static segment, valid on both channels (two-channel cluster), is measured. The calculation of correction terms is done during network idle time (NIT) (offset: every cycle, rate: odd cycle) by using a FTA / FTM algorithm. For details see FlexRay™ protocol specification v2.1, chapter 8.

Offset (phase) Correction

- Only deviation values measured and stored in the current cycle used
- For a two channel node the smaller value will be taken
- Calculation during network idle time (NIT) of **every** communication cycle, value may be negative
- Offset correction value calculated in even cycles used for error checking only
- Checked against limit values (violation: "NORMAL_ACTIVE" → "NORMAL_PASSIVE" → "HALT")
- Correction value is an integer number of Microticks
- Correction done in **odd** numbered cycles, distributed over the Macroticks beginning at offset correction start up to cycle end (end of network idle time (NIT)) to shift nodes next start of cycle (Macroticks lengthened / shortened)

Rate (frequency) Correction

- Pairs of deviation values measured and stored in even / odd cycle pair used
- For a two channel node the average of the differences from the two channels is used
- Calculated during network idle time (NIT) of **odd** numbered cycles, value may be negative
- Cluster drift damping is performed using global damping value

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- Checked against limit values
- Correction value is a signed integer number of Microticks
- Distributed over Macroticks comprising the next **even / odd** cycle pair (Macroticks lengthened / shortened)

Synchronization Process

Clock synchronization is performed by means of SYNC Frames. Only preconfigured nodes (sync nodes) are allowed to send SYNC Frames. In a two-channel cluster a sync node has to send its SYNC Frame on both channels.

For synchronization in FlexRay™ the following constraints have to be considered:

- Max. one SYNC Frame per node in one communication cycle
- Max. 15 SYNC Frames per cluster in one communication cycle
- Every node has to use all available SYNC Frames for clock synchronization
- Minimum of two sync nodes required for clock synchronization and startup

For clock synchronization the time difference between expected and observed arrival time of SYNC Frames received during the static segment, valid on both channels (two-channel cluster), is measured. The calculation of correction terms is done during network idle time (NIT) (offset: every cycle, rate: odd cycle) by using a FTA / FTM algorithm. For details see FlexRay™ protocol specification v2.1, chapter 8.

SYNC Frame Transmission

SYNC Frame transmission is only possible from buffer 0 and 1. Message Buffer 1 may be used for SYNC Frame transmission in case that SYNC Frames should have different payloads on the two channels. In this case bit **MRC.SPLM** has to be programmed to 1.

Message Buffers used for SYNC Frame transmission have to be configured with the key slot ID and can be (re)configured in "DEFAULT_CONFIG" or "CONFIG" state only. For nodes transmitting SYNC Frames **SUCC1.TXSY** must be set to 1.

21.6.3.4 External Clock Synchronization

During normal operation, independent clusters can drift significantly. If synchronous operation across independent clusters is desired, external synchronization is necessary; even though the nodes within each cluster are synchronized. This can be accomplished with synchronous application of host-deduced rate and offset correction terms to the clusters.

- External offset / rate correction value is a signed integer
- External offset / rate correction value is added to calculated offset / rate correction value
- Aggregated offset / rate correction term (external + internal) is not checked against configured limits

21.6.4 Error Handling

The implemented error handling concept is intended to ensure that in case of a lower layer protocol error in a single node communication between non-affected nodes can be maintained. In some cases, higher layer program command activity is required for the Communication Controller to resume normal operation. A change of the error handling state will set bit **EIR.PEMC** in the Error Service Request Register and may trigger an service request to the Host if enabled. The actual error mode is signalled by **CCEV.ERRM** in the Communication Controller Error Vector register.

Table 51 Error Modes of the POC (Degradation Model)

Error Mode	Activity
ACTIVE (green)	Full operation , State: "NORMAL_ACTIVE" The Communication Controller is fully synchronized and supports the cluster wide clock synchronization. The host is informed of any error condition(s) or status change by interrupt (if enabled) or by reading the error and status interrupt flags from registers EIR and SIR .
PASSIVE (yellow)	Reduced operation , State: "NORMAL_PASSIVE", Communication Controller self rescue allowed The Communication Controller stops transmitting Frames and symbols, but received Frames are still processed. Clock synchronization mechanisms are continued based on received Frames. No active contribution to the cluster wide clock synchronization. The host is informed of any error condition(s) or status change by interrupt (if enabled) or by reading the error and status interrupt flags from registers EIR and SIR .
COMM_HALT (red)	Operation halted , State: "HALT", Communication Controller self rescue not allowed The Communication Controller stops Frame and symbol processing, clock synchronization processing, and the Macro-tick generation. The host has still access to error and status information by reading the error and status interrupt flags from registers EIR and SIR . The bus drivers are disabled.

21.6.4.1 Clock Correction Failed Counter

When the Clock Correction Failed Counter reaches the maximum "without clock correction passive" limit defined by **SUCC3.WCP**, the POC transits from "NORMAL_ACTIVE" to "NORMAL_PASSIVE" state. When it reaches the "maximum without clock correction fatal" limit defined by **SUCC3.WCF**, it transits "NORMAL_ACTIVE" or "NORMAL_PASSIVE" to the "HALT" state. Both limits are defined in the SUC Configuration Register 3.

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The Clock Correction Failed Counter **CCEV.CCFC** allows the Host to monitor the duration of the inability of a node to compute clock correction terms after the Communication Controller passed protocol startup phase. It will be incremented by one at the end of any **odd** numbered communication cycle where either the Missing Offset Correction signal **SFS.MOCS** nor the Missing Rate Correction signal **SFS.MRCS** flag is set. The two flags are located in the SYNC Frame Status register, while the Clock Correction Failed Counter is located in the Communication Controller Error Vector register.

The Clock Correction Failed Counter is reset to zero at the end of an **odd** communication cycle if neither the Missing Offset Correction signal **SFS.MOCS** nor the Missing Rate Correction signal **SFS.MRCS** flag is set.

The Clock Correction Failed Counter stops incrementing when the “maximum without clock correction fatal” value **SUCC3.WCF** as defined in the SUC Configuration Register 3 is reached (i.e. incrementing the counter at its maximum value will not cause it to “wraparound” back to zero). The Clock Correction Failed Counter is initialized to zero when the Communication Controller enters “READY” state or when “NORMAL_ACTIVE” state is entered.

21.6.4.2 Passive to Active Counter

The passive to active counter controls the transition of the POC from “NORMAL_PASSIVE” to “NORMAL_ACTIVE” state. **SUCC1.PTA** in the SUC Configuration Register 1 defines the number of consecutive even / odd cycle pairs that must have valid clock correction terms before the Communication Controller is allowed to transit from “NORMAL_PASSIVE” to “NORMAL_ACTIVE” state. If **SUCC1.PTA** is reset to zero the Communication Controller is not allowed to transit from “NORMAL_PASSIVE” to “NORMAL_ACTIVE” state.

21.6.4.3 HALT Command

In case the Host wants to stop FlexRay™ communication of the local node it can bring the Communication Controller into “HALT” state by asserting the HALT command. This can be done by writing **SUCC1.CMD** = 0110_B in the SUC Configuration Register 1. When called in “NORMAL_ACTIVE” or “NORMAL_PASSIVE” state the POC transits to “HALT” state at the end of the current cycle. When called in any other state **SUCC1.CMD** will be reset to 0000_B = “COMMAND_NOT_ACCEPTED” and bit **EIR.CNA** in the Error Service Request Register is set to 1. If enabled an service request to the Host is generated.

21.6.4.4 FREEZE Command

In case the Host detects a severe error condition it can bring the Communication Controller into “HALT” state by asserting the FREEZE command. This can be done by writing **SUCC1.CMD** = 0111_B in the SUC Configuration Register 1. The FREEZE

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command triggers the entry of the "HALT" state immediately regardless of the actual POC state.

The POC state from which the transition to HALT state took place can be read from **CCSV.PSL**.

21.6.5 Communication Controller States

This chapter introduces the states of the Communication Controller.

21.6.5.1 Communication Controller State Diagram

State transitions are controlled by external the application reset or RXDA/B, by the POC state machine, and by the CHI Command Vector **SUCC1.CMD** located in the SUC Configuration Register 1.

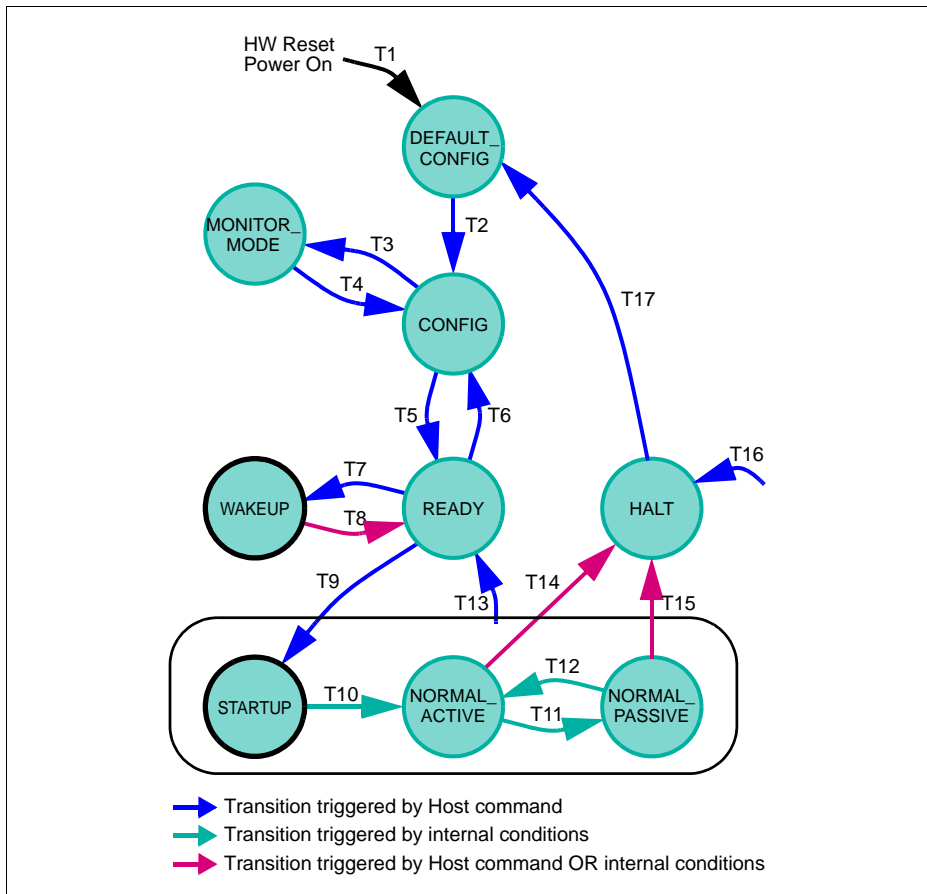


Figure 16 Overall State Diagram of E-Ray Communication Controller

The Communication Controller exits from all states to “HALT” state after application of the FREEZE command (SUCC1.CMD = 0111_B).

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Table 52 State Transitions of E-Ray Overall State Machine

T#	Condition	From	To
1	application reset	HW Reset	DEFAULT_CONFIG
2	Command CONFIG, SUCC1.CMD = 0001 _B	DEFAULT_CONFIG	CONFIG
3	Unlock sequence followed by command MONITOR_MODE, SUCC1.CMD = 1011 _B	CONFIG	MONITOR_MODE
4	Command CONFIG, SUCC1.CMD = 0001 _B	MONITOR_MODE	CONFIG
5	Unlock sequence followed by command READY, SUCC1.CMD = 0010 _B	CONFIG	READY
6	Command CONFIG, SUCC1.CMD = 0001 _B	READY	CONFIG
7	Command WAKEUP, SUCC1.CMD = 0011 _B	READY	WAKEUP
8	Complete, non-aborted transmission of wakeup pattern OR received WUP OR received Frame Header OR command READY, SUCC1.CMD = 0010 _B	WAKEUP	READY
9	Command RUN, SUCC1.CMD = 0100 _B	READY	STARTUP
10	Successful startup	STARTUP	NORMAL_ACTIVE
11	Clock Correction Failed counter reached Maximum Without Clock Correction Passive limit configured by WCP in SUC Configuration Register 3	NORMAL_ACTIVE	NORMAL_PASSIVE
12	Number of valid correction terms reached the Passive to Active limit configured by PTA in SUC Configuration Register 1	NORMAL_PASSIVE	NORMAL_ACTIVE
13	Command READY, SUCC1.CMD = 0010 _B	STARTUP, NORMAL_ACTIVE, NORMAL_PASSIVE	READY

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Table 52 State Transitions of E-Ray Overall State Machine (cont'd)

T#	Condition	From	To
14	Clock Correction Failed counter reached Maximum Without Clock Correction Fatal limit configured by WCF in SUC Configuration Register 3 AND bit HCSE in the SUC Configuration Register 1 set to 1 OR command HALT, SUCC1.CMD = 0110 _B	NORMAL_ACTIVE	HALT
15	Clock Correction Failed counter reached Maximum Without Clock Correction Fatal limit configured by WCF in SUC Configuration Register 3 AND bit HCSE in the SUC Configuration Register 1 set to 1 OR command HALT, SUCC1.CMD = 0110 _B	NORMAL_PASSIVE	HALT
16	Command FREEZE, SUCC1.CMD = 0111 _B	All States	HALT
17	Command CONFIG, SUCC1.CMD = 0001 _B	HALT	DEFAULT_CONFIG

21.6.5.2 DEFAULT_CONFIG State

In “DEFAULT_CONFIG” state, the Communication Controller is stopped. All configuration registers are accessible and the pins to the physical layer are in their inactive state.

The Communication Controller enters this state

- When leaving application reset
- When exiting from “HALT” state

To leave “DEFAULT_CONFIG” state the Host has to write SUCC1.CMD = 0001_B in the SUC Configuration Register 1. The Communication Controller transits to “CONFIG” state.

CONFIG State

In “CONFIG” state, the Communication Controller is stopped. All configuration registers are accessible and the pins to the physical layer are in their inactive state. This state is used to initialize the Communication Controller configuration.

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The Communication Controller enters this state

- When exiting from “DEFAULT_CONFIG” state
- When exiting from “MONITOR_MODE” or “READY” state

When the state has been entered via “HALT” and “DEFAULT_CONFIG” state, the Host can analyze status information and configuration. Before leaving “CONFIG” state the Host has to assure that the configuration is fault-free.

To leave “CONFIG” state, the Host has to perform the unlock sequence as described on **“LCK” on Page 40**. Directly after unlocking the “CONFIG” state the Host has to write **SUCC1.CMD** in the SUC Configuration Register 1 to enter the next state.

Internal counters and the Communication Controller status flags are reset when the Communication Controller leaves “CONFIG”.

*Note: The Message Buffer Status Registers (**MHDS**, **TXRQ1** to **TXRQ4**, **NDAT1** to **NDAT4**, **MBSC1** to **MBSC4**) and status data stored in the Message RAM and are not affected by the transition of the POC from “CONFIG” to “READY” state.*

When the Communication Controller is in “CONFIG” state it is also possible to bring the Communication Controller into a power saving mode by halting the module clocks (f_{SCLK} , f_{CLC_ERAY}). To do this the Host has to assure that all Message RAM transfers have finished before turning off the clocks.

21.6.5.3 MONITOR_MODE

After unlocking “CONFIG” state and writing **SUCC1.CMD** = 0011_B the Communication Controller enters “MONITOR_MODE”. In this mode the Communication Controller is able to receive FlexRay™ Frames and to detect wakeup pattern. The temporal integrity of received Frames is not checked, and therefore cycle counter filtering is not supported. It is not possible to distinguish between static and dynamic frames, because limited functions in Monitor Mode (FRF.RSS will be ignored, filtering not functional). This mode can be used for debugging purposes in case e.g. that startup of a FlexRay™ network fails. After writing **SUCC1.CMD** = 0001_B the Communication Controller transits back to “CONFIG” state.

In MONITOR_MODE the pick first valid mechanism is disabled. This means that a receive Message Buffer may only be configured to receive on one channel. Received Frames are stored into Message Buffers according to Frame ID and receive channel. NULL Frames are handled like Data Frames. After Frame reception only status bits **MBS.VFRA**, **MBS**, **MBS.MLST**, **MBS.RCIS**, **MBS.SFIS**, **MBS.SYNS**, **MBS.NFIS**, **MBS.PPIS**, **MBS.RESS** have valid value.

In “MONITOR_MODE” the Communication Controller is not able to distinguish between CAS and MTS symbols. In case one of these symbols is received on one or both of the two channels, the flags **SIR.MTSA** resp. **SIR.MTSB** are set. **SIR.CAS** has no function in “MONITOR_MODE”.

21.6.5.4 READY State

After unlocking “CONFIG” state and writing **SUCC1.CMD** = 0010_B the Communication Controller enters “READY” state. From this state the Communication Controller can transit to WAKEUP state and perform a cluster wakeup or to “STARTUP” state to perform a coldstart or to integrate into a running communication.

The Communication Controller enters this state

- When exiting from “CONFIG”, “WAKEUP”, “STARTUP”, “NORMAL_ACTIVE”, or “NORMAL_PASSIVE” state by writing **SUCC1.CMD** = 0010_B (READY command).

The Communication Controller exits from this state

- To “CONFIG” state by writing **SUCC1.CMD** = 0001_B (CONFIG command)
- To “WAKEUP” state by writing **SUCC1.CMD** = 0011_B (WAKEUP command)
- To “STARTUP” state by writing **SUCC1.CMD** = 0100_B (RUN command)

Internal counters and the Communication Controller status flags are reset when the Communication Controller enters “STARTUP” state.

*Note: Status bits **MHDS**, registers **TXRQ1** to **TXRQ4**, and status data stored in the Message RAM are not affected by the transition of the POC from “READY” to “STARTUP” state.*

21.6.5.5 WAKEUP State

The description below is intended to help configuring wakeup for the E-Ray IP-module. A detailed description of the wakeup procedure together with the respective SDL diagrams can be found in the FlexRay™ protocol specification v2.1, section 7.1.

The Communication Controller enters this state

- When exiting from “READY” state by writing **SUCC1.CMD** = 0011_B (WAKEUP command).

The Communication Controller exits from this state to “READY” state

- After complete non-aborted transmission of wakeup pattern
- After WUP reception
- After detecting a WUP collision
- After reception of a Frame Header
- By writing **SUCC1.CMD** = 0010_B (READY command)

The cluster wakeup must precede the communication startup in order to ensure that all mechanisms defined for the startup work properly. The minimum requirement for a cluster wakeup is that all bus drivers are supplied with power. A bus driver has the ability to wake up the other components of its node when it receives a wakeup pattern on its channel. At least one node in the cluster needs an **external** wakeup source.

The Host completely controls the wakeup procedure. It is informed about the state of the cluster by the bus driver and the Communication Controller and configures bus guardian

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(if available) and Communication Controller to perform the cluster wakeup. The Communication Controller provides to the Host the ability to transmit a special wakeup pattern on each of its available channels separately. The Communication Controller needs to recognize the wakeup pattern only during “WAKEUP” state.

Wakeup may be performed on only one channel at a time. The Host has to configure the wakeup channel while the Communication Controller is in “CONFIG” state by writing bit **SUCC1.WUCS** in the SUC Configuration Register 1. The Communication Controller ensures that ongoing communication on this channel is not disturbed. The Communication Controller cannot guarantee that all nodes connected to the configured channel awake upon the transmission of the wakeup pattern, since these nodes cannot give feedback until the startup phase. The wakeup procedure enables single-channel devices in a two-channel system to trigger the wakeup, by only transmitting the wakeup pattern on the single channel to which they are connected. Any coldstart node that deems a system startup necessary will then wake the remaining channel before initiating communication startup.

The wakeup procedure tolerates any number of nodes simultaneously trying to wakeup a single channel and resolves this situation such that only one node transmits the pattern. Additionally the wakeup pattern is collision resilient, so even in the presence of a fault causing two nodes to simultaneously transmit a wakeup pattern, the resulting collided signal can still wake the other nodes.

After wakeup the Communication Controller returns to “READY” state and signals the change of the wakeup status to the Host by setting bit **SIR.WST** in the Status Service Request Register. The wakeup status vector can be read from the Communication Controller Status Vector register **CCSV.WSV**. If a valid wakeup pattern was received also either flag **SIR.WUPA** or flag **SIR.WUPB** in the Status Service Request Register is set.

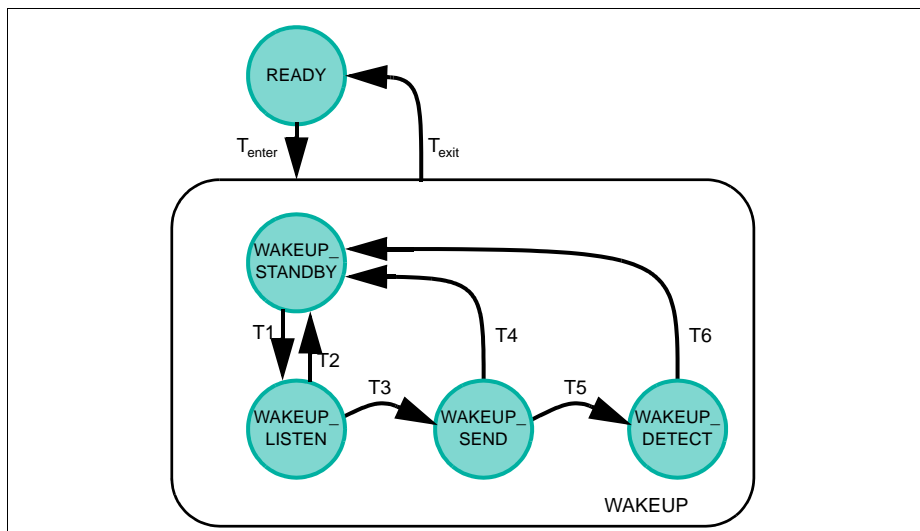


Figure 17 Structure of POC State WAKEUP

Table 53 State Transitions WAKEUP

T#	Condition	From	To
enter	Host commands change to "WAKEUP" state by writing SUCC1.CMD = 0011 _B (WAKEUP command)	READY	WAKEUP
1	CHI command WAKEUP triggers wakeup FSM to transit to "WAKEUP_LISTEN" state	WAKEUP_STANDBY	WAKEUP_LISTEN
2	Received WUP on wakeup channel selected by flag SUCC1.WUCS in the SUC Configuration Register 1 OR Frame Header on either available channel	WAKEUP_LISTEN	WAKEUP_STANDBY
3	Timer event	WAKEUP_LISTEN	WAKEUP_SEND
4	Complete, non-aborted transmission of wakeup pattern	WAKEUP_SEND	WAKEUP_STANDBY

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Table 53 State Transitions WAKEUP (cont'd)

T#	Condition	From	To
5	Collision detected	WAKEUP_SEND	WAKEUP_DETECT
6	Wakeup timer expired OR WUP detected on wakeup channel selected by flag SUCC1.WUCS in the SUC Configuration Register 1 OR Frame Header received on either available channel	WAKEUP_DETECT	WAKEUP_STANDBY
exit	Wakeup completed (after T2 or T4 or T6) OR Host commands change to “READY” state by writing SUCC1.CMD = 0010 _B (READY command). This command also resets the wakeup FSM to “WAKEUP_STANDBY” state	WAKEUP	READY

The “WAKEUP_LISTEN” state is controlled by the wakeup timer and the wakeup noise timer. The two timers are controlled by the parameters listen timeout **SUCC2.LT** and listen timeout noise **SUCC2.LTN**. Both values can be configured in the SUC Configuration Register 2. listen timeout enables a fast cluster wakeup in case of a noise free environment, while listen timeout noise enables wakeup under more difficult conditions regarding noise interference.

In “WAKEUP_SEND” state the Communication Controller transmits the wakeup pattern on the configured channel and checks for collisions. After return from wakeup the Host has to bring the Communication Controller into “STARTUP” state by CHI command RUN.

In “WAKEUP_DETECT” state the Communication Controller attempts to identify the reason for the wakeup collision detected in “WAKEUP_SEND” state. The monitoring is bounded by the expiration of listen timeout as configured by **SUCC2.LT** in the SUC Configuration Register 2. Either the detection of a wakeup pattern indicating a wakeup attempt by another node or the reception of a Frame Header indication existing communication, causes the direct transition to “READY” state. Otherwise WAKEUP_DETECT is left after expiration of listen timeout; in this case the reason for wakeup collision is unknown.

The Host has to be aware of possible failures of the wakeup and act accordingly. It is advisable to delay any potential startup attempt of the node having instigated the wakeup by the minimal time it takes another coldstart node to become awake and to be configured.

The FlexRay™ Protocol Specification v2.1 recommends that two different Communication Controllers shall awake the two channels.

Host activities

The host must coordinate the wakeup of the two channels and must decide whether, or not, to wake a specific channel. The sending of the wakeup pattern is initiated by the Host and generated by the Communication Controller. The wakeup pattern is detected by the remote BDs and signalled to their local Hosts.

Wakeup procedure controlled by Host (single-channel wakeup):

- Configure the Communication Controller in “CONFIG” state
 - Select wakeup channel by programming bit **SUCC1.WUCS**
- Check local BDs whether a WUP was received
- Activate BD of selected wakeup channel
- Command Communication Controller to start wakeup on the configured channel by writing **SUCC1.CMD** = 0011_B
 - Communication Controller enters “WAKEUP”
 - Communication Controller returns to “READY” state and signals status of wakeup attempt to Host
- Wait predefined time to allow the other nodes to wakeup and configure themselves
- Coldstart node: wait for WUP on the other channel
 - In a dual channel cluster wait for WUP on the other channel
 - Reset coldstart inhibit flag **CCSV.CSI** by writing **SUCC1.CMD** = 1001_B (ALLOW_COLDSTART command)
- Reset Coldstart Inhibit flag **CCSV.CSI** in the CCSV register by writing **SUCC1.CMD** = 1001_B (ALLOW_COLDSTART command), coldstart node only
- Command Communication Controller to enter startup by writing **SUCC1.CMD** = 0100_B (RUN command)

Wakeup procedure triggered by BD:

- Wakeup recognized by BD
- BD triggers power-up of Host (if required)
- BD signals wakeup event to Host
- Host configures its local Communication Controller
- If necessary Host commands wakeup of second channel and waits predefined time to allow the other nodes to wakeup and configure themselves
- Host commands Communication Controller to enter “STARTUP” state by writing **SUCC1.CMD** = 0100_B (RUN command)

Wakeup pattern (WUP)

The wakeup pattern is composed of at least two wakeup symbols (WUS). Wakeup symbol and wakeup pattern are configured by the PRT Configuration Registers **PRTC1** and **PRTC2**.

- Single channel wakeup, wakeup symbol may not be sent on both channels at the same time

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- Wakeup symbol collision resilient for up to two sending nodes (two overlapping wakeup symbols still recognizable)
- Wakeup symbol must be configured identical in all nodes of a cluster
- Wakeup symbol transmit low time configured by **PRTC2.TXL**
- Wakeup symbol idle time used to listen for activity on the bus, configured by **PRTC2.TXI**
- A wakeup pattern composed of at least two Tx-wakeup symbols needed for wakeup
- Number of repetitions configurable by **PRTC1.RWP** (2 to 63 repetitions)
- Wakeup symbol receive window length configured by **PRTC1.RXW**
- Wakeup symbol receive low time configured by **PRTC2.RXL**
- Wakeup symbol receive idle time configured by **PRTC2.RXI**

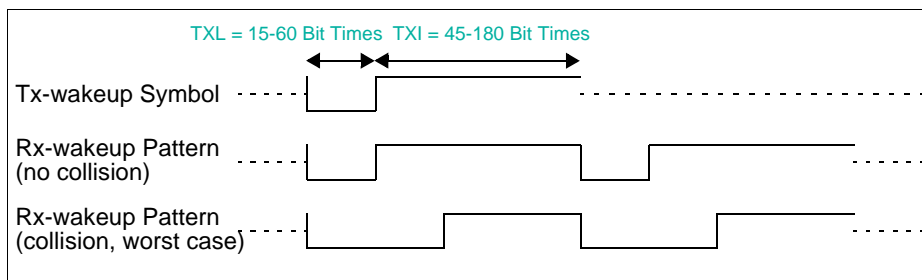


Figure 18 Timing of Wakeup Pattern

21.6.5.6 STARTUP State

The description below is intended to help configuring startup for the E-Ray IP-module. A detailed description of the startup procedure together with the respective SDL diagrams can be found in the FlexRay™ protocol specification v2.1, section 7.2.

Any node entering “STARTUP” state that has coldstart capability should assure that both channels attached have been awakened before initiating coldstart.

It cannot be assumed that all nodes and stars need the same amount of time to become completely awake and to be configured. Since at least two nodes are necessary to start up the cluster communication, it is advisable to delay any potential startup attempt of the node having instigated the wakeup by the minimal amount of time it takes another coldstart node to become awake, to be configured and to enter startup. It may require several hundred milliseconds (depending on the hardware used) before all nodes and stars are completely awakened and configured.

Startup is performed on all channels synchronously. During startup, a node only transmits startup Frames.

A fault-tolerant, distributed startup strategy is specified for initial synchronization of all nodes. In general, a node may enter “NORMAL_ACTIVE” state via (see **Figure 19**):

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- Coldstart path initiating the schedule synchronization (leading coldstart node)
- Coldstart path joining other coldstart nodes (following coldstart node)
- Integration path integrating into an existing communication schedule (all other nodes)

A coldstart attempt begins with the transmission of a collision avoidance symbol (CAS). Only a coldstart node that had transmitted the CAS transmits Frames in the first four cycles after the CAS, it is then joined firstly by the other coldstart nodes and afterwards by all other nodes.

A coldstart node has the Transmit SYNC Frame in Key Slot bits **SUCC1.TXST** and **SUCC1.TXSY** in the SUC Configuration Register 1 set to 1. The Message Buffer 0 holds the key slot ID which defines the slot number where the Startup Frame is send. In the Frame Header of the Startup Frame the Startup Frame indicator bit is set.

In clusters consisting of three or more nodes, at least three nodes shall be configured to be coldstart nodes. In clusters consisting of two nodes, both nodes must be coldstart nodes. At least two fault-free coldstart nodes are necessary for the cluster to startup.

Each Startup Frame must also be a SYNC Frame; therefore each coldstart node will also be a sync node. The number of coldstart attempts is configured by **SUCC1.CSA** in the SUC Configuration Register 1.

A non-coldstart node requires at least two startup Frames from distinct nodes for integration. It may start integration before the coldstart nodes have finished their startup. It will not finish its startup until at least two coldstart nodes have finished their startup.

Both non-coldstart nodes and coldstart nodes start passive integration via the integration path as soon as they receive SYNC Frames from which to derive the TDMA schedule information. During integration the node has to adapt its own clock to the global clock (rate and offset) and has to make its cycle time consistent with the global schedule observable at the network. Afterwards, these settings are checked for consistency with all available network nodes. The node can only leave the integration phase and actively participate in communication when these checks are passed.

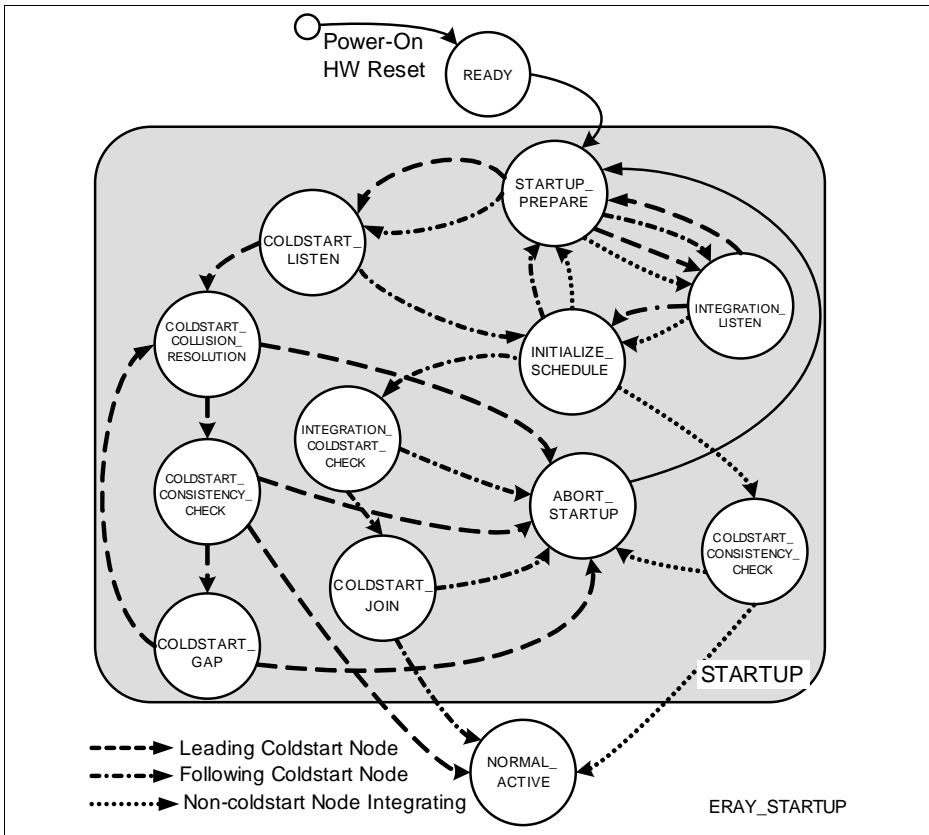


Figure 19 State Diagram Time-Triggered Startup

Coldstart Inhibit Mode

In coldstart inhibit mode the node is prevented from initializing the TDMA communication schedule. If bit **CCSV.CSI** in the Communication Controller Status Vector register is set, the node is not allowed to initialize the cluster communication, i.e. entering the coldstart path is prohibited. The node is allowed to integrate to a running cluster or to transmit startup Frames after another coldstart node started the initialization of the cluster communication.

The coldstart inhibit bit **CCSV.CSI** is set whenever the POC enters “READY” state. The bit has to be cleared under control of the Host by CHI command **ALLOW_COLDSTART** (**SUCC1.CMD** = 1001_B)

21.6.5.7 Startup Timeouts

The Communication Controller supplies two different Microtick timers supporting two timeout values, startup timeout and startup noise timeout. The two timers are reset when the Communication Controller enters the “COLDSTART_LISTEN” state. The expiration of either of these timers causes the node to leave the initial sensing phase (“COLDSTART_LISTEN” state) with the intention of starting up communication.

*Note: The startup and startup noise timers are identical with the wakeup and wakeup noise timers and use the same configuration values **SUCC2.LT** and **SUCC2.LTN** from the SUC Configuration Register 2.*

Startup Timeout

The startup timeout limits the listen time used by a node to determine if there is already communication between other nodes or at least one coldstart node actively requesting the integration of others.

The startup timer is configured by programming **SUCC2.LT** (pdListenTimeout) in the SUC Configuration Register 2.

The startup timer is restarted upon:

- Entering the “COLDSTART_LISTEN” state
- Both channels reaching idle state while in “COLDSTART_LISTEN” state

The startup timer is stopped:

- If communication channel activity is detected on one of the configured channels while the node is in the “COLDSTART_LISTEN” state
- When the “COLDSTART_LISTEN” state is left

Once the startup timeout expires, neither an overflow nor a cyclic restart of the timer is performed. The timer status is kept for further processing by the startup state machine.

Startup Noise Timeout

At the same time the startup timer is started for the first time (transition from “STARTUP_PREPARE” state to “COLDSTART_LISTEN” state), the startup noise timer is started. This additional timeout is used to improve reliability of the startup procedure in the presence of noise.

The startup noise timer is configured by programming **SUCC2.LTN** (gListenNoise - 1) in the SUC Configuration Register 2 (see “**SUC Configuration Register 2 (SUCC2)**” on [Page 97](#)).

The startup noise timeout is:

$\text{pdListenTimeout} \cdot \text{gListenNoise} = \text{SUCC2.LT} \cdot (\text{SUCC2.LTN} + 1)$

The startup noise timer is restarted upon:

- Entering the “COLDSTART_LISTEN” state
- Reception of correctly decoded Headers or CAS symbols while the node is in “COLDSTART_LISTEN” state

The startup noise timer is stopped when the “COLDSTART_LISTEN” state is left.

Once the startup noise timeout expires, neither an overflow nor a cyclic restart of the timer is performed. The status is kept for further processing by the startup state machine. Since the startup noise timer won't be restarted when random channel activity is sensed, this timeout defines the fall-back solution that guarantees that a node will try to start up the communication cluster even in the presence of noise.

21.6.5.8 Path of leading Coldstart Node (initiating coldstart)

When a coldstart node enters “COLDSTART_LISTEN”, it listens to its attached channels.

If no communication is detected, the node enters the “COLDSTART_COLLISION_RESOLUTION” state and commences a coldstart attempt. The initial transmission of a CAS symbol is succeeded by the first regular cycle. This cycle has the number zero.

From cycle zero on, the node transmits its startup Frame. Since each coldstart node is allowed to perform a coldstart attempt, it may occur that several nodes simultaneously transmit the CAS symbol and enter the coldstart path. This situation is resolved during the first four cycles after CAS transmission.

As soon as a node that initiates a coldstart attempt receives a CAS symbol or a Frame Header during these four cycles, it re-enters the “COLDSTART_LISTEN” state. Thereby, only one node remains in this path. In cycle four, other coldstart nodes begin to transmit their startup Frames.

After four cycles in “COLDSTART_COLLISION_RESOLUTION” state, the node that initiated the coldstart enters the “COLDSTART_CONSISTENCY_CHECK” state. It collects all startup Frames from cycle four and five and performs the clock correction. If the clock correction does not deliver any errors and it has received at least one valid Startup Frame pair, the node leaves “COLDSTART_CONSISTENCY_CHECK” and enters “NORMAL_ACTIVE” state.

The number of coldstart attempts that a node is allowed to perform is configured by **SUCC1.CSA** in the SUC Configuration Register 1. The number of remaining coldstarts attempts **CCSV.RCA** can be read from Communication Controller Status Vector register. The number of remaining attempts is reduced by one for each attempted coldstart. A node may enter the “COLDSTART_LISTEN” state only if this value is larger than one and it may enter the “COLDSTART_COLLISION_RESOLUTION” state only if this value is larger than zero. If the number of coldstart attempts is one, coldstart is inhibited but integration is still possible.

FlexRay™ Protocol Controller (E-Ray)**Path of following Coldstart Node (responding to leading Coldstart Node)**

When a coldstart node enters the "COLDSTART_LISTEN" state, it tries to receive a valid pair of startup Frames to derive its schedule and clock correction from the leading coldstart node.

As soon as a valid Startup Frame has been received the "INITIALIZE_SCHEDULE" state is entered. If the clock synchronization can successfully receive a matching second valid Startup Frame and can derive a schedule from this startup Frames, the "INTEGRATION_COLDSTART_CHECK" state is entered.

In "INTEGRATION_COLDSTART_CHECK" state it is assured that the clock correction can be performed correctly and that the coldstart node from which this node has initialized its schedule is still available. The node collects all SYNC Frames and performs clock correction in the following double-cycle. If clock correction does not signal any errors and if the node continues to receive sufficient Frames from the same node it has integrated on, the "COLDSTART_JOIN" state is entered.

In "COLDSTART_JOIN" state integrating coldstart nodes begin to transmit their own startup Frames. Thereby the node that initiated the coldstart and the nodes joining it can check if their schedules agree to each other. If for the following three cycles the clock correction does not signal errors and at least one other coldstart node is visible, the node leaves "COLDSTART_JOIN" state and enters "NORMAL_ACTIVE" state. Thereby it leaves "STARTUP" at least one cycle after the node that initiated the coldstart.

Path of Non-coldstart Node

When a non-coldstart node enters the INTEGRATION_LISTEN state, it listens to its attached channels and tries to receive FlexRay™ Frames.

As soon as a valid Startup Frame has been received the "INITIALIZE_SCHEDULE" state is entered. If the clock synchronization can successfully receive a matching second valid Startup Frame and derive a schedule from this, the INTEGRATION_CONSISTENCY_CHECK state is entered.

In "INTEGRATION_CONSISTENCY_CHECK" state it is verified that the clock correction can be performed correctly and that enough coldstart nodes (at least 2) send startup Frames that agree to the nodes own schedule. Clock correction is activated, and if any errors are signalled, the integration attempt is aborted.

During the first even cycle in this state, either two valid startup Frames or the Startup Frame of the node that this node has integrated on must be received; otherwise the node aborts the integration attempt.

During the first double-cycle in this state, either two valid Startup Frame pairs or the Startup Frame pair of the node that this node has integrated on must be received; otherwise the node aborts the integration attempt.

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If after the first double-cycle less than two valid startup Frames are received within an even cycle, or less than two valid Startup Frame pairs are received within a double-cycle, the startup attempt is aborted.

Nodes in this state need to see two valid Startup Frame pairs for two consecutive double-cycles each to be allowed to leave STARTUP and enter NORMAL_OPERATION. Consequently, they leave startup at least one double-cycle after the node that initiated the coldstart and only at the end of a cycle with an odd cycle number.

21.6.5.9 NORMAL_ACTIVE State

As soon as the node that transmitted the first CAS symbol (resolving the potential access conflict and entering "STARTUP" via coldstart path) and one additional node have entered the "NORMAL_ACTIVE" state, the startup phase for the cluster has finished. In the "NORMAL_ACTIVE" state, all configured messages are scheduled for transmission. This includes all Data Frames as well as the SYNC Frames. Rate and offset measurement is started in all even cycles (even/odd cycle pairs required).

In "NORMAL_ACTIVE" state the Communication Controller supports regular communication functions

- The Communication Controller performs transmissions and reception on the FlexRay™ bus as configured
- Clock synchronization is running
- The Host interface is operational

The Communication Controller exits from that state to

- "HALT" state by writing **SUCC1.CMD** = 0110_B (HALT command, at the end of the current cycle)
- "HALT" state by writing **SUCC1.CMD** = 0111_B (FREEZE command, immediately)
- "HALT" state due to change of the error state from "ACTIVE" to "COMM_HALT"
- "NORMAL_PASSIVE" state due to change of the error state from "ACTIVE" to "PASSIVE"
- "READY" state by writing **SUCC1.CMD** = 0010_B (READY command)

21.6.5.10 NORMAL_PASSIVE State

"NORMAL_PASSIVE" state is entered from "NORMAL_ACTIVE" state when the error state changes from ACTIVE (green) to PASSIVE (yellow).

In "NORMAL_PASSIVE" state, the node is able to receive all Frames (node is fully synchronized and performs clock synchronization). In comparison to the "NORMAL_ACTIVE" state the node does not actively participate in communication, i.e. neither symbols nor Frames are transmitted.

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In “NORMAL_PASSIVE” state

- The Communication Controller performs reception on the FlexRay™ bus
- The Communication Controller does not transmit any Frames or symbols on the FlexRay™ bus
- Clock synchronization is running
- The Host interface is operational

The Communication Controller exits from this state to

- “HALT” state by writing **SUCC1.CMD** = 0110_B (HALT command, at the end of the current cycle)
- “HALT” state by writing **SUCC1.CMD** = 0111_B (FREEZE command, immediately)
- “HALT” state due to change of the error state from “PASSIVE” to “COMM_HALT”
- “NORMAL_ACTIVE” state due to change of the error state from “PASSIVE” to “ACTIVE”. The transition takes place when **CCEV.PTAC** from the Communication Controller Error Vector register equals **SUCC1.PTA** - 1.
- “READY” state by writing **SUCC1.CMD** = 0010_B (READY command)

21.6.5.11 HALT State

In this state all communication (reception and transmission) is stopped.

The Communication Controller enters this state

- By writing **SUCC1.CMD** = 0110_B (HALT command) while the Communication Controller is in “NORMAL_ACTIVE” or “NORMAL_PASSIVE” state
- By writing **SUCC1.CMD** = 0111_B (FREEZE command) from all states
- When exiting from “NORMAL_ACTIVE” state because the clock correction failed counter reached the “maximum without clock correction fatal” limit
- When exiting from “NORMAL_PASSIVE” state because the clock correction failed counter reached the “maximum without clock correction fatal” limit

The Communication Controller exits from this state to “CONFIG” state

- By writing **SUCC1.CMD** = 0001_B (DEFAULT_CONFIG command)

When the Communication Controller enters “HALT” state, all configuration and status data is maintained for analyzing purposes.

When the Host writes **SUCC1.CMD** = 0110_B (HALT command) in the SUC Configuration Register 1 to 1, the Communication Controller sets bit **CCSV.HRQ** in the Communication Controller Status Vector register and enters “HALT” state after the current communication cycle has finished.

When the Host writes **SUCC1.CMD** = 0111_B (FREEZE command) in the SUC Configuration Register to 1, the Communication Controller enters “HALT” state immediately and sets the **CCSV.FSI** bit in the Communication Controller Status Vector register.

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The POC state from which the transition to HALT state took place can be read from **CCSV.PSL**.

21.6.6 Network Management

The accrued Network Management (NM) vector is located in the Network Management Register 1 to Network Management Register 3 (**NMV_x (x = 1-3)**). The Communication Controller performs a logical OR operation over all Network Management (NM) vectors out of all received valid Network Management (NM) Frames with the Payload Preamble Indicator (PPI) bit set. Only a static Frame may be configured to hold Network Management (NM) information. The Communication Controller updates the Network Management (NM) vector at the end of each cycle.

The length of the Network Management (NM) vector can be configured from 0 to 12 byte by NML in the NEM Configuration Register. The Network Management (NM) vector length must be configured identically in all nodes of a cluster.

To configure a transmit buffer to send FlexRay™ Frames with the PPI bit set, the PPIT bit in the Header Section of the respective transmit buffer has to be set via **WRHS1.PPIT**. In addition the Host has to write the Network Management (NM) information to the Data Section of the respective transmit buffer.

The evaluation of the Network Management (NM) vector has to be done by the application running on the Host.

*Note: In case a Message Buffer is configured for transmission / reception of Network Management Frames, the payload length configured in Header 2 of that Message Buffer should be equal or greater than the length of the NM Vector configured by **NEMC.NML**.*

When the Communication Controller transits to "HALT" state, the cycle count is not incremented and therefore the NM Vector is not updated. In this case NMV1 to NMV3 holds the value from the cycle before.

21.6.7 Filtering and Masking

Filtering is done by checking specific fields in a received Frame against the corresponding configuration constants of the valid Message Buffers and the actual slot and cycle counter values (acceptance filtering), or by comparing the configuration constants of the valid Message Buffers against the actual slot and cycle counter values (transmit filtering). A Message Buffer is only updated / transmitted if the required matches occur.

Filtering is done on the following fields:

- Channel ID
- Frame ID
- Cycle Counter

The following filter combinations for acceptance / transmit filtering are allowed:

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- Frame ID + Channel ID
- Frame ID + Channel ID + Cycle Counter

In order to store a received message in a Message Buffer all configured filters must match.

Note: For the FIFO the acceptance filter is configured by the FIFO Rejection Filter and the FIFO Rejection Filter Mask.

A message will be transmitted in the time slot corresponding to the configured Frame ID on the configured channel(s). If cycle counter filtering is enabled the configured cycle filter value must also match.

21.6.7.1 Frame ID Filtering

Every transmit and receive buffer contains a Frame ID stored in the Header Section. This Frame ID is used differently for receive and transmit buffers.

Receive Buffers

A received message is stored in the first receive buffer where the received Frame ID matches the configured Frame ID, provided channel ID and cycle counter criteria are also met.

Transmit Buffers

For transmit buffers the configured Frame ID is used to determine the appropriate slot for message transmission. The Frame will be transmitted in the time slot corresponding to the configured Frame ID, provided channel ID and cycle counter criteria are also met.

21.6.7.2 Channel ID Filtering

There is a 2-bit channel filtering field (CHA, CHB) located in the Header Section of each Message Buffer in the Message RAM. It serves as a filter for receive buffers, and as a control field for transmit buffers (see [Table 54](#)).

Table 54 Channel Filtering Configuration

CHA	CHB	Transmit Buffer transmit Frame	Receive Buffer store valid receive Frame
1	1	on both channels (static segment only)	received on channel A or B (store first semantically valid Frame, static segment only)
1	0	on channel A	received on channel A
0	1	on channel B	received on channel B
0	0	no transmission	ignore Frame

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Note: If a Message Buffer is configured for the dynamic segment and both bits of the channel filtering field are set to 1, no Frames are transmitted resp. received Frames are ignored (same function as CHA = CHB = 0)

Receive Buffers

Valid received Frames are stored if they are received on the channels specified in the channel filtering field. Only in static segment a receive buffer may be setup for reception on both channels (CHA and CHB set). Other filtering criteria must also be met.

If a valid Header Segment was stored, the respective MBC flag in the Message Buffer Status Changed register is set. If a valid Payload Segment was stored, the respective **NDn (n = 0-31)** to **NDn (n = 96-127)** flag in the New Data **NDAT1** to **NDAT4** register is set. In both cases, if bit **RDHS1.MBI** in the Header Section of the respective Message Buffer is set, the RXI flag in the Status Service Request Register is set to 1. If enabled an service request is generated.

Transmit Buffers

The content of the buffer is transmitted only on the channels specified in the channel filtering field when the Frame ID filtering and cycle counter filtering criteria are also met. Only in static segment a transmit buffer may be setup for transmission on both channels (CHA and CHB set). After transmission has completed, and if bit **WRHS1.MBI** in the Header Section of the respective Message Buffer is set, the TXI flag in the Status Service Request Register is set to 1. If enabled an service request is generated.

21.6.7.3 Cycle Counter Filtering

Cycle counter filtering is based on the notion of a cycle set. For filtering purposes, a match is detected if any one of the elements of the cycle set is matched. The cycle set is defined by the cycle code field in the Header Section of each Message Buffer.

If Message Buffer 0 is configured to hold the startup / SYNC Frame or the single slot Frame by bits TXST, TXSY, and TSM in the SUC Configuration Register 1, cycle counter filtering for Message Buffer 0 should be disabled.

*Note: Sharing of a static time slot via cycle counter filtering between different nodes of a FlexRay™ network is **not** allowed.*

The set of cycle numbers belonging to a cycle set is determined as described in [Table 55](#).

Table 55 **Definition of Cycle Set**

Cycle Code	Matching Cycle Counter Values		
000000x _B	all Cycles		
000001c _B	every second Cycle	at (Cycle Count)mod2	= c
00001cc _B	every fourth Cycle	at (Cycle Count)mod4	= cc
0001ccc _B	every eighth Cycle	at (Cycle Count)mod8	= ccc
001cccc _B	every sixteenth Cycle	at (Cycle Count)mod16	= cccc
01ccccc _B	every thirty-second Cycle	at (Cycle Count)mod32	= cccccc
1cccccc _B	every sixty-fourth Cycle	at (Cycle Count)mod64	= ccccccc

Table 56 below gives some examples for valid cycle sets to be used for cycle counter filtering:

Table 56 **Examples for Valid Cycle Sets**

Cycle Code	Matching Cycle Counter Values
0000011 _B	1-3-5-7--63 ↓
0000100 _B	0-4-8-12--60 ↓
0001110 _B	6-14-22-30--62 ↓
0011000 _B	8-24-40-56 ↓
0100011 _B	3-35 ↓
1001001 _B	9 ↓

Receive Buffers

The received message is stored only if the received cycle counter matches an element of the receive buffer's cycle set. Channel ID and Frame ID criteria must also be met.

Transmit Buffers

The content of the buffer is transmitted on the configured channels when an element of the cycle set matches the current cycle counter value and the Frame ID matches the slot counter value.

21.6.7.4 FIFO Filtering

For FIFO filtering there is one rejection filter and one rejection filter mask available. The FIFO rejection filter consists of 20 bits for **Channel** (2 bits), **Frame ID** (11 bits), and **Cycle Code** (7 bits). Rejection filter and rejection filter mask can be configured in

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DEFAULT_CONGIF or "CONFIG" state only. The filter configuration in the Header Sections of Message Buffers belonging to the FIFO is ignored.

A valid received Frame is stored in the FIFO if channel ID, Frame ID, and cycle counter are not rejected by the configured rejection filter and rejection filter mask, and if there is no matching dedicated receive buffer.

21.6.8 Transmit Process

The transmit process is described in the following sections.

21.6.8.1 Static Segment

For the static segment, if there are several messages pending for transmission, the message with the Frame ID corresponding to the next sending slot is selected for transmission.

The Data Section of transmit buffers assigned to the static segment can be updated until the end of the preceding time slot. This means that a transfer from the Input Buffer has to be started by writing to the Input Buffer Command Request register latest at this time.

21.6.8.2 Dynamic Segment

In the dynamic segment, if several messages are pending, the message with the highest priority (lowest Frame ID) is selected next. Only Frame ID's which are higher than the largest static Frame ID are allowed for the dynamic segment.

In the dynamic segment different slot counter sequences are possible (concurrent sending of different Frame ID's on both channels). Therefore pending messages are selected according to their Frame ID and their channel configuration bit.

The Data Section of transmit buffers assigned to the dynamic segment can be updated until the end of the preceding slot. This means that a transfer from the Input Buffer has to be started by writing to the Input Buffer Command Request register latest at this time.

The start of latest transmit configured by SLT in the MHD Configuration Register 1 defines the maximum minislot value allowed before inhibiting new Frame transmission in the dynamic segment of the current cycle.

21.6.8.3 Transmit Buffers

A portion of the E-Ray Message Buffers can be configured as transmit buffers by programming bit CFG in the Header Section of the respective Message Buffer to 1. This can be done via the Write Header Section 1 register.

There exist the following possibilities to assign a transmit buffer to the Communication Controller channels:

- Static segment: channel A **or** channel B, channel A **and** channel B

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- Dynamic segment: channel A **or** channel B

Message Buffer 0 is dedicated to hold the startup Frame, the SYNC Frame, or the designated single slot Frame as configured by TXST, TXY, and TSM in the SUC Configuration Register 1. In this case it can be reconfigured in “DEFAULT_CONFIG” or “CONFIG” state only. This ensures that any node transmits at most one startup / SYNC Frame per communication cycle. Transmission of startup / SYNC Frames from other Message Buffers is not possible.

All other Message Buffers configured for transmission in static or dynamic segment are reconfigurable during runtime. Due to the organization of the Data Partition in the Message RAM (reference by data pointer), reconfiguration of the configured payload length and the data pointer in the Header Section of a Message Buffer may lead to erroneous configurations. If a Message Buffer is reconfigured during runtime it may happen that this Message Buffer is not send out in the respective communication cycle.

The Communication Controller does not have the capability to calculate the Header CRC. The Host is supposed to provide the Header CRCs for all transmit buffers. If Network Management is required the Host has to set the PPIT bit in the Header Section of the respective Message Buffer to 1 and write the Network Management information to the Data Section of the Message Buffer (see [Section 21.6.6](#)).

The payload length field configures the data payload length in 2-byte words. If the configured payload length of a static transmit buffer is shorter than the payload length configured for the static segment by SFDL in the Message Handler Configuration Register 1, the Communication Controller generates padding byte to ensure that Frames have proper physical length. The padding pattern is logical zero.

Each transmit buffer provides a transmission mode flag TXM that allows the Host to configure the transmission mode for the transmit buffer in the static segment. If this bit is set, the transmitter operates in the single-shot mode. If this bit is cleared, the transmitter operates in the continuous mode. In dynamic segment the transmitter always works in single-shot mode.

If a Message Buffer is configured in the continuous mode, the Communication Controller does not reset the transmission request flag TXR after successful transmission. In this case a Frame is sent out each time the Frame ID and cycle counter filter match. The TXR flag can be reset by the Host by writing the respective Message Buffer number to the Input Buffer Command Request register while bit **STXRH** in the Input Buffer Command Mask register is reset to 0.

If two or more transmit buffers are configured with the same Frame ID **and** cycle counter filter value, the transmit buffer with the lowest Message Buffer number will be transmitted in the respective slot.

21.6.8.4 Frame Transmission

To prepare a transmit buffer for transmission the following steps are required:

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- Configure the Message Buffer as transmit buffer by writing bit CFG = 1 in the Write Header Section 1 register
- Write transmit message (Header and Data Section) to the Input Buffer.
- To transfer a transmit message from Input Buffer to the Message RAM proceed as described on **“Data Transfer from Input Buffer to Message RAM” on Page 234**.
- If configured in the Input Buffer Command Mask register the Transmission Request flag for the respective Message Buffer will be set as soon as the transfer has completed, and the Message Buffer is ready for transmission.
- Check whether the Message Buffer has been transmitted by checking the TXR bits (TXR = 0) in the Transmission Request 1,2 registers (single-shot mode only).

In single-shot mode the Communication Controller resets the TXR flag after transmission has been completed. Now the Host may update the transmit buffer with the next message. The Communication Controller does not transmit the message before the Host has indicated that the update is completed by setting the Transmission Request flag TXR again. The Host can check the actual state of the TXR flags of all Message Buffers by reading the Transmission Request registers. After successful transmission, if bit **WRHS1.MBI** in the Header Section of the respective Message Buffer is set, the transmit service request flag in the Status Service Request Register is set (TXI = 1). If enabled an service request is generated.

21.6.8.5 NULL Frame Transmission

If in static segment the Host does not set the transmission request flag before transmit time, and if there is no other transmit buffer with matching filter criteria (matching Frame ID and cycle counter filter), the Communication Controller transmits a NULL Frame with the NULL Frame indication bit reset to 0 and the payload data reset to zero.

In the following cases the Communication Controller transmits a NULL Frame with the NULL Frame indication bit reset to 0, and the rest of the Frame Header and the Frame length unchanged (payload data is reset to zero):

- All transmit buffers configured for the slot have cycle counter filters that do not match the current cycle
- There are matching Frame ID's and cycle counter filters, but none of these transmit buffers has the transmission request flag TXR set

NULL Frames are not transmitted in the dynamic segment.

21.6.9 Receive Process

The receive process is described in the following sections.

21.6.9.1 Frame Reception

To prepare or change a Message Buffer for reception the following steps are required:

- Configure the Message Buffer as receive buffer by writing bit CFG = 0 in the Write Header Section 1 register
- Configure the receive buffer by writing the configuration data (Header Section) to the Input Buffer
- Transfer the configuration from Input Buffer to the Message RAM by writing the number of the target Message Buffer to the Input Buffer Command Request register.

Once these steps are performed, the Message Buffer functions as an active receive buffer and participates in the internal acceptance filtering process, which takes place every time the Communication Controller receives a message. The first matching receive buffer is updated from the received message. If the Message Buffer holds an unprocessed Data Section (ND = 1) it is overwritten with the new message and the MLST bit in the respective Message Buffer Status register is set.

If the payload length of a received Frame PLC is longer than the value programmed by PLC in the Header Section of the respective Message Buffer, the data field stored in the Message Buffer is truncated to that length.

If no Frame, a NULL Frame, or a corrupted Frame is received in a slot, the Data Section of the Message Buffer configured for this slot is not updated. In this case only the flags in the Message Buffer Status register are updated to signal the cause of the problem. In addition the respective MBC flag in the Message Buffer Status Changed 1,2,3,4 registers is set.

When the Data Section of a receive buffer has been updated from a received Frame, the respective New Data **NDn (n = 0-31)** to **NDn (n = 96-127)** flag in the New Data **NDAT1** to **NDAT4** registers is set. When the Message Handler has updated the Message Buffer status, the respective MBC flag in the Message Buffer Status Changed 1,2,3,4 registers is set. If bit **RDHS1.MBI** in the Header Section of the respective Message Buffer is set, the receive service request flag in the Status Service Request Register is set (RXI = 1). If enabled an service request is generated.

To read a receive buffer from the Message RAM via the Output Buffer proceed as described on **“Data Transfer from Message RAM to Output Buffer” on Page 236**.

Note: The ND and MBC flags are automatically cleared by the Message Handler when the received message has been transferred to the Output Buffer.

21.6.9.2 NULL Frame reception

The Payload Segment of a received NULL Frame is **not** copied into the matching receive buffer. If a NULL Frame has been received, the Header Section of the matching Message Buffer is updated from the received NULL Frame. The NULL Frame indication bit in the Header Section 3 of the respective Message Buffer is reset (NFI = 0) and the respective MBC flag in the Message Buffer Status Changed 1,2,3,4 registers is set.

In case that bit ND and / or MBC were already set before this event because the Host did not read the last received message, bit MLST in the Message Buffer Status register of the respective Message Buffer is also set.

21.6.10 FIFO Function

A group of the Message Buffers can be configured as a cyclic First-In-First-Out (FIFO). The group of Message Buffers belonging to the FIFO is contiguous in the register map starting with the Message Buffer referenced by FFB and ending with the Message Buffer referenced by LCB in the Message RAM Configuration register. Up to 128 Message Buffers can be assigned to the FIFO.

21.6.10.1 Description

Every valid incoming message not matching with any dedicated receive buffer but passing the programmable FIFO filter is stored into the FIFO. In this case Frame ID, payload length, receive cycle count, and the status bits of the addressed FIFO Message Buffer are overwritten with Frame ID, payload length, receive cycle count, and the status from the received message and can be read by the Host for message identification. Bit RFNE in the Status Service Request Register shows that the FIFO is not empty, bit RFF in the Status Service Request Register is set when the last available Message Buffer belonging to the FIFO is written, bit RFO in the Error Service Request Register shows that a FIFO overrun has been detected. If enabled, service requests are generated.

There are two index registers associated with the FIFO. The PUT Index Register (PIDX) is an index to the next available location in the FIFO. When a new message has been received it is written into the Message Buffer addressed by the PIDX register. The PIDX register is then incremented and addresses the next available Message Buffer. If the PIDX register is incremented past the highest numbered Message Buffer of the FIFO, the PIDX register is loaded with the number of the first (lowest numbered) Message Buffer in the FIFO chain. The GET Index Register (GIDX) is used to address the next Message Buffer of the FIFO to be read. The GIDX register is incremented after transfer of the contents of a Message Buffer belonging to the FIFO to the Output Buffer. The PUT Index Register and the GET Index Register are not accessible by the Host.

The FIFO is completely filled when the PUT index (PIDX) reaches the value of the GET index (GIDX). When the next message is written to the FIFO before the oldest message has been read, both PUT index and GET index are incremented and the new message

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overwrites the oldest message in the FIFO. This will set FIFO overrun flag RFO in the Error Service Request Register.

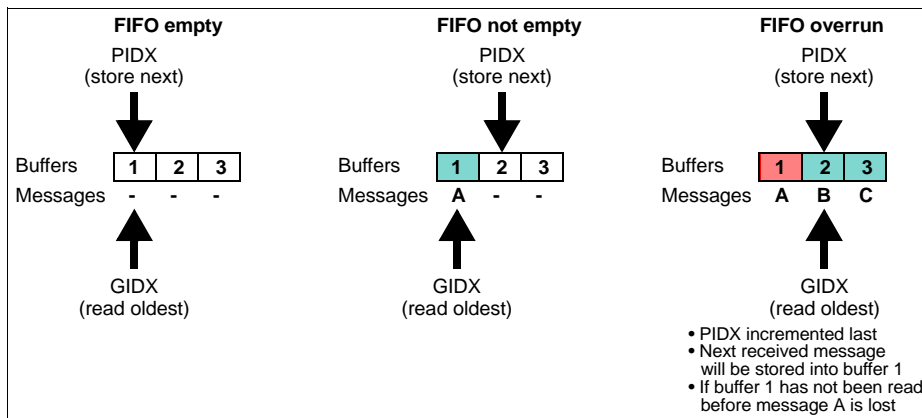


Figure 20 FIFO Status: Empty, Not Empty, Overrun

A FIFO non empty status is detected when the PUT index (PIDX) differs from the GET index (GIDX). In this case flag RFNE is set. This indicates that there is at least one received message in the FIFO. The FIFO empty, FIFO not empty, and the FIFO overrun states are explained in [Figure 20](#) for a three Message Buffer FIFO.

There is a programmable FIFO rejection filter for the FIFO. The FIFO Rejection Filter register (FRF) defines a filter pattern for messages to be rejected. The FIFO rejection filter consists of channel filter, Frame ID filter, and cycle counter filter. If bit RSS is set to 1 (default), all messages received in the static segment are rejected by the FIFO. If bit RNF is set to 1 (default), received NULL Frames are not stored in the FIFO.

The FIFO Rejection Filter Mask register (FRFM) specifies which bits of the Frame ID filter in the FIFO Rejection Filter register are marked “don’t care” for rejection filtering.

21.6.10.2 Configuration of the FIFO

For all Message Buffers belonging to the FIFO the data pointer to the first 32-bit word of the Data Section of the respective Message Buffer in the Message RAM has to be configured via the Write Header Section 3 register. All information required for acceptance filtering is taken from the FIFO rejection filter and the FIFO rejection filter mask and needs not be configured in the Header Sections of the Message Buffers belonging to the FIFO.

When programming the data pointers for the Message Buffers belonging to the FIFO, the payload length of all Message Buffers should be programmed to the same value.

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*Note: It is recommended to program the MBI bits of the Message Buffers belonging to the FIFO to 0 via **WRHS1.MBI** to avoid generation of RX interrupts.*

*If the payload length of a received Frame is longer than the value programmed by **WRHS2.PLC** in the Header Section of the respective Message Buffer, the data field stored in a Message Buffer of the FIFO is truncated to that length.*

21.6.10.3 Access to the FIFO

To read from the FIFO the Host has to trigger a transfer from the Message RAM to the Output Buffer by writing the number of the first Message Buffer of the FIFO (referenced by FFB) to the Output Buffer Command Request register. The Message Handler then transfers the Message Buffer addressed by the GET Index Register (GIDX) to the Output Buffer. After this transfer the GET Index Register (GIDX) is incremented.

21.6.11 Message Handling

The Message Handler controls data transfers between the Input / Output Buffer and the Message RAM and between the Message RAM and the two Transient Buffer RAMs. All accesses to the internal RAM's are 32 bit accesses.

Access to the Message Buffers stored in the Message RAM is done under control of the Message Handler state machine. This avoids conflicts between accesses of the two protocol controllers and the Host to the Message RAM.

Frame IDs of Message Buffers assigned to the static segment have to be in the range from 1 to NSS as configured in the GTU Configuration Register 7. Frame IDs of Message Buffers assigned to the dynamic segment have to be in the range from NSS + 1 to 2047.

Received messages with no matching dedicated receive buffer (static or dynamic segment) are stored in the receive FIFO (if configured) if they pass the FIFO rejection filter.

21.6.11.1 Host access to Message RAM

The message transfer between Input Buffer and Message RAM as well as between Message RAM and Output Buffer is triggered by the Host by writing the number of the target / source Message Buffer to be accessed to the Input or Output Buffer Command Request register.

The Input / Output Buffer Command Mask registers can be used to write / read Header and Data Section of the selected Message Buffer separately. If bit **STXRS** in the Input Buffer Command Mask register is set (**STXRS** = 1), the transmission request flag TXR of the selected Message Buffer is automatically set after the Message Buffer has been updated.

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If bit **STXRS** in the Input Buffer Command Mask register is reset (**STXRS** = 0), the transmission request flag TXR of the selected Message Buffer is reset. This can be used to stop transmission from Message Buffers operated in continuous mode.

Input Buffer (IBF) and the Output Buffer (OBF) are build up as a double buffer structure. One half of this double buffer structure is accessible by the Host (IBF Host / OBF Host), while the other half (IBF Shadow / OBF Shadow) is accessed by the Message Handler for data transfers between IBF / OBF and Message RAM.

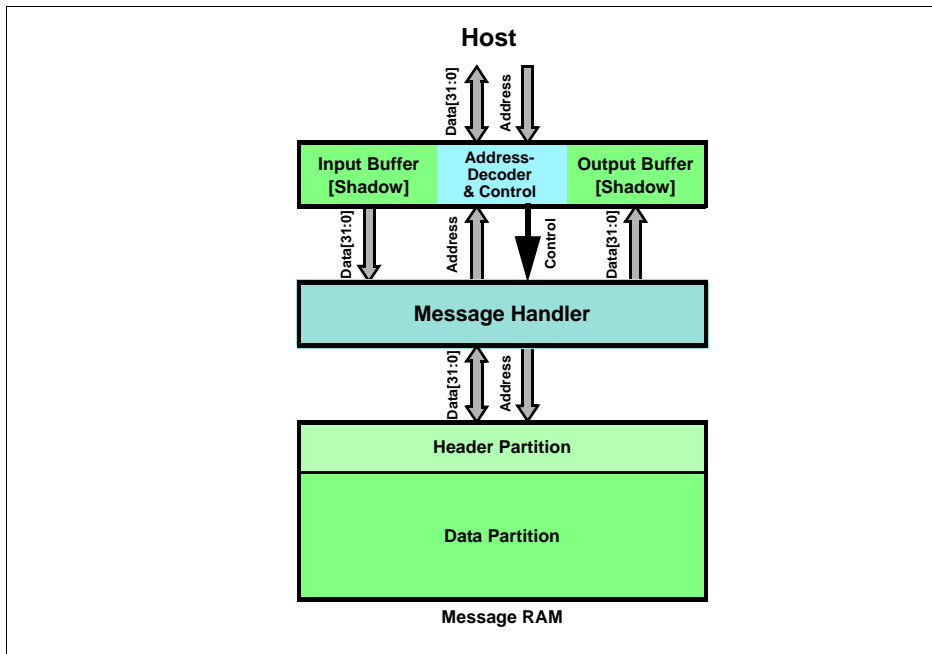


Figure 21 Host Access to Message RAM

Data Transfer from Input Buffer to Message RAM

To configure / update a Message Buffer in the Message RAM, the Host has to write the data to **WRDSnn (nn = 01-64)** and the Header to **WRHS1**, **WRHS2**, **WRHS3**. Two sets of **WRDSnn (nn = 01-64)** are available in parallel and selected by **CUST1.IBF1PAG** and **CUST1.IBF2PAG**. **CUST1.IBFS** shows which Input Buffer is currently used as Input Shadow Buffer and which as Input Host Buffer. **WRHS1**, **WRHS2**, and **WRHS3** does only exist once. The specific action is selected by configuring the Input Buffer Command Mask **IBCM**.

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When the Host writes the number of the target Message Buffer in the Message RAM to IBRH in the Input Buffer Command Request register **IBCR**, IBF Host and IBF Shadow are swapped (see **Figure 22**).

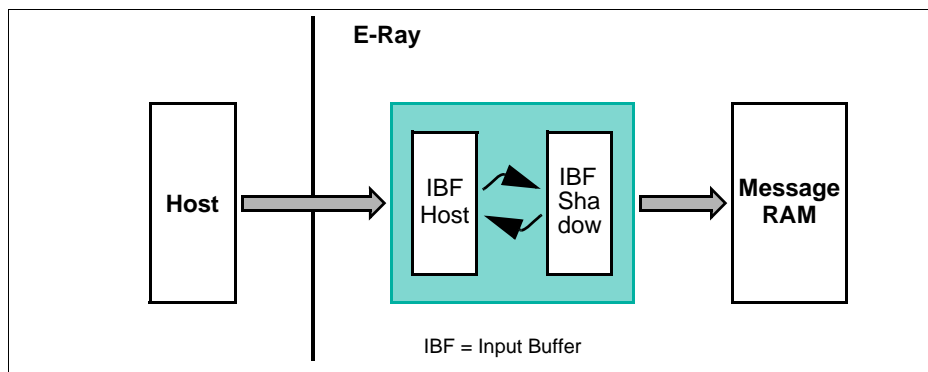


Figure 22 Double Buffer Structure Input Buffer

In addition the bits in the Input Buffer Command Mask and Input Buffer Command Request registers are also swapped to keep them attached to the respective IBF section (see **Figure 23**).

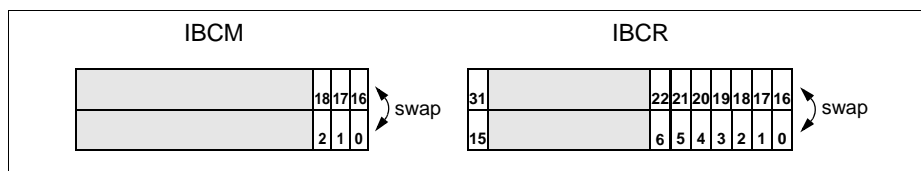


Figure 23 Swapping of IBCM and IBCR Bit

With this write operation the IBSYS bit in the Input Buffer Command Request register is set to 1. The Message Handler then starts to transfer the contents of IBF Shadow to the Message Buffer in the Message RAM selected by IBRS.

While the Message Handler transfers the data from IBF Shadow to the target Message Buffer in the Message RAM, the Host may write the next message to IBF Host. After the transfer between IBF Shadow and the Message RAM has completed, the IBSYS bit is set back to 0 and the next transfer to the Message RAM may be started by the Host by writing the respective target Message Buffer number to IBRH in the Input Buffer Command Request register.

If a write access to IBRH occurs while IBSYS is 1, IBSYH is set to 1. After completion of the ongoing data transfer from IBF Shadow to the Message RAM, IBF Host and IBF Shadow are swapped, IBSYH is reset to 0, IBSYS remains set to 1, and the next transfer

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to the Message RAM is started. In addition the Message Buffer numbers stored under IBRH and IBRS and the Command Mask flags are also swapped.

Table 57 Assignment of Input Buffer Command Mask Bit

Pos.	Access	Bit	Function
18	rh	STXRS	Set Transmission Request Shadow
17	rh	LDSS	Load Data Section Shadow
16	rh	LHSS	Load Header Section Shadow
2	rw	STXRH	Set Transmission Request Host
1	rw	LDSH	Load Data Section Host
0	rw	LHSH	Load Header Section Host

Table 58 Assignment of Input Buffer Command Request Bit

Pos.	Access	Bit	Function
31	rh	IBSYS	IBF Busy Shadow , signals ongoing transfer from IBF Shadow to Message RAM
21–16	rh	IBRS	IBF Request Shadow , number of Message Buffer currently / last updated
15	rh	IBSYH	IBF Busy Host , transfer request pending for Message Buffer referenced by IBRH
5-0	rwh	IBRH	IBF Request Host , number of Message Buffer to be updated next

Data Transfer from Message RAM to Output Buffer

To read a Message Buffer from the Message RAM, the Host has to write to Command Request register **OBCR** to trigger the data transfer as configured in Output Buffer Command Mask **OBCM** register. After the transfer has completed, the Host can read the transferred data from **RDDSnn (nn = 01-64)**, **RDHS1**, **RDHS2**, **RDHS2**, and **MBS**.

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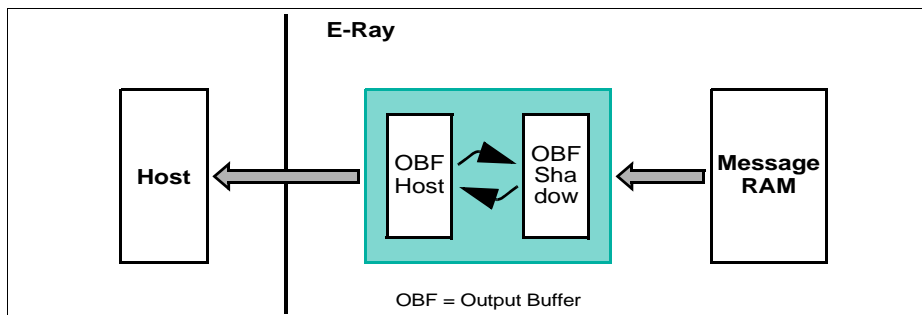


Figure 24 Double Buffer Structure Output Buffer

OBF Host and OBF Shadow as well as bits **OBCM.RHSS**, **OBCM.RDSS**, **OBCM.RHSH**, **OBCM.RDSH** and bits **OBCR.OBRS**, **OBCR.OBRH** are swapped under control of bits **OBCR.VIEW** and **OBCR.REQ**.

Writing bit **OBCR.REQ** to 1 copies bits **OBCM.RHSS**, **OBCM.RDSS** and bits **OBCR.OBRS** to an internal storage (see [Figure 25](#)).

After setting **OBCR.REQ** to 1, **OBCR.OBSYS** is set to 1, and the transfer of the Message Buffer selected by **OBCR.OBRS** from the Message RAM to OBF Shadow is started. After the transfer between the Message RAM and OBF Shadow has completed, the **OBCR.OBSYS** bit is set back to 0. Bits **OBCR.REQ** and **OBCR.VIEW** can only be set to 1 while **OBCR.OBSYS** is 0.

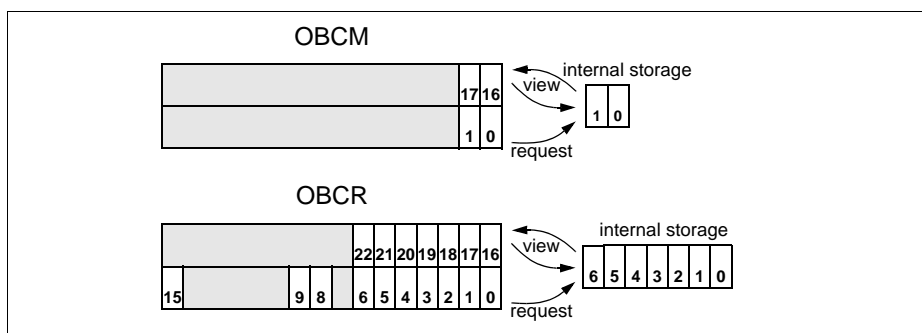


Figure 25 Swapping of OBCM and OBCR Bit

OBF Host and OBF Shadow are swapped by setting bit **OBCR.VIEW** to 1 while bit **OBCR.OBSYS** is 0 (see [Figure 24](#)).

In addition bits **OBCR.OBRH** and bits **OBCM.RHSH**, **OBCM.RDSH** are swapped with the registers internal storage thus assuring that the Message Buffer number stored in

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OBCR.OBRH and the mask configuration stored in **OBCM.RHSH**, **OBCM.RDSH** matches the transferred data stored in OBF Host (see **Figure 25**).

Now the Host can read the transferred Message Buffer from OBF Host while the Message Handler may transfer the next message from the Message RAM to OBF Shadow.

Table 59 Assignment of Output Buffer Command Mask Bit

Pos.	Access	Bit	Function
17	rh	RDSH	Data Section available for Host access
16	rh	RHSH	Header Section available for Host access
1	rw	RDSS	Read Data Section Shadow
0	rw	RHSS	Read Header Section Shadow

Table 60 Assignment of Output Buffer Command Request Bit

Pos.	Access	Bit	Function
22–16	rh	OBRH	OBF Request Host , number of Message Buffer available for Host access
15	rh	OBSYS	OBF Busy Shadow , signals ongoing transfer from Message RAM to OBF Shadow
9	rw	REQ	Request Transfer from Message RAM to OBF Shadow
8	rwh	VIEW	View OBF Shadow, swap OBF Shadow, and OBF Host
6–0	rwh	OBRs	OBF Request Shadow , number of Message Buffer for next request

21.6.11.2 Data Transfers between IBF / OBF and Message RAM

This document uses the following terms and abbreviations:

Table 61 Terms and Abbreviations

Term	Meaning
MHD	Message Handler
IBF	Input Buffer 1 or 2 RAM
OBF	Output Buffer 1 or 2 RAM
MBF	Message Buffer RAM
TBF	Transient Buffer RAM Channel A (TBF1) or Channel B (TBF2)

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Table 61 Terms and Abbreviations (cont'd)

IBF \Rightarrow MBF	Transfer from IBF to MBF
MBF \Rightarrow OBF	Transfer from MBF to OBF
MBF \Rightarrow TBF	Transfer from MBF to TBF
TBF \Rightarrow MBF	Transfer from TBF to MBF
SS	Slot Status
SS \Rightarrow MBF	Transfer SS to MBF

Message Handler functionality

The MHD controls the access to the MBF. It manages data-transfer between MBF and IBF, OBF, TBF1, TBF2. The data-path are shown in Figure 26.

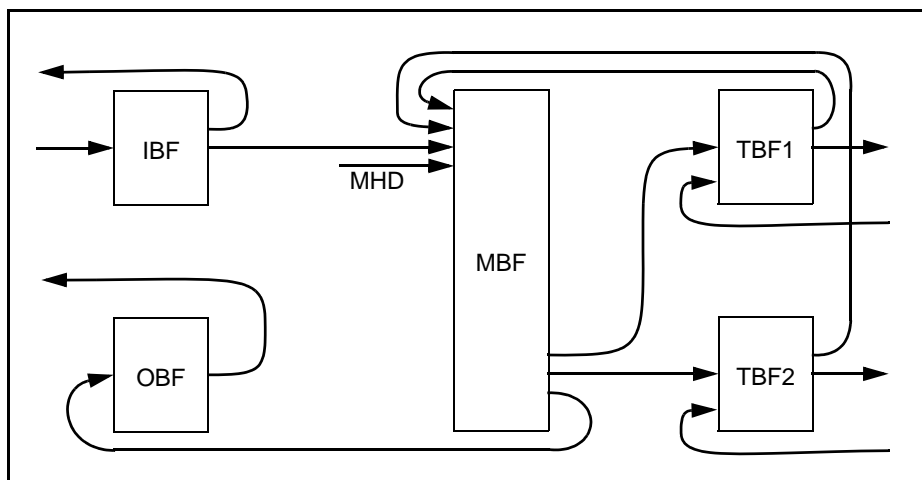


Figure 26 Interconnection of RAMs

Furthermore a search-algorithm allows to find the next valid message object in the MBF for transmission or reception.

Each transfer consists of a setup-time, four time steps to transfer the Header-section and a payload-length-dependent number of time steps to transfer the data-section. The internal data-busses have a width of 32 bits. Thereby it is possible to transfer two 2-byte words in one time step. If the payload consists of an odd number of 2-byte words the last time step of the data-section contains only 16 bit of valid data. If the Payload-Length (PL) is e.g. 7, the data-section consists of 4 time steps.

The maximum length for the data-section is 64 time steps, the minimum length is zero time steps.

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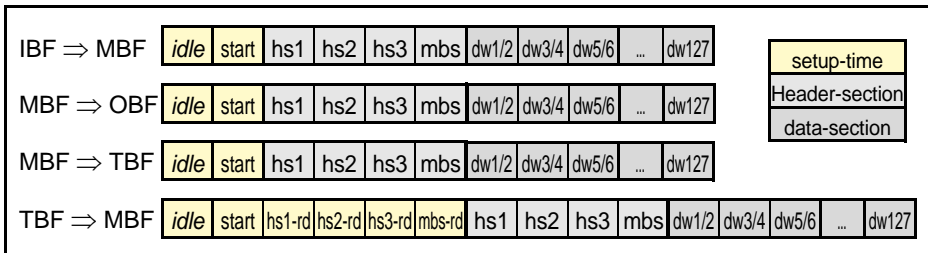


Figure 27 Different Possible Buffer Transfers

The update of the Slot-Status consists of a setup-time and one time-step to write the new Slot-Status.

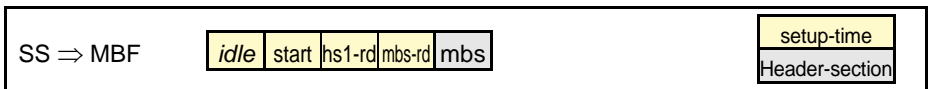


Figure 28 Update of Slot Status

The length of a time step depends on the number of concurrent tasks.

The following concurrent tasks are executed under control of the Message Handler:

- Data transfer between IBF or OBF and MBF
- Data transfer between TBF1 and MBF, search next TX / RX Message Buffer CHA
- Data transfer between TBF2 and MBF, search next TX / RX Message Buffer CHB

Thereby the time step length can vary between one and three $f_{\text{CLC_ERAY}}$ periods.

Under certain conditions it is possible that a transfer is stopped or interrupted for a number of time steps until it is continued.

When a IBF \Rightarrow MBF is started short after a TBF \Rightarrow MBF or SS \Rightarrow MBF the transfer from IBF has to wait until the setup-time of the internal transfer has finished (see Figure 29)

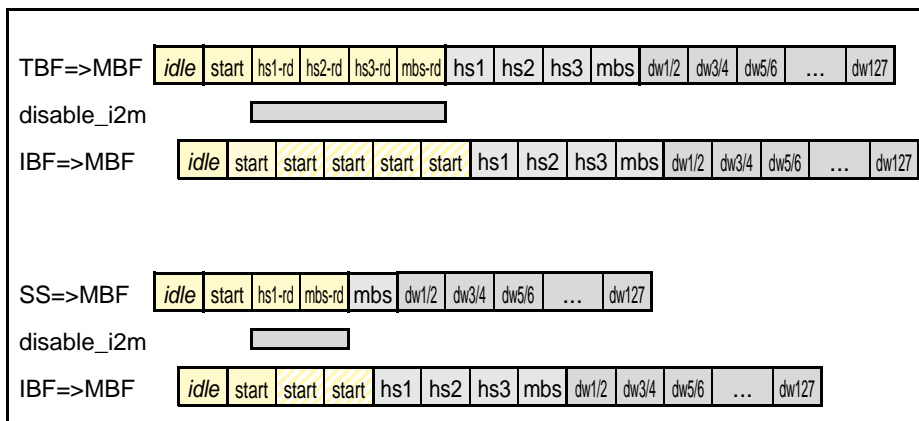


Figure 29 Delay start of IBF⇒MBF

The internal signal “disable_i2m” is always active when the TBF ⇒ MBF is in state “hs1-rd”, “hs2-rd”, “hs3-rd” or “mbs-rd” and when the SS ⇒ MBF is in state “hs1-rd” or “mbs-rd”.

The IBF ⇒ MBF is hold in state “start” until the internal signal “disable_i2m” gets inactive.

These additional time-steps are independent of any address-counter-values. This means, the IBF ⇒ MBF has to wait even if it writes to another buffer than the internal transfer.

Multiple requests of transfers between IBF/OBF and Message RAM

The time required to transfer the contents of a Message Buffer between IBF / OBF and Message RAM depends on the number of 4-byte words to be transferred, the number of concurrent tasks to be managed by the Message Handler, and in special cases the type and address range of the internal transfer. The number of 4-byte words varies from 4 (Header Section only) to 68 (Header + maximum Data Section) plus a short setup time to start the first transfer, while the number of concurrent task varies from one to three. The 4 Header words have to be included in calculation even if only the Data Section is requested for transfer.

The following concurrent tasks are executed under control of the Message Handler:

- Data transfer between IBF or OBF and MBF
- Data transfer between TBF1 and MBF, search next TX / RX Message Buffer CHA
- Data transfer between TBF2 and MBF, search next TX / RX Message Buffer CHB

Transfers between IBF and MBF respectively MBF and OBF can only be handled one after another. In case that e.g. a IBF ⇒ MBF has been started shortly before a

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MBF \Rightarrow OBF is requested, the MBF \Rightarrow OBF has to wait until the IBF \Rightarrow MBF has completed.

In case that e.g. a second IBF \Rightarrow MBF is requested, a MBF \Rightarrow OBF is requested and a IBF \Rightarrow MBF is ongoing, the MBF \Rightarrow OBF has to wait until the first IBF \Rightarrow MBF has completed. The second IBF \Rightarrow MBF has to wait until the MBF \Rightarrow OBF has completed (see figure 30) independent whether MBF \Rightarrow OBF or second IBF \Rightarrow MBF is requested first.

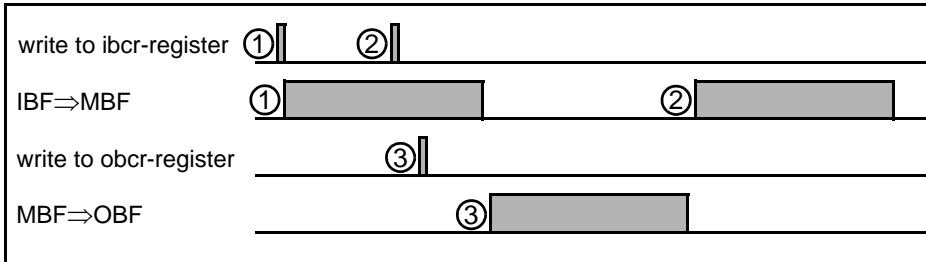


Figure 30 Multiple IBF/OBF Request

Worst case for single request

When a message with a large payload length is received the TBF \Rightarrow MBF is started at the begin of the next slot (n+1). If the next slot is a dynamic slot without transmission/reception (minislot), it may happen that the TBF \Rightarrow MBF has not finished until begin of the next but one slot (n+2). In this case the TBF \Rightarrow MBF will be service requested (break) to start a transmission in the next but one slot (MBF \Rightarrow TBF) and/or to update the slot status (SS \Rightarrow MBF) for the RX-buffer corresponding with next slot (n+1). After this interruption the TBF \Rightarrow MBF is continued.

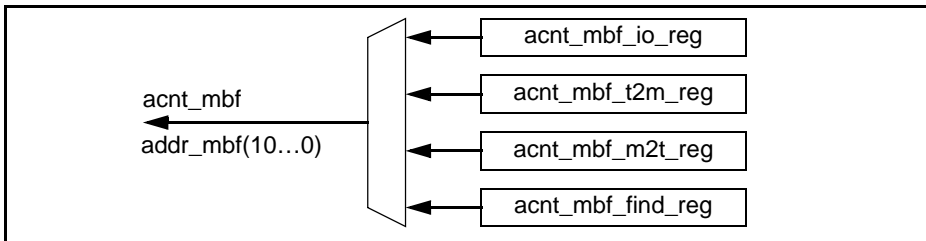


Figure 31 Address Counter Scheme of Message RAM (simplified)

For the transfers IBF \Rightarrow MBF / MBF \Rightarrow OBF, TBF \Rightarrow MBF and MBF \Rightarrow TBF separate address-counter are implemented (see Figure 31).

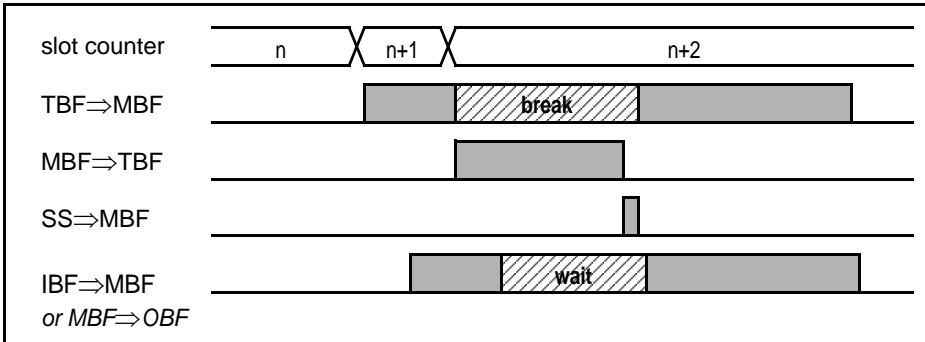


Figure 32 interruption of TBF=>MBF

If the address-counter for IBF=>MBF / MBF=>OBF (acnt_mbf_io_reg) reaches the address of the interrupted TBF=>MBF (acnt_mbf_t2m_reg) the IBF=>MBF / MBF=>OBF has to wait until the TBF=>MBF is continued (see Figure 32).

The relative time is measured in f_{CLC_ERAY} cycles. Absolute time depends on the actual f_{CLC_ERAY} cycle period.

$$\begin{aligned}
 \text{tb_to_mbf_break time}_{\max} &= (\text{setup time} + \text{mbf_to_tb time}_{\max}) \\
 &\quad + (\text{setup time} + \text{ss_to_mbf}) \\
 \text{cycles}_{\text{req}} &= (\text{number of concurrent tasks}) \\
 &\quad \times ((\text{setup time} + (\text{number of 4-byte words})_{\text{req}}) \\
 &\quad \quad + \text{tb_to_mbf_break time}) \\
 \text{setup time} &= 2 \cdot f_{CLC_ERAY} \text{ cycles}
 \end{aligned}$$

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Worst case for one IBF⇒MBF or MBF⇒OBF:

$$\text{Max. break time: } \text{tbf_to_mbf_break time}_{\text{max}} = (2+68) + (4+1) = 75$$

$$\text{Max. number of } f_{\text{CLC_ERAY}} \text{ cycles: } \text{cycles}_{\text{req}} = 3 \times (6 + 68 + 75) = 435$$

Worst case for multiple transfers

If a second IBF⇒MBF and a MBF⇒OBF (see Figure 30) is requested directly after the first IBF⇒MBF has started following worst case timing could appear:

$$\begin{aligned} \text{cycles}_{\text{trans}} = & \text{ (remaining cycles of transfer running)} \\ & + \text{ (cycles of second requested transfer)} \\ & + \text{ (cycles of third requested transfer)} \end{aligned}$$

$$\text{cycles}_{\text{trans}} = \text{cycles}_{\text{rem}} + \text{cycles}_{\text{req_2}} + \text{cycles}_{\text{req_3}}$$

$$\text{Max. number of } f_{\text{CLC_ERAY}} \text{ cycles: } \text{cycles}_{\text{trans}} = 447 + 435 + 447 = 1329$$

21.6.11.3 Minimum $f_{\text{CLC_ERAY}}$

To calculate the minimum $f_{\text{CLC_ERAY}}$ the worst case scenario has to be considered.

The worst case scenario depends on the following parameters

- maximum payload length
- minimum minislot length
- number of configured Message Buffers (excluding FIFO)
- used channels (single/dual channel)

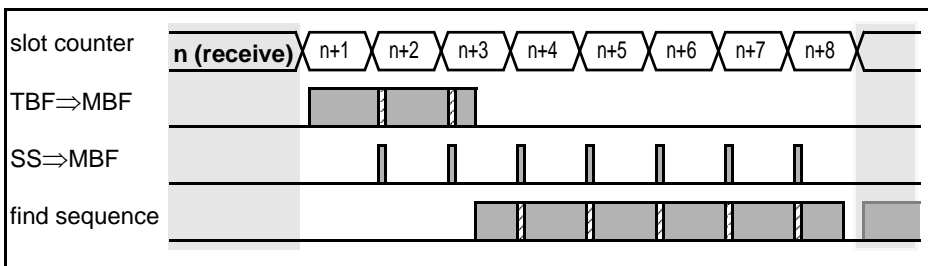


Figure 33 worst case scenario

FlexRay™ Protocol Controller (E-Ray)

Worst case scenario:

- reception of message with a maximum payload length in Slot n (n is 7,15,23,31,39,...)
- slot n+1 to n+7 are empty dynamic slots (minislot) and configured as receive buffer
- the find-sequence (usually started in slot 8,16,24,32,40,...) has to scan the maximum number of configured buffers
- the number of concurrent tasks has its maximum value of three

The find-sequence is executed each 8 Slots (slot 8,16,24,32,40,...). It has to be finished until the next find-sequence is requested.

The length of a TBF⇒MBF varies from 4 (Header Section only) to 68 (Header + maximum Data Section) time step plus a setup time of 6 time steps.

$$f_{\text{CLC_ERAY}} \text{ cycles}_{t2m} = \frac{\text{number of concurrent tasks} \times (\text{setup time}_{t2m} + (\text{number of 4-byte words})_{t2m})}{1}$$

A SS⇒MBF has a fixed length of 1 time steps plus a setup time of 4 time steps.

$$f_{\text{CLC_ERAY}} \text{ cycles}_{ss2m} = \frac{(\text{number of concurrent tasks}) \times 5}{1}$$

The find sequence has a maximum length of 128 (maximum number of buffers) time steps plus a setup time of 2 time steps.

$$f_{\text{CLC_ERAY}} \text{ cycles}_{\text{find}} = \frac{(\text{number of concurrent tasks}) \times (\text{setup time}_{\text{find}} + (\text{number of configured buffers}))}{1}$$

A minislot has a length of 2 to 63 MacroTICK (gdMinislot). The minimum nominal MacroTICK period (cdMinMTNom) is 1 μs. A sequence of 8 minislots has a length of

$$\text{time}_{8\text{minislots}} = 8 \times \text{gdMinislot} \times \text{cdMinMTNom}$$

FlexRay™ Protocol Controller (E-Ray)

The maximum period $T_{\text{CLC_ERAY}} = 1/f_{\text{CLC_ERAY}}$ can be calculated as followed:

$$\text{time}_{8\text{minislots}} \geq (f_{\text{CLC_ERAY}} \text{ period in } \mu\text{s}) \times ((f_{\text{CLC_ERAY}} \text{ cycles}_{\text{t2m}}) + 7 \times (f_{\text{CLC_ERAY}} \text{ cycles}_{\text{ss2m}}) + (f_{\text{CLC_ERAY}} \text{ cycles}_{\text{find}}))$$

$$f_{\text{CLC_ERAY}} \text{ period in ms} \leq \frac{\text{time}_{8\text{minislots}}}{(\text{cycles}_{\text{t2m}}) + 7 \times (\text{cycles}_{\text{ss2m}}) + (\text{cycles}_{\text{find}})}$$

$$\text{minimum time}_{8\text{minislots}} = 8 \times 2 \times 1 \mu\text{s} = 16 \mu\text{s}$$

$$\text{maximum } f_{\text{CLC_ERAY}} \text{ cycles}_{\text{t2m}} = 3 \times (6 + 68) = 222$$

$$\text{maximum } f_{\text{CLC_ERAY}} \text{ cycles}_{\text{ss2m}} = 3 * 5 = 15$$

$$\text{maximum } f_{\text{CLC_ERAY}} \text{ cycles}_{\text{find}} = 3 * (2 + 128) = 390$$

$$f_{\text{CLC_ERAY}} \text{ period in ms} \leq \frac{16\mu\text{s}}{222 + 7 \times 15 + 390} = 22.315... \text{ns}$$

The minimum $f_{\text{CLC_ERAY}}$ frequency for this worst case scenario is 44.8125 MHz.

A too low $f_{\text{CLC_ERAY}}$ frequency can cause a malfunction of the E-Ray.

The E-Ray can detect several malfunctions and reports this by setting the corresponding flag in the Message Handler Constraints Flags (**MHDF**) register.

Minimum $f_{\text{CLC_ERAY}}$ for various maximum payload length

Table 62 summarizes the minimum required $f_{\text{CLC_ERAY}}$ frequency for various maximum payload length assuming:

- a minimum minislot length of 2μs.
- a maximum of 128 configured Message Buffers.
- dual channels in use.

Table 62 Minimum $f_{\text{CLC_ERAY}}$ for different maximum payload length

Maximum payload length of 32 bit words	4	8	16	32	64
minimum $f_{\text{CLC_ERAY}}$	32,82 MHz	33,57 MHz	35,07 MHz	38,07 MHz	44,82 MHz

Minimum $f_{\text{CLC_ERAY}}$ for various minimum minislot length

Table 63 summarizes the minimum required $f_{\text{CLC_ERAY}}$ frequency for various minimum minislot length assuming:

FlexRay™ Protocol Controller (E-Ray)

- a maximum payload length of 254 bytes / 64 four-byte-words.
- a maximum 128 configured Message Buffers.
- dual channels in use.

Table 63 Minimum $f_{\text{CLC_ERAY}}$ for different minimum minislot length

gdMinislot at dMinMTNom = 1 μs	2 μs	3 μs	4 μs	7 μs	8 μs
minimum $f_{\text{CLC_ERAY}}$	44,82 MHz	29,88 MHz	22,412 MHz	12,8 MHz	9,96 MHz

Minimum $f_{\text{CLC_ERAY}}$ for various amount of configured Message Buffers

Table 64 summarizes the minimum required $f_{\text{CLC_ERAY}}$ frequency for various amount of configured Message Buffers assuming:

- a maximum payload length of 254 bytes / 64 four-byte-words.
- a minimum minislot length of 2 μs.
- dual channels in use.

Table 64 Minimum $f_{\text{CLC_ERAY}}$ for different amount of configured Message Buffers

Configured maximum amount of Message Buffers	128	64	32
minimum $f_{\text{CLC_ERAY}}$	44,82 MHz	32,82 MHz	26,82 MHz

Minimum $f_{\text{CLC_ERAY}}$ for a typical configuration

The minimum required $f_{\text{CLC_ERAY}}$ frequency for various assuming the following typical E-Ray configuration:

- a maximum payload length of 32 bytes / 8 four-byte-words.
- a minimum minislot length of 7 μs.
- a maximum 128 configured Message Buffers.
- dual channels in use

The minimum $f_{\text{CLC_ERAY}}$ frequency for this typical example would be 10 MHz.

FlexRay™ Protocol Controller (E-Ray)**21.6.11.4 FlexRay™ Protocol Controller access to Message RAM**

The two Transient Buffer RAMs (TBF 1, TBF 2) are used to buffer the data for transfer between the two FlexRay™ Protocol Controllers and the Message RAM.

Each Transient Buffer RAM is build up as a double buffer, able to store two complete FlexRay™ messages. There is always one buffer assigned to the corresponding Protocol Controller while the other one is accessible by the Message Handler.

If e.g. the Message Handler writes the next message to be send to Transient Buffer Tx, the FlexRay™ Channel Protocol Controller can access Transient Buffer Rx to store the message it is actually receiving. During transmission of the message stored in Transient Buffer Tx, the Message Handler transfers the last received message stored in Transient Buffer Rx to the Message RAM (if it passes acceptance filtering) and updates the respective Message Buffer.

Data transfers between the Transient Buffer RAMs and the shift registers of the FlexRay™ Channel Protocol Controllers are done in words of 32 bit. This enables the use of a 32 bit shift register independent of the length of the FlexRay™ messages.

FlexRay™ Protocol Controller (E-Ray)

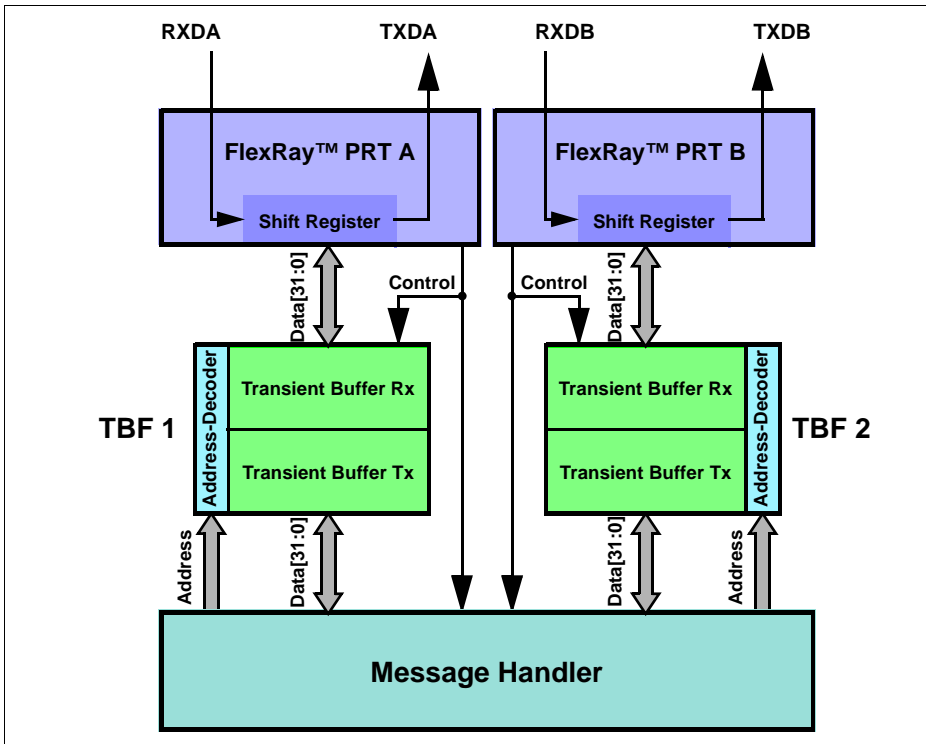


Figure 34 Access to Transient Buffer RAMs

21.6.12 Message RAM

To avoid conflicts between Host access to the Message RAM and FlexRay™ message reception / transmission, the Host cannot directly access the Message Buffers in the Message RAM. These accesses are handled via the Input and Output Buffers. The Message RAM is able to store up to 128 Message Buffers depending on the configured payload length.

The Message RAM is organized 2048 x 32. To achieve the required flexibility with respect to different numbers of data byte per FlexRay™ Frame (0 to 254), the Message RAM has a structure as shown in [Figure 35](#).

The Data Partition is allowed to start at Message RAM word number: $(MRC.LCB + 1) \cdot 4$

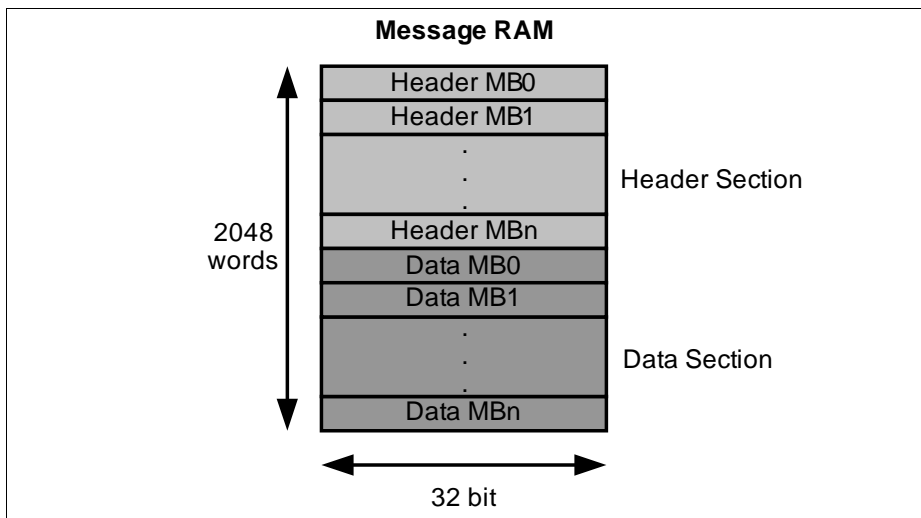


Figure 35 Structure of Message RAM

Header Partition

Stores Header Segments of FlexRay™ Frames:

- Supports a maximum of 128 Message Buffers
- Each Message Buffer has a Header of four 32 bit words
- Header 3 of each Message Buffer holds the 11 bit pointer to the respective Data Section in the Data Partition

Data Partition

Flexible storage of Data Sections with different length. Some maximum values are:

- 30 Message Buffers with 254 byte Data Section each
- Or 56 Message Buffers with 128 byte Data Section each
- Or 128 Message Buffers with 48 byte Data Section each

Restriction: Header Partition + Data Partition may not occupy more than 2048 32-bit words.

21.6.12.1 Header Partition

The Header of each Message Buffer occupies four 32-bit words in the Header Partition of the Message RAM. The Header of Message Buffer 0 starts with the first word in the Message RAM.

For transmit buffers the Header CRC has to be calculated by the Host.

Payload Length Received **PLR**, Receive Cycle Count **RCC**, Received on Channel Indication **RCI**, Startup Frame Indication bit **SFI**, Sync bit **SYN**, NULL Frame Indication bit **NFI**, Payload Preamble Indication bit **PPI**, and Reserved bit **RES** are only updated from received valid Frames (including valid NULL Frames).

Header word 4 of each configured Message Buffer holds the respective Message Buffer Status **MBS** information.

Table 65 Header Section of a Message Buffer in the Message RAM

Bit Word	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1			M B I	T X I	N F M	C F E	C H B	C H A	Cycle Code										Frame ID													
2		Payload Length Received						Payload Length Configured										Tx Buffer: Header CRC Configured Rx Buffer: Header CRC Received														
3			R E S	P F S	N F I	S Y N	S F I	R C I	Receive Cycle Count										Data Pointer													
4			R E S	P F S	N F I	S Y N	S F I	R C I	Cycle Count Status						T F B	F T Y	M E S	E L S	T C C	T C C	S V V	S C C	C V V	S E E	C E E	S E E	V E E	V E E	F F F	F F F		

	Frame Configuration
	Filter Configuration
	Message Buffer Control
	Message RAM Configuration
	Updated from received Frame
	Message Buffer Status
	unused

Header 1 (word 0)

Write access via **WRHS1**, read access via **RDHS1**:

- Frame ID: Slot counter filtering configuration
- Cycle Code: Cycle counter filtering configuration
- CHA, CHB: Channel filtering configuration
- CFG: Message Buffer configuration: receive / transmit
- PPIT: Payload Preamble Indicator Transmit
- XMI: Transmit mode configuration: single-shot / continuous
- MBI: Message Buffer receive / transmit service request enable

Header 2 (word 1)

Write access via **WRHS2**, read access via **RDHS2**:

- Header CRC
 - Transmit Buffer: Configured by the Host (calculated from Frame Header Segment)
 - Receive Buffer: Updated from received Frame
- Payload Length Configured
 - Length of Data Section (2-byte words) as configured by the Host
- Payload Length Received
 - Length of Payload Segment (2-byte words) stored from received Frame

Header 3

Write access via **WRHS3**, read access via **RDHS3**:

- Data Pointer
 - Pointer to the beginning of the corresponding Data Section in the Data Partition

Read access via **RDHS3**, valid for receive buffers only, updated from received Frames:

- Receive Cycle Count: Cycle count from received Frame
- RCI: Received on Channel Indicator
- SFI: Startup Frame Indicator
- SYN: SYNC Frame Indicator
- NFI: NULL Frame Indicator
- PPI: Payload Preamble Indicator
- RES: Reserved bit

Message Buffer Status MBS (word 3)

Read access via MBS, updated by the Communication Controller at the end of the configured slot.

- VFRA: Valid Frame Received on channel A
- VFRB: Valid Frame Received on channel B
- SEOA: Syntax Error Observed on channel A
- SEOB: Syntax Error Observed on channel B
- CEOA: Content Error Observed on channel A
- CEOb: Content Error Observed on channel B
- SVOA: Slot boundary Violation Observed on channel A
- SVOB: Slot boundary Violation Observed on channel B
- TCIA: Transmission Conflict Indication channel A
- TCIB: Transmission Conflict Indication channel B
- ESA: Empty Slot Channel A
- ESB: Empty Slot Channel B
- MLST: Message LoST
- FTA: Frame Transmitted on Channel A
- FTA: Frame Transmitted on Channel B
- Cycle Count Status: Actual cycle count when status was updated
- RCIS: Received on CHannel Indicator Status
- SFIS: Startup Frame Indicator Status
- SYNS: SYNC Frame Indicator Status
- NFIS: NULL Frame Indicator Status
- PPIS: Payload Preamble Indicator Status
- RESS: Reserved Bit Status

21.6.12.2 Data Partition

The Data Partition of the Message RAM stores the Data Sections of the Message Buffers configured for reception / transmission as defined in the Header Partition. The number of data bytes for each Message Buffer can vary from 0 to 254. To optimize the data transfer between the shift registers of the two FlexRay™ Protocol Controllers and the Message RAM as well as between the Host interface and the Message RAM, the physical width of the Message RAM is set to 4 bytes.

The Data Partition starts after the last word of the Header Partition. When configuring the Message Buffers in the Message RAM the programmer has to assure that the data pointers point to addresses within the Data Partition. **Table 66** below shows an example how the Data Sections of the configured Message Buffers can be stored in the Data Partition of the Message RAM.

The beginning and the end of a Message Buffer's Data Section is determined by the data pointer and the payload length configured in the Message Buffer's Header Section,

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respectively. This enables a flexible usage of the available RAM space for storage of Message Buffers with different data length.

If the size of the Data Section is an odd number of 2-byte words, the remaining 16 bits in the last 32-bit word are unused (see [Table 66](#) below)

Table 66 Example for Structure of the Data Section in the Message RAM

Bit Word	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
...	unused								unused								unused								unused							
...	unused								unused								unused								unused							
...	MB1 Data3								MB1 Data2								MB1 Data1								MB1 Data0							
...							
...							
...	MB1 Data(n)								MB1 Data(n-1)								MB1 Data(n-2)								MB1 Data(n-3)							
...							
...							
...							
...	MB1 Data3								MB1 Data2								MB1 Data1								MB1 Data0							
...							
...	MB1 Data(k)0								MB1 Data(k-1)0								MB1 Data(k-2)0								MB1 Data(k-3)0							
2046	MB80 Data3								MB80 Data2								MB80 Data2								MB80 Data0							
2047	unused								unused								MB80 Data5								MB80 Data4							

21.6.12.3 ECC Check

There is an ECC checking mechanism implemented in the E-Ray module to assure the integrity of the data stored in the seven RAM blocks of the module. The RAM blocks have an ECC generator / checker attached as shown in [Figure 36](#). When data is written to a RAM block, the local ECC generator generates the ECC data. The ECC data is stored together with the respective data word. The ECC data is checked each time a data word is read from any of the RAM blocks.

If an ECC error is detected, the respective error flag is set. The ECC error flags [MHDS.EIBF](#), [MHDS.EOBF](#), [MHDS.EMR](#), [MHDS.ETBF1](#), [MHDS.ETBF2](#), and the faulty Message Buffer indicators [MHDS.FMBD](#), [MHDS.MFMB](#), [MHDS.FMB](#) are located in the Message Handler Status register. These error flags control the error interrupt flag [EIR.EERR](#).

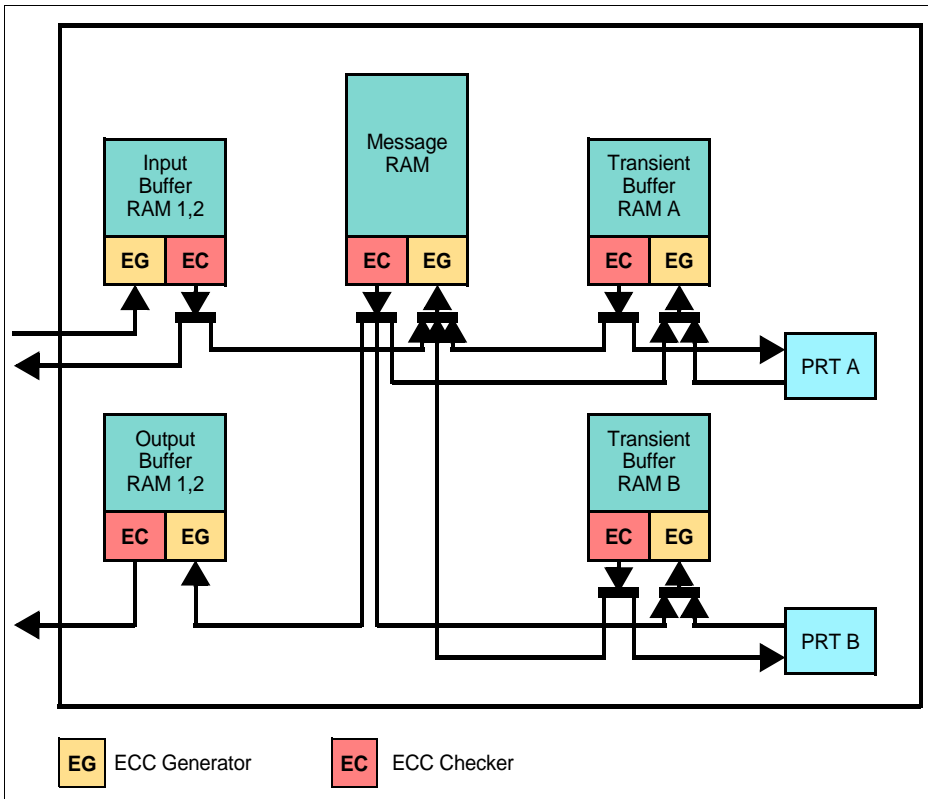


Figure 36 **ECC Generation and Check**

When an ECC error has been detected the following actions will be performed:

In all cases

- The respective ECC error flag in the Message Handler Status **MHDS** register is set
- The ECC error flag **EIR.EERR** in the Error Service Request Register is set, and if enabled, a module service request to the Host will be generated.

Additionally in specific cases

1. ECC error in data transfer from Input Buffer RAM 1,2 \Rightarrow Message RAM
(Transfer of Header and Data Section)
 - a) **MHDS.EIBF** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** has been updated
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
 - d) Transmit buffer: Transmission request for the respective Message Buffer is not set
2. ECC error in data transfer from Input Buffer RAM 1,2 \Rightarrow Message RAM
(Transfer of Data Section only)
 - a) **MHDS.EMR** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
 - d) The Data Section of the respective Message Buffer is not updated
 - e) Transmit buffer: Transmission request for the respective Message Buffer is not set
3. ECC error during host reading Input Buffer RAM
 - a) • **MHDS.EIBF** bit is set
4. ECC error during scan of Header Sections in Message RAM
 - a) **MHDS.EMR** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
 - d) Ignore Message Buffer (Message Buffer is skipped)
5. ECC error during data transfer from Message RAM \Rightarrow Transient Buffer RAM A, B
 - a) **MHDS.EMR** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
 - d) Frame not transmitted, Frames already in transmission are invalidated by setting the Frame CRC to zero
6. ECC error during data transfer from Transient Buffer RAM A, B \Rightarrow Protocol Controller 1, 2
 - a) **MHDS.ETBF1**, **MHDS.ETBF2** bit is set
7. ECC error in data transfer from Transient Buffer RAM A, B \Rightarrow Message RAM
(ECC error when reading Header Section of respective Message Buffer from Message RAM)
 - a) **MHDS.EMR** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
 - d) The Data Section of the respective Message Buffer is not updated

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8. ECC error in data transfer from Transient Buffer RAM A, B \Rightarrow Message RAM (ECC error when reading Transient Buffer RAM A, B)
 - a) **MHDS.ETBF1**, **MHDS.ETBF2** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
9. ECC error during data transfer from Message RAM \Rightarrow Output Buffer RAM
 - a) **MHDS.EMR** bit is set
 - b) **MHDS.FMBD** bit is set to indicate that **MHDS.FMB** points to a faulty Message Buffer
 - c) **MHDS.FMB** indicates the number of the faulty Message Buffer
10. ECC error during Host reading Output Buffer RAM
 - a) • **MHDS.EOBF** bit is set
11. ECC error during data read of Transient Buffer RAM A, B

If an ECC error occurs while the Message Handler reads a Frame with Network Management information (PPI = 1) from the Transient Buffer RAM A, B the corresponding Network Management vector registers NMV1 to NMV3 are not updated from that Frame.

21.6.13 Host Handling of Errors

An ECC error caused by transient bit flips can be fixed by:

21.6.13.1 Self-Healing

ECC errors located in

- Input Buffer RAM 1,2
- Output Buffer RAM 1,2
- Data Section of Message RAM
- Transient Buffer RAM A
- Transient Buffer RAM B

are overwritten with the next write access to the disturbed bit(s) caused by Host access or by FlexRay communication.

21.6.13.2 CLEAR_RAMs Command

When called in DEFAULT_CONFIG or CONFIG state POC command CLEAR_RAMs initializes all module-internal RAMs to zero.

21.6.13.3 Temporary Unlocking of Header Section

An ECC error in the header section of a locked message buffer can be fixed by a transfer from the Input Buffer to the locked buffer Header Section. For this transfer, the write-

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access to the IBCR (specifying the message buffer number) must be immediately preceded by the unlock sequence normally used to leave CONFIG state (see **“Lock Register (LCK)” on Page 40**).

For that single transfer the respective message buffer header is unlocked, regardless whether it belongs to the FIFO or whether its locking is controlled by MRC.SEC[1:0], and will be updated with new data.

21.7 Module Service Request

In general, service requests provide a close link to the protocol timing as they are triggered almost immediately when an error or status change is detected by the controller, a Frame is received or transmitted, a configured timer service request is activated, or a stop watch event occurred. This enables the Host to react very quickly on specific error conditions, status changes, or timer events. On the other hand too many service requests can cause the Host to miss deadlines required for the application. Therefore the Communication Controller supports disable / enable controls for each individual service request source separately.

An service request may be triggered when

- An error was detected
- A status flag is set
- A timer reaches a preconfigured value
- A message transfer from Input Buffer to Message RAM or from Message RAM to Output Buffer has completed
- A stop watch event occurred

Tracking status and generating service requests when a status change or an error occurs are two independent tasks. Regardless of whether an service request is enabled or not, the corresponding status is tracked and indicated by the Communication Controller. The Host has access to the actual status and error information by reading the Error Service Request Register **EIR** and the Status Service Request **SIR** Register.

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Table 67 Module Service Request Flags and Service Request Line Enable

Register	Bit	Function
SIR	WST	Wakeup Status
	CAS	Collision Avoidance Symbol
	CYCS	Cycle Start Service Request
	TXI	Transmit Service Request
	RXI	Receive Service Request
	RFNE	Receive FIFO not Empty
	RFF	Receive FIFO Full
	NMVC	Network Management Vector Changed
	TI0	Timer Service Request 0
	TI1	Timer Service Request 1
	TIBC	Transfer Input Buffer Completed
	TOBC	Transfer Output Buffer Completed
	SWE	Stop Watch Event
	SUCS	Startup Completed Successfully
	MBSI	Message Buffer Status Interrupt
	SDS	Start of Dynamic Segment
	WUPA	Wakeup Pattern Channel A
	MTSA	MTS Received on Channel A
	WUPB	Wakeup Pattern Channel B
	MTSB	MTS Received on Channel B
ILE	EINT0	Enable Service Request Line 0
	EINT1	Enable Service Request Line 1
EIR	PEMC	Protocol Error Mode Changed
	CNA	Command Not Valid
	SFBM	SYNC Frames Below Minimum
	SFO	SYNC Frame Overflow
	CCF	Clock Correction Failure
	CCL	CHI Command Locked
	EERR	ECC Error
	RFO	Receive FIFO Overrun

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Table 67 Module Service Request Flags and Service Request Line Enable

Register	Bit	Function
EIR	EFA	Empty FIFO Access
	IIBA	Illegal Input Buffer Access
	IOBA	Illegal Output Buffer Access
	MHF	Message Handler Constraints Flag
	EDA	Error Detected on Channel A
	LTV A	Latest Transmit Violation Channel A
	TABA	Transmission Across Boundary Channel A
	EDB	Error Detected on Channel B
	LTV B	Latest Transmit Violation Channel B
	TABB	Transmission Across Boundary Channel B

The interrupt lines to the Host TINT0SR and TINT1SR are controlled by the enabled interrupts. In addition each of the two interrupt lines can be enabled / disabled separately by programming bit **ILE.EINT0/INT0SRC.SRE** and **ILE.EINT1/INT1SRC.SRE**.

The interrupt lines to the Host NDAT0SR and NDAT1SR are controlled by the enabled new data interrupts (**NDIC1** to **NDIC4**). In addition each of the two interrupt lines can be enabled / disabled separately by programming bit **NDAT0SRC.SRE** and **NDAT1SRC.SRE**.

The interrupt lines to the Host MBSC0SR and MBSC1SR are controlled by the enabled new data interrupts (**MSIC1** to **MSIC4**). In addition each of the two interrupt lines can be enabled / disabled separately by programming bit **MBSC0SRC.SRE** and **MBSC1SRC.SRE**.

The two timer service requests generated by service request timer 0 and 1 are available on pins TINT0SR and TINT1SR. They can be configured via the Timer 0 and Timer 1 Configuration register. In addition each of the two interrupt lines can be enabled / disabled separately by programming bit **TINT0SRC.SRE** and **TINT1SRC.SRE**.

A stop watch event may be triggered via input pin STPWn.

The status of the data transfer between IBF / OBF and the Message RAM is signalled on signals IBUSY and OBUSY. When a transfer has completed bit **SIR.TIBC** or **SIR.TOBC** is set.

21.8 Restrictions

The following restrictions have to be considered when programming the E-Ray IP-module. A violation of these restrictions may lead to an erroneous behavior of the E-Ray IP-module.

21.8.1 Message Buffers with the same Frame ID

If two or more Message Buffers are configured with the same Frame ID, and if they have a matching cycle counter filter value for the same slot, then the Message Buffer with the lowest Message Buffer number is used.

Sharing of a static time slot via cycle counter filtering between different nodes of a FlexRay™ network is **not** allowed.

21.8.2 Data Transfers between IBF / OBF and Message RAM

The time required to transfer the contents of a Message Buffer between IBF / OBF and Message RAM depends on the setup time to start the first transfer, the number of 4-byte words to be transferred, and the number of concurrent tasks to be managed by the Message Handler. The number of 4-byte words varies from 4 (Header Section only) to 68 (Header + maximum Data Section) while the number of concurrent task varies from one to three.

The following concurrent tasks are executed under control of the Message Handler:

- Data transfer between IBF or OBF and Message RAM
- Data transfer between TBF1 and Message RAM, search next TX / RX Message Buffer CHA
- Data transfer between TBF2 and Message RAM, search next TX / RX Message Buffer CHB

Transfers between IBF and Message RAM respectively Message RAM and OBF can only be handled one after another. In case that e.g. a transfer between IBF and Message RAM has been started shortly before a transfer between Message RAM and OBF is requested, the OBF transfer has to wait until the IBF transfer has completed.

The relative time is measured in f_{CLC_ERAY} cycles. Absolute time depends on the actual f_{CLC_ERAY} cycle period.

$cycletrans = (remaining\ cycles\ of\ transfer\ running) + (cycles\ of\ requested\ transfer)$

$cycletrans = cyclesrem + cyclesreq$

$cyclesrem = (number\ of\ concurrent\ tasks) * (setup\ time + (number\ of\ 4\text{-byte\ words})rem)$

$cyclesreq = (number\ of\ concurrent\ tasks) * (setup\ time + (number\ of\ 4\text{-byte\ words})req)$

$setup\ time = 2 f_{CLC_ERAY}\ cycles$

Under worst case conditions a transfer is requested directly after the previous transfer started:

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Max. number of $f_{\text{CLC_ERAY}}$ cycles: $\text{cyclestrans} = (3 * (2 + 68)) + (3 * (2 + 68)) = 420$

Worst case timing: $\text{timetrans}(40\text{MHz}) = 420 * 25\text{ns} = 10.5 \text{ ms}$

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21.9 E-Ray Module Implementation

This section describes the E-Ray interfaces as implemented in TC1728 with the clock control, port and DMA connections, interrupt control, and address decoding.

Figure 37 shows a detailed view of the E-Ray interface.

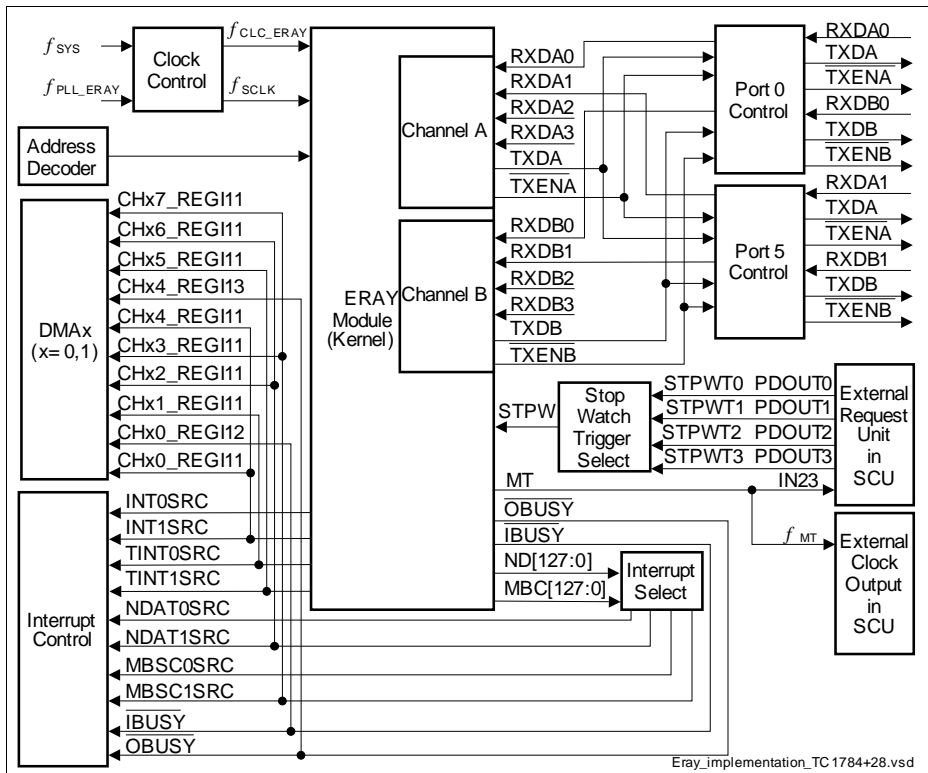


Figure 37 Detailed Block Diagram of the E-Ray Interface

21.9.1 Interconnections of the E-Ray Module

The E-Ray module has 2 FlexRay™ communication channels, channel A and channel B. Each channel provides a set of signals to drive a bus driver. The E-Ray module requires two different clocks, a sampling clock of the FlexRay™ bus f_{SCLK} . f_{SCLK} has to be 8 times the baud rate of the FlexRay™ communication. A second clock f_{CLC_ERAY} is used for the main protocol controller state machine and the customer interface logic. To enable deactivation of the E-Ray Module, f_{CLC_ERAY} and f_{SCLK} may be disabled (clock

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gated) by the **CLC.DISR** Enable E-Ray (Clock Gating) bit. The following items are described in this section:

- E-Ray module (kernel) external registers
- Port control and connections
 - I/O port line assignment
 - I/O function selection
 - Pad driver characteristics selection
- On-chip connections
 - SCU Connections
 - DMA connections
- Module clock generation
- Interrupt registers
- E-Ray address map

21.9.2 Port Control and Connections

This section describes the I/O connections of the E-Ray module.

21.9.2.1 Input/Output Function Selection

Table 68 shows how bits and bit fields must be programmed for the required I/O functionality of the E-Ray I/O lines. This table also shows the values of the peripheral input select registers.

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Table 68 E-Ray I/O Control Selection and Setup

FlexRay TM Channel	Port Lines	Input Select Register	Input/Output Control Register Bits	I/O
A	RXDA0/ P0.8	ERAY_CUST1.RISA = 00 _B	P0_IOC8.PC8 = 0XX _B	Input
	RXDA1/ P5.14	ERAY_CUST1.RISA = 01 _B	P5_IOC12.PC14 = 0XX _B	Input
	RXDA2	ERAY_CUST1.RISA = 10 _B	reserved	Input
	RXDA3	ERAY_CUST1.RISA = 11 _B	reserved	Input
	TXDA/ P0.10	not applicable	P0_IOC8.PC10 = 1X11 _B	Output
	TXDA/ P5.8	not applicable	P5_IOC8.PC8 = 1X10 _B	Output
	TXENA/ P0.12	not applicable	P0_IOC12.PC12 = 1X11 _B	Output
	TXENA/ P5.10	not applicable	P5_IOC8.PC10 = 1X10 _B	Output
B	RXDB0/ P0.9	ERAY_CUST1.RISB = 00 _B	P0_IOC8.PC9 = 0XX _B	Input
	RXDB1/ P5.15	ERAY_CUST1.RISB = 01 _B	P5_IOC12.PC15 = 0XX _B	Input
	RXDB2	ERAY_CUST1.RISB = 10 _B	reserved	Input
	RXDB3	ERAY_CUST1.RISB = 11 _B	reserved	Input
	TXDB/ P0.11	not applicable	P0_IOC8.PC11 = 1X11 _B	Output
	TXDB/ P5.9	not applicable	P5_IOC8.PC9 = 1X10 _B	Output
	TXENB/ P0.13	not applicable	P0_IOC12.PC13 = 1X11 _B	Output
	TXENB/ P5.11	not applicable	P5_IOC8.PC11 = 1X10 _B	Output

21.9.3 On-Chip Connections

This section describes all on-chip interconnections of the E-Ray modules except the connections to I/O ports (see [Section 21.9.2](#)).

21.9.3.1 E-Ray Connections with DMA

The E-Ray module of the TC1728 has several on-chip interconnections to the DMA modules. [Table 69](#) shows these interconnections. These enable the DMA to handle different service request of E-Ray module via the DMA.

Table 69 DMA Request Assignment for DMA Sub-Block 0 and DMA Sub-Block 1

DMA Channel	ERAY Output Signal	DMA Request Input Line	Selected by
00	INT1SRC	CH00_REGI11	CHCR00.PRSEL = 1011 _B
00	IBUSY	CH00_REGI12	CHCR00.PRSEL = 1100 _B
01	TINT0SRC	CH01_REGI11	CHCR01.PRSEL = 1011 _B
02	NDAT1SRC	CH02_REGI11	CHCR02.PRSEL = 1011 _B
03	MBSC1SRC	CH03_REGI11	CHCR03.PRSEL = 1011 _B
04	INT1SRC	CH04_REGI11	CHCR04.PRSEL = 1011 _B
04	OBUSY	CH04_REGI13	CHCR04.PRSEL = 1101 _B
05	TINT1SRC	CH05_REGI11	CHCR05.PRSEL = 1011 _B
06	NDAT1SRC	CH06_REGI11	CHCR06.PRSEL = 1011 _B
07	MBSC1SRC	CH07_REGI11	CHCR07.PRSEL = 1011 _B
10	INT1SRC	CH10_REGI11	CHCR10.PRSEL = 1011 _B
10	IBUSY	CH10_REGI12	CHCR10.PRSEL = 1100 _B
11	TINT0SRC	CH11_REGI11	CHCR11.PRSEL = 1011 _B
12	NDAT1SRC	CH12_REGI11	CHCR12.PRSEL = 1011 _B
13	MBSC1SRC	CH13_REGI11	CHCR13.PRSEL = 1011 _B
14	INT1SRC	CH14_REGI11	CHCR14.PRSEL = 1011 _B
14	OBUSY	CH14_REGI13	CHCR14.PRSEL = 1101 _B
15	TINT1SRC	CH15_REGI11	CHCR15.PRSEL = 1011 _B
16	NDAT1SRC	CH16_REGI11	CHCR16.PRSEL = 1011 _B
17	MBSC1SRC	CH17_REGI11	CHCR17.PRSEL = 1011 _B

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21.9.3.2 E-Ray Connections with the External Request Unit of SCU

The E-Ray module of the TC1728 has several on-chip interconnections to the External Request Unit (ERU) in the SCU to externally trigger stop watch events and to provide a global time e.g. to the on chip timers. [Table 70](#) and [Table 71](#) show these interconnections.

Table 70 External Stop Watch Request Assignment

ERAY Input Signal	ERU Request Output Line	Selected by
STPWT0	ERU_PDOUT0	CUST1.STPWTS = 00 _B
STPWT1	ERU_PDOUT1	CUST1.STPWTS = 01 _B
STPWT2	ERU_PDOUT2	CUST1.STPWTS = 10 _B
STPWT3	ERU_PDOUT3	CUST1.STPWTS = 11 _B

Table 71 Global Macrotick Connection to ERU

ERAY Output Signal	ERU Request Input Line	Selected by
MT	ERU_IN23	ERU_EICR1.EXIS2 = 11 _B

21.9.3.3 E-Ray Connections with the ECC Error Handling Unit of SCU

The E-Ray module of the TC1728 has one on-chip interconnection to the ECC Error Handling Unit in the SCU to trigger an ECC Error Trap. [Table 72](#) shows this interconnection.

Table 72 ECC Error Signalling to SCU

ERAY Output Signal	SCU Line	Selected by
EERR	ECCT	TRAPDIS.ECCT = 0 _B

21.9.3.4 E-Ray Connections with the External Clock Output of SCU

The E-Ray module of the TC1728 has one on-chip interconnections to the External Clock Output Unit in the SCU to distribute externally as also internally the Macro Tick as time base for distributed system control e.g. to the GPTA® as global system timer or external devices. [Table 73](#) shows this interconnection.

Table 73 Global Macrotick Connection to External Clock Output

ERAY Output Signal	External Clock Output	Selected by
MT	f_{MT}	SCU_EXCTCON.SEL0 = 1111 _B

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21.9.4 Clock Control Register

The clock control register makes it possible to control (enable/disable) the E-Ray module control clock f_{CLC_ERAY} . The clock signal f_{CLC_ERAY} is used by the E-Ray as a clock for internal control operations but not for FlexRay™ Bus Signal Sampling.

After an application reset, by default, the startup software (SSW) will disable the module by setting CLC.DISR and thereby requesting the HW to set bit CLC.DISS. In consequence, the initial value readable by the application is 0x0000 0003_H.

Note: The application SW must make sure that the Transceiver Enable (TXENA, TXENB) pins are forced to their inactive state first, before the module clock is switched off.

CLC

ERAY Clock Control Register

(0000_H)

Reset Value: 0000 0100_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				RMC				0		FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
r				rw				r		rw	w	rw	rw	rh	rw

Field	Bits	Type	Description
DISR	0	rw	E-Ray Module Disable Request Bit Used for enable/disable control of the E-Ray module. <i>Note: This bit disables the kernel clocks f_{CLC_ERAY} and the sampling clock f_{SCLK}.</i>
DISS	1	rh	E-Ray Module Disable Status Bit Bit indicates the current status of the E-Ray module.
SPEN	2	rw	E-Ray Module Suspend Enable for OCDS Used to enable the suspend mode.
EDIS	3	rw	External Request Disable Used to control the external clock disable request.
SBWE	4	w	E-Ray Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.

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Field	Bits	Type	Description
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch off in suspend mode.
RMC	[10:8]	rw	Clock Divider in Run Mode 000 _B No clock signal f_{CLC_ERAY} generated (default after reset) 001 _B Clock $f_{CLC_ERAY} = f_{SYS}$ selected 010 _B Clock $f_{CLC_ERAY} = f_{SYS} / 2$ selected 011 _B Clock $f_{CLC_ERAY} = f_{SYS} / 3$ selected 100 _B Clock $f_{CLC_ERAY} = f_{SYS} / 4$ selected 101 _B Clock $f_{CLC_ERAY} = f_{SYS} / 5$ selected 110 _B Clock $f_{CLC_ERAY} = f_{SYS} / 6$ selected 111 _B Clock $f_{CLC_ERAY} = f_{SYS} / 7$ selected <i>Note: This bit field is not affected by an application reset.</i> <i>Note: This bit field only controls the kernel clock f_{CLC_ERAY} and not the sampling clock f_{SCLK}.</i>
0	[7:6], [31:11]	r	Reserved Read as 0; should be written with 0.

Note: After an application reset, the f_{CLC_ERAY} clock is disabled (DISS set). Therefore, the E-Ray modules clock generation is completely disabled.

21.9.5 Interrupt Registers

Two different type of Interrupt Registers are described within this chapter.

The Interrupt Control register enable the selection of the Service Request used to signal an event. The Interrupt Control registers **NDIC1** to **NDIC4** select the service request node used for New Data Events. The Interrupt Control registers **MSIC1** to **MSIC4** select the service request node used for Message Buffer Status Changed Events.

The Interrupt Service Request Control Registers control the eight service request nodes.

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New Data Interrupt Control 1 (NDIC1)

This New Data Interrupt Control register controls the interrupt that becomes active (**NDAT0SRC** or **NDAT1SRC**) on a ND flag turning active of all configured Message Buffers 0 to Message Buffers 31.

NDIC1

New Data Interrupt Control 1

(03A8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
NDIP 31	NDIP 30	NDIP 29	NDIP 28	NDIP 27	NDIP 26	NDIP 25	NDIP 24	NDIP 23	NDIP 22	NDIP 21	NDIP 20	NDIP 19	NDIP 18	NDIP 17	NDIP 16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDIP 15	NDIP 14	NDIP 13	NDIP 12	NDIP 11	NDIP 10	NDIP 9	NDIP 8	NDIP 7	NDIP 6	NDIP 5	NDIP 4	NDIP 3	NDIP 2	NDIP 1	NDIP 0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
NDIPn (n = 0-31)	n	rw	New Data Interrupt Pointer n (n = 0-31) NDIPn determines the interrupt (NDAT0SRC or NDAT1SRC) of the service request output that becomes active on a New Data Flag becoming active. 0 _B NDAT0SRC selected for New Data Service Request 1 _B NDAT1SRC selected for New Data Service Request

FlexRay™ Protocol Controller (E-Ray)

New Data Interrupt Control 2 (NDIC2)

This New Data Interrupt Control register controls the interrupt that becomes active (**NDAT0SRC** or **NDAT1SRC**) on a ND flag turning active of all configured Message Buffers 32 to Message Buffers 63.

NDIC2

New Data Interrupt Control 2

(03AC_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
NDIP 63	NDIP 62	NDIP 61	NDIP 60	NDIP 59	NDIP 58	NDIP 57	NDIP 56	NDIP 55	NDIP 54	NDIP 53	NDIP 52	NDIP 51	NDIP 50	NDIP 49	NDIP 48
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDIP 47	NDIP 46	NDIP 45	NDIP 44	NDIP 43	NDIP 42	NDIP 41	NDIP 40	NDIP 39	NDIP 38	NDIP 37	NDIP 36	NDIP 35	NDIP 34	NDIP 33	NDIP 32
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
NDIPn (n = 32-63)	n - 32	rw	New Data Interrupt Pointer n (n = 32-63) NDIPn determines the interrupt (NDAT0SRC or NDAT1SRC) of the service request output that becomes active on a New Data Flag becoming active. 0 _B NDAT0SRC selected for New Data Service Request 1 _B NDAT1SRC selected for New Data Service Request

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New Data Interrupt Control 3 (NDIC3)

This New Data Interrupt Control register controls the interrupt that becomes active (**NDAT0SRC** or **NDAT1SRC**) on a ND flag turning active of all configured Message Buffers 64 to Message Buffers 95.

NDIC3

New Data Interrupt Control 3

(03B0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
NDIP 95	NDIP 94	NDIP 93	NDIP 92	NDIP 91	NDIP 90	NDIP 89	NDIP 88	NDIP 87	NDIP 86	NDIP 85	NDIP 84	NDIP 83	NDIP 82	NDIP 81	NDIP 80
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDIP 79	NDIP 78	NDIP 77	NDIP 76	NDIP 75	NDIP 74	NDIP 73	NDIP 72	NDIP 71	NDIP 70	NDIP 69	NDIP 68	NDIP 67	NDIP 66	NDIP 65	NDIP 64
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
NDIPn (n = 64-95)	n - 64	rw	New Data Interrupt Pointer n (n = 64-95) NDIPn determines the interrupt (NDAT0SRC or NDAT1SRC) of the service request output that becomes active on a New Data Flag becoming active. 0 _B NDAT0SRC selected for New Data Service Request 1 _B NDAT1SRC selected for New Data Service Request

FlexRay™ Protocol Controller (E-Ray)

New Data Interrupt Control 4 (NDIC4)

This New Data Interrupt Control register controls the interrupt that becomes active (**NDAT0SRC** or **NDAT1SRC**) on a ND flag turning active of all configured Message Buffers 96 to Message Buffers 127.

NDIC4

New Data Interrupt Control 4

(03B4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
NDIP 127	NDIP 126	NDIP 125	NDIP 124	NDIP 123	NDIP 122	NDIP 121	NDIP 120	NDIP 119	NDIP 118	NDIP 117	NDIP 116	NDIP 115	NDIP 114	NDIP 113	NDIP 112
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDIP 111	NDIP 110	NDIP 109	NDIP 108	NDIP 107	NDIP 106	NDIP 105	NDIP 104	NDIP 103	NDIP 102	NDIP 101	NDIP 100	NDIP 99	NDIP 98	NDIP 97	NDIP 96
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
NDIPn (n = 96-127)	n - 96	rw	New Data Interrupt Pointer n (n = 96-127) NDIPn determines the interrupt (NDAT0SRC or NDAT1SRC) of the service request output that becomes active on a New Data Flag becoming active. 0 _B NDAT0SRC selected for New Data Service Request 1 _B NDAT1SRC selected for New Data Service Request

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Message Buffer Status Changed Interrupt Control 1 (MSIC1)

This Message Buffer Status Change Interrupt Control register controls the interrupt that becomes active (**MBSC0SRC** or **MBSC1SRC**) on a MBC flag of all configured Message Buffer 0 to Message Buffer 31 turning active.

MSIC1

Message Buffer Status Changed Interrupt Control 1

(03B8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP	MSIP
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MSIPn (n = 0-31)	n	rw	Message Buffer Status Changed Interrupt Pointer n (n = 0-31) MSIPn determines the interrupt (MBSC0SRC or MBSC1SRC) of the service request output that becomes active on a Message Buffer Status Changed Flag becoming active. 0 _B MBSC0SRC selected for Message Buffer Status Changed Service Request 1 _B MBSC1SRC selected for Message Buffer Status Changed Service Request

FlexRay™ Protocol Controller (E-Ray)

Message Buffer Status Changed Interrupt Control 2 (MSIC2)

This Message Buffer Status Change Interrupt Control register controls the interrupt that becomes active (**MBSC0SRC** or **MBSC1SRC**) on a MBC flag of all configured Message Buffer 32 to Message Buffer 63 turning active.

MSIC2

Message Buffer Status Changed Interrupt Control 2

(03BC_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSIP 63	MSIP 62	MSIP 61	MSIP 60	MSIP 59	MSIP 58	MSIP 57	MSIP 56	MSIP 55	MSIP 54	MSIP 53	MSIP 52	MSIP 51	MSIP 50	MSIP 49	MSIP 48
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSIP 47	MSIP 46	MSIP 45	MSIP 44	MSIP 43	MSIP 42	MSIP 41	MSIP 40	MSIP 39	MSIP 38	MSIP 37	MSIP 36	MSIP 35	MSIP 34	MSIP 33	MSIP 32
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MSIPn (n = 32-63)	n - 32	rh	Message Buffer Status Changed Interrupt Pointer n (n = 32-63) MSIPn determines the interrupt (MBSC0SRC or MBSC1SRC) of the service request output that becomes active on a Message Buffer Status Changed Flag becoming active. 0 _B MBSC0SRC selected for Message Buffer Status Changed Service Request 1 _B MBSC1SRC selected for Message Buffer Status Changed Service Request

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Message Buffer Status Changed Interrupt Control 3 (MSIC3)

This Message Buffer Status Change Interrupt Control register controls the interrupt that becomes active (**MBSC0SRC** or **MBSC1SRC**) on a MBC flag of all configured Message Buffer 64 to Message Buffer 95 turning active.

MSIC3

Message Buffer Status Changed Interrupt Control 3

(03C0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSIP 95	MSIP 94	MSIP 93	MSIP 92	MSIP 91	MSIP 90	MSIP 89	MSIP 88	MSIP 87	MSIP 86	MSIP 85	MSIP 84	MSIP 83	MSIP 82	MSIP 81	MSIP 80
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSIP 79	MSIP 78	MSIP 77	MSIP 76	MSIP 75	MSIP 74	MSIP 73	MSIP 72	MSIP 71	MSIP 70	MSIP 69	MSIP 68	MSIP 67	MSIP 66	MSIP 65	MSIP 64
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MSIPn (n = 64-95)	n - 64	rw	Message Buffer Status Changed Interrupt Pointer n (n = 64-95) MSIPn determines the interrupt (MBSC0SRC or MBSC1SRC) of the service request output that becomes active on a Message Buffer Status Changed Flag becoming active. 0 _B MBSC0SRC selected for Message Buffer Status Changed Service Request 1 _B MBSC1SRC selected for Message Buffer Status Changed Service Request

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Message Buffer Status Changed Interrupt Control 4 (MSIC4)

This Message Buffer Status Change Interrupt Control register controls the interrupt that becomes active (**MBSC0SRC** or **MBSC1SRC**) on a MBC flag of all configured Message Buffer 96 to Message Buffer 127 turning active.

MSIC4

Message Buffer Status Changed Interrupt Control 4

(03C4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSIP 127	MSIP 126	MSIP 125	MSIP 124	MSIP 123	MSIP 122	MSIP 121	MSIP 120	MSIP 119	MSIP 118	MSIP 117	MSIP 116	MSIP 115	MSIP 114	MSIP 113	MSIP 112
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSIP 111	MSIP 110	MSIP 109	MSIP 108	MSIP 107	MSIP 106	MSIP 105	MSIP 104	MSIP 103	MSIP 102	MSIP 101	MSIP 100	MSIP 99	MSIP 98	MSIP 97	MSIP 96
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MSIPn (n = 96-127)	n - 96	rw	Message Buffer Status Changed Interrupt Pointer n (n = 96-127) MSIPn determines the interrupt (MBSC0SRC or MBSC1SRC) of the service request output that becomes active on a Message Buffer Status Changed Flag becoming active. 0 _B MBSC0SRC selected for Message Buffer Status Changed Service Request 1 _B MBSC1SRC selected for Message Buffer Status Changed Service Request

Service Request Control Registers

Each of the service request outputs of the E-Ray module kernels is able to generate an interrupt and is controlled by an interrupt service request control register **INT0SRC**, **INT1SRC**, **TINT0SRC**, **TINT1SRC**, **NDAT0SRC**, **NDAT1SRC**, **MBSC0SRC**, **MBSC1SRC**, **OBUSYSRC**, and **IBUSYSRC**. The service request **OBUSYSRC**, and **IBUSYSRC** is generated, when the Output Buffer or Input Buffer switches from busy state to the state being accessible by the host.

INT0SRC

Interrupt 0 Service Request Control Register
(3EC_H)

Reset Value: 0000 0000_H

INT1SRC

Interrupt 1 Service Request Control Register
(3E8_H)

Reset Value: 0000 0000_H

TINT0SRC

Timer Interrupt 0 Service Request Control Register
(3E4_H)

Reset Value: 0000 0000_H

TINT1SRC

Timer Interrupt 1 Service Request Control Register
(3E0_H)

Reset Value: 0000 0000_H

NDAT0SRC

New Data 0 Service Request Control Register
(3DC_H)

Reset Value: 0000 0000_H

NDAT1SRC

New Data 1 Service Request Control Register
(3D8_H)

Reset Value: 0000 0000_H

MBSC0SRC

Message Buffer Status Changed 0 Service Request Control Register
(3D4_H)

Reset Value: 0000 0000_H

MBSC1SRC

Message Buffer Status Changed 1 Service Request Control Register
(3D0_H)

Reset Value: 0000 0000_H

OBUSYSRC

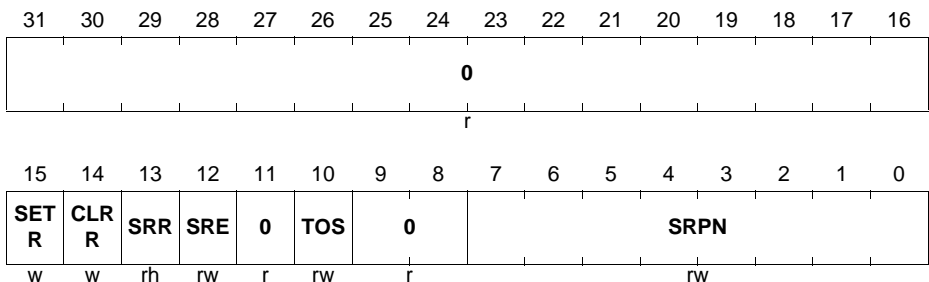
Output Buffer Busy Service Request Control Register
(3CC_H)

Reset Value: 0000 0000_H

IBUSYSRC

Input Buffer Busy Service Request Control Register
(3C8_H)

Reset Value: 0000 0000_H



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Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Note: Additional details on service request nodes and the service request control registers are described in Chapter “Interrupt System” of the TC1728 User’s Manual System Units part (Volume 1).

21.9.6 E-Ray Access Delay

Due to a hierarchical design approach read and write accesses require FPI wait states.

Table 74 E-Ray Access Time

Address Range	FPI Wait States for Reading	FPI Wait States for Writing
Customer Register (ID , CUST1 , CUST3)	1 wait state	0 wait state
Input Buffer and Output Buffer	2 wait states	1 wait state
Bus Interface Register: CLC , NDIC1 to NDIC4 , MSIC1 to MSIC4 , INT0SRC , INT1SRC , TINT0SRC , TINT0SRC , NDAT0SRC , NDAT1SRC , MBSC0SRC , MBSC1SRC .	1 wait states	0 wait state
ERAY Kernel Register	2 wait states	1 wait state

21.9.7 E-Ray Register Address Map

The E-Ray register map shown in **Figure 38**.

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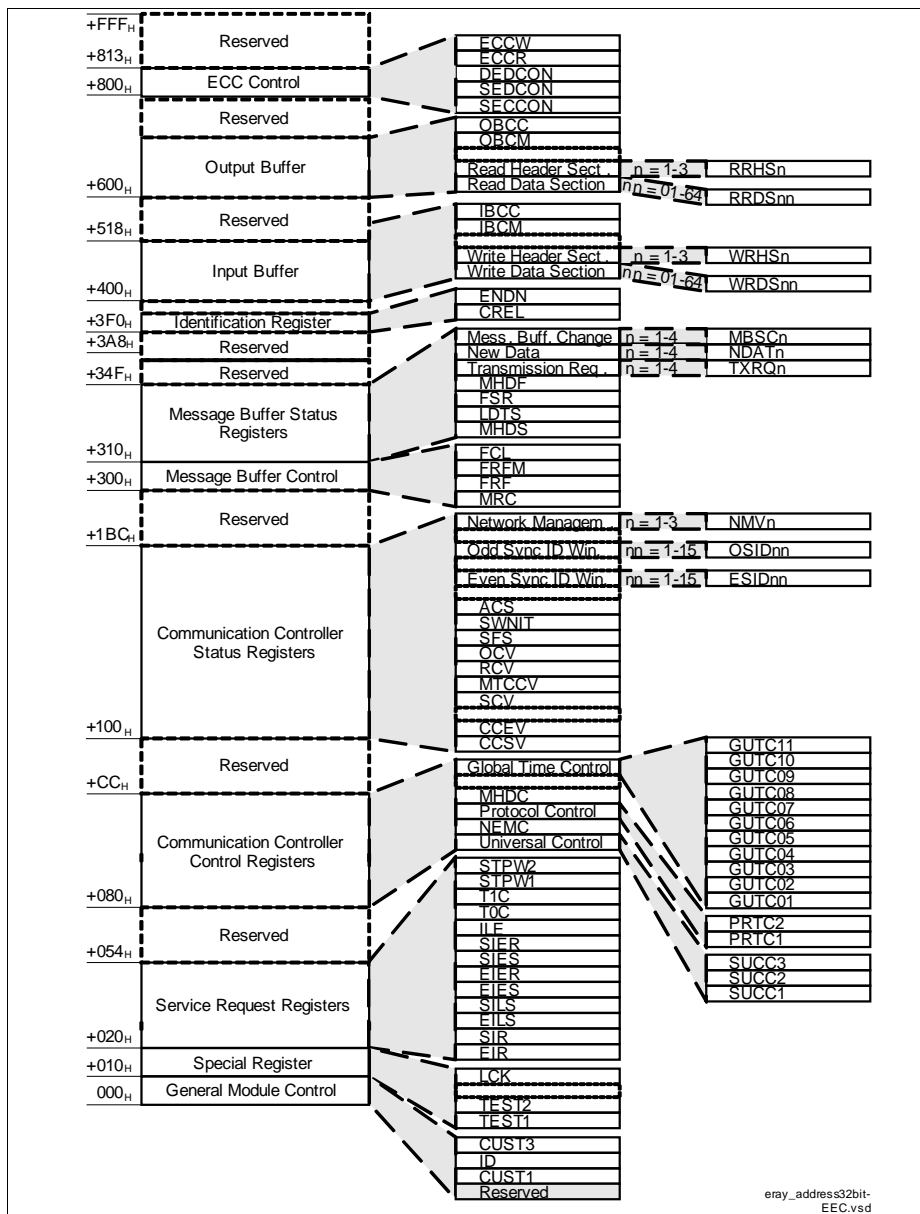


Figure 38 E-Ray Register Map

22 Micro Link Interface (MLI)

This chapter describes the Micro Link Interface module and the MLI protocol. It contains the following sections:

- Functional description of the MLI (see [Page 22-2](#))
- Module kernel description (see [Page 22-27](#))
- Operation of the MLI module (see [Page 22-69](#))
- MLI kernel register descriptions (see [Page 22-77](#))
- Device implementation-specific descriptions and details (see [Page 22-127](#))

Note: The MLI kernel register names described in [Section 22.3](#) are referenced in the TC1728 User's Manual by the module name prefix "MLIO_" for the MLIO interface.

22.1 Functional Description

This chapter describes the functionality of the MLI interface.

- A general introduction to the interface (see [Page 22-2](#))
- The MLI frame structure for data exchange (see [Page 22-10](#))

22.1.1 General Introduction

The introduction comprises:

- An overview about the MLI (see [Page 22-2](#))
- Naming conventions (see [Page 22-4](#))
- A description of the MLI communication principles (see [Page 22-6](#))

22.1.1.1 MLI Overview

The Micro Link Interface (MLI) is a fast synchronous serial interface to exchange data between microcontrollers or other devices, such as stand-alone peripheral components. [Figure 22-1](#) shows how two microcontrollers are typically connected together via their MLI interfaces.

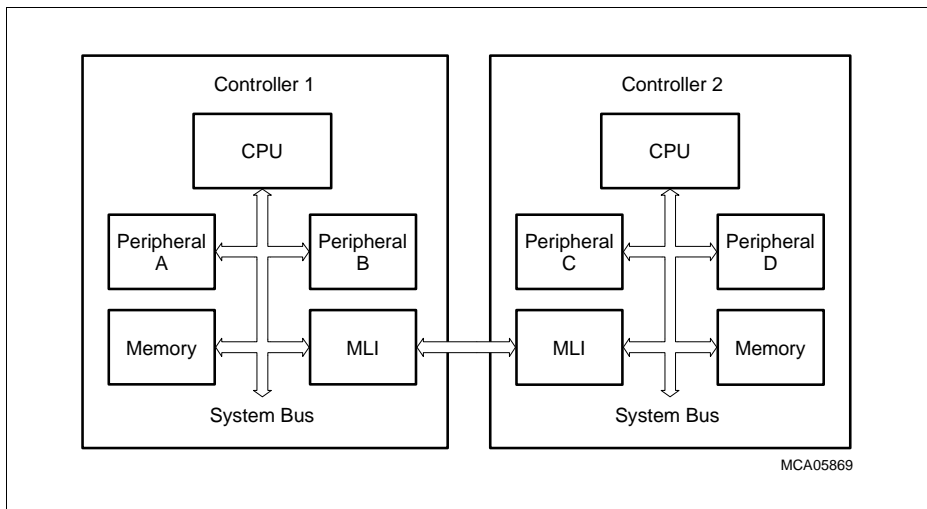


Figure 22-1 Typical Micro Link Interface Connection

Micro Link Interface (MLI)**Features**

- Synchronous serial communication between an MLI transmitter and an MLI receiver
- Different system clock speeds supported in MLI transmitter and MLI receiver due to full handshake protocol (4 lines between a transmitter and a receiver)
- Fully transparent read/write access supported (= remote programming)
- Complete address range of target device available
- Specific frame protocol to transfer commands, addresses and data
- Error detection by parity bit
- 32-bit, 16-bit, or 8-bit data transfers supported
- Programmable baud rates
 - MLI transmitter baud rate: $\max. f_{\text{MLI}}/2$
 - MLI receiver baud rate: $\max. f_{\text{MLI}}$
- Address range protection scheme to block unauthorized accesses
- Multiple receiving devices supported

22.1.1.2 Naming Conventions

Local and Remote Controller

The terms “Local” and “Remote” Controller are assigned to the two partners (microcontrollers or other devices with MLI modules) of a serial MLI connection. The controller with an MLI module initiating a data exchange or a control task is defined as Local Controller. Each data exchange and control task starts with a frame transmission of the Local Controller. The controller with an MLI module reacting on received data exchange requests or executing control tasks is defined as Remote Controller. The terms “Local” and “Remote” are independent of the direction of the information flow (transmission or reception), except for Read Frames (always transmitted by the Local Controller) and Answer Frames (always transmitted by the Remote Controller). A Triggered Command Frame is transferred from the Local to the Remote Controller.

Due to the full duplex operation capability of an MLI module (independent transmitter and receiver), each microcontroller with an MLI module is able to operate as a Local Controller (e.g. for data transmission) as well as a Remote Controller (e.g. for data reception) at the same time.

Transmitting and Receiving Controller

The terms “transmitting” and “receiving” controller are referring to the direction of the information flow. These terms are independent from the terms “Local” and “Remote”. For example, the initialization of a bidirectional MLI connection between two controllers (or between a controller and a stand-alone device) is always controlled and initiated by one controller (named Local), although during this phase, both MLI participants can transmit and receive frames.

Due to the full duplex operation capability of the MLI module (independent transmitter and receiver), each microcontroller with an MLI module is able to operate as a transmitting controller as well as a receiving controller at the same time.

Transfer Window

A Transfer Window is an address space in the address map of the transmitting controller. Transfer Windows are typically assigned to a fixed address space (base address and size). The Transfer Windows are the logical data inputs for the MLI transmitter. Data write actions via MLI are initiated by a write access to a Transfer Window, whereas data read actions are started by a read access from a Transfer Window.

Each MLI module supports up to four independent Transfer Windows, one for each pipe. In the implementation of a specific device, a Transfer Window can appear at several locations in the address map. Here, each Transfer Window can be accessed at two different address ranges with two different window sizes (one 64 Kbyte and one 8 Kbyte area for each Transfer Window), leading to:

- Four Small Transfer Windows STW with 8 Kbyte address range each and

Micro Link Interface (MLI)

- Four Large Transfer Windows LTW with 64 Kbyte address range each

Remote Window

A Remote Window is an area in the address space of the receiving controller. Remote Window parameters (base address and size) of the receiving controller are programmable by the transmitting microcontroller by MLI transfers, independently for each pipe. Each Remote Window of a receiving controller is related to specific Transfer Window of the transmitting controller.

The Remote Windows are the logical data outputs of the MLI receiver. If enabled, the MLI module can automatically execute the requested data transfer to/from the defined address location in the Remote Window. If the automatic data handling is disabled, the offset and the data are available in the MLI receiver registers and have to be handled by software. Remote windows can not be accessed by read or write accesses by software of the Remote Controller (either the data is automatically transferred or it is located in receiver registers).

Pipe

A pipe defines the logical connection between a Transfer Window in the transmitting controller and the associated Remote Window in the receiving controller. The MLI protocol supports four independent pipes.

Frame

A frame is a contiguous set of bits forming a message sent by an MLI transmitter to an MLI receiver.

A **Normal Frame** is a frame used for data exchange between a transmitting and a receiving controller (read request and write data from a Local Controller to a Remote Controller, as well as the answer to a read request back to the Local Controller). Base address copy frames are also considered as Normal Frames.

A **Command Frame** contains information about the receiver setting or triggers actions in the MLI receiver.

A **Triggered Command Frame** is generated under hardware control and can be used to transfer interrupt or service requests between the MLI participants.

Offset

The offset is an address distance relative to the base address of the Transfer Window in the transmitting controller and the base address of the Remote Window in the receiving controller. For example, a write access to the 10th byte of the Transfer Window is transferred to a write to the 10th byte of the Remote Window.

The offset of a write access to a Transfer Window is also called write offset, whereas a read offset is related to a read access from a Transfer Window.

22.1.1.3 MLI Communication Principles

The communication principle of the MLI modules allows data to be transferred between a Local and a Remote Controller without intervention of a CPU in the Remote Controller. Data transfers are always triggered in the Local Controller by read or write operations to an address location in a Transfer Window. All control tasks, address and data transmissions that are required for the data transfer/request between Local and Remote Controller can be handled autonomously by the two connected MLI modules.

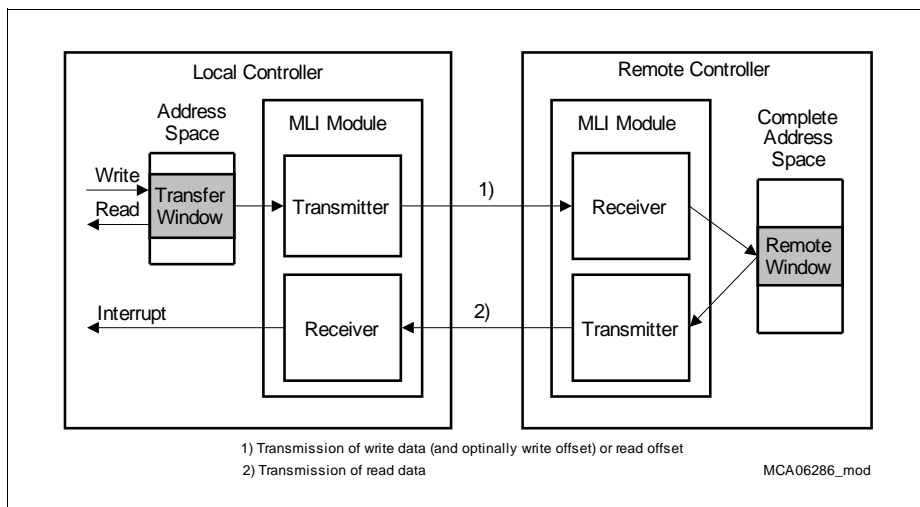


Figure 22-2 MLI Communication Principles

Write Access to a Transfer Window

A write access to a location within a Transfer Window of the transmitting (Local) controller is detected by the MLI transmitter. This detection initiates a transfer of the data that has been written to the Transfer Window together with the write offset to the MLI of the receiving controller. The receiving controller stores the data internally and can also automatically place the data in the Remote Window of the receiving controller (at the address location defined by the write offset plus the base address).

Read Access from a Transfer Window

A read access from a location of a Transfer Window in the Local Controller is detected by the MLI transmitter and delivers dummy data. This detection initiates a transfer of the read offset from the Local microcontroller to the MLI receiver to request data from the Remote Controller. This data can be automatically read or prepared by a CPU in the Remote Controller. When the requested data is available in the Remote Controller, it is

Micro Link Interface (MLI)

introduced into the data stream back to the Local Controller (Answer Frame). Then, the CPU in the Local Controller is informed by an MLI event that the requested data is now available and can be read.

Transfer Window Organization

Figure 22-3 shows an example of the organization of Transfer Windows and Remote Windows with a possible assignment in Local and Remote Controller. Each of the four pipes assigns one Transfer Window to one Remote Window with its base address and window size. For reasons of simplicity, a pipe to a Remote Window is only shown either from a LTW or from a STW, although each Transfer Window can be accessed at both address locations, its LTW and its STW.

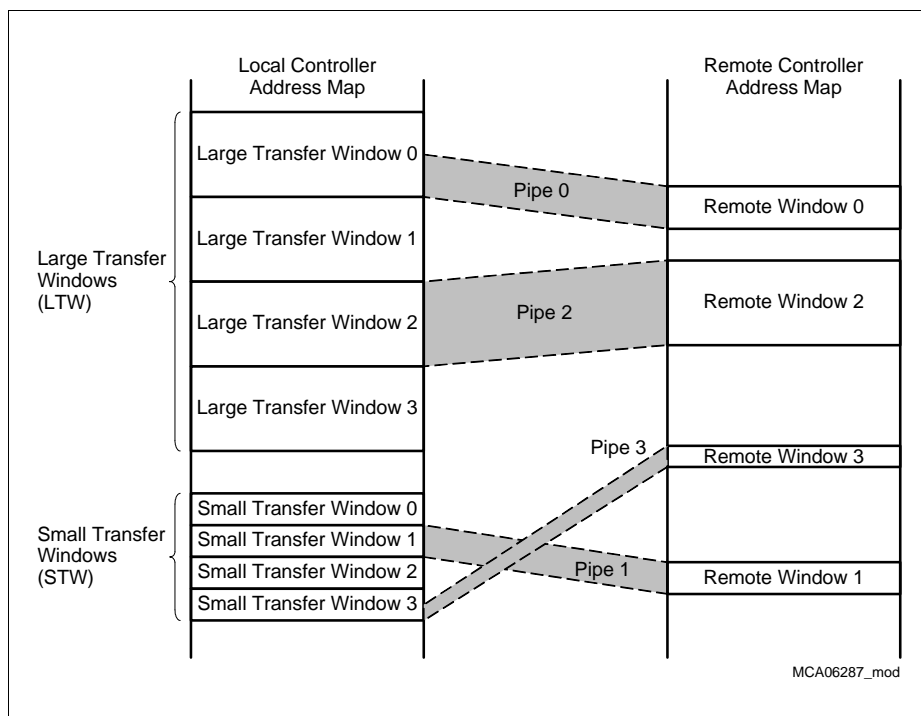


Figure 22-3 Transfer/Remote Window Assignment Example

During initialization of the pipes, base addresses and sizes of the Remote Windows are transmitted from the Local Controller to the Remote Controller. In the example of **Figure 22-3**, pipe 1 and pipe 2 cover the full range of their Transfer and Remote

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Windows. The ranges of the Remote Windows of pipe 0 and pipe 3 are sub-ranges of the related Transfer Windows.

The location of a Transfer Window (base address and size) in the Local Controller is always fixed in a specific product device. Remote windows can be freely moved and located within the address space of the receiving controller. They are used to overlay address ranges of peripheral modules or internal memories.

Remote Window Address Generation

Figure 22-4 shows the generation of the Remote Window address ranges, with fixed base address part and additional variable address part. The variable address part is determined by the available address area for each Remote Window (also named buffer size, value of BS_x = buffer size for Remote Window x indicates how many address bits are variable, defining the available address range).

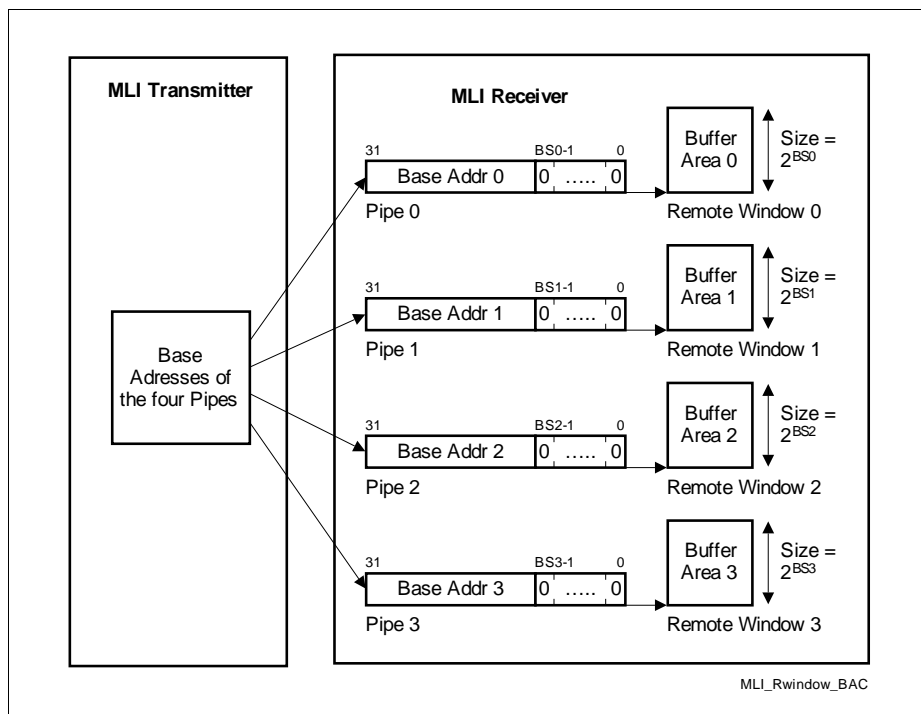


Figure 22-4 Base Address Definition of Remote Windows

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Figure 22-5 shows the generation of the complete Remote Window address without address prediction. The variable address part can be transferred as offset by a write or a Read Frame, or it can be predicted in case of regular address modifications, whereas the fixed part of the address is defined by the upper bits of the base address. In case of address prediction, the variable address part is internally calculated and taken as lower address bits of the target address (the upper address bits are given by the Remote Window's base address).

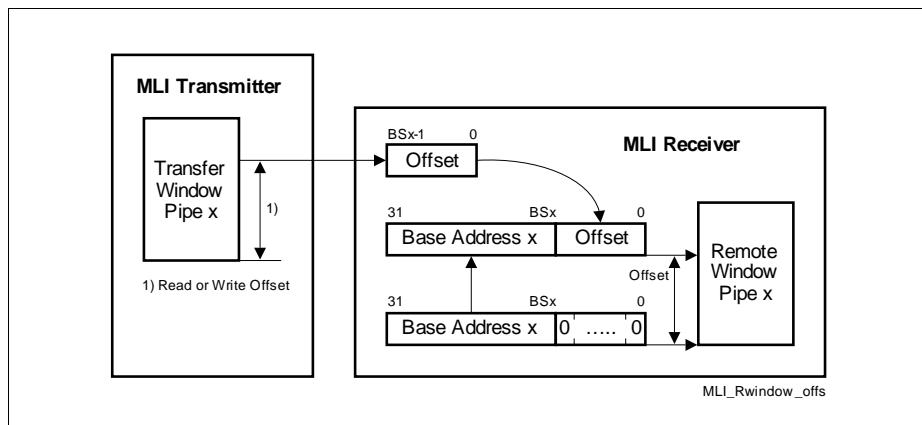


Figure 22-5 Remote Window Address Generation without Address Prediction

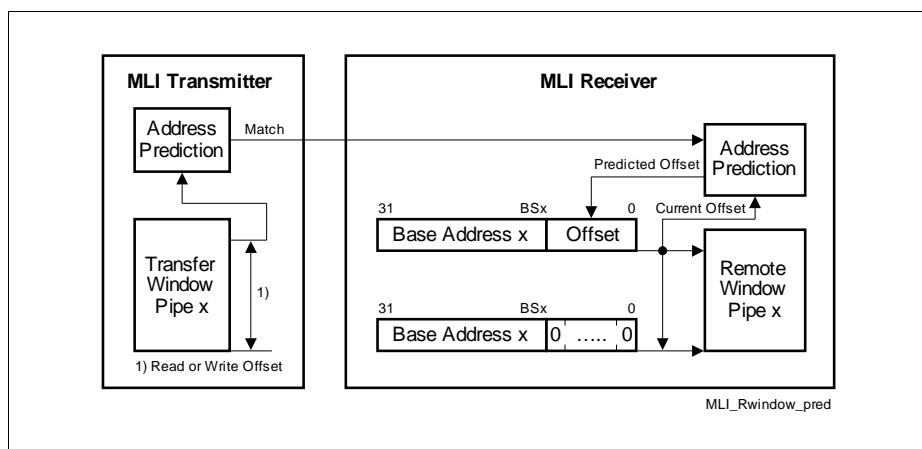


Figure 22-6 Remote Window Address Generation with Address Prediction

Micro Link Interface (MLI)

22.1.2 MLI Frame Structure

A frame is a message sent by an MLI transmitter to an MLI receiver. Depending on the desired behavior, different frame types exist:

- Copy Base Address Frame to define location and size of a Remote Window (see [Page 22-12](#))
- Write Offset and Data Frame to transmit the write offset and the write data (see [Page 22-13](#))
- Optimized Write Frame to transmit write data without write offset in case of an address prediction match (see [Page 22-14](#))
- Discrete Read Frame to transmit read request with the read offset (see [Page 22-15](#))
- Optimized Read Frame to transmit the read request without read offset in case of an address prediction match (see [Page 22-16](#))
- Command Frame to transmit a command, e.g. setup information or MLI service request generation (see [Page 22-17](#))
- Answer Frame to transmit the data previously requested by a Read Frame (see [Page 22-18](#))

The local/remote structure of an MLI connection between two microcontrollers requires a transmitter unit and a receiver unit in both MLI modules (local and remote) for communication.

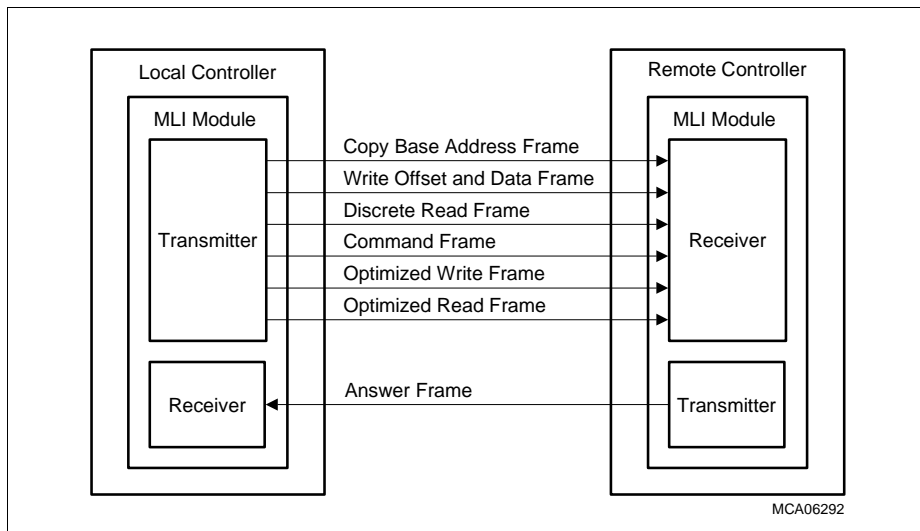


Figure 22-7 Logic Frame Assignment to Local/Remote Controller

22.1.2.1 General Frame Layout

The general layout of a frame is shown in [Figure 22-8](#). It contains the following parts:

- A frame starts with a 4-bit header field that contains a 2-bit frame code (FC) and a 2-bit pipe number (PN).
- The data field can contain address, data, or control information. The width of the data field depends on the frame type.
- The frame is terminated by a parity bit (P) with even parity (see [Page 22-26](#)), calculated over header and data field bits.

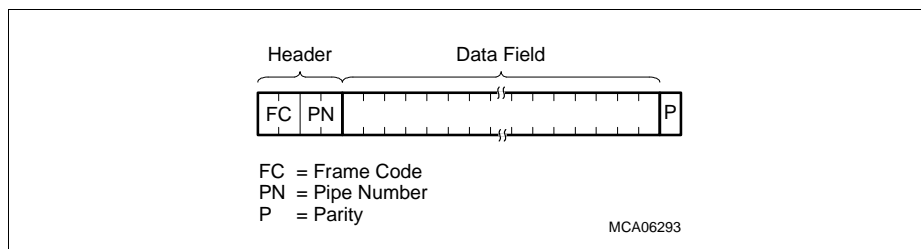


Figure 22-8 General Frame Layout

The frame code (FC) determines the frame type of the transmitted frame. The pipe number (PN) indicates the pipe that is related to the frame content (the value of PN is defined as 00_B for pipe 0, 01_B for pipe 1, 10_B for pipe 2, and 11_B for pipe 3).

The FC parameter is coded according to [Table 22-1](#). If more than one frame type is defined with the same frame code value (see FC = 01_H, 10_H or 11_H), the width of the received frame defines the type. The value given by m in the table below represents the number of address bits transferred as offset (defined by the buffer size BSx of the Remote Window x).

Table 22-1 Frame Code Definition

Frame Code FC	Frame Type	Data Field Width [bits]	Description see
00 _B	Copy Base Address Frame	32	Page 22-12
01 _B	Write Offset and Data Frame	8+m, 16+m, or 32+m	Page 22-13
	Discrete Read Frame	2+m	Page 22-15
10 _B	Command Frame	4	Page 22-17
	Answer Frame	8, 16, or 32	Page 22-18
11 _B	Optimized Write Frame	8, 16, or 32	Page 22-14
	Optimized Read Frame	2	Page 22-16

22.1.2.2 Copy Base Address Frame

With a Copy Base Address Frame, the two parameters of a Remote Window are transferred from the transmitting controller to the receiving controller to initialize or to redirect the Remote Window.

The Copy Base Address Frame contains the following parts:

- **Header:**
The header starts with frame code FC = 00_B followed by the pipe number PN of the pipe targeted by the transmitted base address bits and the size code.
- **Remote Window address location:**
The 28 most significant bits of the 32-bit base address bits can be programmed by the transmitting controller (the 4 LSBs are considered as 0). The base address of a Remote Window has to be aligned to its size, e.g. a window of 1 Kbyte has to start at 1Kbyte address boundaries.
- **Remote Window size:**
The size is defined by the 4-bit coded buffer size BS. The maximum size is 64 Kbytes.
- **Parity bit P**

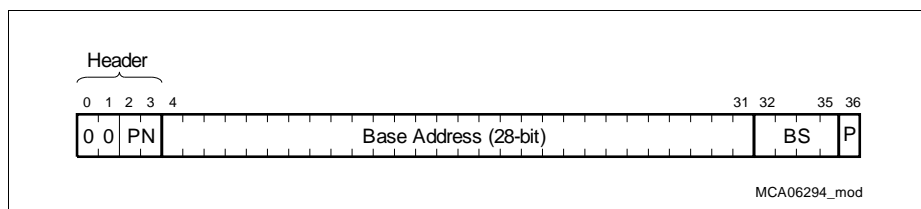


Figure 22-9 Copy Base Address Frame

Table 22-2 BS Coding

Buffer Size Code BS	Remote Window Size (also named Buffer Size)	Number m of Offset Bits
0000 _B	2 bytes	m = 1
0001 _B	4 bytes	m = 2
...
1110 _B	32 Kbytes	m = 15
1111 _B	64 Kbytes	m = 16

More details about the Copy Base Address Frame handling of the MLI module are described on [Page 22-28](#).

22.1.2.3 Write Offset and Data Frame

A Write Offset and Data Frame is used by the transmitting controller to send an address offset and data to the receiving controller. This frame is initiated by a write operation to one of the Transfer Windows in the transmitting controller.

The Write Offset and Data Frame contains the following parts:

- Header:
The header starts with frame code $FC = 01_B$ followed by the pipe number PN of the Transfer Window that has been the target of the write operation.
- m-Bits of write offset:
These bits define the write offset. The value of m depends on the size of the Remote Window, defined by the Copy Base Address Frame ($m = 1-16$).
- Write data field:
The write data field can be 8-bit, 16-bit, or 32-bit wide, depending on the data width of the write access to the Transfer Window.
- Parity bit P

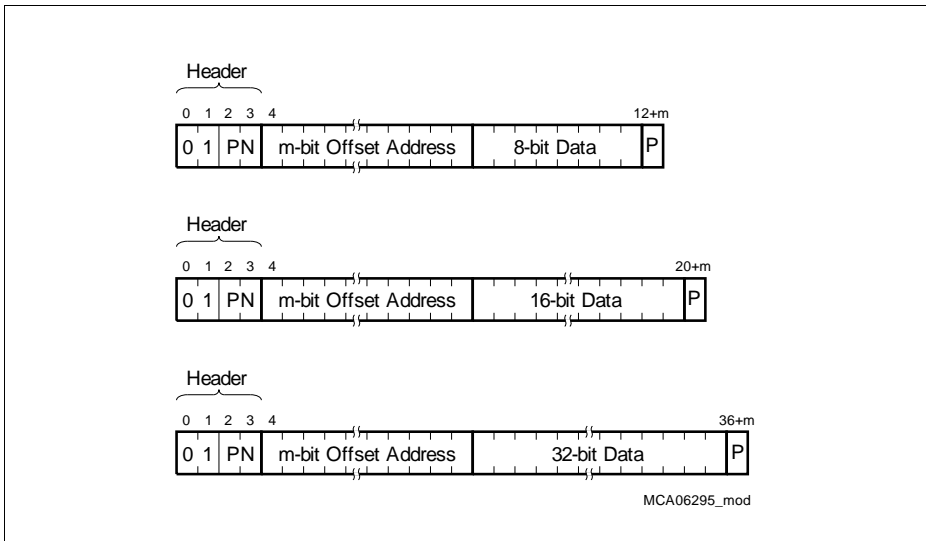


Figure 22-10 Write Offset and Data Frame

More details about the Write Offset and Data Frame handling of the MLI module are provided on [Page 22-30](#).

22.1.2.4 Optimized Write Frame

An Optimized Write Frame is used by the transmitting controller to send 8-bit, 16-bit, or 32-bit wide data to the receiving controller. This frame is initiated by a write operation to one of the Transfer Windows in the transmitting controller. In contrast to a Write Offset and Data Frame, no write offset is transmitted because the offset address for the write data can be predicted and calculated by the receiving controller. An Optimized Write Frame allows a higher data bandwidth than Write Offset and Data Frames, because they are shorter. An optimized frame is only possible if the predicted address matches with the actually written one.

The Optimized Write Frame contains the following parts:

- Header:
The header starts with frame code FC = 11_B followed by the pipe number PN of the Transfer Window that has been the target of the write operation.
- Write data field:
The write data field can be 8-bit, 16-bit, or 32-bit wide, depending on the data width of the write access to the Transfer Window.
- Parity bit P

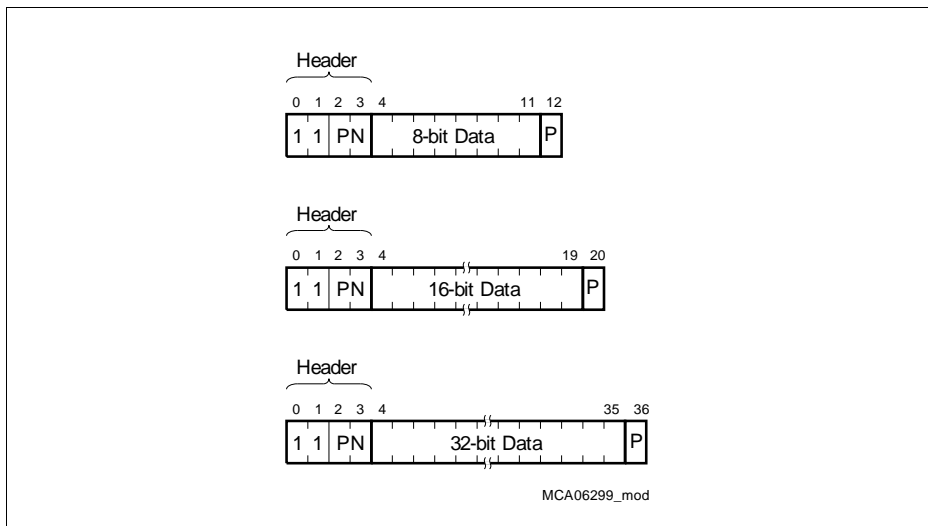


Figure 22-11 Optimized Write Frame

More details about the Optimized Write Frame handling of the MLI module are provided on [Page 22-30](#).

22.1.2.5 Discrete Read Frame

A Discrete Read Frame is used by the Local Controller to request data to be read from the Remote Window in the Remote Controller. If the data is available, the Remote Controller typically responds to this request by sending an Answer Frame with the requested read data back to the Local Controller.

The Discrete Read Frame contains the following parts:

- Header:
The header starts with frame code $FC = 01_B$ followed by the pipe number PN of the Transfer Window that has been the target of the read operation.
- m-Bits of write offset:
These bits define the read offset. The value of m depends on the size of the Remote Window, defined by the Copy Base Address Frame ($m = 1-16$).
- Data Width DW:
The data width DW indicates if the read from the Transfer Window was a 8-bit, 16-bit, or 32-bit read action. It defines how many bytes have to be delivered to the Local Controller by the Answer Frame.
- Parity bit P

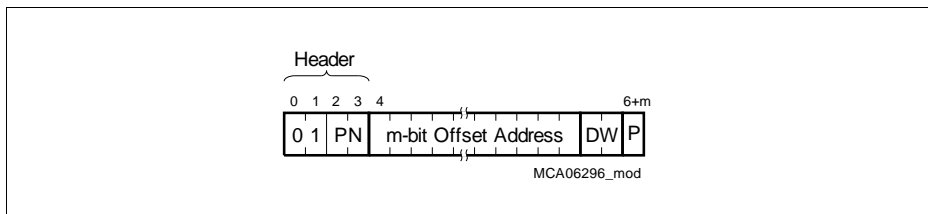


Figure 22-12 Discrete Read Frame

Table 22-3 Data Width DW Coding

Data Width DW	Number of Data Bits to be transferred
00 _B	8-bit read access
01 _B	16-bit read access
10 _B	32-bit read access
11 _B	reserved for future use

More details about the Discrete Read Frame handling of the MLI module are provided on [Page 22-34](#).

22.1.2.6 Optimized Read Frame

An Optimized Read Frame is used by the Local Controller to request 8-bit, 16-bit, or 32-bit wide data from the Remote Controller without sending any offset address. The address for the requested data can be predicted and calculated by the MLI receiver of the Remote Controller.

The Optimized Read Frame contains the following parts:

- Header:
The header starts with frame code $FC = 11_B$ followed by the pipe number PN of the Transfer Window that has been the target of the read operation.
- Data Width DW:
The data width DW indicates if the read from the Transfer Window was a 8-bit, 16-bit, or 32-bit read action. It defines how many bytes have to be delivered to the Local Controller by the Answer Frame. Same coding as for the Discrete Read Frame.
- Parity bit P

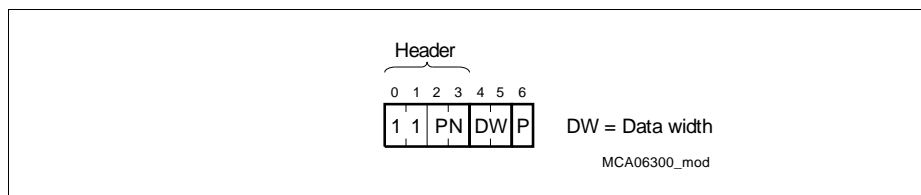


Figure 22-13 Optimized Read Frame

More details about the Optimized Read Frame handling of the MLI module are provided on [Page 22-30](#).

22.1.2.7 Command Frame

The transmitting controller is able to initiate control actions to be executed by the receiving controller by sending a Command Frame.

The Command Frame contains the following parts:

- Header:
The header starts with frame code FC = 10_B followed by the pipe number PN. The pipe number defines the type of command to be executed.
- Command Code CMD:
Pipe number PN and a 4-bit CMD field are used for command coding. The command coding of some control actions is fixed, but free programmable software commands can also be defined (with PN = 11_B). The coding of the command bit field is pipe-specific and depends on the transmitted pipe number x.
- Parity bit P

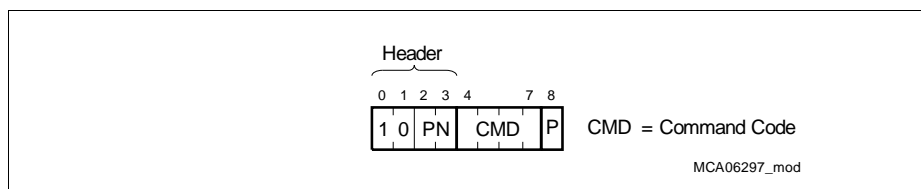


Figure 22-14 Command Frame

Table 22-4 PN for Command Coding

Pipe Number PN	Command Type
00 _B	Activate MLI service request or other control signal(s) of the receiving controller. The definition which signal becomes activated is defined by CMD. The usage of these lines depends on the implementation.
01 _B	Define delay for parity error indication in the receiving controller. The delay in RCLK cycles is defined by the value of CMD.
10 _B	Control of internal functions of the receiving controller. The value of CMD indicates which function is controlled. The coding of CMD and the control mechanisms depend on the implementation.
11 _B	Freely programmable software command.

More details about the Command Frame handling of the MLI module are provided on [Page 22-41](#).

22.1.2.8 Answer Frame

An Answer Frame is used by the Remote Controller to send 8-bit, 16-bit, or 32-bit wide data to the Local Controller. The Answer Frame is the only frame that is transmitted within a logic Local/Remote Controller assignment from the Remote Controller to the Local Controller. It is the answer to a Discrete Read Frame or an Optimized Read Frame that has been sent by the Local Controller to request data from the Remote Controller.

The Answer Frame contains the following parts:

- Header:
The header starts with frame code FC = 10_B followed by the pipe number PN. The value of PN is taken from the Read Frame that has triggered the Answer Frame.
- Read data field:
The read data field can be 8-bit, 16-bit, or 32-bit wide, depending on the data width requested by the Read Frame that triggered the Answer Frame.
- Parity bit P

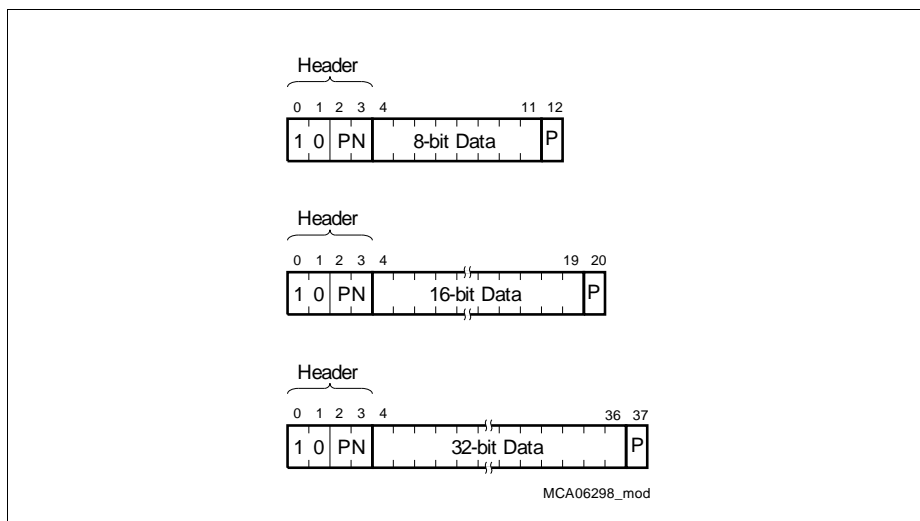


Figure 22-15 Answer Frame

More details about the Answer Frame handling of the MLI module are provided on [Page 22-39](#).

22.1.3 Handshake Description

The description of the transmitter/receiver signal handshaking refers to an MLI connection between an MLI transmitter and an MLI receiver. MLI module transmitter I/O signals are indicated with prefix “T” and MLI receiver I/O signals are indicated with the prefix “R”. The 4-line MLI bus between a transmitter and a receiver outside the controllers uses signal names without any prefix.

In order to lay emphasis where a signal is generated or sampled, actions taken by the transmitter are described referring to signals with the prefix “T”, whereas receiver actions are referring to signals with the prefix “R”.

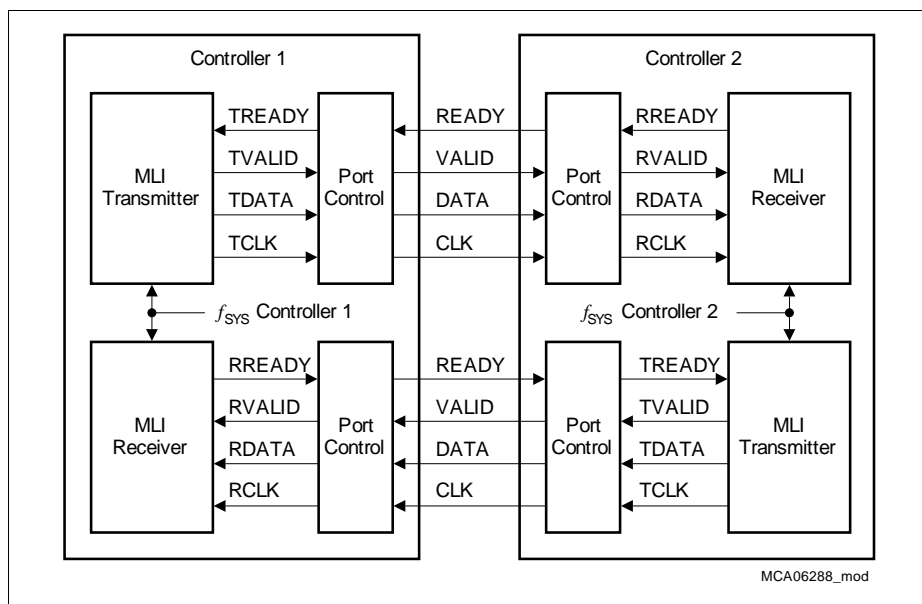


Figure 22-16 Transmitter/Receiver Signal Definitions

The MLI connection allows high data rates and, at the same time, supports significant signal propagation delays between the transmitter and the receiver. As shown in [Figure 22-16](#), each output signal passes through the port stage, reaches the physical interface line between the MLI modules, enters via an input stage and can be finally evaluated. All these steps introduce an accumulating propagation delay. In standard synchronous serial connections (such as SPI), this delay limits the reachable baud rate to a few Mbit/s (closed-loop delay problem). In order to support higher baud rates than a standard SPI, the MLI protocol is based on a full handshake (READY-VALID) to deal with propagation delays in the range of some shift clock cycles and to avoid the closed-loop delay limitations of an SPI connection.

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In a full handshake, each edge of the handshake signals has a defined meaning and the sequence of edges is clearly specified.

As a result, the propagation delays do not directly limit the MLI baud rate. Therefore, the points in time when a signal is generated, when it is visible on the physical interface line, or when it is evaluated have to be considered independently. This is done by defining 3 different names for a signal, referring to the 3 significant locations:

- The place where it is generated, also in relation to the generation clock edge
- The physical interface line where it can be observed
- The place where it is evaluated, also in relation to the evaluation clock edge

If a Local Controller should be connected to more than one Remote Controller, the transmitter signals CLK and DATA can be used as broadcast signals (parallel connection to the Remote Controllers), whereas the handshake signals VALID and READY have to be established as independent signal pairs for each device. As a result, a Local Controller only needs one CLK and one DATA output, but an individual set of READY and VALID handshake signals for each Remote Controller. Please note that Read Frames and Answer Frames are based on an established connection between a Local and a Remote Controller (because the Answer Frame is the only frame sent back to the Local Controller). Therefore, switching between several Remote Controllers can only be done while no read request is pending in the Local Controller. If no Read Frames are used by the Local Controller, frames can be sent out in parallel to all Remote Controllers if their READY signals are all respected.

If a Remote Controller should be connected to several Local Controllers, it may have several DATA and CLK inputs in addition to the READY-VALID signal sets. Please note that an active switching of a Remote Controller between several Local Controllers requires that all Local Controllers have the information which connection is active. In any case, switching between Local and Remote Controllers is not allowed while frame transmission is in progress.

22.1.3.1 Handshake Signals

The synchronous serial frame transfer from an MLI transmitter to an MLI receiver is based on the following 4 signals (the MLI protocol only defines the signal transitions, but neither the signaling level nor the driver characteristics):

- **Shift clock CLK:**
This signal is used as serial shift clock that is generated by the transmitter during the complete frame transfer (TVALID is active) and until the end of ready delay time. Signal TCLK can also be generated while no frame is transferred. In this case, the receiving controller can use the incoming RCLK receiver signal as base for its internal clock generation.
The transmitter signals are always referring to the rising edge of TCLK, so TREADY is sampled and the output signals TDATA and TVALID are changing with the rising edge of TCLK.
The MLI receiver actions refer to the falling edges of its RCLK input. The receiver samples the RVALID and RDATA signals and outputs its RREADY line with the falling edges of RCLK.
- **Shift data DATA:**
This signal represents the transmit data TDATA transferred from the MLI transmitter to the MLI receiver input RDATA. Changes on transmitter side take place with rising edges of TCLK, whereas sampling on the receiver side takes place with falling edges of RCLK.
- **Transmitter valid handshake VALID:**
This signal indicates the start and the end of each frame. It is active (1-level) during a frame transmission and passive (0-level) while no frame is transferred. Changes of TVALID on transmitter side take place with rising edges of TCLK, whereas sampling of RVALID on the receiver side takes place with falling edges of RCLK.
An activation of TVALID to start a new frame can only take place if TREADY is 1.
- **Receiver ready handshake READY:**
This signal indicates that the receiver is ready for a data transfer. Additionally, this line is used to indicate reception errors (parity error indication). Changes of RREADY on receiver side take place with falling edges of RCLK, whereas sampling of TREADY on the transmitter side takes place with rising edges of TCLK.

22.1.3.2 Error-free Handshake

A transmission can be started by an MLI transmitter when the MLI receiver is ready to receive data indicated by RREADY = 1 by the receiver. When the MLI transmitter detects TREADY = 1 and starts its transmission, TVALID is asserted to 1 level while a frame transfer is in progress. When the MLI receiver has detected the 0-to-1 transition of the RVALID signal it will de-assert RREADY back to 0 (transmission start acknowledged by receiver). At the end of the frame transmission, the MLI transmitter also de-asserts signal TVALID back to 0 and checks if the TREADY signal is at 0 level,

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too. This check is used as life-sign of the receiver and the MLI transmitter can detect whether the receiver is able to react in-time to the transmitter actions (see also [Page 22-23](#)).

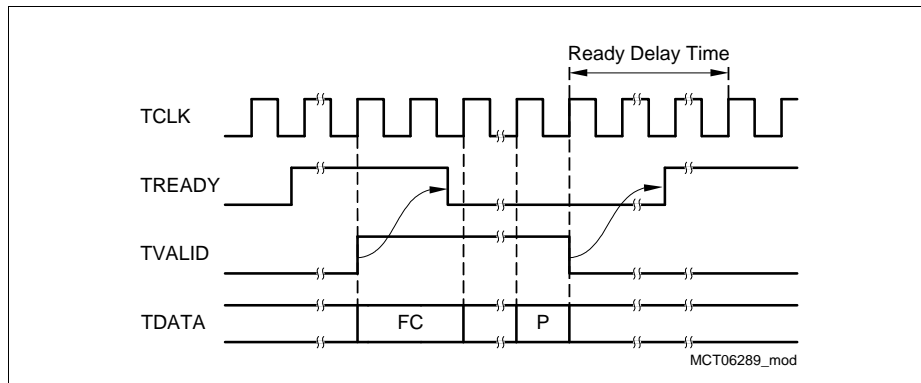


Figure 22-17 MLI Handshake without Error Indication

22.1.3.3 Ready Delay Time

In order to support significant propagation delays, the handshake signal TREADY is evaluated with respect to TVALID and TCLK in an time interval called Ready Delay Time after the end of the frame (see [Figure 22-17](#)). The length of the Ready Delay Time is programmable, defining the size of the time interval.

When a transmission is finished (RVALID becomes 0), the MLI receiver checks the received frame for correct reception (parity error). If no parity error has been detected, the MLI receiver asserts its RREADY signal again to 1 to indicate the correct reception with the next falling edge of RCLK. The MLI transmitter checks its TREADY input with each rising edge of TCLK after TVALID has become 0 and increments a counter. This counter is started from 0 at the end of a frame transmission (TVALID becomes 0) and counts TCLK periods (Ready Delay Time Counter). If the condition TREADY = 1 is detected before the programmed Ready Delay Time has elapsed, the MLI receiver has indicated a frame reception without parity error to the MLI transmitter. In this case, a new frame transmission can be started. The transfer handshake signalling without a parity error indication is shown in [Figure 22-17](#).

[Figure 22-18](#) shows the transfer handshake if a parity error condition has been detected by the MLI receiver and indicated to the MLI transmitter. In this case, the receiver waits a programmable number of RCLK clock cycles before setting RREADY to 1. If the TREADY = 1 condition is detected by the transmitter after the ready delay has elapsed, a parity error has been indicated by the MLI receiver. In this case, it is assumed that the MLI receiver has detected a frame with a parity error and has discarded the frame. The

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transmitter automatically sends the last frame again after a parity error indication. Optionally, this MLI event can activate a service request output.

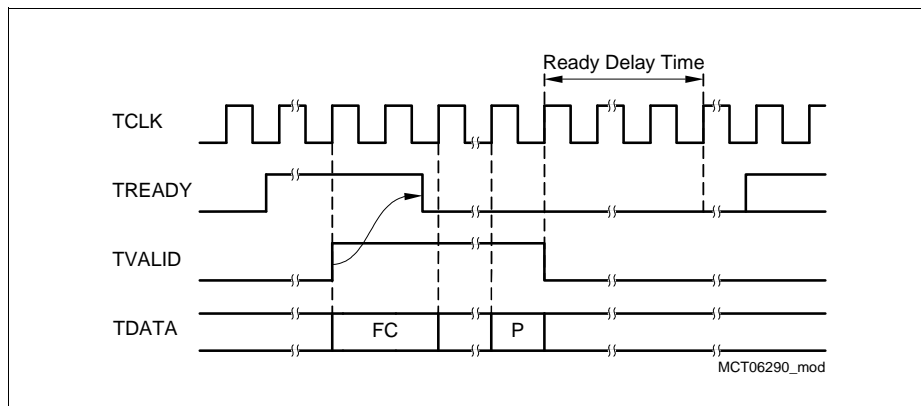


Figure 22-18 MLI Handshake with Parity Error Indication

22.1.3.4 Non-Acknowledge Error

A transmitter of an MLI module is able to detect an inoperable receiver by analyzing the handshake signal TREADY. After TVALID has been asserted to 1, the transmitter checks the receiver's acknowledge (TREADY becoming 0). A Non-Acknowledge error condition is detected by the transmitter when at the end of a frame transmission the TREADY signal is still at high level (TREADY = 1 when TVALID becomes 0). **Figure 22-19** shows the Non-Acknowledge error case. In this case, the transmitter automatically sends the last frame again. Optionally, this MLI event can activate a service request output.

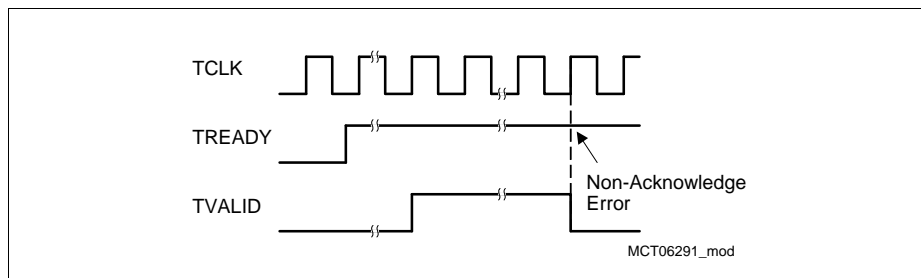


Figure 22-19 Non-Acknowledge Error

22.1.3.5 Signal Timing

Figure 22-20 shows the MLI timing requirements.

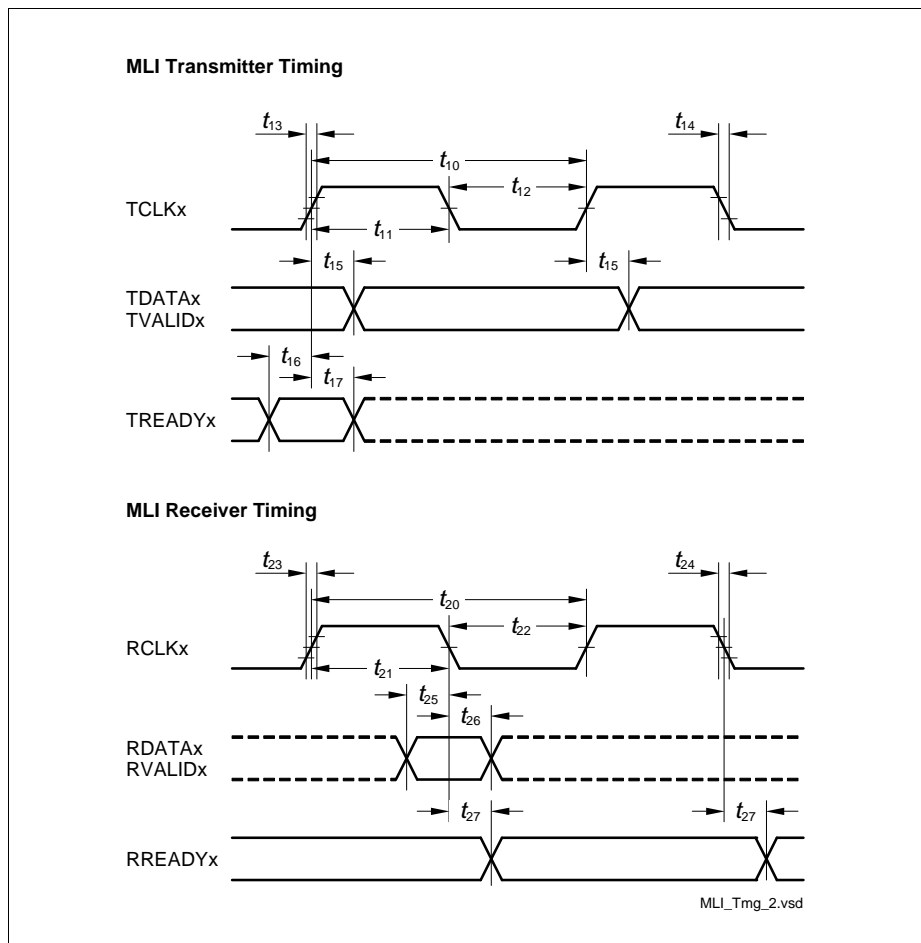


Figure 22-20 Signal Timing

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The transmitter output signals TDATA and TVALIDx might have a certain delay to the transmitter clock output TCLK due to on-chip variation of the driver stages and differences in the propagation delays. The transmitter TREADY input can change at any point in time compared to TCLK. In order to ensure stability, it is internally synchronized to f_{MLI} of the transmitter before being evaluated with the rising TCLK edge when TVALID becomes 0. For the calculation of the signal propagation time, these 2 clock cycles have to be taken into account.

The transmitter input TREADYx has to be stable a certain time before TVALID becomes low, referring to the rising edge of TCLK when TVALID becomes low. If at this point in time, TREADYx is detected at a high level, a Non-Acknowledge error is signaled. The same timing relation has to be considered at the end of the ready delay time for the parity error detection.

The receiver input signals are handled asynchronously based on the RCLK signal. The synchronization to the receiver's system clock f_{SYS} is done in the receiver logic. The input signals RDATA and RVALID have to respect a certain setup and hold time at the falling edge of RCLK.

22.1.4 Parity Generation

For parity generation, the number of transmitted bits with the value of 1 is counted over the header and the complete data field of a frame. For even parity, the parity bit is set if the result of a modulo-2 division of the elaborated number is 1. For error-free MLI traffic, even parity generation and checking is defined.

More details about the parity handling of the MLI module are provided on [Page 22-44](#).

22.1.5 Address Prediction

An address prediction method can be enabled to support communication between MLI transmitter and MLI receiver without sending address offset information in the frames. This feature reduces the required bandwidth for MLI communication. Both of the communication partners, MLI transmitter and receiver are able to detect regular offset differences of consecutive window accesses to the same window. The address prediction mechanism working independently for each pipe, different prediction values can be handled in parallel for the different pipes.

The MLI transmitter can compare the offset of each Transfer Window read or write access with the offset of the previous access to the same Transfer Window. Between the accesses to a specific window, other windows can be accessed without disturbing the prediction. Bigger offset differences than 512 bytes are not supported by the address prediction.

If the offset differences are identical in at least two accesses to the same Transfer Window, an address prediction is possible and Optimized Write Frames or Optimized Read Frames can be sent to the receiving controller for this pipe. If the offset difference of a next access to this Transfer Window does not match the former ones (predicted offset), address prediction is not possible. In this case, a Normal Frame for writing or reading (Write Offset and Data Frame or Discrete Read Frame) is started.

The identical address prediction mechanism is built in the receiver. As a result, the receiver can elaborate the original offset value in the transmitter when receiving an optimized frame for any pipe.

More details about the address prediction mechanism of the MLI module are provided on [Page 22-47](#).

22.2 Module Kernel Description

This chapter describes how the MLI protocol is implemented in the MLI module and how frame handling can be done by software, comprising:

- The frame handling (see [Page 22-27](#))
- The general MLI features (see [Page 22-44](#))
- The interface signals (see [Page 22-51](#))
- The general MLI service request structure (see [Page 22-57](#))
- The MLI transmitter events (see [Page 22-59](#))
- The MLI receiver events (see [Page 22-62](#))
- The baud rate generation (see [Page 22-67](#))

22.2.1 Frame Handling

The frame handling is based on receiver and transmitter registers and the Transfer Windows. Depending on the type of access to the Transfer Windows, different actions take place inside the MLI module. Please refer to the following pages for the handling of:

- Copy Base Address Frame (see [Page 22-28](#))
- Data Frames (see [Page 22-30](#))
- Read Frames (see [Page 22-34](#))
- Answer Frame (see [Page 22-39](#))
- Command Frame (see [Page 22-41](#))

22.2.1.1 Copy Base Address Frame

A Copy Base Address Frame defines the location and the size of a Remote Window.

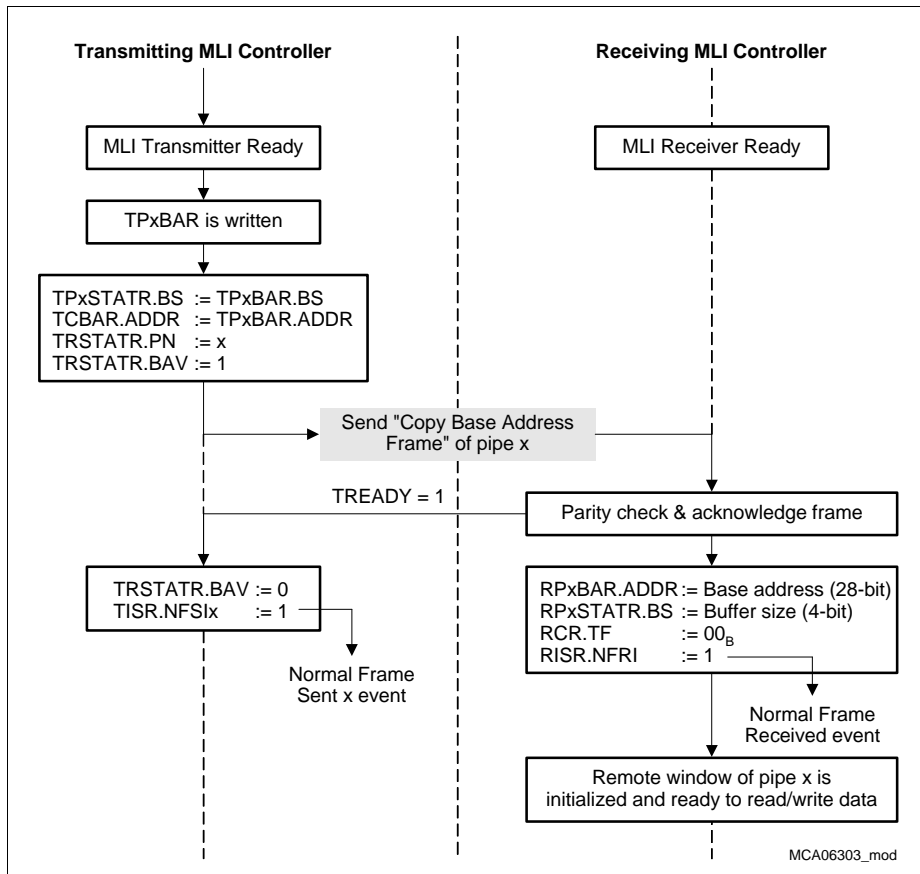


Figure 22-21 Copy Base Address Frame Flow

Transmitting Controller

The transmission of a Copy Base Address Frame is started after a transmitter pipe x base address registers TPxBAR has been written, triggering the following actions for pipe x.

- Bit field TPxBAR.BS (4-bit coded buffer size) is loaded into bit field TPxSTATR.BS
- Bit field TPxBAR.ADDR (28 most significant base address bits) is loaded into bit field TCBAR.ADDR.

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- Status bit field TRSTATR.PN is updated with the pipe number x (for example $x = 2$ when TP2BAR has been written).
- Status flag TRSTATR.BAV (base address valid) becomes set.
- The transmission of a Copy Base Address Frame with the two buffered parameters TCBAR.ADDR and TPxSTATR.BS is started for pipe x (if the corresponding pipe is idle and TREADY = 1).
- Status flag TRSTATR.BAV (in the transmitting controller) is cleared after the Copy Base Address Frame has been finished and correctly acknowledged by the MLI receiver of the receiving controller.
- MLI event status flag TISR.NFSIx (Normal Frame Sent event in pipe x) is set and a service request output is activated if enabled by TIER.NFSIE x = 1.

Note: After the transfer of a Copy Base Address Frame the optimized mode will be suppressed automatically by hardware for the next two data frames. This ensures a correct offset prediction afterwards.

Receiving Controller

When a Copy Base Address Frame for pipe x has been received correctly and acknowledged, the following actions are executed in the MLI receiver.

- The received 28 most significant address bits are written into the receiver pipe x base address register bit field RPxBAR.ADDR. This bit field determines the base address of the pipe x Remote Window.
- The received 4-bit coded buffer size is stored in the receiver pipe x status register bit field RPxSTATR.BS. This bit field determines the number of variable address bits for the offset (determining the size) of the pipe x Remote Window.
- The information about the received frame type (= 00_B for Copy Base Address Frame) is written into the receiver control register bit field RCR.TF.
- MLI event status flag RISR.NFRI (Normal Frame Received event) is set and a service request output is activated if enabled by RIER.NFRIE = 01_B or 10_B.

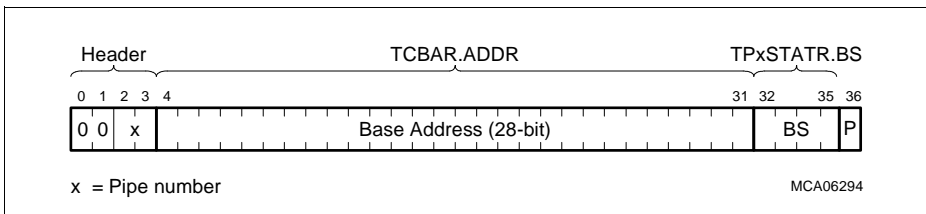


Figure 22-22 Copy Base Address Frame

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22.2.1.2 Write/Data Frames

Write Frames (also named Data Frames) transmit the write data and optionally the write offset.

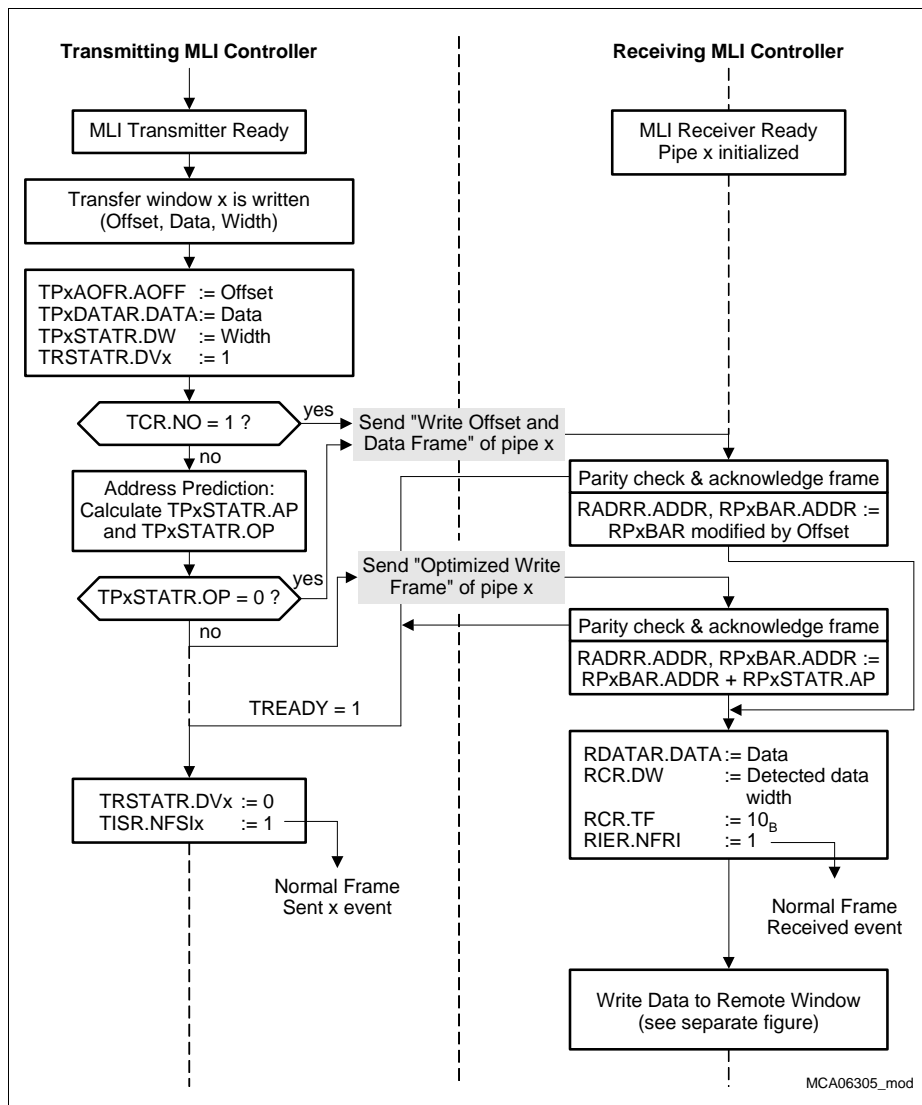


Figure 22-23 Write Frame Flow

Transmitting Controller

In the transmitting controller, a write operation to a location within a Transfer Window delivers the address, the data, and the data size to the transmitter and triggers the following actions in the MLI transmitter.

- The 16 least significant address bits of the Transfer Window write access are stored in TPxAOFR.AOFF as write offset address. In case of a an access to a Small Transfer Window, also 16 bits are stored, but the higher bits are not taken into account assuming the buffer size is configured correctly (see [Page 22-105](#)).
- The data of the write access to the Transfer Window is stored in TPxDATAR.DATA.
- The data width of the write access to the Transfer Window (8-bit, 16-bit, or 32-bit) is stored in bit field TPxSTATR.DW.
- Status flag TRSTATR.DVx (data valid) is set, indicating that the pipe contains valid data for transmission.
- If the address prediction method is disabled (TCR.NO = 1), the transmission of a Write Offset and Data Frame is started as soon as the MLI transmitter is idle, no higher priority frames are pending, and TREADY = 1.
If the address prediction method is enabled (TCR.NO = 0), a Write Offset and Data Frame is started only if an address prediction is not possible (indicated by TPxSTATR.OP = 0). If TPxSTATR.OP = 1, an address prediction is possible in the MLI transmitter (and the MLI receiver) and an Optimized Write Frame can be started. The address prediction method used is described on [Page 22-47](#).
- Status flag TRSTATR.DVx is cleared by hardware and MLI event status flag TISR.NFSIx (Normal Frame Sent event in pipe x) is set (and a service request output is activated if enabled by TIER.NFSIEx = 1) after the Write Frame has been finished and correctly acknowledged by the MLI receiver.

The number m of offset address bits that are transmitted at a Write Offset and Data Frame is determined by the size of the Remote Window in the receiving controller that has been previously initialized by the transmission of a Copy Base Address Frame. Parameter m is referring to bit field TPxSTATR.BS (and RPxSTATR.BS) and can be in the range of 1 to 16 bits.

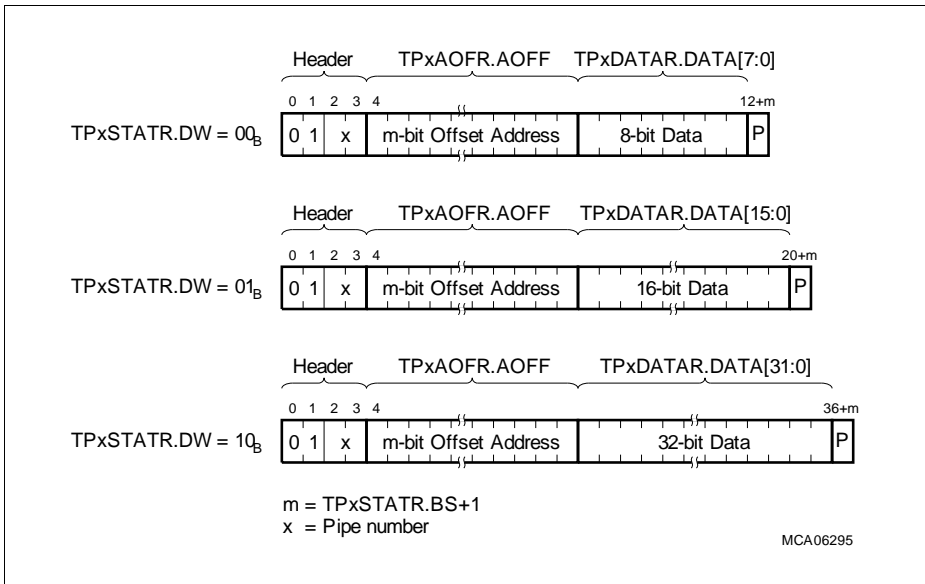


Figure 22-24 Write Offset and Data Frame

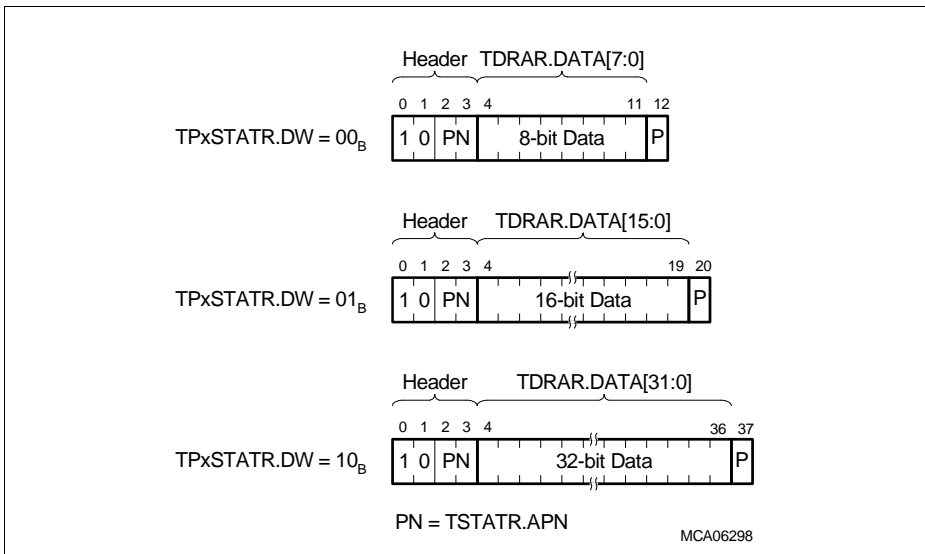


Figure 22-25 Optimized Write Frame

Receiving Controller

After a Write Frame has been received correctly and acknowledged, the following actions are automatically executed in the MLI receiver:

- In the case of a Write Offset and Data Frame:
The result of the internal address prediction is not taken into account. The received offset address is added to the base address of the pipe x Remote Window and the result is stored in RPxBAR.ADDR. It is also stored in RADDR.ADDR and represents the destination address in the receiving controller where data should be written to.
In the case of an Optimized Write Frame:
The result of the internal address prediction is taken into account. The next address in the receiving controller where data should be written to is calculated by adding the detected receiver address prediction value RPxSTATR.AP to the actual address stored in RPxBAR.ADDR and the result is stored in RPxBAR.ADDR and in RADDR.ADDR.
- The received data is written into the receiver data register RDATAR (right aligned, unused bits are 0).
- The detected data width of the received data is written into bit field RCR.DW.
- The information about the received frame type ($= 10_B$ for a Write Frame) is written into bit field RCR.TF.
- MLI event status flag RISR.NFRI (Normal Frame Received event) is set and an SR output line is activated if enabled by RIER.NFRIE $= 01_B$ or 10_B .

After these actions related to the reception of a Write Frame by the receiving controller, the data that has been received from the transmitting controller is ready to be written into the Remote Window related to the receiving pipe.

This write operation can be executed in two ways:

- RCR.MOD = 0: Automatic Data Mode is disabled.
In this mode, a bus master of the receiving controller, typically a CPU, is informed by a Normal Frame received event RISR.NFRI (a service request output is activated if RIER.NFRIE $= 10_B$) to transfer the received write data from the MLI receiver to the Remote Window. Therefore, it must read the data from RDATAR, together with width RCR.DW and the address stored in RADDR and write it to the indicated address location.
- RCR.MOD = 1: Automatic Data Mode is enabled.
In this mode, the MLI module automatically writes the received write data to the Remote Window. This automatic action is controlled by a move engine block in the MLI receiver. It also sets event status flag RISR.MEI (move engine event when the access is terminated). A service request output is activated if enabled by RIER.MEIE = 1.
The write operation to the Remote Window is executed only if the write address is within an enabled access protection range. If the address range is disabled for the write address, the automatic write action does not take place and event status flag RISR.MPEI (memory protection error) is set and a service request output is activated

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if enabled by $RIER.MPEIE = 1$. In this case, the receiving controller software can analyze the values in $RDATAR$, together with width $RCR.DW$ and the address stored in $RADRR$.

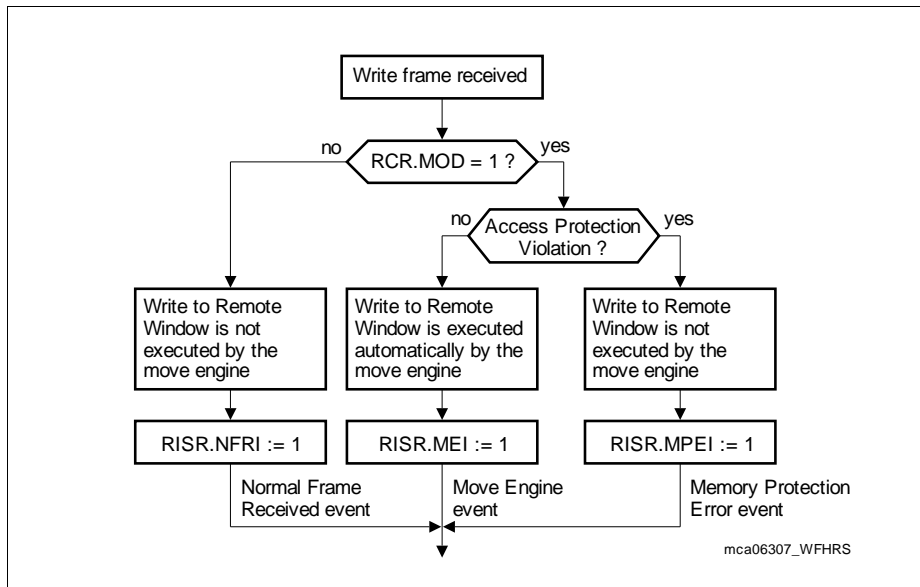


Figure 22-26 Write Frame Handling on Receiving Side

Note: In Automatic Data Mode, Write Frames are leading to a write action executed by the MLI move engine. During the move engine operation, only one more MLI frame can be received (stored in a waiting position to be executed). Then the reception of more frames is blocked by Non-Acknowledge handshake. If the move engine operation is finished, frame execution and reception continue normally. If Automatic Data Mode is disabled, no blocking mechanism has been implemented. The receiving controller software has to take care to deal with the received data before it is overwritten by new incoming frames.

22.2.1.3 Read Frames

Read Frames transmit read request and optionally the read offset from the Local Controller to the Remote Controller.

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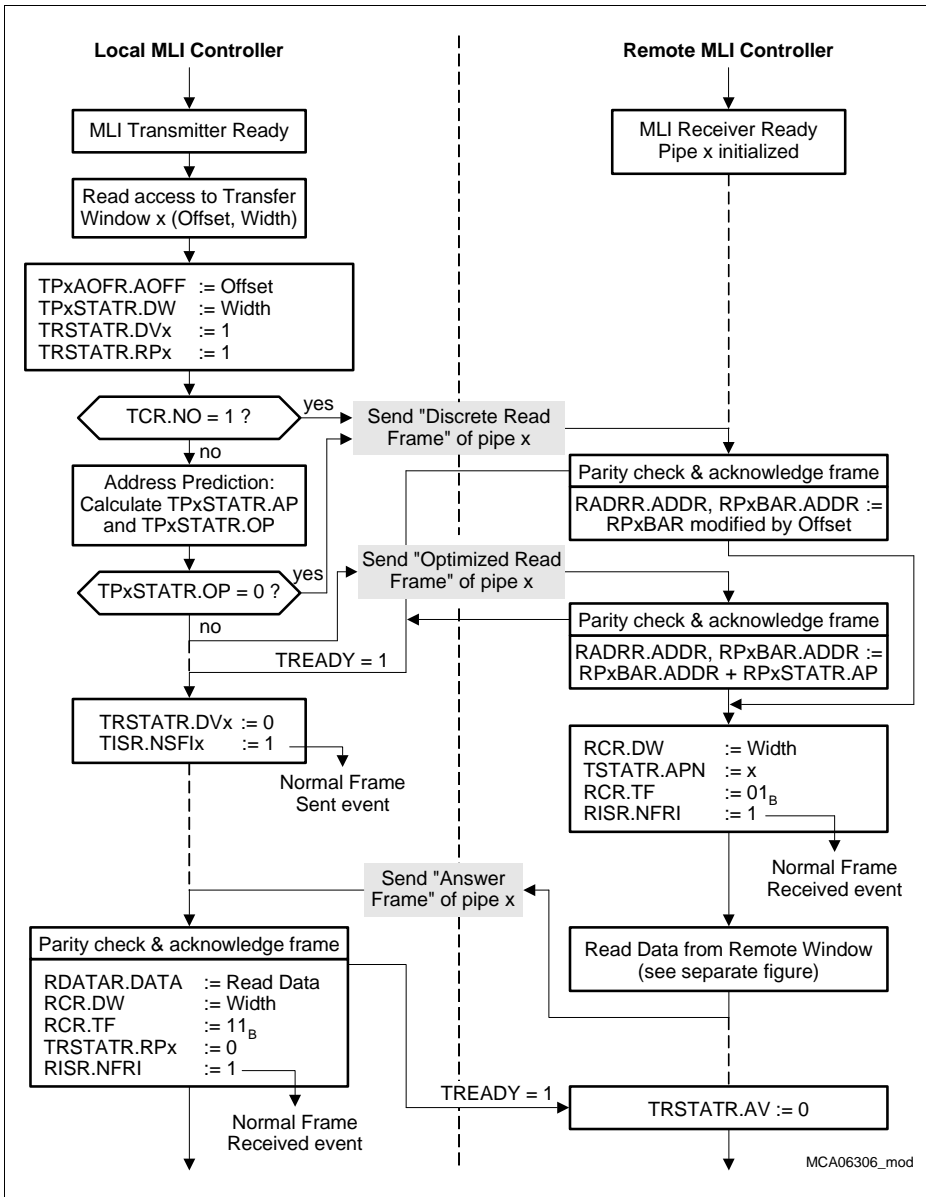


Figure 22-27 Read Frame and Answer Frame Flow

Local Controller

A read operation from a location within a Transfer Window x of the Local Controller delivers a dummy value as result of the read action and triggers the transmission of a Read Frame. The dummy value of the initial read action should be ignored and the software has to wait for the reception of the Answer Frame to get the desired data.

- The 16 least significant address bits of the Transfer Window read access are stored in TPxAOFR.AOFF as read offset address. In case of an access to a Small Transfer Window, also 16 bits are stored, but the higher bits are not taken into account assuming the buffer size is configured correctly (see [Page 22-105](#)).
- The data width of the Transfer Window read access (8-bit, 16-bit, or 32-bit) is stored in bit field TPxSTATR.DW.
- Status flag TRSTATR.DV x (data valid) is set.
- Status flag TRSTATR.RPx (read pending) is set. This bit is cleared by hardware when an Answer Frame has been received correctly.
- If the address prediction method is not enabled (TCR.NO = 1), transmission of a Discrete Read Frame is started. If the address prediction method is enabled (TCR.NO = 0), a Discrete Read Frame is started only if an address prediction is not possible (indicated by TPxSTATR.OP = 0). If TPxSTATR.OP = 1, an address prediction is possible and an Optimized Read Frame is started.
- Status flag TRSTATR.DV x is cleared by hardware and MLI event status flag TISR.NFSIx (Normal Frame Sent event in pipe x) is set (and a service request output is activated if enabled by TIER.NFSIEx = 1) after the Read Frame has been finished and correctly acknowledged by the MLI receiver of the Remote Controller.

The number m of offset address bits that are transmitted at a Discrete Read Frame is determined by the (coded) size of the Remote Window in the Remote Controller that has been previously initialized by the transmission of a Copy Base Address Frame. Parameter m is stored in bit field TPxSTATR.BS (and RPxSTATR.BS) and can be in the range of 1 to 16 bits.

After a completed transmission of a Read Frame, the Local Controller expects the reception of an Answer Frame. The Answer Frame is introduced with the highest priority into the data flow of the transmitter of the Remote Controller.

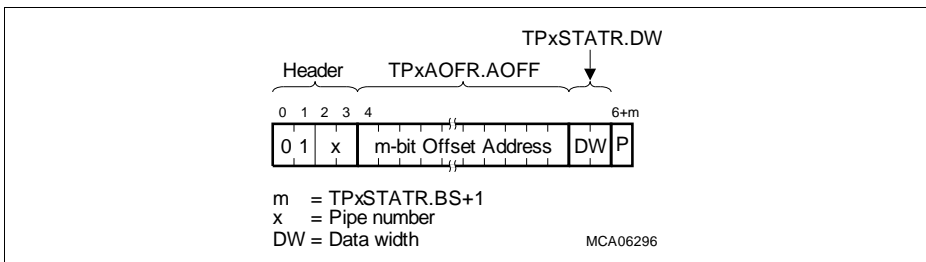


Figure 22-28 Discrete Read Frame

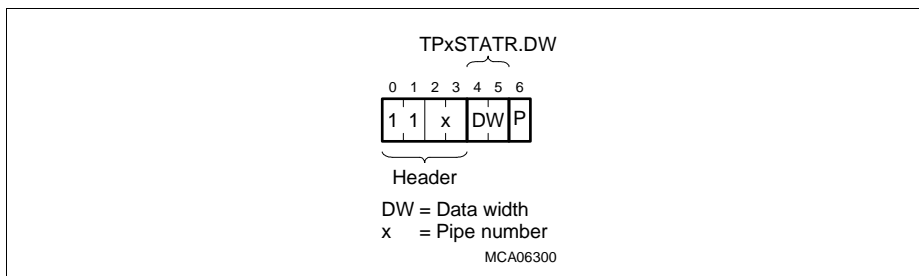


Figure 22-29 Optimized Read Frame

Remote Controller

After a Read Frame has been correctly received and acknowledged, the following actions are executed in the MLI receiver of the Remote Controller:

- In the case of a Discrete Read Frame:

The result of the address prediction is not taken into account. The received offset address is added to the base address of the pipe x Transfer Window (stored in RPxBAR.ADDR). The result of this addition is stored in RADRR.ADDR and also in RPxBAR.ADDR and represents the destination address in the Remote Controller from where data should be read.

- In the case of an Optimized Read Frame:

The result of the address prediction is taken into account. The next address in the Remote Controller where data should be read is calculated by adding the detected receiver address prediction value RPxSTATR.AP to the actual address stored in RPxBAR.ADDR. The result of this addition is stored in RADRR.ADDR and also in RPxBAR.ADDR and represents the destination address in the Remote Controller from where data should be read.

- The transmitted data width DW is written into bit field RCR.DW.
- The information about the received frame type (= 01_B for a Read Frame) is written into bit field RCR.TF.
- MLI event status flag RISR.NFRI (Normal Frame Received event) is set and a service request output is activated if enabled by RIER.NFRIE = 01_B or 10_B.

After correct reception of a Read Frame by the Remote Controller, the data requested by the Local Controller can be read by the Remote Controller and sent back to the Local Controller in form of an Answer Frame.

This read operation can be executed in two ways:

- RCR.MOD = 0:
Automatic Data Mode is disabled. In this mode, a bus master of the Remote Controller, typically a CPU, is informed by a Normal Frame received event to read the requested read data and transfer it to the MLI receiver. Therefore, it must read data

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with width RCR.DW from the address stored in RADRR and write the data into TDRAR.DATA.

- RCR.MOD = 1:

Automatic Data Mode is enabled. In this mode, the move engine of the MLI automatically reads data from the Remote Window and sets event status flag RISR.MEI (move engine access terminated). A service request output is activated if enabled by RIER.MEIE = 1.

The read operation from the Remote Window is executed only if the read address is within an enabled access protection range. If no address range is enabled for the actual read address, the automatic read action is not executed by the move engine, event status flag RISR.MPEI (memory protection error) is set and a service request output is activated if enabled by RIER.MPEIE = 1. In the interrupt handler routine, a bus master (e.g. CPU or PCP) must then take care of the remote window read operation and the data transfer to TDRAR.

- After TDRAR.DATA has been updated, status flag TRSTATR.AV of the Remote Controller is set and the transmission of an Answer Frame is started.

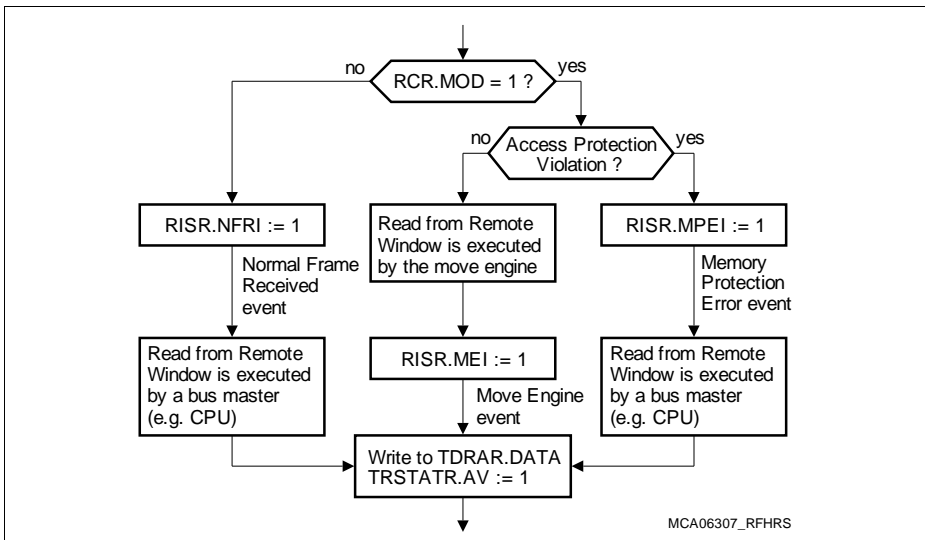


Figure 22-30 Read Frame Handling on Remote Side

Note: In Automatic Data Mode, Read Frames are leading to a read action executed by the MLI move engine. During the move engine operation, only one more MLI frame can be received (stored in a waiting position to be executed). Then the reception of more frames is blocked by a Non-Acknowledge handshake. If the move engine operation is finished, frame execution and reception can continue normally. If Automatic Data Mode is disabled, no blocking mechanism has been

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implemented. The Remote Controller software has to take care to read the received data.

22.2.1.4 Answer Frame

Please note that only one Answer Frame can be handled by the system at a time (no Read Frame request while any TRSTATR.RPx is set). Make sure that not more than one Read Frame is pending at a time. If a Read Frame is not answered by an Answer Frame during a certain time interval, a time-out criterion should be handled in software. The Remote Controller has to take care that no Answer Frame is delivered after the time-out criterion has been detected (e.g. by a software-triggered Command Frame). Do not start a new Read Frame while waiting for an Answer Frame if the time-out criterion has not yet been detected and the Answer Frame has not yet been received. The length of the time-out interval depends on the application and has to be defined accordingly on a case by case base (e.g. the transfer rates between MLI modules, bus architecture, etc. have to be considered). In the case a time-out has been detected, the Local Controller software has to clear the TRSTATR.RPx bit by writing 1 to SCR.CDVx and can start a new Read Frame.

Remote Controller (Receiving the read request)

The Answer Frame is the only frame sent from the Remote Controller back to the Local Controller. The transmitter registers of the Remote Controller are used to generate the Answer Frame.

Every time the transmitter data read answer register TDRAR is written in the Remote Controller, the transmission of an Answer Frame is started and the following actions are triggered.

- Status flag TRSTATR.AV is set to trigger the transmission of an Answer Frame.

The following parameter is transmitted in the data field of the Answer Frame:

- Read data: stored in TDRAR.DATA; data width is determined by TRSTATR.DW.
- Status flag TRSTATR.AV is cleared after the Answer Frame has been finished and correctly acknowledged by the MLI receiver of the Local Controller.

An Answer Frame should be sent through the pipe that has received a read request but there must be only one MLI Transfer Window read access pending on any side of a MLI connection at any time, because the answer mechanism does not contain buffers for multiple Answer Frames.

Local Controller (Transmitting the read request)

If an Answer Frame has been received correctly and acknowledged, the following actions are executed in the MLI receiver of the Local Controller:

- The TRSTATR.RPx flags are cleared.

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- The received data is written into the receiver data register RDATAR.
If 8 data bits are received, they are duplicated to all 4 bytes in RDATAR.
If 16 data bits are received, they are duplicated to both half-words in RDATAR.
- The detected data width of the received data is written into bit field RCR.DW.
- The received Pipe Number x represents the answer Pipe Number and is written into bit field TSTATR.APN.
- The information about the received frame type ($= 11_B$ for an Answer Frame) is written into bit field RCR.TF.
- MLI event status flag RISR.NFRI (Normal Frame Received event) is set and a service request output is activated if enabled by RIER.NFRIE $= 01_B$ or 10_B .
- The content of RADRR becomes invalid.
- The data that has been previously requested from the Remote Controller by a Read Frame is now available in RDATAR and can be read by a bus master (e.g. the CPU) of the Local Controller.
- If an Answer Frame is received while the corresponding TRSTATR.RPx bit is 0, the reception is declared as unintended and a Discarded Read Answer event is generated (see [Page 22-62](#)).

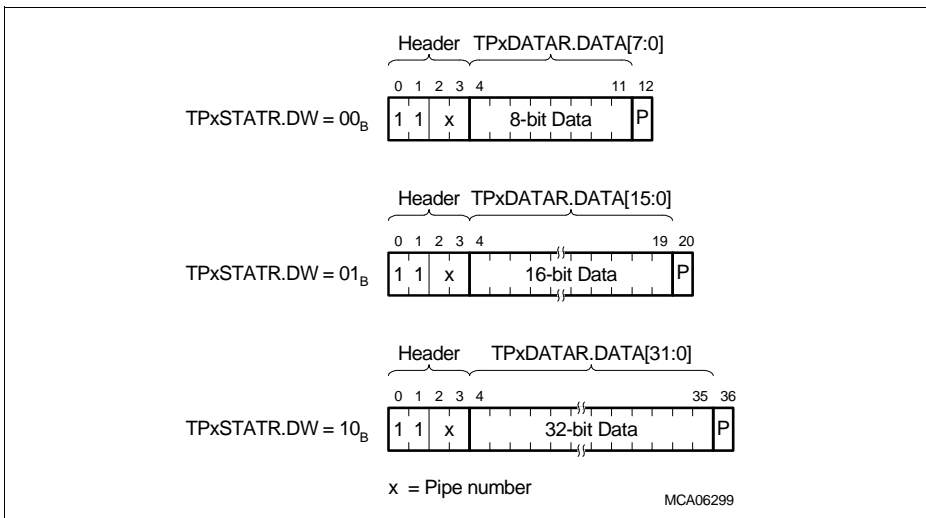


Figure 22-31 Answer Frame

Note: If an Answer Frame has been correctly received in the Local Controller, the Local Controller's software has to read it. As long as at least one byte of this data has not yet been read out, only one more MLI frame can be received (stored in a waiting position to be executed). Then the reception of more frames is blocked by Non-Acknowledge handshake. If the received data has been read out, frame execution and reception continue normally.

22.2.1.5 Command Frame

Command Frames transmit a command (e.g. setup information or service request) from a transmitting controller to a receiving controller.

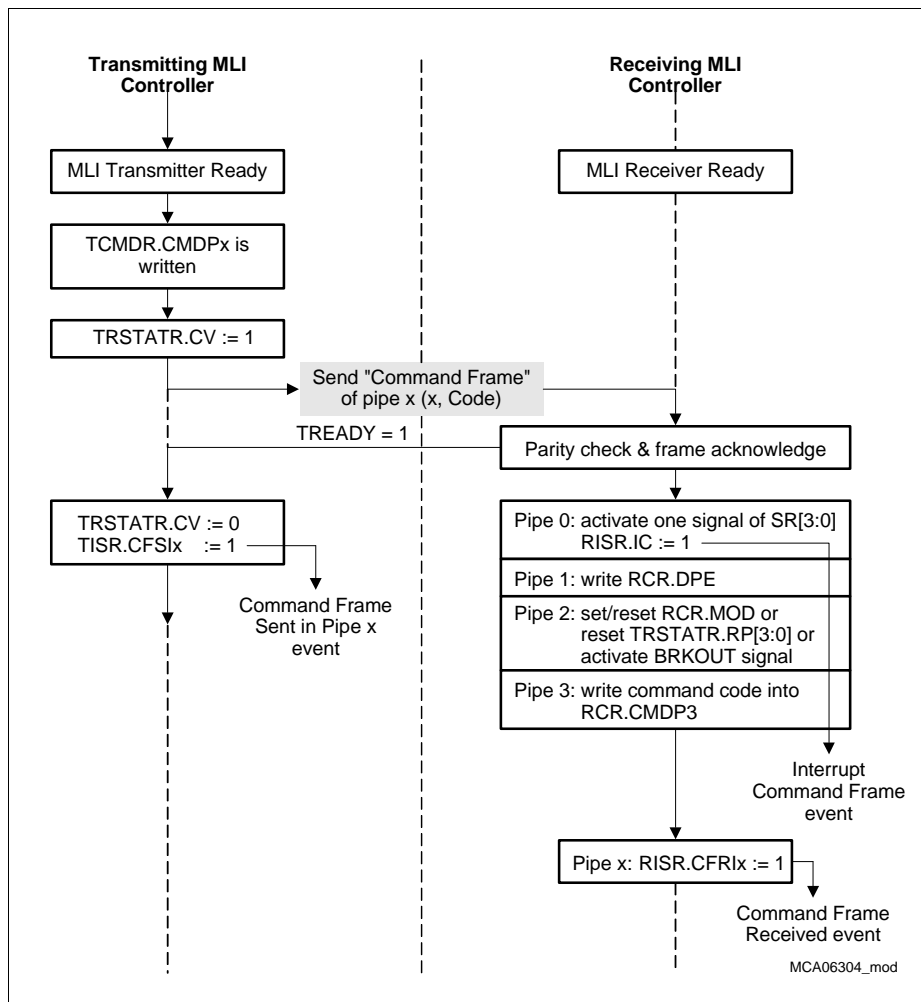


Figure 22-32 Command Frame Transaction Flow

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Transmitting Controller

The transmission of a Command Frame is initiated by writing one of the four pipe x related command code bit fields in register TCMDR.CMDPx, triggering the following actions:

- Status flag TPxSTATR.CVx (command valid) is set and the Command Frame transmission is started using x as pipe number PN and the command code stored in TCMDR.CMDPx as parameters.
- TRSTATR.CVx is cleared after the Command Frame has been finished and correctly acknowledged by the MLI receiver of the Remote Controller.
- MLI event status flag TISR.CFSIx (Command Frame Sent event in pipe x) is set and a service request output is activated if enabled by TIER.CFSIEx = 1.

Receiving Controller

Depending on the pipe x related command code that is transmitted by a Command Frame, different actions are triggered in the receiving controller. [Table 22-5](#) describes the actions that are transmitted by a Command Frame and that cause a specific control task in the MLI receiver.

- The received PN value is checked and the corresponding control actions are executed according to [Table 22-5](#).
- Independent of the received Pipe Number, event status flag RISR.CFRIx (Command Frame Received event in pipe x) is set and a service request output is activated if enabled by RIER.CFRIEx = 1.

If a Command Frame is received for pipe 2 with command code 1111_B, the $\overline{\text{BRKOUT}}$ output signal of the MLI module becomes activated if it is enabled by bit RCR.BEN = 1. If disabled by RCR.BEN = 0, signal $\overline{\text{BRKOUT}}$ will not be activated. The usage of $\overline{\text{BRKOUT}}$ is implementation-specific and can be used, for example, to generate a break condition in the on-chip debug support logic or trigger other functions.

Table 22-5 Command Frame Encoding

PN	CMD	Command Description
00 _B	0001 _B	Activate service request output SR0 of receiving MLI module
	0010 _B	Activate service request output SR1 of receiving MLI module
	0011 _B	Activate service request output SR2 of receiving MLI module
	0100 _B	Activate service request output SR3 of receiving MLI module
	Others	no effect, reserved for future use

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Table 22-5 Command Frame Encoding (cont'd)

PN	CMD	Command Description
01 _B	0000 _B	Set RCR.DPE (delay for parity error indication) in receiving MLI to 0000 _B
	0001 _B	Set RCR.DPE in receiving MLI to 0001 _B
	0010 _B	Set RCR.DPE in receiving MLI to 0010 _B

	1111 _B	Set RCR.DPE in receiving MLI to 1111 _B
10 _B	0001 _B	Enable Automatic Data Mode in receiving MLI (set RCR.MOD = 1)
	0010 _B	Disable Automatic Data Mode in receiving MLI (set RCR.MOD = 0)
	0100 _B	Clear bit TRSTATR.RP0 in receiving MLI
	0101 _B	Clear bit TRSTATR.RP1 in receiving MLI
	0110 _B	Clear bit TRSTATR.RP2 in receiving MLI
	0111 _B	Clear bit TRSTATR.RP3 in receiving MLI
	1111 _B	Generate break output signal $\overline{\text{BRKOUT}}$ in receiving MLI (if enabled by RCR.BEN = 1)
11 _B	others	no effect, reserved for future use
	Any	Free programmable software command, written into bit field RCR.CMDP3 of receiving MLI

22.2.2 General MLI Features

The general MLI features comprise the:

- Parity generation and checking (see [Page 22-44](#))
- Non-Acknowledge error (see [Page 22-47](#))
- Address prediction (see [Page 22-47](#))
- Automatic data transfers (see [Page 22-48](#))
- Access protection (see [Page 22-49](#))
- Triggered Command Frames (see [Page 22-49](#))
- Transmit priority (see [Page 22-50](#))
- Transmission delay (see [Page 22-50](#))

22.2.2.1 Parity Check and Parity Error Indication

For parity generation, the number of transmitted bits with the value of 1 is counted over the header and the complete data field of a frame. For even parity, the parity bit is set if the result of a modulo-2 division of the elaborated number is 1. For odd parity, the parity bit is set if the result of a modulo-2 division of the elaborated number is 0.

For a parity error-free MLI connection, even parity must be selected in the transmitter because the receiver operates only with even parity detection. The capability to select odd parity can be used by the transmitter to force a parity error reply from the receiver during the startup procedure of the MLI connection. This can be used to measure the propagation delay and to optimize the ready delay time (see [Page 22-73](#)).

Note: There is no protection against frames where more than one bit is corrupted (e.g. shortened frames). In such a case, an unpredictable behavior of the MLI module may occur.

Transmitting Controller

The MLI transmitter counts the detected parity error conditions and generates a parity error event if a programmable number (max. 16) of parity error conditions has occurred. A parity error condition is indicated to the transmitter by the receiver after the transmission of a frame (see [Page 22-23](#)). The transmitter parity error condition is detected when the TREADY signal is sampled at low level within a programmable number (TCR.MDP = maximum delay for parity errors) of TCLK clock cycles after TVALID has been de-asserted to low.

If a transmitter parity error condition is detected, the MLI transmitter sets the parity error flag TSTATR.PE and also decreases the maximum parity error counter TCR.MPE by 1. The maximum parity error counter of the transmitter TCR.MPE determines the number of transmit parity error conditions that can be still detected until a transmitter parity error event is generated. If a transmitter parity error condition is detected and TCR.MPE is becoming 0 or while it is 0, a transmitter parity error event is generated by setting bit TISR.PEI (see [Figure 22-40](#) on [Page 22-60](#)) and an SRx output line is activated if

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enabled by $TIER.PEIE = 1$. After a transmitter parity error event occurred, $TCR.MPE$ can be set again by software to a value greater 0001_B . Otherwise, each additional transmitter parity error condition will generate a parity error event.

The transmitter parity error flag $TSTATR.PE$ is cleared by hardware when a correct frame transmission and $TREADY$ has been sampled with 1 within the ready delay time. It can be cleared by software by writing a 1 to bit $SCR.CTPE$. If for example, each transmitter parity error condition should generate a transmitter parity error event, $TCR.MPE$ should be set to 0000_B . The software can check for accumulated parity error conditions by reading $TCR.MPE$ or $TISR.PEI$, for the status of the latest received frame, it can check $TSTATR.PE$.

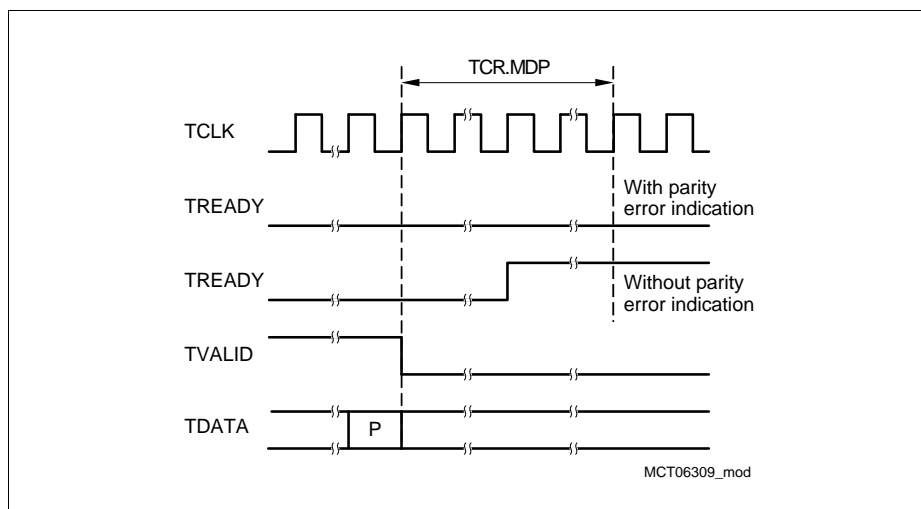


Figure 22-33 Parity Error Indication for the Transmitter

Receiving Controller

The receiver always checks the parity bit of a received frame for even parity. A receiver parity error condition is detected if the received parity bit does not match with the internally calculated one. If no receiver parity error condition is found after the reception of a frame, $RREADY$ is immediately set to 1, otherwise $RREADY$ is kept at 0 until a defined number of $RCLK$ cycles (determined by bit field $RCR.DPE$ = delay for parity error) has been elapsed. Then, $RREADY$ is asserted high.

If a receiver parity error condition is found, the MLI receiver sets the parity error flag $RCR.PE$ and additionally decreases the maximum parity error counter of the receiver $RCR.MPE$ by 1. The maximum parity error counter $RCR.MPE$ determines the number of receiver parity error conditions that can be still detected until a receiver parity error event is generated. If a receiver parity error condition is detected and $RCR.MPE$ is becoming

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0 or while it is already 0, a receiver parity error event is generated by setting bit RISR.PEI (see [Figure 22-44](#) on [Page 22-63](#)) and a service request output is activated if enabled by RIER.PEIE = 1. After a receiver parity error event has occurred, RCR.MPE can set again by software to a value greater 0001_B. If, for example, each receiver parity error condition should generate a receiver parity error event, RCR.MPE can be programmed to 0000_B or 0001_B.

The receiver parity error flag RCR.PE is cleared by hardware if a correct frame transmission has occurred. RCR.PE can be cleared by software by writing a 1 to bit SCR.CRPE.

The receiver parity error flag RCR.PE is cleared by hardware after a correct frame reception. It can be cleared by software by writing a 1 to bit SCR.CRPE. The software can check for accumulated parity error conditions by reading RCR.MPE or RISR.PEI, for the status of the latest received frame, it can check RCR.PE.

The delay for parity error bit field RCR.DPE is a read-only bit field in the receiver that updated by hardware if a Command Frame for pipe 1 is received. With this frame type, the transmitting controller transfers a value for RCR.DPE to the receiving controller during the setup phase of the MLI connection.

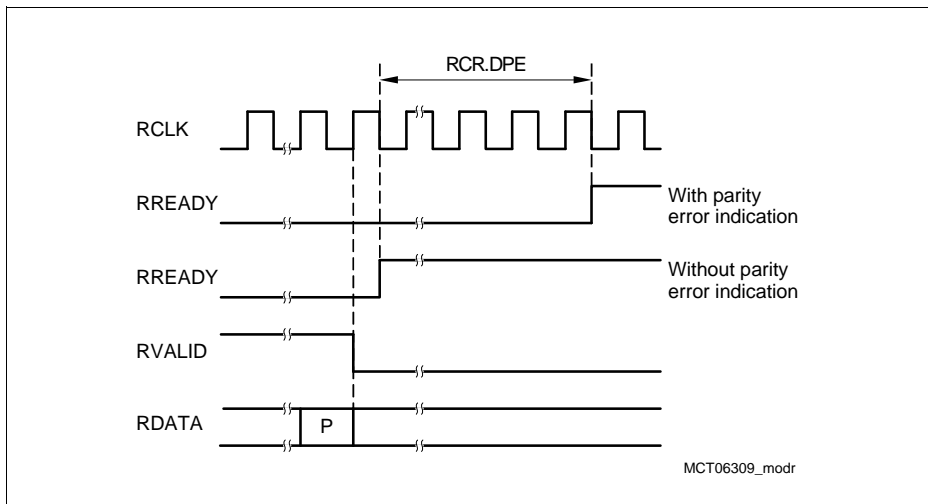


Figure 22-34 Parity Error Indication by the Receiver

22.2.2.2 Non-Acknowledge Error

A Non-Acknowledge error condition is detected by the transmitter when at the end of a frame transmission, the TREADY signal is still at high level (TREADY = 1 when TVALID becomes 0). In this case, the error flag TSTATR.NAE is set and the maximum Non-Acknowledge error counter TCR.MNAE is decremented by 1. If a Non-Acknowledge error condition is detected and TCR.MNAE is becoming 0 or while it is already 0, a time-out event is generated by setting bit TISR.TEI (see [Figure 22-40](#) on [Page 22-60](#)) and an MLI service request is generated if enabled by TIER.TEIE = 1. The Non-Acknowledge error flag TSTATR.NAE is cleared by hardware when a frame transmission has been acknowledged correctly. It can also be cleared by software when writing a 1 to bit SCR.CNAE.

The Non-Acknowledge error counter TCR.MNAE is automatically set to 11_B when a frame has been acknowledged correctly. It can be read and written by software, allowing a limited number of consecutive Non-Acknowledge errors to be defined that can be detected until a time-out error event is generated. If, for example, the first occurrence of a Non-Acknowledge error should lead to a time-out event, bit TCR.MNAE has to be written by software with 00_B or 01_B after each correctly received frame.

22.2.2.3 Address Prediction

An address prediction method can be enabled to support communication between MLI transmitter and MLI receiver without sending address offset information in the frames to optimize the required MLI bandwidth. This feature reduces the required bandwidth for MLI communication. Both communication partners, MLI transmitter and the MLI receiver are able to detect regular offset differences of consecutive window accesses to the same window. The address prediction mechanism working independently for each pipe, different prediction values can be handled in parallel for the different pipes.

Transmitting Controller

If the address prediction method is enabled (TCR.NO = 0), the MLI transmitter compares the offset of each Transfer Window read or write access with the offset of the previous access to the same Transfer Window (stored in TPxAOFR.AOFF). The result of this comparison is stored in two's complement representation in TPxSTATR.AP (limited to 9 bits, otherwise prediction is not possible). Between the accesses to a specific window, other windows can be accessed without disturbing the prediction.

If the offset differences are identical in at least two consecutive accesses to the same Transfer Window, an address prediction is possible (flag TPxSTATR.OP becomes set) and optimized frames can be sent to the receiving controller for this pipe. If the offset difference of a next access to the same Transfer Window does not match the calculated value in TPxSTATR.AP, flag TPxSTATR.OP is cleared and address prediction is not possible. In this case, a Normal Frame for writing or reading (Write Offset and Data Frame or Discrete Read Frame) is started.

Receiving Controller

The MLI receiver operates with an address prediction method equivalent to the MLI transmitter. This means that after receiving at least two consecutive Write Offset and Data Frames and/or Discrete Read Frames that include address information, the MLI receiver is able to follow the address prediction method used by the MLI transmitter. Each received offset is compared in the MLI receiver with the offset of the previously received frame of the same pipe. The result of this comparison is stored in two's complement representation in RPxSTATR.AP (limited 9 bits).

If an optimized frame is received by the MLI receiver, it calculates the next address by adding the value stored in RPxSTATR.AP to the contents of the receiver address register RADRR.

In case of a Write Offset and Data Frame or a Discrete Read Frame (m offset bits), the receiver address registers RADRR and RPxBAR are always loaded with an updated address. This address is calculated by replacing the lowest m bit positions in RPxBAR with the received offset value. In this case, the address delta value stored in RPxSTATR.AP is not taken into account. The programmed size of the Remote Window and the number m of offset bits are given by RPxSTATR.BS. The bit positions RPxBAR[31:m] are kept constant, whereas the bit positions RPxBAR[m-1:0] are replaced.

22.2.2.4 Automatic Data Mode

The MLI module supports automatic data transfers for read or Write Frames without any CPU load in the receiving controller. This feature is based on a move engine block providing the data, the complete address and the data width to an associated bus master on the system bus (see [Figure 22-1](#)). Depending on the implementation, this bus master can be capable of executing the requested data move operations autonomously. The Automatic Data Mode in the receiving controller can be enabled (RCR.MOD = 1) or disabled (RCR.MOD = 0) by software on receiving side or a Command Frame sent by the transmitting controller.

If the Automatic Data Mode is disabled, the receiving controller software has to execute the requested data transfers.

Additionally to the global enable/disable of the automatic mode by RCR.MOD, it is possible to individually exclude address ranges from automatic data transfer by an access protection scheme. The definition of the address ranges depend on the product and has been introduced to support the protection of critical data or modules.

Note: If a device contains the MLI move engine block as the only bus master, automatic mode has to be selected to allow transfers. This could be the case for external peripheral devices without own CPU.

22.2.2.5 Memory Access Protection

The MLI receiver provides a memory access protection logic allowing to exclude read and write accesses of the MLI move engine to specific parts of the memory map from automatic mode. Each address of a data move (read or write) is always checked if it targets an address range that is enabled for read/write access. If a requested data move is targeting an excluded address range, a memory access protection error event is generated and the receiving controller's software can take care of the service request.

The memory access protection logic handles two levels of address range definitions:

- Fixed address ranges (for complete modules or memory areas)
- Programmable address sub-ranges (to limit accesses to specific parts of bigger memory areas)

There is a maximum of 32 fixed address ranges available that can be individually enabled/disabled by the address range enable bits AER.AENx (x = 0-31). If bit AER.AENx is set, read/write accesses to the associated address range x are supported in automatic mode. If bit AENx is cleared, read/write accesses to the associated address range x are not automatically executed, a memory protection error event is generated, and SRx output line is activated if enabled by RISR.MPEI.

The MLI module supports a definition of up to four programmable address sub-ranges (with index n) within fixed address ranges. The parameters for the sub-ranges are stored in the access range register ARR, comprising:

- The size of an address slice defined as sub-range (ARR.SIZEn)
- The location of an address slice defined as sub-range (ARR.SLICEn)

Note: The definition of the fixed address ranges and the sub-ranges is product-specific. Detailed values are given in the module implementation chapter.

22.2.2.6 Triggered Command Transfers

The MLI module supports the transmission of Command Frames triggered by hardware signals (up to 4 trigger inputs TR[3:0]). If a rising edge at a TRx input is detected, a corresponding bit TRSTATR.CIVx is set. The MLI transmitter sends out a Command Frame with PN = 00_B and CMD = x + 1 if bit CIVx = 1. This Command Frame can then trigger the activation of the corresponding SRx service request output of the Remote Controller. A Triggered Command Frame can be used monitor service request signals in the Local Controller and to transfer the requests to the Remote Controller, without intervention of any CPU.

Bit CIVx is automatically cleared after successful transmission of the related Command Frame or by writing 1 to SCR.CCIVx.

Note: The connection of the TR[3:0] input lines is product-specific. Detailed information is given in the module implementation chapter (see [Page 22-135](#)).

22.2.2.7 Transmit Priority

In the case that several requests for frame transmission are pending at the same time in a MLI transmitter, the following priority scheme is applied, starting with the highest priority.

For the Answer Frame, only one frame can be pending at a time in the transmitter. So the user has to take care that an older Answer Frame is completely handled before requesting a new one. The same applies for the base address copy frame.

For the Triggered Command Frames, the software driven Command Frames and the read or Write Frames, one frame of each type can be pending per pipe at a time.

Note: The MLI has 4 inputs for Triggered Command Frames. They are not necessarily connected in all devices. Please refer to the device specific implementation chapter for details (see [Page 22-135](#)).

- Answer Frame (only one frame pending allowed at a time)
- Triggered Command Transfer (CIV0 before CIV1 before CIV2 before CIV3)
- Software driven Command Frames (CV0 before CV1 before CV2 before CV3)
- Read or Write Frames (DV0 before DV1 before DV2 before DV3)
- Base Address Copy Frame (only one frame pending allowed at a time)

22.2.2.8 Transmission Delay

A transmission delay can be introduced in the transmitter between the detection of the rising edge of the RREADY input signal and the next possible frame start. This delay represents the minimum time between the acknowledge of a former frame by RREADY and a new frame (if a request is pending). The delay is defined by bit field TCR.TDEL in cycles of the transmitter system clock f_{SYS} .

The purpose of the transmission delay is to compensate for the time required for data to be transferred from the receiver frequency domain into the microcontroller frequency domain.

22.2.3 Interface Description

The MLI transmitter and MLI receiver communicate with other MLI receivers and MLI transmitters via a four-line serial connection each. Several I/O lines of these connections are available outside the MLI module kernel as a four-line output or input vector with index numbering A, B, C and D. The MLI module internal I/O control blocks define which signal of a vector is actually taken into account and also allow polarity inversions (to adapt to different physical interconnection means).

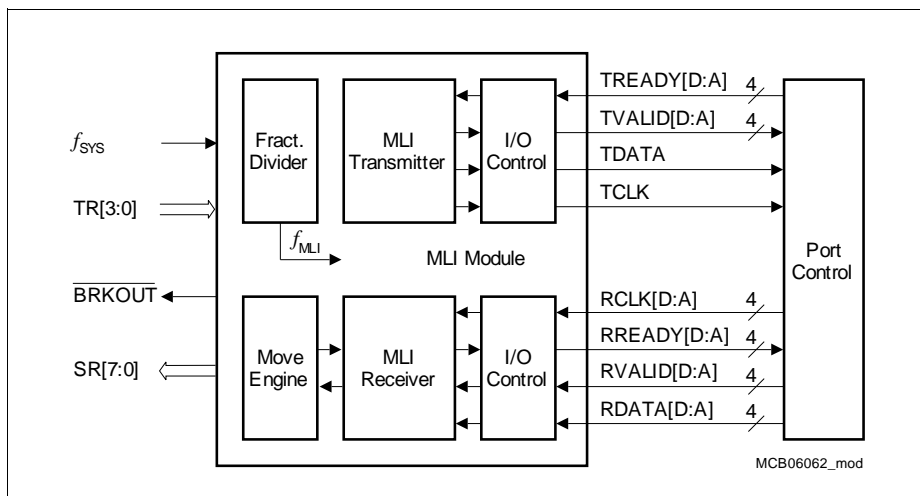


Figure 22-35 General Block Diagram of the MLI Module

Each input/output signal used for MLI communication between a transmitter and a receiver can be disabled and inverted in its polarity. Please note that all waveform diagrams in the MLI chapter refer to non-inverted signals. If polarity inversions are programmed, the waveform diagrams have to be interpreted accordingly. In order to avoid naming mismatches, the signals keep their names, although a polarity inversion might have been programmed. If desired, polarity inversions for the same signal have to be programmed in the transmitter and in the receiver to guaranty signal consistency (there has always to be an even number of inversions between an MLI transmitter and receiver). After reset, the following setting is applied, allowing MLI communication without modification of register OICR¹⁾:

- The signal with the index A is selected from each input/output vector.
- TCLK generation is enabled and RCLK reception is enabled.

1) Other services (e.g. an automatic boot sequence or a boot routine) can change the OICR setting. Differing values are then indicated in the corresponding implementation chapter.

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- Polarity inversion is disabled for all signals (no inversion).
- Not selected output signals are at low level.

The usage of signal BRKOUT is implementation-specific and can be used, for example, to generate a break condition in the on-chip debug support logic or trigger other functions. This signal is activated (as a pulse) by a Command Frame.

The service request outputs SR[7:0] of the MLI module can be activated (as a pulse) by transmitter or receiver events (for all SRx), as well as by Command Frames (only for SR[3:0]).

The MLI module also supports 4 trigger inputs TR[3:0]. A rising edge at input TRx sets bit TRSTATR.CIVx and requests the transfer of a Triggered Command Frame in pipe 0, with a $CMD = x + 1$.

22.2.3.1 Transmitter I/O Line Control

Figure 22-36 shows the MLI transmitter I/O control logic.

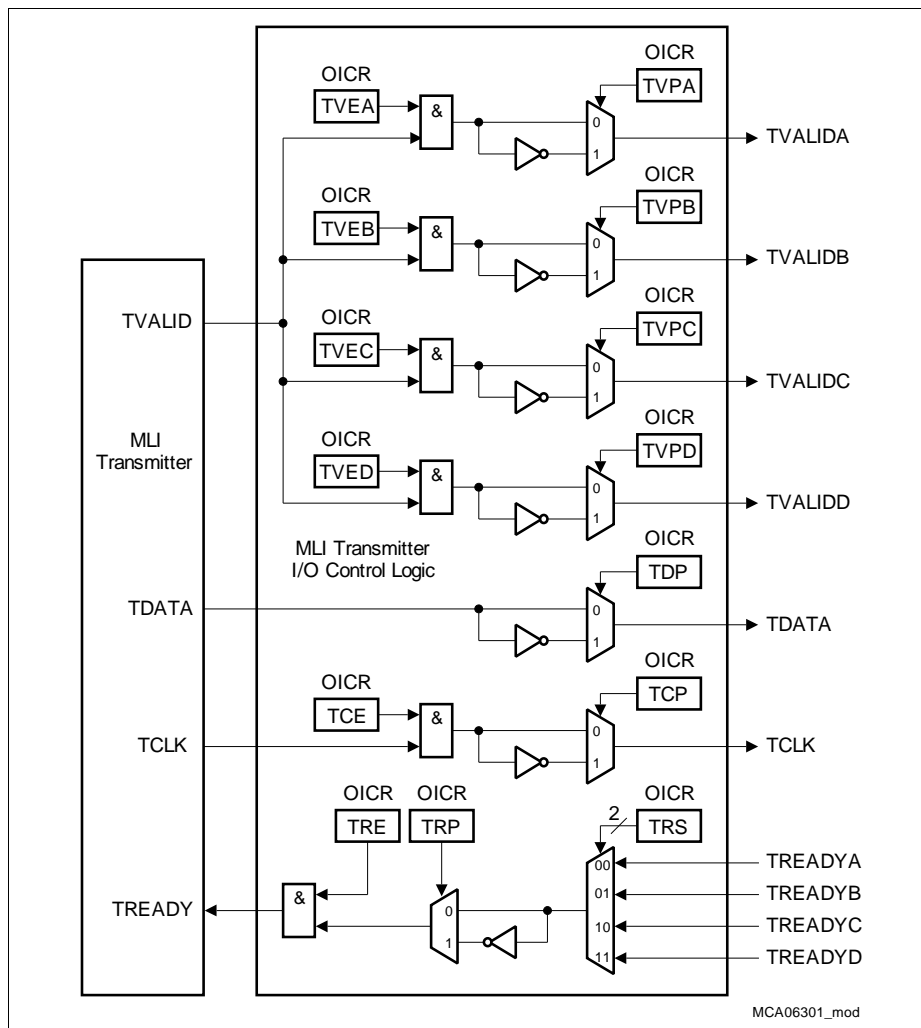


Figure 22-36 Transmitter Input/Output Control Logic

22.2.3.2 Receiver I/O Line Control

Figure 22-37 shows the MLI receiver I/O control logic.

22.2.3.3 Connecting Several MLI Modules

The MLI structure also allows to connect several MLI modules together, e.g. two Remote Controllers (X and Y) to one Local Controller. In this case, the Local Controller can send data to either one or the other or to both Remote Controllers in parallel. Each Remote Controller is connected via an own set of READY/VALID signals to the Local Controller, whereas the transmitter DATA and CLK are broadcast signals. The status of the VALID lines defines, which Remote Controller is accessed.

Only one receiver being available in the Local Controller, the reception of data can be handled only either from one or the other Remote Controller. The software has to ensure that only one Remote Controller sends data back to the Local Controller, e.g. by using Read Frames or by enabling/disabling the generation of Write Frames in the Remote Controllers.

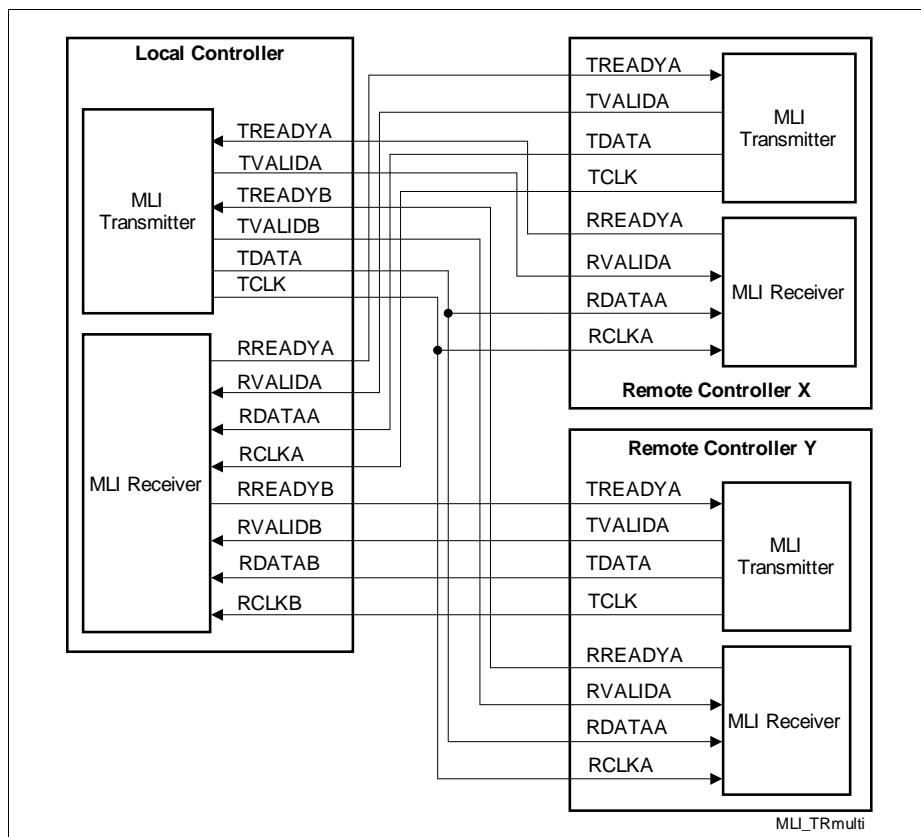


Figure 22-38 Connecting Two Remote Controllers

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Another possibility to connect several MLI modules is a ring structure, with (at least) one dedicated pipe per device. This leads to a structure where the Local Controller's transmitter is connected to the receiver of Remote Controller X, the transmitter of Remote Controller X to the receiver of Remote Controller Y, and the transmitter of Remote Controller Y to the Local Controller's receiver.

This structure supports autonomous data generation and transfer in both Remote Controllers, for example to transfer data generated in a Remote Controller to the Local Controller without using Read Frames. In a ring structure, the Read Frame handling should be avoided. It is possible for the Local Controller to access both Remote Controllers independently. For example, the Remote Window of pipe x covers the address range of Remote Controller X, whereas pipe y targets the Transfer Window y of Remote Controller X. In Remote Controller Y, the pipe y targets the available address range. If the Local Controller issues a Write Frame on pipe x, the Remote Controller X is addressed. In case of a Write Frame on pipe y, the Remote Controller Y is targeted, passing through a Transfer Window of Remote Controller X. The two remaining pipes could be used for Write Frames issued by Remote Controller X (passing through a Transfer Window of Remote Controller Y) and by Remote Controller Y.

22.2.4 MLI Service Request Generation

The MLI module's service request outputs SRx are used to indicate module internal MLI events to other modules or devices outside the MLI module, depending on the device implementation. They can trigger interrupts of a CPU (if available), can be used as DMA request lines (if available), or for other trigger purposes. The MLI events being able to trigger interrupts or other service requests, names of some flags and control registers refer to interrupt generation.

MLI module events are generated by event sources in the transmitter and in the receiver. Each event source provides a status flag and an enable bit with software clear capability. In some cases, several event sources are combined to a common event. An MLI event, internally generated by an event source, is stored in a status flag that is located in the interrupt status registers TISR (for transmitter events) or RISR (for receiver events). All event flags can be cleared individually by software write actions to bits located in the interrupt enable registers TIER (for transmitter events) or RIER (for receiver events). These two registers also contain the enable control bits that allow each event source to be enabled/disabled individually for service request activation. Each event can be connected to exactly one of the eight service request outputs SR[7:0] by a 3-bit interrupt node pointer.

One additional register, the Global Interrupt Set Register GINTR, allows each service request output to be activated separately without setting the status flags of the event sources (see [Page 22-58](#)). This feature is sometimes helpful for software test purposes or to trigger MLI external actions.

Interrupt Registers

The MLI event sources are controlled by several registers (see [Table 22-6](#) and [Page 22-107](#)). The register name prefixes "T" and "R" indicate if a register is assigned to the MLI transmitter or to the MLI receiver.

Table 22-6 Interrupt Registers

Unit	Registers with		
	Request Flags	Enable Bits/ Req. Flag Clear Bits	Node Pointer
MLI Transmitter	TISR	TIER	TINPR
MLI Receiver	RISR	RIER	RINPR

Service Request Compressor

The MLI event logic uses a compressing scheme for flexible service request processing. Eleven MLI events (six transmitter events and four of the five receiver events) are directed via a 3-bit interrupt node pointer to one of the eight service request outputs

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SR[7:0]. Each demultiplexer output selected by its Node Pointer = x ($x = 0-7$) is connected to one input of the SR x OR-Gate. This wiring scheme also supports the connection of more than one event source to an service request output SR x . One receiver event, the interrupt Command Frame event, has a special characteristic: its node pointer is controlled by the received CMD value directly and only SR[3:0] OR-Gates are selectable.

Figure 22-39 shows the service request compressing logic. For reasons of simplicity, not all MLI events, connections, and OR-Gates are explicitly shown. The OR-Gate inputs are connected to the demultiplexers of the MLI event specific lines. Furthermore, a service request output SR x can be triggered by software if the corresponding interrupt set bit in register GINTR is written with a 1.

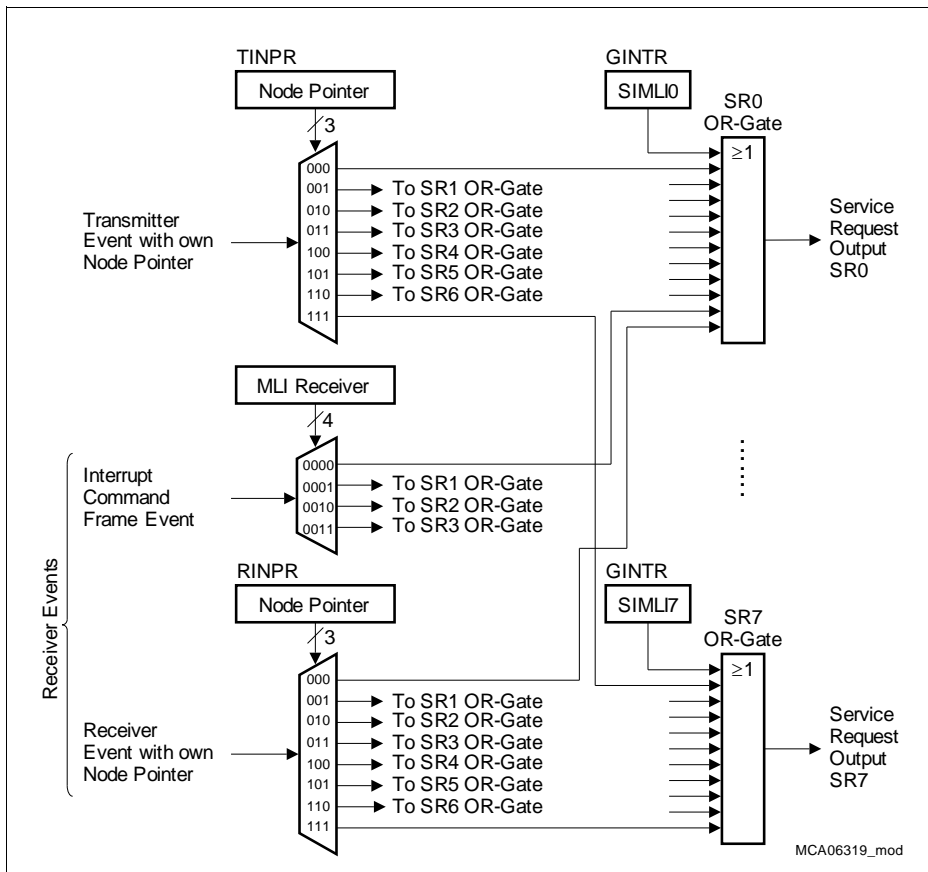


Figure 22-39 Service Request Compressor

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Note: The number of SRx outputs of an MLI module and their connection to other modules depends on the implementation of the MLI module in the specific product.

22.2.5 Transmitter Events

The MLI transmitter can generate the following MLI events:

Table 22-7 MLI Transmitter Events

Events	Events combined to	See
Parity Error	Parity/Time-out Error	Page 22-60
Time-out Error		
Normal Frame Sent in Pipe 0	Normal Frame Sent in Pipe 0	Page 22-60
Normal Frame Sent in Pipe 1	Normal Frame Sent in Pipe 1	
Normal Frame Sent in Pipe 2	Normal Frame Sent in Pipe 2	
Normal Frame Sent in Pipe 3	Normal Frame Sent in Pipe 3	
Command Frame Sent in Pipe 0	Command Frame Sent	Page 22-61
Command Frame Sent in Pipe 1		
Command Frame Sent in Pipe 2		
Command Frame Sent in Pipe 3		

22.2.5.1 Parity/Time-out Error Event

A parity/time-out error event is generated when a programmable maximum number of parity errors or a programmable maximum number of Non-Acknowledge errors have been reached. Both events have separate status/control bits but are concatenated to one common error event.

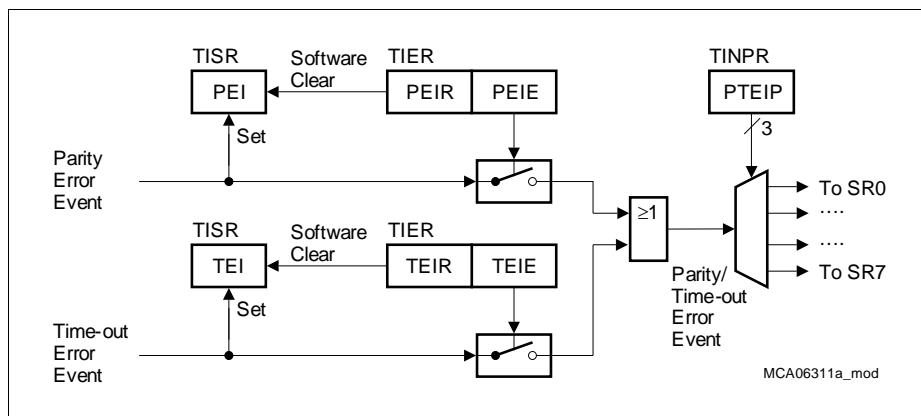


Figure 22-40 Parity/Time-out Error Event Logic

22.2.5.2 Normal Frame Sent x Event

A Normal Frame sent x (x = 0-3) event is generated when a Normal Frame has been sent and correctly received in pipe x.

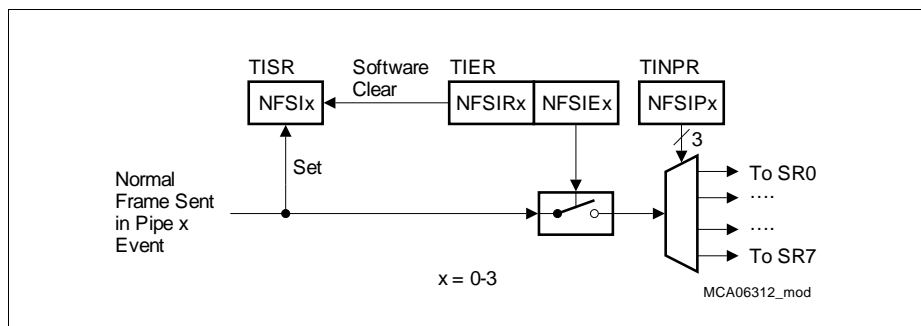


Figure 22-41 Normal Frame Sent x Event Logic

22.2.5.3 Command Frame Sent Events

A Command Frame sent event is generated when the MLI transmitter has sent a Command Frame through pipe x (x = 0-3) that has been correctly received. Separate status/control bits are assigned to each pipe. All four pipe related Command Frame sent events are concatenated to one common Command Frame sent event.

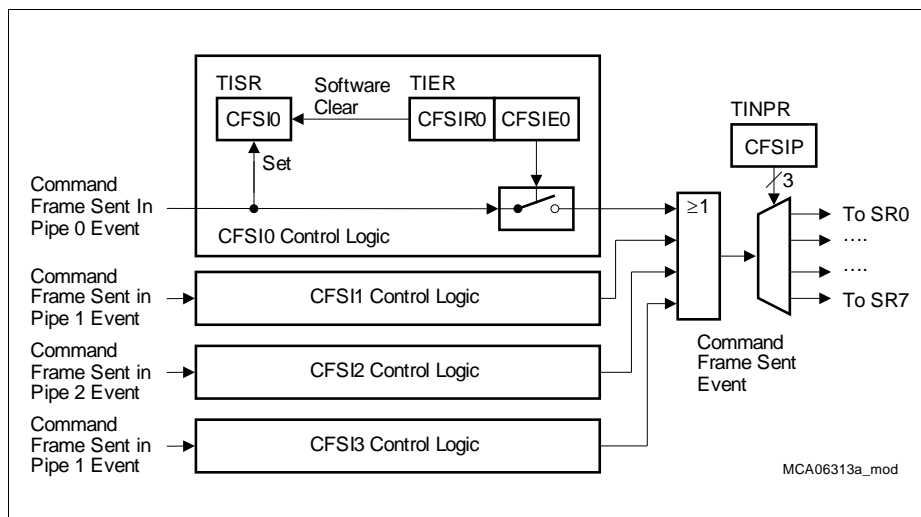


Figure 22-42 Command Frame Sent Event Logic

22.2.6 Receiver Events

The MLI receiver can generate the following MLI events:

Table 22-8 MLI Receiver Interrupts

Events	Events combined to	See
Discarded Read Answer	Discarded Read Answer	Page 22-62
Memory Access Protection Error	Memory Access Protection/ Parity Error	Page 22-63
Parity Error		
Normal Frame Correctly Received	Normal Frame Received	Page 22-64
Move Engine Access Terminated		
Interrupt Command Frame	Interrupt Command Frame	Page 22-65
Command Frame Received on Pipe 0	Command Frame Received	Page 22-66
Command Frame Received on Pipe 1		
Command Frame Received on Pipe 2		
Command Frame Received on Pipe 3		

22.2.6.1 Discarded Read Answer Event

A discarded read answer received event is generated if an Answer Frame has been received and the read pending flag TRSTATR.RPx of its correspondent pipe is 0. Although named “discarded”, the received data is available in the receiver data register until it is overwritten by the next incoming data.

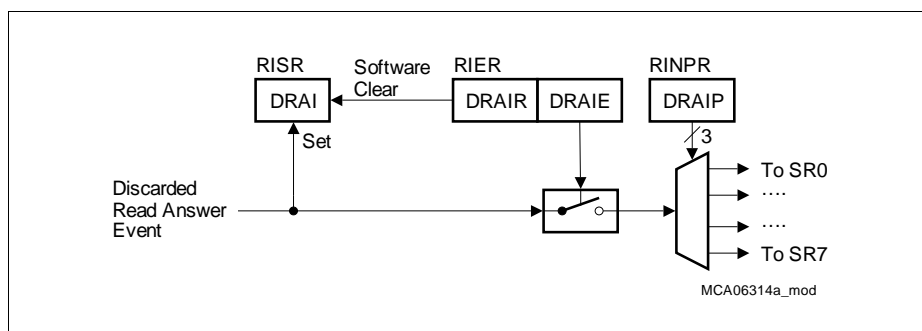


Figure 22-43 Discarded Read Answer Event Logic

22.2.6.2 Memory Access Protection/Parity Error Event

A memory access protection/parity error event is detected if a non allowed read or write access has been detected or if a programmable maximum number of receiver parity errors is reached. Both MLI events have separate status/control bits but are concatenated to one common error event.

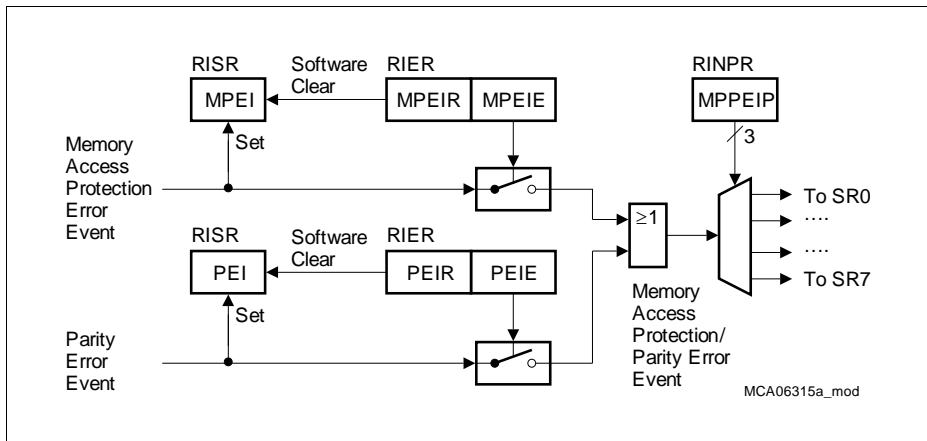


Figure 22-44 Memory Access Protection/Parity Error Event Logic

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22.2.6.3 Normal Frame Received/Move Engine Terminated Event

A Normal Frame received event is generated if the MLI receiver has correctly received a Normal Frame (a Copy Base Address Frame, a Read or a Write Frame, an Answer Frame, but not a Command Frame) or if the move engine has terminated its read or write access. Both event sources have separate status/control bits but are concatenated to one common Normal Frame received event.

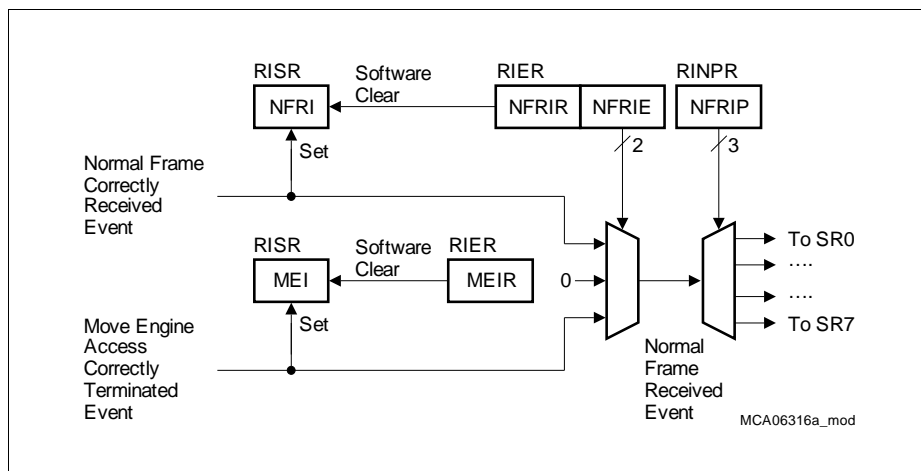


Figure 22-45 Normal Frame Received Event Logic

22.2.6.4 Interrupt Command Frame Event

An interrupt Command Frame event is generated if a Command Frame is received correctly on pipe 0 with a valid command code for service request output activation ($CMD = 0000_B$ to 0011_B). The received command code determines which of the service request outputs $SR[3:0]$ should be activated.

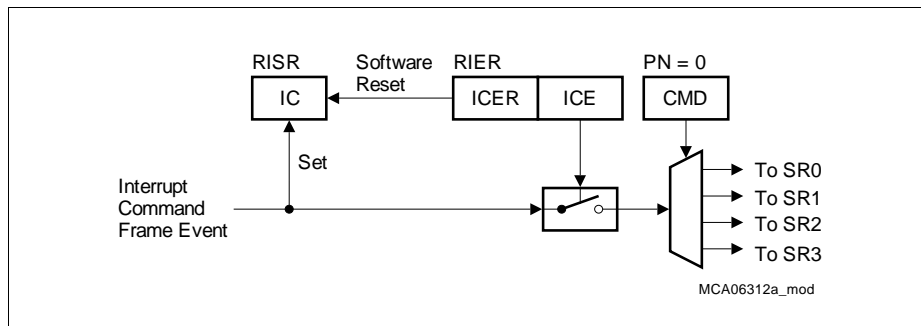


Figure 22-46 Interrupt Command Frame Event Logic

22.2.6.5 Command Frame Received Event

A Command Frame received event is generated if the MLI receiver has correctly received a Command Frame through Pipe Number x ($x = 0-3$). Separate status/control bits are assigned to each pipe. All four pipe related Command Frame received in pipe x events are concatenated to one common Command Frame received event.

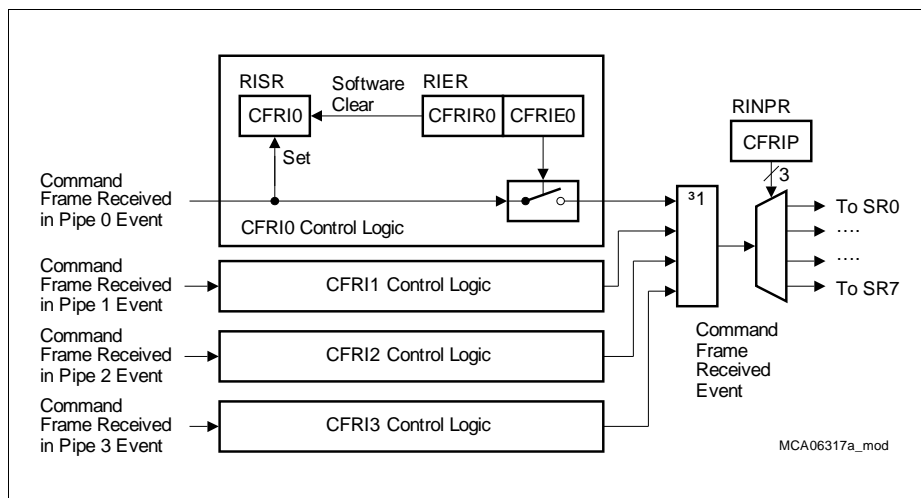


Figure 22-47 Command Frame Received Event Logic

22.2.7 Baud Rate Generation

The MLI transmitter baud rate is given by $f_{\text{MLI}}/2$. The MLI shift clock output signal TCLK of the transmitter toggles with each clock cycle of f_{MLI} in order to obtain a 50% duty cycle (the 50% duty cycle can vary up to one clock cycle of f_{SYS} in fractional divider mode). The MLI receiver automatically adapts to the incoming receive shift clock signal RCLK. The received baud rate is determined by the connected transmitter and has no direct relation to f_{SYS} except that it should not exceed f_{SYS} .

The frequency f_{MLI} is generated by the fractional divider FDIV.

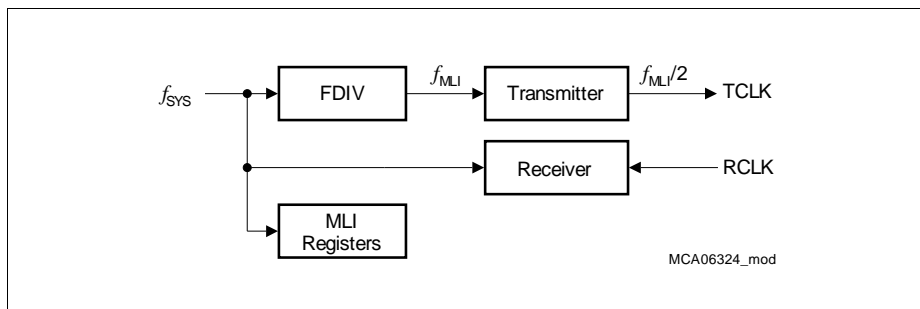


Figure 22-48 MLI Baud Rate Generation

Normal Divider Mode

In normal divider mode ($\text{FDR.DM} = 01_{\text{B}}$) the fractional divider behaves like a reload counter (addition of +1) that generates a clock f_{MLI} on the transition from 3FF_{H} to 000_{H} . FDR.RESULT represents the counter value and FDR.STEP defines the reload value. In order to achieve $f_{\text{MLI}} = f_{\text{SYS}}$, FDR.STEP must be programmed with 3FF_{H} . The output frequency in normal divider mode is defined according the following equation:

$$f_{\text{MLI}} = f_{\text{SYS}} \times \frac{1}{1024 - \text{FDR.STEP}} \quad (22.1)$$

Fractional Divider Mode

If the fractional divider mode is selected ($\text{FDR.DM} = 10_{\text{B}}$), the clock f_{MLI} is derived from the input clock f_{SYS} by division of a fraction of $\text{STEP}/1024$ for any value of STEP from 0 to 1023. In general, the fractional divider mode allows to program the average clock frequency with a higher accuracy than in normal divider mode. In fractional divider mode a clock pulse f_{MLI} is generated depending on the result of the addition $\text{FDR.RESULT} + \text{FDR.STEP}$. The frequency f_{MLI} corresponds to the overflows over 3FF_{H} . Note that in fractional divider mode the clock f_{MLI} can have a maximum period jitter of one f_{SYS} clock period. This jitter is not accumulated over several cycles and does not

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exceed one cycle of f_{SYS} .

The frequency in fractional divider mode is defined according the following equation:

$$f_{\text{MLI}} = f_{\text{SYS}} \times \frac{\text{STEP}}{1024} \quad (22.2)$$

The baud rate of MLI transmissions equals f_{TCLK} , that is defined by the frequency of clock signal f_{MLI} divided by 2 to create the 50% duty cycle of the shift clock signal TCLK. The signal TCLK toggling with each period of f_{MLI} , a jitter due to fractional dividing is propagated to TCLK.

$$f_{\text{TCLK}} = \frac{f_{\text{MLI}}}{2} \quad (22.3)$$

22.2.8 Automatic Register Overwrite

The value of register OICR and bit RCR.RCVRST is overwritten by hardware in the next two clock cycles after a reset (first OICR, followed by RCR). The value applied during reset is given in the register description. This automatic overwrite allows adapting the module to different application requirements without changing the module itself. For example, during reset the receiver is set to a defined state and can be used afterwards for reception without the need to modify it by a write action (if the bit RCVRST is modified to 0).

The values applied after the overwrite can be identical to the indicated reset values. Please refer to the implementation chapter for the modified values (see [Page 22-129](#)).

22.3 Operating the MLI

Data transfer via MLI between a Local Controller and a Remote Controller is only possible if both are initialized correctly by following sequence of 4 steps. Steps 3 and 4 are necessary if the initialization sequence is exclusively controlled by the Local Controller. If both communication partners are able to run initialization software, steps 1 and 2 can be executed separately by both controllers to initialize both transmitters and both receivers.

1. The transmitter of the Local Controller has to be initialized by write actions to the transmitter registers.
2. The pipes from the Local Controller's transmitter to the Remote Controller's receiver and the Remote Controller's receiver have to be initialized.
3. The Remote Controller's transmitter has to be initialized by data write actions from the Local Controller via the Remote Controller's receiver to the Remote Controller's transmitter registers.
4. The pipes from the Remote Controller's transmitter back to the Local Controller's receiver and the Local Controller's receiver have to be initialized. This is done by frames from the Remote Controller's transmitter. These frames are the result of data write actions of the Local Controller to the Remote Controller's transmitter registers.

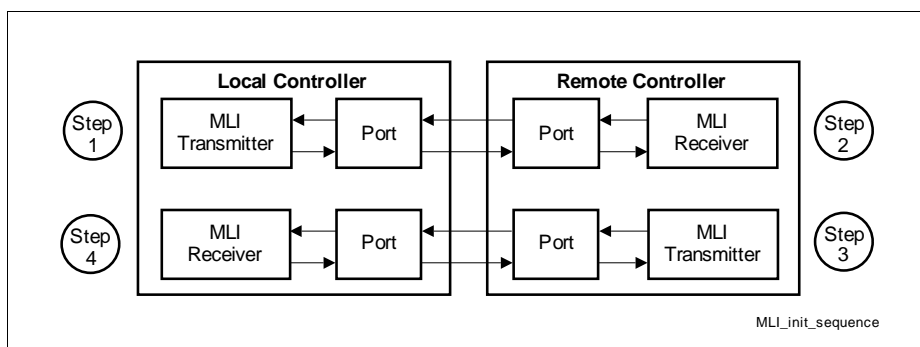


Figure 22-49 Initialization Sequence for an MLI Connection

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To initialize and to operate the MLI, the following items should be taken into account:

- Connection setup (see [Page 22-70](#))
- Local Controller transmitter and pipe setup (see [Page 22-71](#))
- Remote Controller receiver setup (see [Page 22-71](#))
- Remote Controller transmitter and Local Controller receiver setup (see [Page 22-72](#))
- Delay adjustment (see [Page 22-73](#))
- Connection to DMA mechanism (see [Page 22-75](#))
- Connection of MLI to SPI (see [Page 22-75](#))

22.3.1 Connection Setup

For the general setup of an MLI connection, several steps have to be respected.

- There is the possibility to change the signal routing to adapt to different applications. If another connection than the default one from an input/output vector of the MLI signals is desired, register OICR has to be programmed (see also [Section 22.2.8](#)).
- In some devices (mainly stand-alone peripheral devices without CPU, where the MLI module is a possible communication channel), the setting “A” can be modified by hardware to another setting (e.g. to setting “B”) during the boot phase. In this case, the initial setting “A” can correspond to an inactive setting (MLI not used for communication), whereas the setting “B” is used for MLI communication.
- In the case a memory access protection is implemented in the receiver and automatic handling of data is desired, the user has to enable the corresponding address range in registers AER and ARR. After a reset, in most microcontrollers, the access protection is generally disabled to avoid access to safety-critical data. Depending on the device, some specific address ranges can already be enabled for automatic access by default.
- In devices with explicit port control (such as microcontrollers), the port pins are generally set to input after a reset. In order to allow MLI communication, the MLI-related port pins have to be configured to make the MLI signals externally available and to adapt the driver setting (refer to port chapter).

The MLI module should not be enabled for reception ($\text{RCR.RCVRST} = 1$) before programming the desired port setting, because changing the port setting can lead to unintended edges at the module inputs due to setting changes. If the MLI module is already enabled for reception, unintended edges are interpreted as communication signals, so the receiver might deliver wrong results. If this has happened unintentionally, the receiver can be reset by $\text{RCR.RCVRST}=1$.

22.3.2 Local Transmitter and Pipe Setup

The initialization of the transmitter of the Local Controller is done by writing to the transmitter registers. The Remote Controller's MLI receiver can then be initialized by the Local Controller's transmitter.

- After a hardware reset operation, the MLI transmitter is disabled ($TCR.MOD = 0$). In disabled mode, no frame transmission can take place. After writing $TCR.MOD = 1$, the transmitter is enabled to send frames.
- The desired transmitter baud rate can be adjusted by the fractional divider $FDIV$. It has to be ensured that the fractional divider is set to a value that is supported by the port structures of the Local and the Remote Controllers (rise/fall times) and the physical layer. For example, if a division by 1,5 is selected, the fractional divider will deliver count pulses for f_{MLI} with a sequence of 1-2-1-2-1-2- clock cycles of f_{SYS} . The shortest interval between two count pulses in a sequence (given by the truncated divider factor, so 1 cycle of in this example) has to be handled by the communicating devices. f_{SYS}
- Depending on the application requirements, a desired service request output SRx can be activated if a transmitter event is detected.
- The maximum delay for parity error detection in the transmitter has to be programmed. There are two possibilities to get the MLI communication started. First (easier) possibility is to write $TCR.MDP$ to 14 and to set $RCR.DPE$ to 15. The second possibility could be used to optimize the bandwidth of the MLI connection. It is described in [Section 22.3.5](#) on [Page 22-73](#).

22.3.3 Remote Receiver Setup

The initialization of the Remote Controller's receiver is done by frames sent by the Local transmitter. Therefore, the Remote Controller's receiver has to be able to receive frames.

- In order to allow communication, the Remote Controller's MLI signals have to be connected to the Local Controller's transmitter signals (see register $OICR$ and port settings).
- The Remote Controller's bit $RCR.RCVRST$ has to be 0 to enable frame reception.
- The buffer area size and the base address of the Remote Window for pipe x are defined by the data written to registers $TPxBAR$. Bit $TRSTATR.BAV$ has to be 0 before each write action to one of these registers. With this information, the buffer area sizes (defining the number of address bits in data frames or Read Frames) are known in the transmitter and in the receiver for each pipe.
The base addresses for the Remote Windows have to be selected to cover the target address ranges in the Remote Controller. It is recommended to use the minimum buffer size required by the application in order to minimize the bandwidth taken by the transfer of the address bits. The base address of a Remote Window has to be set to a value aligned to its size, e.g. a Remote Window of 8 Kbytes must start at an 8 Kbyte address boundary.

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- In devices with access protection mechanism against unauthorized accesses via MLI, the Remote Controller has to enable the desired address range(s) to support automatic mode. If automatic mode is not desired, the Remote Controller has to handle the complete data traffic by software.
- A possibility to test the setup in devices with the capability to run own test software is the local loop back (the transmitter is connected locally to the receiver of the same MLI module). In devices without this capability, the module loop back can be hardly used (or it is even not implemented, refer the connection table in the implementation chapter).

If implemented, for local loop back, the signal connections have to be programmed to setting "D", leading to the local receiver being connected directly to the local transmitter (without using a port structure). In this case, the local receiver seems to be the remote receiver. Data written to a local Transfer Window are received and handled by the local receiver. Test software in the Local Controller can check for correct setup, data consistency, MLI event handling, and correct address handling in the Local Controller.

- If automatic data handling is desired (necessary for devices without the capability to handle data traffic by its CPU), the Automatic Data Mode has to be enabled by sending a Command Frame in pipe 2 with CM = 0001_B to set RCR.MOD = 1 in the Remote Controller.

22.3.4 Remote Transmitter and Local Receiver Setup

The initialization of the Remote Controller's transmitter and the Local Controller's receiver can be done by data frames sent by the local transmitter. Therefore, the Remote Controller's receiver has to be able to receive frames (the port structure has to be set up accordingly).

- The Remote Window of pipe x (x can be freely chosen) has to be set to the MLI register address range in the Remote Controller. The initialization by data frames is then done via pipe x.
- The automatic mode has to be enabled in the Remote Controller (Command Frame in pipe 2 with CM = 0001_B).
- The connections between the remote transmitter and the local receiver have to be established (if not already done by the default setting), similar to [Section 22.3.2](#).
- The remote transmitter has to be enabled, similar procedure as for the local transmitter. The data word to be written to the Remote Controller's MLI registers have to be written to the corresponding address in the local Transfer Window of pipe x.
- The local receiver can then be configured by writing the appropriate data (similar scenario as for the remote receiver) to the local Transfer Window of pipe x.
- A possibility to test the complete setup is the remote loop back. In this case another Remote Window is overlaid directly to a Transfer Window in the Remote Controller. Writing data to the corresponding Transfer Window in the Local Controller leads to a data frame sent to the Remote Controller. There, the received data is written to the

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Transfer Window and a new data frame is sent back to the Local Controller. The MLI move engine in the Local Controller's receiver can be used to write the received data to a defined location, e.g. to a memory location. Test software in the Local Controller can check for correct setup, data consistency, MLI event handling, and correct address handling in the Local and the Remote Controllers.

22.3.5 Delay Adjustment

The local MLI transmitter is measuring the number of TCLK clock cycles between TVALID becoming 0 after a transmission and TREADY becoming 1 again. This time represents the overall loop delay of the MLI connection. The loop delay is the time used for signal propagation, input/output driver delay and remote receiver reaction. For example, with slow drivers and a high load (due to long wires, etc.), the signals take a longer time to propagate from the local transmitter to the remote receiver and back again (READY-VALID control handshake). This delay (also visible when TVALID becomes 1 at the beginning of a frame) limits the maximum baud rate of an MLI connection, because the answer of the receiver has to be detected by the transmitter with TREADY = 0 at the end of the frame. The value measured after the end of the frame is indicated in bit field TSTATR.RDC.

The receiver participates in the control handshake by changing its RREADY output as a reaction to an incoming RVALID signal. For the transmitter, the TREADY input delivers the information that a receiver is connected and that it is ready for reception (transfer only starts if TREADY = 1). If a receiver is not able to handle the data or is not connected, the TREADY line will not become low after TVALID becomes 1 (Non-Acknowledge).

In addition to this information, the MLI protocol offers the possibility to use the control handshake also to indicate that the receiver has detected a parity error in the received frame. If a correct frame has been received, the receiver immediately asserts RREADY = 1 after the reception of a frame when detecting RVALID = 0. If the receiver has detected a parity error, it waits for a programmable number of RCLK cycles before setting RREADY = 1 again. This additional delay is defined by bit field RCR.DPE.

The transmitter measuring the delay and comparing it to a programmed value, it can detect that the receiver has signaled a parity error by introducing the additional delay. The compare value for the transmitter is programmed by bit field TCR.MDP. A measured value of TSTATR.RDC above TCR.MDP is interpreted as parity error by the transmitter (for parity error handling refer to [Page 22-44](#)).

In the receiver, frames with parity error are ignored for data transfers and don't lead to internal move actions.

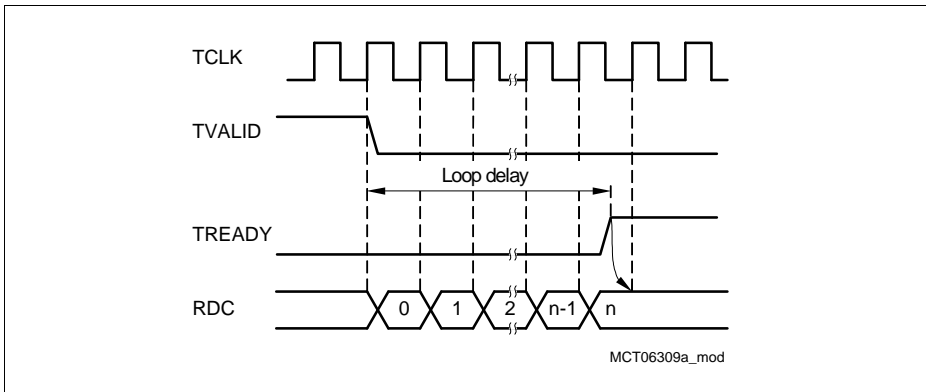


Figure 22-50 Loop Delay Measurement

To adjust the generated parity delay in the local transmitter and in the remote receiver, the following steps are necessary:

- Send a dummy frame to the receiver for measuring the loop delay. This frame should not lead to internal data move actions in the receiver, so a parity error can be simulated in the transmitter. The receiver has a fixed even parity scheme, whereas the transmitter can be programmed either for even or for odd parity. Programming odd parity before sending a frame will generate a (dummy) frame that will be discarded by the receiver (assuming a correct transfer). For a dummy frame, it is recommended to use a data frame with disabled Automatic Data Mode in the receiver ($\text{RCR.MOD} = 0$).
- The receiver delay RCR.DPE being 0 after a module reset, the transmitter can measure the loop delay and the receiver discards the frame (without modification of DPE, there is no difference in time between a frame with or without a parity error having been detected). The value given by TSTATR.RDC indicates how many TCLK cycles are necessary for a control handshake. This value should be incremented by a value Δ (value see below) and written to TCR.MDP .
- The transmitter parity has to be programmed to even parity to be able to generate frames that are not discarded by the receiver.
- Programming the receiver delay for parity error (RCR.DPE) to a value bigger than Δ will lead to a value of TSTATR.RDC bigger than TCR.MDP if the receiver detects a parity error. The value of DPE in the remote receiver is modified by the local transmitter by sending a Command Frame in pipe 1 with the desired value. The difference between TSTATR.RDC and TCR.MDP allows a certain timing tolerance between local transmitter and remote receiver.
- The value of Δ depends on the possible variations of the propagation characteristics of the MLI connection. If the environment does not significantly change, Δ can be 1. For systems with variations, Δ could be bigger. The

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user can check about changing propagation characteristics by reading TSTATR.RDC from time to time and to check if it is constant for correct transfers. If it changes, either a bigger DELTA value can be applied, or the delay adjustment can be repeated, adapting to the new circumstances.

22.3.6 Connection to DMA Mechanism

The MLI module supports the connection to a DMA (direct memory access) mechanism. This mechanism allows the transfer of blocks of data of programmable size via an MLI connection without CPU intervention. Therefore, a DMA mechanism can be used in the Local Controller to write the desired number of data words one after the other to the corresponding MLI Transfer Window. The address ranges of the data blocks and their length has to be handled by the DMA module.

An MLI pipe supporting only one pending Write Frame request at a time, the DMA has to wait until the pipe is capable to handle new data before writing another data word to the Transfer Window. Therefore, the Normal Frame sent events of the pipes can trigger DMA data transfers. Depending on the connection of the MLI module's service request outputs SRx to the DMA trigger inputs, the Normal Frame sent events have to be enabled for service request activation and directed to the desired SRx outputs. It is recommended to use only one type of MLI event per SRx output to trigger a data transfer by DMA. If the DMA mechanism needs a start trigger for the first data word transfer, register GINTR can be written with the appropriate pattern to activate an SRx output.

22.3.7 Connection of MLI to SPI

The handshake signals between a transmitter and a receiver are based on a synchronous transfer protocol. In the SPI protocol, the shift clock and the data signal are equivalent to CLK and DATA. In case of an 4-wire SPI, the slave select signal represents the VALID signal (the leading and the trailing delay have to be set up accordingly).

Contrary to the MLI, in the SPI protocol, a complete control handshake is not defined, so the READY signal does not exist in SPI modules. As a result, the SPI communication does not check by hardware for correct data transfer, but has to handle this on an upper software layer. If using an SPI module for communication with an MLI transmitter or an MLI receiver, the READY signal has to be handled by software or the handshake has to be given up. This can be done by connecting the TVALID signal of an MLI transmitter to one of its own TREADY inputs with polarity inversion. Like this, the TREADY input directly following the inverted TVALID signal, the parity error indication and the Non-Acknowledge error detection are not possible.

Furthermore, in the MLI protocol, the frames may have a different width, depending on their type and selected buffer size. The different numbers of data bits per frame have also to be handled by the SPI module. In order to minimize the number of different frames, it is recommended to restrict the possibility to program different buffer sizes, the use of Read Frames or Command Frames. In order to simplify the data handling by an

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SPI module, the parity generation could be skipped for frames received by the SPI module and an error detection mechanism on an upper software layer could be implemented. For frames sent by an SPI module, the parity bit has to be calculated and sent correctly. Otherwise, the MLI receiver will discard the received frame.

22.4 MLI Kernel Registers

This section describes the kernel registers of the MLI module. All registers can be accessed with 8-bit, 16-bit or 32-bit write or read operations. Accesses to address locations inside the MLI address range not targeting the indicated registers are not allowed. The complete and detailed address map of the of the MLI module and its registers is described in [Table 22-14](#) on [Page 22-136](#).

All registers in the MLI address spaces are reset with the application reset.

MLI Kernel Register Overview

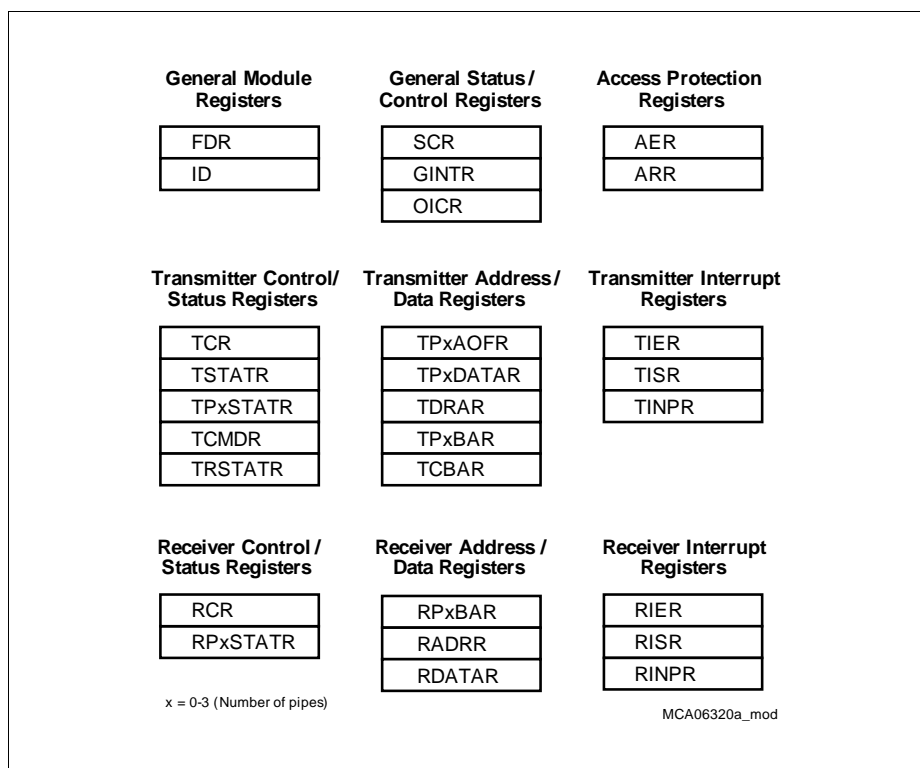


Figure 22-51 MLI Kernel Registers

Table 22-9 Registers Address Space - MLI Kernel Registers

Module	Base Address	End Address	Note
MLIO	F010 C000 _H	F010 C0FF _H	—

Table 22-10 Registers Overview - MLI Kernel Registers

Register Short Name	Register Long Name	Offset Address ¹⁾	Description see
ID	Module Identification Register	08 _H	Page 22-82
FDR	Fractional Divider Register	0C _H	Page 22-79
TCR	Transmitter Control Register	10 _H	Page 22-92
TSTATR	Transmitter Status Register	14 _H	Page 22-95
TPxSTATR	Transmitter Pipe x Status Register	18 _H + (x * 4)	Page 22-97
TCMDR	Transmitter Command Register	28 _H	Page 22-99
TRSTATR	Transmitter Receiver Status Register	2C _H	Page 22-101
TPxAOFR	Transmitter Pipe x Address Offset Register	30 _H + (x * 4)	Page 22-103
TPxDATAR	Transmitter Pipe x Data Register	40 _H + (x * 4)	Page 22-104
TDRAR	Transmitter Data Read Answer Register	50 _H	Page 22-104
TPxBAR	Transmitter Pipe x Base Address Register	54 _H + (x * 4)	Page 22-105
TCBAR	Transmitter Copy Base Address Register	64 _H	Page 22-106
RCR	Receiver Control Register	68 _H	Page 22-113
RPxBAR	Receiver Pipe x Base Address Register	6C _H + (x * 4)	Page 22-117
RPxSTATR	Receiver Pipe x Status Register	7C _H + (x * 4)	Page 22-116
RADDR	Receiver Address Register	8C _H	Page 22-118
RDATAR	Receiver Data Register	90 _H	Page 22-119
SCR	Set Clear Register	94 _H	Page 22-84
TIER	Transmitter Interrupt Enable Register	98 _H	Page 22-107
TISR	Transmitter Interrupt Status Register	9C _H	Page 22-109
TINPR	Transmitter Interrupt Node Pointer Register	0A0 _H	Page 22-111
RIER	Receiver Interrupt Enable Register	A4 _H	Page 22-120
RISR	Receiver Interrupt Status Register	A8 _H	Page 22-123
RINPR	Receiver Interrupt Node Pointer Register	AC _H	Page 22-125
GINTR	Global Interrupt Set Register	B0 _H	Page 22-83
OICR	Output Input Control Register	B4 _H	Page 22-86
AER	Access Enable Register	B8 _H	Page 22-90
ARR	Access Range Register	BC _H	Page 22-91

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- 1) The absolute register address is calculated as follows:
Module Base Address ([Table 22-9](#)) + Offset Address (shown in this column)

22.4.1 General Module Registers

Fractional Divider Register

The fractional divider register allows to program the frequency f_{MLI} to generate the baud rate of the 50% duty cycle transmitter shift clock TCLK.

FDR

Fractional Divider Register (0C_H) **Reset Value: 03FF 43FF_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS CLK	EN HW	SUS REQ	SUS ACK	0	RESULT										
rw	rw	rh	rh	r	rh										
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM		SC		SM	0	STEP									
rw		rw		rw	r	rw									

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value In normal divider mode STEP contains the reload value for RESULT. In fractional divider mode this bit field defines the 10-bit value that is added to the RESULT with each input clock cycle.
SM	11	rw	Suspend Mode SM selects between granted or immediate suspend mode. This bit is only taken into account in devices supporting suspend mode. 0 _B Granted suspend mode selected 1 _B Immediate suspend mode selected

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Field	Bits	Type	Description
SC	[13:12]	rw	<p>Suspend Control</p> <p>This bit field defines the behavior of the fractional divider in suspend mode (bit SUSREQ and SUSACK set). This bit field is only taken into account in devices supporting suspend mode.</p> <p>01_B Clock generation is stopped and the clock output signals are not generated. RESULT is not changed except when writing bit field DM with 01_B or 10_B.</p> <p>00_B Clock generation continues.</p> <p>10_B Clock generation is stopped and the clock output signals are not generated. RESULT is loaded with 3FF_H.</p> <p>11_B Same as SC = 10_B but RST_EXT_DIV is 1 (independently of bit field DM).</p>
DM	[15:14]	rw	<p>Divider Mode</p> <p>This bit fields defines the functionality of the fractional divider block.</p> <p>00_B Fractional divider is switched off; no output clock is generated. RST_EXT_DIV is 1. RESULT is not updated (default after reset).</p> <p>01_B Normal divider mode selected.</p> <p>10_B Fractional divider mode selected.</p> <p>11_B Fractional divider is switched off; no output clock is generated. RESULT is not updated.</p>
RESULT	[25:16]	rh	<p>Result Value</p> <p>In normal divider mode RESULT acts as reload counter (addition +1).</p> <p>In fractional divider mode this bit field contains the result of the addition RESULT+STEP.</p> <p>If DM is written with 01_B or 10_B, RESULT is loaded with 3FF_H.</p>
SUSACK	28	rh	<p>Suspend Mode Acknowledge</p> <p>0_B Suspend mode is not acknowledged.</p> <p>1_B Suspend mode is acknowledged.</p> <p>Suspend mode is entered when SUSACK and SUSREQ are set.</p>

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Field	Bits	Type	Description
SUSREQ	29	rh	Suspend Mode Request 0_B Suspend mode is not requested. 1_B Suspend mode is requested. Suspend mode is entered when SUSACK and SUSREQ are set.
ENHW	30	rw	Enable Hardware Clock Control 0_B Bit DISCLK cannot be cleared by hardware by a high level at input signal ECEN. 1_B Bit DISCLK is cleared by hardware while input signal ECEN is at high level.
DISCLK	31	rwh	Disable Clock 0_B Clock generation of $f_{OUT} = f_{MLI}$ is enabled according to the setting of bit field DM. 1_B Fractional divider is stopped. Signal $f_{OUT} = f_{MLI}$ becomes inactive. No change except when writing bit field DM. In case of a conflict between hardware reset and software set of DISCLK, the software set wins. Any write or read-modify-write action leads to the described behavior. As a result read-modify-write operations should be avoided.
0	10, [27:26]	r	Reserved Read as 0; should be written with 0.

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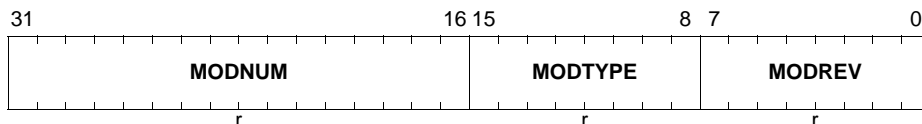
Module Identification Register

The MLI Module Identification Register ID contains read-only information about the module version.

ID

Module Identification Register

(08_H)

Reset Value: 0025 XXXX_H


Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number This bit field defines the module revision number. The value of a module revision starts with 01 _H (first revision).
MODTYPE	[15:8]	r	Module Type This bit field defines the module as a 32-bit module: C0 _H
MODNUM	[31:16]	r	Module Number Value This bit field defines the module identification number for the MLI: 0025 _H

22.4.2 General Status/Control Registers

Global Interrupt Set Register

The Global Interrupt Set Register GINTR is a write only register (always reads 0) that allows each of the service request outputs SRx to be activated under software control (see [Page 22-58](#)).

GINTR

Global Interrupt Set Register

(B0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								SI	SI	SI	SI	SI	SI	SI	SI
								MLI7	MLI6	MLI5	MLI4	MLI3	MLI2	MLI1	MLI0
r								w	w	w	w	w	w	w	w

Field	Bits	Type	Description
SIMLIX (x = 0-7)	x	w	Set MLI Service Request Output Line x 0 _B No action 1 _B Service request output SRx is activated (pulse).
0	[31:8]	r	Reserved Read as 0; should be written with 0.

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Set Clear Register

The Set Clear Register SCR is a write only register that makes it possible to set or clear by software several status flags located in registers TSTATR, TRSTATR and RCR. Reading register SCR always returns zeros at all bit locations. Bits that are not written with a 1 have no effect.

SCR

Set Clear Register

(94_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
C CIV3	C CIV2	C CIV1	C CIV0	C NAE	C TPE	C RPE	C AV				0			C BAV	C MOD
w	w	w	w	w	w	w	w				w			w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
C CV3	C CV2	C CV1	C CV0	C DV3	C DV2	C DV1	C DV0		0		S MOD	S CV3	S CV2	S CV1	S CV0
w	w	w	w	w	w	w	w		w		w	w	w	w	w

Field	Bits	Type	Description
SCV0 , SCV1 , SCV2 , SCV3	0, 1, 2, 3	w	Set Command Valid 0 _B No effect 1 _B Bit TRSTATR.CVx is set.
SMOD	4	w	Set MOD Flag 0 _B No effect 1 _B If CMOD = 0, RCR is set. If CMOD = 1, RCR.MOD is cleared.
CDV0 , CDV1 , CDV2 , CDV3	8, 9, 10, 11	w	Clear Data Valid x Flag 0 _B No effect 1 _B Bits TRSTATR.DVx and TRSTATR.RPx are cleared.
CCV0 , CCV1 , CCV2 , CCV3	12, 13, 14, 15	w	Clear Command Valid x Flag 0 _B No effect. 1 _B If SCVx = 0, bit TRSTATR.CVx is cleared. If SCVx = 1, bit TRSTATR.CVx is set.
CMOD	16	w	Clear MOD Flag 0 _B No effect. 1 _B Bit RCR.MOD is cleared.

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Field	Bits	Type	Description
CBAV	17	w	Clear BAV Flag 0 _B No effect. 1 _B Bit TRSTATR.BAV is cleared.
CAV	24	w	Clear AV Flag 0 _B No effect. 1 _B Bit TRSTATR.AV is cleared.
CRPE	25	w	Clear Receiver PE Flag 0 _B No effect. 1 _B Bit RCR.PE is cleared.
CTPE	26	w	Clear Transmitter PE Flag 0 _B No effect. 1 _B Bit TSTATR.PE is cleared.
CNAE	27	w	Clear NAE Flag 0 _B No effect. 1 _B Bit TSTATR.NAE is cleared.
CCIV0, CCIV1, CCIV2, CCIV3	28, 29, 30, 31	w	Clear Command Interrupt Valid x Flag 0 _B No effect. 1 _B Bit TSTATR.CIVx is cleared.
0	[7:5], [23:18]	w	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Output Input Control Register

The Output Input Control Register OICR determines the functionality of the MLI transmitter and MLI receiver I/O control logic. The bits in this register are automatically overwritten after a reset with a value given in the implementation chapter (see [Page 22-129](#)). Furthermore, the connection table of the MLI module signals is given there.

Note: The value of register OICR should not be modified while a data transfer (reception or transmission) is ongoing (bits in OICR directly control the I/O signal paths).

OICR

Output Input Control Register

(B4_H)
Reset Value: 1000 8000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RDP	RDS	RCE	RCP	RCS	RVP	RVS	RRP D	RRP C	RRP B	RRP A	RRS				
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RVE	TDP	TCP	TCE	TRE	TRP	TRS	TVP D	TVP C	TVP B	TVP A	TVE D	TVE C	TVE B	TVE A	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
TVEA, TVEB, TVEC, TVED	0, 1, 2, 3	rw	Transmitter Valid Enable These bits enable the module kernel output signals TVALIDx (x = A, B, C, D) to be driven by MLI transmitter output signal TVALID. 0 _B TVALIDx is disabled and remains at passive level (as selected by TVPx). 1 _B Transmitter output signal TVALIDx is enabled and driven by TVALID.
TVPA, TVPB, TVPC, TVPD	4, 5, 6, 7	rw	Transmitter Valid Polarity These bits determine the polarity of the module kernel transmitter output signals TVALIDx (x = A, B, C, D). 0 _B Non-inverted polarity for TVALIDx selected: TVALIDx is passive when driving a 0. TVALIDx is active when driving a 1. 1 _B Inverted polarity for TVALIDx selected: TVALIDx is passive when driving a 1. TVALIDx is active when driving a 0.

Micro Link Interface (MLI)

Field	Bits	Type	Description
TRS	[9:8]	rw	Transmitter Ready Selection This bit field determines the module kernel input signal TREADYx (x = A, B, C, D) that is used as MLI transmitter input signal TREADY. 00 _B TREADYA is selected. 01 _B TREADYB is selected. 10 _B TREADYC is selected. 11 _B TREADYD is selected.
TRP	10	rw	Transmitter Ready Polarity This bit determines the polarity of TREADYx. 0 _B Non-inverted polarity for TREADYx selected: TREADYx is passive if 0. TREADYx is active if 1. 1 _B Inverted polarity for TREADYx selected: TREADYx is passive if 1. TREADY is active if 0.
TRE	11	rw	Transmitter Ready Enable This bit enables the MLI transmitter input signal TREADY. 0 _B TREADY signal is disabled (always at 0 level). 1 _B TREADY signal is enabled and driven by TREADYx according to the settings of TRS and TRP.
TCE	12	rw	Transmitter Clock Enable This bit enables the module kernel output signal TCLK. 0 _B TCLK is disabled and remains at passive level (as selected by TCP). 1 _B TCLK is enabled and driven according to the setting of TCP.
TCP	13	rw	Transmitter Clock Polarity This bit determines the polarity of the module kernel output clock signal TCLK. 0 _B Non-inverted polarity for TCLK selected: TCLK is driving a 0 when it is passive. 1 _B Inverted polarity for TCLK selected: TCLK is driving a 1 when it is passive.

Micro Link Interface (MLI)

Field	Bits	Type	Description
TDP	14	rw	Transmitter Data Polarity This bit determines the polarity of the module kernel output clock signal TDATA. 0 _B TDATA is directly driven by MLI transmitter output signal TDATA (non-inverted). 1 _B TDATA is directly driven by the inverted MLI transmitter output signal TDATA.
RVE	15	rw	Receiver Valid Enable This bit enables the MLI receiver input signal RVALID. 0 _B RVALID signal is disabled (always at 0 level). 1 _B RVALID signal is enabled and driven by RVALIDx according to the settings of RVS and RVP (default after reset).
RRS	[17:16]	rw	Receiver Ready Selector This bit field determines the module kernel output signal RREADYx (x = A, B, C, D) that is driven by the MLI receiver output signal RREADY. The RREADYx output signals that are not selected drives a passive level according to the setting of RRPx. 00 _B RREADYA is selected. 01 _B RREADYB is selected. 10 _B RREADYC is selected. 11 _B RREADYD is selected.
RRPA, RRPB, RRPC, RRPD	18, 19, 20, 21	rw	Receiver Ready Polarity These bits determine the polarity of the module kernel receiver output signals RREADYx (x = A, B, C, D). 0 _B Non-inverted polarity for RREADYx selected: RREADYx is passive if 0. RREADYx is active if 1. 1 _B Inverted polarity for RREADYx selected: RREADYx is passive if 1. RREADYx is active if 0.
RVS	[23:22]	rw	Receiver Valid Selector This bit field determines the module kernel input signal RVALIDx (x = A, B, C, D) that is used as MLI receiver input signal RVALID. 00 _B RVALIDA is selected. 01 _B RVALIDB is selected. 10 _B RVALIDC is selected. 11 _B RVALIDD is selected.

Micro Link Interface (MLI)

Field	Bits	Type	Description
RVP	24	rw	Receiver Valid Polarity This bit determines the polarity of RVALIDx. 0 _B Non-inverted polarity for RVALIDx selected: RVALIDx is passive if 0. RVALIDx is active if 1. 1 _B Inverted polarity for RVALIDx selected: RVALIDx is passive if 1. RVALIDx is active if 0.
RCS	[26:25]	rw	Receiver Clock Selector This bit field determines the module kernel input signal RCLKx (x = A, B, C, D) that is used as MLI receiver input clock CLK. 00 _B RCLKA is selected. 01 _B RCLKB is selected. 10 _B RCLKC is selected. 11 _B RCLKD is selected.
RCP	27	rw	Receiver Clock Polarity This bit determines the polarity of RCLKx. 0 _B Non-inverted polarity for RCLKx selected: RCLKx is at 0 level in passive state. 1 _B Inverted polarity for RCLK selected: RCLKx is at 1 level in passive state.
RCE	28	rw	Receiver Clock Enable This bit enables the MLI receiver input clock RCLK. 0 _B RCLK signal is disabled (always at 0 level). 1 _B RCLK signal is enabled and driven by RCLKx according to the settings of RCS and RCP.
RDS	[30:29]	rw	Receiver Data Selector This bit field determines the module kernel input signal RDATAx (x = A, B, C, D) that is used as MLI receiver data input line RDATA. 00 _B RDATAA is selected. 01 _B RDATAB is selected. 10 _B RDATAAC is selected. 11 _B RDATAAD is selected.
RDP	31	rw	Receiver Data Polarity This bit determines the polarity of RDATAx. 0 _B Non-inverted polarity for RDATAx selected: RDATAx is passive if 0. RDATAx is active if 1. 1 _B Inverted polarity for RDATAx selected: RDATAx is passive if 1. RDATAx is active if 0.

22.4.3 Access Protection Registers

Access Enable Register

The Access Enable Register AER enables write and read operations in the corresponding address ranges ($x = 0$ to 31) in addition to the global move engine enable RCR.MOD. Each address range can be individually enabled or excluded from automatic mode.

Note: Please refer to the implementation chapter for the device specific access protection (see [Page 22-135](#)).

AER

Access Enable Register

(B8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AEN 31	AEN 30	AEN 29	AEN 28	AEN 27	AEN 26	AEN 25	AEN 24	AEN 23	AEN 22	AEN 21	AEN 20	AEN 19	AEN 18	AEN 17	AEN 16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AEN 15	AEN 14	AEN 13	AEN 12	AEN 11	AEN 10	AEN 9	AEN 8	AEN 7	AEN 6	AEN 5	AEN 4	AEN 3	AEN 2	AEN 1	AEN 0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
AENx (x = 0-31)	x	rw	Address Range x Enable This bit enables the read and write capability of the MLI move engine for address range x ($x = 0-31$). 0_B Automatic MLI read and write moves to address range x are disabled. Read/write moves to address range x are not executed automatically and an MLI service request can be generated. The receiving controller's software has to take care about the move. 1_B Automatic MLI read and write moves to address range x are enabled if RCR.MOD = 1.

Micro Link Interface (MLI)

Access Range Register

The Access Range Register ARR determines size and number of the address sub-range n (n = 0-3).

ARR

Access Range Register

(BC_H)

Reset Value: 0000 0000_H

31	29	28	24	23	21	20	16	15	13	12	8	7	5	4	0
SIZE3	SLICE3	SIZE2	SLICE2	SIZE1	SLICE1	SIZE0	SLICE0								
rw	rw	rw	rw	rw	rw	rw	rw								

Field	Bits	Type	Description
SLICE0	[4:0]	rw	Address Slice 0 SLICE0 selects a specific sub-range within address sub-range 0.
SIZE0	[7:5]	rw	Address Size 0 SIZE0 determines the sub-range size within address sub-range 0.
SLICE1	[12:8]	rw	Address Slice 1 SLICE1 selects a specific sub-range within address sub-range 1.
SIZE1	[15:13]	rw	Address Size 1 SIZE1 determines the sub-range size within address sub-range 1.
SLICE2	[20:16]	rw	Address Slice 2 SLICE2 selects a specific sub-range within address sub-range 2.
SIZE2	[23:21]	rw	Address Size 2 SIZE2 determines the sub-range size within address sub-range 2.
SLICE3	[28:24]	rw	Address Slice 3 SLICE3 selects a specific sub-range within address sub-range 3.
SIZE3	[31:29]	rw	Address Size 3 SIZE3 determines the sub-range size within address sub-range 3.

22.4.4 Transmitter Control/Status Registers

Transmitter Control Register

The Transmitter Control Register TCR includes transmitter related control bits and bit fields that are used for parity/acknowledge, address optimization, TDATA idle polarity, retry, and transmitter enable/disable control.

TCR

Transmitter Control Register

(10_H)

Reset Value: 0000 0110_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												TDEL			
r												rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TP	NO	MDP				MNAE		MPE				0	0	DNT	MOD
rw	rw	rw				rwh		rwh				r	rw	rw	rw

Field	Bits	Type	Description
MOD	0	rw	Mode of Operation This bit enables the MLI transmitter. 0 _B The MLI transmitter is disabled. 1 _B The MLI transmitter is enabled.
DNT	1	rw	Data in Not Transmission This bit determines the level of the transmitter data line TDATA when no transmission is in progress. 0 _B TDATA is at low level if no transmission is running. 1 _B TDATA is at high level if no transmission is running.
0	2	rw	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Field	Bits	Type	Description
MPE	[7:4]	rwh	<p>Maximum Parity Errors</p> <p>This bit field determines the maximum number of transmitter parity error conditions that can be still detected until a transmitter parity error event is generated (see Page 22-44). With each condition detected, MPE is decremented down to 0.</p> <p>0000_B A parity error event is generated if a transmitter parity error condition is detected.</p> <p>0001_B A parity error event is generated if a transmitter parity error condition is detected.</p> <p>0010_B A parity error event is generated if 2 transmitter parity error conditions are detected.</p> <p>0011_B A parity error event is generated if 3 transmitter parity error conditions are detected.</p> <p>..._B ...</p> <p>1110_B A parity error event is generated if 14 transmitter parity error conditions are detected.</p> <p>1111_B A parity error event is generated if 15 transmitter parity error conditions are detected.</p>
MNAE	[9:8]	rwh	<p>Maximum Non Acknowledge Errors</p> <p>This bit field determines the maximum number of consecutive Non-Acknowledge error conditions that can be still detected in the transmitter until a time-out event is generated. MNAE is decremented down to 0 at each Non-Acknowledge error condition. When MNAE = 0 or becoming 0, a time-out event is generated. MNAE is automatically set to 11_B after a successful frame transmission (see Page 22-47).</p> <p>00_B A time-out event is generated if a non-ack condition is detected.</p> <p>01_B A time-out event is generated if a non-ack condition is detected.</p> <p>10_B A time-out event is generated if 2 consecutive non-ack conditions are detected.</p> <p>11_B A time-out event is generated if 3 consecutive non-ack conditions are detected.</p>

Micro Link Interface (MLI)

Field	Bits	Type	Description
MDP	[13:10]	rw	Maximum Delay for Parity Error This bit field determines a window for the transmitter in number of TCLK clock periods where a TREADY low-to-high signal transition signal is considered as “correctly received” condition (see Page 22-22). 0000 _B Zero clock periods selected (not useful) 0001 _B 1 clock period selected ... _B ... 1110 _B 14 clock periods selected 1111 _B 15 clock periods selected
NO	14	rw	No Optimized Method This bit field enables/disables the address prediction for read or Write Frames (see Page 22-47). 0 _B Optimized method (address prediction) enabled. 1 _B Optimized method (address prediction) disabled.
TP	15	rw	Type of Parity This bit will determines the type of parity used in frame transmissions. For correct data transfers, TP = 0 has to be programmed. The value TP = 1 can be selected to force parity errors to analyze the propagation delay (see Page 22-26). 0 _B Even parity is selected. 1 _B Odd parity selected.
TDEL	[19:16]	rw	Transmission Delay This bit field defines a delay in cycles of f_{SYS} of the transmitter between the reception of the rising edge of RREADY and the next possible frame start (see Page 22-50). 0000 _B No transmission delay selected 0001 _B One f_{SYS} cycle delay selected ... _B ... 1110 _B Fourteen f_{SYS} cycles delay selected 1111 _B Fifteen f_{SYS} cycles delay selected
0	3, [31:20]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

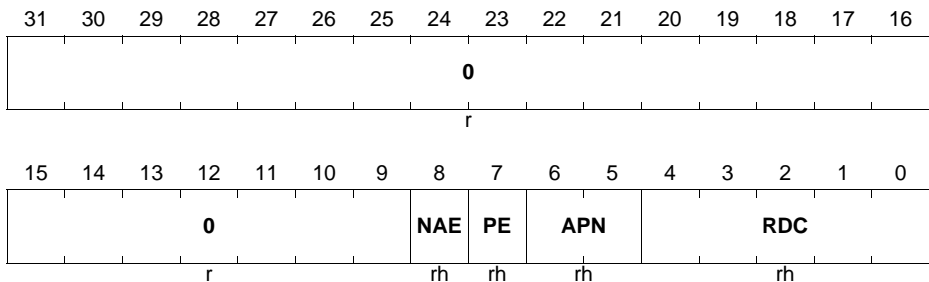
Transmitter Status Register

The Transmitter Status Register TSTATR contains transmitter specific status information.

TSTATR

Transmitter Status Register

(14_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
RDC	[4:0]	rh	Ready Delay Counter This bit field counts TCLK periods after the end of a frame transmission. When the TVALID signal goes to low level, RDC is cleared to zero and starts counting up the TCLK clock periods until a TREADY high level is detected (see Page 22-22).
APN	[6:5]	rh	Answer Pipe Number This bit field is written by the MLI receiver with the Pipe Number of a received Read Frame. APN is used by an Answer Frame that is transmitted as response to the Read Frame. 00 _B Pipe 0 is used in Answer Frame. 01 _B Pipe 1 is used in Answer Frame. 10 _B Pipe 2 is used in Answer Frame. 11 _B Pipe 3 is used in Answer Frame.
PE	7	rh	Parity Error Flag This bit is set if a transmitter parity error condition is detected by the transmitter after a frame transmission. PE is cleared by hardware when a frame has been transmitted without a parity error (see Page 22-44). Bit PE can be cleared by software via bit SCR.CTPE.

Micro Link Interface (MLI)

Field	Bits	Type	Description
NAE	8	rh	Non Acknowledge Error Flag This bit is set when a Non-Acknowledge error condition is detected by the MLI transmitter after a frame transmission (see Page 22-47). NAE is cleared by hardware if a transmitted frame has been acknowledged correctly. Bit NAE can be cleared by software via bit SCR.CNAE.
0	[31:9]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

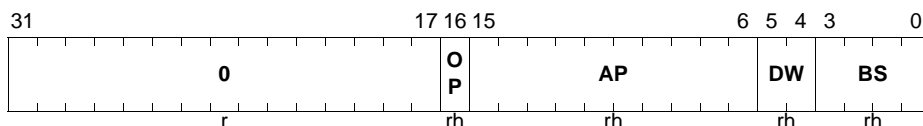
Transmitter Pipe x Status Registers

The Transmitter Pipe x Status Registers TPxSTATR contain pipe-specific status information related to address optimization and prediction, data width for transmit data, and Remote Window size.

TPxSTATR (x = 0-3)

Transmitter Pipe x Status Register

 $(18_H + 4_H * x)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
BS	[3:0]	rh	Buffer Size This bit field indicates the coded buffer size of the pipe x Remote Window in the receiving controller. BS further determines how many address offset bits are transmitted in a Write Offset and Data Frame or in a Discrete Read Frame. When register TPxBAR is written for generation of a Copy Base Address Frame, BS is updated by the Copy Base Address Frame (see Page 22-28). 0000 _B 1-bit offset address of Remote Window 0001 _B 2-bit offset address of Remote Window 0010 _B 3-bit offset address of Remote Window ... _B ... 1110 _B 15-bit offset address of Remote Window 1111 _B 16-bit offset address of Remote Window
DW	[5:4]	rh	Data Width This bit field indicates the data width that has been detected for a read or write access of a bus master to a Transfer Window of pipe x (see Page 22-30 and Page 22-34). 00 _B 8-bit data width detected 01 _B 16-bit data width detected 10 _B 32-bit data width detected 11 _B Reserved

Micro Link Interface (MLI)

Field	Bits	Type	Description
AP	[15:6]	rh	Address Prediction Factor This bit field indicates the delta value (positive or negative number) of offset address used by the MLI transmitter for the next address prediction. AP is a signed 9-bit number (10th bit is the sign bit) that is written with each transmitter address prediction calculation (see Page 22-26 and Page 22-47).
OP	16	rh	Use Optimized Frame When address optimization is enabled with TCR.NO = 0, this bit indicates if address prediction is possible in the transmitter. OP is written with each transmitter address prediction calculation (see Page 22-26 and Page 22-47). 0 _B No address prediction is possible. A Write Offset and Data Frame or a Discrete Read Frame are used for transmission. 1 _B Address prediction is possible. An Optimized Write Frame or an Optimized Read Frame are used for transmission.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Transmitter Command Register

The Transmitter Command Register TCMDR contains the command codes that are used during Command Frame transmission (see [Page 22-41](#)). Each time one of the CMDPx bit fields is written, a Command Frame transmission is triggered. Independent of the transferred command code value, a Command Frame transmitted event can be generated in the transmitter for each pipe and a Command Frame received event for each pipe in the receiver, respectively.

TCMDR

Transmitter Command Register

(28_H)

Reset Value: 0000 0000_H

31	28	27	24	23	20	19	16	15	12	11	8	7	4	3	0
0	CMDP3			0	CMDP2			0	CMDP1			0	CMDP0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
CMDP0	[3:0]	rw	Command Code for Pipe 0 This bit field contains the command code related to pipe 0. The pipe 0 command codes allow an activation (pulse) of one of the service request outputs SR[3:0] in the receiving controller. 0001 _B Activate SR0 0010 _B Activate SR1 0011 _B Activate SR2 0100 _B Activate SR3 Other bit combinations are reserved for future use; no further action in the receiver.
CMDP1	[11:8]	rw	Command Code for Pipe 1 This bit field contains the command code related to pipe 1. The pipe 1 command codes allow to adjust the receiver delay for the parity error condition (see RCR.DPE) in the MLI receiver of the receiving controller. 0000 _B Set RCR.DPE = 0000 _B 0001 _B Set RCR.DPE = 0001 _B ... _B ... 1110 _B Set RCR.DPE = 1110 _B 1111 _B Set RCR.DPE = 1111 _B

Micro Link Interface (MLI)

Field	Bits	Type	Description
CMDP2	[19:16]	rw	Command Code for Pipe 2 This bit field contains the command code related to pipe 2. The pipe 2 command codes allow to control the MLI receiver in the receiving controller. 0001 _B Enable Automatic Data Mode (RCR.MOD = 1) 0010 _B Disable Automatic Data Mode (RCR.MOD = 0) 0100 _B Clear bit TRSTATR.RP0 0101 _B Clear bit TRSTATR.RP1 0110 _B Clear bit TRSTATR.RP2 0111 _B Clear bit TRSTATR.RP3 1111 _B Activate a pulse at <u>BRKOUT</u> Other bit combinations are reserved for future use; no further action in the receiver.
CMDP3	[27:24]	rw	Command Code for Pipe 3 This bit field contains the command code related to pipe 3. The command codes for pipe 3 are free programmable by software.
0	[7:4], [15:12], [23:20], [31:28]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Transmitter-Receiver Status Register

The Transmitter Receiver Status Register TRSTATR contains read-only flags that indicate the status of MLI operations.

TRSTATR

Transmitter Receiver Status Register

(2C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						PN	RP3	RP2	RP1	RP0	DV3	DV2	DV1	DV0	
r						rh	rh	rh	rh	rh	rh	rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						BAV	AV	CV3	CV2	CV1	CV0	CIV3	CIV2	CIV1	CIV0
r						rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
CIV0, CIV1, CIV2, CIV3	0, 1, 2, 3	rh	Command Interrupt Valid Bit is set to 1 by the MLI transmitter whenever it detects a rising edge at the corresponding TRx input line (for Triggered Command Frames in pipe 0). It is cleared by hardware when the Command Frame has been correctly transmitted. CIVx can be cleared by software via bit SCR.CCIVx.
CV0, CV1, CV2, CV3	4, 5, 6, 7	rh	Command Valid Bit is set by hardware when a TCMDR.CMDPx bit field is written. It is cleared by hardware when the Command Frame has been correctly transmitted. CVx can be set or cleared by software via bits SCR.SCVx or SCR.CCVx.
AV	8	rh	Answer Valid Bit is set by hardware when the TDRAR register in the the MLI transmitter (in the Remote Controller) is written. AV is cleared by hardware when the Answer Frame has been correctly sent. AV can be cleared by software via bit SCR.CAV.

Micro Link Interface (MLI)

Field	Bits	Type	Description
BAV	9	rh	Base Address Valid Bit is set by hardware when the TCBAR register in the MLI transmitter is written. BAV is cleared by hardware when the Copy Base Address Frame has been correctly sent. BAV can be cleared by software via bit SCR.CBAV.
DV0, DV1, DV2, DV3	16, 17, 18, 19	rh	Data Valid Bit is set by hardware when the TPxDATAR and/or the TPxAOFR registers of the MLI transmitter are updated after a read or write access to a Transfer Window of pipe x. DVx is cleared again by hardware when the read or Write Frame has been correctly sent. DVx can be cleared by software via bit SCR.CDVx.
RP0, RP1, RP2, RP3	20, 21, 22, 23	rh	Read Pending Bit is set by hardware when the TPxAOFR register of the MLI transmitter is updated after a read access to a Transfer Window of pipe x. RPx is cleared by hardware when the MLI receiver in the Local Controller receives an Answer Frame for pipe x from the Remote Controller. RPx can be cleared by software via bit SCR.CDVx.
PN	[25:24]	rh	Pipe Number This bit field indicates the Pipe Number x of the base address that has been written into register TPxBAR. 00 _B TP0BAR has been last written. 01 _B TP1BAR has been last written. 10 _B TP2BAR has been last written. 11 _B TP3BAR has been last written.
0	[15:10], [31:26]	r	Reserved Read as 0; should be written with 0.

22.4.5 Transmitter Pipe x Address Offset Register

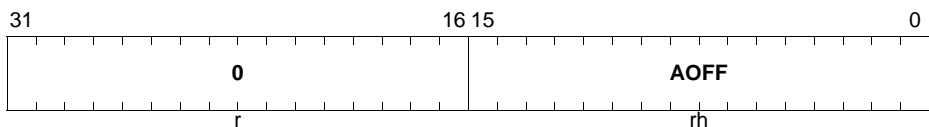
Transmitter Pipe x Address Offset Register

The Transmitter Pipe x Address Offset Register TPxAOFR is a read-only register that stores the offset address that has been used by the last read or write access to a Transfer Window of pipe x.

TPxAOFR (x = 0-3)

Transmitter Pipe x Address Offset Register

 $(30_H + 4_H * x)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
AOFF	[15:0]	rh	Address Offset Whenever a location within a Transfer Window is accessed (read or written) AOFF is loaded with the lowest 16 address bits of the access. Also in the case of a small Transfer Window access, all AOFF bits are loaded, but AOFF[15:13] are not taken into account for further actions assuming the buffer size is configured correctly (see Page 22-105).
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

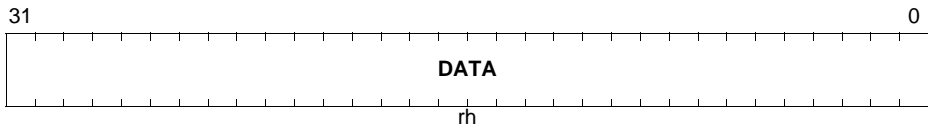
Transmitter Pipe x Data Register

The Transmitter Pipe x Data Register TPxDATAR is a read-only register that stores the data that has been written during the last write access to a Transfer Window of pipe x.

TPxDATAR (x = 0-3)

Transmitter Pipe x Data Register $(40_H + 4_H * x)$

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DATA	[31:0]	rh	Data Whenever a location within a Transfer Window is written, the data is loaded in this bit field.

Transmitter Data Read Answer Register

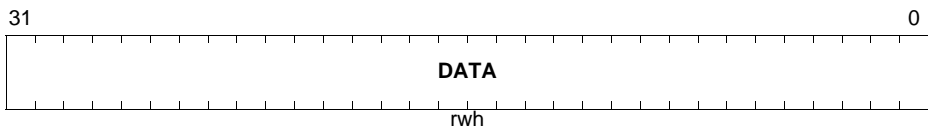
The Transmitter Data Read Answer Register TDRAR contains the read data for the transmission of an Answer Frame.

TDRAR

Transmitter Data Read Answer Register

(50_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DATA	[31:0]	rwh	Data This bit field is loaded with data that is read from the address requested by a Read Frame. An update of this bit field triggers the start of an Answer Frame with DATA used as content of the Answer Frame. This bit field can be updated either automatically by the move engine (if Automatic Data Mode is enabled) or by the CPU (if Automatic Data Mode is disabled).

Micro Link Interface (MLI)

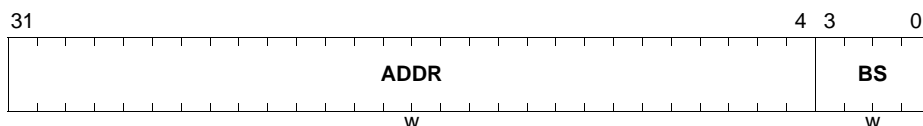
Transmitter Pipe x Base Address Register

The write-only Transmitter Pipe x Base Address Register TPxBAR represents the 28-bit pipe x Remote Window base address and the Remote Window size that is transmitted to the receiving controller via a Copy Base Address Frame.

TPxBAR (x = 0-3)

Transmitter Pipe x Base Address Register

 $(54_H + 4_H * x)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
BS	[3:0]	w	Buffer Size This bit field determines the coded buffer size of the pipe x Remote Window in the receiving controller. When writing TPxBAR, BS is copied into bit field TPxSTATR.BS. 0000 _B 1-bit offset address of Remote Window 0001 _B 2-bit offset address of Remote Window 0010 _B 3-bit offset address of Remote Window ... _B ... 1101 _B 14-bit offset address of Remote Window 1110 _B 15-bit offset address of Remote Window 1111 _B 16-bit offset address of Remote Window Do not use the coding values 1101 _B , 1110 _B , and 1111 _B as buffer size for Small Transfer Windows.
ADDR	[31:4]	w	Address This bit field determines the most significant 28 bits of the pipe x Remote Window base address. When writing TPxBAR, ADDR is copied into bit field TCBAR.ADDR[31:4].

Micro Link Interface (MLI)

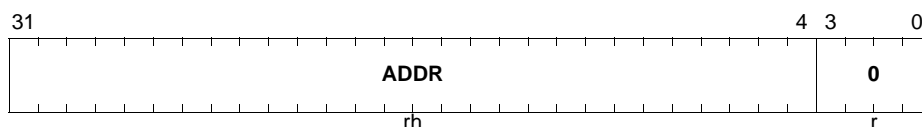
Transmitter Copy Base Address Register

The Transmitter Copy Base Address Register TCBAR contains the 28-bit pipe x Remote Window base address of the latest write access to TPxBAR.ADDR.

TCBAR

Transmitter Copy Base Address Register

(64_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ADDR	[31:4]	rh	Address This bit field contains the 28 address bits written to TPxBAR.ADDR. This value will be transferred to the receiving controller to define the base address of the Remote Window for pipe x.
0	[3:0]	r	Reserved Read as 0; should be written with 0.

22.4.6 Transmitter Interrupt Registers

Transmitter Interrupt Enable Register

The Transmitter Interrupt Enable Register TIER contains the interrupt enable bits and the clear bits for all transmitter events. The bits marked w always read as 0.

TIER

Transmitter Interrupt Enable Register (98_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
			0			TE IR	PE IR	CFS IR3	CFS IR2	CFS IR1	CFS IR0	NFS IR3	NFS IR2	NFS IR1	NFS IR0
			r			w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			0			TE IE	PE IE	CFS IE3	CFS IE2	CFS IE1	CFS IE0	NFS IE3	NFS IE2	NFS IE1	NFS IE0
			r			rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
NFSIE0, NFSIE1, NFSIE2, NFSIE3	0, 1, 2, 3	rw	Normal Frame Sent in Pipe x Interrupt Enable 0 _B Normal frame sent in pipe x event is disabled for activation of an SRx line. 1 _B Normal frame sent in pipe x event is enabled for activation of an SRx line.
CFSIE0, CFSIE1, CFSIE2, CFSIE3	4, 5, 6, 7	rw	Command Frame Sent in Pipe x Interrupt Enable 0 _B Command frame sent in pipe x event is disabled for activation of an SRx line. 1 _B Command frame sent in pipe x event is enabled for activation of an SRx line.
PEIE	8	rw	Parity Error Interrupt Enable 0 _B Parity error event is disabled for activation of an SRx line. 1 _B Parity error event is enabled for activation of an SRx line.

Micro Link Interface (MLI)

Field	Bits	Type	Description
TEIE	9	rw	Time-Out Error Interrupt Enable 0_B Time-out error event is disabled for activation of an SRx line. 1_B Time-out error event is enabled for activation of an SRx line.
NFSIR0, NFSIR1, NFSIR2, NFSIR3	16, 17, 18, 19	w	Normal Frame Sent in Pipe x Flag Clear 0_B No action. 1_B Clear TISR.NFSIx.
CFSIR0, CFSIR1, CFSIR2, CFSIR3	20, 21, 22, 23	w	Command Frame Sent in Pipe x Flag Clear 0_B No action. 1_B Clear TISR.CFSIx.
PEIR	24	w	Parity Error Flag Clear 0_B No action. 1_B Clear TISR.PEIx.
TEIR	25	w	Time Out Error Flag Clear 0_B No action. 1_B Clear TISR.TEIx.
0	[15:10], [31:26]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Transmitter Interrupt Register

The Transmitter Interrupt Status Register TISR contains all MLI event (or interrupt) flags of the MLI transmitter. These flags can be cleared by software when writing the appropriate bits in the TIER register; they are not cleared by hardware.

TISR

Transmitter Interrupt Status Register (9C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						TE I	PE I	CFS I3	CFS I2	CFS I1	CFS I0	NFS I3	NFS I2	NFS I1	NFS I0
r						rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
NFSI0, NFSI1, NFSI2, NFSI3	0, 1, 2, 3	rh	Normal Frame Sent in Pipe x Flag The service request output that can be activated is defined by TINPR.NFSIPx. 0 _B A Normal Frame has not yet been sent. 1 _B A Write or Read Frame has been correctly sent and acknowledged for pipe x.
CFSI0, CFSI1, CFSI2, CFSI3	4, 5, 6, 7	rh	Command Frame Sent in Pipe x Flag The service request output that can be activated is defined by TINPR.CFSIP. 0 _B A Command Frame has not yet been sent. 1 _B A Command Frame has been correctly sent and acknowledged for pipe x.
PEI	8	rh	Parity Error Flag The service request output that can be activated is defined by TINPR.PTEIPx. 0 _B A parity error event has not yet been detected. 1 _B A parity error event has been detected.

Micro Link Interface (MLI)

Field	Bits	Type	Description
TEI	9	rh	Time-Out Error Flag The service request output that can be activated is defined by TINPR.PTEIPx. 0 _B A time-out error event has not yet been detected. 1 _B A time-out error event has been detected.
0	[31:10]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

Transmitter Interrupt Node Pointer Register

The Transmitter Interrupt Node Pointer Register TINPR contains the node pointers for the MLI transmitter events.

TINPR

Transmitter Interrupt Node Pointer Register

(A0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0									PTEIP			0	CFSIP		
r									rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	NFSIP3			0	NFSIP2			0	NFSIP1			0	NFSIP0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
NFSIP0	[2:0]	rw	Normal Frame Sent in Pipe 0 Interrupt Pointer This bit field determines which service request output SRx becomes active when a Normal Frame sent in pipe 0 event occurs (if enabled). 000 _B The service request output SR0 is selected. 001 _B The service request output SR1 is selected. ... _B ... 110 _B The service request output SR6 is selected. 111 _B The service request output SR7 is selected.
NFSIP1	[6:4]	rw	Normal Frame Sent in Pipe 1 Interrupt Pointer This bit field determines which service request output SRx becomes active when a Normal Frame sent in pipe 1 event occurs (if enabled). Coding see NFSIP0.
NFSIP2	[10:8]	rw	Normal Frame Sent in Pipe 2 Interrupt Pointer This bit field determines which service request output SRx becomes active when a Normal Frame sent in pipe 2 event occurs (if enabled). Coding see NFSIP0.
NFSIP3	[14:12]	rw	Normal Frame Sent in Pipe 3 Interrupt Pointer This bit field determines which service request output SRx becomes active when a Normal Frame sent in pipe 3 event occurs (if enabled). Coding see NFSIP0.

Micro Link Interface (MLI)

Field	Bits	Type	Description
CFSIP	[18:16]	rw	Command Frame Sent Interrupt Pointer This bit field determines which service request output SRx becomes active when a Command Frame sent event occurs (if enabled). Coding see NFSIP0.
PTEIP	[22:20]	rw	Parity or Time Out Interrupt Pointer This bit field determines which service request output SRx becomes active when a parity/time-out event occurs (if enabled). Coding see NFSIP0.
0	3, 7, 11, 15, 19, [31:23]	r	Reserved Read as 0; should be written with 0.

22.4.7 Receiver Control/Status Registers

Receiver Control Register

The Receiver Control Register RCR contains control and status bits/bit fields that are related to the MLI receiver operation.

Bit RCVRST is automatically overwritten after a reset (see [Page 22-68](#)) with a value given in the implementation chapter (see [Page 22-129](#)).

RCR

Receiver Control Register

(68_H)

Reset Value: 0100 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							RCV RST	0			BEN	MPE			
r							rw	r			rw	rwh			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RPN		PE	TF		DW		MOD	CMDP3				DPE			
rh		rh	rh		rh		rh	rh				rh			

Field	Bits	Type	Description
DPE	[3:0]	rh	Delay for Parity Error DPE determines the number of RCLK clock periods that the MLI receiver waits before the RREADY signal is raised again when it has detected a parity error (see Page 22-22). When a pipe 1 Command Frame is received by the MLI receiver, the command code is stored in this bit field (see Page 22-41). 0000 _B Zero RCLK clock period delay is selected. 0001 _B One RCLK clock period delay is selected. 0010 _B Two RCLK clock periods delay is selected. ... _B ... 1110 _B Fourteen RCLK clock periods delay is selected. 1111 _B Fifteen RCLK clock periods delay is selected.
CMDP3	[7:4]	rh	Command From Pipe 3 When a pipe 3 Command Frame is received by the MLI receiver, the command code is stored in this bit field. Pipe 3 commands are free for software use.

Micro Link Interface (MLI)

Field	Bits	Type	Description
MOD	8	rh	<p>Mode of Operation</p> <p>This bit determines the data transfer operation mode of the MLI receiver. Bit MOD can be set by hardware with the reception of a pipe 2 Command Frame (see Page 22-100). It can be set or cleared by software via bits SCR.SMOD or SCR.CMOD.</p> <p>0_B Automatic Data Mode is disabled. Data read/write operations from/to a Remote Window must be executed by a bus master (e.g. the CPU).</p> <p>1_B Automatic Data Mode is enabled. Data read/write operations from/to a Remote Window are executed by the MLI's move engine.</p>
DW	[10:9]	rh	<p>Data Width</p> <p>This bit field is updated by the MLI receiver whenever new data is received in the RDATAR register. It indicates the relevant data width.</p> <p>00_B 8-bit relevant data width in RDATAR 01_B 16-bit relevant data width in RDATAR 10_B 32-bit relevant data width in RDATAR 11_B Reserved</p>
TF	[12:11]	rh	<p>Type of Frame</p> <p>This bit field determines the frame type that has most recently been received by the MLI receiver. It is updated whenever the MLI receiver updates RDATAR, RADDR, or RPxBAR. The most recently received frame was a:</p> <p>00_B Copy Base Address Frame 01_B Discrete Read Frame or Optimized Read Frame 10_B Write Offset and Data Frame or Optimized Write Frame 11_B Answer frame</p> <p>Note that the coding of TF is different from the frame coding as defined in Table 22-1 on Page 22-11.</p>
PE	13	rh	<p>Parity Error</p> <p>PE is set when a parity error is detected in a received frame (see Page 22-44). PE is cleared by hardware when a frame has been received without parity error. PE can be cleared by software via bit SCR.CRPE.</p>

Micro Link Interface (MLI)

Field	Bits	Type	Description
RPN	[15:14]	rh	Received Pipe Number This bit field contains the Pipe Number that was indicated by the Pipe Number bit field of the latest received frame. It is updated by any received frame.
MPE	[19:16]	rwh	Maximum Parity Errors This bit field indicates the number of receive parity error conditions after which a receiver parity error event will be generated. It is set to a desired value by software and it is decremented down to 0 automatically by the MLI each time it detects a receiver parity error condition. If a receiver parity error condition is detected and MPE becomes 0 or is already 0, a receiver parity error event is generated (see Page 22-44). 0000 _B A receiver parity event is generated if a receiver error condition is detected. 0001 _B A receiver parity event is generated if a receiver error condition is detected. 0010 _B A receiver parity event is generated if 2 receiver error conditions are detected. ... _B ... 1110 _B A receiver parity event is generated if 14 receiver error conditions are detected. 1111 _B A receiver parity event is generated if 15 receiver error conditions are detected.
BEN	20	rw	Break Out Enable When setting BEN = 1, the MLI receiver generates a pulse on its break output signal $\overline{\text{BRKOUT}}$ when a pipe 2 Command Frame with command code CMD = 1111 _B is received. 0 _B Break output signal generation is disabled. 1 _B Break output signal is enabled.
RCVRST	24	rw	Receiver Reset This bit forces the receiver to be reset in order to be able to change OICR settings without affecting the receiver registers. 0 _B The MLI receiver is in operating mode. 1 _B The MLI receiver is held in reset state and OICR can be modified without unintentional actions in the receiver.

Micro Link Interface (MLI)

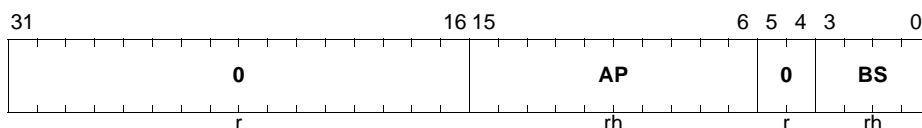
Field	Bits	Type	Description
0	[23:21], [31:25]	r	Reserved Read as 0; should be written with 0.

Receiver Pipe x Status Register

The Receiver Pipe x Status Register RPxSTATR indicates the coded buffer size which represents the Remote Window Size of 2 Bytes to 64 Kbytes and the address prediction factor that has been calculated for pipe x in the receiving controller.

RPxSTATR (x = 0-3)

Receiver Pipe x Status Register ($7C_H + 4_H \cdot x$) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
BS	[3:0]	rh	Buffer Size This bit field indicates the size of pipe x Remote Window in the receiving controller. It is updated by hardware when a Copy Base Address Frame has been received (see Page 22-28). 0000 _B 1-bit offset address of Remote Window 0001 _B 2-bit offset address of Remote Window 0010 _B 3-bit offset address of Remote Window ... 1110 _B 15-bit offset address of Remote Window 1111 _B 16-bit offset address of Remote Window
AP	[15:6]	rh	Address Prediction Factor AP contains the address prediction factor that has been calculated for pipe x in the receiving controller. It is a signed 9-bit number with the sign in its most significant bit (see Page 22-47).
0	[5:4], [31:16]	r	Reserved Read as 0; should be written with 0.

22.4.8 Receiver Address/Data Registers

Receiver Pipe x Base Address Register

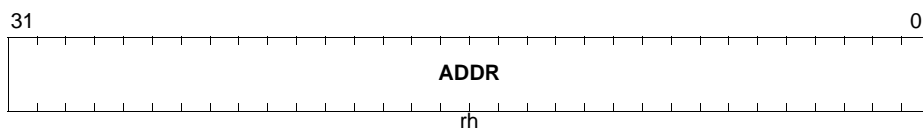
The Receiver Pipe x Base Address Register RPxBAR is a read-only register that contains the complete target address in the Remote Window of pipe x.

RPxBAR (x = 0-3)

Receiver Pipe x Base Address Register

($6C_H + 4_H * x$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
ADDR	[31:0]	rh	<p>Address</p> <p>ADDR indicates the complete target address for the pipe x Remote Window.</p> <p>If a pipe x Copy Base Address Frame is received, ADDR[31:4] becomes loaded with the transmitted 28-bit address and bits [3:0] are cleared.</p> <p>If a write or Read Frame with m bits of address offset is received, bits ADDR[31:m] are held constant and bits ADDR[m-1:0] are replaced by the received offset.</p> <p>If an optimized read or data frame is received, the address prediction mechanism adds the predicted address offset RPxSTATR.AP to ADDR and stores the result in ADDR.</p> <p>If an Answer Frame is received, ADDR is not changed.</p>

Micro Link Interface (MLI)

Receiver Address Register

The Receiver Address Register RADRR is a read-only register storing the complete address of the most recently (or currently) targeted Remote Window.

RADRR

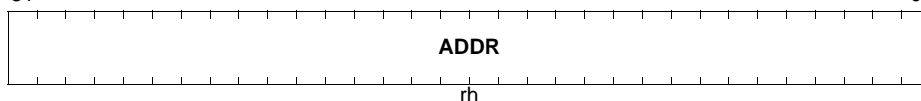
Receiver Address Register

(8C_H)

Reset Value: 0000 0000_H

31

0



Field	Bits	Type	Description
ADDR	[31:0]	rh	<p>Address</p> <p>ADDR indicates the complete target address for the most recently (or currently) targeted Remote Window (pipe x).</p> <p>If a Copy Base Address Frame is received, ADDR is unchanged.</p> <p>If a write or Read Frame with m bits of address offset is received, bits ADDR[31:m] replaced by the bits RPxBAR.ADDR[31:m] and bits ADDR[m-1:0] are replaced by the received offset.</p> <p>If an optimized read or data frame is received, the address prediction mechanism adds the predicted address offset RPxSTATR.AP to RPxBAR.ADDR and stores the result in ADDR.</p> <p>If an Answer Frame is received, ADDR becomes invalid.</p>

Micro Link Interface (MLI)

Receiver Data Register

The Receiver Data Register RDATAR is a read-only register that stores data received by a Write Frame or an Answer Frame.

RDATAR

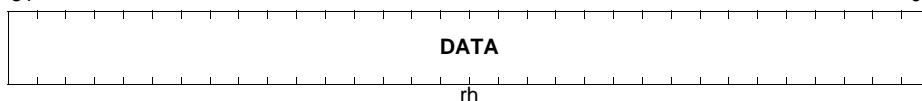
Receiver Data Register

(90_H)

Reset Value: 0000 0000_H

31

0



Field	Bits	Type	Description
DATA	[31:0]	rh	Data In the receiving controller, DATA contains the data received by a Write Frame or an Answer Frame. Bit field RCR.DW determines the width of the relevant data that is stored in RDATAR. RCR.DW = 00 _B : RDATAR[7:0] are relevant (8-bit) RCR.DW = 01 _B : RDATAR[15:0] are relevant (16-bit) RCR.DW = 10 _B : RDATAR[31:0] are relevant (32-bit)

22.4.9 Receiver Interrupt Registers

Receiver Interrupt Enable Register

The Receiver Interrupt Enable Register RIER contains the interrupt enable bits and the clear bits for all receiver events. The bits marked w are always read as 0.

RIER

Receiver Interrupt Enable Register (A4_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
			0			DRA IR	MPE IR	PE IR	ICE R	CFR IR3	CFR IR2	CFR IR1	CFR IR0	ME IR	NFR IR
			r			w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			0			DRA IE	M PEIE	PEIE	ICE	CFR IE3	CFR IE2	CFR IE1	CFR IE0		NFR IE
			r			rw	rw	rw	rw	rw	rw	rw	rw		rw

Field	Bits	Type	Description
NFRIE	[1:0]	rw	Normal Frame Received Interrupt Enable This bit field defines if an SRx output is activated if a Normal Frame is correctly received. 00 _B The SRx activation is disabled. 01 _B The selected SRx line is activated each time a Normal Frame is correctly received. 10 _B The selected SRx line is activated each time a Normal Frame is correctly received that is not handled automatically by the MLI move engine (e.g. an Answer Frame). 11 _B Reserved
CFRIE0, CFRIE1, CFRIE2, CFRIE3	2, 3, 4, 5	rw	Command Received in Pipe x Interrupt Enable This bit determines if an SRx output is activated if a Command Frame for pipe x has been received correctly. 0 _B Command received in pipe x event is disabled for activation of an SRx line. 1 _B Command received in pipe x event is enabled for activation of an SRx line.

Micro Link Interface (MLI)

Field	Bits	Type	Description
ICE	6	rw	Interrupt Command Enable This bit determines if an SRx output line is activated if a Command Frame is received in pipe 0. 0 _B Command frame received in pipe 0 event is disabled for activation of an SRx line. 1 _B Command frame received in pipe 0 event is enabled for activation of an SRx line.
PEIE	7	rw	Parity Error Interrupt Enable This bit determines if an SRx output line is activated if receiver a parity error event is detected. 0 _B Parity error event is disabled for activation of an SRx line. 1 _B Parity error event is enabled for activation of an SRx line.
MPEIE	8	rw	Memory Access Protection Interrupt Enable This bit determines if an SRx output line is activated if a memory access protection error is detected. 0 _B Memory access protection error event is disabled for activation of an SRx line. 1 _B Memory access protection error event is enabled for activation of an SRx line.
DRAIE	9	rw	Discarded Read Answer Interrupt Enable This bit determines if an SRx output line is activated if a discarded read Answer Frame condition is detected. 0 _B Discarded read answer event is disabled for activation of an SRx line. 1 _B Discarded read answer event is enabled for activation of an SRx line.
NFRIR	16	w	Normal Frame Received Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.NFRI.
MEIR	17	w	MLI Move Engine Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.MEI.
CFRIR0, CFRIR1, CFRIR2, CFRIR3	18, 19, 20, 21	w	Command Frame Received in Pipe x Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.CFRIRx.

Micro Link Interface (MLI)

Field	Bits	Type	Description
ICER	22	w	Interrupt Command Flag Clear 0 _B No action. 1 _B Clear RISR.ICE.
PEIR	23	w	Parity Error Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.PEI.
MPEIR	24	w	Memory Protection Error Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.MPEI.
DRAIR	25	w	Discarded Read Answer Interrupt Flag Clear 0 _B No action. 1 _B Clear RISR.DRAI.
0	[15:10], [31:26]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

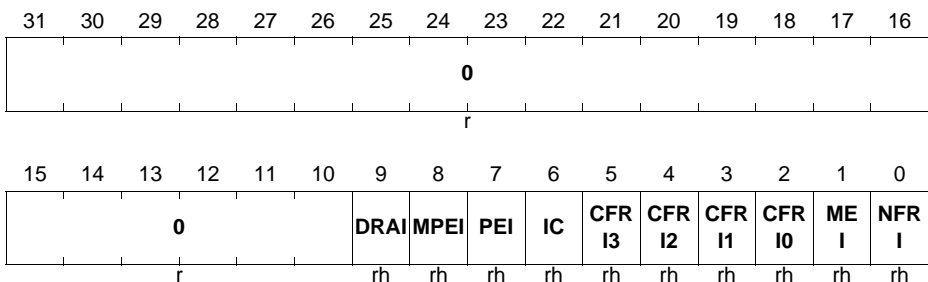
Receiver Interrupt Status Register

The Receiver Interrupt Status Register RISR contains all event (interrupt) flags of the MLI receiver. These flags can be cleared by software when writing the appropriate bits in the RIER register; they are not cleared by hardware.

RISR

Receiver Interrupt Status Register (A8_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
NFRI	0	rh	Normal Frame Received Interrupt Flag This flag is set when a write or a Read Frame has been received. The service request output that is activated is defined by RINPR.NFRIP.
MEI	1	rh	MLI Move Engine Interrupt Flag This flag is set when the move engine has finished an operation (read or write, depending on received frame). The service request output that is activated is defined by RINPR.MPPEIP.
CFRI0, CFRI1, CFRI2, CFRI3	2, 3, 4, 5	rh	Command Frame Received in Pipe x Interrupt Flag This flag is set when a Command Frame has been received in pipe x. The service request output that is activated is defined by RINPR.CFRIP.
IC	6	rh	Interrupt Command Flag This flag is set when a Command Frame has been received in pipe 0 leading to an activation of one of the service request outputs SR[3:0]. The service request output that is activated is defined by the received command CMD.

Micro Link Interface (MLI)

Field	Bits	Type	Description
PEI	7	rh	Parity Error Interrupt Flag This flag is set when a parity error event has occurred. The service request output that is activated is defined by RINPR.MPPEIP.
MPEI	8	rh	Memory Protection Error Interrupt Flag This flag is set when a memory protection event has occurred. The service request output that is activated is defined by RINPR.MPPEIP.
DRAI	9	rh	Discarded Read Answer Interrupt Flag This flag is set when the discarded read answer event has occurred. This condition occurs if an Answer Frame is received while none of the TRSTATR.RPx bits is set (the Answer Frame was not expected). The service request output that is activated is defined by RINPR.DRAIP.
0	[31:10]	r	Reserved Read as 0; should be written with 0.

Micro Link Interface (MLI)

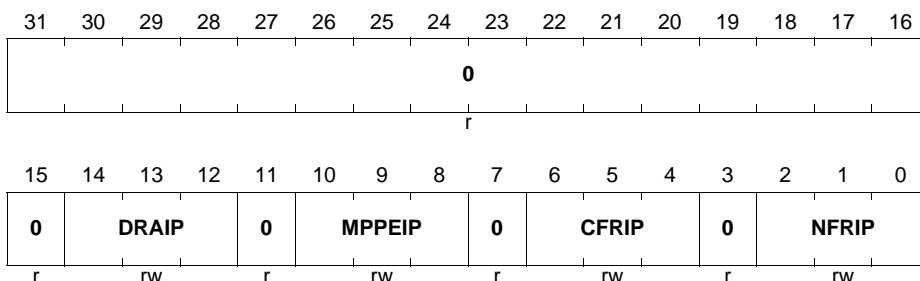
Receiver Interrupt Node Pointer Register

The Receiver Interrupt Node Pointer Register RINPR contains the node pointers for the MLI receiver events.

RINPR

Receiver Interrupt Node Pointer Register

 (AC_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
NFRIP	[2:0]	rw	Normal Frame Received Interrupt Pointer This bit field determines which service request output SRx becomes active when a Normal Frame received event occurs. 000 _B The service request output SR0 is selected. 001 _B The service request output SR1 is selected. ... _B ... 110 _B The service request output SR6 is selected. 111 _B The service request output SR7 is selected.
CFRIP	[6:4]	rw	Command Frame Received Interrupt Pointer This bit field determines which service request output SRx becomes active when a Command Frame received event occurs. Coding see NFRIP.
MPPEIP	[10:8]	rw	Memory Protection or Parity Error Interrupt Pointer This bit field determines which service request output SRx becomes active when a memory protection/parity error event occurs. Coding see NFRIP.
DRAIP	[14:12]	rw	Discarded Read Answer Interrupt Pointer This bit field determines which service request output SRx becomes active when a discarded read answer event occurs. Coding see NFRIP.

Micro Link Interface (MLI)

Field	Bits	Type	Description
0	3, 7, 11, [31:15]	r	Reserved Read as 0; should be written with 0.

22.5 Implementation of the MLI0 in TC1728

This section describes the MLI0 module related external functions such as port connections, interrupt and service request control, connections to other on-chip modules, clock control, and the address map.

22.5.1 Interfaces of the MLI Modules

Figure 22-52 shows how the MLI0 module is interconnected to port lines and other on-chip functional blocks.

The MLI0 module is supplied with clock control, address decoding, and interrupt control logic. Four of the eight module service request outputs are connected to interrupt nodes. Four service request outputs of the MLI0 module are connected as DMA request input to the DMA controller.

The four data, clock, and control lines of the MLI receiver and transmitter are connected to GPIO lines. Alternate functions of Port 2 lines are assigned to the MLI0 module I/O lines. Within the MLI0 module, transmitter and receiver signals can be dynamically connected among each other without using pins; this is useful for test purposes.

Micro Link Interface (MLI)

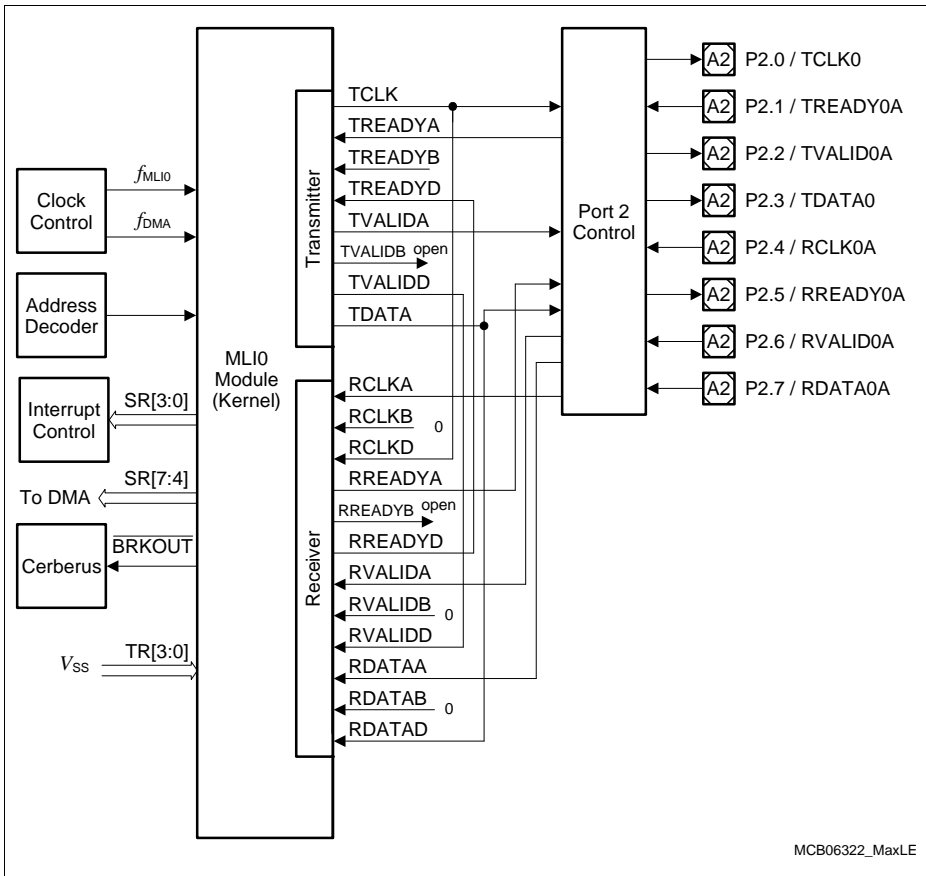


Figure 22-52 MLI0 Module Implementation and Interconnections

When programming the MLI0_OICR register, the following additional items must be considered:

- Unused transmitter/receiver output lines with index “C” (TVALIDC and RREADYC) are not connected.
- Unused transmitter/receiver input lines with index “C” (TREADYC, RCLKC, RVALIDC, and RDATA C) are connected to low level.

Micro Link Interface (MLI)

22.5.2 MLI Module External Registers

Figure 22-53 summarizes the module related external registers that are required for MLI0 programming. Details on MLI0 related register settings are shown in the following sections.

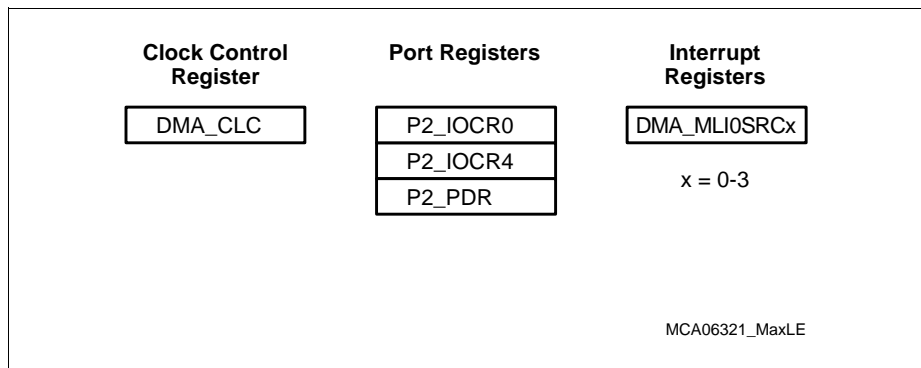


Figure 22-53 MLI0 Implementation-Specific Special Function Registers

22.5.2.1 Automatic Register Overwrite

The following values are applied after reset (see [Page 22-68](#)).

- `OICR = 1000 8000H`; Setting “A” is selected
- `RCR.RCVRST = 0`: the receiver is enabled for reception.

22.5.3 Module Clock Generation

The module clock generation configuration for the MLI module is shown in [Figure 22-54](#).

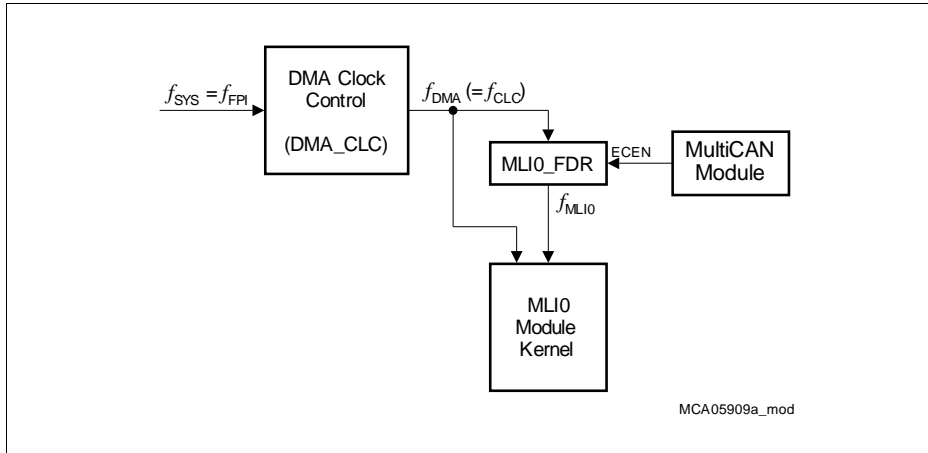


Figure 22-54 Clock Configuration of the MLI Module

The DMA controller and the MLI module are supplied from a common module clock f_{DMA} , that has the frequency of the system clock $f_{SYS} (= f_{FPI})$ and is controlled via the DMA_CLC clock control register. The MLI0 module does not have its own clock control registers. Its module clock f_{MLI0} is derived from f_{DMA} by the fractional divider register MLI0_FDR (description see [Page 22-79](#)).

Output signal CAN_INT_O15 of the MultiCAN module can be used for external clock enable control of the fractional divider.

- f_{DMA}
This is the module clock used inside the MLI kernels for control purposes such as for clocking of control logic and register operations. The clock control register DMA_CLC makes it possible to enable/disable f_{DMA} under certain conditions. DMA_CLC is described in the DMA chapter of this document.
- f_{MLI0}
This clock is the module clock used in the MLI0 kernel as base for the shift clock and therefore determines the baud rate of the synchronous serial data transmission. The fractional divider register MLI0_FDR controls the frequency of f_{MLI0} . This configuration makes it possible to enable/disable the module clock f_{MLI0} independently of f_{DMA} .

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Combined with the baud rate as derived in the MLI module (see [Equation \(22.1\)](#) on [Page 22-67](#)) and the MLI0_FDR fractional divider setup, the resulting MLI baud rate is defined by:

$$\text{Baud rate}_{\text{MLIx}} = \frac{f_{\text{DMA}}}{2} \times \frac{1}{n} \quad \text{with } n = 1024 - \text{FDR.STEP} \quad (22.4)$$

$$\text{Baud rate}_{\text{MLIx}} = \frac{f_{\text{DMA}}}{2} \times \frac{n}{1024} \quad \text{with } n = 0-1023 \quad (22.5)$$

[Equation \(22.4\)](#) applies to normal divider mode of the fractional divider (FDR.DM = 01_B). [Equation \(22.5\)](#) applies to fractional divider mode (FDR.DM = 10_B).

After a reset operation, the MLI module is enabled in normal divider mode. According to the MLI0_FDR register's reset value of 03FF 43FF_H, the selected baud rate is $f_{\text{DMA}}/2$. Note that the DMA controller is also enabled after a reset operation with clock $f_{\text{DMA}} = f_{\text{SYS}}$.

22.5.4 Port Control and Connections

MLIO clock and data output lines are connected to GPIO ports and are, therefore, controlled in the port logics (see also [Page 22-128](#)). The following port control operations selections must be executed for these I/O lines:

- Input/output function selection (IOCR registers)
- Pad driver characteristics selection for the outputs (PDR registers)

22.5.4.1 Input/Output Function Selection

The port input/output control registers contain the bit fields that select the digital output and input driver characteristics such as port direction (input/output) with alternate output selection, pull-up/down devices, and open-drain selections. The I/O lines for the MLI modules are controlled by the Port 2 input/output control registers. When the MLI0 module is connected to the GPIO port lines, the correct settings of the enable/polarity control bits and bit fields in the output input control register MLI0_IOCR must also be regarded (transmitter I/O line control see [Page 22-53](#), receiver I/O line control see [Page 22-54](#)). Note that after a reset operation the MLI0 module (although enabled) have no direct connections to the GPIO lines.

[Table 22-11](#) shows how OICR register bits and bit fields must be programmed for the required GPIO functionality of the MLI I/O lines.

Table 22-11 MLI0 I/O Line Selection and Setup

Module	Port Lines	Input/Output Control Register Bits	I/O
MLI0	P2.0 / TCLK0	P2_IOCR0.PC0 = 1X10 _B MLI0_IOCR.TCE = 1 MLI0_IOCR.TCP = X	Output
	P2.1 / TREADY0A	P2_IOCR0.PC1 = 0XXX _B MLI0_IOCR.TRE = 1 MLI0_IOCR.TRP = X MLI0_IOCR.TRS = 00 _B	Input
	P2.2 / TVALID0A	P2_IOCR0.PC2 = 1X10 _B MLI0_IOCR.TVEA = 1 MLI0_IOCR.TVPA = X	Output
	P2.3 / TDATA0	P2_IOCR0.PC3 = 1X10 _B MLI0_IOCR.TDP = X	Output
	P2.4 / RCLK0A	P2_IOCR4.PC4 = 0XXX _B MLI0_IOCR.RCE = 1 MLI0_IOCR.RCP = X MLI0_IOCR.RCS = 00 _B	Input

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Table 22-11 MLI0 I/O Line Selection and Setup (cont'd)

Module	Port Lines	Input/Output Control Register Bits	I/O
MLI0	P2.5 / RREADY0A	P2_IOC4.PC5 = 1X10 _B MLI0_OICR.RRS = 00 _B MLI0_OICR.RRPA = X	Output
	P2.6 / RVALID0A	P2_IOC4.PC6 = 0XXX _B MLI0_OICR.RVE = 1 MLI0_OICR.RVP = X MLI0_OICR.RVS = 00 _B	Input
	P2.7 / RDATA0A	P2_IOC4.PC7 = 0XXX _B MLI0_OICR.RDP = X MLI0_OICR.RDS = 00 _B	Input

22.5.5 On-Chip Connections

22.5.5.1 Service Request Output Connections

The MLI0 module provides eight service request outputs SR[7:0] that can be used to generate interrupts or DMA requests. In the TC1728, four service request outputs SR[3:0] of the MLI0 module are connected to an interrupt node. Four service request outputs (SR[7:4]) of the MLI0 module are connected to DMA request inputs of the TC1728 DMA controller.

Each of the service request outputs used as interrupt requests are controlled by a service request control register. The service request control registers of the MLI modules are located inside the DMA address area. Therefore, all MLI0 service request control registers are named as DMA_MLI0SRCy and described in the DMA chapter implementation part of the TC1728 User's Manual.

All MLI service request output connections are listed in [Table 22-12](#).

Table 22-12 Service Request Lines and Interconnections of MLI0

Module	Service Req. Output Line	Connected to Node or DMA Request Input	Description
MLI0	SR0	DMA_MLI0SRC0	MLI0 Service Request Node 0 (in DMA)
	SR1	DMA_MLI0SRC1	MLI0 Service Request Node 1 (in DMA)
	SR2	DMA_MLI0SRC2	MLI0 Service Request Node 2 (in DMA)
	SR3	DMA_MLI0SRC3	MLI0 Service Request Node 3 (in DMA)
	SR4	CH00_REQI7	DMA Channel 00 Request Input 7
		CH04_REQI7	DMA Channel 04 Request Input 7
	SR5	CH01_REQI7	DMA Channel 01 Request Input 7
		CH05_REQI7	DMA Channel 05 Request Input 7
	SR6	CH02_REQI7	DMA Channel 02 Request Input 7
		CH06_REQI7	DMA Channel 06 Request Input 7
	SR7	CH03_REQI7	DMA Channel 03 Request Input 7
		CH07_REQI7	DMA Channel 07 Request Input 7

22.5.5.2 Break Signals

The **BRKOUT** output signal of the MLI0 is connected as break input signals to the Multi Core Break Switch (MCBS) that is a part of the Cerberus on-chip debug control module. These connections allow MLI0 initiated break conditions to be generated in the Cerberus.

22.5.5.3 Trigger Input Signals

The five Trigger Input Signals TR[4:0] are connected to V_{SS} .

22.5.6 Access Protection

The access protection parameters for the MLI module in the TC1728 are identical with access protection parameters of the DMA Controller. Details of the access protection parameters are defined in the DMA chapter at “DMA Module Implementation” - “Access Protection Assignment”.

The Table “DMA Access Protection Address Ranges” in the DMA chapter is also valid for MLI register bits AER.AENRx ($x = 0-31$).

The Tables “... Address Protection Sub-Range Definition” for PMI, OVRAM, DMI, and PCP PRAM in the DMA chapter are also valid for MLI register bits ARR.SLICEn and ARR.SIZEEn ($n = 0-3$).

22.5.7 MLI0 Transfer Window Address Maps

The MLI0 module supports four Small Transfer Windows STW (one for each pipe) and four Large Transfer Windows LTW (one for each pipe). In the TC1728, the transfer windows for the MLI0 module are located in the address ranges as defined in [Table 22-13](#).

Table 22-13 MLI0 Transfer Windows

Module	Window Type	Pipe	Address Range
MLI0	Small Transfer Window (STW)	Pipe 0	F01E 0000 _H to F01E 1FFF _H
		Pipe 1	F01E 2000 _H to F01E 3FFF _H
		Pipe 2	F01E 4000 _H to F01E 5FFF _H
		Pipe 3	F01E 6000 _H to F01E 7FFF _H
	Large Transfer Window (LTW)	Pipe 0	F020 0000 _H to F020 FFFF _H
		Pipe 1	F021 0000 _H to F021 FFFF _H
		Pipe 2	F022 0000 _H to F022 FFFF _H
		Pipe 3	F023 0000 _H to F023 FFFF _H

Micro Link Interface (MLI)

22.5.8 MLI0 Address Map

An absolute register address is given by the offset address of the register (given in [Table 22-10](#)) plus the module base address (given in [Table 22-9](#)).

Table 22-14 Address Map of MLI0

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
Multi Link Interface 0 (MLI0)					
–	Reserved	F010 C000 _H	nBE	SV, E	–
–	Reserved	F010 C004 _H	nBE	nBE	–
MLI0_ ID	MLI0 Module Identification Register	F010 C008 _H	U, SV	BE	0025 XXXX _H
MLI0_ FDR	MLI0 Fractional Divider Register	F010 C00C _H	U, SV	SV, E	03FF 43FF _H
MLI0_ TCR	MLI0 Transmitter Control Register	F010 C010 _H	U, SV	U, SV	0000 0110 _H
MLI0_ TSTATR	MLI0 Transmitter Status Register	F010 C014 _H	U, SV	BE	0000 0000 _H
MLI0_ TP0STATR	MLI0 Transmitter Pipe 0 Status Register	F010 C018 _H	U, SV	BE	0000 0000 _H
MLI0_ TP1STATR	MLI0 Transmitter Pipe 1 Status Register	F010 C01C _H	U, SV	BE	0000 0000 _H
MLI0_ TP2STATR	MLI0 Transmitter Pipe 2 Status Register	F010 C020 _H	U, SV	BE	0000 0000 _H
MLI0_ TP3STATR	MLI0 Transmitter Pipe 3 Status Register	F010 C024 _H	U, SV	BE	0000 0000 _H
MLI0_ TCMDR	MLI0 Transmitter Command Register	F010 C028 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TRSTATR	MLI0 Transmitter Registers Status Register	F010 C02C _H	U, SV	BE	0000 0000 _H
MLI0_ TP0AOFR	MLI0 Transmitter Pipe 0 Address Offset Register	F010 C030 _H	U, SV	BE	0000 0000 _H
MLI0_ TP1AOFR	MLI0 Transmitter Pipe 1 Address Offset Register	F010 C034 _H	U, SV	BE	0000 0000 _H
MLI0_ TP2AOFR	MLI0 Transmitter Pipe 2 Address Offset Register	F010 C038 _H	U, SV	BE	0000 0000 _H

Micro Link Interface (MLI)

Table 22-14 Address Map of MLI0 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
MLI0_ TP3AOFR	MLI0 Transmitter Pipe 3 Address Offset Register	F010 C03C _H	U, SV	BE	0000 0000 _H
MLI0_ TP0DATAR	MLI0 Transmitter Pipe 0 Data Register	F010 C040 _H	U, SV	BE	0000 0000 _H
MLI0_ TP1DATAR	MLI0 Transmitter Pipe 1 Data Register	F010 C044 _H	U, SV	BE	0000 0000 _H
MLI0_ TP2DATAR	MLI0 Transmitter Pipe 2 Data Register	F010 C048 _H	U, SV	BE	0000 0000 _H
MLI0_ TP3DATAR	MLI0 Transmitter Pipe 3 Data Register	F010 C04C _H	U, SV	BE	0000 0000 _H
MLI0_ TDRAR	MLI0 Transmitter Data Read Answer Register	F010 C050 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TP0BAR	MLI0 Transmitter Pipe 0 Base Address Register	F010 C054 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TP1BAR	MLI0 Transmitter Pipe 1 Base Address Register	F010 C058 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TP2BAR	MLI0 Transmitter Pipe 2 Base Address Register	F010 C05C _H	U, SV	U, SV	0000 0000 _H
MLI0_ TP3BAR	MLI0 Transmitter Pipe 3 Base Address Register	F010 C060 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TCBAR	MLI0 Transmitter Copy Base Address Register	F010 C064 _H	U, SV	BE	0000 0000 _H
MLI0_ RCR	MLI0 Receiver Control Register	F010 C068 _H	U, SV	U, SV	0100 0000 _H
MLI0_ RP0BAR	MLI0 Receiver Pipe 0 Base Address Register	F010 C06C _H	U, SV	BE	0000 0000 _H
MLI0_ RP1BAR	MLI0 Receiver Pipe 1 Base Address Register	F010 C070 _H	U, SV	BE	0000 0000 _H
MLI0_ RP2BAR	MLI0 Receiver Pipe 2 Base Address Register	F010 C074 _H	U, SV	BE	0000 0000 _H
MLI0_ RP3BAR	MLI0 Receiver Pipe 3 Base Address Register	F010 C078 _H	U, SV	BE	0000 0000 _H

Micro Link Interface (MLI)

Table 22-14 Address Map of MLI0 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
MLI0_ RP0STATR	MLI0 Receiver Pipe 0 Status Register	F010 C07C _H	U, SV	BE	0000 0000 _H
MLI0_ RP1STATR	MLI0 Receiver Pipe 1 Status Register	F010 C080 _H	U, SV	BE	0000 0000 _H
MLI0_ RP2STATR	MLI0 Receiver Pipe 2 Status Register	F010 C084 _H	U, SV	BE	0000 0000 _H
MLI0_ RP3STATR	MLI0 Receiver Pipe 3 Status Register	F010 C088 _H	U, SV	BE	0000 0000 _H
MLI0_ RADRR	MLI0 Receiver Address Register	F010 C08C _H	U, SV	BE	0000 0000 _H
MLI0_ RDATAR	MLI0 Receiver Data Register	F010 C090 _H	U, SV	BE	0000 0000 _H
MLI0_ SCR	MLI0 Set Clear Register	F010 C094 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TIER	MLI0 Transmitter Interrupt Enable Register	F010 C098 _H	U, SV	U, SV	0000 0000 _H
MLI0_ TISR	MLI0 Transmitter Interrupt Status Register	F010 C09C _H	U, SV	BE	0000 0000 _H
MLI0_ TINPR	MLI0 Transmitter Interrupt Node Pointer Register	F010 C0A0 _H	U, SV	U, SV	0000 0000 _H
MLI0_ RIER	MLI0 Receiver Interrupt Enable Register	F010 C0A4 _H	U, SV	U, SV	0000 0000 _H
MLI0_ RISR	MLI0 Receiver Interrupt Status Register	F010 C0A8 _H	U, SV	BE	0000 0000 _H
MLI0_ RINPR	MLI0 Receiver Interrupt Node Pointer Register	F010 C0AC _H	U, SV	U, SV	0000 0000 _H
MLI0_ GINTR	MLI0 Global Interrupt Set Register	F010 C0B0 _H	U, SV	U, SV	0000 0000 _H
MLI0_ OICR	MLI0 Output Input Control Register	F010 C0B4 _H	U, SV	U, SV	1000 8000 _H
MLI0_ AER	MLI0 Access Enable Register	F010 C0B8 _H	U, SV	SV, E	0000 0000 _H

Micro Link Interface (MLI)
Table 22-14 Address Map of MLI0 (cont'd)

Short Name	Description	Address	Access Mode		Reset Value
			Read	Write	
MLI0_ ARR	MLI0 Access Range Register	F010 C0BC _H	U, SV	SV, E	0000 0000 _H
–	Reserved	F010 C0C0 _H - F010 C0FC _H	BE	BE	–

General Purpose Timer Array (GPTA[®]v5)

23 General Purpose Timer Array (GPTA[®]v5)

This chapter describes the General Purpose Timer Array of the TC1728. The GPTA¹⁾ consists of the following units: GPTA0.

This chapter contains the following sections:

- A summary on the structure and basic functionalities (see [Page 23-4](#))
- Functional description of the GPTA[®]v5 kernel, applicable for GPTA0 (see [Page 23-8](#))
- Register descriptions of all GPTA[®]v5 kernel specific registers, applicable for GPTA0 (see [Page 23-160](#))
- TC1728 implementation-specific details and registers of the GPTA[®]v5 module, including port connections and control, interrupt control, address decoding, and clock control (see [Page 23-229](#)).

Note: The GPTA[®]v5 kernel register names described in [Section 23.4](#) and [Section 23.5.2](#) will be referenced in the TC1728 User's Manual by the unit name prefix "GPTA0_" for the GPTA0 unit.

23.1 What is new?

The major updates from GPTAv4 to GPTAv5 are:

- The flexibility to generate on-chip trigger and gating signals have been increased. The GPTAv5 provides 16 such signals. Each of the signals may be mapped to any output signal of a Local or Global Timer Cell. Therefore it is not limited as before to a single group of Global or Local Timer Cells (25% of the GTC or LTC). Limitation now is, that no more than 4 different on-chip trigger and gating signals may be mapped to one group of LTC or GTC. Details concerning this new on-chip trigger and gating signal multiplexer are described in [Section 23.3.4.3](#) (see [Page 23-108](#)). This new features is not fully upwards compatible to the GPTAv4. Additional output multiplexer registers have to be configured to achieve the same functionality (see ["Multiplexer Register Array Programming" on Page 23-121](#)). Some very minor issue may occur due to a minor reduction of on-chip signal and trigger signals compared to GPTAv4, but on the other hand the increased flexibility should nearly always compensated this. The following list summarizes the principle of mapping former GPTAv4 signals to the new GPTAv5 signals:
 - GPTAv4 Signal GPTA0_OUT0 is replaced by GPTAv5 Signal GPTA0_TRIG01
 - GPTAv4 Signal GPTA0_OUT1 is replaced by GPTAv5 Signal GPTA0_TRIG11
 - GPTAv4 Signal GPTA0_OUT2 is replaced by GPTAv5 Signal GPTA0_TRIG00
 - GPTAv4 Signal GPTA0_OUT3 is replaced by GPTAv5 Signal GPTA0_TRIG10
 - GPTAv4 Signal GPTA0_OUT8 is replaced by GPTAv5 Signal GPTA0_TRIG03
 - GPTAv4 Signal GPTA0_OUT9 is replaced by GPTAv5 Signal GPTA0_TRIG13
 - GPTAv4 Signal GPTA0_OUT10 is replaced by GPTAv5 Signal GPTA0_TRIG02

1) TriCore[®], C166[®], Infineon[®], Infineon Technologies[®], and GPTA[®] are trademarks of Infineon Technologies AG.

General Purpose Timer Array (GPTA[®]v5)

- GPTAv4 Signal GPTA0_OUT11 is replaced by GPTAv5 Signal GPTA0_TRIG12
- GPTAv4 Signal GPTA0_OUT16 is replaced by GPTAv5 Signal GPTA0_TRIG05
- GPTAv4 Signal GPTA0_OUT18 is replaced by GPTAv5 Signal GPTA0_TRIG15
- GPTAv4 Signal GPTA0_OUT19 is replaced by GPTAv5 Signal GPTA0_TRIG04
- GPTAv4 Signal GPTA0_OUT24 is replaced by GPTAv5 Signal GPTA0_TRIG07
- GPTAv4 Signal GPTA0_OUT26 is replaced by GPTAv5 Signal GPTA0_TRIG17
- GPTAv4 Signal GPTA0_OUT27 is replaced by GPTAv5 Signal GPTA0_TRIG06
- GPTAv4 Signal GPTA0_OUT28 is replaced by GPTAv5 Signal GPTA0_TRIG07
- GPTAv4 Signal GPTA0_OUT4 is no longer available in GPTAv5. This signal was routed to the ERU (TC1766 only) to cover 75% of the GTC and LTC cells as input to Input channel 1. But Signal GPTA0_TRIG12 may be routed to all (100%) GTC and LTC cells due to the on-chip trigger and gating multiplexer and therefore fulfills this requirement already.
- GPTAv4 Signal GPTA0_OUT7 is no longer available in GPTAv5. This signal was routed to the ERU (TC1766 only) to cover 75% of the GTC and LTC cells as input to Input channel 2. But Signal GPTA0_TRIG14 may be routed to all (100%) GTC and LTC cells due to the on-chip trigger and gating multiplexer and therefore fulfills this requirement already.
- To be consistent to TC1797, the double connected input group of IOG3 is renamed to IOG6 and the Output Group OG1-7 are renamed to OG0-OG6 and the OG0 is renamed to IOG7.
- GPTAv4 Signal GPTA0_OUT17 is no longer available in GPTAv5. This signal was routed to the ERU to cover 50% of the GTC and LTC cells as input to Input channel 2. But Signal GPTA0_TRIG14 may be routed to all (100%) GTC and LTC cells due to the on-chip trigger and gating multiplexer and therefore fulfills this requirement already.
- GPTAv4 Signal GPTA0_OUT22 is no longer available in GPTAv5. This signal was routed to the ERU (TC1766 only) to cover 75% of the GTC and LTC cells as input to Input channel 3. But Signal GPTA0_TRIG16 may be routed to all (100%) GTC and LTC cells due to the on-chip trigger and gating multiplexer and therefore fulfills this requirement already.
- GPTAv4 Signal GPTA0_OUT25 is no longer available in GPTAv5. This signal was routed to the ERU to cover 50% of the GTC and LTC cells as input to Input channel 3. But Signal GPTA0_TRIG16 may be routed to all (100%) GTC and LTC cells due to the on-chip trigger and gating multiplexer and therefore fulfills this requirement already.
- GPTAv4 Signal GPTA0_OUT5 is no longer required (Time Trigger CAN) but GPTAv5 Signal GPTA0_TRIG05 is reserved for it.
- To improve effective usage of the Local Timer Cells, a new cell bypassing, so called global bypass, is introduced. This bypassing enables more flexible cell allocation and also reduces the number of LTC required for coherent update. Details on the two different Local Timer Cell Bypass mechanism may be found in the section **“Data Output Line Control” on Page 23-73**. Two different application examples using the

General Purpose Timer Array (GPTA[®]v5)

global and local bypass may be found in [Section 23.3.3.5](#)(see [Page 23-85](#)). This new features is upwards compatible to the GPTAv4.

- Due to the new bypassing mechanism, a new coherent update mechanism has been introduced, the Local Coherent update described within [Section 23.3.3.5](#) (see [Page 23-85](#)). This new local coherent update or double action principle, is very useful to update single Local Timer Cells or a couple of Local Timer Cells within a Group sequentially (not simultaneously) without signal distortion (no other signal output beside the previously configured and the new configured). The new update principle allows to update a local timer cell within a group of local timer cells independent of other local timer cells and therefore also not synchronous/coherent to other local timer cells. This new mechanism upgrades the older mechanism of global coherent update. This older principle of global coherent is very useful to update a number of Local Timer Cells simultaneously. This new features is upwards compatible to the GPTAv4.
- The common IN0 of GPTA0/GPTA1/LTCA2 is multiplexed within the SCU to connect either to a port pin or the EXTCLK0 (see [Page 23-241](#)).

General Purpose Timer Array (GPTA[®]v5)

23.2 GPTA[®]v5 Overview

The TC1728 contains the General Purpose Timer Array (GPTA0). **Figure 23-1** shows a global view of the GPTA[®]v5 unit.

The GPTA[®]v5 provides a set of timer, compare, and capture functionalities that can be flexibly combined to form signal measurement and signal generation cells. They are optimized for tasks typical of engine, gearbox, and electrical motor control applications, but can also be used to generate simple and complex signal waveforms required for other industrial applications.

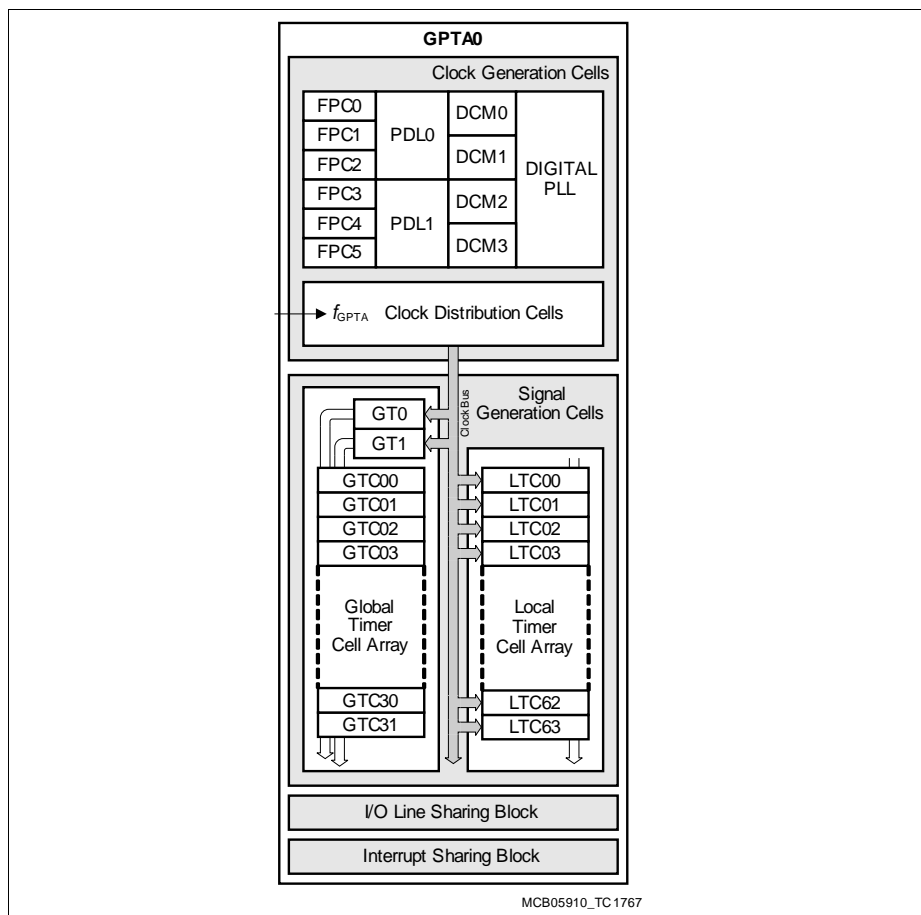


Figure 23-1 General Block Diagram of the GPTA[®]v5 units in the TC1728

General Purpose Timer Array (GPTA[®]v5)

23.2.1 Functionality of GPTA0

The General Purpose Timer Array (GPTA0) provides a set of hardware cells required for high-speed digital signal processing:

- Filter and Prescaler Cells (FPC) support input noise filtering and prescaler operation.
- Phase Discrimination Logic cells (PDL) decode the direction information output by a rotation tracking system.
- Duty Cycle Measurement Cells (DCM) provide pulse-width measurement capabilities.
- A Digital Phase Locked Loop cell (PLL) generates a programmable number of GPTA[®]v5 unit ticks during an input signal's period.
- Global Timer cells (GT) driven by various clock sources are implemented to operate as a time base for the associated Global Timer Cells.
- Global Timer Cells (GTC) can be programmed to capture the contents of a Global Timer on an external or internal event. A GTC may also be used to control an external port pin depending on the result of an internal compare operation. GTCs can be logically concatenated to provide a common external port pin with a complex signal waveform.
- Local Timer Cells (LTC) operating in Timer, Capture, or Compare Mode may also be logically tied together to drive a common external port pin with a complex signal waveform. LTCs – enabled in Timer Mode or Capture Mode – can be clocked or triggered by various external or internal events.
- On-chip Trigger and Gating Signals (OTGS) can be configured to provide trigger or gating signals to integrated peripherals.

Input lines can be shared by an LTC and a GTC to trigger their programmed operation simultaneously.

The following list summarizes the specific features of the GPTA[®]v5 cells.

Clock Generation Cells

- Filter and Prescaler Cell (FPC)
 - Six independent cells
 - Three basic operating modes:
Prescaler, Delayed Debounce Filter, Immediate Debounce Filter
 - Selectable input sources:
Port lines, GPTA[®]v5 unit clock, FPC output of preceding FPC cell
 - Selectable input clocks:
GPTA[®]v5 unit clock, prescaled GPTA[®]v5 unit clock, DCM clock, compensated or uncompensated PLL clock.
 - $f_{\text{GPTA}}/2$ maximum input signal frequency in Filter Modes
- Phase Discriminator Logic (PDL)
 - Two independent cells
 - Two operating modes (2- and 3- sensor signals)

General Purpose Timer Array (GPTA®v5)

- $f_{\text{GPTA}}/4$ maximum input signal frequency in 2-sensor Mode, $f_{\text{GPTA}}/6$ maximum input signal frequency in 3-sensor Mode
- Duty Cycle Measurement (DCM)
 - Four independent cells
 - 0 - 100% margin and time-out handling
 - f_{GPTA} maximum resolution
 - $f_{\text{GPTA}}/2$ maximum input signal frequency
- Digital Phase Locked Loop (PLL)
 - One cell
 - Arbitrary multiplication factor between 1 and 65535
 - f_{GPTA} maximum resolution
 - $f_{\text{GPTA}}/2$ maximum input signal frequency
- Clock Distribution Cells (CDC)
 - One unit
 - Provides nine clock output signals: f_{GPTA} , divided f_{GPTA} clocks, FPC1/FPC4 outputs, DCM clock, LTC prescaler clock

Signal Generation Cells

- Global Timers (GT)
 - Two independent cells
 - Two operating modes (Free-Running Timer and Reload Timer)
 - 24-bit data width
 - f_{GPTA} maximum resolution
 - $f_{\text{GPTA}}/2$ maximum input signal frequency
- Global Timer Cell (GTC)
 - 32 cells related to the Global Timers
 - Two operating modes (Capture, Compare and Capture after Compare)
 - 24-bit data width
 - f_{GPTA} maximum resolution
 - $f_{\text{GPTA}}/2$ maximum input signal frequency
- Local Timer Cell (LTC)
 - 64 independent cells
 - Three basic operating modes (Timer, Capture and Compare) for 63 cells
 - Special compare modes for one cell
 - 16-bit data width
 - f_{GPTA} maximum resolution
 - $f_{\text{GPTA}}/2$ maximum input signal frequency

Interrupt Sharing Block

- 111 interrupt sources, generating up to 38 service requests

General Purpose Timer Array (GPTA[®]v5)**On-chip Trigger Block**

- 16 on-chip trigger signals

I/O Sharing Block

- Interconnecting inputs and outputs from internal clocks, FPC, GTC, LTC, ports, and MSC interface

General Purpose Timer Array (GPTA®v5)

23.3 GPTA0 Kernel Description

The functionality of the General Purpose Timer Arrays GPTA0 kernel is described in this section. Clock control, address decoding, and service (interrupt) request control are managed outside the GPTA0 unit kernel.

Figure 23-2 shows a global unit diagram of the GPTA®v5 unit kernel.

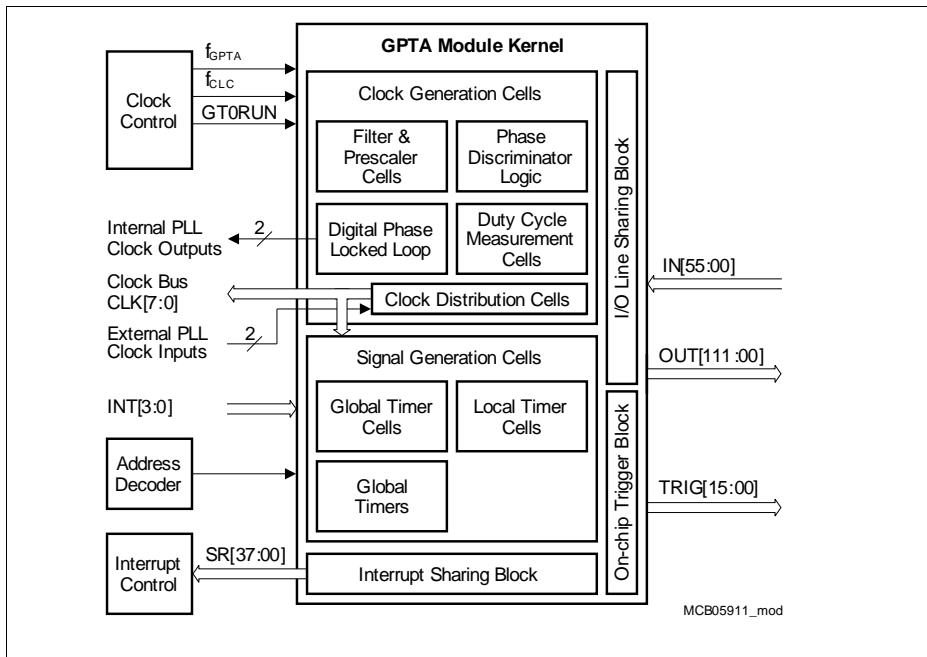


Figure 23-2 Block Diagram of GPTA®v5 Kernel

The GPTA0 kernel has 56 input signals, 112 output signals, and four input signals, that can be connected to port pins or other on-chip logic modules (see **“GPTA®v5 Module Implementation” on Page 23-229** for the TC1728 specific interconnections). Further, several clock input and output signals are provided.

General Purpose Timer Array (GPTA[®]v5)

23.3.1 GTPA Units

The General Purpose Timer Arrays GPTA0 ([Figure 23-2](#)) is split into Clock Generation Cells (CGC) and a Signal Generation Cells (SGC):

- The **Clock Generation Cells** (see [Page 23-10](#)) allow a preprocessing of the input signals using filter, timer, capture, compare and enhanced digital PLL cells:
 - The **Filter and Prescaler Cells** (FPC) provide input noise filtering (Immediate Debounce and Delayed Debounce) and may also work as prescalers for the GPTA[®]v5 module clock and external signals.
 - The **Phase Discrimination Logic** (PDL) may take the outputs of the FPCs to decode phase encoded signals from a position and rotation direction sensor system.
 - The **Duty Cycle Measurement Cells** (DCM) provide signal measurement capabilities (timer plus capture register, single and double capture on rising and falling edges or both) as well as missing pulse detection/reconstruction functions.
 - The **Digital Phase Locked Loop** (Digital PLL) generates a clock with higher clock resolution (harmonic) out of the signal measured by DCM cells. Any arbitrary multiplication factor between 1 and 65535 is supported and may be changed each PLL clock period.
 - The **Clock Distribution Cells** (CDC) provide all LTCs and GTs with a variety of different clock signals. It is equipped with GPTA[®]v5 module clock prescalers and multiplexers supporting alternate clock sources.

The original signals and all outputs of the preprocessing cells are distributed to the Global Timers and LTCs via the clock bus.

- The **Signal Generation Cells** (see [Page 23-38](#)) provide a set of timers, capture and compare cells:
 - The two 24-bit **Global Timers** (GT) can be individually configured as free-running counters or as reload counters starting at a programmable value from 0_H to FFFFFF_H. Each GT is equipped with a scalable greater-or-equal comparator; the number of bits to be compared is selectable.
 - The **Global Timer Cell** registers (GTC) are 24-bit wide. GTCs may be used as comparators (modifying the logical state of a related output port pin), or as capture cells, storing the current GT0 or GT1 value on rising, falling or both signal edges detected on a related input port pin. Several adjacent GTCs may be connected to logical cells operating on the same pin, allowing complex functions to be implemented.
 - The **Local Timer Cell** registers (LTC) are 16-bit wide. 63 LTCs can be configured to operate in one of four different modes: free-running or resettable counter, capture or compare cell. Adjacent cells can be combined to operate on the same pin, thus generating complex waveforms. One LTC (LTC63) can be used for special compare modes.

General Purpose Timer Array (GPTA[®]v5)

23.3.2 Clock Generation Cells

As described in detail in the following sections, the Clock Generation Cells (CGC) provides the following signal pre-processing cells:

- Filter and Prescaler Cell (FPC)
- Phase Discrimination Logic (PDL)
- Duty Cycle Measurement cell (DCM)
- Digital Phase Locked Loop Cell (PLL)
- Clock Distribution Cells (CDC)

The **Filter and Prescaler Cells** (FPC) provide input noise filtering using a debounce filter. FPCs are also able to operate as a prescaler for the GPTA[®]v5 module clock and external signals. Each FPC can select among different data and clock input signals.

The **Phase Discrimination Logic** (PDL) is able to decode FPC debounce filtered and phase encoded signals coming from a position and rotation direction sensor system. In the PDL, phase encoding can be bypassed.

The **Duty Cycle Measurement Cells** (DCM) provide signal measurement capabilities (timer plus capture register, single and double capture on rising and falling edges or both) as well as missing pulse detection/reconstruction functions.

The **Digital Phase Locked Loop** (PLL) is intended to generate a higher resolution clock out of the values measured by DCM cells. Any arbitrary multiplication factor between 1 and 65535 is supported and may be changed from input clock period to input clock period.

The **Clock Distribution Cells** (CDC) provide all Local and Global Timer Cells with a variety of different clock signals. It is equipped with GPTA[®]v5 module clock prescalers and multiplexers supporting alternate clock sources.

Figure 23-3 shows how the cells of the CGC are interconnected. The external interface signals of the CGC are:

- GPTA[®]v5 module clock f_{GPTA}
- GPTA[®]v5 module input signals (connected to the FPCs)
- Clock bus outputs (generated by the CDC)
- PDL bus outputs
- External PLL clock inputs (fed into CDC)

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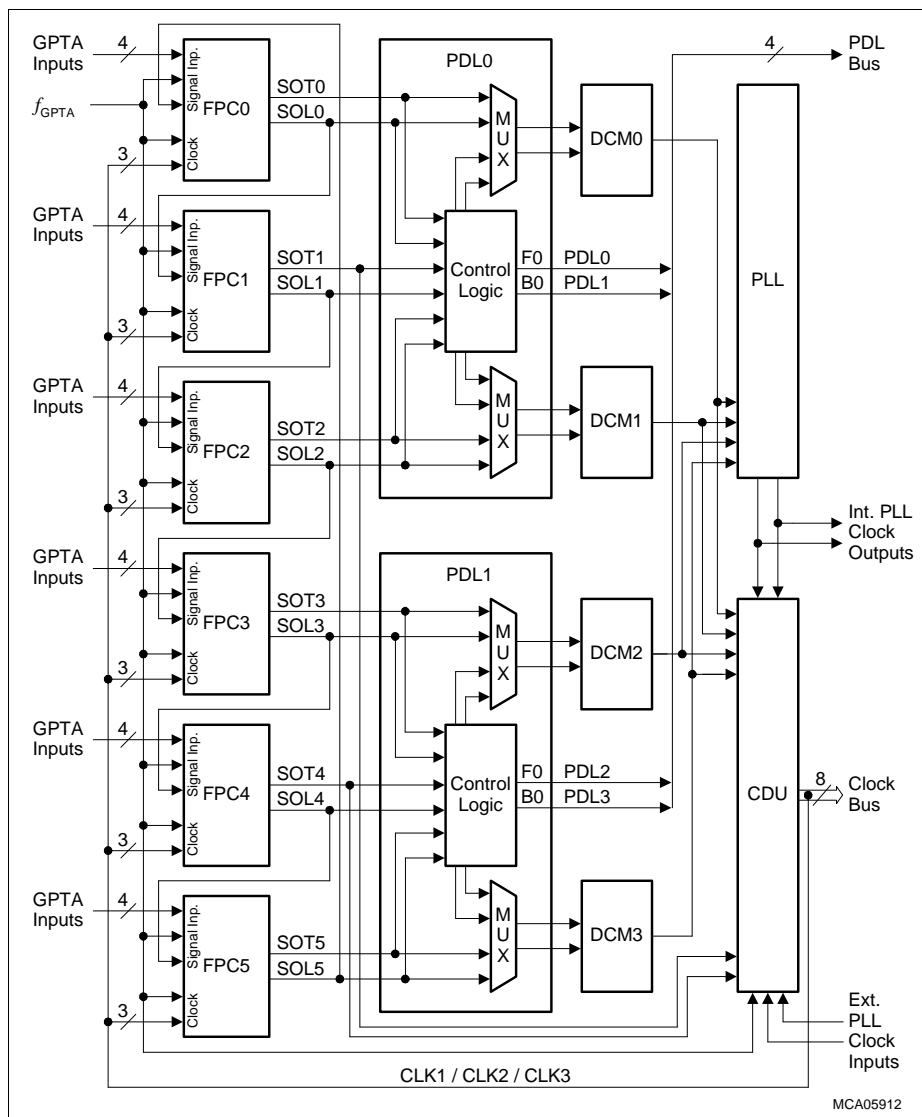


Figure 23-3 Interconnections in the Clock Generation Cells

General Purpose Timer Array (GPTA[®]v5)

FPC Operating Modes

Each filter and prescaler cell can be individually configured to operate in one of the following operating modes:

- Delayed Debounce Filter Mode on both edges
- Immediate Debounce Filter Mode on both edges
- Rising edge: Immediate Debounce Filter Mode, falling edge: No filtering
- Rising edge: No filtering, falling edge: Immediate Debounce Filter Mode
- Rising edge: Delayed Debounce Filter Mode, falling edge: Immediate Debounce Filter Mode
- Rising edge: Immediate Debounce Filter Mode, falling edge: Delayed Debounce Filter Mode
- Prescaler Mode (triggered by edge detection circuitry on rising edge)
- Prescaler Mode (triggered by edge detection circuitry on falling edge)

The operation mode is selected by bit field FPCCTRk.MOD ([Page 23-168](#)).

FPC Input Signals

Bit field FPCCTRk.IPS (see [Page 23-168](#)) selects one of the following inputs for FPCk:

- Signal input 0 (SINK0)
- Signal input 1 (SINK1)
- Signal input 2 (SINK2)
- Signal input 3 (SINK3)
- GPTA[®]v5 module clock f_{GPTA} (SINK4)
- Preceding FPC level output signal SOLk-1 (SIN05 is connected to SOL5)

When the preceding FPC level output signal is selected as input, two or more FPCs may be concatenated; for example, to combine a delayed debounce filter and an immediate debounce filter.

The maximum FPC input signal frequency must be less than or equal to the sampling rate ($f_{GPTA}/2$). The assignment of GPTA[®]v5 I/O line and FPC signal inputs SINKk is defined in [“FPC Input Line Selection” on Page 23-102](#).

FPC Filter Clocks

Bit field FPCCTRk.CLK (see [Page 23-169](#)) selects one of four filter clocks for FPCk:

- Clock input line 0 (CINK0) = GPTA[®]v5 module clock f_{GPTA}
- Clock input line 1 (CINK1) = local PLL clock,
- Clock input line 2 (CINK2) = (prescaled) GPTA[®]v5 module clock f_{GPTA} or PLL clock from other unit or DCM 3 clock
- Clock input line 3 (CINK3) = DCM 2 clock or PLL clock of other unit or uncompensated PLL clock or uncompensated PLL clock of other unit

When using a PLL clock for the FPC, no software is needed to adapt the FPC filter to changing speed for angle-based input signals. The standard PLL clock can be either the

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compensated or uncompensated PLL clock or can be the PLL clock of the other GPTA®v5 units. The uncompensated PLL clock is useful in applications in which bursts (due to acceleration) might disturb the filter function.

With a prescaled GPTA®v5 module clock, very long time filter time periods can be achieved.

Note: All filter operation are always synchronously to f_{GPTA} . Therefore the further signal analysis (e.g. glitch detection) is not processed on the rising edge of the selected filter clock CIN, but on the next rising edge of f_{GPTA} following the rising edge of selected CIN (gated clock principle). Therefore CIN clock rates above f_{GPTA} will lead to non deterministic behavior.

Output Signal Splitting

Two output lines are provided by each FPC cell as follows:

- An trigger output signal SOTk, reporting a falling or rising signal edge on the FPC input by a single f_{GPTA} clock pulse,
- A level output signal SOLk, indicating the direction of the detected signal transition.

This signal-splitting scheme (pair of trigger and level output) provides subsequent PDL and DCM cells with the information about an input signal transition in the same f_{GPTA} clock cycle. This feature avoids cascading a one clock delay per edge detection circuitry implemented at the input of each subsequent cell. **Figure 23-5** shows the FPC output signal splitting scheme.

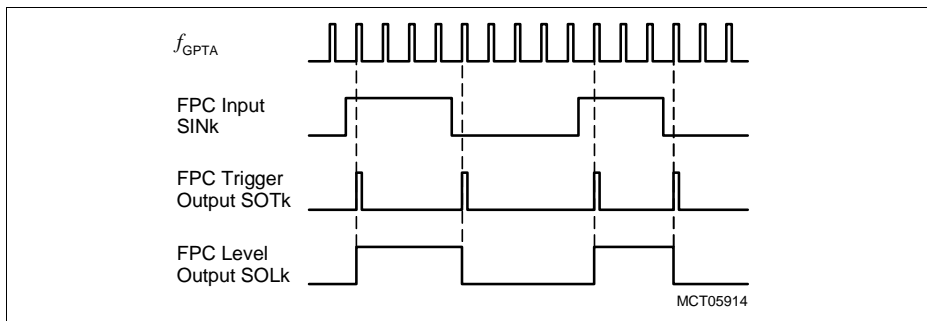


Figure 23-5 FPC Output Splitting into Trigger and Level Information

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Delayed Debounce Filter Mode

In Delayed Debounce Filter Mode, the signal input SIN is filtered from all signal transitions and glitches with a width smaller than the selected clock period length multiplied by the compare register value.

The input signal SIN (sampled with f_{GPTA}) is analyzed at the selected filter clock rate of CIN. If the state of the input sample differs from the current output signal value, the 16-bit timer is incremented by one. When the timer register FPCTIMk is not in its idle state (0000_H) **and** the state of the input sample matches the current output signal value, the 16-bit timer is decremented by one (see [Figure 23-6](#)); if bit FPCCTRk.RTG is set, the timer will be set to idle state again (see [Figure 23-7](#)). A rising or falling edge, occurring on the signal input line SIN when the timer is greater than zero but less than the compare value, sets the corresponding glitch flag FPCSTAT.REG (on rising edge glitch) or FPCSTAT.FEGk (on falling edge glitch). When the timer matches the 16-bit compare value stored in FPCCTRk.CMP (timer threshold), the level output signal line SOLk is inverted, a GPTA[®]v5 module clock pulse is generated at the trigger output signal SOTk, and the timer is reset to 0000_H. The rising/falling edge glitch flags must be reset by software.

The filter is by-passed if the compare value FPCCTRk.CMP is programmed to zero (0000_H). In this case, the input signal is directly copied to the output signal.

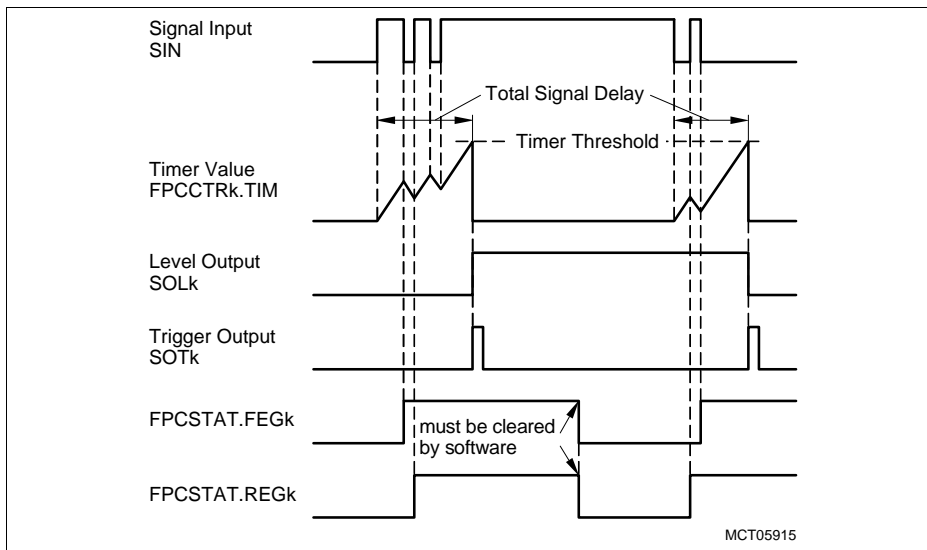


Figure 23-6 FPC Delayed Debounce Filter Algorithm with Timer Decrement

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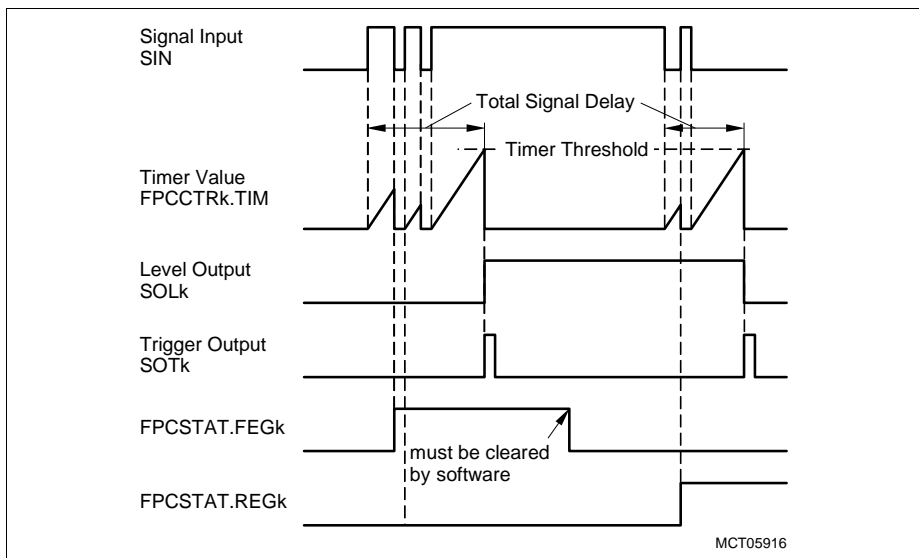


Figure 23-7 FPC Delayed Debounce Filter Algorithm with Timer Reset

The total signal delay from input to output depends on the programmed compare register value, the number of high-frequency pulses (glitches) during the filter operating time, and the timer behavior in case of a glitch (decrement or reset).

The FPC Delayed Debounce Filter Mode is selected by:

- FPCCTRk.MOD = 000_B

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Immediate Debounce Filter Mode

In Immediate Debounce Filter Mode, the input signal is filtered from signal transitions and glitches arriving a programmable time after an input signal edge detection (see [Figure 23-8](#)).

The input signal SIN is sampled with f_{GPTA} and the input signal SIN edge detection is also performed with f_{GPTA} . The further analysis (e.g. filter timer increment, glitch detection) is done at the selected filter clock rate of CIN.

As long as the timer is reset, the FPC control circuitry copies the sampled input value directly to the level output signal line SOLk. When a rising or falling edge occurs on the signal input line SIN and the 16-bit compare value FPCCTRk.CMP is not zero, the timer is enabled to be incremented by the selected clock and the copy mechanism is disabled. When the timer value FPCTIMk.TIM matches the compare value FPCCTRk.CMP, the timer is reset and the copy mechanism is enabled again. A rising or falling edge, occurring on SIN while the timer is greater than zero but less than the compare value, sets the corresponding glitch flag FPCSTAT.REG (on rising edge glitch) or FPCSTAT.FEGk (on falling edge glitch). The rising/falling edge glitch flags must be reset by software.

The filter is by-passed if the compare value FPCCTRk.CMP is programmed to zero (0000_H). In this case, the input signal is directly copied to the output signal without any disable periods.

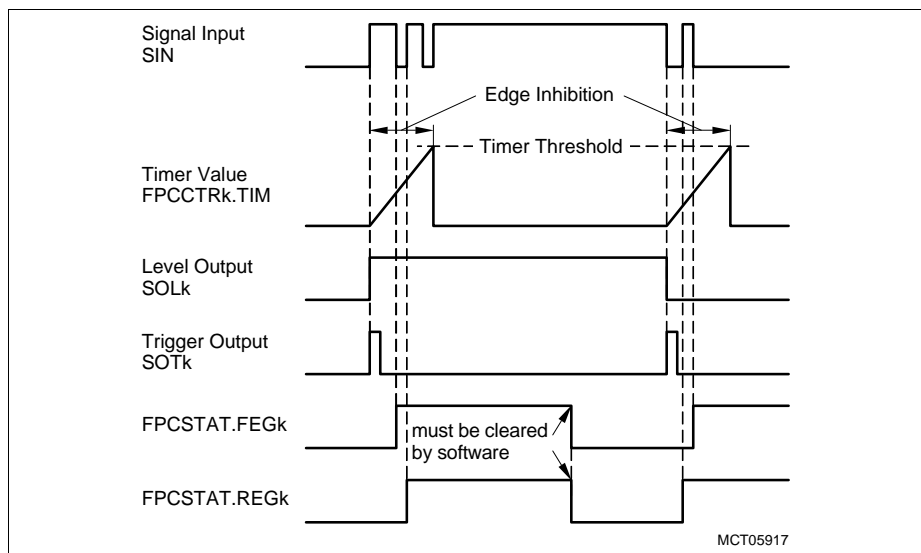


Figure 23-8 FPC Immediate Debounce Filter Algorithm on Both Edges

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Note: During the last clock cycle of edge inhibition time (where timer value is equal to the compare value) an input signal glitch will be filtered but the corresponding glitch status flag in register FPCSTAT is not set.

The Immediate Debounce Filter can be enabled only for one edge, either rising or falling. In this case, the signal output follows the signal input value immediately after the timer threshold of the filtered edge is reached, without re-starting the timer (see [Figure 23-9](#)).

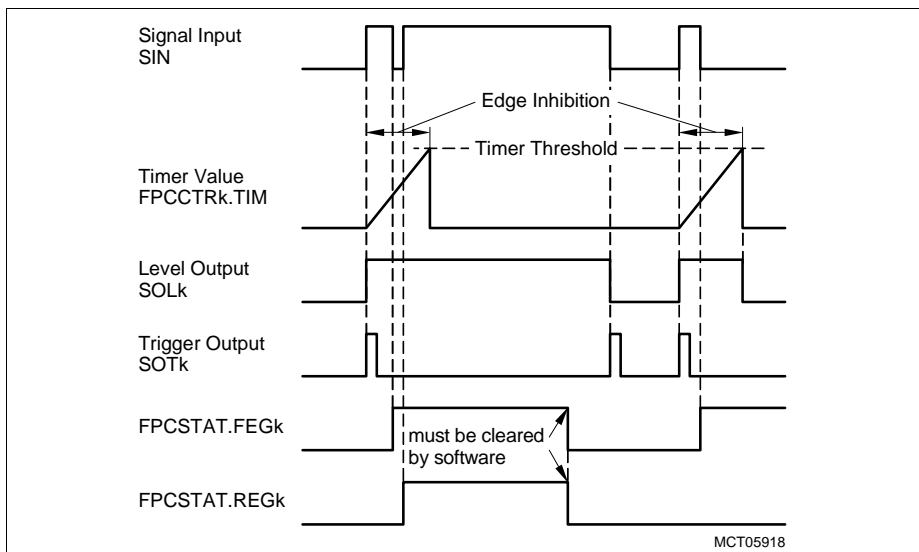


Figure 23-9 FPC Immediate Debounce Filter Algorithm on Rising Edge only

The FPC Immediate Debounce Filter Modes are selected by:

- FPCCTRk.MOD = 001_B: Immediate Debounce Filter Mode on both edges
- FPCCTRk.MOD = 010_B: Immediate Debounce Filter Mode on rising edge only, no filtering on falling edge.
- FPCCTRk.MOD = 011_B: Immediate Debounce Filter Mode on falling edge only, no filtering on rising edge.

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Mixed Filter Modes

In the Mixed Filter Modes, one edge of a signal is filtered in the Delayed Debounce Mode, and the other edge is filtered in the Immediate Debounce Mode. The Debounce Mode is switched when the timer threshold is reached. Note that both filter modes use the same timer threshold in this case (see [Figure 23-10](#), demonstrating Delayed Debounce Mode with Timer Decrement on Rising Edge and Immediate Debounce of on Falling Edge).

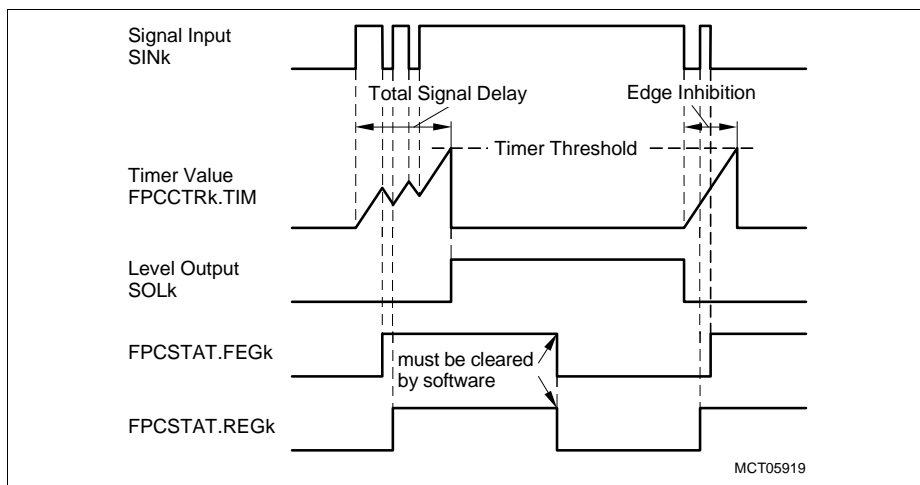


Figure 23-10 FPC Mixed Filter Algorithm

The FPC Mixed Filter Modes are selected by:

- $\text{FPCCTRk.MOD} = 100_{\text{B}}$: Delayed Debounce Filter Mode on rising edge
Immediate Debounce Filter Mode on falling edge
- $\text{FPCCTRk.MOD} = 101_{\text{B}}$: Immediate Debounce Filter Mode on rising edge
Delayed Debounce Filter Mode on falling edge

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Prescaler Mode

In Prescaler Mode, the input signal is sampled and analyzed with f_{GPTA} . The FPC control circuitry counts each rising (or falling) edge of the input signal. When the timer value matches the compare value:

- one GPTA[®]v5 module clock pulse is generated at the trigger output signal SOTk and level output signal SOLk
- the timer FPCTIMk.TIM is reset to 0000_H

Figure 23-11 shows a divide-by-6 operation using the FPC in Prescaler Mode with trigger on rising edge selected.

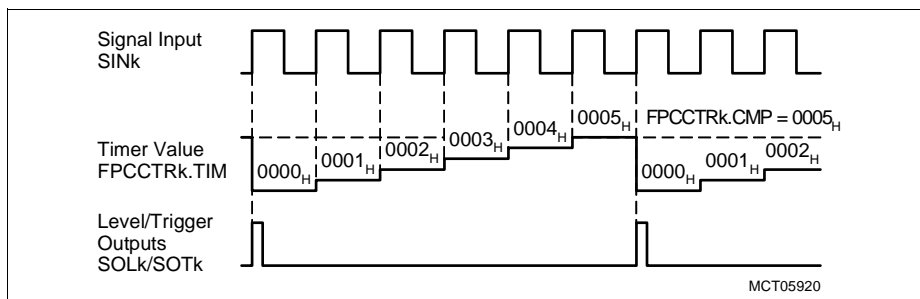


Figure 23-11 FPC Prescaler Mode

For a divide-by-n operation, the compare value FPCCTRk.CMP must be set to n - 1.

The FPC Prescaler Modes are selected by:

- FPCCTRk.MOD = 110_B: Prescaler Mode triggered by edge detection circuitry on rising edge
- FPCCTRk.MOD = 111_B: Prescaler Mode triggered by edge detection circuitry on falling edge

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23.3.2.2 Phase Discrimination Logic (PDL)

The GPTA[®]v5 provides two Phase Discrimination Logic cells (PDL0, PDL1) driven by two signal lines coming from an FPC cell (for description, see [Page 23-14](#)):

- An event input signal
- A level input signal

Both Phase Discrimination Logic cells are controlled by the Phase Discrimination Logic Control Register PDLCTR (see [Page 23-171](#)).

Each PDL is equipped with an edge detection circuitry, a phase detection circuitry, a PDL control circuitry, and an output multiplexer. Six output lines are provided by each PDL Cell:

- A forward output signal (F0, F1) is driven by one f_{GPTA} clock pulse if an input signal edge is recognized as forward rotation. These signals can be connected to any Local Timer Cell via the PDL bus.
- A backward output signal (B0, B1) is driven by one f_{GPTA} clock pulse if an input signal edge is recognized as backward rotation. This signal can be connected to any Local Timer Cell via the PDL bus.
- Two pairs of output signals, carrying the bypassed input level and event information from the driving FPC cells or the angular velocity and error information provided by the PDL function. These output lines are directly connected to the adjacent Duty Cycle Measurement Cells, DCM0/DCM1(for PDL0) and DCM2/DCM3 (for PDL1).

The PDL processes the output signal of a 2-sensor or 3-sensor positioning system. With bit PDLCTR.TSEx = 1, a 3-sensor system execution is selected providing the DCM1 and/or DCM3 cell with information concerning erroneous states in the signal input. When PDLCTR.TSEx = 0, a 2-sensor system is selected and DCM1 and/or DCM3 are supplied with the input event and level information from the driving FPC2 and/or FPC5.

The rotation direction, monitored by the connected sensors, is automatically derived from the sequence in which the input signals change. Each edge detected on an input signal line generates a pulse on the F0, F1 forward output lines or on the B0, B1 backward output lines. Input jitter, which might occur if a sensor rests near to one of its switching points, is compensated.

If bit PDLCTR.MUXx = 1, the trigger output signal to DCM0/DCM2 (angular velocity information) is driven by a boolean 'OR' operation of the corresponding forward trigger and backward trigger signal while the level output signal at DCM0/DCM2 is at fixed high level. In this case, every pulse at F0/B0 and F1/B1 generates a rising edge at the DCM0/DCM trigger signal.

If bit PDLCTR.MUXx = 0, the associated DCM0/DCM2 signals are directly connected with the input event and level signals from the driving FPC0/FPC3.

To calculate the sensor's current position, the associated LTCs should be clocked with the PDL forward and backward output pulses. A software operation, subtracting the backward counter contents from the forward counter contents, provides the absolute

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position. Dynamic information (speed, acceleration, deceleration) may be obtained by analyzing the angular velocity signal periods with the associated DCM cell.

The maximum input frequency is $f_{\text{GPTA}}/4$ for a 2-sensor positioning system and $f_{\text{GPTA}}/6$ for a 3-sensor positioning system. To ensure that a transition of any input signal is correctly recognized, its level should be held high or low for at least two f_{GPTA} cycles before it changes (three f_{GPTA} cycles for a 3-sensor positioning system).

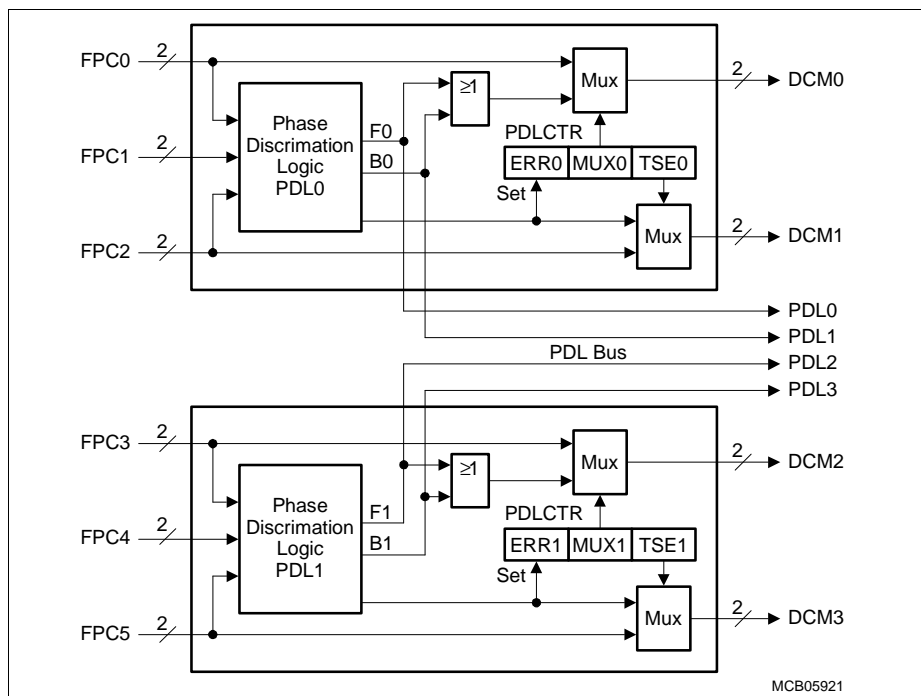


Figure 23-12 Block Diagram of Phase Discrimination Logic Cells

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Positioning System With Two Sensors

The 2-sensor Mode is enabled when bit PDLCTR.TSEx is reset. The sensors are mounted at a 90° angle to each other (see [Figure 23-13](#)). The third sensor input of the PDL cell is internally disabled and DCM1/DCM3 cell inputs are driven by fed-through FPC2/FPC5 output lines.

This configuration can measure an absolute position with a resolution of 90°. No error conditions can be detected.

!	Means not
Re	Means rising edge
Fe	Means falling edge
Forward	$ReS1!S2 + S1*ReS2 + FeS1*S2 + !S1*FeS2$
Backward	$ReS1*S2 + !S1*ReS2 + FeS1!S2 + S1*FeS2$
Position	Forward_Counter - Backward_Counter

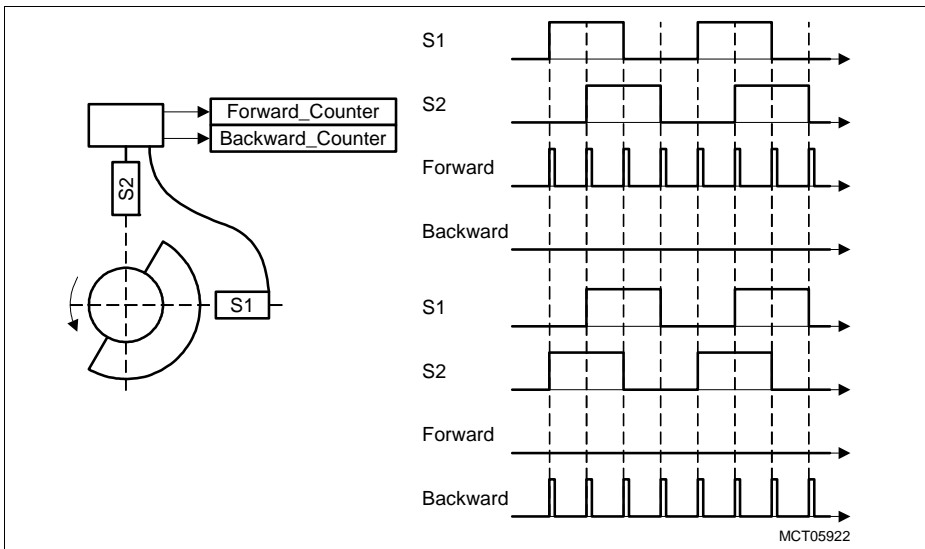


Figure 23-13 Interface Signals of a PDL in a 2-Sensor Positioning System

Figure 23-14 illustrates how the output signals of a 2-sensor system superimposed with noise are processed by the PDL cell. Jitter pulses are completely compensated if they do not occur on both signal lines simultaneously.

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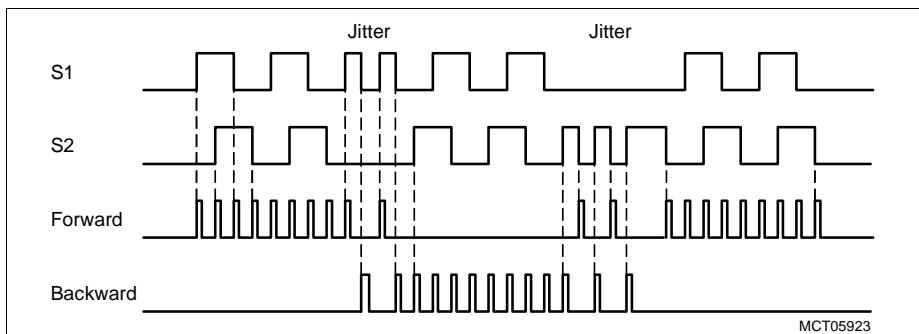


Figure 23-14 Compensation of Input Jitter

Positioning System with Three Sensors

The 3-sensor Mode is enabled when bit PDLCTR.TSEx is set to 1. The sensors are mounted at an 120° angle to each other (see [Figure 23-15](#)). This configuration can measure an absolute position with a resolution of 60°.

Input signal combinations that are not allowed in a properly-working positioning system (all inputs low or all inputs high) cause the following to occur:

- An error signal is generated, driving the Duty Cycle Measurement cells DCM1 and/or DCM3,
- The error flag PDLCTR.ERRx is set,
- No forward or backward pulses are generated.

When the error disappears, the error signal will be cleared. The error flag PDLCTR.ERRx must be reset by software.

!	Means not
Re	Means rising edge
Fe	Means falling edge
Forward	$ReS1*!S2*S3 + FeS3*S1*!S2 + ReS2*S1*!S3 + FeS1*S2*!S3 + ReS3*!S1*S2 + FeS2*!S1*S3$
Backward	$ReS1*S2*!S3 + FeS3*!S1*S2 + ReS2*!S1*S3 + FeS1*!S2*S3 + ReS3*S1*!S2 + FeS2*S1*!S3$
Error	The input signal states $S1*S2*S3$ and $!S1*!S2*!S3$ are not allowed
Position	Forward_Counter - Backward_Counter

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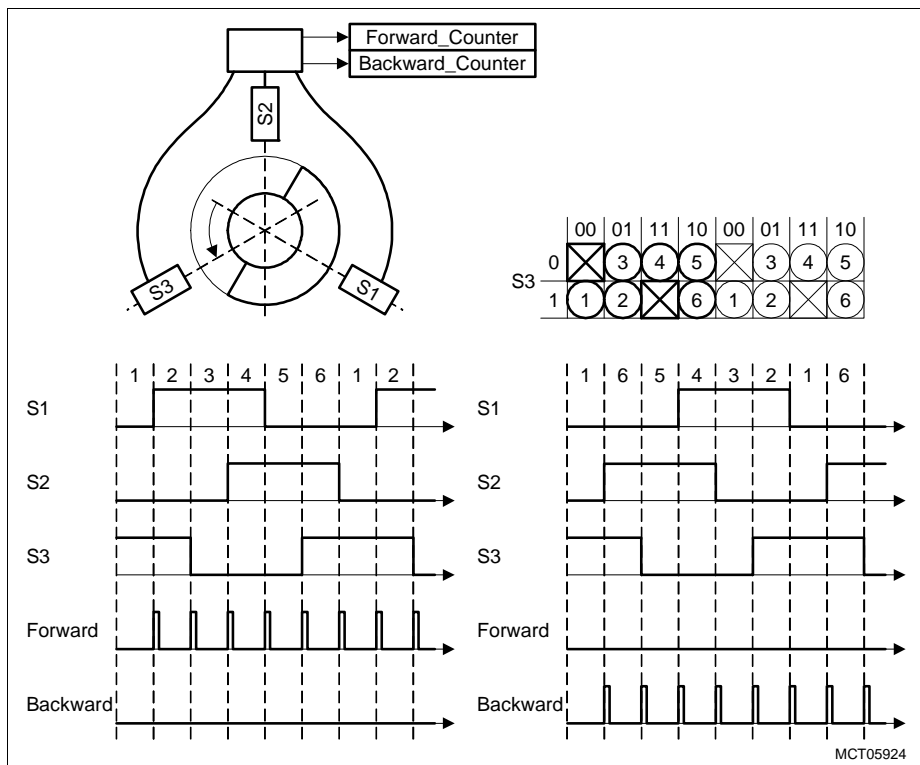


Figure 23-15 Interface Signals of a PDL in a 3-Sensor Positioning System

Jitter pulses are completely compensated as illustrated in [Figure 23-14](#).

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23.3.2.3 Duty Cycle Measurement Cell (DCM)

The GPTA[®]v5 contains four DCM cells (DCM0 to DCM3). The input signal to be analyzed is delivered as a 2-line signal input (see [Figure 23-5](#) for the event/level input signal splitting scheme). It is build by:

- An event input, and
- A signal level input.

Each DCM cell has four outputs:

- An event output line,
- An interrupt output that can become active at a signal input rising edge,
- An interrupt output that can become active at a signal input falling edge,
- An interrupt output that can become active at a compare event.

Each DCM cell is equipped with a 24-bit timer, a 24-bit capture register, a 24-bit capture/compare register, a 24-bit comparator and a DCM control circuitry ([Figure 23-16](#)).

The following registers are assigned to the DCM cells:

- DCMCTRk = Duty Cycle Measurement Control Register k (see [Page 23-173](#))
- DCMTIMk = Duty Cycle Measurement Timer Register k (see [Page 23-174](#))
- DCMCAV_k = Duty Cycle Measurement Capture Register k (see [Page 23-175](#))
- DCMCOV_k = Duty Cycle Measurement Capture/Compare Register k (also referred as “CAPCOM”, see [Page 23-175](#))
- SRSC0 = Service Request State Clear Register 0 (see [Page 23-219](#))
- SRSS0 = Service Request State Set Register 0 (see [Page 23-221](#))

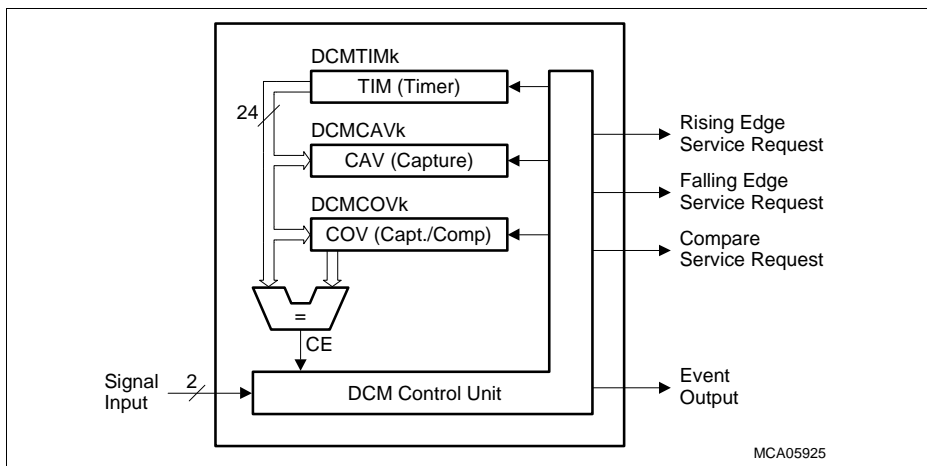


Figure 23-16 Block Diagram of a Duty Cycle Measurement Cell

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The DCM cell inputs are connected to the PDL outputs. Depending on the configuration of the associated PDL cell, the DCM cells can also be driven by a FPC directly (as shown in [Figure 23-12](#)):

- DCM0 is driven by FPC0 or PDL0 angular velocity signal,
- DCM1 is driven by FPC2 or PDL0 error signal,
- DCM2 is driven by FPC3 or PDL1 angular velocity signal,
- DCM3 is driven by FPC5 or PDL1 error signal.

When the driving FPCs and PDL cells are programmed in feed-through mode, an external port pin signal as selected by the FPC input multiplexer can be directly processed by a DCM cell.

The duty cycle of the DCM cell signal input can be determined by measuring its period length and the width of its low or high state. For this purpose, several operations can be started on an signal input edge:

- **Reset Timer**

The local timer can be reset on rising, falling, or both edges of the signal input line as selected via control bits DCMCTRk.RZE (for rising edge) and DCMCTRk.FZE (for falling edge). After a reset timer event, the timer is continuously incremented by the GPTA®v5 module clock f_{GPTA} until the next reset condition occurs. If no reset timer event is enabled, the timer operates in Free-Running Timer Mode, repeatedly counting from its lower limit (000000_H) to its upper limit (FFFFFF_H).

- **Capture**

The current timer value is stored in the capture register DCMCAV on the rising edge (DCMCTR.RCA = 1) or falling edge (DCMCTRk.RCA = 0) of the signal input line.

The current timer value is stored in the capture/compare register DCMCOV on the opposite signal edge as selected by DCMCTRk.RCA and if enabled by bit DCMCTRk.OCA = 1. With DCMCTRk.OCA = 0 the capture/compare register DCMCOV is not affected.

- **Edge Service Request and Interrupt Request**

On a rising input signal edge of the DCMk cell ($k = 0-3$) the service request flag SRS0.DCM0kR is set. Additionally, a service request signal is triggered if bit DCMCTRk.RRE = 1. A falling input signal edge sets the service request flag SRS0.DCM0kF. An interrupt request generation on this edge is triggered if bit DCMCTRk.FRE = 1. Both edges of the signal input line initiate an interrupt request when both bits, DCMCTRk.FRE and DCMCTRk.RRE, are set. The interrupt on signal input edges is disabled if both bits are cleared.

- **Hardware Generated Output Pulse**

A single f_{GPTA} clock pulse is generated on the DCM output line if enabled by control register bit DCMCTRk.RCK (rising edge at signal line) and/or DCMCTRk.FCK (falling edge at signal line) and an appropriate edge is detected at the input.

The 0% or 100% duty cycle exception (no edge or only one edge detected) can be handled by a **limit checking** option. The expected input signal's maximum period length (measured in f_{GPTA} clock ticks) can be loaded into the capture/compare

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register DCMCOV that is continuously compared with the timer value. When the timer is incremented up to the limit stored in capture/compare register, the service request flag SRS0.DCM0xC is set. If the compare service request is enabled (control register bit DCMCTRk.CRE = 1), an interrupt request is generated.

- **Software Generated Output Pulse**

If the **software** intends to compensate an input pulse backlog, bit DCMCTRk.QCK should be set to 1. This immediately triggers a single **clock pulse generation** on the DCM output signal line.

General Purpose Timer Array (GPTA®v5)

DCM Interrupt Control

Each DCM cell is able to generate three service request output signals. The service request outputs of a DCM_k cell are controlled as shown in [Figure 23-17](#). When a service request condition occurs, the corresponding service request flag is always set. The service request output is activated only if it is enabled by the corresponding enable bit. Further details on service request and interrupt handling are provided in section [“Interrupt Sharing Block \(IS\)” on Page 23-123](#).

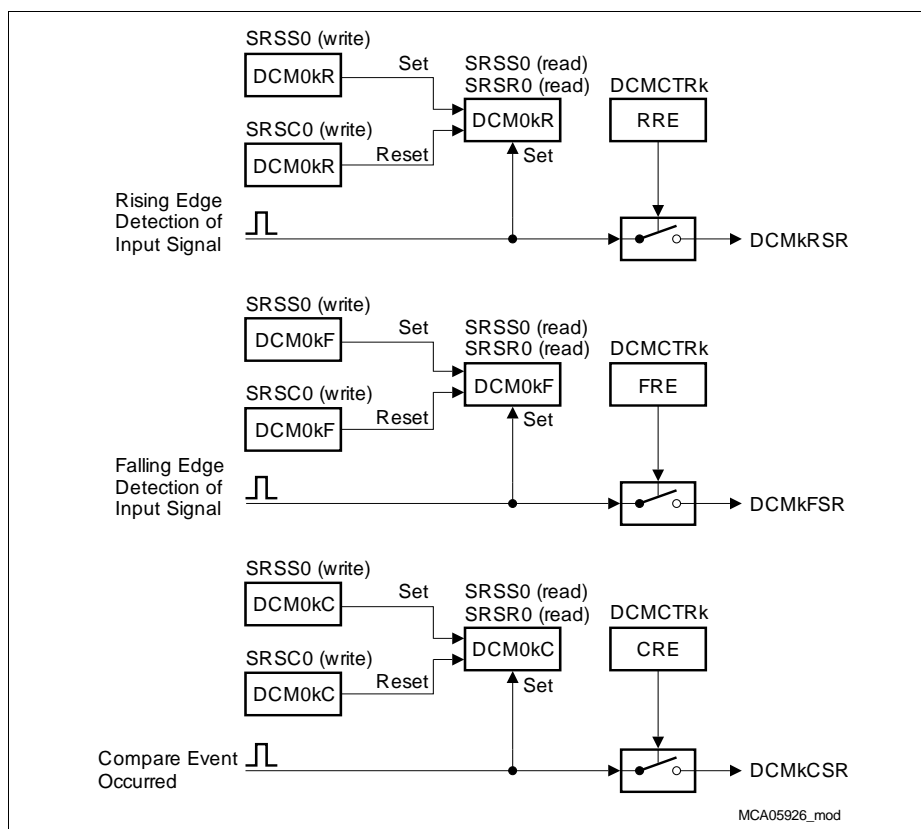


Figure 23-17 DCM_k Service Request Generation

General Purpose Timer Array (GPTA[®]v5)

23.3.2.4 Digital Phase Locked Loop Cell (PLL)

The GPTA[®]v5 provides a digital Phase Locked Loop cell (PLL) with a frequency multiplier function. An input signal edge is used as a trigger to generate a programmable number of GPTA[®]v5 module clocks f_{GPTA} on the output signal line. The four signal output lines of the DCM cells can be used as PLL trigger input. The PLL control circuitry distributes the desired number of GPTA[®]v5 clocks in regular time intervals over the input signal period length. The PLL can automatically follow an acceleration or deceleration of the input signal. Alternatively, an external software routine may handle the input signal's period length variation.

The PLL includes a 4-channel input multiplexer, a 16-bit timer, a 16-bit step register, a 24-bit reload register, a 24-bit adder, a 24-bit multiplexer, a 25-bit delta register extended by one sign bit and a PLL control circuitry (see [Figure 23-18](#)).

The following registers are assigned to the Phase Locked Loop cell:

- PLLCTR = Phase Locked Loop Control Register (see [Page 23-176](#))
- PLLMTI = Phase Locked Loop Microtick Register (see [Page 23-177](#))
- PLLCNT = Phase Locked Loop Counter Register (see [Page 23-178](#))
- PLLSTP = Phase Locked Loop Step Register (see [Page 23-177](#))
- PLLREV = Phase Locked Loop Reload Register (see [Page 23-178](#))
- PLLDTR = Phase Locked Loop Delta Register (see [Page 23-179](#))
- SRSC0 = Service Request State Clear Register 0 (see [Page 23-219](#))
- SRSS0 = Service Request State Set Register 0 (see [Page 23-221](#))

Three output signals are available on the PLL cell:

- PLL signal output line
- Uncompensated PLL signal output line
- Service request line

The desired input signal is selected by programming bit field PLLCTR.MUX. The number of output pulses to be generated within one input signal period must be stored in the microtick register PLLMTI and (coded in 2-complement data format) in the step register PLLSTP. The PLLREV reload register must be programmed with a reload value. This reload value is calculated by subtracting the number of output pulses to be generated within one input signal period from the input signal's period length (measured in number of f_{GPTA} clocks). An automatic compensation of an input signal acceleration or deceleration is enabled by setting bit PLLCTR.AEN to 1 (Automatic End Mode). After disabling the Automatic End Mode, the PLL continuously generates output pulses without synchronization to an input signal edge.

When the counter for the number of remaining output signal pulses PLLCNT decrements to zero, the PLL service request flag is set. Additionally, a service request signal PLLSR will be generated if the control register bit PLLCTR.REN is set.

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Steady Input Signal Example

In the following example, the input signal's period length is $13 f_{\text{GPTA}}$ clock periods, which should be subdivided into three equally spaced sections. The reload value to be stored in PLLREV.REV register is calculated to $0A_H$ ($10 = 13 - 3$). PLLMTI.MTI is loaded with 03_H (number of output pulses) and its 2-complement representation (FFD_H) is written into PLLSTP.STP.

After a reset, a state machine driven by the GPTA[®]v5 module clock, updates the delta register PLLDTR with the reload value. Afterwards, the PLLSTP register's contents are continuously added to the delta register value (Figure 23-20). In fact, the difference between both values is computed and stored in the PLLDTR register again, because the PLLSTP register has been loaded with a negative value (2-complement data format). When the PLLDTR register has been decremented to a negative value, the reload register contents are added to Delta register's current contents.

A rising edge detected on the selected input signal triggers the counter register PLLCNT to load the number of requested output pulses from PLLMTI. When a negative content of the PLLDTR register is detected, the microtick counter is decremented by one. In Automatic Mode ($AEN = 1$), the output pulse generation is stopped when the microtick counter reaches zero.

The period length of a single output pulse varies between four and five f_{GPTA} clocks; the maximum period length variation of output pulses is restricted to one f_{GPTA} clock. The total period length of all three output pulses, generated by one PLL loop corresponds to the input signal period width ($5 + 4 + 4 = 13 f_{\text{GPTA}}$ clocks).

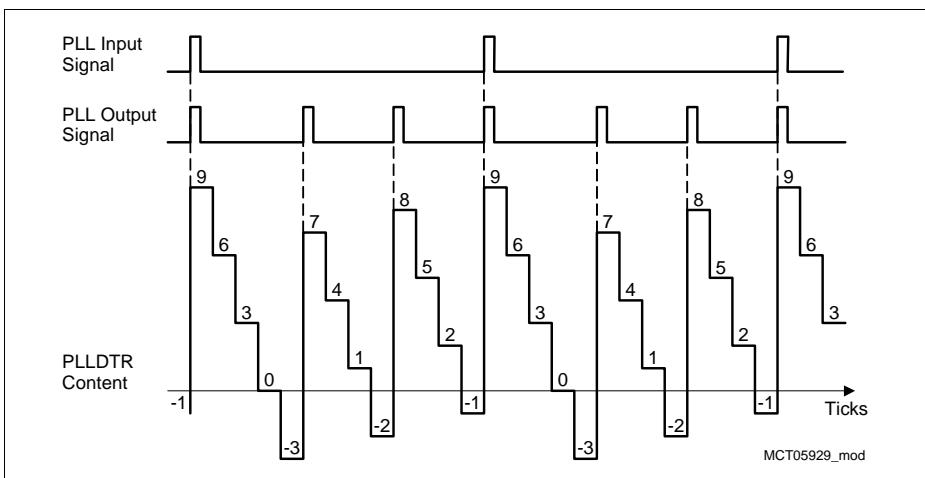


Figure 23-20 Digital PLL Steady State Simulation

General Purpose Timer Array (GPTA®v5)

This type of PLL implementation presents a valuable advantage compared to classic PLL implementation. Indeed, the generated microticks are equally distributed. The division reminder is distributed to several clocks instead of adding this reminder to the last pulse clock of the period.

Figure 23-21 illustrates this advantage. Considering a period of 15 clock pulses to be divided by a factor of 4, it gives a result of 3 with a reminder equal to 3. The reload value is calculated to $0B_H$ ($11 = 15 - 4$). The number of output pulses is equal to 4 and its 2-complement representation ($FFFC_H$) is written into the step register.

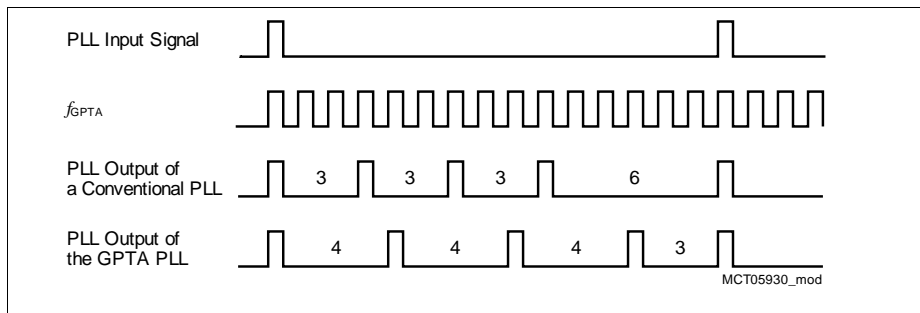


Figure 23-21 Advantage of the GPTA®v5 PLL

Input Signal Acceleration and Deceleration

The consequence of an input signal acceleration or deceleration can be compensated either automatically or by an external software routine. It detects an input signal's period length variation by comparing the current period length (measured in the associated DCM cell) with the expected period length used as calculation base for the PLLREV register contents.

- Compensation of input signal deceleration
 - Compensation by PLL Automatic End Mode

If Automatic End Mode is enabled ($PLLCTR.AEN = 1$), the PLL stops at the calculated end of the current input signal period. Due to the deceleration, the rising edge of the following input signal period is delayed, starting the next PLL operation later than expected. A gap occurs between the last output pulse of the current input signal period and the first pulse of the following one (see [Figure 23-22](#)).
 - Compensation by Software

After disabling the Automatic End Mode ($PLLCTR.AEN = 0$), the PLL generates output pulses without synchronization to an input signal edge. In case of a deceleration, more output pulses than calculated are generated during one input signal period. Several algorithms can be implemented to compensate the surplus of generated output pulses:

The length of the current input signal period has been underestimated by a certain

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number of f_{GPTA} clock periods. This deficit could be added to the calculated length of the next input signal period.

The PLL can continue to operate with the old input signal period length estimation, but the number of output pulses to be generated during the next input clock period may be decreased by the surplus of output pulses initiated during the last signal period.

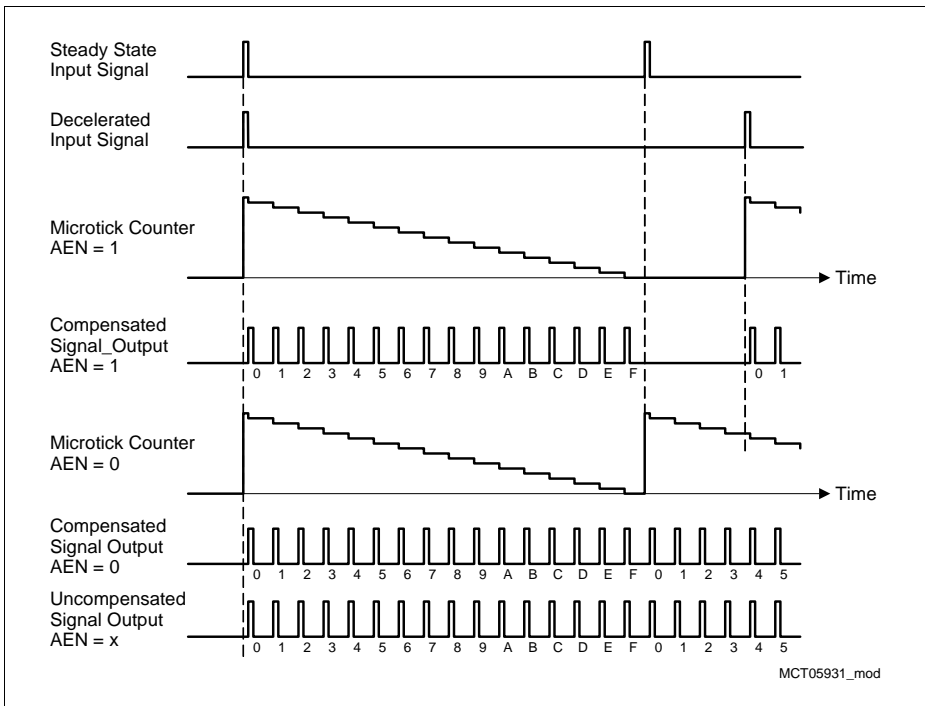


Figure 23-22 Compensation of Input Signal Deceleration

- Compensation of input signal acceleration
 - Compensation by PLL Automatic End Mode

The next rising edge of the input signal arrives while the counter has not been decremented to zero. The PLL performs all remaining output signal pulses at full speed (f_{GPTA}), when control register bit AEN is set to 1. Afterwards, counter and Delta register are reloaded with their calculated values and the PLL operates at normal speed (see [Figure 23-23](#)).
 - Compensation by Software

After disabling the Automatic End Mode, the PLL generates fewer output pulses than calculated during one input signal period. Several algorithm can be

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implemented to compensate for the lack of generated output pulses:

The length of the current input signal period has been overestimated by a certain number of f_{GPTA} clock periods. This deficit should be subtracted from the calculated length of the next input signal period.

The PLL can continue to operate with the old input signal period length estimation, but the number of output pulses to be generated during the next input clock period may be increased by the lack of output pulses initiated during the last signal period.

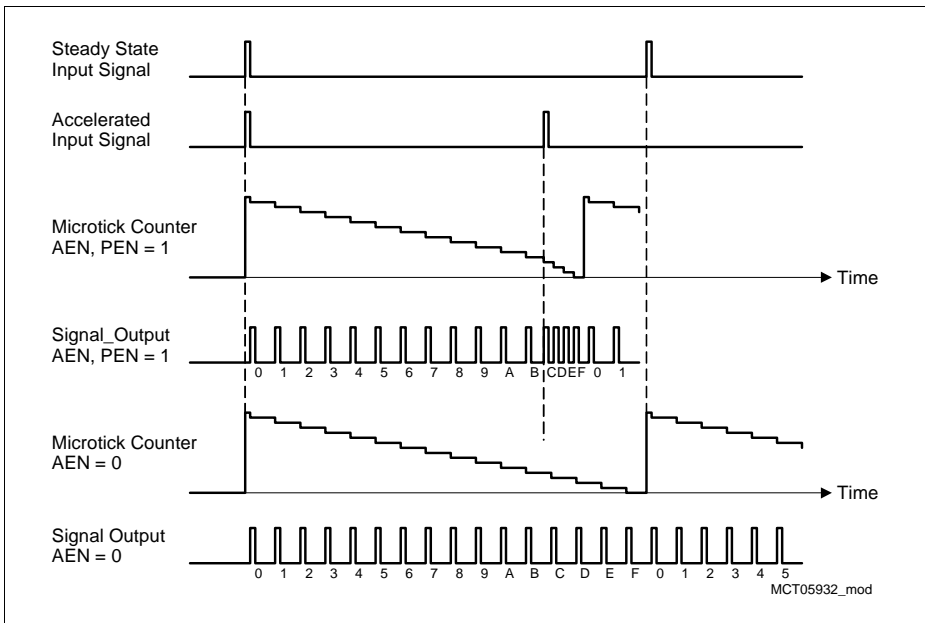


Figure 23-23 Compensation of Input Signal Acceleration

Additionally to the normal output signal, the PLL provides an uncompensated output signal. This signal has no gaps or acceleration bursts. However, the number of microticks during one signal period may be incorrect.

23.3.2.5 Clock Distribution Cell (CDC)

The Clock Distribution Cells (CDC) provides all Local and Global Timer Cells with a clock bus containing eight different clock output signals CLK[7:0] and a special LTC prescaler clock LTCPRE. These nine clock signals are generated out of eleven clock input signals coming from different clock sources (see [Figure 23-24](#)).

The prescalers divide the GPTA[®]v5 module clock f_{GPTA} by a programmable 2^n factor. Factor n is defined by bit fields DFA02, DFA04, DFA06 and DFA07 of control register

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CKBCTR. A bit field value of 15 disables the related prescaler and selects alternate sources for clock bus lines 2, 4, 6 and 7. For clock bus line CLK2, a bit field value of 14 selects an alternate source.

For clock bus line CLK3, the 2-bit wide bit field DFA03 of control register CKBCTR selects one of the four available clocks.

The LTC prescaler clock LTCPRE is generated by dividing the f_{GPTA} module clock by a factor defined by the 3-bit wide bit field DFALTC of control register CKBCTR. Note that the LTCPRE clock is not a part of the clock bus but a clock signal that is distributed directly from the CDC to each LTC except LTC63.

General Purpose Timer Array (GPTA®v5)

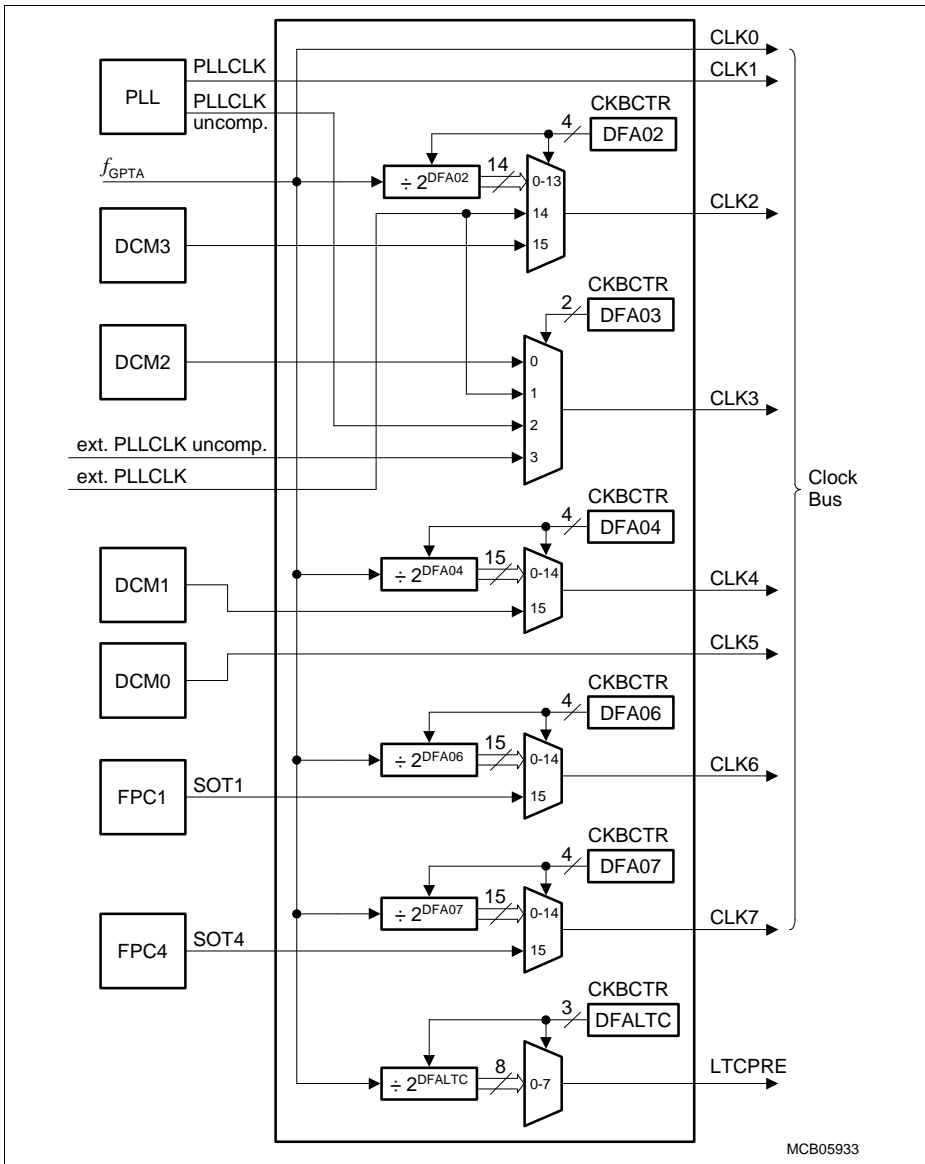


Figure 23-24 Block Diagram of Clock Distribution Cells

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23.3.3 Signal Generation Cells

As described in detail in the following sections, the Signal Generation Cells contains the following types of cells:

- Global Timer (GT)
- Global Timer Cell (GTC)
- Local Timer Cell (LTC)

23.3.3.1 Global Timers (GT)

The GPTA[®]v5 provides two global 24-bit timers (GT) that are connected to the clock bus with its eight clock lines. Each GT is locally equipped with a clock source multiplexer, a 24-bit up-counter, a 24-bit reload register, and a 24-bit greater/equal comparator (see [Figure 23-25](#)).

Note: Index variable k ($= 0, 1$) determines the number of the Global Timer.

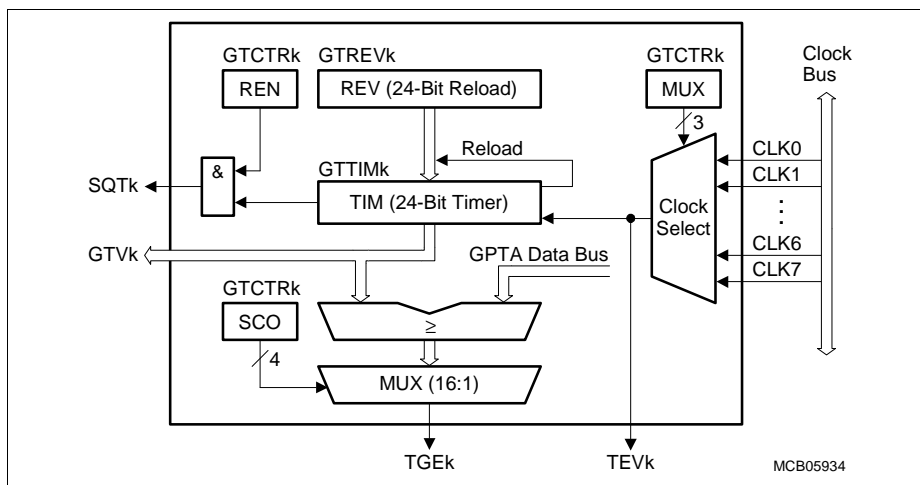


Figure 23-25 Block Diagram of Global Timer (GT)

The following registers are assigned to the Global Timers GT k ($k = 0, 1$):

- GTCTR k = Global Timer Control Register k (see [Page 23-180](#))
- GTREV k = Global Timer Reload Value Register k (see [Page 23-181](#))
- GTTIM k = Global Timer Register k (see [Page 23-181](#))
- SRSC0 = Service Request State Clear Register 0 (see [Page 23-219](#))
- SRSS0 = Service Request State Set Register 0 (see [Page 23-221](#))

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Each of the two GT cells provides the following input/output signals:

- Eight clock inputs, connected to the clock bus from the clock distribution cells (CDC)
- Global timer value bus GTVk (outputs), carrying the 24-bit GTk counter value
- TEVk output, indicating a GT counter update
- TGEk output, indicating the result of a compare operation
- SQTk service request output, triggered at a timer overflow.

The Global Timer output signals GTVk, TEVk, and TGEk are available as input signals at each GTC (see also [Page 23-56](#)).

Global timer k can be initialized with a start value, that is written by software into the GTTIMk register. The 24-bit Global Timer value GTTIMk.TIM is incremented by each rising edge of clock input signal TEVk that is selected from the 8-bit clock bus via bit field GTCTRk.MUX. On a Global Timer overflow (transition of FFFFFFF_H to 000000_H), the following events occur:

- The 24-bit reload value GTREVk.REV is copied into GTTIMk.TIM
- Bit SRSC0.GT0k is set
- The service request output SQTk is activated (if enabled by bit GTCTRk.REN)

A free-running timer is configured by programming GTREVk.REV with 000000_H.

The “Timer Event” (TEVk) output is activated if the GTk value changes because of a clock edge, a timer reload operation, or a software write access to GTCTRk. The TEVk output is connected to all GTCs. TEVk is used in the GTCs to trigger a compare operation, re-checking the equality of their compare register contents and the updated Global Timer value.

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GT Interrupt Control

Each of the GTs is able to generate a service request output signal SQTk. This signal is controlled as shown in [Figure 23-26](#). On a GTk timer overflow, the service request flag GT0k is always set. The service request output SQTk is activated only if it is enabled by the enable bit GTCTRk.REN. Additional information about service request and interrupt handling is given in section [“Interrupt Sharing Block \(IS\)” on Page 23-123](#).

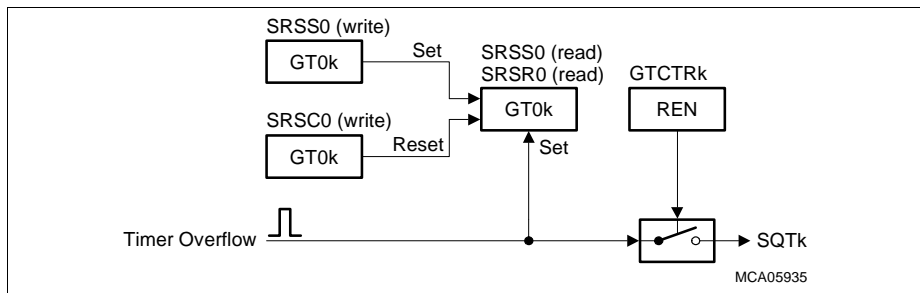


Figure 23-26 GTk Service Request Generation

Synchronization of Global Timers

Both Global Timers, GT0 and GT1, can be enabled and disabled individually. Each GT has its own run signal GTkRUN that is generated outside the GPTA[®]v5 kernel (see also [Page 23-8](#)). Signal GTkRUN is generated in a GPTA[®]v5 clock control circuitry. This external control capability allows the run signals GTkRUN to be controlled in a way that all Global Timers of one or more GPTA[®]v5 units can be enabled/disabled synchronously.

The two Global Timers will run synchronously only if all of the following conditions are true:

- Timers use the same input signal
- Timers are started (and stopped, if required) synchronously
- Timers use identical start and reload values
- Timers are not written while they are running

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Scalable Signed Greater or Equal Compare

This section (up to [Page 23-54](#)) explains the **classical timer update problem**, and the solutions supported by the GPTA[®]v5.

The two Global Timers embedded into the GPTA[®]v5 include a 24-bit greater/equal comparator. This comparator cell performs compare operations between the GT timer contents and the data value found on the GPTA[®]v5-internal data bus (coming from a GTC compare register update). The goal of this comparator is to be able to perform an action immediately if the compare cell is updated with a new threshold but the timer has already passed this value. [Figure 23-27](#) gives an example on this greater/equal concept.

Assumption: a timer is running and a new threshold (value T) is set.

The different points Px represent different cases of present time. When at P1 or P2, the moment represented by T lies in the future and no action is yet required. When at P3 or P4, the moment represented by T lies in the past, and an action is required immediately.

So, the problem is to determine if the threshold T has been passed or not.

Considering an **infinite counter**, the situation is simple. The evaluation consists in determining if point P is before or after T.

Considering a **reloaded counter**, as the timer rolls over at its maximum value, the situation is more complex.

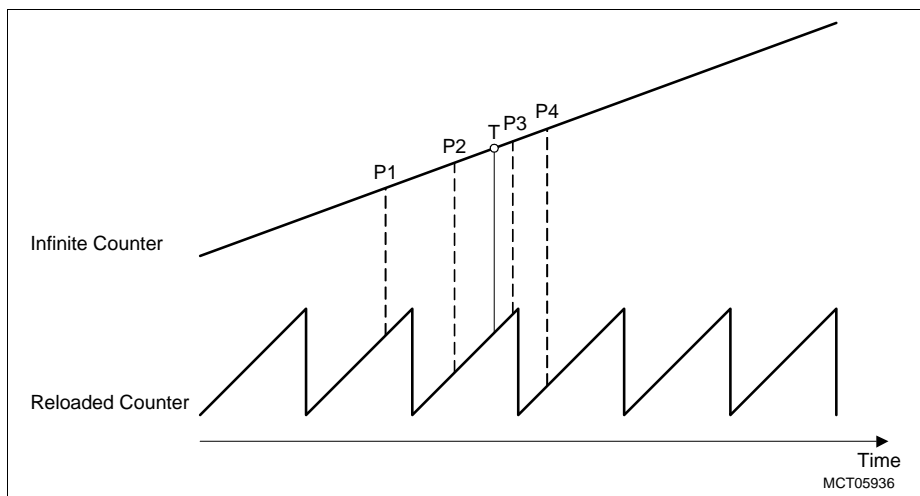


Figure 23-27 Greater/Equal Concept

The **observation window** determines the space in time where writing the value T to the comparator will lead to correct observation (meaning, there is an event if “After”; there is no event if “Before”). Considering an observation window, an event (threshold T) is

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programmed and then the window is split into two windows, the “After” window and the “Before” window (**Figure 23-28**). If the timer lies in the “After” window at the time of programming the threshold, the event is performed immediately. If it lies in the “Before” window, the event will happen later when the timer reaches the threshold T . The “Before” window refers to a “prediction range”, and the “After” window refers to the “history buffer”.

From a practical point of view, once the value T is determined, it is necessary to calculate the observation window (position and width). Before updating the value T , the application must assure that the observation window was entered but has not yet been left.

The width of the **observation window** cannot exceed the timer period. To support reloaded counters where the overflow can occur within the observation window, a **signed** comparison is performed.

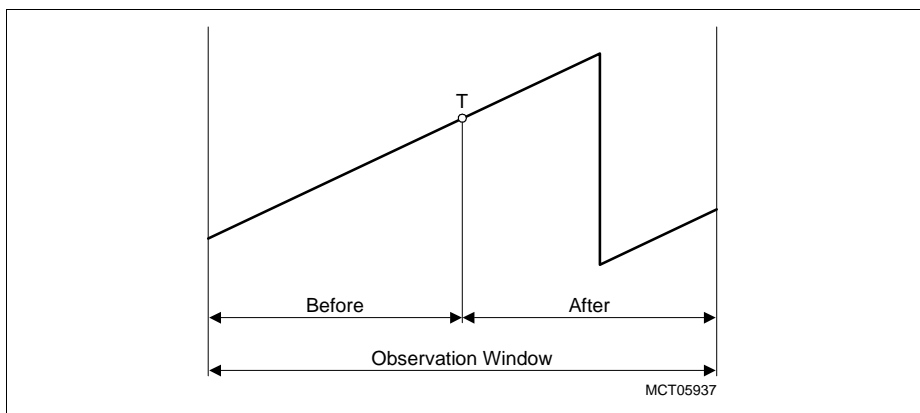


Figure 23-28 Before and After Windows

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Comparison Between Unsigned and Signed Compare

To be able to support different timer periods and to support correct observation even beyond timer overflow, the GPTA[®]v5 embeds the **scalable** and **signed** greater/equal comparator. Using a signed comparison allows one overflow of the timer to occur within the observation window. This is illustrated in [Figure 23-29](#).

Using a signed compare in order to take into account the timer overflow, the comparator window is introduced. The comparator window is centered to the point T and its width can be selected by the user.

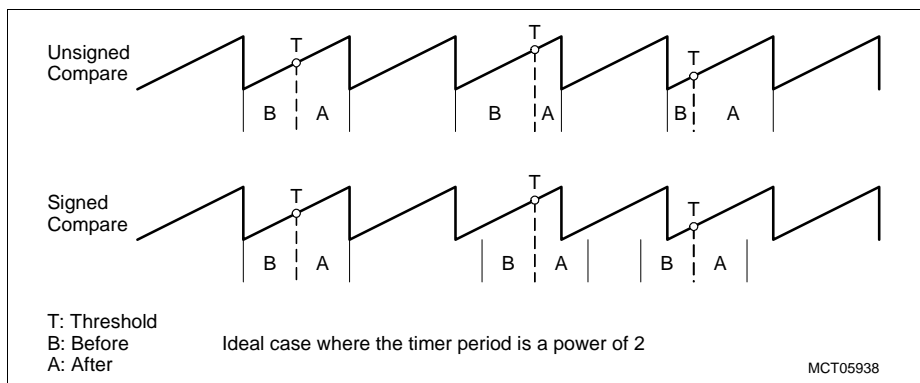


Figure 23-29 Unsigned Versus Signed Compare

When the timer range is a multiple of 2 and because the comparator is scalable, the observation window and the comparator window are identical. See [Figure 23-30](#).

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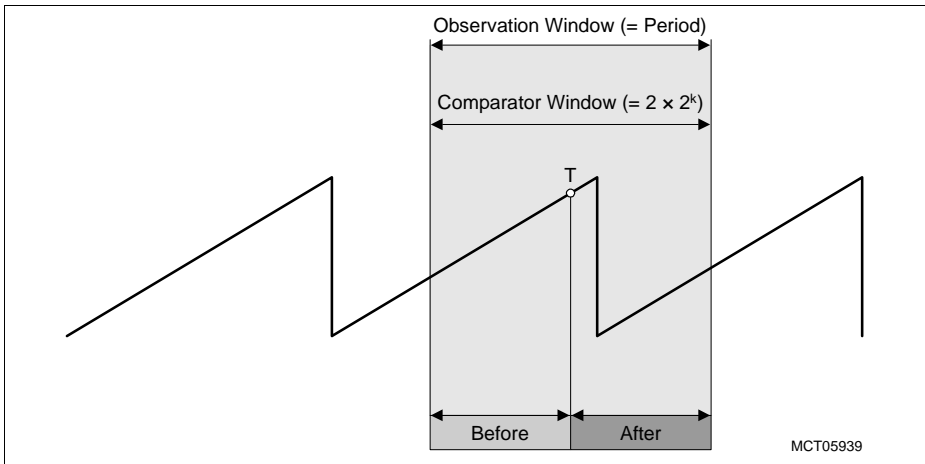


Figure 23-30 Observation and Comparator Windows (timer is a power of 2)

The scalable and signed greater/equal comparator scheme leads to a limitation that must be considered when programming the GPTA®v5 Module. If the timer range is not a power of 2, the comparator window (always a power of 2) will no longer match the timer period. This will impact the observation window as described in the following paragraph.

Observation window for reloaded timers (period is not a power of 2)

In that case, the comparator window must exceed the timer period. The user must find the comparator window (by selecting the scale factor k) which fits best the timer period.

The following equation must apply:

$$2^k < \text{Period} \leq 2 \times 2^k \quad (23.1)$$

Figure 23-31 and **Figure 23-32** show that one part of the comparator window must be discarded in order to avoid inconsistency, resulting in the observation window.

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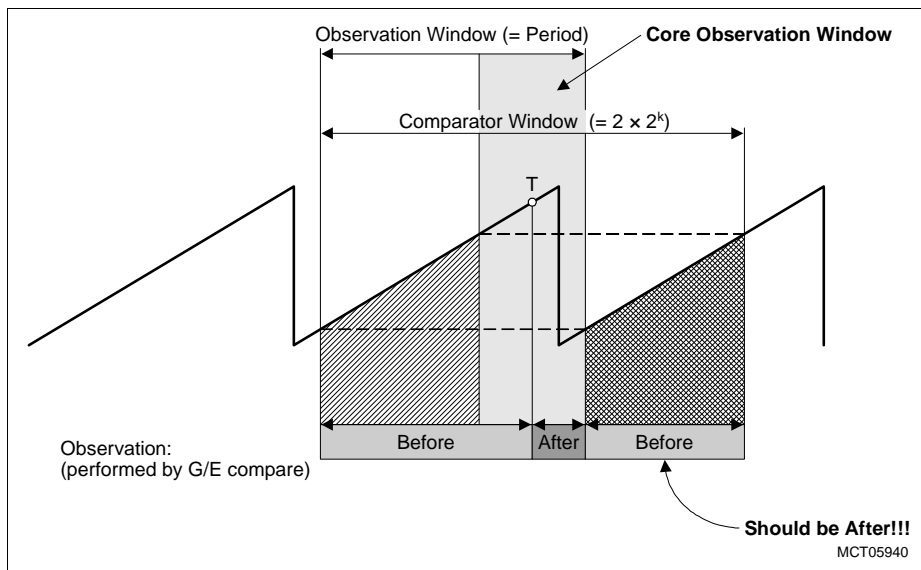


Figure 23-31 Observation Window when Threshold T is High

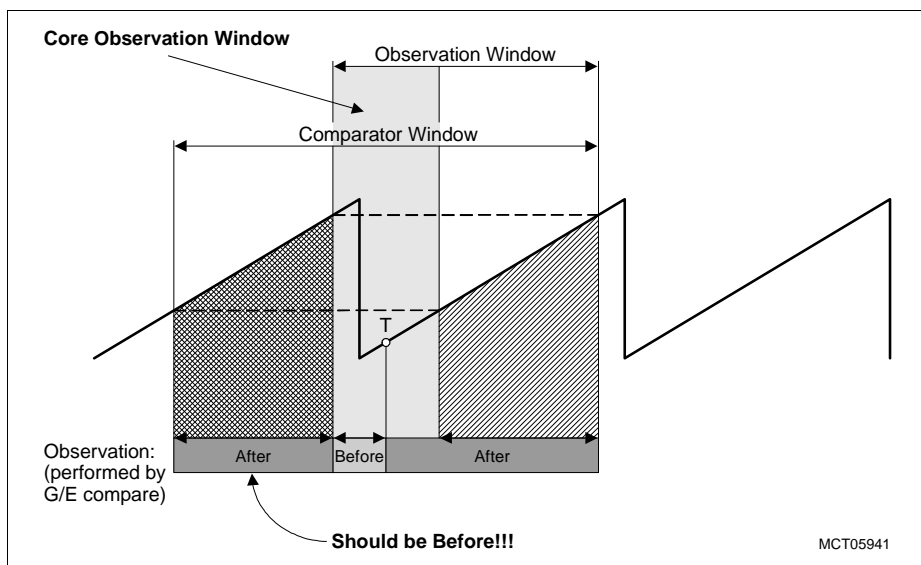


Figure 23-32 Observation Window when Threshold T is Low

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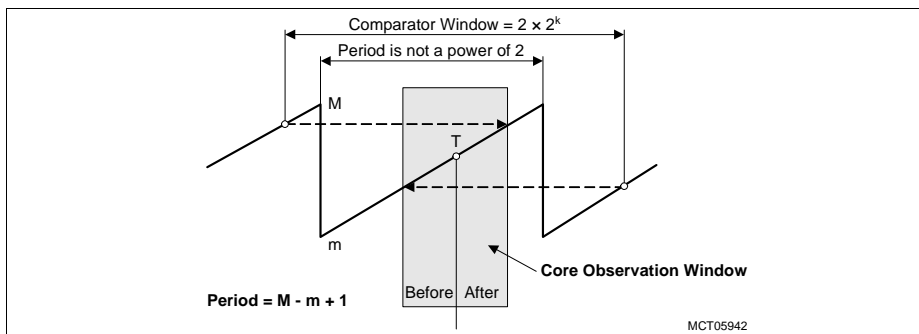


Figure 23-33 The Core Observation Window

A comparison of the previous figures shows that the position of the observation window with respect to T is dependent on the value of T itself. That means the user, before updating the comparator with T , needs to calculate the observation window as a function of T . To avoid this calculation, a **core observation window** can be defined that is independent of T . It will always be centered on T , whatever its value. However, one particularity exists when using the core observation window: the size of the core observation window varies depending on two static values: the timer period and the comparator window's sizes. In particular, the core observation window reduces as the value of the timer period is just after a power of 2. This is shown in [Figure 23-34](#).

For any timer period (whatever the range) and any threshold position, a symmetrical core observation window of a statically defined size can be determined.

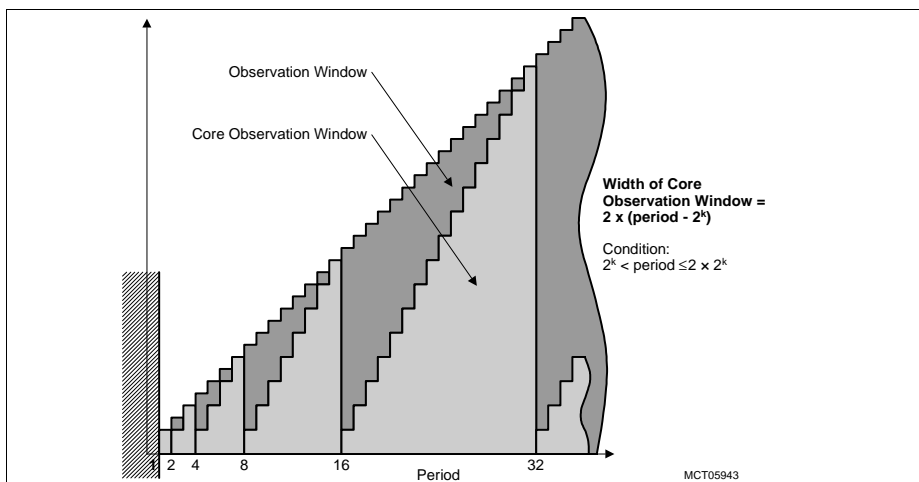


Figure 23-34 Core Observation Window Sizes Versus Period Sizes

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Implementation

The hardware implementation of the **scalable and Signed/Unsigned** Greater/Equal compare is illustrated in **Figure 23-35**. The function consists of subtracting the threshold T from the GT timer value. The result is in 2s complement format. The result's sign bit and the 15 most significant bits are available for observation. One of those bits is selected according to the mode of operation (Unsigned or Signed) and the period length (bit field GTCTRk.SCO). This bit drives the TGE (Timer Greater Equal) flag.

Unsigned compare: Select Sign bit (SCO = 0F_H)

Signed compare: Select one of the 15 most significant result bits (SCO = 00_H to 0E_H)

Note: How to choose one of the 15 bits is explained later.

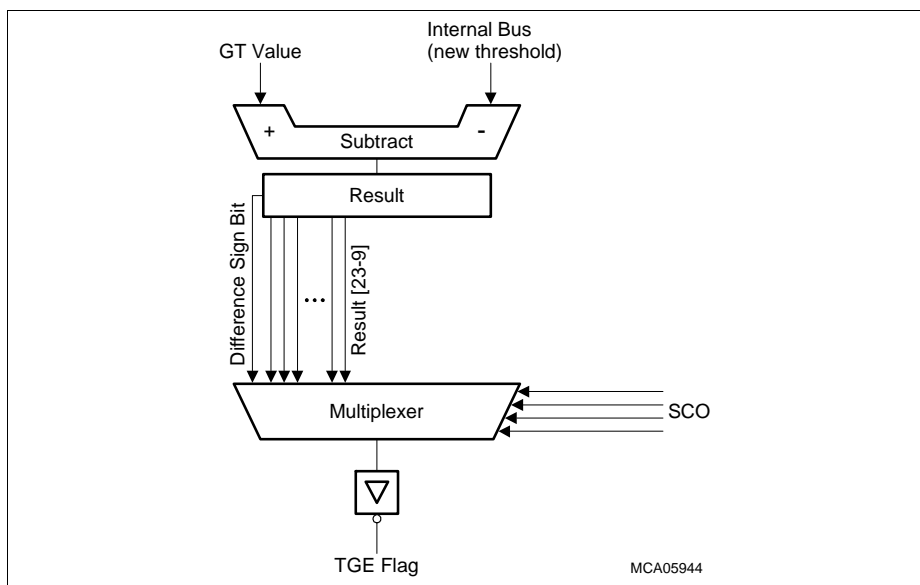


Figure 23-35 Comparator Implemented by a Subtraction Circuitry

The interpretation of the selected result bit is provided in the following simple example: For a 4-bit timer, the subtraction of the threshold T from the timer value, leads to a 4-bit signed result, as illustrated in **Figure 23-36**. This example is selected for simplicity although 4-bit periods are not covered by the implementation.

When using Unsigned compare, the sign bit S is selected. If it equals 0, the result is positive, indicating that the timer is greater or equal the threshold, and hence **After**. If it equals 1, the result is negative, and the observation indicates **Before**.

When using Signed compare, the result bit R₃ can be selected and interpreted, provided that the timer period is at least 9. Here, the range of the result can be split into four sub-

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ranges. Because the result is in 2s complement format, a value of 0 for R_3 is interpreted as **After**, and a value of 1 is interpreted as **Before**. A comparison of [Figure 23-36](#) and [Figure 23-37](#) shows why this proceeding leads to correct interpretation within the observation window. [Figure 23-37](#) shows the case of a period equal a multiple of 2.

Result in 2s Complement					Observation Unsigned Compare	Result in Decimal	Observation Signed Compare Using R_3
S	R_3	R_2	R_1	R_0			
0	1	1	1	1	After S = 0	+15	Before $R_3 = 1$
0	1	1	1	0		+14	
0	1	1	0	1		+13	
0	1	1	0	0		+12	
0	1	0	1	1		+11	After $R_3 = 0$
0	1	0	1	0		+10	
0	1	0	0	1		+9	
0	1	0	0	0		+8	
0	0	1	1	1		+7	
0	0	1	1	0		+6	
0	0	1	0	1		+5	
0	0	1	0	0		+4	
0	0	0	1	1		+3	
0	0	0	1	0		+2	
0	0	0	0	1		+1	
0	0	0	0	0		0	
1	1	1	1	1	Before S = 1	-1	Before $R_3 = 1$
1	1	1	1	0		-2	
1	1	1	0	1		-3	
1	1	1	0	0		-4	
1	1	0	1	1		-5	After $R_3 = 0$
1	1	0	1	0		-6	
1	1	0	0	1		-7	
1	1	0	0	0		-8	
1	0	1	1	1		-9	
1	0	1	1	0		-10	
1	0	1	0	1		-11	
1	0	1	0	0		-12	
1	0	0	1	1		-13	
1	0	0	1	0		-14	
1	0	0	0	1		-15	
1	0	0	0	0		-16	

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Figure 23-36 Result and Observation for a 4-Bit Timer

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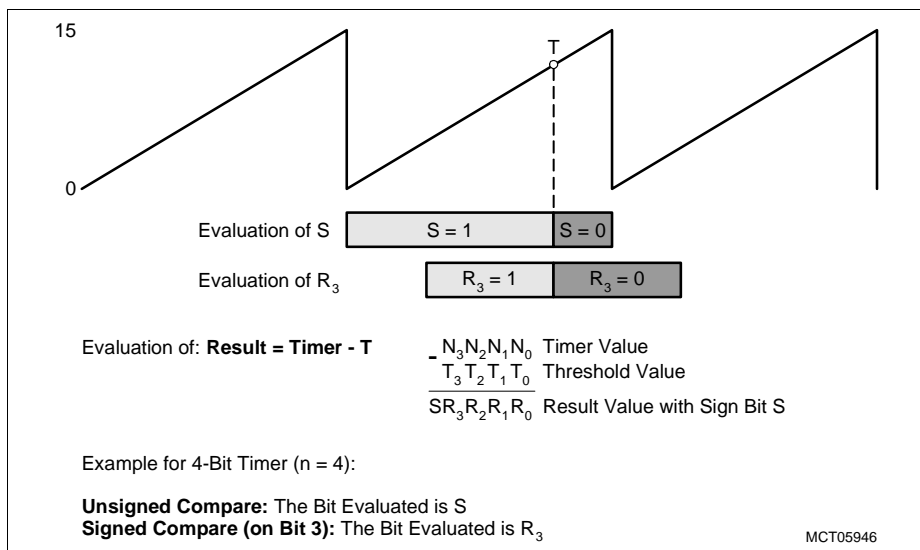


Figure 23-37 Result and Observation (Period = 16)

Figure 23-38 shows the case of a period of 12 which is not a power of 2. Here again, the Table in Figure 23-36 applies.

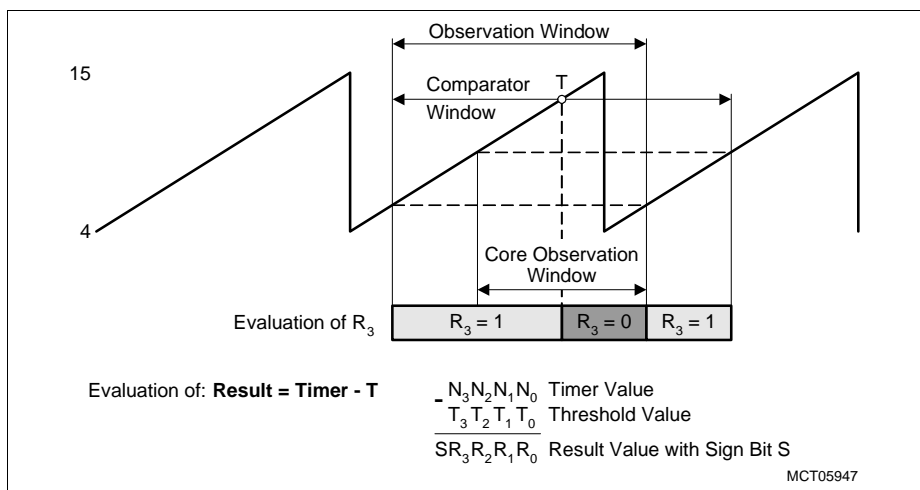


Figure 23-38 Result and Observation (Period = 12)

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The previous examples show that the result bit to select for observation (R_3) corresponds to the comparator window's size ($k = 3$).

Considering the case in which the period is not a multiple of 2, choose a comparator window whose width is between 1 and 2 times the timer period:

$$2^k < \text{Period} \leq 2 \times 2^k \quad (23.2)$$

In no case may the comparator window be equal to or greater than twice the period.

k represents the Result bit to select.

How to Proceed

- Unsigned greater/equal compare:

SCO bit field = $0F_H$ (15_d)

Thereby, the sign bit of the result is selected to drive TGE flag.

This setting is valid for all possible periods. The observation window always matches the period.

- Signed greater/equal compare:

Depending on the period, the appropriate k is selected, so that:

$$\text{Period} = M - m + 1 \quad (= \text{Max} - \text{Min} + 1) \quad (23.3)$$

$$2^k < \text{Period} \leq 2 \times 2^k \quad (23.4)$$

SCO bit field = 0 to $0E_H$ (0 to 14_d)

Thereby, the result bit R_k is selected to drive TGE flag.

This setting is possible for periods greater than 512.

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Table 23-1 Period Range Depending on Selected k

$2^k < \text{Period} \leq 2 \times 2^k$	k	SCO Bit Field (decimal)
$0 < \text{period} \leq 512$	Not covered by implementation	
$512 < \text{period} \leq 1024$	9	0
$1024 < \text{period} \leq 2048$	10	1
$2048 < \text{period} \leq 4096$	11	2
$4096 < \text{period} \leq 8192$	12	3
$8192 < \text{period} \leq 16384$	13	4
$16384 < \text{period} \leq 32768$	14	5
$32768 < \text{period} \leq 65536$	15	6
$65536 < \text{period} \leq 131072$	16	7
$131072 < \text{period} \leq 262144$	17	8
$262144 < \text{period} \leq 524288$	18	9
$524288 < \text{period} \leq 1048576$	19	10
$1048576 < \text{period} \leq 2097152$	20	11
$2097152 < \text{period} \leq 4194304$	21	12
$4194304 < \text{period} \leq 8388608$	22	13
$8388608 < \text{period} \leq 16777216$	23	14

The width of the core observation window is defined by:

$$2 \times (\text{period} - 2^k) \quad (23.5)$$

As a consequence, the width of the “Before” window within the core observation window is $(\text{period} - 2^k)$ and the width of the “After” window within the core observation window is $(\text{period} - 2^k)$, including the value T.

Additional Information: Illustration on the General Case

The previous section illustrated the greater/equal compare for the particular case of a 4-bit timer. The purpose of this section is to describe the implementation from a general point of view, that is, for a timer period equal to $M - m + 1$.

In the following figures, the X axis indicates the timer value (elapsing time) and the Y axis indicates the threshold value T. The 45° line starting at (m, m) represents the position in time of T. The graphic shows the observation performed by the hardware for all cases of T ($m \leq T \leq M$).

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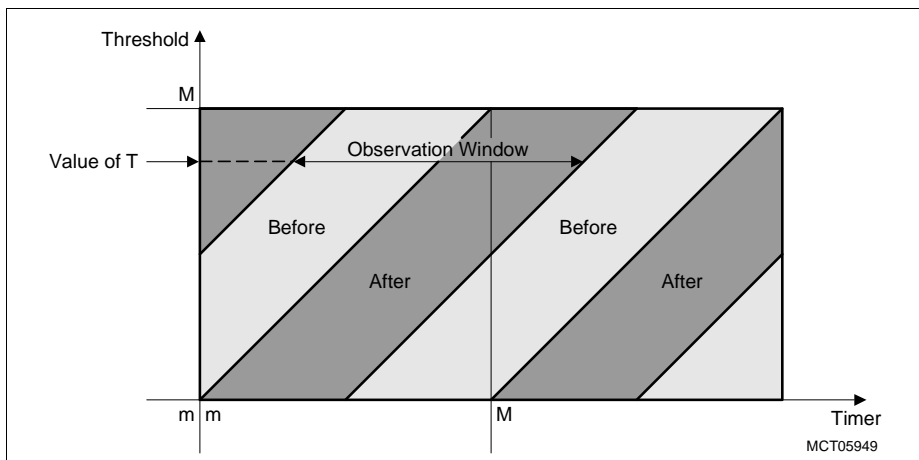


Figure 23-40 Graphical Representation of Signed Compare (Period = 2×2^k)

The [Figure 23-41](#) illustrates the Signed compare where the period may also be unequal a multiple of 2. The graphical representation of this general case is analogous to the one described in [Figure 23-31](#).

If the period is not a multiple of 2, the graphical representation of the Signed compare shows a discontinuity in the “Before” and “After” ranges. Indeed, the widths of the “Before” and “After” windows are not constant, as they depend on the value T . As a consequence, the observation window is not centered on T . The result is that the position of the observation window would have to be re-evaluated for each value T (i.e. determining the widths of the “After” and the “Before” window). For this calculation, the principal characteristic is shown in [Table 23-41](#) (2×2^k - period = comparator window - period).

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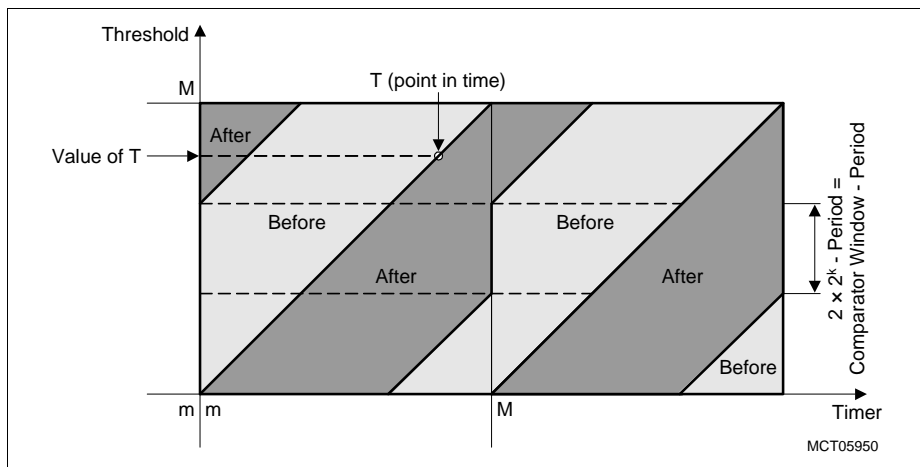


Figure 23-41 Graphical Representation of Signed Compare ($2^k < \text{Period} \leq 2 \times 2^k$)

Figure 23-42 shows how the observation window is positioned with respect to T. It also shows the **core observation window** that is always centered on T and which has a constant width.

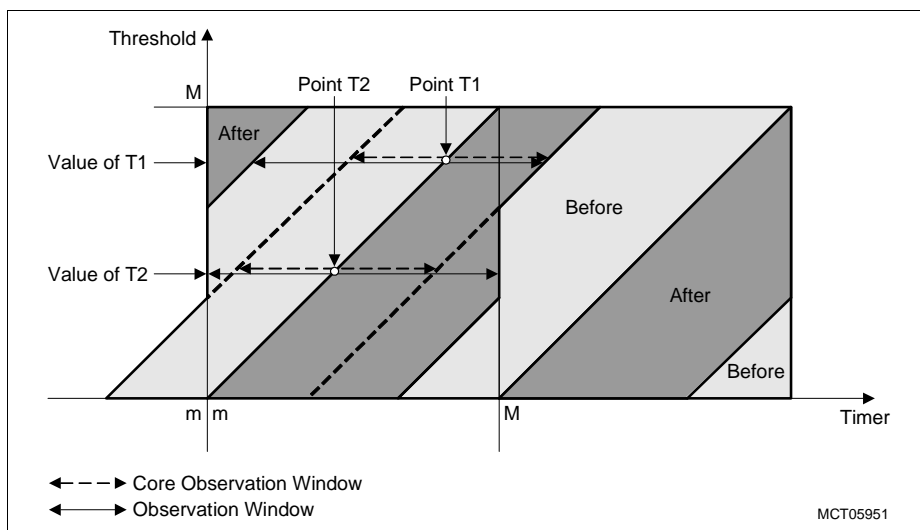


Figure 23-42 Core Observation Window in the Graphic

General Purpose Timer Array (GPTA[®]v5)

23.3.3.2 Global Timer Cell (GTC)

The GPTA[®]v5 provides 32 Global Timer Cells (GTC00 to GTC31) used for capture/compare operations.

Registers

The following registers are assigned to a GTCK (k = 00-31):

- GTCCTRk = Global Timer Cell Control Register k (see [Page 23-184](#))
- GTCXRk = Global Timer Cell X Register k (see [Page 23-188](#))
- SRSC1 = Service Request State Clear Register 1 (see [Page 23-222](#))
- SRSS1 = Service Request State Set Register 1 (see [Page 23-223](#))

Features

- **24-bit based timer cells** related to two Global Timers GT0 and GT1.
- **Capture Mode** on rising, falling or both edges with following actions:
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal)
- **Compare Mode** on equal compare, or greater than, or equal to compare with following actions:
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal)
 - Capture (after compare match) the value of the selected Global Timer or the opposite Global Timer
- **One Shot Mode** allows the selected (capture or compare) mode to be stopped after the first event.
- **Flexible mechanism** to link pin actions and allow complex combination of cells. (A cell has the ability to propagate actions over adjacent cells with higher number, in order to perform complex waveforms such as PWMs).

Architecture

The architecture of a GTC is shown in [Figure 23-43](#). Each GTC has a multiplexer that allows selection of the GT0 or GT1 Global Timer value bus as data source, a 24-bit capture/compare register GTCXRk, and a 24-bit equal comparator.

The 32 Global Timer Cells (GTC00 to GTC31) have the following inputs:

- Two Global Timer value buses, GTV0 and GTV1, coming from the two Global Timers and carrying the GT0 and GT1 timer values
- Two inputs, TEV0 and TEV1, reporting GT0 and GT1 timer value updates
- Two inputs, TGE0 and TGE1, reporting the result of the GT0 and GT1 compare operations
- A trigger input (GTCKIN) that is connected via the GTC input multiplexer to one of the following signal sources:

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- External port lines
- Local Timer Cell outputs
- Filter and Prescaler Cell outputs
- Internal input signals INTx
- Two action mode inputs (M0I, M1I) coming from the adjacent GTC with lower order number (M1I and M0I of GTC00 are 0)

Each GTC provides the following outputs:

- One data output (GTCKOUT) that can be connected to:
 - External port lines
 - Inputs of an MSC module
 - Outputs and/or inputs of Local Timer Cell inputs
- Two action mode outputs (M0O, M1O) going to the adjacent GTC with higher order number
- One service request line (SQSk) triggered by a capture/compare event.

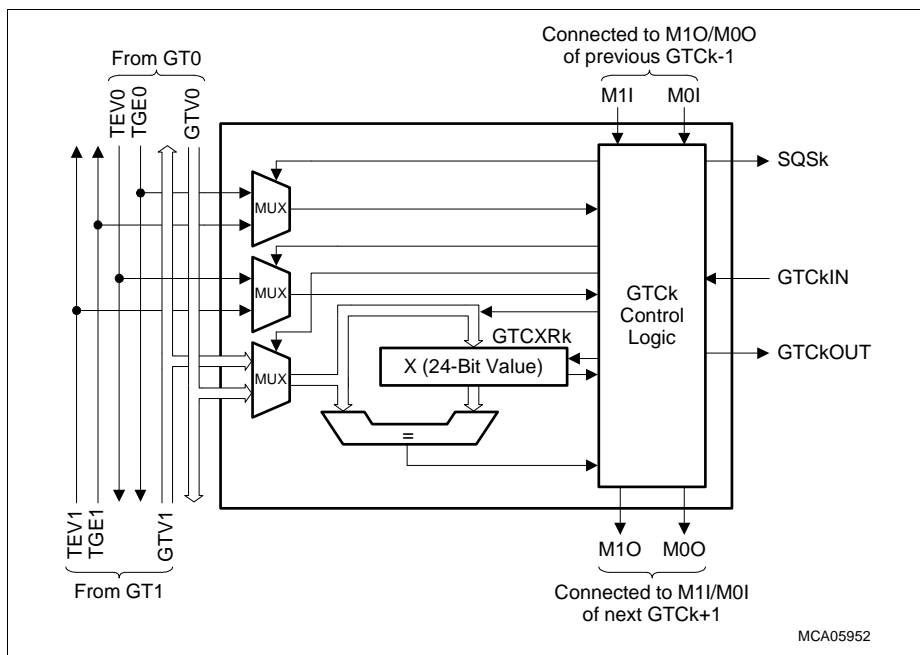


Figure 23-43 Architecture of Global Timer Cells

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Figure 23-44 shows how the GTCs are arranged and connected to the adjacent GTCs and with the Global Timers GT0 and GT1.

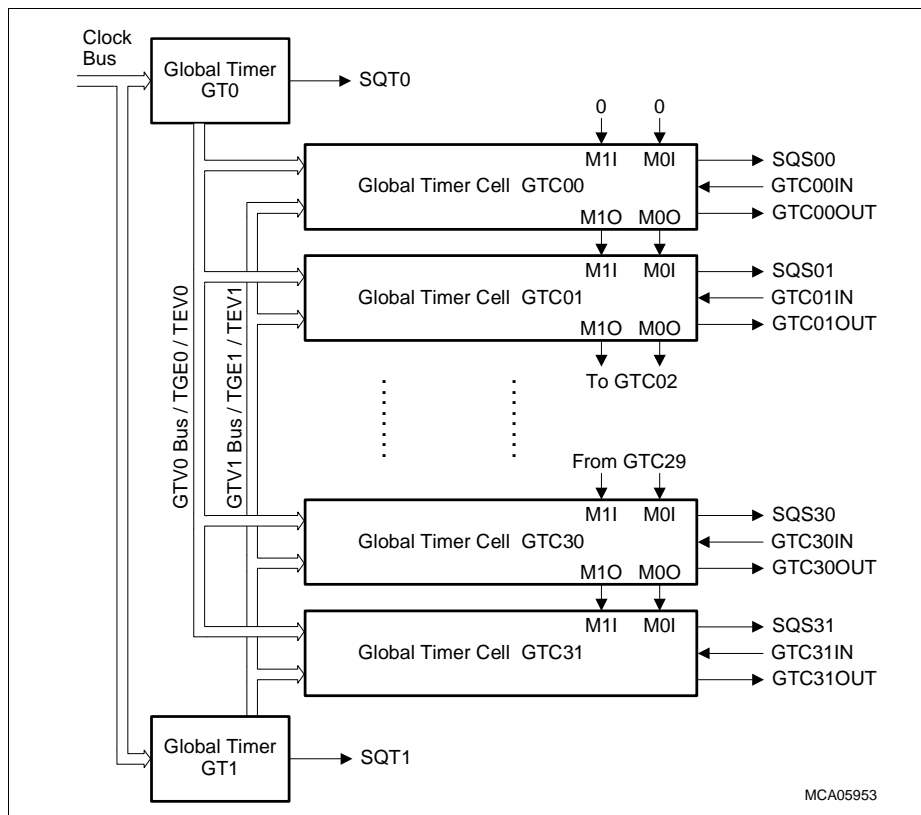


Figure 23-44 GTC Interconnections

Note: Cascading of GTCs is limited. TC1728 specific details are given on [Page 23-250](#).

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Capture Mode

The capture function of a GTCK cell is performed on a rising edge (GTCCTRk.REN = 1), a falling edge (GTCCTRk.FED = 1) or both edges of the selected GTCKIN input signal. On the requested event, the GTC:

- Copies the 24-bit value of the selected Global Timer into the 24-bit capture/compare register GTCXRk.X,
- Sets the GTCK service request flag in register SRSS1/SRSC1,
- Activates the service request output SQSk if control register bit GTCCTRk.REN = 1,
- Performs an GTCKOUT output signal line manipulation (set, reset, toggle, unchanged) as defined by bit field GTCCTRk.OCM,
- Transfers an action request, generated by an internal event or received on the M1I, M0I input lines, to the M1O, M0O output lines.

Compare Mode

In the Compare Code of a GTCK cell, several functions can be performed when the value of the selected Global Timer matches and/or exceeds the value stored in register GTCXR. With GTCCTRk.GES = 0 an "Equal Compare" match is selected while GTCCTRk.GES = 1 selects a "Greater Equal Compare" match. On the requested event, the GTC:

- Sets the GTCK service request flag in register SRSS1/SRSC1,
- Activates service request output SQSk if control register bit GTCCTRk.REN = 1,
- Performs an GTCKOUT output signal line manipulation (set, reset, toggle, unchanged) as defined by bit field GTCCTRk.OCM,
- Transfers an action request, generated by an internal event or received on the M1I, M0I input lines, to the M1O, M0O output lines.

If a greater or equal compare is selected, the condition is evaluated only when the compare value is written to the GTCXRk register. The user should then assure that the GTC is already enabled so that the evaluation can take place.

Capture after Compare Mode

When bit GTCCTRk.CAC = 1 and a compare event has occurred, register GTCXR is loaded with:

- The Global Timer value as selected by bit field GTCCTRk.MOD (GTCCTRk.CAT = 0),
- The alternate Global Timer value (GTCCTRk.CAT = 1). If a greater or equal compare match has been detected, the GTCK should be set into One Shot Mode in order to prevent double capturing.

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One Shot Mode

In One Shot Mode (GTCCTRk.OSM = 1), a self-disable of GTCK is executed after each GTC event (GTCCTRk.CEN = 0). The current state of a GTCK can be evaluated by reading the control register flag bit GTCCTRk.CEN.

Note: The contents of the GTCK capture/compare register GTCXRk are write-protected for Capture_After_Compare in Single Shot Mode. Write protection is activated when the compare value is reached and released after a read access of register GTCXRk occurred.

Data Output Line Control

The data output GTCKOUT can be controlled by the GTCK itself and by adjacent GTCs with a lower order number. For this purpose, two communication signals between GTCs are available connecting all GTCs via their M1I/M0I inputs and their M1O/ M0O outputs respectively (see [Figure 23-45](#)).

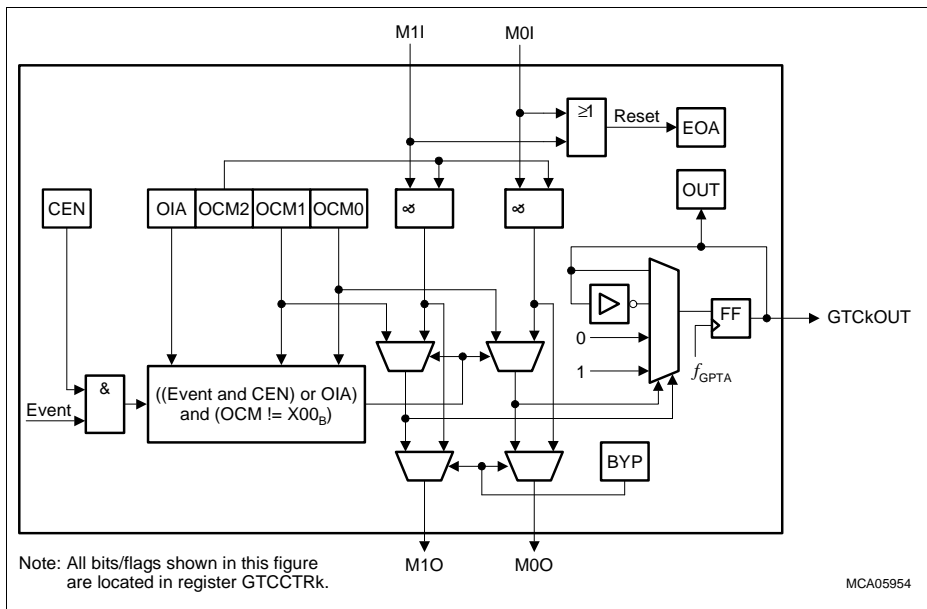


Figure 23-45 GTC Output Operation and Action Transfer

General Purpose Timer Array (GPTA®v5)

When bit GTCCTRk.OCM2 is reset, the data output GTCKOUT is only controlled by the local GTCK. A set, reset, toggle, or hold operation can be performed as selected by bits GTCCTRk.OCM1 and GTCCTRk.OCM0 ([Table 23-2](#)).

When bit GTCCTRk.OCM2 is set, the data output GTCKOUT is affected either by the local GTCCTRk.OCM1 and GTCCTRk.OCM0 bits or by the M1I/M0I input lines, which are connected to the adjacent GTCK-1 Global Timer output lines M1O/M0O. An enabled GTCK event superimposes an action request generated simultaneously by the M1I/M0I inputs.

When the bypass bit GTCCTRk.BYP is cleared, the M1O/M0O output lines logically OR together the local GTCK events and, if enabled by bit GTCCTRk.OCM2, the action requests received via the M1I/M0I input lines.

When bit GTCCTRk.BYP is set to 1, a local GTCK event will not modify the M1O/M0O output lines.

Table 23-2 Selection of GTC Output Operations and Action Transfer Modes

Bit Field OCM[2:0]	Local Capture or Compare Event	M1O/M0O BYP = 0	M1O/M0O BYP = 1	State of Local Data Output Line
0 0 0	not occurred	0 0	0 0	not modified
	occurred	0 0	0 0	not modified
0 0 1	not occurred	0 0	0 0	not modified
	occurred	0 1	0 0	inverted
0 1 0	not occurred	0 0	0 0	not modified
	occurred	1 0	0 0	0
0 1 1	not occurred	0 0	0 0	not modified
	occurred	1 1	0 0	1
1 0 0	not occurred	M1I M0I	M1I M0I	modified according M1I/M0I
	occurred	M1I M0I	M1I M0I	modified according M1I/M0I
1 0 1	not occurred	M1I M0I	M1I M0I	modified according M1I/M0I
	occurred	0 1	M1I M0I	inverted
1 1 0	not occurred	M1I M0I	M1I M0I	modified according M1I/M0I
	occurred	1 0	M1I M0I	0
1 1 1	not occurred	M1I M0I	M1I M0I	modified according M1I/M0I
	occurred	1 1	M1I M0I	1

The GTCKOUT output line can be connected to output ports, on-chip peripheral inputs, and/or LTC inputs via the I/O Line Sharing Block (see [Page 23-98](#)). GTCKOUT can be updated directly by software (setting bit GTCCTRk.OIA = 1) or upon a timer, capture or compare event within the local GTCK or a preceding GTC. The current state of the data output line can be evaluated by reading status flag GTCCTRk.OUT.

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Cell Enabling

After reset all GTCs are disabled. A GTC may be enabled by resetting GTCCTRk.EOA (Enable-Of-Action) to 0 in Capture Mode or Compare Mode using a standard write assembler operation¹⁾. Because bit EOA is hardware protected, intrinsic read-modify-write assembler operations²⁾ only enable the GTC if bit EOA is modified from 1 to 0.

Cell Deactivation

By programming a GTC to Capture Mode with no edge selected (GTCCTRk.FED = GTCCTRk.RED = 0), an enabled cell becomes inactive and performs no action, but continues passing action commands via the communication link from M1I/M0I to M1O/M0O.

Cell Enabling on Event

A GTC can be enabled by an event in a GTC with lower index number. For this purpose, the local event function of a GTC must be temporary disabled by setting GTCCTRk.EOA (Enable-Of-Action) to 1. Because bit EOA is hardware protected, intrinsic read-modify-write assembler operations²⁾ only disable the GTC if bit EOA is modified from 0 to 1. Both operations will clear GTCCTRk.CEN and now a local event cannot affect the GTC. When a preceding GTC generates and communicates an event (or OIA) via its communication link M1O/M0O, at least one of the M1I/ M0I input lines changes its state to 1. This condition clears bit GTCCTRk.EOA of the disabled GTC via the OR gate as shown in [Figure 23-45](#). Now GTCCTRk.CEN is set and the cell is enabled for local events.

It is also possible to enable the following GTC via the communication link for local events. For this purpose, the GTCCTRk.EOA bit of the following GTC must be set, too. If bit GTCCTRk.OCM2 of the preceding GTC is 1, the enable action will take place at the same time as in the preceding GTC. Otherwise, the GTC will be enabled later on a capture/compare event in the preceding GTC, provided OCM0 or OCM1 of this GTC is different from 0.

In this way, several GTCs can be enabled at the same time or one after the other. Normally, the cells will be used in One Shot Mode, and an interrupt will be generated after the last event to evaluate the data and to prepare the next enable sequence.

A disabled GTC (GTCCTRk.CEN = 0) behaves as an inactive cell.

1) Standard TriCore[®] write operations: ST.A, ST.B, ST.D, ST.DA, ST.DD, ST.HST.Q, ST.W
Standard PCP write operations: ST.F, ST.IF, BCOPY, COPY

2) Intrinsic TriCore[®] read-modify-write Operations: LDMST, ST.T, SWAP
Intrinsic PCP read-modify-write Operations: SET.F, XCH.F, CLR.F

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Logical Operating Cells

The inter-cell communication architecture allows implementation of a complex waveform generation to be distributed over several GTCs, controlling a common port pin.

For example, one GTC may be configured in Capture Mode triggered by a rising edge detected on the associated input pin line. The related interrupt service routine can increment the captured timer value by a delay offset and store the result in the GTCXR register of the adjacent GTC configured in Compare Mode. Upon a compare event in the second GTC, the output port line of a third GTC can be set via MIO, M00 interface lines. When the GTCXR register of the third cell is loaded with another compare value by the interrupt service routine related to the second GTC, the output port line may be reset by the next compare event within GTC3.

This logical operating cell provides an output signal with programmable pulse width and configurable delay with minimal software overhead.

GTC Service Request

The service request output SQSk of a Global Timer Cell GTCK is controlled as shown in [Figure 23-46](#). When the GTCK service request condition becomes active, the service request flag always becomes set. The service request output SQSk is only activated if it is enabled by the enable bit GTCCTRk.REN. Additional information about service request and interrupt handling is given on [Page 23-123](#).

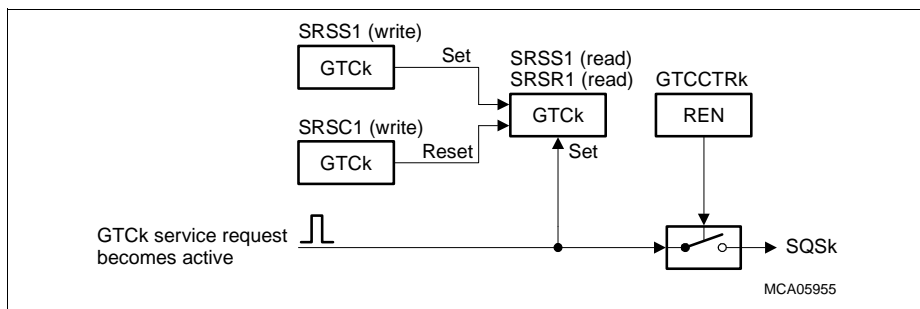


Figure 23-46 GTCK Service Request Generation

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GTC Application Examples

The Global Timers together with GTCs can typically be used for input signal timing analysis of very complex input signals as well as for generation of complex output signals. [Figure 23-47](#) shows a configuration with Global Timer 0 and four GTCs, which is used in the following two examples:

- Example 1: Complex input signal capturing and analyzing
- Example 2: Complex periodical output signal generation

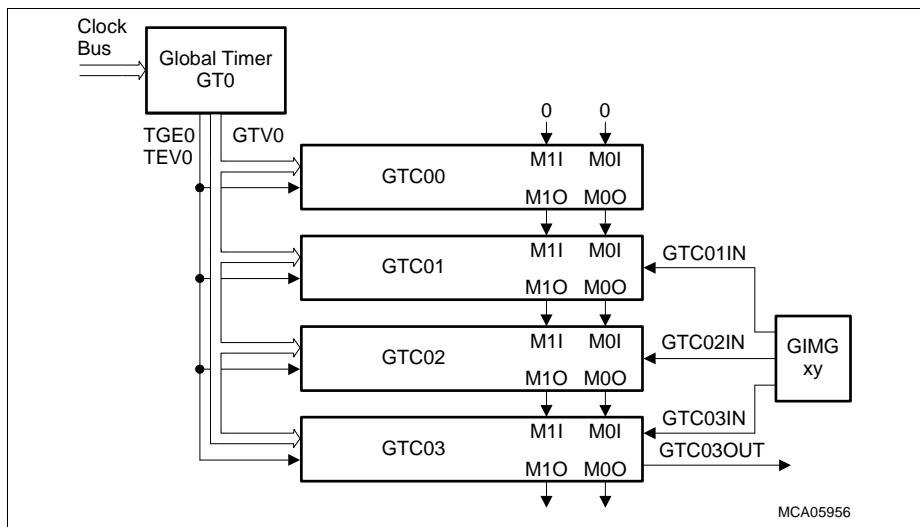


Figure 23-47 Complex Input/Output Signal Capturing/Generation with GTs and GTCs

Complex Input Signal Capturing and Analyzing

In this application example, one input signal from a GTC input multiplexer group becomes analyzed from a timing reference point for three consecutive signal transitions. This common input signal (e.g. a port line) is selected by a GTC input multiplexer group (GIMG) common for GTC01, GTC02, and GTC03 (see also [Page 23-111](#)). The GTCs are configured in the following way:

- GT0 operates as free-running up-counting 24-bit timer with reload to GTREV0.REV on overflow. It is clocked by one clock signal from the clock bus.
- GTC00 operates in Compare Mode with timer GT0. The compare match event is reported on the M0O/M1O output lines to the GTC01.
- GTC01 operates in Capture Mode at **rising** edge with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set).

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- GTC02 operates in Capture Mode at **falling** edge with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set).
- GTC03 operates in Capture Mode at **rising** edge with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set).

With the compare event of GTC00 (time stamp), GTC01 becomes active and waits for the next rising edge at its data input GTC01IN. While GTC01 is active, GTC02 and GTC03 are inactive.

When GTC01 detects a rising edge at its data input, it captures the current GT0 value into its GTCXR01 register, enables GTC02, and becomes disabled afterwards because it was operating in One Shot Mode. When GTC02 detects a falling edge at its data input, it captures the current GT0 value into its GTCXR02 register, enables GTC03, and becomes disabled afterwards because it was operating in One Shot Mode. When GTC03 detects a rising edge at its data input, it captures the current GT0 value into its GTCXR03 register and becomes disabled afterwards because it was operating in One Shot Mode. Optionally, the capture event at GTC03 may generate a service request to indicate that the three capture events have occurred and the captured values can be checked by software. Note that all of these capture events are executed by the GPTA[®]v5 hardware without any software interactions and with a resolution of the GT0 clock rate.

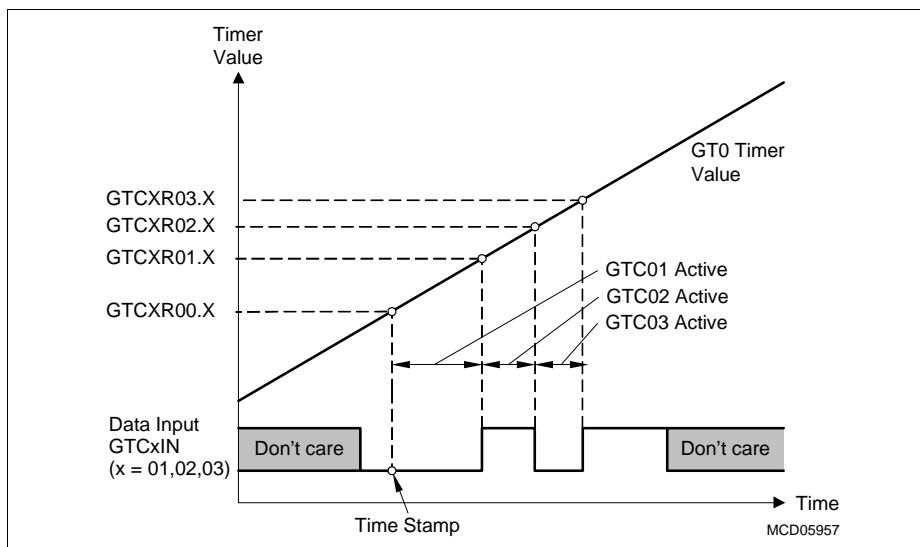


Figure 23-48 Complex Input Signal Analysis/Capturing with GTCs

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Complex Periodic Output Signal Generation

This application example uses the GT/GTC configuration as shown in [Figure 23-47](#). The generated output signal is available at GTC03OUT. The GTC input signals of the GT/GTC configuration are not used in this example.

- GT0 operates as free-running up-counting 24-bit timer with reload to GTREV0.REV on overflow. It is clocked by a clock signal from the clock bus. Its reload period determines the period of the generated PWM output signal.
- GTC00 operates in Compare Mode with timer GT0 with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set). Furthermore, the output GTC03OUT becomes **set** on a local event (OCM = $X11_B$).
- GTC01 operates in Compare Mode with timer GT0 with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set). Furthermore, the output GTC03OUT becomes **reset** on a local event (OCM = 110_B).
- GTC02 operates in Compare Mode with timer GT0 with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set). Furthermore, the output GTC03OUT becomes **set** on a local event (OCM = 111_B).
- GTC03 operates in Compare Mode with timer GT0 with enable-on-action set (EOA set) and One Shot Mode enabled (OSM set). Furthermore, the output GTC03OUT becomes **reset** on a local event (OCM = 110_B).

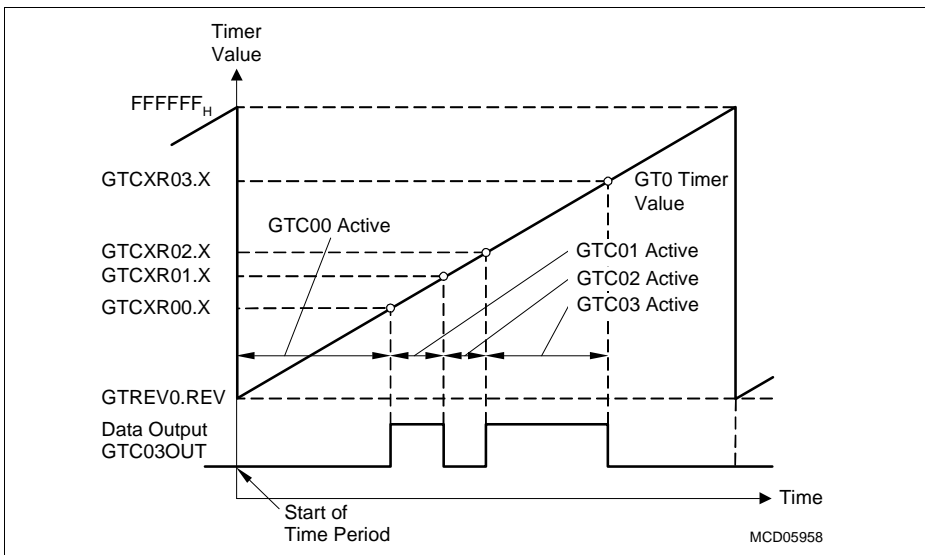


Figure 23-49 Complex Output Signal Generation with GTCs

At the start of the time period (reload of GT0), GTC00 becomes active and waits for the compare event. At this event, it sets the output signal GTC03OUT, enables GTC01 for

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compare operation, and becomes disabled afterwards because it was operating in One Shot Mode. When the GTC01 compare event occurs, the output signal GTC03OUT is reset, GTC02 becomes enabled, and GTC01 becomes disabled because it was operating in One Shot Mode. When the GTC02 compare event occurs, the output signal GTC03OUT is set, GTC03 becomes enabled, and GTC02 becomes disabled because it was operating in One Shot Mode. When the GTC03 compare event occurs, the output signal GTC03OUT is reset, and GTC02 becomes disabled because it was operating in One Shot Mode.

The capture event at GTC03 should generate a service request to indicate that the three compare events have occurred and that GTC01 can be enabled again (setting EOA and OSM). Note that all of the compare events are executed by the GPTA[®]v5 hardware without any software interactions and with a resolution of the GT0 clock rate.

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23.3.3.3 Local Timer Cell (LTC00 to LTC62)

LTC00 to LTC62 are functionally identical. The functionality of LTC63 is different to LTC00 to LTC62 and therefore described separately at [Page 23-79](#).

Registers

The following registers are assigned to a Local Timer Cell LTCK (k = 00-62):

- LTCCTRk = Local Timer Cell Control Register k (see [Page 23-189](#))
- LTCXRk = Local Timer Cell X Register k (see [Page 23-201](#))
- SRSC2 = Service Request State Clear Register 2 (see [Page 23-224](#))
- SRSC3 = Service Request State Clear Register 3 (see [Page 23-226](#))
- SRSS2 = Service Request State Set Register 2 (see [Page 23-225](#))
- SRSS3 = Service Request State Set Register 3 (see [Page 23-227](#))

Features

- **16-bit based timer cells** providing capture, compare, and timer functions.
- **Capture Mode** on rising, falling or both edges with following actions:
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal).
- **Compare Mode** on equal compare of the corresponding (Reset-)Timer LTC with following actions:
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal).
- **Timer Mode** incremented on hardware signal with following actions:
 - Event generation at overflow
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal).
- **Reset Timer Mode** allows the selected LTC to be reset by an adjacent cell. Coherent update capability of adjacent LTCs for PWM management is provided.
- **One Shot Mode** allows the selected (capture, compare, timer or reset timer) mode to be stopped after the first event.
- **Flexible mechanism** to link pin actions and allow complex combination of cells. (A cell has the ability to propagate actions over adjacent cells with higher number, in order to perform complex waveforms such as multi channel PWMs).

Architecture

The architecture of an LTC is shown in [Figure 23-50](#). Each LTC has a 16-bit capture/compare register and a 16-bit equal to comparator.

The first 63 Local Timer Cells (LTC00 to LTC62) have the following inputs:

- A local input data bus (YI) carrying the local timer value of the adjacent LTC with lower order number (YI of LTC00 is always 0000_H)

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- A TI input reporting the occurrence of a local timer value update of the adjacent LTC with lower order number (TI of LTC00 is 0)
- A SI input used by the LTC in Compare Mode as enable line (SI of LTC00 is 0)
- Four action mode inputs (M3I, M2I, M1I, M0I) coming from the adjacent LTC cell with lower order number (M3I, M2I, M1I, and M0I of LTC00 are 0)
- An EI input reporting an event coming from the adjacent LTC with higher order number
- A trigger/clock/enable input LTCKIN hooked to one of the following signals sources:
 - External port lines
 - GTC00 to GTC31 outputs
 - Clock bus signals
 - PDL0 or PDL1 outputs
 - Internal GPTA®v5 kernel input signals INTx (x = 0-3)

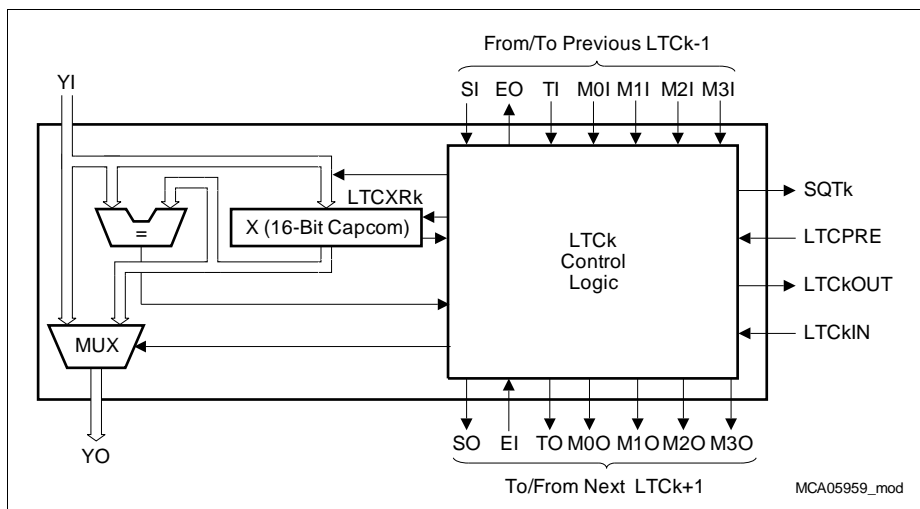


Figure 23-50 Architecture of Local Timer Cells

Each LTC provides the following input / output signals:

- One data output line (LTCKOUT) that can be connected to:
 - External port lines
 - Inputs of an MSC module
 - Outputs and/or inputs of Global Timer Cell inputs
- One LTC prescaler clock input (LTCPRE) for Timer Mode
- One service request line (SQT) triggered by a capture/compare event
- A local output data bus (YO) carrying the local timer value to the adjacent LTC with higher order number or the value on YI

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- A TO output reporting the occurrence of a local timer value update to the adjacent LTC with higher order number
- An SO output used by the adjacent LTC with higher order number as enable signal for a compare function
- An EO output reporting the occurrence of a local event to the adjacent LTC with lower order number
- Four mode lines (M3O, M2O, M1O, M0O) going to the adjacent LTC with higher order number.

Figure 23-51 shows the arrangement of the LTCs and the connections with adjacent LTCs. LTC63 is a Local Timer Cell that differs from all other LTCs (LTC00 to LTC62). LTC63 is described in detail on [Page 23-79](#).

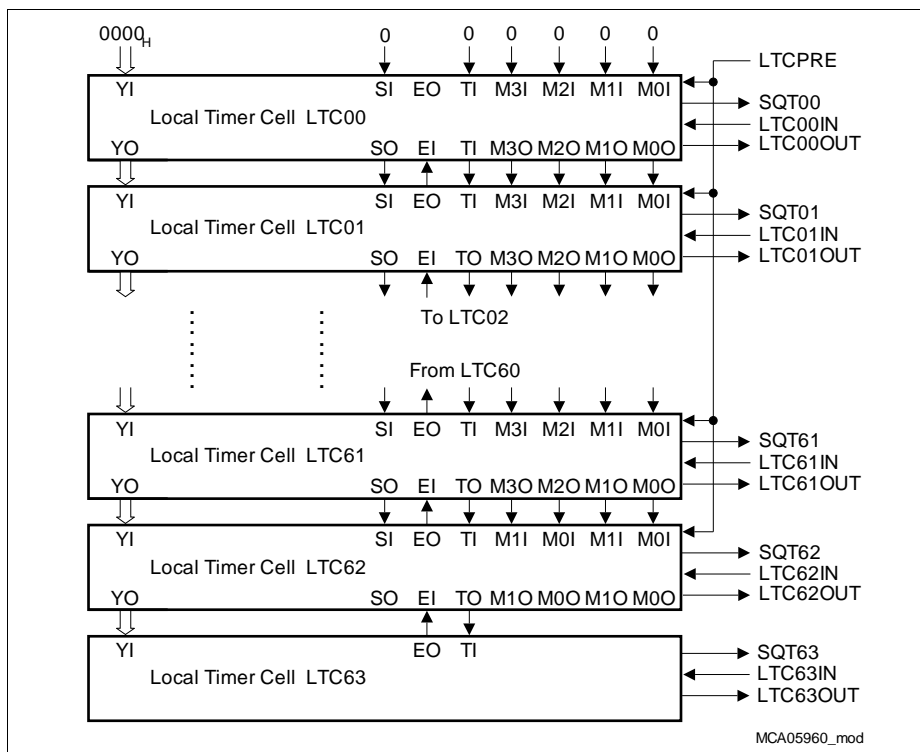


Figure 23-51 Interconnections between the LTCs

Note: Cascading of LTCs is limited. TC1728 specific details are given on [Page 23-250](#).

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Operating Mode Selection

The operating mode of an LTC – Free-Running Timer, Reset Timer, Capture, or Compare Mode – is defined by bit field LTCCTRk.MOD.

Free-Running Timer Mode

The content of the Local Timer Cell Register LTCXRk is initialized by a software write operation. LTCXRk is incremented by the selected LTCKIN input signal. Level or Edge Sensitive Mode can be selected for LTCKIN (see [Page 23-72](#)). In Level Sensitive Mode prescaler clock from the CDC (LTCPRE) can be used to reduce the timer frequency. Every change of the Local Timer Cell Register LTCXRk (increment, reset, or write access) is indicated by output signal TO = 1. When the timer reaches its overflow value (FFFF_H),

- the LTCK service request flag is set,
- the service request output SQTk is activated if control register bit LTCCTRk.REN = 1,
- the LTCK output line LTCKOUT can be altered (set, reset, toggle, unchanged),
- the LTCKOUT output line can be altered (set, reset, toggle, unchanged), depending on bit field LTCCTRk.OCM,
- an action request, generated by an LTCK internal event or received on the M1I/M0I input lines, is transferred via the M1O/M0O output lines to the LTC with higher order number (LTCK+1).

The event output line EO is also activated (set to high) by a software reset when writing FFFF_H to register LTCXRk.

Reset Timer Mode

An LTC that is configured in Reset Timer Mode provides the same functionality as in Free-Running Timer Mode, but is extended by two additional features:

- The Local Timer Cell Register LTCXRk can be reset to FFFF_H via the EI line, which can be activated by an event that occurred in the adjacent LTC with higher order number.
- If bit LTCCTRk.CUD is set to 1, the EI line reset event also toggles the logic state of the SO output line before it clears register bit LTCCTRk.CUD automatically. By accessing register bit LTCCTRk.SLO, the state of the timer's output line SO can be read or explicitly written.

Capture Mode

In Capture Mode, the LTCKIN input signal is used for capture function. Level or edge Sensitive Modes can be selected (see [Page 23-72](#)). On a capture event, the LTCK:

- copies the state of the local input data bus (YI) to the LTCXRk register (LTC00 always copies 0000_H),
- sets the LTCK service request flag,

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- activates the service request line SQTk, if LTCCTRk.REN is set to 1,
- changes the LTCKOUT output line state (set, reset, toggle, unchanged), depending on bit field LTCCTRk.OCM and the M1I/ M0I input line state,
- generates and/or passes an action request via the M1O/M0O output lines to the LTC with higher order number (LTCK+1),
- sets the event output EO to high level for one f_{GPTA} clock cycle.

Compare Mode

The Compare Mode can be enabled on a low, high, or both levels of the select input line SI (LTCCTRk.SOL = 1, LTCCTRk.SOH = 1). The current state of SI is indicated by bit field LTCCTRk.SLL and can be read. When the value of the local input data bus (YI) matches the LTCXRk contents,

- The LTCK service request flag is set,
- The service request line SQTk is activated if LTCCTRk.REN is set to 1,
- The LTCKOUT output line state is changed (set, reset, toggle, unchanged), depending on bit field LTCCTRk.OCM,
- An action request is generated and/or passed via the M1O/M0O output lines to the LTC with higher order number (LTCK+1),
- The event output EO is set to high level for one f_{GPTA} clock cycle.

Note: To enable the compare function in all cases (on every timer or compare register update caused by a software write access, a reset event or a compare match), bits LTCCTRk.SOL and LTCCTRk.SOH must be set to 1.

An inactive cell (LTCCTRk.SOL = LTCCTRk.SOH = 0, or SI does not match the programmed value) will transfer the state of the event input line EI to the event output line EO.

One Shot Operation

When bit LTCCTRk.OSM is set to 1, a self-disable is executed after each LTC event. The current state of LTCK can be checked by reading the control register flag bit LTCCTRk.GEN.

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Data Input Line Control

The data input line LTCCKIN can operate in two modes (selected by bit LTCCTRk.ILM):

- Level Sensitive or
- Edge Sensitive.

In Edge Sensitive Mode, the active edges are selected by bits LTCCTRk.FED and LTCCTRk.RED. For the Level Sensitive Mode, the active level of the input signal can be selected by bit FED/AIL of register LTCCTRk.

Depending on which source is selected for the input line by the input multiplexer, different clocking modes of the LTC cell are possible ([Table 23-3](#)).

Table 23-3 LTC Data Input Line Operation (in Timer Mode)

Input Source	Level Sensitive Input Line LTCCTRk.ILM = 1	Edge Sensitive Input Line LTCCTRk.ILM = 0
External Signal (Port line)	The external signal operates as gating signal for the cell. The active input level can be selected with control register bit AIL. Additionally, the LTC prescaler mode can be enabled with LTCCTRk.PEN to reduce the timer frequency. The programmed function of the LTC is performed with the GPTA®v5 module clock frequency, or with the programmed prescaler clock LTCPRE (see Page 23-37).	The programmed function of the LTC cell is performed on selected edge(s).
Internal Clock Bus Line or PDL output or INT input	The programmed function is performed with the internal clock or PDL/INT signal. Note that all internal clock bus lines and PDL signals are active high pulses. The LTC Prescaler Mode and the input signal inversion must not be used.	The programmed function of the LTC cell is performed on selected edge(s). In case of full speed GPTA®v5 module clock selection as input clock, the Level Sensitive Mode must be selected. The Edge Sensitive Mode will not produce an event in this special case.

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Table 23-3 LTC Data Input Line Operation (in Timer Mode) (cont'd)

Input Source	Level Sensitive Input Line LTCCTRk.ILM = 1	Edge Sensitive Input Line LTCCTRk.ILM = 0
GTC output	The GTC output signal operates as gating signal for the cell. The active input level can be selected with bit LTCCTRk.AIL. Additionally, the LTC prescaler clock LTCPRE can be enabled with bit LTCCTRk.PEN to reduce the timer frequency.	The programmed function of the LTC cell is performed on selected edge(s).

Note: If Capture Mode and level sensitive input is selected for an LTCK (bit LTCCTRk.ILM = 1), a capture event occurs on every LTC timer clock event if the corresponding LTC input signal is a high level.

Data Output Line Control

The data output LTCKOUT can be controlled by the LTCK itself and by adjacent LTCs with a lower order number. For this purpose, two communication signals between LTCs are available that make it possible to connect all LTCs via their M11/M01 inputs and their M10/ M00 outputs respectively (**Figure 23-52**).

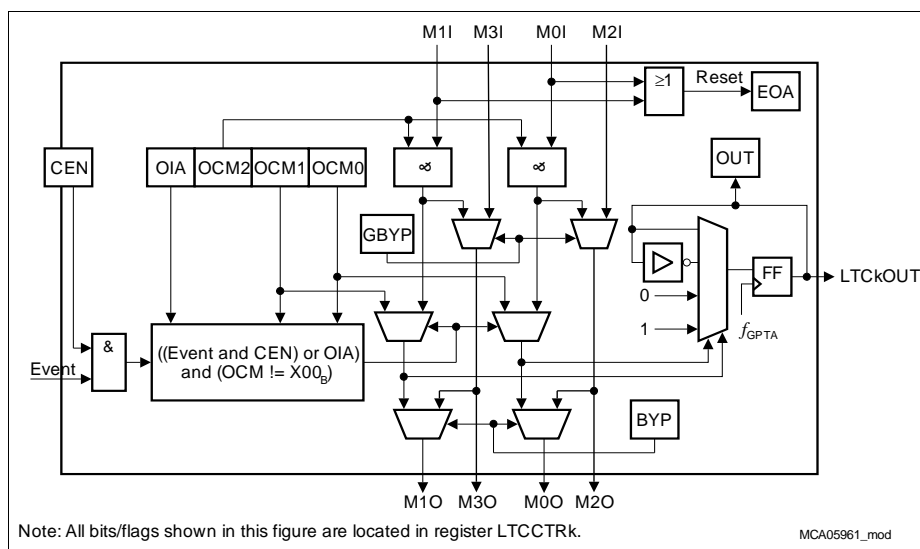


Figure 23-52 LTC Output Operation and Action Transfer

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When bit LTCCTRk.OCM2 is reset, the data output LTCKOUT is controlled only by the local LTCK. A set, reset, toggle, or hold operation can be performed as selected by bits LTCCTRk.OCM1 and LTCCTRk.OCM0 (see [Table 23-4](#)).

When bit LTCCTRk.OCM2 is set, the data output LTCKOUT is affected either by the local LTCCTRk.OCM1 and LTCCTRk.OCM0 bits or by the M1I/M0I input lines, which are connected to the adjacent LTCK-1 Global Timer output lines M1O/M0O. An enabled LTCK event superimposes an action request generated simultaneously by the M1I/M0I inputs.

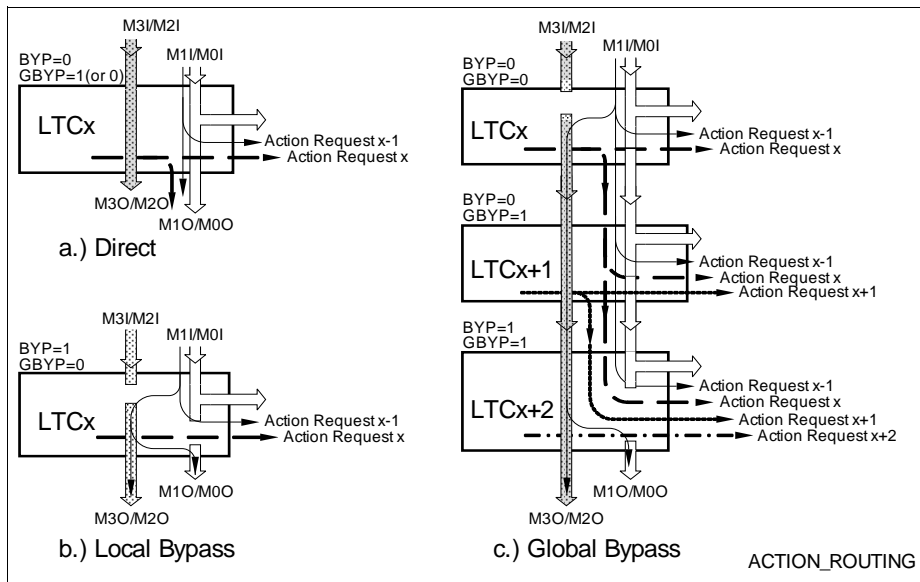


Figure 23-53 Direct, Local Bypass, and Global Bypass Action Request Routing

When the bypass bit LTCCTRk.BYP is cleared, the M1O/M0O output lines logically OR together the local LTCK events and, if enabled by bit LTCCTRk.OCM2, the action requests received via the M1I/M0I input lines.

When the bypass bit LTCCTRk.GBYP is cleared, the action requests received via M1I/M0I input lines, if enabled by bit LTCCTRk.OCM2, are forwarded to the subsequent LTCK+1 via the M3O/M2O output lines. If LTCCTRk.GBYP is set to 1, the action requests received via M3I/M2I input lines are forwarded to the subsequent LTCK+1 via the M3O/M2O output lines. Therefore the M3I/M2I may be used to pass the action requests of a reseted timer cross a group of LTC generating a complex signal or providing coherent update.

The two bypass bit LTCCTRk.BYP and LTCCTRk.GBYP enable three different types of action request routing, a direct routing, a local bypass routing and a global bypass

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routing. These three different types of action request routing is sketched in [Figure 23-53](#). The direct routing uses only the action request lines M1I/M0I. All action request run done the same path. The M3I/M2I are forwarded unchanged to M3O/M2O (next cells).

The local bypass copies all action request coming into a cell (M1I/M0I) to the outputs of the cell (M1O/M0O and M3O/M2O). The following cells do not see any action request generated within this locally bypassed cell.

The global bypass routing copies all action request coming into a group of sequential cells (M1I/M0I) to the outputs of this group of sequential cells (M1O/M0O and M3O/M2O). The following cells do not see any action request generated within this group of cells. Typically for edge aligned signals, the one action request for the edge is globally or locally bypassed, an all non edge aligned action request then locally generated within the group or local bypassed cell. Within a group complex signals may be generated or two cells used for local coherent update (double action principle).

Table 23-4 Selection of LTC Output Operations and Action Transfer Modes

Bit Field OCM [2:0]	Local Event	M1O/M0O						State of Local Data Output Line
		BYP = 0		BYP = 1				
		GBYP =0	GBYP=1	GBYP = 0		GBYP = 1		
0 0 0	No	0 0	0 0	0 0	M3I	M2I	not modified	
	Yes	0 0	0 0	0 0	M3I	M2I	not modified	
0 0 1	No	0 0	0 0	0 0	M3I	M2I	not modified	
	Yes	0 1	0 1	0 0	M3I	M2I	inverted	
0 1 0	No	0 0	0 0	0 0	M3I	M2I	not modified	
	Yes	1 0	1 0	0 0	M3I	M2I	0	
0 1 1	No	0 0	0 0	0 0	M3I	M2I	not modified	
	Yes	1 1	1 1	0 0	M3I	M2I	1	
1 0 0	No	M1I M0I	M1I M0I	M1I M0I	M3I	M2I	modified according M1I/M0I	
	Yes	M1I M0I	M1I M0I	M1I M0I	M3I	M2I	modified according M1I/M0I	
1 0 1	No	M1I M0I	M1I M0I	M1I M0I	M3I	M2I	modified according M1I/M0I	
	Yes	0 1	0 1	M1I M0I	M3I	M2I	inverted	
1 1 0	No	M1I M0I	M1I M0I	M1I M0I	M3I	M2I	modified according M1I/M0I	
	Yes	1 0	1 0	M1I M0I	M3I	M2I	0	
1 1 1	No	M1I M0I	M1I M0I	M1I M0I	M3I	M2I	modified according M1I/M0I	
	Yes	1 1	1 1	M1I M0I	M3I	M2I	1	
		M3O/M2 O = ¹⁾	M3O/M2 O = M3I/M2I	M3O/M2O = ¹⁾	M3O/M2O = M3I/M2I			

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- 1) If OCM2 = 0: M3O/M2O = 0/0
If OCM2 = 1: M3O/M2O = M11/M01

The LTCKOUT output line can be connected to output ports, on-chip peripheral inputs (OTGS) and/or LTC inputs via the I/O Line Sharing Block (see [Page 23-98](#)). LTCKOUT can be updated directly by software (setting bit LTCCTRk.OIA = 1) or upon a timer, capture, or compare event within the local LTCK or a preceding LTC. The current state of the data output line can be evaluated by reading status flag LTCCTRk.OUT.

Global bypass may also be used to move a group of Local Timer Cells (Consecutive Local Timer Cells using the same Local Timer) into the previous group of Local Timer to e.g. hit a specific output pin. The previous Local Timer Group will therefore have some Local Timer before and some after the to be moved Local Timer Group. Because the Local Time Bus YI and YO is driven by every LTC configured as timer regardless of the chosen bypass mechanism, special care has to be taken. An example is sketched in [Figure 23-54](#). Three Local Timer for an edge aligned PWM, using the same time base as the local Timer Cell Group1 but different offsets (not edge aligned), is inserted into another group of Local Timer Cells implementing an independent other signal.

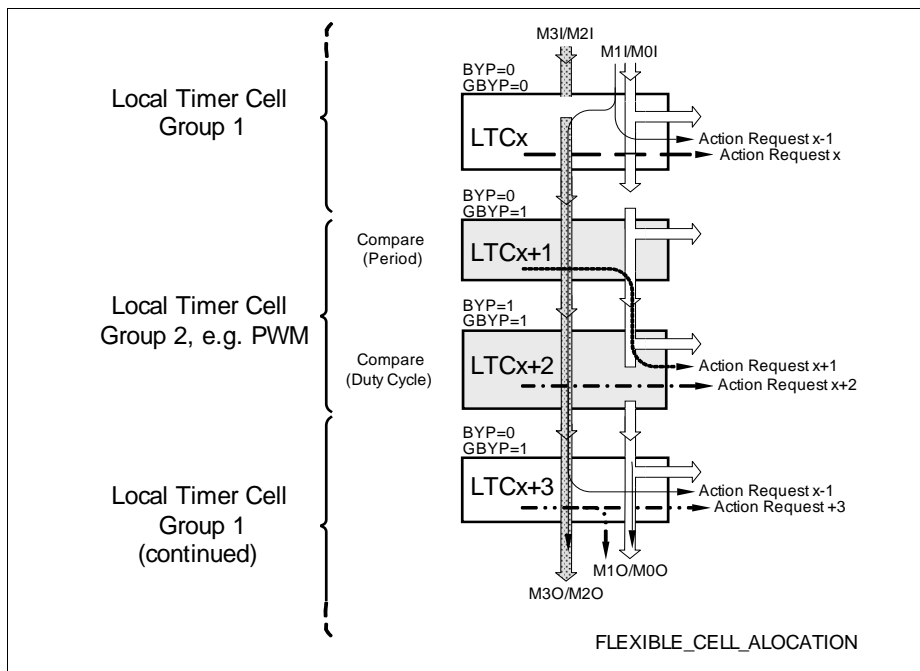


Figure 23-54 Global Bypass Action Request Routing for Flexible Cell Allocation

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Cell Enabling

After reset all LTCs are disabled. An LTC may be enabled by resetting LTCCTRk.EOA (Enable-Of-Action) to 0 in Capture Mode or Compare Mode using a standard write assembler operation¹⁾. Because bit EOA is hardware protected, intrinsic read-modify-write assembler operations²⁾ only enable the LTC in Capture Mode or Compare Mode if bit EOA is modified from 1 to 0. If switching to Timer Mode, the LTC cell is enabled. In Timer Mode every write operation to bit 0...7 of LTCCTRk will enable the LTC.

Cell Deactivation

By programming an LTC to Capture Mode with no edge selected (LTCCTRk.ILM = LTCCTRk.FED = LTCCTRk.RED = 0), an enabled cell becomes inactive and performs no action, but continues passing action commands via the communication link from M1I/M0I to M1O/M0O. Output EO is inactive.

Alternatively, the LTC can be deactivated by setting it into Compare Mode with no active select line level (LTCCTRk.SOL = LTCCTRk.SOH = 0) but the communication link remains active. In this mode configuration, EI will be passed to EO.

Cell Enabling on Event

An LTC can be enabled in Capture Mode or Compare Mode by an event in an LTC with lower index number. For this purpose, the local event function of an LTC must be temporary disabled by setting LTCCTRk.EOA (Enable-Of-Action) to 1. Because bit EOA is hardware protected, intrinsic read-modify-write assembler operations²⁾ only disables the LTC if bit EOA is modified from 0 to 1. Both operations will clear LTCCTRk.CEN and now a local event cannot affect the LTC. When a preceding LTC generates and communicates an event (or OIA) via the communication link M1O/M0O, at least one of the M1I/M0I input lines changes its state to 1. This condition clears bit LTCCTRk.EOA of the disabled LTC via the OR gate as shown in [Figure 23-52](#). Now LTCCTRk.CEN is set and the LTC is enabled for local events.

It is also possible to enable the following LTC via the communication link for local events. For this purpose, the bit LTCCTRk.EOA of this cell must be set, too. If bit LTCCTRk.OCM2 of the preceding cell is 1, the enable action will take place at the same time as in the preceding cell. Otherwise, the LTC will be enabled later on a capture/compare event in the preceding LTC, provided LTCCTRk.OCM0 or LTCCTRk.OCM1 of this cell is different from 0.

In this way, several LTCs can be enabled at the same time or one after the other. Normally, the LTCs will be used in One Shot Mode, and a service request will be

1) Standard TriCore[®] write operations: ST.A, ST.B, ST.D, ST.DA, ST.DD, ST.HST.Q, ST.W
Standard PCP write operations: ST.F, ST.IF, BCOPY, COPY

2) Intrinsic TriCore[®] read-modify-write Operations: LDMST, ST.T, SWAP
Intrinsic PCP read-modify-write Operations: SET.F, XCH.F, CLR.F

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generated after the last event to evaluate the data and to prepare the next enable sequence. A disabled LTC (LTCCTRk.CEN = 0) behaves as an inactive capture LTC.

Logical Operating Cells

The inter-cell communication architecture allows concatenation of several LTCs to a logical cell. A logical cell contains any number of LTCs communicating via M1 and M0 lines and ends at an LTC disabled for action input or transfer (such as an LTC configured as timer, reset timer or LTC initiated with LTCCTRk.OCM2 = 0).

Therefore, the LTC with the lowest order number should be configured in Reset Timer Mode, thus providing all other LTCs of the logical cell with a time base (YO) and a compare enable signal (SO). Another LTC of the same logical cell can be initiated in Compare Mode to reset the LTC via its event output line EO, when a programmed threshold value is reached (register LTCXR) and the current state of its select line input SI matches the condition selected by the LTCCTRk bits SOH/SOL. Additional LTCs of the same logical cell can operate in Capture Mode triggered by a rising edge, falling edge, or both edges of a GPTA[®]v5 input line or a clock line of the clock bus. On the generated event, these LTCs capture the current contents of the timer cell, can generate a service request, can perform a manipulation of a GPTA[®]v5 output line (set, reset or toggle), and can also reset the LTC via the event output line EO.

LTC Service Request

The service request output SQTk of a Local Timer Cell LTCK is controlled as shown in [Figure 23-55](#). When the LTCK service request condition becomes active, the service request flag becomes always set. The service request output SQTk is only activated if it is enabled by the enable bit LTCCTRk.REN. Additional information about service request and interrupt handling is given on [Page 23-123](#).

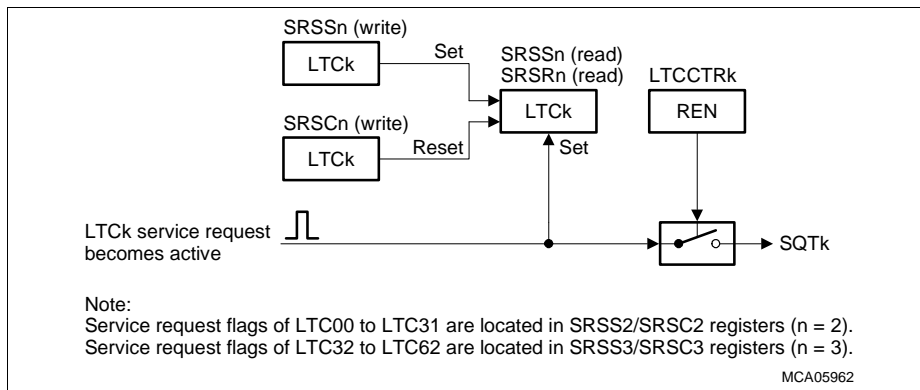


Figure 23-55 LTCK Service Request Generation

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23.3.3.4 Local Timer Cell LTC63

The functionality of LTC63 is different to LTC00 to LTC62 and therefore described below.

Registers

The following registers are assigned to Local Timer Cell LTC63:

- LTCCTR63 = Local Timer Cell Control Register 63 (see [Page 23-200](#))
- LTCXR63 = Local Timer Cell X Register 63 (see [Page 23-202](#))
- SRSC3 = Service Request State Clear Register 3 (see [Page 23-226](#))
- SRSS3 = Service Request State Set Register 3 (see [Page 23-227](#))

Features

The GPTA®v5 Local Timer Cell array has one special cell, LTC63, which provides the following special features:

- **Compare Mode** on greater equal compare of the last timer, 16-bit based with following actions:
 - Service request generation
 - Output signal transition generation (set, reset, toggle the output signal).
- **Bit Reversal Mode:**
 - Timer can be selected to enable a special PWM Mode, called pulse count modulation (PCM)
- **Compare Value Switching** can be triggered by a hardware signal. This function can generate a service request. One Shot Mode makes it possible to stop the function after the first event.

Architecture

LTC63 is locally equipped with a 16-bit compare register, a 16-bit shadow register and a 16-bit greater comparator ([Figure 23-56](#)).

The LTC63 has the following inputs:

- A local input data bus (YI) carrying the local timer value of the adjacent LTC with lower order number
- A TI input reporting the occurrence of a local timer value update of the adjacent LTC with lower order number
- A trigger/enable input LTCKIN for compare value switching hooked to one of the following signals sources:
 - External port lines
 - GTC00 to GTC31 outputs
 - Clock bus signals
 - PDL0 or PDL1 outputs
 - Internal GPTA®v5 kernel input signals INTx (x = 0-3)

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The LTC63 provides the following output signals:

- One data output line (LTCKOUT) that can be connected to:
 - External port lines
 - Inputs of an MSC module
 - Outputs and/or inputs of Global Timer Cell inputs
- One service request line (SQT) triggered by a compare or copy event
- An EO output reporting the occurrence of a local event to the adjacent LTC with lower order number

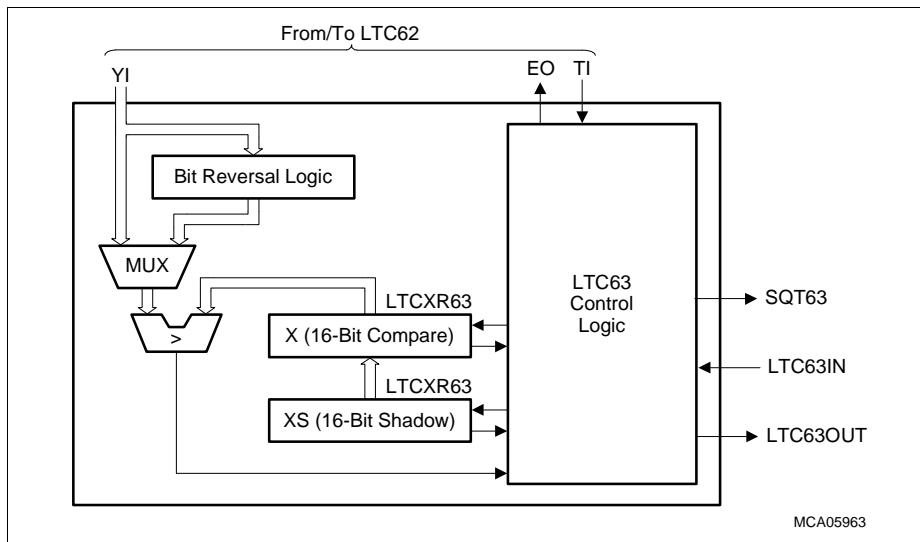


Figure 23-56 Architecture of Local Timer Cell 63

Compare

The compare function is always enabled. As long as the 16-bit compare value LTCXR63.X is greater than the timer value provided at YI, the comparator output signal is 1. The timer value at YI comes from the LTC62 either in original or in reversed order (Bit0 <-> Bit15, Bit1 <-> Bit14, etc.). The greater comparator output is connected directly to the output line LTC63OUT.

The 16-bit compare value LTCXR63.X is never greater than the LTC timer value (FFFF_H) coming from YI and which is used on LTC timer reset. Without special measures, a duty cycle of 100% cannot be achieved. There is always one LTC timer clock missing. Therefore, additional logic generates a permanent high signal whenever the 16-bit compare value LTCXR63.X is FFFF_H.

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When the comparator output signal changes from 1 to 0,

- the service request flag LTC63 is set,
- an interrupt request will be activated if enabled by bit field LTCCTR63.REN,
- the event output line EO is set to high level for one f_{GPTA} clock cycle.

As well as the 16-bit compare register LTCXR63.X, the LTC63 also contains a 16-bit shadow register LTCXR63.XS. Both 16-bit registers are combined in the 32-bit register LTCXR. On an LTC input signal selected via the LTC input multiplexer, the contents of the shadow register are copied to the compare register.

Standard PWM Mode

The LTC63 can be used for standard PWM duty cycle generation with enhanced update features. For this purpose, a pair of LTCs with lower index is configured as reset timer/period compare register. The user must set the period compare register to the desired period - 2 and LTC63 to the desired duty cycle. With LTCCTR63.BRM = 0 (Bit Reversal Mode), timer bit reversal is disabled. LTC63 is used for standard PWM Mode but with enhanced update features due to the “greater” comparator. The compare register LTCXR63.X can be written on-the-fly. If the duty cycle is changed at an arbitrary time, the actual duty cycle for the current period will reflect the old duty cycle, the new one, or a mixture of both. A duty cycle of 100% will be generated if the compare register is set to FFFF_{H} .

Pulse Count Modulation Mode (PCM)

With a period of 100 clocks and a duty cycle of 64%, standard PWM will produce an output signal that is ON for 64 clock cycles and OFF for the remaining 36 clock cycles. In contrast, pulse count modulation will generate 64 ON pulses and 36 OFF pulses distributed over the whole period as evenly as possible. PCM offers higher output frequency than standard PWM. This allows faster settling time e.g. when building a D/A converter in conjunction with an external low-pass filter. Only for very short or very long duty cycles does the method show no advantage or just little advantage compared to standard PWM.

As with standard PWM, a pair of LTCs with lower index is configured as reset timer/period compare register and LTC63 is used as duty cycle compare register. But now, Bit BRM (Bit Reversal Mode) in the LTCCTR63 register is set to 1 which enables the timer bit reversal to activate PCM.

The algorithm will also work if fewer than 16 timer bits are effectively used, even if the period is not a power of two. In any case, the user must write the duty cycle in unsigned 16-bit fractional format to the compare register.

Figure 23-57 shows an PCM example for an effective period of 6 clocks.

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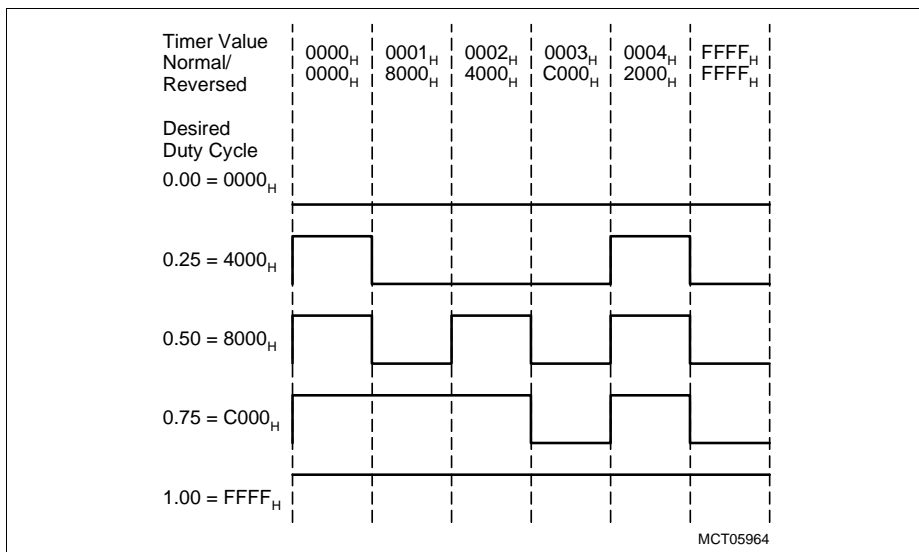


Figure 23-57 Pulse Count Modulation Example 1

Table 23-5 shows the rounding behavior for a period of 100 clocks.

Table 23-5 Implicit PCM Rounding

Desired Duty Cycle	Expected ON Pulses	Actual ON Pulses
0.000 = 0000	0	0
0.100 = 199A _H	10	11
0.500 = 8000 _H	50	50
0.800 = CCCD _H	80	82
0.900 = E666 _H	90	90
0.999 = FFBE _H	100	99
1.000 = FFFF _H	100	100

The output is OFF for the remaining cycles of the period. The worst case error is approximately +2/-1 ON pulses. A subtraction performed via software may be used to reduce the worst case error.

If the duty cycle is changed at an arbitrary time, the actual duty cycle for the entire current period will reflect the old duty cycle, the new one, or a mixture of both.

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Figure 23-58 shows another PCM example that demonstrates the difference between a standard PWM signal and the derived PCM signal. During one PWM period (128 clock cycles), the standard PWM signal is ON for 8 clock cycles and OFF for the remaining 120 clock cycles (duty cycle of 6.25%). The PCM signal operates with a PCM duty cycle of $1/8 = 0.125$ resulting in 8 ON pulses of 1 clock cycle width within 1 PWM period.

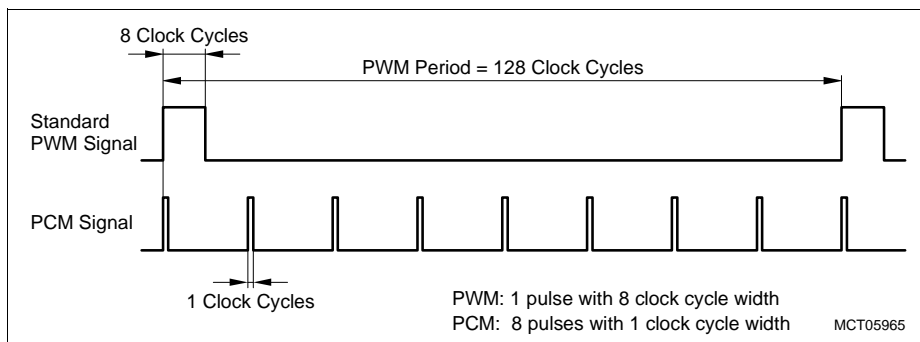


Figure 23-58 Pulse Count Modulation Example 2

Compare Value Switching

In both pulse modulation modes, it is possible to change the duty cycle either by software or on an LTC input signal. LTC63 contains two registers, the compare register and a shadow register. For software access, the compare register LTCXR63.X (= 16-bit low part of LTCXR63) is written directly.

For compare value switching triggered by hardware, the shadow register LTCXR63.XS (= 16-bit high part of LTCXR63) is pre-loaded with the desired duty cycle. On an LTC input signal selected via the LTC input multiplexer,

- The shadow register content LTCXR63.XS is copied to the compare register LTCXR63.X,
- The LTC63 service request flag is set,
- An interrupt request will be activated if enabled by bit field LTCCTR63.REN.

The data input line LTC63IN can operate in two modes (selected by bit LTCCTR63.ILM):

- Level Sensitive Mode or
- Edge Sensitive Mode

In Edge Sensitive Mode, the active edges are selected by bits LTCCTR63.FED and LTCCTR63.RED. In Level Sensitive Mode, the data input line LTC63IN is sensitive on a high level.

Various clocking modes of the LTC63 copy function are possible, depending on the source selected for the input line by the input multiplexer (see [Table 23-6](#)).

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Table 23-6 LTC63 Data Input Line Operation

Input Source	Level Sensitive Input Line	Edge Sensitive Input Line
External Signal (Port line)	The external signal operates as gating signal for the cell. If the input is high the copy function of the LTC cell is performed with each rising edge of the GPTA [®] v5 module clock f_{GPTA} .	The copy function of the LTC cell is performed on selected edge(s).
Internal Clock Bus Line or PDL output or INT input	The copy function is performed with the internal clock or PDL/INT signal.	The copy function of the LTC cell is performed on selected edge(s). In case of full speed GPTA [®] v5 module clock selection, the Level Sensitive Mode must be selected. The Edge Sensitive Mode will not produce an event in this special case.
GTC output	The GTC output signal operates as gating signal for the cell. If the input is high the copy function of the LTC cell is performed with each rising edge of the GPTA [®] v5 module clock f_{GPTA} .	The copy function of the LTC cell is performed on selected edge(s).

When bit LTCCTR63.OSM is set to 1, a self-disable is executed after each copy event (PWM is not affected). The current state of the LTC copy enable may be evaluated by reading the control register flag bit LTCCTR63.CEN.

The output can be switched immediately to 0 or 1 in any pulse modulation mode by writing 0000_H or FFFF_H to the duty cycle compare register LTCXR63.X.

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LTC63 Service Request

The service request SQT63 can be generated by one of the following events:

- Comparator output changes from 1 to 0 (this makes sense mainly for standard PWM),
- Copy event.

Bit combinations 01_B and 10_B of bit field LTCCTR63.REN selects one of the two service request sources and enables it. Output SQT63 becomes active in these two cases. With the other two bit combinations of bit field LTCCTR63.REN (00_B , 11_B), the SQT63 output will not be activated. The LTC63 service request flag SRSS3.LTC63 will be set on a service request independently of LTCCTR63.REN. Additional information on service request and interrupt handling is provided on [Page 23-123](#).

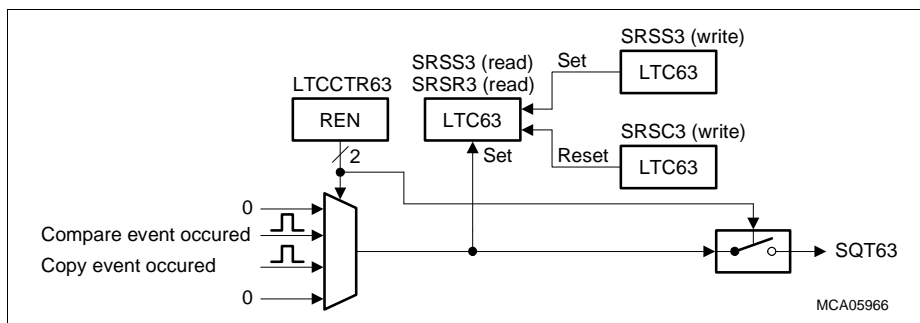


Figure 23-59 LTC63 Service Request Generation

23.3.3.5 Coherent Update

This section describes the two different mechanism to update signal features (e.g. period, duty cycle) if using Local Timer Cells. Both mechanism grant a coherent update only if a single update within a group of Local Timer Cells using a common Local Timer is performed within a timer period. So coherent update can only be granted if between coherent updating routine exit and coherent updating routine entry a time period of more then a period is maintained. If updating more frequently, software has to take care of coherency.

Global Coherent Update

The first mechanism, the so called global coherent update, is very useful to update a number of Local Timer Cells simultaneously. Furthermore this is the only way to grant a coherent update of a Local Timer Cell used as the period cell for a Reseted Timer. This global coherent update uses a common signal line (SI/SO) within a group of Local Timer Cells (all Local Timer Cells following an LTC configured as Timer). A pair of Local Timer Cells are configured so one cell being active on a high level of this SI/SO

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(LTCCTRk.SOH = 1, LTCCTRk.SOL = 0) signal and the other cell being active on a low level of this SI/SO (LTCCTRk.SOH = 0, LTCCTRk.SOL = 1) signal. This pair of Local Timer Cells are configured to generate both action request for a single output signal (e.g. pin). If the global SI/SO is in a low state, all Local Timer Cells to be active on a high level of SI/SO can be configured (programmed with new values) without distortion of the output signal, because of being inactive. By setting the LTCCTRk.CUD bit within the Local Timer Cell used as Local Timer, the SI/SO bit will be toggled at the start of the next timer period, so all pair of Local Timer Cells simultaneously switch from active to passive (LTCCTRk.SOH = 0, LTCCTRk.SOL = 1) or passive to active state. Now the Local Timer Cells being inactive (LTCCTRk.SOH = 0, LTCCTRk.SOL = 1) may be configured (programmed) for the next update. No Local Timer Cell may be configured (programmed) while respective timer bit LTCCTRk.CUD = 1, else wise a coherent update is no longer granted. Either the LTCCTRk.CUD has to be reset to 0 by software or a update of the Local Timer Registers have to be delayed to the next start of the period (LTCCTRk.CUD is reset by hardware to 0). The following example shows a PWM using global coherent update.

Fully Programmable PWM Signal Generation with 5 LTCs (global coherent update)

As shown in [Figure 23-59](#), a logical cell of five LTCs can be used to generate a PWM signal with a programmable duty cycle, period length, and fully global coherent update of the period and duty cycle. In this example, LTC00 up to LTC04 are used to generate a PWM signal at the output of LTC04. To reduce complexity of this example, only a single duty cycle pair is described in the following text. More duty cycle cells may follow using the same reseted timer and pair of period cells. So if requiring a second duty cycle LTC pair, the first pair would be located to LTC2 and LTC6, the next pair on LTC 3 and LTC7 and the period cells would be assigned to LTC1 and LTC4.

LTC00 is configured in Reset Timer Mode thus providing all subsequent cells with a time base. LTC00 is clocked by a clock signal at the LTC00IN which has been selected by the LTC input multiplexer. LTC00 counts after reseted by LTC01 or LTC02 from $FFFF_H$, 0000_H , 0001_H ... LTCXR01.X or LTCXR01.X. The period of the generated PWM is therefore $LTCXR01.X + 2$ or $LTCXR02.X + 2$.

LTC01 and LTC02 are configured in Compare Mode. They are enabled if its SI inputs are at low level and responsible for the LTC04OUT signal generation in Phase 1. With the programmed values from [Table 23-7](#), the LTC04OUT signal of Phase 1 has a period of 1000_D ($= 3E8_H$) clocks of the LTC00IN clock signal and a duty cycle of 20% ($= 200_D$ or $C8_H$).

LTC01 is configured in such a way ($LTCCTR01.OCM = 011_B$) that its output LTC01OUT is set to 1 whenever the LTC00 timer value LTCXR00.X is equal to the LTC01 compare value LTCXR01.X.

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LTC02 is configured in such a way (LTCCTR02.OCM = 110_B) that its output LTC02OUT is reset whenever the LTC00 timer value LTCXR00.X is equal to the LTC02 compare value LTCXR02.X or it copies the action from the previous LTC01.

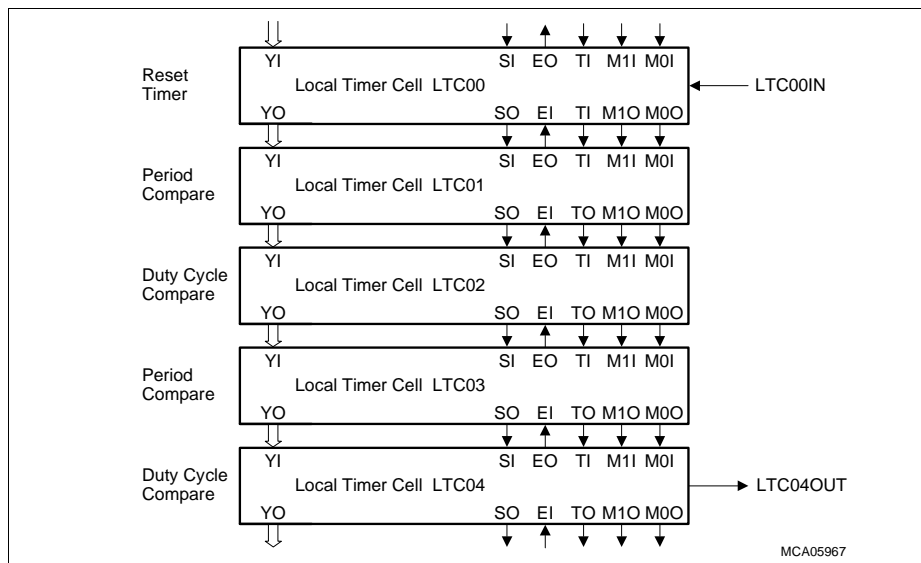


Figure 23-60 PWM Signal Generation with LTCs (Global Coherent Update)

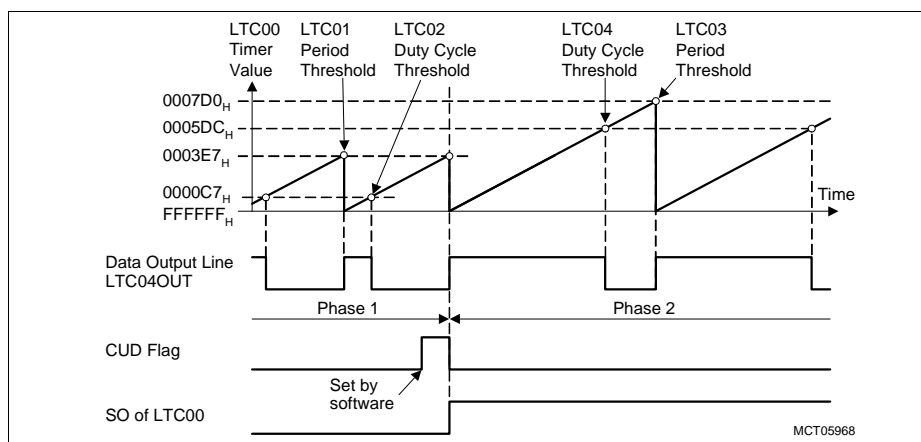


Figure 23-61 Internal Signal States of the PWM Signal Generation with 5 LTCs

General Purpose Timer Array (GPTA[®]v5)

LTC03 and LTC04 are configured in Compare Mode. They are enabled if its SI inputs are at high level and are responsible for the LTC04OUT signal generation in Phase 2. With the programmed values from [Table 23-7](#), the LTC04OUT signal of Phase 2 has a period of $2000_{D_{\text{D}}} (= 7D0_{H_{\text{H}}})$ clocks of the LTC00IN clock signal and a duty cycle of 75% ($= 1500_{D_{\text{D}}}$ or $5DC_{H_{\text{H}}}$).

LTC00 to LTC04 for the PWM example must be configured as defined in [Table 23-7](#).

Note: Special care has to be taken not to reprogrammed the group of local timer cells (LTC) CAPCOM register before the previous global or local coherent update has been completed (end of current local timer period). Therefore maximum only one global coherent update within a timer period is possible! No Local coherent updates may be activated while a global coherent update modifying the period has not been completed.

Note: If several sequential coherent updates within a group of Local Timer Cells (LTC) is required, instead of using the global coherent update feature, the local coherent update mechanism (double action principle) is preferable. Mixing both principle, so updating the period using the coherent update and updating one or more duty cycle using local coherent update (double action principle) may result under specific condition in distorted signals (new duty cycle, old period or old duty cycle and new period). Therefore within a period either a global coherent update or multiple local coherent updates may be scheduled.

Note: To generate an output signal having 0% duty cycle (continuously low), the duty compare of the active cells must be set to $FFFF_{H_{\text{H}}}$. The timer sets the data output line by generating a respective signal on MO0 and MO1, but this signal is overruled by the dominating duty compare cell resetting the same data output line and therefore not passing the MIO and MI1 signal from the timer to the data output line. This result in a data output line remaining continuously low.

Note: To generate an output signal having 100% duty cycle (continuously high), the duty cycle threshold must be set above the period threshold value. Therefore no reset event for the data line is generated and periodically the timer generates a set event. This result in a data output line remaining continuously high.

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Table 23-7 Programming Values for PWM Signal Generation with 5 LTCs

Register	Value	Function
LTC00 Configuration Setup		
GPTA0_LTCXR00	0000 0000 _H	LTC00 data register value = 0
GPTA0_LTCCTR00	0001 0413 _H	MOD = 11 _B : Reset Timer Mode selected OSM = 0: LTC00 continuously enabled ILM = 0, RED = 1, FED = 0: Input LTC00IN operates in Edge Sensitive Mode with rising edge; one clock bus signal is selected via the LTC input multiplexer SLO = 0: state of select line output SO is 0 CEN = 0: enable LTC00 for local events OCM = 000 _B : hold LTC00OUT state
LTC01 Configuration Setup		
GPTA0_LTCXR01	0000 03E7 _H	Load compare value = 3E7 _H = 999 _D
GPTA0_LTCCTR01	0001 5C11 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC01 continuously enabled SOH = 0, SOL = 1: compare enabled by low level at SI BYP = 0: local bypass in LTC01 is disabled GBYP = 1: global bypass in LTC01 is disabled EOA = 0: LTC02 enabled for local events OCM = 011 _B : set LTC01OUT by a local event only OIA = 1: output action defined by OCM must be performed immediately
LTC02 Configuration Setup		
GPTA0_LTCXR02	0000 00C7 _H	Load compare value = C7 _H = 199 _D
GPTA0_LTCCTR02	0001 3411 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC02 continuously enabled SOH = 0, SOL = 1: compare enabled by low level at SI BYP = 0: local bypass in LTC02 is disabled GBYP = 1: global bypass in LTC02 is disabled EOA = 0: LTC02 enabled for local events OCM = 110 _B : reset LTC02OUT by a local event or copy the previous cell action OIA = 0: no immediate output action required

General Purpose Timer Array (GPTA[®]v5)

Table 23-7 Programming Values for PWM Signal Generation with 5 LTCs (cont'd)

Register	Value	Function
LTC03 Configuration Setup		
GPTA0_LTCXR03	0000 07CF _H	Load compare value = 7CF _H = 1999 _D
GPTA0_LTCCTR03	0001 7C21 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC03 continuously enabled SOH = 1, SOL = 0: compare enabled by high level at SI BYP = 0: local bypass in LTC03 is disabled GBYP = 1: global bypass in LTC03 is disabled EOA = 0: LTC03 enabled for local events OCM = 111 _B : set LTC04OUT by a local event or copy the previous cell action OIA = 1: output action defined by OCM must be performed immediately
LTC04 Configuration Setup		
GPTA0_LTCXR04	0000 05DB _H	Load compare value = 5DB _H = 1499 _D
GPTA0_LTCCTR04	0001 3421 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC04 continuously enabled SOH = 1, SOL = 0: compare enabled by high level at SI BYP = 0: local bypass in LTC04 is disabled GBYP = 1: global bypass in LTC04 is disabled EOA = 0: LTC04 enabled for local events OCM = 110 _B : reset LTC04OUT by a local event or copy the previous cell action OIA = 0: no immediate output action required

General Purpose Timer Array (GPTA[®]v5)**Local Coherent Update**

The second mechanism, the so called local coherent update or double action principle, is very useful to update single Local Timer Cells without signal distortion (no other signal output beside the previously configured and the new configured). This coherent update may not be used for Local Timer Cells generating toggle action requests ($\text{LTCCTRk.OCM} = \text{OCM} = \text{x01}_B$). The local coherent update is useful to configure (programme) several Local Timer Cells within a group of Local Timer Cells (all using the same Local Timer Cell as time base) sequentially (not simultaneously), e.g. within different routines of the application software. The only restriction to grant non distorted output signals by hardware is to update (configure or programme) every single pair of Local Timer Cells no often than once within a timer period (time measured from previous routine exit and current routine entry), else wise software has to take care of coherency (non distorted signals). A pair of Local Timer Cells are configured one cell being active ($\text{LTCCTRk.SOH} = 1$, $\text{LTCCTRk.SOL} = 1$) and the other being inactive ($\text{LTCCTRk.SOH} = 0$, $\text{LTCCTRk.SOL} = 0$, $\text{LTCCTRk.CEN} = 0$). This pair of Local Timer Cells are configured to generate both action requests for a single output signal (e.g. pin). A Local Timer Cell being inactive may be configured (programmed with a new value) without distortion of the output signal, because of being inactive. By activating the newly configured Local Timer Cell ($\text{LTCCTRk.SOH} = 1$, $\text{LTCCTRk.SOL} = 1$, $\text{LTCCTRk.OSM} = 0$), now two Local Timer Cells generate the same type of action request. The one being earlier within the period will now drive the output signal (either the newly configured or the previously configured one). Now the Local Timer Cell being active before configuration is coherently deactivated ($\text{LTCCTRk.OSM} = 1$) on its next action. So one period later this cell will be inactive ($\text{LTCCTRk.CEN} = 0$) and may be used for the next local coherent update. Local and coherent update may be used simultaneously within a group of Local Timer Cells. The following example shows a PWM using local coherent update. To reduce complexity of this example, only a single duty cycle pair is described in the following text. More duty cycle cells may follow using the same reseted timer and pair of period cells. So if requiring a second duty cycle LTC pair, the first pair would remain on LTC2 and LTC3 and the next pair on LTC 4and LTC5 using LTC05 as output.

General Purpose Timer Array (GPTA[®]v5)

Programmable PWM Signal Generation with 4 LTCs (local coherent update)

As shown in [Figure 23-62](#), a logical cell of four LTCs can be used to generate a PWM signal with a programmable duty cycle and local coherent update of this duty cycle. In this example, LTC00 up to LTC03 are used to generate a PWM signal at the output of LTC03.

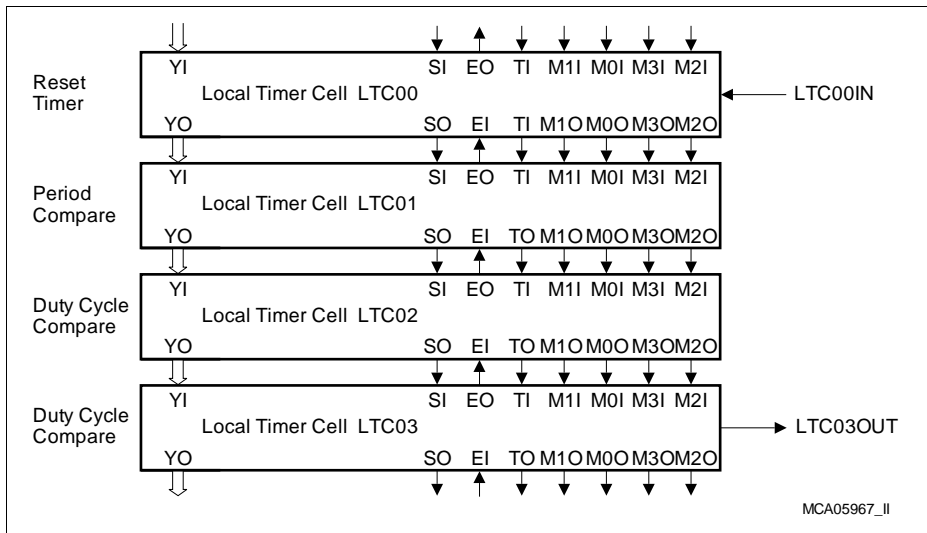


Figure 23-62 PWM Signal Generation with LTCs (Local Coherent Update)

LTC00 is configured in Reset Timer Mode thus providing all subsequent cells with a time base. LTC00 is clocked by a clock signal at the LTC00IN which has been selected by the LTC input multiplexer. LTC00 counts after reset by LTC01 or LTC02 from $FFFF_H$, 0000_H , 0001_H ... LTCXR01.X or LTCXR01.X. The period of the generated PWM is therefore $LTCXR01.X + 2$ or $LTCXR02.X + 2$.

LTC01 is configured in Compare Mode. It is always active and responsible for the LTC03OUT signal generation in Phase 1. With the programmed value from [Table 23-8](#), the LTC03OUT signal of Phase 1 has a period of 1000_D ($= 3E8_H$) clocks of the LTC00IN clock signal and a duty cycle of 20% ($= 200_D$ or $C8_H$).

LTC01 is configured in such a way ($LTCCTR01.OCM = 011_B$) that its output LTC01OUT is set to 1 whenever the LTC00 timer value LTCXR00.X is equal to the LTC01 compare value LTCXR01.X.

LTC02 and LTC03 are configured in Compare Mode. They are responsible for the LTC03OUT signal generation in Phase 2. With the programmed values from [Table 23-8](#), the LTC03OUT signal of Phase 2 has a duty cycle of 77% ($= 770_D$ or 302_H).

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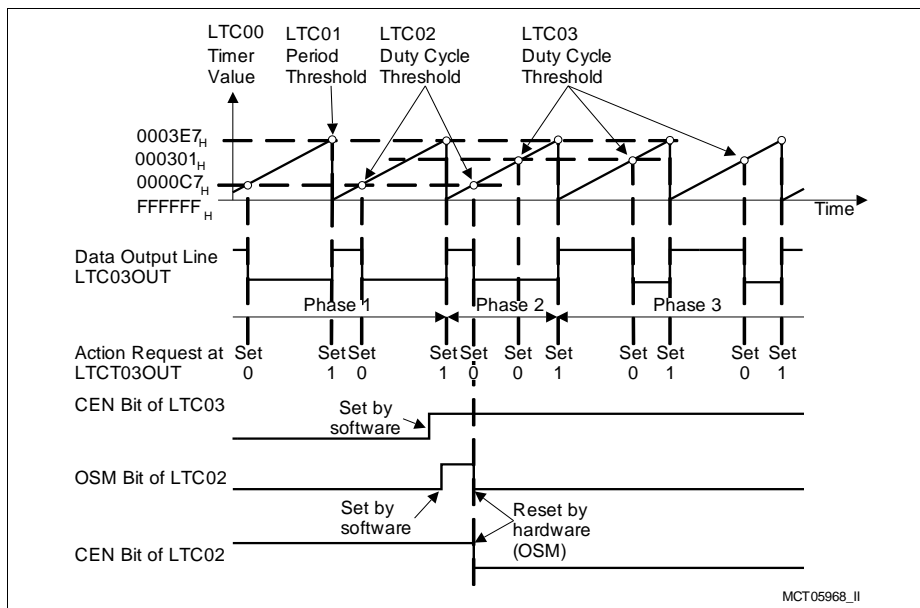


Figure 23-63 Internal Signal States of the PWM Signal Generation with 4 LTCs

LTC00 to LTC03 for the PWM example must be configured as defined in [Table 23-8](#).

Note: Special care has to be taken not to reprogram LTCXR02.X or LTCXR03.X before the previous local coherent update has been completed (LTCXR02.CEN = 0 or LTCXR03.CEN = 0). Therefore maximum one coherent update within a timer period is possible (measured from previous routine exit to current routine entry)!

Note: If simultaneous coherent updates of several Local Timer Cells within a group of Local Timer Cells (LTC) is required, instead of using the local coherent update (double action principle), the global coherent update mechanism must be used.

Note: If coherent updating the period of a Timer in Reset Timer Mode is required, the global coherent update mechanism must be used.

Note: Global bypass may be used to route e.g. period action request (edge aligned PWM) around the pair of locally coherent updated Local Timer Cells to following Local Timer Cells. But special care has to be taken, because the timer bus is not routed over a LTC configured as timer.

Note: This scheme activates for one period two cells in parallel. Therefore, if enabled, also two interrupts for this one signal are generated, one for the old (previous) edge, one for the new (updated) edge.

General Purpose Timer Array (GPTA[®]v5)

Note: To generate an output signal having 0% duty cycle (continuously low), the duty compare of the active cells must be set to $FFFF_H$. The timer sets the data output line by generating a respective signal on MO0 and MO1, but this signal is overruled by the dominating duty compare cell resetting the same data output line and therefore not passing the MIO and MI1 signal from the timer to the data output line. This result in a data output line remaining continuously low.

Note: To generate an output signal having 100% duty cycle (continuously high), the duty cycle threshold must be set above the period threshold value. Therefore no reset event for the data line is generated and periodically the timer generates a set event. This result in a data output line remaining continuously high.

General Purpose Timer Array (GPTA[®]v5)

Table 23-8 Programming Values for PWM Signal Generation with 4 LTCs

Register	Value	Function
LTC00 Configuration Setup		
GPTA0_LTCXR00	0000 0000 _H	LTC00 data register value = 0
GPTA0_LTCCTR00	0000 0413 _H	MOD = 11 _B : Reset Timer Mode selected OSM = 0: LTC00 continuously enabled ILM = 0, RED = 1, FED = 0: Input LTC00IN operates in Edge Sensitive Mode with rising edge; one clock bus signal is selected via the LTC input multiplexer SLO = 0: state of select line output SO is 0 CEN = 0: enable LTC00 for local events OCM = 000 _B : hold LTC00OUT state
LTC01 Configuration Setup		
GPTA0_LTCXR01	0000 03E7 _H	Load compare value = 3E7 _H = 999 _D
GPTA0_LTCCTR01	0000 5C11 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC01 continuously enabled SOH = 1, SOL = 1: enabled by both level at SI BYP = 0: bypass in LTC02 is disabled GBYP = 0: global bypass in LTC02 is disabled EOA = 0: LTC02 enabled for local events OCM = 011 _B : set LTC01OUT by a local event only OIA = 1: output action defined by OCM must be performed immediately

General Purpose Timer Array (GPTA®v5)

Table 23-8 Programming Values for PWM Signal Generation with 4 LTCs (cont'd)

Register	Value	Function
LTC02 Configuration Setup		
GPTA0_LTCXR02	0000 00C7 _H	Load compare value = C7 _H = 199 _D
GPTA0_LTCCTR02	0000 3431 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC02 continuously enabled SOH = 1, SOL = 1: compare enabled by low and high level at SI BYP = 0: local bypass in LTC02 is disabled GBYP = 0: begin of global bypass in LTC02 EOA = 0: LTC02 enabled for local events OCM = 110 _B : reset LTC02OUT by a local event or copy the previous cell action OIA = 0: no immediate output action required
LTC03 Configuration Setup		
GPTA0_LTCXR03	0000 0301 _H	Load compare value = 301 _H = 769 _D
GPTA0_LTCCTR03	0001 3401 _H	MOD = 01 _B : Compare Mode with LTC00 selected OSM = 0: LTC03 continuously enabled SOH = 0, SOL = 0: compare disabled by low and high level at SI BYP = 1: local bypass in LTC03 is disabled GBYP = 1: end of global bypass in LTC03 EOA = 0: LTC04 enabled for local events OCM = 110 _B : reset LTC03OUT by a local event or copy the previous cell action OIA = 0: no immediate output action required

General Purpose Timer Array (GPTA®v5)

The following code exemplifies the scheme to update the duty cycle of the PWM signal generation with 4 LTCs

Read LTCCTR02

If (LTCCTR02.SOL=1 and LTCCTR02.SOH=1 and LTCCTR02.CEN=1 and LTCCTR02.OSM=0) Then

Write New_Value into LTCXR03 of LTC03

Set LTCCTR03.OSM=0 and LTCCTR03.SOL=LTCCTR03.SOH=1 for LTC03

(Do not use LOAD/MODIFY/STORE, SWAP, or CLEAR_BIT assembler instructions)

Set LTCCTR02.OSM=1 of LTC02

(Use LOAD/MODIFY/STORE, SWAP, or CLEAR_BIT assembler instructions)

Read LTCXR02

Read LTCXR00

If LTCXR00>Read_LTCXR02 then

Clear LTCCTR02.SOL=LTCCTR02.SOH=0 of LTC02

End If

Else

Write New_Value into LTCXR02 of LTC02

Set LTCCTR02.OSM=0 and LTCCTR02.SOL=LTCCTR02.SOH=1 for LTC02

(Do not use LOAD/MODIFY/STORE, SWAP, or CLEAR_BIT assembler instructions)

Set LTCCTR03.OSM=1 of LTC03

(Use LOAD/MODIFY/STORE, SWAP, or CLEAR_BIT assembler instructions)

Read LTCXR03

Read LTCXR00

If LTCXR00>Read_LTCXR03 then

Clear LTCCTR03.SOL=LTCCTR03.SOH=0 of LTC03

End If

End If

General Purpose Timer Array (GPTA[®]v5)

23.3.4 Input/Output Line Sharing Block (IOLS)

The I/O Line Sharing Block allows the 56 inputs and 112 outputs of the GPTA[®]v5 units to be routed with high flexibility between I/O lines, output lines, clock inputs, other on-chip peripherals and other GPTA[®]v5 cells. The GPTA[®]v5 module provides a total of 56 input lines and 112 output lines, assigned to seven I/O groups IOG[6:0], two on-chip trigger and gating signal groups OTG[1:0], and seven output groups OG[6:0].

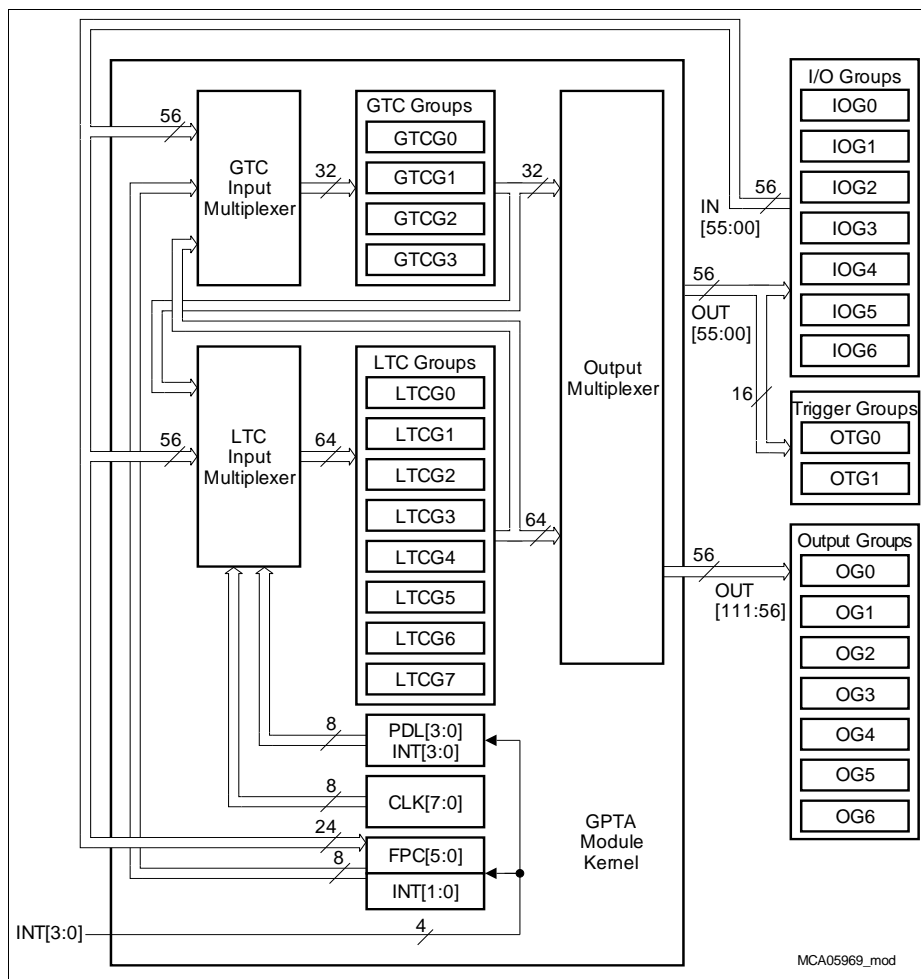


Figure 23-64 Input/Output Line Sharing Block Overview

General Purpose Timer Array (GPTA®v5)

The I/O Line Sharing Block does the following selections:

- FPC input line selection
- GTC and LTC output multiplexer selection
- On-chip trigger and gating signal selection
- GTC input multiplexer selection
- LTC input multiplexer selection

For choosing these selection, the input and output lines of the related cells are integrated into groups with eight parts each. Seven I/O groups, two on-chip and gating signal groups, seven output groups, four GTC groups, eight LTC groups, one clock group, one FPC/INT group, and one PDL/INT group are defined.

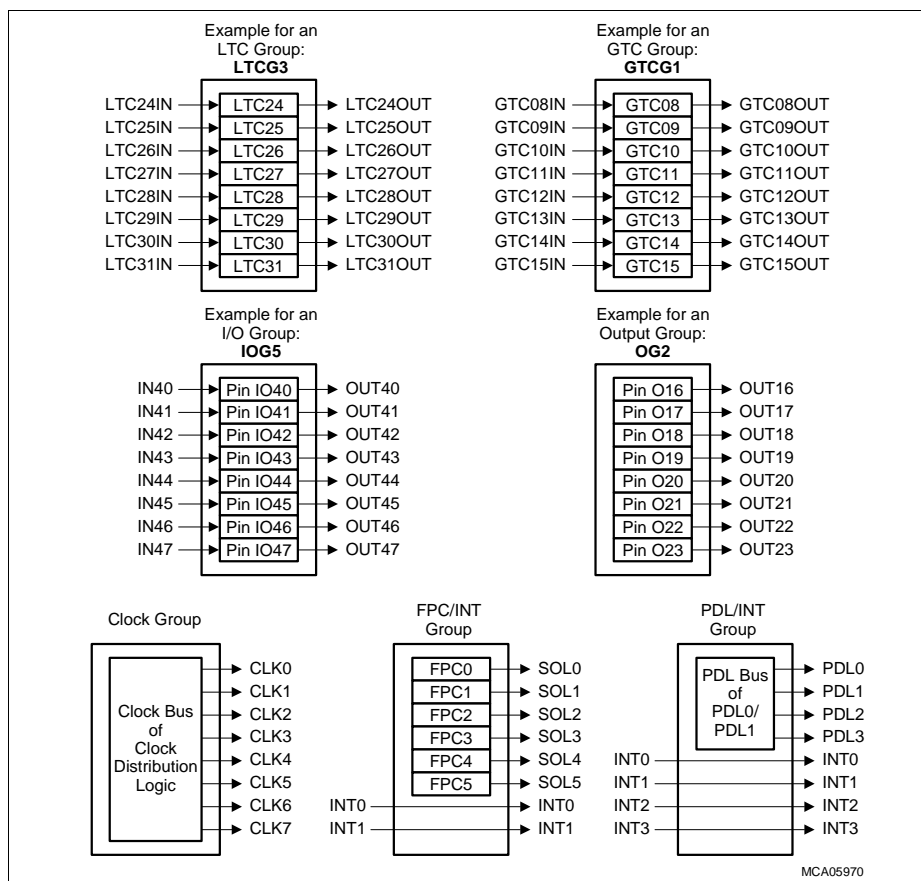


Figure 23-65 Groups Definitions for I/O Line Sharing Block

General Purpose Timer Array (GPTA[®]v5)

An **LTC group** combines eight LTC cells with its input and output lines. This results in eight LTC groups, LTCG0 to LTCG7.

A **GTC group** combines eight GTC cells with its input and output lines. This results in four GTC groups, GTCG0 to GTCG3.

An **I/O group** combines eight GPTA[®]v5 I/O lines connected to bi-directional device pins with its input and output lines. This results in seven I/O groups, IOG0 to IOG6, supporting 56 I/O lines.

An **Output group** combines eight GPTA[®]v5 output lines connected to device pins as an output. This results in seven output groups, OG0 to OG6, supporting 56 output lines.

The **Clock group** is a group that combines the eight clock bus output signals CLK[7:0] generated by the clock distribution cells.

The **FPC/INT group** is a group that combines the six level output signals SOL[5:0] of the FPCs with two external input lines INT[1:0] of the GPTA[®]v5 unit.

The **PDL/INT group** is a group that combines the four PDL output lines of the PDL bus with four external input lines INT[3:0] of the GPTA[®]v5 unit.

An **On-chip trigger and gating signal group** combines eight GPTA[®]v5 output lines connected to on-chip peripherals. This results in two on-chip trigger and gating signal groups, OTG0 to OTG1, supporting 16 on-chip trigger and gating lines.

Table 23-9 Group to I/O Line/Cell Assignment

Group/Unit	Cell/Line	Input	Output
LTC Groups			
LTCG0	LTC[07:00]	LTC[07:00]IN	LTC[07:00]OUT
LTCG1	LTC[15:08]	LTC[15:08]IN	LTC[15:08]OUT
LTCG2	LTC[23:16]	LTC[23:16]IN	LTC[23:16]OUT
LTCG3	LTC[31:24]	LTC[31:24]IN	LTC[31:24]OUT
LTCG4	LTC[39:32]	LTC[39:32]IN	LTC[39:32]OUT
LTCG5	LTC[47:40]	LTC[47:40]IN	LTC[47:40]OUT
LTCG6	LTC[55:48]	LTC[55:48]IN	LTC[55:48]OUT
LTCG7	LTC[63:56]	LTC[63:56]IN	LTC[63:56]OUT
GTC Groups			
GTCG0	GTC[07:00]	GTC[07:00]IN	GTC[07:00]OUT
GTCG1	GTC[15:08]	GTC[15:08]IN	GTC[15:08]OUT
GTCG2	GTC[23:16]	GTC[23:16]IN	GTC[23:16]OUT
GTCG3	GTC[31:24]	GTC[31:24]IN	GTC[31:24]OUT

General Purpose Timer Array (GPTA®v5)

Table 23-9 Group to I/O Line/Cell Assignment (cont'd)

Group/Unit	Cell/Line	Input	Output
I/O Groups			
IOG0	–	IN[07:00]	OUT[07:00]
IOG1	–	IN[15:08]	OUT[15:08]
IOG2	–	IN[23:16]	OUT[23:16]
IOG3	–	IN[31:24]	OUT[31:24]
IOG4	–	IN[39:32]	OUT[39:32]
IOG5	–	IN[47:40]	OUT[47:40]
IOG6	–	IN[55:48]	OUT[55:48]
Output Groups			
OG0	–	–	OUT[63:56]
OG1	–	–	OUT[71:64]
OG2	–	–	OUT[79:72]
OG3	–	–	OUT[87:80]
OG4	–	–	OUT[95:88]
OG5	–	–	OUT[103:96]
OG6	–	–	OUT[111:104]
On-Chip Trigger and Gating Signals Groups			
OTG0	–	–	OTGS[07:00]
OTG1	–	–	OTGS[15:08]
Clock Group			
–	–	–	CLK[7:0]
FPC/INT Groups			
FPC[5:0]	–	–	SOL[5:0]
External Input [1:0]	–	–	INT[1:0]
PDL/INT Groups			
PDL[1:0] PDL Bus	–	–	PDL[3:0]
External Input [3:0]	–	–	INT[3:0]

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23.3.4.1 FPC Input Line Selection

As shown on [Page 23-12](#), each FPC cell can be connected to one out of four input lines SINK[3:0], to the GPTA[®]v5 module clock f_{GPTA} , or to the output of the preceding FPC. In total, 24 input lines out of the 56 input lines IN[55:00] from the I/O groups are connected (not programmable) with the FPCK inputs. The FPCK input line selection is controlled by the FPCCTRk.IPS bit fields. [Table 23-10](#) shows the FPC input line connections.

Table 23-10 FPC Input Line Assignments

FPC Control Register	Bit Field IPS	Selected Input Signal
FPCCTR0	000 _B	IN0
	001 _B	IN12
	010 _B	IN24
	011 _B	IN36
FPCCTR1	000 _B	IN2
	001 _B	IN14
	010 _B	IN26
	011 _B	IN38
FPCCTR2	000 _B	IN4
	001 _B	IN16
	010 _B	IN28
	011 _B	IN40
FPCCTR3	000 _B	IN6
	001 _B	IN18
	010 _B	IN30
	011 _B	IN42
FPCCTR4	000 _B	IN8
	001 _B	IN20
	010 _B	IN32
	011 _B	IN44
FPCCTR5	000 _B	IN10
	001 _B	IN22
	010 _B	IN34
	011 _B	IN46

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23.3.4.2 GTC and LTC Output Multiplexer Selection

The output multiplexer shown in [Figure 23-64](#) and [Figure 23-66](#) below connects the 32 GTC output lines and the 64 LTC output lines with the I/O groups (7 × 8 = 56 output lines) and the output groups (7 × 8 = 56 output lines).

In case of low pin count packages, not all I/O groups may be routed to a pin.

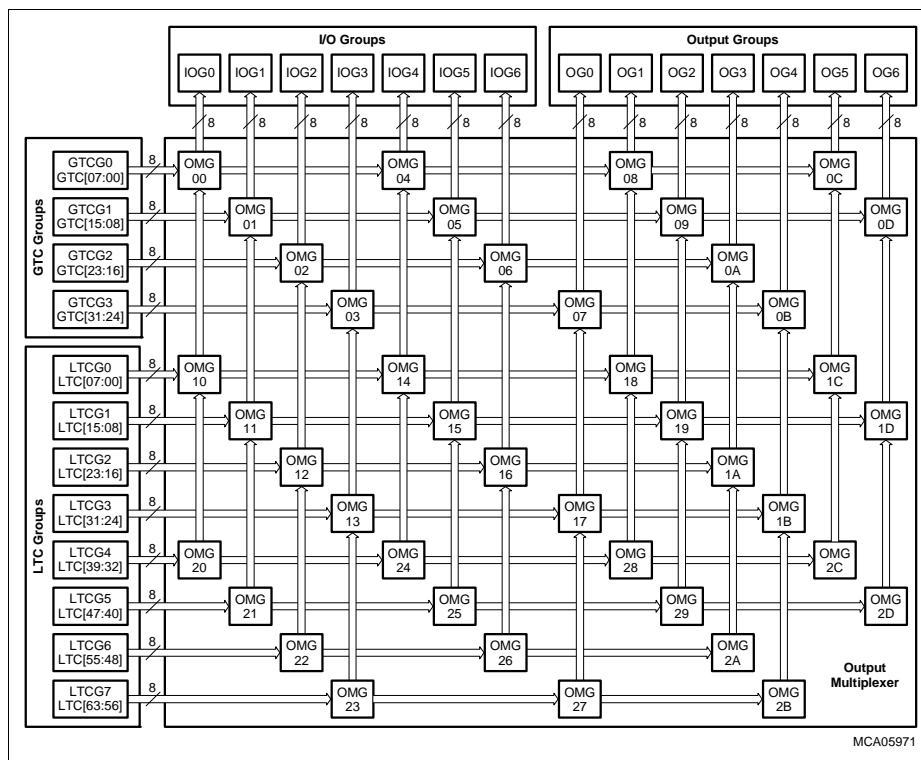


Figure 23-66 Output Multiplexer

The output multiplexer contains Output Multiplexer Groups (OMGs) that connect the Global Timer Cells or Local Timer Cells with the input lines of the I/O groups and output groups. GTCs and LTCs are grouped into four GTC groups (GTCG[3:0]) and eight LTC groups (LTCG[7:0]) with 8 cells each. In the same way, I/O groups and output groups are grouped into 14 groups (seven I/O groups and seven output groups) with 8 lines each.

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Figure 23-67 shows the logical structure of an OMG.

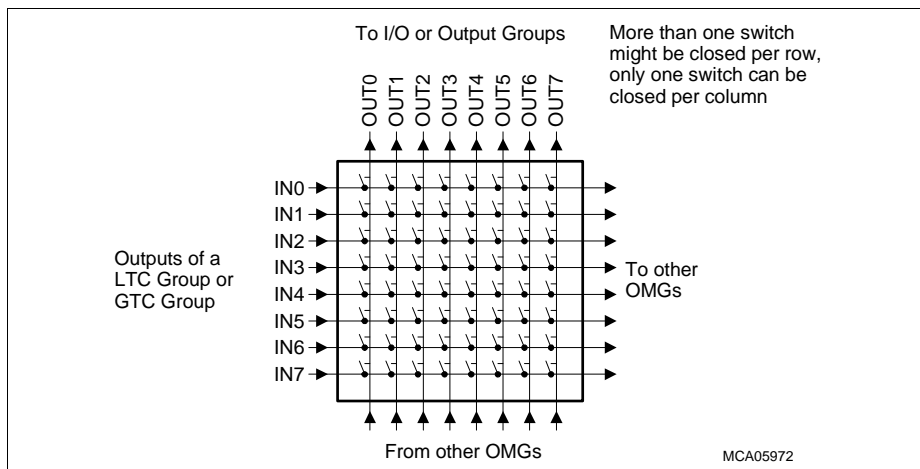


Figure 23-67 Output Multiplexer Group (OMG) Structure

Rules for connections to Output Multiplexer Group OMG:

- Within a GTC or LTC group, the output of the cell with the lowest index number is connected to OMG input line IN0. The remaining cells of a cell group are connected to OMG input lines IN1 to IN7 with ascending cell index numbers.
Example: for OMG13 (see [Figure 23-66](#)), the cells LTC24 up to LTC31 are wired to the OMG13 input lines IN0 to line IN7.
- OMG output line OUT0 is always connected to the input of an I/O or output group with the lowest index. The remaining output lines OUT1 to OUT7 are connected to the I/O or Output lines with ascending index.
Example: for OMG13 (see [Figure 23-66](#)), the outputs OUT0 to OUT7 are wired (via OMG03) to input lines 0 to 7 of I/O group 3 (IOG3).
- One input of an I/O or output group can be connected to the output of only one timer cell. This is guaranteed by the OMG control register layout. Otherwise, short circuits and unpredictable behavior would occur. On the other hand, it is permissible for the output of a GTC or LTC to be connected to more than one input of an I/O or output group.

The output multiplexer group configuration is based on the following principles:

- Each OMG is referenced with two index variables: n and g (OMGng)
- Index n is a group number. Global timer cell groups GTCG[3:0] have the group number 0, Local Timer Cell Groups LTCG[3:0] have the group number 1, and Local Timer Cell Groups LTCG[7:4] have the group number 2.

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- Index g indicates the number of an I/O or output group g ($g = 0-13_D$) to which the outputs of the output multiplexer group OMCn g are connected. I/O groups IOG0 to IOG6 are assigned to index variable $g = 0$ to 6 and output groups OG0 to OG6 are assigned to index variable $g = 7$ to 13.

The output multiplexer logic as seen for programming is shown in **Figure 23-68**. With this logic, always three GTC or LTC group signals are combined to one output line that leads to the input of an I/O or output group. For example, when looking at **Figure 23-66**, each of the eight output multiplexer output lines to I/O group IOG5 is connected via three OMCn5 ($n = 0, 1, 2$) with the eight outputs of one GTC group (GTCG1) and two LTC groups (LTCG1 and LTCG5).

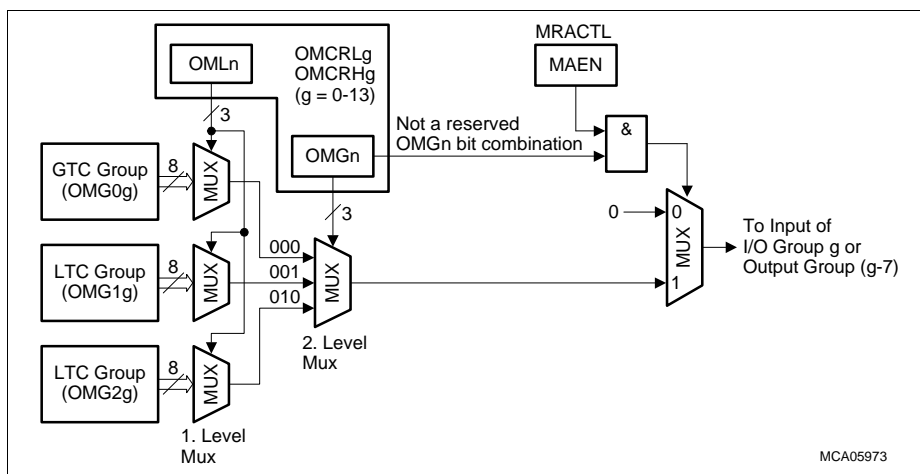


Figure 23-68 Output Multiplexer Group (Programmer's View)

The 1. level multiplexer is built up by three 8:1 multiplexers that are controlled in parallel by bit field OMLn. Bit field OMCn controls the 2. level multiplexer and connects one of the 1. level multiplexer outputs to output n . The output of the 2. level multiplexer is connected only to the input of an I/O group or output group if bit MRCTL.MAEN is set (multiplexer array enabled) and no reserved bit combination of OMCn is selected. If one of these conditions is not true, the corresponding OMC output will be held at a low level.

Two Output GPTA[®]v5, OMCRL and OMCRH (see also **Page 23-121**), are assigned to each of the I/O or output groups. Therefore, a total of 28 registers control the connections within the output multiplexer of the GPTA[®]v5 module.

The OMCRL registers control the OMC output lines 0 to 3. The OMCRH registers control the OMC output lines 4 to 7. **Table 23-11** lists all Output Multiplexer Control Registers with its control functions. Please note that the Output Multiplexer Control Registers are

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not directly accessible but must be written or read using a FIFO array structure as described on [Page 23-121](#).

Table 23-11 Output Multiplexer Control Register Assignments

I/O Group or Output Group		Controlled by Multiplexer Control Register	Selectable Groups via OMGng
IOG0	IN[03:00]/OUT[03:00]	OMCRL0	GTCG0, LTCG0, LTCG4
	IN[07:04]/OUT[07:04]	OMCRH0	
IOG1	IN[11:08]/OUT[11:08]	OMCRL1	GTCG1, LTCG1, LTCG5
	IN[15:12]/OUT[15:12]	OMCRH1	
IOG2	IN[19:16]/OUT[19:16]	OMCRL2	GTCG2, LTCG2, LTCG6
	IN[23:20]/OUT[23:20]	OMCRH2	
IOG3	IN[27:24]/OUT[27:24]	OMCRL3	GTCG3, LTCG3, LTCG7
	IN[31:28]/OUT[31:28]	OMCRH3	
IOG4	IN[35:32]/OUT[35:32]	OMCRL4	GTCG0, LTCG0, LTCG4
	IN[39:36]/OUT[39:36]	OMCRH4	
IOG5	IN[43:40]/OUT[43:40]	OMCRL5	GTCG1, LTCG1, LTCG5
	IN[47:44]/OUT[47:44]	OMCRH5	
IOG6	IN[51:48]/OUT[51:48]	OMCRL6	GTCG2, LTCG2, LTCG6
	IN[55:52]/OUT[55:52]	OMCRH6	
OG0	OUT[59:56]	OMCRL7	GTCG3, LTCG3, LTCG7
	OUT[63:60]	OMCRH7	
OG1	OUT[67:64]	OMCRL8	GTCG0, LTCG0, LTCG4
	OUT[71:68]	OMCRH8	
OG2	OUT[75:72]	OMCRL9	GTCG1, LTCG1, LTCG5
	OUT[79:76]	OMCRH9	
OG3	OUT[83:80]	OMCRL10	GTCG2, LTCG2, LTCG6
	OUT[87:84]	OMCRH10	
OG4	OUT[91:88]	OMCRL11	GTCG3, LTCG3, LTCG7
	OUT[95:92]	OMCRH11	
OG5	OUT[99:96]	OMCRL12	GTCG0, LTCG0, LTCG4
	OUT[103:100]	OMCRH12	

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Table 23-11 Output Multiplexer Control Register Assignments (cont'd)

I/O Group or Output Group		Controlled by Multiplexer Control Register	Selectable Groups via OMGng
OG6	OUT[107:104]	OMCRL13	GTCG1, LTCG1, LTCG5
	OUT[111:108]	OMCRH13	

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23.3.4.3 On-chip Trigger and Gating Output Multiplexer Selection

The On-chip Trigger and Gating Signal (OTGS) multiplexer shown in [Figure 23-64](#) and [Figure 23-69](#) below connects the 32 GTC output lines and the 64 LTC output lines with the on-chip trigger and gating signal groups ($2 \times 8 = 16$ output lines).

In case of low pin count packages, not all I/O groups may be routed to a pin.

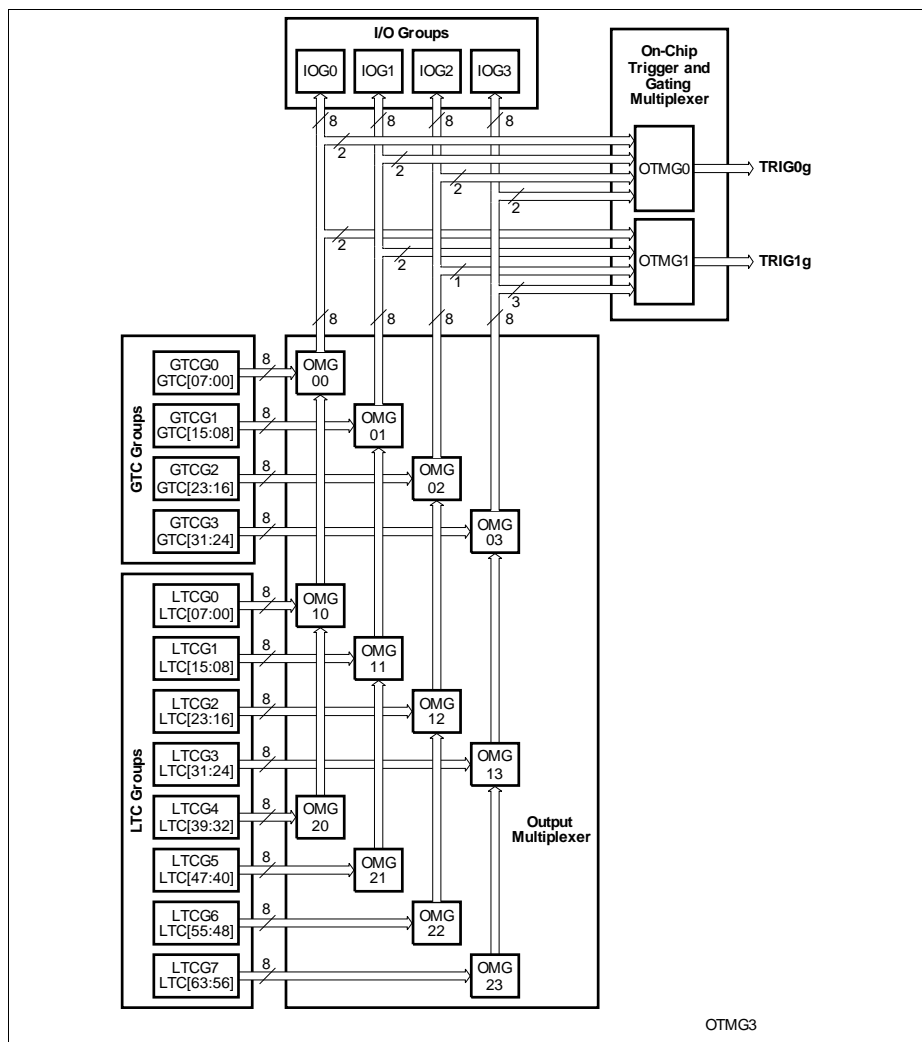


Figure 23-69 On-Chip Trigger and Gating Signal Multiplexer

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The On-chip Trigger and Gating Signal multiplexer contains Output Multiplexer Groups (OMGs) that connect the Outputs of the I/O groups with the On-Chip Trigger Signals. These On-Chip Trigger Signals are grouped into two On-Chip Trigger groups (OTMG[1:0]) with 8 cells each.

Figure 23-67 shows the logical structure of an OTMG.

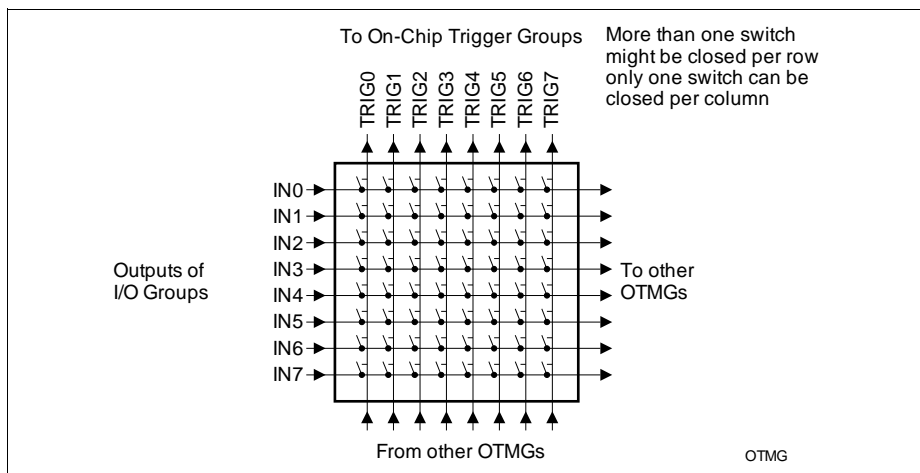


Figure 23-70 On-Chip Trigger and Gating Multiplexer Group (OTMG) Structure

Rules for connections to Output Multiplexer Group OTMG:

- Only one input of an On-chip Trigger and Gating Signal group can be connected to a On-chip Trigger and Gating Signal (TRIG). This is guaranteed by the OTMG control register layout. Otherwise, short circuits and unpredictable behavior would occur. On the other hand, it is permissible for the output of a I/O Group to be connected to more than one on-chip trigger and gating signal (TRIG).

The on-chip trigger and gating multiplexer group configuration is based on the following principles:

- Each OTMG is referenced with a single index variables: g (OTMGg)
- Index g indicates the number of an On-Chip Trigger and Gating Signal multiplexer group g ($g = 0-1_D$) to which the outputs of the On-Chip Trigger and Gating Signal multiplexer group OTMGg are connected. TRIG00 to TRIG07 are assigned to OTMG0 and TRIG10 to TRIG17 are assigned to OTMG1.

The on-chip trigger and gating signal multiplexer logic as seen for programming is shown in **Figure 23-71**.

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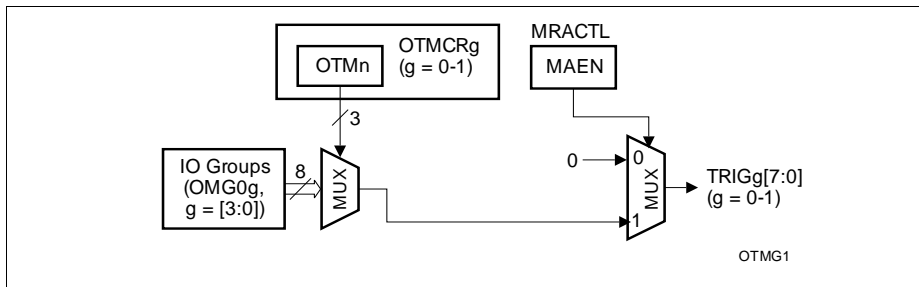


Figure 23-71 On-Chip Trigger and Gating Multiplexer Group (Programmer's View)

The multiplexer is built up by three 8:1 multiplexer that is controlled by bit field OTMn. Bit field The output of the multiplexer is connected only to the on-chip trigger and gating signal TRIGn if bit MRCTL.MAEN is set (multiplexer array enabled). If this condition is not true, the corresponding OTMG output will be held at a low level.

Sixteen on-chip trigger and gating signals are assigned to the GPTA0. Therefore, a total of 2 registers control the connections within the on-chip gating and trigger signal multiplexer of the GPTA0 unit.

Further sixteen on-chip trigger and gating signals are assigned to the GPTA1. Therefore, a total of 2 registers control the connections within the on-chip gating and trigger signal multiplexer of the GPTA1 unit.

The OTMCR0 register control the OTMG output lines TRIG00 to TRIG07. The OTMCR1 register control the OTMG output lines TRIG10 to TRIG17. **Table 23-12** lists all On-Chip Trigger and Gating Signal Multiplexer Control Registers with its control functions. Please note that the On-Chip Trigger and Gating Signal Multiplexer Control Registers are not directly accessible but must be written or read using a FIFO array structure as described on [Page 23-121](#).

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Table 23-12 On-Chip Trigger/Gating Multiplexer Control Register Assignments

I/O Group Signal		OTMG Input Signal	Controlled by Multiplexer Control Register	Trigger/Gating Signal (x=0-7)	Selectable Groups via OMGng
IOG0	OUT00	IN00	OTMCR0	TRIG0x	GTGCG0, LTCG0, LTCG4
IOG0	OUT02	IN01	OTMCR0	TRIG0x	GTGCG0, LTCG0, LTCG4
IOG1	OUT08	IN02	OTMCR0	TRIG0x	GTGCG1, LTCG1, LTCG5
IOG1	OUT10	IN03	OTMCR0	TRIG0x	GTGCG1, LTCG1, LTCG5
IOG2	OUT16	IN04	OTMCR0	TRIG0x	GTGCG2, LTCG2, LTCG6
IOG2	OUT19	IN05	OTMCR0	TRIG0x	GTGCG2, LTCG2, LTCG6
IOG3	OUT24	IN06	OTMCR0	TRIG0x	GTGCG3, LTCG3, LTCG7
IOG3	OUT27	IN07	OTMCR0	TRIG0x	GTGCG3, LTCG3, LTCG7
IOG0	OUT01	IN10	OTMCR1	TRIG1x	GTGCG0, LTCG0, LTCG4
IOG0	OUT03	IN11	OTMCR1	TRIG1x	GTGCG0, LTCG0, LTCG4
IOG1	OUT09	IN12	OTMCR1	TRIG1x	GTGCG1, LTCG1, LTCG5
IOG1	OUT11	IN13	OTMCR1	TRIG1x	GTGCG1, LTCG1, LTCG5
IOG2	OUT18	IN14	OTMCR1	TRIG1x	GTGCG2, LTCG2, LTCG6
IOG3	OUT25	IN15	OTMCR1	TRIG1x	GTGCG3, LTCG3, LTCG7
IOG3	OUT26	IN16	OTMCR1	TRIG1x	GTGCG3, LTCG3, LTCG7
IOG3	OUT28	IN17	OTMCR1	TRIG1x	GTGCG3, LTCG3, LTCG7

23.3.4.4 GTC Input Multiplexer Selection

The GTC input multiplexer as shown in [Figure 23-64](#) and [Figure 23-72](#) connects the 56 (= 7 × 8) input lines of the I/O groups, the 64 LTC output lines of the eight LTC groups, the six FPC output lines, and two internal input lines INT[1:0] with the 32 (= 4 × 8) LTC input lines, organized into eight LTC groups.

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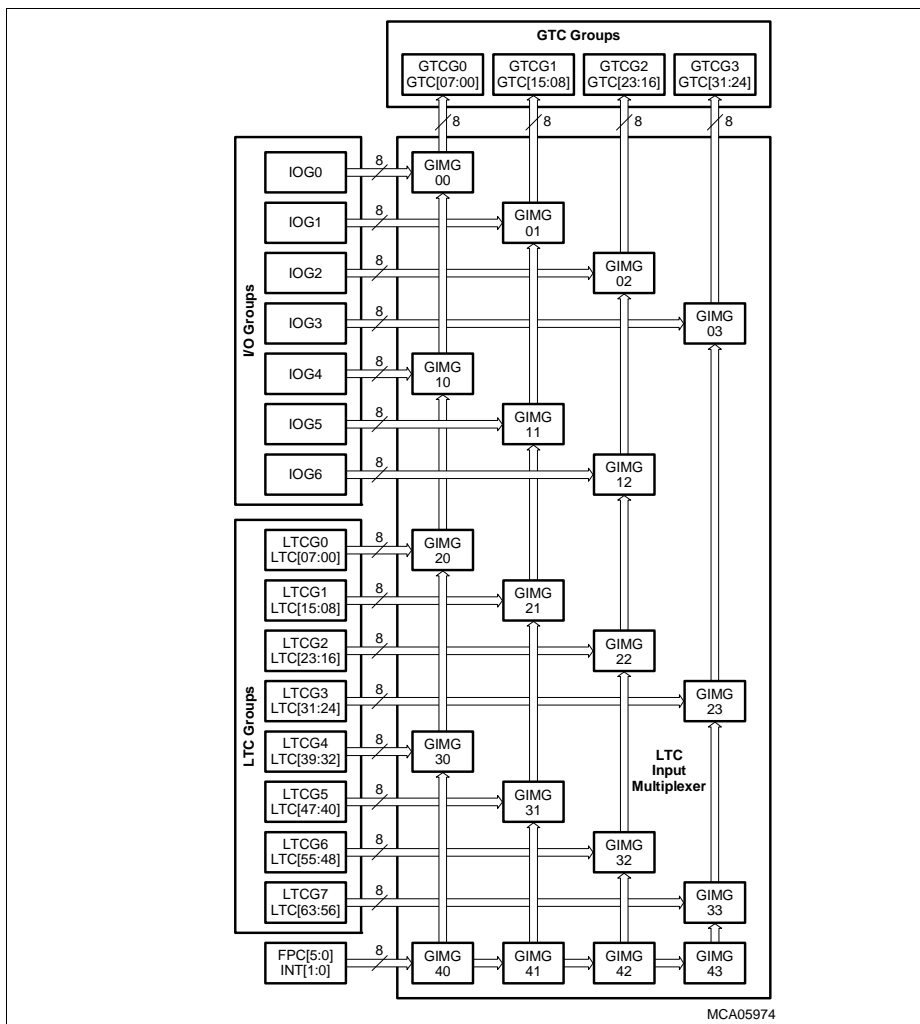


Figure 23-72 GTC Input Multiplexer

The GTC input multiplexer contains GTC input Multiplexer Groups (GIMGs) that connect the I/O groups or Local Timer Cells with the input lines of the GTC input lines, organized into four GTC groups with 8 cells each. GTC input Multiplexer Group are grouped into seven IOGs (IOG[6:0]) with eight lines each and eight LTC groups (LTCG[7:0]) with 8 cells each. One special FPC/INT group with eight outputs is established that combines the six FPC outputs and two internal input lines INT[1:0] as a group of GIMGs inputs.

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Figure 23-73 shows the logical structure of a GIMG.

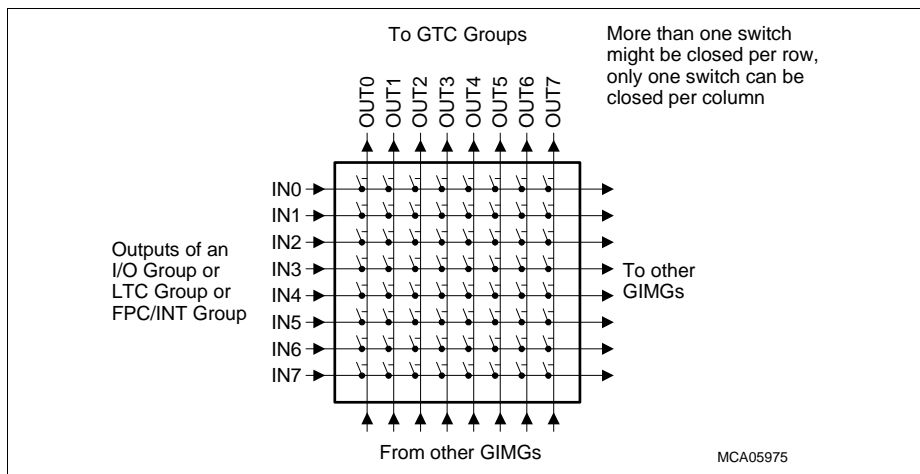


Figure 23-73 GTC Input Multiplexer Group (GIMG) Structure

Rules for connections to GTC Input Multiplexer Group GIMG:

- Within a I/O group or LTC group, the line or the output of the cell with the lowest index number is connected to GIMG input line IN0. The remaining lines, cells or lines of a group are connected to GIMG input lines IN1 to IN7 with ascending index numbers. At the FPC/INT group, FPC[5:0] is connected to IN[5:0] and INT[1:0] is connected to IN[7:6].
Example: for GIMG23 (see Figure 23-72), the cells LTC24 up to LTC31 are wired to the GIMG23 input lines IN0 to line IN7.
- Multiplexer output OUT0 is always connected to the input of a GTC group with the lowest index. The remaining output lines OUT1 to OUT7 are connected to the GTC inputs with ascending index.
Example: for GIMG23 (see Figure 23-72), the outputs OUT0 to OUT7 are wired to the inputs of GTC16 to GTC23.
- A GTC input can be connected either to an I/O group output, or to an LTC output, or to an FPC/INT output. This is guaranteed by the GIMG control register layout. Otherwise, short circuits and unpredictable behavior would occur. In contrast, it is permissible for an I/O group output, or an LTC output, or an FPC/INT output to be connected to more than one GTC input.

The GTC input multiplexer group configuration is based on the following principles:

- Each GIMG is referenced with two index variables: n and g (GIMGng)
- Index n is a group number. I/O groups IOG[3:0] have group number 0, I/O groups IOG[6:4] have group number 1, Local Timer Cell Groups LTCG[3:0] have group

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number 2, Local Timer Cell Groups LTCG[7:4] have group number 3, and the FPC/INT group has group number 4.

- Index g indicates the number of the GTC group g (g = 0-3) to which the outputs of the input multiplexer group GIMGng are connected.

The GTC input multiplexer logic as seen for programming is shown in **Figure 23-74**. With this logic, five group signals (from an I/O group, LTC group, or FPC/INT group) are always combined to one output line that leads to the input of a GTC of GTC group g. For example, when looking at **Figure 23-73**, each of the eight GTC input multiplexer output lines to GTC group GTCG2 is connected via five OMGn2 (n = 0-4) with the eight outputs of two I/O group (IOG2 and IOG6), two LTC groups (LTCG2 and LTCG6), and the FPC/INT group.

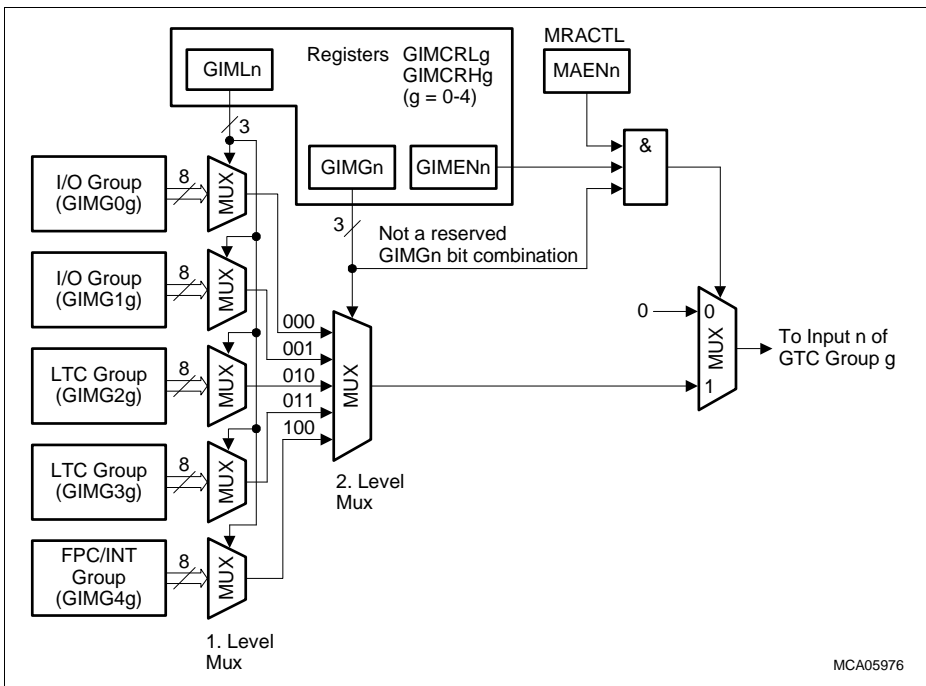


Figure 23-74 GTC Input Multiplexer Group (Programmer's View)

The 1. level multiplexer is built up by five 8:1 multiplexers that are controlled in parallel by bit field GIMLn. Bit field GIMGn controls the 2. level multiplexer and connects one of the 1. level multiplexer outputs to one of the GIMGng outputs. The output of the 2. level multiplexer is only connected to the input of an GTC if bit GIMENn (enable multiplexer connection) is set, and bit MRACTL.AEN is set (multiplexer array enabled), and no

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reserved bit combination of GIMGn is selected. If one of these conditions is not true, the corresponding GIMG output will be held at a low level.

If one of these bit is not set, the corresponding GTC input will be held at a low level.

Two GTC Input Multiplexer Control Registers, GIMCRL and GIMCRH (see also [Page 23-211](#)), are assigned to each of the GTC groups. Therefore, a total of eight registers control the connections within the GTC input multiplexer of the GPTA[®]v5 module.

The GIMCRL registers control the GIMG output lines 0 to 3 and the GIMCRH registers control the GIMG output lines 4 to 7. [Table 23-13](#) lists all of the GTC Input Multiplexer Control Registers with its control functions. Please note that all GTC Input Multiplexer Control Registers are not directly accessible but must be written or read using a FIFO array structure as described on [Page 23-121](#).

Table 23-13 GTC Input Multiplexer Control Register Assignments

GTC Group and GTCs		Controlled by Multiplexer Control Register	Selectable Groups via GIMGng
GTGCG0	GTC[03:00]	GIMCRL0	IOG0, IOG4, LTCG0, LTCG4, FPC/INT
	GTC[07:04]	GIMCRH0	
GTGCG1	GTC[11:08]	GIMCRL1	IOG1, IOG5, LTCG1, LTCG5, FPC/INT
	GTC[15:12]	GIMCRH1	
GTGCG2	GTC[19:16]	GIMCRL2	IOG2, IOG6, LTCG2, LTCG6, FPC/INT
	GTC[23:20]	GIMCRH2	
GTGCG3	GTC[27:24]	GIMCRL3	IOG3, LTCG3, LTCG7, FPC/INT
	GTC[31:28]	GIMCRH3	

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23.3.4.5 LTC Input Multiplexer Selection

The LTC input multiplexer as shown in [Figure 23-64](#) and [Figure 23-75](#) connects the 56 ($= 7 \times 8$) input lines of the I/O groups, the 32 ($= 4 \times 8$) GTC output lines of the GTC groups, the eight clock bus lines, or the four PDL output lines with four internal input lines INT[3:0] with the 64 ($= 8 \times 8$) LTC input lines, organized into eight LTC groups.

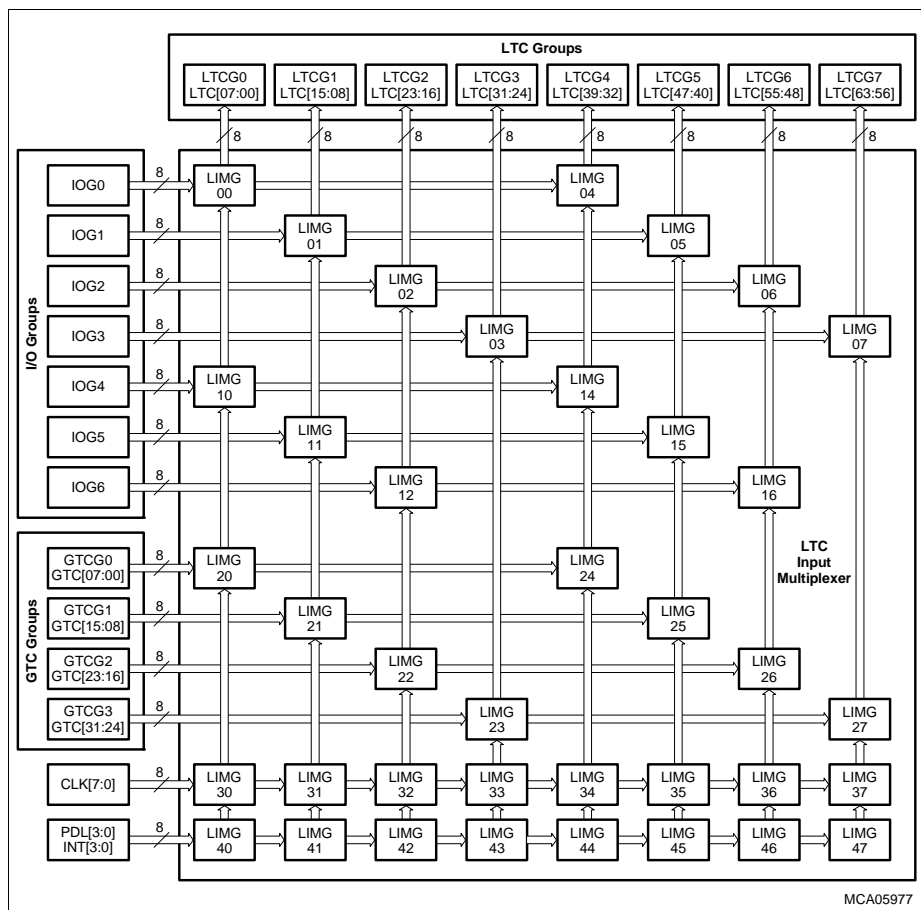


Figure 23-75 LTC Input Multiplexer

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The LTC input multiplexer contains LTC input Multiplexer Groups (LIMGs) that connect the I/O groups or Global Timer Cells with the input lines of the LTCs, organized into eight LTC groups with 8 cells each. IOGs and GTCs are grouped into seven IOGs (IOG[6:0]) with eight lines each and four GTC groups (GTCG[3:0]) with 8 cells each. Two special groups are available: a clock group with eight lines representing the clock bus lines CLK[7:0] of the clock distribution cells and a PDL/INT group with eight outputs that combines the four PDL outputs and four internal input lines INT[3:0] as a group of LIMGs inputs.

Note: GPTA0 generates the clock bus lines CLK[7:0] and the four PDL outputs.

Figure 23-76 shows the logical structure of a LIMG.

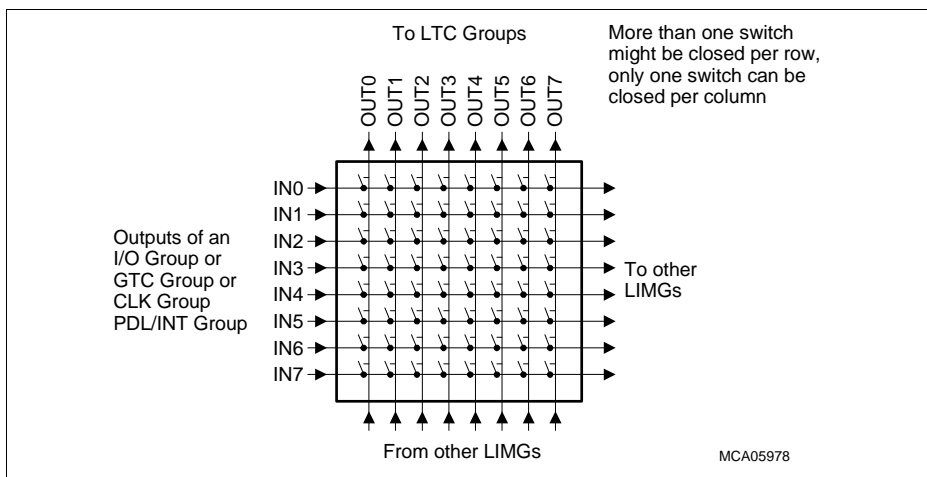


Figure 23-76 LTC Input Multiplexer Group (LIMG) Structure

Rules for connections to LTC Input Multiplexer Group LIMG:

- Within a I/O group or GTC group, the line or the output of the cell with the lowest index number is connected to LIMG input line IN0. The remaining lines, cells or lines of a group are connected to LIMG input lines IN1 to IN7 with ascending index numbers. At the clock group, CLK0 is connected to IN0 and the remaining clock lines are connected to LIMG input lines IN1 to IN7 with ascending index numbers. At the PDL/INT group, PDL[3:0] (see [Figure 23-22](#)) is connected to IN[3:0] and INT[3:0] is connected to IN[7:4].

Example: for LIMG23 (see [Figure 23-75](#)), the cells GTC24 up to GTC31 are wired to the LIMG23 input lines IN0 to line IN7.

- Multiplexer output OUT0 is always connected to the input of an LTC group with the lowest index. The remaining output lines OUT1 to OUT7 are connected to the LTC inputs with ascending index.

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Example: for LIMG23 (see [Figure 23-75](#)), the outputs OUT0 to OUT7 are wired to the inputs of LTC24 to GTC31.

- An LTC input can be connected either to an I/O group output, or to an GTC output, or to a clock bus output, or to an PDL/INT output. This is guaranteed by the LIMG control register layout. Otherwise, short circuits and unpredictable behavior would occur. In contrast, it is permitted that an I/O group output, or an GTC output, or an PDL/INT output is connected to more than one LTC input.

The LTC input multiplexer group configuration is based on the following principles:

- Each LIMG is referenced with two index variables: n and g (LIMGn_g)
- Index n is a group number. I/O groups IOG[3:0] have group number 0, I/O groups IOG[6:4] have group number 1, Global Timer Cell Groups GTCG[3:0] have group number 2, clock bus lines CLK[7:0] have group number 3, and the PDL/INT group has group number 4.
- Index g indicates the number of the LTC group g (g = 0-7) to which the outputs of the input multiplexer group LIMGn_g are connected.

The LTC input multiplexer logic as seen for programming is shown in [Figure 23-77](#). With this logic, five group signals (from an I/O group, GTC group, clock group, or PDL/INT group) are always combined to one output line that leads to the input of an LTC of LTC group g. For example, when looking at [Figure 23-75](#), each of the eight LTC input multiplexer output lines to LTC group LTCG2 is connected via five LIMGn₂ (n = 0-4) with the eight outputs of two I/O group (IOG2 and IOG6), one GTC group (GTCG2), the clock group, and the PDL/INT group.

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Table 23-14 LTC Input Multiplexer Control Register Assignments

LTC Group and LTCs		Controlled by Register	Selectable Groups via LIMGng
LTCG0	LTC[03:00]	LIMCRL0	IOG0, IOG4, GTCG0, CLOCK, PDL/INT
	LTC[07:04]	LIMCRH0	
LTCG1	LTC[11:08]	LIMCRL1	IOG1, IOG5, GTCG1, CLOCK, PDL/INT
	LTC[15:12]	LIMCRH1	
LTCG2	LTC[19:16]	LIMCRL2	IOG2, IOG6, GTCG2, CLOCK, PDL/INT
	LTC[23:20]	LIMCRH2	
LTCG3	LTC[27:24]	LIMCRL3	IOG3, GTCG3, CLOCK, PDL/INT
	LTC[31:28]	LIMCRH3	
LTCG4	LTC[35:32]	LIMCRL4	IOG0, IOG4, GTCG0, CLOCK, PDL/INT
	LTC[39:36]	LIMCRH4	
LTCG5	LTC[43:40]	LIMCRL5	IOG1, IOG5, GTCG1, CLOCK, PDL/INT
	LTC[47:44]	LIMCRH5	
LTCG6	LTC[51:48]	LIMCRL6	IOG2, IOG6, GTCG2, CLOCK, PDL/INT
	LTC[55:52]	LIMCRH6	
LTCG7	LTC[59:56]	LIMCRL7	IOG3, GTCG3, CLOCK, PDL/INT
	LTC[63:60]	LIMCRH7	

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23.3.4.6 Multiplexer Register Array Programming

A total of 54 control registers are required to program the configuration of the output multiplexer, the On-chip trigger and gating multiplexer, and the two input multiplexers of the Input/Output Line Sharing Block. These IOLS control registers are combined into a Multiplexer Register Array FIFO that can only be read or written sequentially. Therefore, the control registers values cannot be accessed directly but must be accessed in a specific sequential order.

Three registers are available for controlling the Multiplexer Register Array:

- Multiplexer Register Array Control Register MRACTL
- Multiplexer Register Array Data In Register MRADIN
- Multiplexer Register Array Data Out Register MRADOUT

Figure 23-78 shows the structure of the multiplexer array FIFO with the arrangement of the multiplexer control registers.

For programming of the multiplexer array FIFO, the following steps must be executed:

1. Disable interconnections of the multiplexer array by writing MRACTL.MAEN = 0 (default after reset). The multiplexer array is disabled, all cell input lines are driven with 0, and device pins assigned to GPTA[®]v5 I/O lines or output lines are disconnected.
2. Reset the write cycle counter to 0 by writing MRACTL.WCRES = 1.
3. Write sequentially the multiplexer control register contents one after the other (54 values) into MRADIN, starting with the register values for OTMCR1, OTMCR0, ... up to GIMCRH0, GIMCRL0 (see **Figure 23-78**). After the first MRADIN write operation, the contents for OTMCR1 is at FIFO position 1. With each following MRADIN write operation, it becomes shifted one FIFO position upwards. After the 54. MRADIN write operation, the OTMCR1 value is at its final position. The contents of FIFO position 54 can be read via register MRADOUT. With each MRADIN write operation the write cycle counter MRACTL.FIFOFILLCNT is incremented by 1. After all FIFO entries have been written, the FIFO is locked, bit MRACTL.FIFOFULL is set, and further MRADIN write operations are discarded until bit MRACTL.WCRES is written again with a 0.
4. Enable the multiplexer array by writing MRACTL.MAEN = 1. This establishes and enables all programmed interconnections.

To check the FIFO contents, the FIFO can be written a second time. At this check MRADIN is written before MRADOUT is read. This will return the FIFO contents of the first write sequence in the order of OTMCR1, OTMCR0, ..., GIMCRH0, GIMCRL0.

Before disabling the multiplexer array FIFO, GPTA[®]v5 output pins that are already enabled as GPTA[®]v5 output should be switched to GPIO function to avoid output spikes. After enabling the multiplexer array FIFO again, the GPTA[®]v5 output can be switched again back to GPTA[®]v5 output function.

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Shifting the write data through the FIFO requires a few clock cycles. When new data becomes written before the FIFO is ready to accept them, wait states will be inserted into the write access.

If the OMCRLg register bit field OMGn of the multiplexer array is programmed with an invalid (reserved) value, the related outputs will be forced to 0. When the array is disabled (MRACTL.MAEN = 0), all cell inputs and outputs are disconnected from the GPIO lines and are driven with 0.

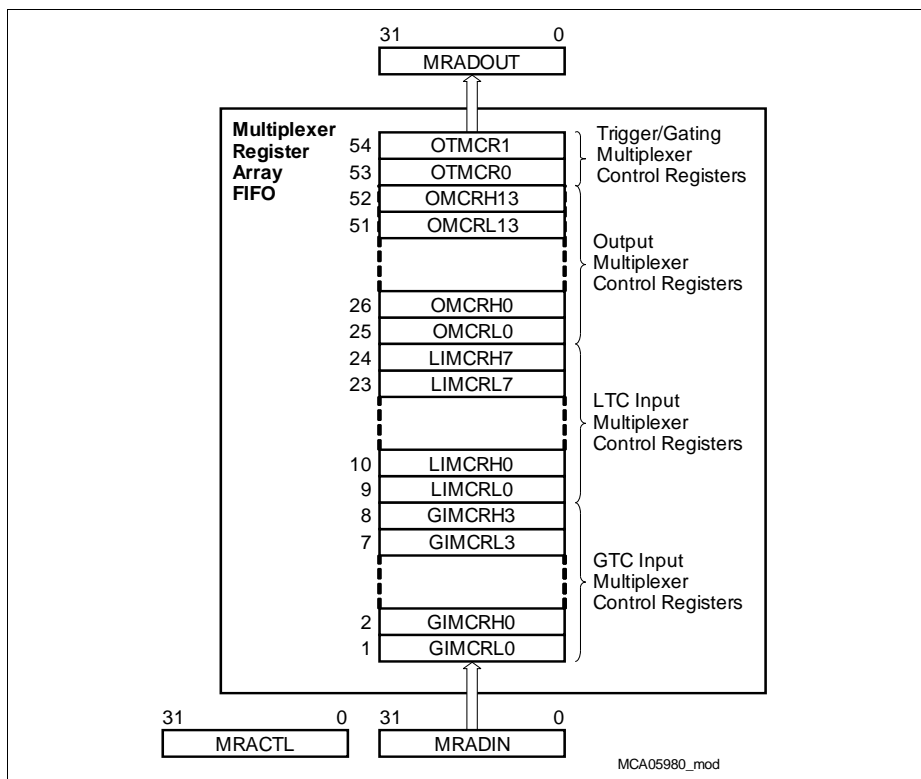


Figure 23-78 GPTA®v5 Multiplexer Array Control Register FIFO Structure

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23.3.5 Interrupt Sharing Block (IS)

The GPTA[®]v5 provides 111 service request sources. These service request sources are generated by different cell types, as shown in [Table 23-15](#).

Table 23-15 GPTA[®]v5 Number of Service Request Sources

Cell Type	Number of Cells	Number of Service Request Sources/Cell	Total Number of Request Sources
DCM	4	3	12
PLL	1	1	1
GT	2	1	2
GTC	32	1	32
LTC	64	1	64

Sum: 111

To reduce hardware and software overhead, at maximum five request sources are combined together in service request groups. A service request group has up to five service request inputs and one service request output SR_y which is typically connected outside the GPTA[®]v5 kernel with a standard interrupt node y and controlled by its SRC_y register.

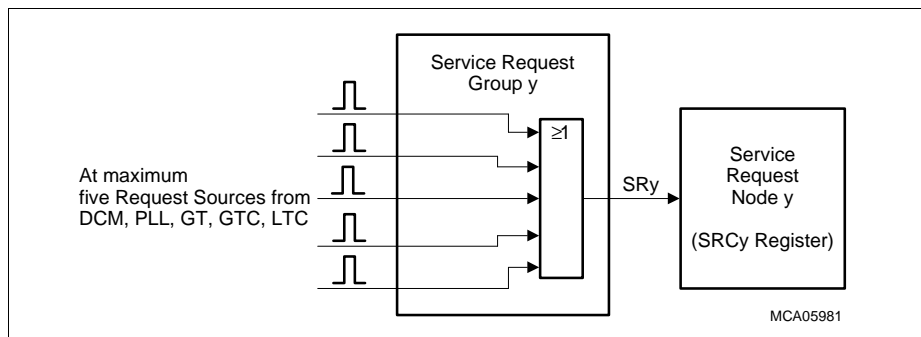


Figure 23-79 Service Request Groups

The bits in the Service Request State Registers (SRSS_x and SRSC_x) are service request status flags that are set by hardware (type “h”) when the related event occurs. Each GPTA[®]v5 service request source has its own service request flag. This flag is normally set by hardware but can be set and reset by software. Each service request status flag can be read twice, at the same bit location in the SRSC_x register and in the SRSS_x register, and cleared or set by software when writing to the corresponding request bit in SRSC_x or SRSS_x. When writing to SRSC_x or SRSS_x, several request flags

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can be cleared at once by one write operation. Request flags of bit positions that are written with 0 are not changed. This feature allows fast, simple clearing or setting of request flags without affecting other bits in the same service request state register.

Note that service request flag is always set independently of whether it is enabled or disabled by the related cell; but the service request line to the corresponding service request group becomes only active if the corresponding service request is enabled by the related cell. Finally, each service request group y must be enabled by the enable flag that is located in SRC register y .

Table 23-16 lists all of the service requests groups with its request sources. Note that service requests of GTCs with an odd index number k can be individually redirected via register SRNR to a service request group that is assigned mainly to four LTCs.

Table 23-16 GPTA®v5 Service Request Groups

Service Request Group Number y	Request Source 1	Request Source 2	Request Source 3	Request Source 4	Request Source 5
00	DCM0 rising	DCM0 falling	DCM0 comp.	—	—
01	DCM1 rising	DCM1 falling	DCM1 comp.	—	—
02	DCM2 rising	DCM2 falling	DCM2 comp.	—	—
03	DCM3 rising	DCM3 falling	DCM3 comp.	—	—
04	PLL	—	—	—	—
05	GT0	GT1	—	—	—
06	GTC00	GTC01 ¹⁾	—	—	—
07	GTC02	GTC03 ¹⁾	—	—	—
08	GTC04	GTC05 ¹⁾	—	—	—
09	GTC06	GTC07 ¹⁾	—	—	—
10	GTC08	GTC09 ¹⁾	—	—	—
11	GTC10	GTC11 ¹⁾	—	—	—
12	GTC12	GTC13 ¹⁾	—	—	—
13	GTC14	GTC15 ¹⁾	—	—	—
14	GTC16	GTC17 ¹⁾	—	—	—
15	GTC18	GTC19 ¹⁾	—	—	—
16	GTC20	GTC21 ¹⁾	—	—	—
17	GTC22	GTC23 ¹⁾	—	—	—
18	GTC24	GTC25 ¹⁾	—	—	—
19	GTC26	GTC27 ¹⁾	—	—	—

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Table 23-16 GPTA[®]v5 Service Request Groups (cont'd)

Service Request Group Number y	Request Source 1	Request Source 2	Request Source 3	Request Source 4	Request Source 5
20	GTC28	GTC29 ¹⁾	–	–	–
21	GTC30	GTC31 ¹⁾	–	–	–
22	LTC00	LTC01	LTC02	LTC03	GTC01 ²⁾
23	LTC04	LTC05	LTC06	LTC07	GTC03 ²⁾
24	LTC08	LTC09	LTC10	LTC11	GTC05 ²⁾
25	LTC12	LTC13	LTC14	LTC15	GTC07 ²⁾
26	LTC16	LTC17	LTC18	LTC19	GTC09 ²⁾
27	LTC20	LTC21	LTC22	LTC23	GTC11 ²⁾
28	LTC24	LTC25	LTC26	LTC27	GTC13 ²⁾
29	LTC28	LTC29	LTC30	LTC31	GTC15 ²⁾
30	LTC32	LTC33	LTC34	LTC35	GTC17 ²⁾
31	LTC36	LTC37	LTC38	LTC39	GTC19 ²⁾
32	LTC40	LTC41	LTC42	LTC43	GTC21 ²⁾
33	LTC44	LTC45	LTC46	LTC47	GTC23 ²⁾
34	LTC48	LTC49	LTC50	LTC51	GTC25 ²⁾
35	LTC52	LTC53	LTC54	LTC55	GTC27 ²⁾
36	LTC56	LTC57	LTC58	LTC59	GTC29 ²⁾
37	LTC60	LTC61	LTC62	LTC63	GTC31 ²⁾

1) Redirection bit SRNR.GTCkR = 0 (k = 01, 03, 05, ... 27, 29, 31).

2) Redirection bit SRNR.GTCkR = 1 (k = 01, 03, 05, ... 27, 29, 31).

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23.3.6 Pseudo Code Description of GPTA[®]v5 Kernel Functionality

This section describes the functional algorithms of the GPTA[®]v5 cells in a pseudo code language.

23.3.6.1 FPC Algorithm

FPCK_Control_Logic() “to be performed every GPTA[®]v5 clock”

```

switch (FPCK.Mode)
  case PRESCALER_RISING:
    if (FPCK.Rising_Edge) then
      Prescaler()
    endif
    break
  case PRESCALER_FALLING:
    if (FPCK.Falling_Edge) then
      Prescaler()
    endif
    break
  case DELAYED_FILTER_BOTH:
    Delayed_Filter()
    break
  case IMMEDIATE_FILTER_BOTH:
  case IMMEDIATE_FILTER_RISING:
  case IMMEDIATE_FILTER_FALLING:
    Immediate_Filter()
    break
  case MIXED_FILTER_RISING_DELAYED:
    if (FPCK.Signal_Filtered == 0) then
      Delayed_Filter()
    else
      Immediate_Filter()
    endif
    break
  case MIXED_FILTER_RISING_IMMEDIATE:
    if (FPCK.Signal_Filtered == 0) then
      Immediate_Filter()
    else
      Delayed_Filter()
    endif
    break
endswitch

```

General Purpose Timer Array (GPTA®v5)

Delayed_Filter()

```

if (FPCK.Filter_Clock[n]) then
  if (FPCK.Timer >= FPCK.Compare_Value) then
    if (FPCK.Compare_Value == 0) then    //by-pass
      if (FPCK.Signal_Output.Level != FPCK.Signal_Input[m]) then
        generate pulse on FPCK.Signal_Output.Transition
        FPCK.Signal_Output.Level = FPCK.Signal_Input[m]
        FPCK.Signal_Filtered = FPCK.Signal_Output.Level
      endif
    else    //delay time is over
      generate pulse on FPCK.Signal_Output.Transition
      FPCK.Signal_Output.Level = !FPCK.Signal_Output.Level
      FPCK.Signal_Filtered = FPCK.Signal_Output.Level
    endif
    FPCK.Timer = 0
  else
    if (FPCK.Timer != 0) then    //delay time is running
      if (FPCK.Rising_Edge is detected) then    //edge detection done at clock input
        FPCK.Rising_Edge_Glitch = 1
      else
        if (FPCK.Falling_Edge is detected) then    //edge detection done at clock input
          FPCK.Falling_Edge_Glitch = 1
        endif
      endif
    endif
    if (FPCK.Signal_Output.Level != FPCK.Signal_Input[m])
    then    //expected level
      FPCK.Timer ++
    else    //unexpected level
      if (FPCK.Timer != 0) then
        if (FPCK.Reset_Timer) then
          FPCK.Timer = 0
        else
          FPCK.Timer --
        endif
      endif
    endif
  endif
endif
endif

```

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Prescaler()

```

if (FPCh.Timer >= FPCh.Compare_Value) then
    generate pulse on FPCh.Signal_Output.Transition
    generate pulse on FPCh.Signal_Output.Level
    FPCh.Timer = 0
else
    FPCh.Timer ++
endif

```

Immediate_Filter()

```

if (FPCh.Filter_Clock[n]) then
    if (FPCh.Timer == 0) then
        if (FPCh.Signal_Output.Level != FPCh.Signal_Input[m]) ) then    //change detected
            generate pulse on FPCh.Signal_Output.Transition
            FPCh.Signal_Output.Level = FPCh.Signal_Input[m]
            if ( (FPCh.Compare_Value == 0) or
                ((FPCh.Mode == IMMEDIATE_FILTER_RISING) and !FPCh.Signal_Input[m]) or
                ((FPCh.Mode == IMMEDIATE_FILTER_FALLING) and FPCh.Signal_Input[m]) )
            then    //by-pass
                FPCh.Signal_Filtered = FPCh.Signal_Output.Level
            else    //start delay time
                FPCh.Timer ++
            endif
        endif
    endif
else
    if (FPCh.Timer >= FPCh.Compare_Value) then    //delay time is over
        FPCh.Timer = 0
        FPCh.Signal_Filtered = FPCh.Signal_Output.Level
    else    //delay time is running
        FPCh.Timer ++
        if (FPCh.Rising_Edge) then
            FPCh.Rising_Edge_Glitch = 1
        else
            if (FPCh.Falling_Edge) then
                FPCh.Falling_Edge_Glitch = 1
            endif
        endif
    endif
endif
endif
endif

```

General Purpose Timer Array (GPTA®v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name k = [0 to 5] for FPC m = [0 to 5] for Signal n = [0 to 3] for Clock	Short Name (*)FPC	Used (ILO)	Comment
FPCk.Signal_Input[m]	*SINm	I	Signal input selected by FPCk.Input_Source
FPCk.Filter_Clock[n]	*CINn	I	Filter Clock selected by FPCk.Clock_Source
FPCk.Rising_Edge	*RE	L	Signal coming from the edge detect
FPCk.Falling_Edge	*FE	L	Signal coming from the edge detect
FPCk.Signal_Filtered	*SF	L	Filtered output signal (after delay time), initialized to 0 at reset
FPCk.Signal_Output.Transition FPCk.Signal_Output.Level	*SOTk *SOLk	O	Transition/Level of the output signal, initialized to 0 at reset

General Purpose Timer Array (GPTA®v5)

Global variables

Name k = [0 to 5] for FPC	Short Name (*)FPC	Size (bits)	Function
FPCk.Mode	*MODk	3	Selects one of these modes: DELAYED_FILTER_BOTH IMMEDIATE_FILTER_BOTH IMMEDIATE_FILTER_RISING IMMEDIATE_FILTER_FALLING MIXED_FILTER_RISING_DELAYED MIXED_FILTER_RISING_IMMEDIATE PRESCALER_RISING PRESCALER_FALLING
FPCk.Input_Source	*IPSk	3	Selects input signal
FPCk.Clock_Source	*CLKk	2	Selects FPC clock
FPCk.Rising_Edge_Glitch	*REGk	1	Bit is set when rising edge glitch occurs during filtering
FPCk.Falling_Edge_Glitch	*FEGk	1	Bit is set when falling edge glitch occurs during filtering
FPCk.Timer	*TIMk	16	Timer value
FPCk.Reset_Timer	*RTGk	1	Reset timer on glitch in Delayed Filter Mode
FPCk.Compare_Value	*CMPk	16	Compare value

General Purpose Timer Array (GPTA®v5)

23.3.6.2 PDL-Algorithm

PDLx_Control_Logic() “to be performed every GPTA®v5 clock”

```

if (x == 0) then
    S1.Level = FPC0.Signal_Output.Level
    S1.Transition = FPC0.Signal_Output.Transition
    S2.Level = FPC1.Signal_Output.Level
    S2.Transition = FPC1.Signal_Output.Transition
    S3.Level = FPC2.Signal_Output.Level
    S3.Transition = FPC2.Signal_Output.Transition
else //x = 1
    S1.Level = FPC3.Signal_Output.Level
    S1.Transition = FPC3.Signal_Output.Transition
    S2.Level = FPC4.Signal_Output.Level
    S2.Transition = FPC4.Signal_Output.Transition
    S3.Level = FPC5.Signal_Output.Level
    S3.Transition = FPC5.Signal_Output.Transition
endif

if (PDLx.Three_Sensors_Enable) then
    Three_Sensors()
else
    Two_Sensors()
endif

if (PDLx.Mux) then
    PDLx.Signal_Output1.Level = 1
    if (PDLx.Signal_Forward or PDLx.Signal_Backward) then
        PDLx.Signal_Output1.Transition = 1
    else
        PDLx.Signal_Output1.Transition = 0
    endif
else
    PDLx.Signal_Output1.Transition = S1.Transition
    PDLx.Signal_Output1.Level = S1.Level
endif
    
```

General Purpose Timer Array (GPTA®v5)

Two_Sensors()

```
if ( ( S1.Level and !S2.Level and S1.Transition) or
    ( S1.Level and S2.Level and S2.Transition) or
    (!S1.Level and S2.Level and S1.Transition) or
    (!S1.Level and !S2.Level and S2.Transition) ) then
    generate pulse on PDLx.Signal_Forward
else
    if ( ( S1.Level and S2.Level and S1.Transition) or
        (!S1.Level and S2.Level and S2.Transition) or
        (!S1.Level and !S2.Level and S1.Transition) or
        ( S1.Level and !S2.Level and S2.Transition) ) then
        generate pulse on PDLx.Signal_Backward
    endif
endif
```

```
PDLx.Signal_Output2.Level = S3.Level
PDLx.Signal_Output2.Transition = S3.Transition
```

General Purpose Timer Array (GPTA®v5)

Three_Sensors()

```

if ( ( S1.Level and !S2.Level and S3.Level and S1.Transition) or
    ( S1.Level and !S2.Level and !S3.Level and S3.Transition) or
    ( S1.Level and S2.Level and !S3.Level and S2.Transition) or
    (!S1.Level and S2.Level and !S3.Level and S1.Transition) or
    (!S1.Level and S2.Level and S3.Level and S3.Transition) or
    (!S1.Level and !S2.Level and S3.Level and S2.Transition) ) then
    generate pulse on PDLx.Signal_Forward
else
    if ( ( S1.Level and S2.Level and !S3.Level and S1.Transition) or
        (!S1.Level and S2.Level and !S3.Level and S3.Transition) or
        (!S1.Level and S2.Level and S3.Level and S2.Transition) or
        (!S1.Level and !S2.Level and S3.Level and S1.Transition) or
        ( S1.Level and !S2.Level and S3.Level and S3.Transition) or
        ( S1.Level and !S2.Level and !S3.Level and S2.Transition) ) then
        generate pulse on PDLx.Signal_Backward
    endif
endif

if ( (S1.Level == S2.Level) and (S1.Level == S3.Level) ) then //error
    if (!PDLx.Signal_Output2.Level) then //rising edge
        generate pulse on PDLx.Signal_Output2.Transition
    endif
    PDLx.Signal_Output2.Level = 1
    PDLx.Error = 1
else //no error
    if (PDLx.Signal_Output2.Level) then //falling edge
        generate pulse on PDLx.Signal_Output2.Transition
    endif
    PDLx.Signal_Output2.Level = 0
endif

```

General Purpose Timer Array (GPTA®v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name x = [0,1] for PDL k = [0 to 5] for FPC	Short Name (*)PDL	Used (ILO)	Comment
FPCk.Signal_Output.Transition FPCk.Signal_Output.Level	SOTk SOLk	I	Transition/Level of signals coming from FPC
S1.Transition, S1.Level S2.Transition, S2.Level S3.Transition, S3.Level	S1T, S1L S2T, S2L S3T, S3L	L	Transition/Level of Local FPC signals
PDLx.Signal_Output1.Transition PDLx.Signal_Output1.Level	SIT0, SIL0 SIT2, SIL2	O	Transition/Level of Output 1 signal going to DCM0/DCM2
PDLx.Signal_Output2.Transition PDLx.Signal_Output2.Level	SIT1, SIL1 SIT3, SIL3	O	Transition/Level of Output 2 signal going to DCM1/DCM3
PDLx.Signal_Forward	*F0 *F1	O	Forward signals to be counted by LTC
PDLx.Signal_Backward	*B0 *B1	O	Backward signals to be counted by LTC

Global variables

Name x = [0,1] for PDL	Short Name (*)PDL	Size (bits)	Function
PDLx.Mux	*MUXx	1	Selects PDL speed signal (instead of FPC feed-through signal) for output 1
PDLx.Three_Sensors_Enable	*TSEx	1	Selects 3-sensor option and PDL error signal (instead of FPC feed-through signal) for output 2
PDLx.Error	*ERRx	1	Allows the software to read PDL error

General Purpose Timer Array (GPTA®v5)**23.3.6.3 DCM-Algorithm**

DCMk_Control_Logic() "to be performed every GPTA®v5 clock"

```
Compare()
Add_Clock()
Check_Input()
```

```
Compare()
```

```
if (DCMk.Timer == DCMk.Capcom_Value) then
    trig(DCMk.Service_Request_Compare)
endif
```

```
Add_Clock()
```

```
if (DCMk.Clock_Request) then
    Generate DCMk.Signal_Output
    DCMk.Clock_Request = 0
endif
```

General Purpose Timer Array (GPTA[®]v5)

Check_Input()

```
if (DCMk.Signal_Input.Transition) then
  if (DCMk.Signal_Input.Level) then //rising edge
    trig(DCMk.Service_Request_Rising)
    if (DCMk.Capture_On_Rising_Edge) then
      DCMk.Capture_Value = DCMk.Timer
    else
      if (DCMk.Capcom_Opposite) then
        DCMk.Capcom_Value = DCMk.Timer
      endif
    endif
    if (DCMk.Clear_On_Rising_Edge) then
      DCMk.Timer = 0
    else DCMk.Timer ++
    endif
    if (DCMk.Clock_On_Rising_Edge) then
      Generate pulse on DCMk.Signal_Output
    endif
  else //falling edge
    trig(DCMk.Service_Request_Falling)
    if (!DCMk.Capture_On_Rising_Edge) then
      DCMk.Capture_Value = DCMk.Timer
    else
      if (DCMk.Capcom_Opposite) then
        DCMk.Capcom_Value = DCMk.Timer
      endif
    endif
    if (DCMk.Clear_On_Falling_Edge) then
      DCMk.Timer = 0
    else DCMk.Timer ++
    endif
    if (DCMk.Clock_On_Falling_Edge) then
      Generate pulse on DCMk.Signal_Output
    endif
  endif
else DCMk.Timer ++
endif
```

General Purpose Timer Array (GPTA[®]v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name k = [0 to 3] for DCM	Short Name	Used (ILO)	Comment
DCMk.Signal_Input.Transition DCMk.Signal_Input.Level	*SITk *SILk	I	Input of the cell
DCMk.Signal_Output	*SOk	O	Output of the cell
DCMk.Service_Request_Rising	*RTQk	O	Service request on rising edge
DCMk.Service_Request_Falling	*FTQk	O	Service request on falling edge
DCMk.Service_Request_Compare	*CTQk	O	Service request on compare event

Global variables

Name k = [0 to 3] for DCM	Short Name (*)DCM	Size (bits)	Function
DCMk.Capture_On_Rising_Edge	*RCAk	1	Capture into Capture_Value on rising edge
DCMk.Capcom_Opposite	*OCAk	1	Capture into Capcom_Value on opposite edge defined by RCAk
DCMk.Clear_On_Rising_Edge	*RZEK	1	Clear Timer on rising edge
DCMk.Clear_On_Falling_Edge	*FZEK	1	Clear Timer on falling edge
DCMk.Clock_On_Rising_Edge	*RCKk	1	Generate a single clock pulse on rising edge
DCMk.Clock_On_Falling_Edge	*FCKk	1	Generate a single clock pulse on falling edge
DCMk.Clock_Request	*QCKk	1	Generate a single clock pulse immediately
DCMk.Request_Enable_Rising	*RREk	1	Enable request on rising edge
DCMk.Request_Enable_Falling	*FREk	1	Enable request on falling edge
DCMk.Request_Enable_Compare	*CREk	1	Request enable on compare
DCMk.Timer	*TIMk	24	Timer value
DCMk.Capture_Value	*CAVk	24	Capture value
DCMk.Capcom_Value	*COVk	24	Capture/compare value

General Purpose Timer Array (GPTA[®]v5)

23.3.6.4 PLL-Algorithm

PLL_Control_Logic() “to be performed every GPTA[®]v5 clock”

```

if ( (Pll.Automatic_End) and (Pll.Event) ) then    //allow compensation
    Pll.Perform_End = 1
endif

if ( (Pll.Counter_Mtick == 0) and ((Pll.Perform_End) or (!Pll.Automatic_End)) )
then    //compensation finished or no automatic compensation
    Pll.Counter_Mtick = Pll.Number_Mtick
    Pll.Perform_End = 0
endif

if ( (Pll.Counter_Mtick != 0) and ((Pll.Perform_End) or (Bit 24 of Pll.Delta)) )
then    //output pulse is necessary
    generate pulse on Pll.Signal_Output
    Pll.Counter_Mtick --
    if (Pll.Counter_Mtick == 0) then
        trig(Pll.Service_Request_Trigger)
    endif
endif

if (Bit 24 of Pll.Delta) then    //delta is < 0
    Pll.Delta = Pll.Delta + Pll.Reload_Value
    generate pulse on Pll.Signal_Uncomp
else    //delta is >= 0
    Pll.Delta = Pll.Delta + (0xFFFF0000 or (Pll.Step))
endif

```

General Purpose Timer Array (GPTA®v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name k = [0 to 3] for DCM	Short Name (*)PLL	Used (ILO)	Comment
DCMk.Signal_Output	SOk	I	Input of the cell from DCM
PII.Event	*EVE	L	Input selected by the multiplexer
PII.Signal_Output	*SO	O	Output of the cell
PII.Signal_Uncomp	*SU	O	Uncompensated output of the cell
PII.Service_Request_Trigger	*SQT	O	Service request when Counter reaches zero

Global variables

Name	Short Name (*)PLL	Size (bits)	Function
PII.Mux	*MUX	2	Selects the signal input for PLL
PII.Automatic_End	*AEN	1	Performs the acceleration/ deceleration correction
PII.Perform_End	*PEN	1	Makes it possible to decrement the Counter at full speed
PII.Request_Enable	*REN	1	Allows a request when microtick counter reaches zero
PII.Number_Mtick	*MTI	16	Number of microticks per input signal period
PII.Counter_Mtick	*CNT	16	Microtick counter
PII.Step	*STP	16	Step value, to be added to positive/zero delta register
PII.Reload_Value	*REV	24	Reload value, to be added to negative delta register
PII.Delta	*DTR	25	Delta register

General Purpose Timer Array (GPTA[®]v5)

23.3.6.5 GT-Algorithm

GTm_Control_Logic() “to be performed every GPTA[®]v5 clock”

```

if (GTm.Run) then
  if (Event on GTm.Clock_In[p] selected by GTm.Clock_Mux) then
    GTm.Timer ++
    if (Overflow of GTm.Timer) then
      GTm.Timer = GTm.Reload_Value
      trig(GTm.Service_Request_Trigger)
    endif
  endif
endif
endif

```

Variables

Input, Local, Output variables of the cell (I, L, O)

Name m = [0, 1] for GT p = [0 to 7] for Clock Bus	Short Name (*)GT	Used (ILO)	Comment
GTm.Clock_In[p]	*CINmp	I	Input coming from clock bus
GTm.Timer_Greater_Equal_Comp	TGEm	O	Timer is greater or equal
GTm.Timer_Event	TEVm	O	Signal for timer change
GTm.Service_Request_Trigger	*SQTM	O	Service request line

Global variables

Name m = [0, 1] for GT	Short Name (*)GT	Size (bits)	Function
GTm.Run	*RUNm	1	Enables timer
GTm.Scale_Compare	*SCOm	4	Selects compare flag
GTm.Clock_Mux	*MUXm	3	Selects clock from clock bus
GTm.Request_Enable	*RENm	1	Allows a request when timer overflows
GTm.Timer	*TIMm	24	Timer value
GTm.Reload_Value	*REVM	24	Reload value when timer overflows

General Purpose Timer Array (GPTA[®]v5)

23.3.6.6 GTC-Algorithm

GTck_Control_Logic() "to be performed every GPTA[®]v5 clock"

```
if (GTck.Cell_Enable) then
```

```
  switch (GTck.Mode)
```

```
    case CAPTURE_T0:
```

```
      Capture(0)
```

```
      break
```

```
    case CAPTURE_T1:
```

```
      Capture(1)
```

```
      break
```

```
    case COMPARE_T0:
```

```
      Compare(0)
```

```
      break
```

```
    case COMPARE_T1:
```

```
      Compare(1)
```

```
  endswitch
```

```
if ( (GTck.One_Shot_Mode) and (GTck.Event) ) then
```

```
  GTck.Cell_Enable = 0
```

```
endif
```

```
endif
```

```
Manage_Mux()
```

```
Capture(m)
```

```
if (GTck.Signal_Input) then
```

```
  trig(GTck.Service_Request_Trigger)
```

```
  GTck.X = GTm.Timer
```

```
  GTck.Event = 1
```

```
else
```

```
  GTck.Event = 0
```

```
endif
```

```
Ck.Event = 0
```

General Purpose Timer Array (GPTA[®]v5)

Compare(m)

```
if ( ((GTck.X == GTm.Timer) and ((GTck.X_Write_Access) or (GTm.Timer_Event))) or
    ((GTck.Greater_Equal_Select) and (GTck.X_Write_Access)
    and (GTm.Timer_Greater_Equal_Comp)) ) then
  if (GTck.Capture_After_Compare) then
    if (GTck.Capture_Alternate_Timer) then
      GTck.X = GT(lm).Timer
    else
      GTck.X = GTm.Timer
    endif
  endif
  trig(GTck.Service_Request_Trigger)
  GTck.Event = 1
else
  GTck.Event = 0
endif
```

Set_Data_Out(mode)

```
switch (mode)
  case 00B: //no change
    break
  case 01B: //toggle
    GTck.Data_Out = !GTck.Data_Out
    break
  case 10B: //clear
    GTck.Data_Out = 0
    break
  case 11B: //set
    GTck.Data_Out = 1
    break
endswitch
GTck.Output_State = GTck.Data_Out
```

General Purpose Timer Array (GPTA®v5)

Manage_Mux()

```
if ((GTCK.Event or GTCK.OIA) and GTCK.OCM != x00) then    //local event
  Set_Data_Out(GTCK.Output_Control_Mode.[1:0])
  if (!GTCK.Bypass) then    //no bypass
    GTCK.Output_Mode_Out = GTCK.Output_Control_Mode.[1:0]
  else
    if (GTCK.Output_Control_Mode.2) then    //bypass, input link enabled
      GTCK.Output_Mode_Out = GTCK.Output_Mode_In
    else    //bypass, input link disabled
      GTCK.Output_Mode_Out = 00B
    endif
  endif
else    //no local event
  if (GTCK.Output_Control_Mode.2) then    //input link enabled
    Set_Data_Out(GTCK.Output_Mode_In)
    GTCK.Output_Mode_Out = GTCK.Output_Mode_In
  else    //input link disabled
    Set_Data_Out(00B)
    GTCK.Output_Mode_Out = 00B
  endif
endif
if ( (GTCK.Enable_Of_Action) and
  ((GTCK.Output_Mode_In.1) or (GTCK.Output_Mode_In.0)) ) then
  GTCK.Cell_Enable = 1
  GTCK.Enable_Of_Action = 0
endif
```

General Purpose Timer Array (GPTA[®]v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name k = [0 to 31] for GTC m = [0, 1] for GT	Short Name (*)GTC	Used (ILO)	Comment
GTm.Timer_Greater_Equal_Comp	TGEm	I	Timer is greater or equal
GTm.Timer_Event	TEVm	I	Signal for timer change
GTm.Timer	*TIMm	I	Timer value
GTck.Data_In	*DINK	I	Data input from input multiplexer
GTck.Output_Mode_In	*M1Ik *M0Ik	I	Link signals from preceding cell
GTck.X_Write_Access	*XWA	L	Indicates that GTck.X was modified
GTck.Event	*EVE	L	Local event
GTck.Signal_Input	*INS	L	Qualified input signal
GTck.Service_Request_Trigger	*SQSk	O	Service request line
GTck.Data_Out	*DOUk	O	Data output for output multiplexer
GTck.Output_Mode_Out	*M1Ok *M0Ok	O	Link signals to following cell

General Purpose Timer Array (GPTA®v5)

Global variables

Name k = [0 to 31] for GTC	Short Name (*)GTC	Size (bits)	Comment
GTCK.Mode	*MODk	2	Operation mode: CAPTURE_T0, CAPTURE_T1, COMPARE_T0, COMPARE_T1
GTCK.One_Shot_Mode	*OSMk	1	One shot mode
GTCK.Request_Enable	*RENk	1	Allows a request on event
GTCK.Input_Rising_Edge_Select (Capture Mode)	*REDk	1	Selects rising edge of input pin
GTCK.Greater_Equal_Select (Compare Mode)	*GESk	1	Selects >= Compare Mode
GTCK.Input_Falling_Edge_Select (Capture Mode)	*FEDk	1	Selects falling edge of input pin
GTCK.Capture_After_Compare (Compare Mode)	*CACk	1	Selects capture after compare
GTCK.Capture_Alternate_Timer (Compare Mode)	*CATk	1	Capture alternate global timer after compare
GTCK.Bypass	*BYPk	1	Local events bypassed for output link
GTCK.Enable_Of_Action	*EOAk	1	Enables cell on action communicated via link
GTCK.Cell_Enable	*CENk	1	Cell enable state
GTCK.Output_Control_Mode	*OCMk	3	Output control mode
GTCK.Output_Immediate_Action	*OIAk	1	Forces immediate action
GTCK.Output_State	*OUTk	1	Read value of Data_Out
GTCK.X	*Xk	24	Capture/Compare value

General Purpose Timer Array (GPTA[®]v5)**23.3.6.7 LTC-Algorithm for Cells 0 to 62**

LTck_Control_Logic() “to be performed every GPTA[®]v5 clock”

```
if (LTck.Cell_Enable) then
  switch (LTck.Mode)
    case TIMER_FREE_RUN:
      LTck.Reset_Timer_Bit = 0
      Timer()
      break
    case TIMER_RESET:
      if (LTck.Event_In) then
        LTck.Reset_Timer_Bit = 1
      endif
      Timer()
      break;
    case CAPTURE:
      Capture()
      break
    case COMPARE:
      Compare()
      break
  endswitch
  if ((LTck.One_Shot_Mode) and (LTck.Event)) then
    LTck.Cell_Enable = 0
  endif
endif

Manage_Mux()
```

General Purpose Timer Array (GPTA[®]v5)

Timer()

```
if ( (LTCK.X == 0xFFFF) and (LTCK.X_Write_Access) ) then
    //above condition is also true for timer overflow or software reset
    trig(LTCK.Service_Request_Trigger)
    LTCK.Event = 1
else
    LTCK.Event = 0
endif
if (LTCK.Signal_Input) then
    if (LTCK.Reset_Timer_Bit) then    //timer must be reset
        LTCK.Reset_Timer_Bit = 0
        LTCK.X = 0xFFFF
        if (LTCK.Coherent_Update_Enable) then
            LTCK.Select_Line_Value = !LTCK.Select_Line_Value
            LTCK.Coherent_Update_Enable = 0
        endif
    else    //timer runs normally
        LTCK.X ++
    endif
endif
LTCK.Event_Out = LTCK.Event
```

General Purpose Timer Array (GPTA®v5)

Capture()

```
if (LTck.Signal_Input) then
    trig(LTck.Service_Request_Trigger)
    LTck.X = LTck.Y_In
    LTck.Event = 1
else
    LTck.Event = 0
endif
LTck.Event_Out = LTck.Event
```

Compare()

```
if ( ((LTck.Select_In) and (LTck.Select_On_High_Level)) or
      ((!LTck.Select_In) and (LTck.Select_On_Low_Level)) ) then    //cell is active
    if ( (LTck.X == LTck.Y_In) and
          ((LTck.X_Write_Access) or (LTck.Timer_Event_In)) ) then    //event
        trig(LTck.Service_Request_Trigger)
        LTck.Event = 1
    else
        LTck.Event = 0
    endif
    LTck.Event_Out = LTck.Event
else    //cell is inactive
    LTck.Event_Out = LTck.Event_In
endif
```

General Purpose Timer Array (GPTA®v5)

Manage_Mux()

```

if ( LTck.Mode == TIMER_FREE_RUN) or (LTck.Mode == TIMER_RESET) ) then
    LTck.Y_Out = LTck.X
    if (the timer has been modified) then    //increment, reset, software overwrite
        LTck.Timer_Event_Out = 1
    else
        LTck.Timer_Event_Out = 0
    endif
    LTck.Select_Out = LTck.Select_Line_Value
else    //capture mode or compare mode
    LTck.Y_Out = LTck.Y_In
    LTck.Timer_Event_Out = LTck.Timer_Event_In
    LTck.Select_Line_Value = LTck.Select_In
    LTck.Select_Out = LTck.Select_In
endif
if (LTck.Event) then    //local event
    Set_Data_Out(LTck.Output_Control_Mode.[1:0])
    if (!LTck.Bypass) then    //no bypass
        LTck.Output_Mode_Out = LTck.Output_Control_Mode.[1:0]
    endif
else    //no local event
    if (LTck.Output_Control_Mode.2)    //input link enabled
        Set_Data_Out(LTck.Output_Mode_In)
        if (!LTck.Bypass) then    //no bypass
            LTck.Output_Mode_Out = LTck.Output_Mode_In
        endif
    else    //input link disabled
        Set_Data_Out(00B)
        if (!LTck.Bypass) then    //no bypass
            LTck.Output_Mode_Out = 00B
        endif
    endif
endif
endif

```

General Purpose Timer Array (GPTA®v5)

Manage_Mux() - continued

```
if (LTck.GlobalBypass) then    //global bypass
    LTck.Output_Mode_Alternate_Out = LTck.Output_Mode_Alternate_In
    if (LTck.Bypass) then    // bypass
        LTck.Output_Mode_Out = LTck.Output_Mode_Alternate_In
    endif
else
    if (LTck.Output_Control_Mode.2) then    //bypass, input link enabled
        LTck.Output_Mode_Alternate_Out = LTck.Output_Mode_In
        if (LTck.Bypass) then    // bypass
            LTck.Output_Mode_Out = LTck.Output_Mode_In
        endif
    else    //bypass, input link disabled
        LTck.Output_Mode_Alternate_Out = 00B
        if (LTck.Bypass) then    // bypass
            LTck.Output_Mode_Out = 00B
        endif
    endif
endif
if ( (LTck.Enable_Of_Action) and
    ((LTck.Output_Mode_In.1) or (LTck.Output_Mode_In.0)) ) then    //enable condition
    LTck.Cell_Enable = 1
    LTck.Enable_Of_Action = 0
endif
```

General Purpose Timer Array (GPTA[®]v5)

Set_Data_Out(mode)

```
switch (mode)
case 00B: //no change
    break
case 01B: //toggle
    LTck.Data_Out = !LTck.Data_Out
    break
case 10B: //clear
    LTck.Data_Out = 0
    break
case 11B: //set
    LTck.Data_Out = 1
    break
endswitch
LTck.Output_State = LTck.Data_Out
```

General Purpose Timer Array (GPTA®v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name	Short Name (*)LTC	Used (ILO)	Comment
LTck.Data_In	*DINKp	I	Data input from input multiplexer
LTck.Y_In	*Ylk	I	Timer coming from preceding cell
LTck.Output_Mode_In	*M1lk *M0lk	I	Link signals coming from preceding cell
LTck.Output_Mode_Alternate_In	*M3lk *M2lk	I	Alternative Link signals coming from preceding cell
LTck.Timer_Event_In	*Tlk	I	Signal for timer change from preceding cell
LTck.Event_In	*Elk	I	Signal for event from following cell
LTck.Select_In	*Sl	I	Select signal from preceding cell
LTck.X_Write_Access	*XWA	L	Indicates that LTck.X was modified
LTck.Select_Line_Value	*SLV	L	Internal value for select line reset value: 0
LTck.Signal_Input	*INS	L	Qualified input signal for Timer Mode and Capture Mode
LTck.Reset_Timer_Bit	*RTM	L	Flip-flop to reset timer on next clock
LTck.Event	*EVE	L	Local event
LTck.Data_Out	*DOUk	O	Data output for output multiplexer
LTck.Service_Request_Trigger	*SQTk	O	Service request line
LTck.Y_Out	*YOk	O	Timer going to following cell
LTck.Output_Mode_Out	*M1Ok *M0Ok	O	Link signals to following cell
LTck.Output_Mode_Alternate_Out	*M3Ok *M2Ok	O	Link signals to following cell
LTck.Timer_Event_Out	*TOk	O	Event output to following cell
LTck.Select_Out	*SO	O	Select output to following cell
LTck.Event_Out	*EOk	O	Event output to preceding cell

General Purpose Timer Array (GPTA®v5)

Global variables

Name k = [0 to 62] for LTC	Short Name (*)LTC	Size (bits)	Comment
LTck.Mode	*MODk	2	Operation mode: TIMER, TIMER_RESET, CAPTURE, COMPARE
LTck.One_Shot_Mode	*OSMk	1	One shot mode
LTck.Request_Enable	*RENk	1	Allows a request on event
LTck.Input_Rising_Edge_Select (Timer Mode, Capture Mode)	*REDk	1	Selects rising edge of input pin
LTck.Select_On_Low_Level (Compare Mode)	*SOLk	1	Enables compare on low level of select line
LTck.Input_Falling_Edge_Select (Timer Mode, Capture Mode)	*FEDk	1	Selects falling edge of input pin
LTck.Select_On_High_Level (Compare Mode)	*SOHk	1	Enables compare on high level of select line
LTck.Bypass (Capture Mode, Compare Mode)	*BYPk	1	Local events bypassed for output link
LTck.GlobalBypass	*GBYPk	1	Alternative output links forwarded to alternative output link
LTck.Enable_Of_Action (Capture Mode, Compare Mode)	*EOAk	1	Enables cell on action communicated via link
LTck.Input_Line_Mode	*ILMk	1	Selects edge input line mode
LTck.Coherent_Update_Enable (Timer Mode)	*CUDk	1	Selects coherent update
LTck.Select_Line_Level (Capture Mode, Compare Mode)	*SLLk	1	Select line level
LTck.Cell_Enable	*CENk	1	Cell enable state
LTck.Output_Control_Mode	*OCMk	3	Output control mode
LTck.Output_Immediate_Action	*OIAk	1	Forces immediate action
LTck.Output_State	*OUTk	1	Read value of Data_Out
LTck.X	*Xk	16	Timer/Capture/Compare value

General Purpose Timer Array (GPTA[®]v5)**23.3.6.8 LTC Algorithm for Cell 63**

LTC63_Control_Logic() "to be performed every GPTA[®]v5 clock"

Copy()

Compare()

Copy()

```
if (LTC63.Cell_Enable) then
  if (LTC63.Signal_Input) then
    LTC63.X = LTC63.X_Shadow
    trig(LTC63.Service_Request_Trigger)
    if (LTC63.One_Shot_Mode) then
      LTC63.Cell_Enable = 0
    endif
  endif
endif
endif
```

General Purpose Timer Array (GPTA[®]v5)

Compare()

```
if ( (LTC63.X_Write_Access) or (LTC63.Timer_Event_In) ) then
  if (LTC63.Bit_Rev_Mode) then
    LTC63.Y_Comp = LTC63.Y_Rev
  else
    LTC63.Y_Comp = LTC63.Y_In
  endif
  if ( (LTC63.X > LTC63.Y_Comp) or (LTC63.X == FFFFH) ) then //output must be 1
    LTC63.Data_Out = 1
    LTC63.Event_Out = 0
  else //output must be 0
    if (LTC63.Data_Out == 1) then //falling edge on output
      trig(LTC63.Service_Request_Trigger)
      LTC63.Event_Out = 1
    else
      LTC63.Event_Out = 0
    endif
    LTC63.Data_Out = 0
  endif
  LTC63.Output_State = LTC63.Data_Out
endif
```

General Purpose Timer Array (GPTA[®]v5)

Variables

Input, Local, Output variables of the cell (I, L, O)

Name	Short Name (*)LTC	Used (ILO)	Comment
LTC63.Data_In	*DIN63	I	Data input from input multiplexer
LTC63.Y_In	*YI63	I	Timer coming from preceding cell
LTC63.Timer_Event_In	*TI63	I	Signal for timer change from preceding cell
LTC63.Y_Rev	*YR	L	Timer coming from preceding cell, bit reversed
LTC63.Y_Comp	*YC	L	Timer actually used for compare
LTC63.X_Write_Access	*XWA	L	Indicates that LTC63.X was modified
LTC63.Signal_Input	*INS	L	Qualified input signal
LTC63.Data_Out	*DOU63	O	Data output for output multiplexer
LTC63.Service_Request_Trigger	*SQT63	O	Service request line
LTC63.Event_Out	*EO63	O	Event output to preceding cell

General Purpose Timer Array (GPTA®v5)

Global variables

Name	Short Name (*)LTC	Size (bits)	Comment
LTC63.Bit_Rev_Mode	*BRM63	1	Bit reverse mode
LTC63.One_Shot_Mode	*OSM63	1	One shot mode for copy
LTC63.Request_Enable	*REN63	2	Allows a request on compare or copy
LTC63.Input_Rising_Edge_Select	*RED63	1	Selects rising edge of input pin
LTC63.Input_Falling_Edge_Select	*FED63	1	Selects falling edge of input pin
LTC63.Input_Line_Mode	*ILM63	1	Selects edge input line mode
LTC63.Cell_Enable	*CEN63	1	Cell enable state for copy
LTC63.Output_State	*OUT63	1	Read value of Data_Out
LTC63.X	*X63	16	Compare value
LTC63.X_Shadow	*XS63	16	Shadow compare value

General Purpose Timer Array (GPTA[®]v5)

23.3.7 Programming of a GPTA[®]v5 Unit

A hierarchical top-down design approach may be used to implement a complex signal processing circuitry as follows:

- Partitioning the complex signal processing circuitry into simple function cells.
- Implementing each simple function cell by configuring the LTC and/or GTC cells which can be tied together for realizing a common signal operation.
- Implementing necessary signal pre-processing tasks by configuring the FPC, PDL, DCM and PLL cells accordingly.
- Defining and configuring all input/output port pins required as clock source, trigger input or signal output.

Table 23-17 summarizes all of the software tasks to be implemented for getting a GPTA[®]v5 unit into operation.

Table 23-17 Software Tasks Controlling a GPTA[®]v5 Unit

GPTA [®] v5 Shell Initialization	
GPTA [®] v5 Module Clock Enable	
Fractional Divider Setting	
Unit Enable	
Configuration of Interrupt Handling	
GPTA [®] v5 Kernel Initialization	
FPC:	PDL:
Selection of Operating Mode (Prescaler, Filter or Feed-Through)	Selection of Operating Mode (Phase Discriminator or Feed-Through)
Input Channel Selection	2- or 3-Sensor Mode Selection
Clock Selection	PLL:
Configuration of Prescaler Factor or Debounce Mode	Selection of Input Channel
DCM:	Estimation of Input Signal Period Width
Selection of Reset Event for Timer	Configuration of Output Signal Frequency
Selection of Trigger Source for Capture Event	Handling of Input Signal Period Length Variation
Selection of Trigger Source for Capture Compare Register Update	Interrupt Request Enable on End of Output Pulse Generation
Interrupt Request Enable on Input Edge or Compare Event	

General Purpose Timer Array (GPTA[®]v5)

Table 23-17 Software Tasks Controlling a GPTA[®]v5 Unit (cont'd)

Clock Bus Setup

Selection and Configuration of 8 Clock Sources for GT, GTC and LTC Cells	
GT:	GTC:
Selection of Timer Clock Source	Selection of Operating Mode (Capture or Compare) and Time Base (GT0 or GT1)
Configuration of Timer Width (Reload Value, TGE Flag)	Configuration of Trigger Events for Capture Mode or Selection of a Relational Operator for Compare Mode
Interrupt Request Enable on Timer Overflow	Interrupt Request Enable on Capture or Compare Event
Start Global Timer(s)	Configuration of Data Output triggered by a GTC Event
LTC:	IOLS:
Selection of Operating Mode (Timer, Capture or Compare)	Configuration of the Multiplexer Array to link GTC and LTC data outputs/inputs to external Port Pins or other cells by writing the Multiplexer Register Array FIFO Configuration of the On-chip Trigger and Gating Signal Multiplexer Array to link GTC and LTC data outputs to on-chip modules by writing the Multiplexer Register Array FIFO
Selection of Trigger Source for Timer, Capture or Compare Mode	Configuration of Port Output Source
Configuration of Trigger Event for Timer, Capture or Compare Mode	
Interrupt Request Enable on Timer, Capture or Compare Event	
Configuration of Data Output triggered by an LTC Event	
Port Initialization	
Definition of Electrical Port Characteristic	
Configuration of Port Pin Direction (Input or Output)	

General Purpose Timer Array (GPTA[®]v5)

23.4 GPTA0 Kernel Registers

This section describes the kernel registers of the GPTA0 unit.

GPTA0 Kernel Register Overview

Control Registers	Data Registers	Interrupt & IOLS Registers	Multiplexer Array FIFO Registers
FPCSTAT	FPCTIMk ¹⁾	SRSCn ⁶⁾	OTMRCg ⁷⁾
FPCCTRk ¹⁾	DCMTIMk ²⁾	SRSSn ⁶⁾	OMRCHg ⁸⁾
PDLCTR	DCMCAVg ²⁾	SRNR	LIMCRLg ⁹⁾
DCMCTRk ²⁾	DCMCOVg ²⁾	MRCTL	LIMCRHg ⁹⁾
PLLCTR	PLLMTI	MRADIN	GIMCRLg ¹⁰⁾
CKBCTR	PLLSTP	MRADOUT	GIMCRHg ¹⁰⁾
GTCTRk ³⁾	PLLCNT		
GTCCTRk ⁴⁾	PLLREV		
LTCCTRk ⁵⁾	PLLDTR		
	GTTIMk ³⁾		
	GTREVG ³⁾		
	GTCXRk ⁴⁾		
	LTCXRk ⁵⁾		

¹⁾ k = 0-5
²⁾ k = 0-3
³⁾ k = 0-1
⁴⁾ k = 00-31
⁵⁾ k = 00-63
⁶⁾ n = 0-3
⁷⁾ g = 0-1
⁸⁾ g = 0-13
⁹⁾ g = 0-7
¹⁰⁾ g = 0-3

Note: The Multiplexer Array FIFO registers are not directly accessible !

MCA05982_mod2

Figure 23-80 GPTA0 Kernel Registers

In the TC1728, the registers of the GPTA[®]v5 units are located in the following address ranges.

Table 23-18 Registers Address Space

Module	Base Address	End Address	Note
GPTA0	F000 1800 _H	F000 1FFF _H	-

Table 23-19 Registers Overview - GPTA0 Kernel Registers

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
GPTA0_CLC ²⁾	GPTA Clock Control Register	0000 _H	U, SV	SV, E	3	Page 23-245
GPTA0_DBGCTR ²⁾	GPTA Debug Clock Control Register	0004 _H	U, SV	U, SV	3	Page 23-249

General Purpose Timer Array (GPTA®v5)

Table 23-19 Registers Overview - GPTA0 Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
ID	GPTA Identification Register	0008 _H	U, SV	nBE	3	Page 23-166
GPTA0_FDR ²⁾	GPTA Fractional Divider Register	000C _H	U, SV	SV, E	3	Page 23-246
SRSC0	Service Request State Clear Register 0	010 _H	U, SV	U, SV	3	Page 23-219
SRSS0	Service Request State Set Register 0	014 _H	U, SV	U, SV	3	Page 23-221
SRSC1	Service Request State Clear Register 1	018 _H	U, SV	U, SV	3	Page 23-222
SRSS1	Service Request State Set Register 1	01C _H	U, SV	U, SV	3	Page 23-223
SRSC2	Service Request State Clear Register 2	020 _H	U, SV	U, SV	3	Page 23-224
SRSS2	Service Request State Set Register 2	024 _H	U, SV	U, SV	3	Page 23-225
SRSC3	Service Request State Clear Register 3	028 _H	U, SV	U, SV	3	Page 23-226
SRSS3	Service Request State Set Register 3	02C _H	U, SV	U, SV	3	Page 23-227
SRNR	Service Request Node Redirection Register	030 _H	U, SV	U, SV	3	Page 23-228
MRCTL	Multiplexer Register Array Control Register	0038 _H	U, SV	U, SV	3	Page 23-203
MRADIN	Multiplexer Register Array Data In Register	003C _H	U, SV, 32	U, SV, 32	3	Page 23-204
MRADOUT	Multiplexer Register Array Data Out Register	0040 _H	U, SV, 32	U, SV, 32	3	Page 23-205
FPCSTAT	Filter and Prescaler Cell Status Register	0044 _H	U, SV	U, SV	3	Page 23-167
FPCCTRk	Filter and Prescaler Cell Control Register k (k = 0-5)	0048 _H + k × 8	U, SV	U, SV	3	Page 23-168

General Purpose Timer Array (GPTA®v5)

Table 23-19 Registers Overview - GPTA0 Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
FPCTIMk	Filter and Prescaler Cell Timer Register k (k = 0-5)	004C _H + k × 8	U, SV	U, SV	3	Page 23-170
PDLCTR	Phase Discrimination Logic Control Register	0078 _H	U, SV	U, SV	3	Page 23-171
DCMCTRk	Duty Cycle Measurement Control Register k (k = 0-3)	0080 _H + k × 16	U, SV	U, SV	3	Page 23-173
DCMTIMk	Duty Cycle Measurement Timer Register k (k = 0-3)	0084 _H + k × 16	U, SV	U, SV	3	Page 23-174
DCMCAVk	Duty Cycle Measurement Capture Register k (k = 0-3)	0088 _H + k × 16	U, SV	U, SV	3	Page 23-175
DCMCOVk	Duty Cycle Measurement Capture/Compare Register k (k = 0-3)	008C _H + k × 16	U, SV	U, SV	3	Page 23-175
PLLCTR	Phase Locked Loop Control Register	00C0 _H	U, SV	U, SV	3	Page 23-176
PLLMTI	Phase Locked Loop Micro Tick Register	00C4 _H	U, SV	U, SV	3	Page 23-177
PLLCNT	Phase Locked Loop Counter Register	00C8 _H	U, SV	U, SV	3	Page 23-178
PLLSTP	Phase Locked Loop Step Register	00CC _H	U, SV	U, SV	3	Page 23-177
PLLREV	Phase Locked Loop Reload Register	00D0 _H	U, SV	U, SV	3	Page 23-178
PLLDTR	Phase Locked Loop Delta Register	00D4 _H	U, SV	U, SV	3	Page 23-179
CKBCTR	Clock Bus Control Register	00D8 _H	U, SV	U, SV	3	Page 23-182

General Purpose Timer Array (GPTA®v5)

Table 23-19 Registers Overview - GPTA0 Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
GTCTRk	Global Timer Control Register k (k = 0, 1)	00E0 _H + k × 16	U, SV	U, SV	3	Page 23-180
GTREVK	Global Timer Reload Value Register k (k = 0, 1)	00E4 _H + k × 16	U, SV	U, SV	3	Page 23-181
GTTIMk	Global Timer Register k (k = 0, 1)	00E8 _H + k × 16	U, SV	U, SV	3	Page 23-181
GTCCTRk	Global Timer Cell Control Register k (k = 00-31)	0100 _H + k × 8	U, SV	U, SV	3	Page 23-184 Page 23-186
GTCXRk	Global Timer Cell X Register k (k = 00-31)	0104 _H + k × 8	U, SV	U, SV	3	Page 23-188
LTCCTRk	Local Timer Cell Control Register k (k = 00-62)	0200 _H + k × 8	U, SV	U, SV	3	Page 23-189 Page 23-194 Page 23-197
LTCXRk	Local Timer Cell X Register k (k = 00-62)	0204 _H + k × 8	U, SV	U, SV	3	Page 23-201
LTCCTR63	Local Timer Cell Control Register 63	03F8 _H	U, SV	U, SV	3	Page 23-200
LTCXR63	Local Timer Cell X Register 63	03FC _H	U, SV	U, SV	3	Page 23-202
GPTA0_EDCTR ²⁾	GPTA Clock Enable/Disable Control Register	0400 _H	U, SV	U, SV	3	Page 23-248

General Purpose Timer Array (GPTA®v5)

Table 23-19 Registers Overview - GPTA0 Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr. ¹⁾	Access Mode		Reset Class	Description see
			Read	Write		
OTMCRg	On-Chip Trigger and Gating Signal Multiplexer Control Register of Group g (g = 0-1)	not directly address-able;	n.a.	n.a.	3	Page 23-210
OMCRLg	Output Multiplexer Control Register for Lower Half of Group g (g = 0-13)	see Page 23-121	n.a.	n.a.	3	Page 23-206
OMCRHg	Output Multiplexer Control Register for Upper Half of Group g (g = 0-13)		n.a.	n.a.	3	Page 23-208
GIMCRLg	Input Multiplexer Control Register for Lower Half of GTC Group g (g = 0-3)		n.a.	n.a.	3	Page 23-211
GIMCRHg	Input Multiplexer Control Register for Lower Half of GTC Group g (g = 0-3)		n.a.	n.a.	3	Page 23-213
LIMCRLg	Input Multiplexer Control Register for Upper Half of LTC Group g (g = 0-7)	not directly address-able;	n.a.	n.a.	3	Page 23-215
LIMCRLg	Input Multiplexer Control Register for Upper Half of LTC Group g (g = 0-7)	see Page 23-121	n.a.	n.a.	3	Page 23-217

- 1) The absolute register address is calculated as follows:
Unit Base Address + Offset Address (shown in this column)
- 2) Only implemented in GPTA0 kernel.

Bit Protection

Bits with bit protection (this is valid, for example, for all bits in the Service Request State Registers) are not changed during a read-modify-write instruction, for example when

General Purpose Timer Array (GPTA[®]v5)

hardware sets a request state bit between the read and the write of the read-modify-write sequence. For bit protected bits it is guaranteed that a hardware setting operation always has priority. Thus, no hardware triggered events are lost.

Bits with bit protection are marked in the corresponding bit descriptions.

General Purpose Timer Array (GPTA[®]v5)

23.4.1 GPTA[®]v5 Identification Register

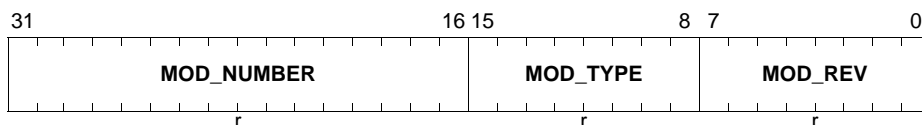
The GPTA[®]v5 Identification Register ID contains read-only information about the module version.

GPTA0_ID

GPTA0 Identification Register

(08_H)

Reset Value: 0029 C0XX_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the Module revision number. The value of a module revision starts with 01 _H (first revision). GPTAv5 will start with module revision 05 _H .
MOD_TYPE	[15:8]	r	Module Number Value This bit field defines the module as a 32 bit module: C0 _H
MOD_NUM	[31:16]	r	Module Number Value This bit field defines the identification number for the GPTA: 0029 _H

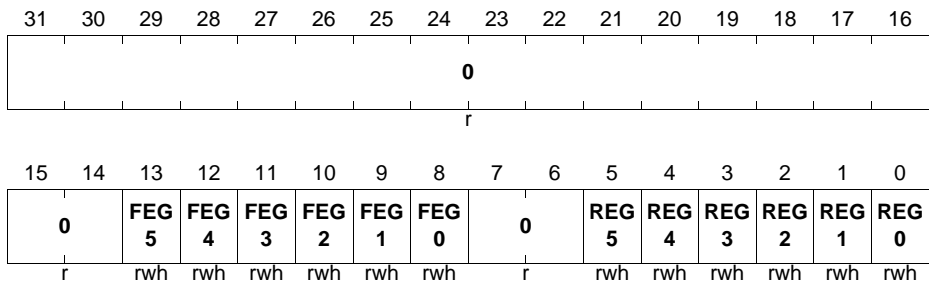
General Purpose Timer Array (GPTA[®]v5)

23.4.2 FPC Registers

GPTA0_FPCSTAT

GPTA0 Filter and Prescaler Cell Status Register

(044_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
REGk (k = 0-5)	k	rwh	Rising Edge Glitch Flag for FPCK 0 _B No rising edge of glitch detected during filtering 1 _B Rising edge of glitch detected during filtering Bits REGk are bit protected (see Section 23.4.2).
FEGk (k = 0-5)	k+8	rwh	Falling Edge Glitch Flag for FPCK 0 _B No falling edge of glitch detected during filtering 1 _B Falling edge of glitch detected during filtering Bits FEGk are bit protected (see Section 23.4.2).
0	[7:6], [31:14]	r	Reserved Read as 0; should be written with 0.

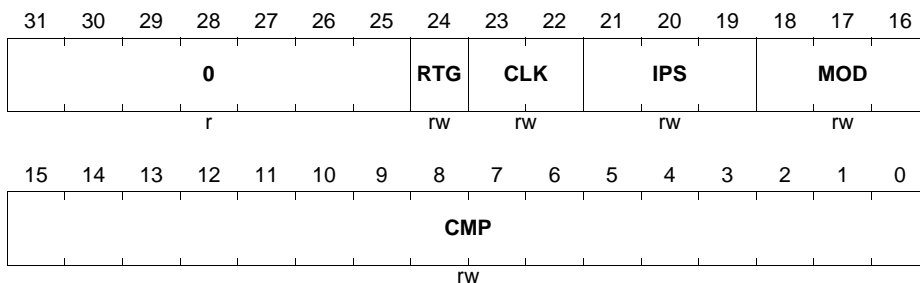
General Purpose Timer Array (GPTA®v5)

GPTA0_FPCCTRk (k = 0-5)

GPTA0 Filter and Prescaler Cell Control Register k

(048_H+k*8_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CMP	[15:0]	rw	Threshold Value of Filter and Prescaler Cell k CMP is the 16-bit threshold value that is compared with the 16-bit timer value FPCTIMk.TIM.
MOD	[18:16]	rw	Operation Mode Selection for FPCk 000 _B Delayed Debounce Filter Mode on both edges 001 _B Immediate Debounce Filter Mode on both edges 010 _B Rising edge: Immediate Debounce Filter Mode, falling edge: no filtering 011 _B Rising edge: no filtering, falling edge: Immediate Debounce Filter Mode 100 _B Rising edge: Delayed Debounce Filter Mode, falling edge: Immediate Debounce Filter Mode 101 _B Rising edge: Immediate Debounce Filter Mode, falling edge: Delayed Debounce Filter Mode 110 _B Prescaler Mode (triggered on rising edge) 111 _B Prescaler Mode (triggered on falling edge)

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
IPS	[21:19]	rw	Input Line Selection for FPCK IPS determines the signal input used for edge detection. 000 _B Signal input SINK0 selected 001 _B Signal input SINK1 selected 010 _B Signal input SINK2 selected 011 _B Signal input SINK3 selected 100 _B Signal input SINK4 = GPTA [®] v5 module clock f_{GPTA} selected 101 _B Signal input SINK5 = preceding FPC output SOLk-1 selected; SIN05 is connected to SOL5 11X _B Reserved
CLK	[23:22]	rw	Clock Selection for FPCK CLK selects the clock signal used for edge detection. 00 _B Clock input line 0 selected (GPTA [®] v5 module clock f_{GPTA}) 01 _B Clock bus line 1 selected (local PLL clock) 10 _B Clock bus line 2 selected (prescaled) GPTA [®] v5 module clock f_{GPTA} or PLL clock from other unit or DCM 3 clock 11 _B Clock bus line 3 selected DCM 2 clock or PLL clock of other unit or uncompensated PLL clock or uncompensated PLL clock of other unit
RTG	24	rw	Reset Timer for FPCK on Glitch 0 _B Timer for FPCK is decremented on glitch 1 _B Timer for FPCK is cleared on glitch This bit is effective in Delayed Debounce Filter Mode only.
0	[31:25]	r	Reserved Read as 0; should be written with 0.

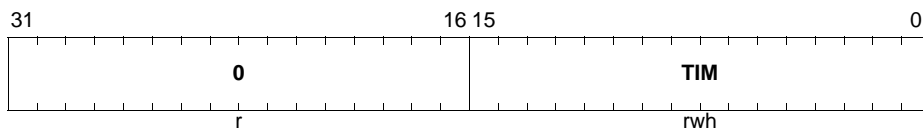
General Purpose Timer Array (GPTA®v5)

GPTA0_FPCTIMk (k = 0-5)

GPTA0 Filter and Prescaler Cell Timer Register k

($048_H + k * 8_H + 4_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TIM	[15:0]	rwh	Timer Value of Filter and Prescaler Cell k
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

23.4.3 Phase Discriminator Registers

GPTA0_PDLCTR

GPTA0 Phase Discrimination Logic Control Register

(078_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
				0					ERR	TSE	MUX	0	ERR	TSE	MUX
									1	1	1	r	0	0	0
									rwh	rw	rw		rwh	rw	rw

Field	Bits	Type	Description
MUX0	0	rw	Output Signal Source Selection for PDL0 0 _B DCM0 cell input is driven by fed-through FPC0 output lines 1 _B DCM0 cell input is provided with PDL0 “Forward” and “Backward” pulses
TSE0	1	rw	3-Sensor Mode Enable for PDL0 0 _B PDL0 operates in “2-Sensor Mode” and DCM1 cell input is driven by fed-through FPC2 output lines 1 _B PDL0 operates in “3-Sensor Mode” and DCM1 cell input is provided with PDL0 error information
ERR0	2	rwh	Error Flag for PDL0 0 _B No error has occurred 1 _B Error detected in “3-Sensor Mode”: all PDL0 input signals are simultaneously provided with high or low level Bit ERR0 is bit protected (see Page 23-167).
MUX1	4	rw	Output Signal Source Selection for PDL1 0 _B DCM2 cell input is driven by fed-through FPC3 output lines 1 _B DCM2 cell input is provided with PDL1 “Forward” and “Backward” pulses
TSE1	5	rw	3-Sensor Mode Enable for PDL1 0 _B PDL1 operates in “2-Sensor Mode” and DCM3 cell input is driven by fed-through FPC5 output lines 1 _B PDL1 operates in “3-Sensor Mode” and DCM3 cell input is provided with PDL1 error information

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
ERR1	6	rwh	Error Flag for PDL1 0_B No error has occurred 1_B Error detected in “3-Sensor Mode”: all PDL1 input signals are simultaneously provided with high or low level Bit ERR1 is bit protected (see Page 23-167).
0	3, [31:7]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

23.4.4 Duty Cycle Measurement Registers

GPTA0_DCMCTRk (k = 0-3)

GPTA0 Duty Cycle Measurement Control Register k

(080_H+k*10_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						CRE	FRE	RRE	QCK	FCK	RCK	FZE	RZE	OCA	RCA
r						rw	rw	rw	w	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
RCA	0	rw	Trigger Source Selection for Capture Event 0 _B Timer contents are copied to DCMCAV _k capture register on a falling input signal edge 1 _B Timer contents are copied to capture register on a rising input signal edge
OCA	1	rw	Trigger Source for Capture/Compare Register Update 0 _B Capture/Compare register DCMCOV _k is not affected. 1 _B Timer contents are copied to DCMCOV _k capture/compare register on the opposite edge selected by RCA _k .
RZE	2	rw	Timer Reset on Rising Edge 0 _B Timer is not affected 1 _B Timer is reset on a rising input signal edge
FZE	3	rw	Timer Reset on Falling Edge 0 _B Timer is not affected 1 _B Timer is reset on a falling input signal edge
RCK	4	rw	Output Pulse on Rising Edge 0 _B DCM output line is not affected 1 _B DCM output line is provided with a single clock pulse generated on a rising input signal edge

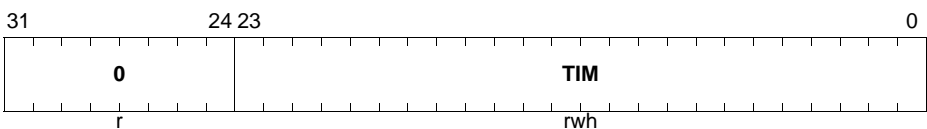
General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
FCK	5	rw	Output Pulse on Falling Edge 0_B DCM output line is not affected 1_B DCM output line is provided with a single clock pulse generated on a falling input signal edge
QCK	6	w	Additional Output Pulse Generation 0_B DCM output line is not affected 1_B DCM output line is immediately provided with a single clock pulse QCK is always read as 0.
RRE	7	rw	Interrupt Request on Rising Edge 0_B Interrupt request is not affected 1_B Interrupt request is set on rising input signal edge
FRE	8	rw	Interrupt Request on Falling Edge 0_B Interrupt request is not affected 1_B Interrupt request is set on falling input signal edge
CRE	9	rw	Interrupt Request on Compare Event 0_B Interrupt request is not affected 1_B Interrupt request is set when the timer matches capture/compare register DCMCOV k
0	[31:10]	r	Reserved Read as 0; should be written with 0.

GPTA0_DCMTIM k ($k = 0-3$)

GPTA0 Duty Cycle Measurement Timer Register k

$$(080_H + k * 10_H + 4_H)$$

Reset Value: 0000 0000 $_H$


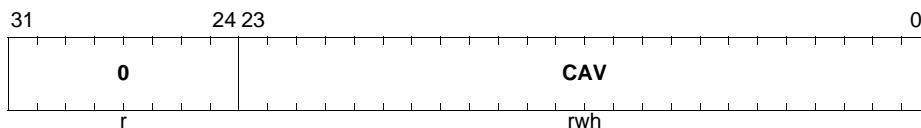
Field	Bits	Type	Description
TIM	[23:0]	rwh	Timer Value of DCMk
0	[31:24]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_DCMCAV_k (k = 0-3)

GPTA0 Duty Cycle Measurement Capture Register k
(088_H+k*10_H)

Reset Value: 0000 0000_H

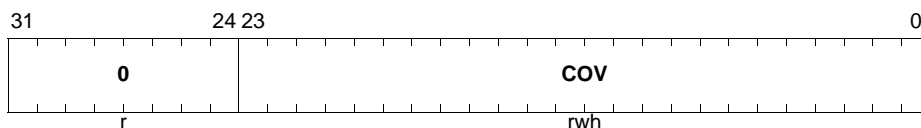


Field	Bits	Type	Description
CAV	[23:0]	rwh	Capture Value of DCMk
0	[31:24]	r	Reserved Read as 0; should be written with 0.

GPTA0_DCMCOV_k (k = 0-3)

GPTA0 Duty Cycle Measurement Capture/Compare Register k
(08C_H+k*10_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
COV	[23:0]	rwh	Capture/Compare Register Value of DCMk
0	[31:24]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

23.4.5 Digital Phase Locked Loop Registers

GPTA0_PLLCTR

GPTA0 Phase Locked Loop Control Register

(0C0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
												REN	PEN	AEN	MUX
												rw	rwh	rw	rw
								r							

Field	Bits	Type	Description
MUX	[1:0]	rw	Trigger Input Channel Selection 00 _B DCM0 output is selected as PLL input 01 _B DCM1 output is selected as PLL input 10 _B DCM2 output is selected as PLL input 11 _B DCM3 output is selected as PLL input
AEN	2	rw	Automatic End Mode Enable With the Automatic End Mode compensation of input signal's period length variation (acceleration, deceleration) is requested 0 _B Automatic End Mode is disabled 1 _B Automatic End Mode is enabled
PEN	3	rwh	Unexpected Period End Behavior 0 _B Counter decrements with constant frequency 1 _B Counter is allowed to decrement with f_{GPTA} frequency in case of an input signal period length' reduction Programming PEN to 1 immediately changes the microtick counter to decrement with f_{GPTA} frequency. This bit is protected during read-modify-write operations (hardware will win).
REN	4	rw	Interrupt Service Request Enable 0 _B Interrupt request is disabled 1 _B An interrupt request is set when the number of remaining output pulses to be generated reaches zero

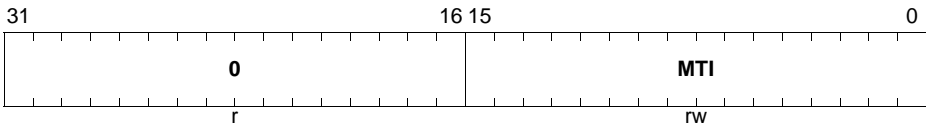
General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
0	[31:5]	r	Reserved Read as 0; should be written with 0.

GPTA0_PLLMTI

GPTA0 Phase Locked Loop Microtick Register

(0C4_H)

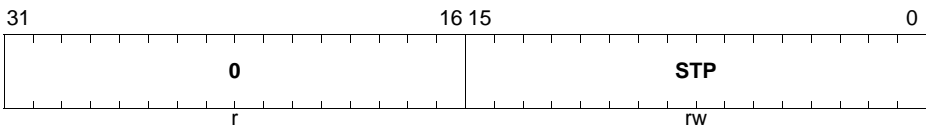
Reset Value: 0000 0000_H


Field	Bits	Type	Description
MTI	[15:0]	rw	Microtick Value Number of output pulses to be generated within one input signal period.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

GPTA0_PLLSTP

GPTA0 Phase Locked Loop Step Register

(0CC_H)

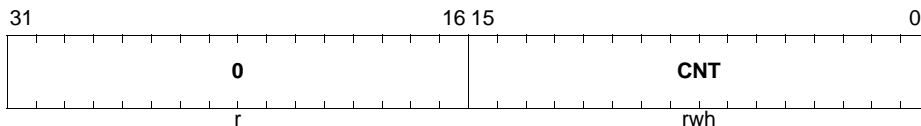
Reset Value: 0000 0000_H


Field	Bits	Type	Description
STP	[15:0]	rw	Step Value Number of output pulses to be generated within one input signal period (2-complement data format).
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_PLLCNT

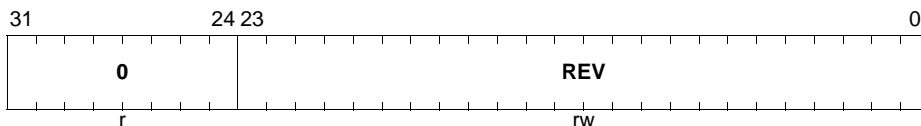
GPTA0 Phase Locked Loop Counter Register (0C8_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CNT	[15:0]	rwh	Pulse Counter Counter for the number of remaining output pulses to be generated.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

GPTA0_PLLREV

GPTA0 Phase Locked Loop Reload Register (0D0_H)

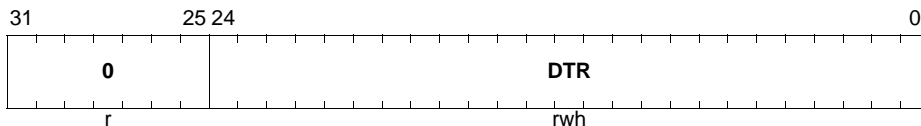
Reset Value: 0000 0000_H


Field	Bits	Type	Description
REV	[23:0]	rw	Reload Value Reload value calculated by a subtraction of the number of output pulses to be generated within one input signal period from the input signal's period length (measured in number of GPTA [®] v5 module clocks).
0	[31:24]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GPTA0_PLLDTR

GPTA0 Phase Locked Loop Delta Register (0D4_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
DTR	[24:0]	rwh	Delta Register Value Internal register used to store intermediate results for output pulse generation. Do not write to this register while PLL is running!
0	[31:25]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

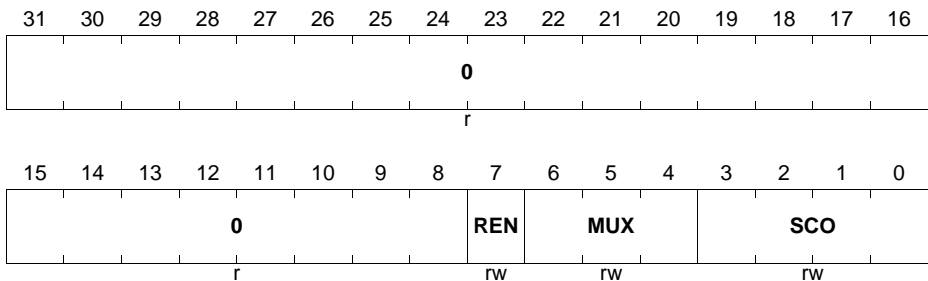
23.4.6 Global Timer Registers

GPTA0_GTCTRk (k = 0-1)

GPTA0 Global Timer Control Register k

(0E0_H+k*10_H)

Reset Value: 0000 0000_H



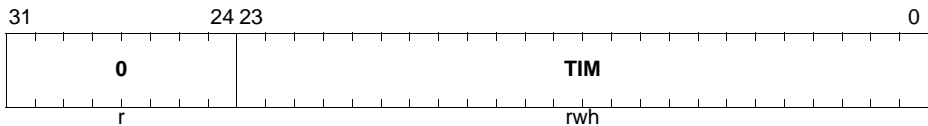
Field	Bits	Type	Description
SCO	[3:0]	rw	TGE Flag Source Selection This bit field determines the bit of the operation result “GTk timer value - data bus value” which is used as TGE flag. 0000 _B 10 th bit is used as TGE flag. 0001 _B 11 th bit is used as TGE flag. ... _B ... 1110 _B 24 th bit is used as TGE flag. 1111 _B 25 th bit is used as TGE flag.
MUX	[6:4]	rw	Timer Clock Selection One of eight available clock bus lines is selected as the timer GTk clock. 000 _B Clock bus line CLK0 selected 001 _B Clock bus line CLK1 selected 010 _B Clock bus line CLK2 selected 011 _B Clock bus line CLK3 selected 100 _B Clock bus line CLK4 selected 101 _B Clock bus line CLK5 selected 110 _B Clock bus line CLK6 selected 111 _B Clock bus line CLK7 selected
REN	7	rw	Interrupt Request Enable 0 _B The interrupt request is disabled 1 _B An interrupt request is generated when timer GTk overflows

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
0	[31:8]	r	Reserved Read as 0; should be written with 0.

GPTA0_GTTIMk (k = 0-1)

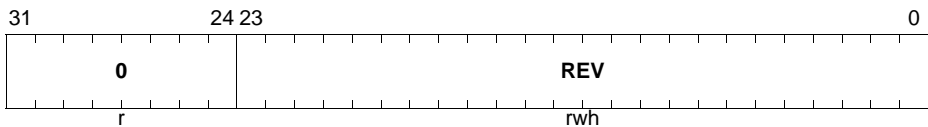
GPTA0 Global Timer Register k ($0E8_H + k * 10_H$) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
TIM	[23:0]	rwh	Timer Value of Global Timer k
0	[31:24]	r	Reserved Read as 0; should be written with 0.

GPTA0_GTREVK (k = 0-1)

GPTA0 Global Timer Reload Value Register k
($0E4_H + k * 10_H$) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
REV	[23:0]	rw	Reload Value of Global Timer k Reload value for timer GTK after an overflow
0	[31:24]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

23.4.7 Clock Bus Register

GPTA0_CKBCTR

GPTA0 Clock Bus Control Register (0D8_H)

Reset Value: 0000 FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0											DFALTC			DFA03	
r											rw			rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DFA07				DFA06				DFA04				DFA02			
rw				rw				rw				rw			

Field	Bits	Type	Description
DFA02	[3:0]	rw	Clock Line 2 Driving Source Selection 0_D CLK2 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA02} 1_D CLK2 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA02} ... 13_D CLK2 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA02} 14_D CLK2 is driven by PLL clock of other GPTA [®] v5 unit 15_D CLK2 is driven by DCM3 output
DFA04	[7:4]	rw	Clock Line 4 Driving Source Selection 0_D CLK4 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA04} 1_D CLK4 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA04} ... 14_D CLK4 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA04} 15_D CLK4 is driven by DCM1 output

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
DFA06	[11:8]	rw	Clock Line 6 Driving Source Selection 0_D CLK6 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA06} 1_D CLK6 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA06} ... 14_D CLK6 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA06} 15_D CLK6 is driven by FPC1 output
DFA07	[15:12]	rw	Clock Line 7 Driving Source Selection 0_D CLK7 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA07} 1_D CLK7 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA07} ... 14_D CLK7 is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFA07} 15_D CLK7 is driven by FPC4 output
DFA03	[17:16]	rw	Clock Line 3 Driving Source Selection 0_D CLK3 is driven by DCM2 output 1_D CLK3 is driven by PLL clock of other GPTA [®] v5 unit 2_D CLK3 is driven by uncompensated PLL clock 3_D CLK3 is driven by uncompensated PLL clock of other GPTA [®] v5 unit
DFALTC	[20:18]	rw	Dividing Factor for LTC Prescaler Clock Selection 0_D The LTCPRE clock is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFALTC} . 1_D The LTCPRE clock is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFALTC} 7_D The LTCPRE clock is provided with the GPTA [®] v5 module clock f_{GPTA} divided by 2^{DFALTC} .
0	[31:21]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

23.4.8 Global Timer Cell Registers

GPTA0_GTCCTRk (k = 00-31)

GPTA0 Global Timer Cell Control Register k [Capture Mode]

(100_H+k*8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA	OCM		CEN		0	EOA	BYP	NE	FED	RED	REN	OSM	MOD	
rh	rw	rw		rh		r	rwh	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00 _B GTCK operates in Capture Mode hooked to GT0. 01 _B GTCK operates in Capture Mode hooked to GT1. 10 _B GTCK operates in Compare Mode hooked to GT0. 11 _B GTCK operates in Compare Mode hooked to GT1.
OSM	2	rw	One Shot Mode Enable 0 _B GTCK is continuously enabled. 1 _B GTCK is enabled for one event only.
REN	3	rw	Interrupt Request Enable 0 _B Service request is disabled. 1 _B Service request line SQSk is activated when a capture or compare event has occurred.
RED	4	rw	Input Rising Edge Select 0 _B Capture event is not triggered by a rising edge. 1 _B Capture event is triggered by a rising edge on the GTCKIN input line.
FED	5	rw	Input Falling Edge Select 0 _B Capture event is not triggered by a falling edge. 1 _B Capture event is triggered by a falling edge on the GTCKIN input line.
NE	6	rw	Not Effective Reserved

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
BYP	7	rw	Bypass 0_B M00/M10 lines are affected either by M0I/M1I lines or by OCM0/OCM1 bits. 1_B M00/M10 lines are affected only by M0I/M1I lines. <i>Note: OCM2 must be set in any case to enable reaction on M0I/M1I changes.</i>
EOA	8	rwh	Enable On Action 0_B GTCK is enabled for local events. 1_B GTCK is disabled for local events. On an event on the communication link via M0I/M1I lines, EOA will be cleared and local events will be enabled. EOA is bit protected (see Section 23.4.2). EOA is cleared if mode is switched to Timer Mode.
CEN	10	rh	Cell Enable 0_B GTCK is currently disabled for local events. 1_B GTCK is currently enabled for local events.
OCM	[13:11]	rw	Output Control Mode Select 000_B Current state of GTCKOUT output line is hold 001_B Current state of GTCKOUT output line is toggled by an internal GTCK event otherwise hold 010_B GTCKOUT output line is forced to 0 by an internal GTCK event otherwise hold 011_B GTCKOUT output line is forced to 1 by an internal GTCK event otherwise hold $1XX_B$ GTCKOUT output line state is affected by an internal GTCK event and/or by an operation occurred in an adjacent GTCn ($n = \text{less or equal } k$) and reported by the M1I, M0I interface lines.
OIA	14	rw	Output Immediate Action 0_B No immediate action required. 1_B Action defined by OCM must be performed immediately. Reading bit OIA always returns 0.
OUT	15	rh	Output State 0_B GTCKOUT output line is 0. 1_B GTCKOUT output line is 1.
0	9, [31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GPTA0_GTCCTRk (k = 00-31)

GPTA0 Global Timer Cell Control Register k [Compare Mode]

 $(100_H + k \cdot 8_H)$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA	OCM		CEN		0	EOA	BYP	CAT	CAC	GES	REN	OSM	MOD	
rh	rw	rw		rh		r	rwh	rw	rw	rw	rw	rw	rw	rw	

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00 _B GTCK operates in Capture Mode hooked to GT0. 01 _B GTCK operates in Capture Mode hooked to GT1. 10 _B GTCK operates in Compare Mode hooked to GT0. 11 _B GTCK operates in Compare Mode hooked to GT1.
OSM	2	rw	One Shot Mode Enable 0 _B GTCK is continuously enabled. 1 _B GTCK is enabled for one event only.
REN	3	rw	Interrupt Request Enable 0 _B Service request is disabled. 1 _B Service request line SQSk is activated when a capture or compare event has occurred.
GES	4	rw	Greater Equal Select 0 _B An "equal" compare is selected. 1 _B A "greater equal" compare is required.
CAC	5	rw	Capture after Compare Select 0 _B Capture after compare is disabled. 1 _B After a compare event, the contents of the associated Global Timer as selected by MOD or (depending on control bit CAT) the contents of the alternate Global Timer are copied to the capture/compare register GTCXRk.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
CAT	6	rw	Capture Alternate Timer 0_B The Global Timer as selected by MOD is captured, if enabled by control bit CAC = 1. 1_B The alternate Global Timer is captured.
BYP	7	rw	Bypass 0_B M10/M00 lines are affected either by M11/M01 lines or by OCM1/OCM0 bits. 1_B M00/M10 lines are affected only by M01/M11 lines. <i>Note: OCM2 must be set in any case to enable reaction on M01/M11 changes.</i>
EOA	8	rwh	Enable On Action 0_B GTCK is enabled for local events. 1_B GTCK is disabled for local events. On an event on the communication link via M01/M11 lines, EOA will be cleared and local events will be enabled. EOA is bit protected (see Section 23.4.2). EOA is cleared if mode is switched to Timer Mode.
CEN	10	rh	Cell Enable 0_B GTCK is currently disabled for local events. 1_B GTCK is currently enabled for local events.
OCM	[13:11]	rw	Output Control Mode Select 000_B Current state of GTCKOUT output line is hold 001_B Current state of GTCKOUT output line is toggled by an internal GTCK event otherwise hold 010_B GTCKOUT output line is forced to 0 by an internal GTCK event otherwise hold 011_B GTCKOUT output line is forced to 1 by an internal GTCK event otherwise hold $1XX_B$ GTCKOUT output line state is affected by an internal GTCK event and/or by an operation occurred in an adjacent GTCn (n = less or equal k) and reported by the M11, M01 interface lines.
OIA	14	rw	Output Immediate Action 0_B No immediate action required. 1_B Action defined by OCM must be performed immediately. Reading bit OIA always returns 0.
OUT	15	rh	Output State 0_B GTCKOUT output line is 0. 1_B GTCKOUT output line is 1.

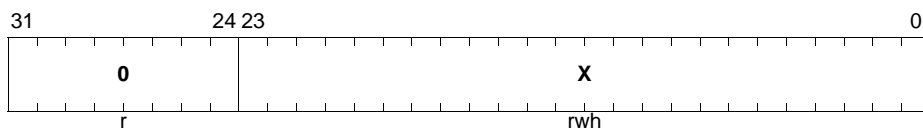
General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
0	9, [31:16]	r	Reserved Read as 0; should be written with 0.

GPTA0_GTCXRk (k = 00-31)

GPTA0 Global Timer Cell X Register k

 $(104_H + k * 8_H)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
X	[23:0]	rwh	Capture/Compare Register Contents of GTck
0	[31:24]	r	Reserved Read as 0; should be written with 0.

Note: GTCXRk is write-protected when control bits CAC and OSM are set to 1 (“capture after compare” in Single Shot Mode). Write protection is activated, when the value of the selected GT timer matches and/or exceeds the capture/compare register contents. Write protection is released after a software access to register GTCXRk.

General Purpose Timer Array (GPTA®v5)

23.4.9 Local Timer Cell Registers

GPTA0_LTCCTRk (k = 00-62)

GPTA0 Local Timer Cell Control Register k [Timer Mode ILM=0]

(200_H+k*8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
							0								G BYP
							r								rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA		OCM		CEN	CUD	ILM	CUD CLR	SLO	FED	RED	REN	OSM		MOD
rh	rw		rw		rh	rwh	rw	w	rwh	rw	rw	rw	rw		rw

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00 _B LTCK operates in Capture Mode. 01 _B LTCK operates in Compare Mode. 10 _B LTCK operates in Free-Running Timer Mode. 11 _B LTCK operates in reset Timer Mode.
OSM	2	rw	One Shot Mode Enable 0 _B LTCK is continuously enabled. 1 _B LTCK is enabled for one event only.
REN	3	rw	Request Enable 0 _B Service request is disabled. 1 _B Service request SQSk is activated when a <ul style="list-style-type: none"> - capture event has occurred - compare event has occurred - timer overflow has happened depending on the operation mode selected by bit field MOD.
RED	4	rw	Input Rising Edge Select 0 _B Timer is not updated by a rising edge. 1 _B Timer is updated by a rising edge on the LTCKIN input line.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
FED	5	rw	Input Falling Edge Select 0_B Timer is not updated by a falling edge. 1_B Timer is updated by a falling edge on the LTCKIN input line.
SLO	6	rwh	Select Line Output 0_B State of select line output SO is 0. 1_B State of select line output SO is 1. SLO is bit protected (see Page 23-167).
CUDCLR	7	w	Coherent Update Disable 0_B No effect. 1_B Coherent update disabled (bit CUD is cleared). If bits CUD and CUDCLR are both written with 1, bit CUD will be set. CUDCLR is always read as 0.
ILM	8	rw	Input Line Mode 0_B Input line is operating in Edge Sensitive Mode. 1_B Input line is operating in Level Sensitive Mode. In case of full speed GPTA [®] v5 module clock selection as input clock, Level Sensitive Mode must be selected. In this case the Edge Sensitive Mode will not produce any event.
CUD	9	rwh	Coherent Update Enable 0_B Select output SO is not toggled on timer reset overflow. 1_B Select output SO is toggled on next timer reset overflow. When CUD is set by software, it remains set until the next timer reset overflow (LTCK reset event) occurs and is cleared by hardware afterwards. CUD can be reset by software by writing bit CUDCLR with 1 and CUD with 0. CUD is automatically cleared after LTCK reset event and when mode is switched to another mode than Reset Timer Mode. This bit can only be set in Reset Timer Mode. If bits CUD and CUDCLR are both written with 1, bit CUD will be set. CUDCLR is always read as 0.
CEN	10	rh	Cell Enable 0_B LTCK is currently disabled for local events. 1_B LTCK is currently enabled for local events.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
OCM	[13:11]	rw	Output Control Mode Select 000 _B Current state of LTCKOUT output line is hold 001 _B Current state of LTCKOUT output line is toggled by an internal LTCK event otherwise hold 010 _B LTCKOUT output line is forced to 0 by an internal LTCK event otherwise hold 011 _B LTCKOUT output line is forced to 1 by an internal LTCK event otherwise hold 1XX _B LTCKOUT output line state is affected by an internal LTCK event and/or by an operation occurred in an adjacent LTCK cell (reported by M1I/M0I interface lines).
OIA	14	rw	Output Immediate Action 0 _B No immediate action required. 1 _B Action defined by bit field OCM must be performed immediately. OIA is always read as 0.
OUT	15	rh	Output State 0 _B LTCKOUT output line is 0. 1 _B LTCKOUT output line is 1.
GBYP	16	rw	Global Bypass 0 _B M3O/M2O lines are affected by M1I/M0I lines. 1 _B M3O/M2O lines are affected by M3I/M2I lines.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

GPTA0_LTCCTRk (k = 00-62)

GPTA0 Local Timer Cell Control Register k [Timer Mode ILM=1]

 $(200_H + k * 8_H)$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															G B Y P
r															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA	OCM			CEN	CUD	ILM	CUD CLR	SLO	AIL	PEN	REN	OSM	MOD	
rh	rw	rw			rh	rwh	rw	w	rwh	rw	rw	rw	rw	rw	rw

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00 _B LTCK operates in Capture Mode. 01 _B LTCK operates in Compare Mode. 10 _B LTCK operates in Free-Running Timer Mode. 11 _B LTCK operates in reset Timer Mode.
OSM	2	rw	One Shot Mode Enable 0 _B LTCK is continuously enabled. 1 _B LTCK is enabled for one event only.
REN	3	rw	Request Enable 0 _B Service request is disabled. 1 _B Service request SQSk is activated when a <ul style="list-style-type: none"> - capture event has occurred - compare event has occurred - timer overflow has happened depending on the operation mode selected by bit field MOD.
PEN	4	rw	LTC Prescaler Enable 0 _B LTC Prescaler Mode is disabled. 1 _B LTC Prescaler Mode with LTC prescaler clock LTCPRE is enabled.
AIL	5	rw	Active Input Level Select 0 _B Input signal is active high. 1 _B Input signal is active low.
SLO	6	rwh	Select Line Output 0 _B State of select line output SO is 0. 1 _B State of select line output SO is 1. SLO is bit protected (see Page 23-167).
CUDCLR	7	w	Coherent Update Disable 0 _B No effect. 1 _B Coherent update disabled (bit CUD is cleared). If bits CUD and CUDCLR are both written with 1, bit CUD will be set. CUDCLR is always read as 0.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
ILM	8	rw	Input Line Mode 0 _B Input line is operating in Edge Sensitive Mode. 1 _B Input line is operating in Level Sensitive Mode. In case of full speed GPTA®v5 module clock selection as input clock, Level Sensitive Mode must be selected. In this case the Edge Sensitive Mode will not produce any event.
CUD	9	rwh	Coherent Update Enable 0 _B Select output SO is not toggled on timer reset overflow. 1 _B Select output SO is toggled on next timer reset overflow. When CUD is set by software, it remains set until the next timer reset overflow (LTck reset event) occurs and is cleared by hardware afterwards. CUD can be reset by software by writing bit CUDCLR with 1 and CUD with 0. CUD is automatically cleared after LTck reset event and when mode is switched to another mode than Reset Timer Mode. This bit can only be set in Reset Timer Mode. If bits CUD and CUDCLR are both written with 1, bit CUD will be set. CUDCLR is always read as 0.
CEN	10	rh	Cell Enable 0 _B LTck is currently disabled for local events. 1 _B LTck is currently enabled for local events.
OCM	[13:11]	rw	Output Control Mode Select 000 _B Current state of LTckOUT output line is hold 001 _B Current state of LTckOUT output line is toggled by an internal LTck event otherwise hold 010 _B LTckOUT output line is forced to 0 by an internal LTck event otherwise hold 011 _B LTckOUT output line is forced to 1 by an internal LTck event otherwise hold 1XX _B LTckOUT output line state is affected by an internal LTck event and/or by an operation occurred in an adjacent LTck cell (reported by M11/M0I interface lines).
OIA	14	rw	Output Immediate Action 0 _B No immediate action required. 1 _B Action defined by bit field OCM must be performed immediately. OIA is always read as 0.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
OUT	15	rh	Output State 0_B LTCKOUT output line is 0. 1_B LTCKOUT output line is 1.
GBYP	16	rw	Global Bypass 0_B M3O/M2O lines are affected by M1I/M0I lines. 1_B M3O/M2O lines are affected by M3I/M2I lines.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

GPTA0_LTCCTRk (k = 00-62)

GPTA0 Local Timer Cell Control Register k [Capture Mode]

 $(200_H + k * 8_H)$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															G BYP
r															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA	OCM			CEN	SLL	ILM	EOA	BYP	FED	RED	REN	OSM	MOD	
rh	rw	rw			rh	rh	rw	rwh	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00_B LTCK operates in Capture Mode. 01_B LTCK operates in Compare Mode. 10_B LTCK operates in Free-Running Timer Mode. 11_B LTCK operates in reset Timer Mode.
OSM	2	rw	One Shot Mode Enable 0_B LTCK is continuously enabled. 1_B LTCK is enabled for one event only.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
REN	3	rw	Request Enable 0_B Service request is disabled. 1_B Service request SQSk is activated when a <ul style="list-style-type: none"> - capture event has occurred - compare event has occurred - timer overflow has happened depending on the operation mode selected by bit field MOD.
RED	4	rw	Input Rising Edge Select 0_B Capture event is not triggered by a rising edge. 1_B Capture event is triggered by a rising edge on the LTCKin input line.
FED	5	rw	Input Falling Edge Select 0_B Capture event is not triggered by a falling edge. 1_B Capture event is triggered by a falling edge on the LTCKin input line.
BYP	6	rw	Local Bypass 0_B M1O/M0O lines are affected either by M1I/M0I lines or by OCM1/OCM0 bits. 1_B M1O/M0O lines are affected only by M1I/M0I (GBYP = 0) or M2I/M2I (GBYP = 1) lines. This bit is cleared if mode is switched to Timer Mode. OCM2 must be set in any case to enable reaction on M1I/M0I change.
EOA	7	rwh	Enable On Action 0_B LTCK is enabled for local events. 1_B LTCK is disabled for local events. On an event on the communication link via M0I/M1I lines, EOA will be cleared and local events will be enabled. EOA is bit protected (see Section 23.4.2). EOA is cleared if mode is switched to Timer Mode.
ILM	8	rw	Input Line Mode 0_B Input line is operating in Edge Sensitive Mode. 1_B Input line is operating in Level Sensitive Mode. In case of full speed GPTA®v5 module clock selection as input clock, Level Sensitive Mode must be selected. In this case the Edge Sensitive Mode will not produce any event.
SLL	9	rh	Capture & Compare Mode: Select Line Level 0_B Current state of select input SI is 0. 1_B Current state of select input SI is 1.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
CEN	10	rh	Cell Enable 0 _B LTCK is currently disabled for local events. 1 _B LTCK is currently enabled for local events.
OCM	[13:11]	rw	Output Control Mode Select 000 _B Current state of LTCKOUT output line is hold 001 _B Current state of LTCKOUT output line is toggled by an internal LTCK event otherwise hold 010 _B LTCKOUT output line is forced to 0 by an internal LTCK event otherwise hold 011 _B LTCKOUT output line is forced to 1 by an internal LTCK event otherwise hold 1XX _B LTCKOUT output line state is affected by an internal LTCK event and/or by an operation occurred in an adjacent LTCK cell (reported by M1I/M0I interface lines).
OIA	14	rw	Output Immediate Action 0 _B No immediate action required. 1 _B Action defined by bit field OCM must be performed immediately. OIA is always read as 0.
OUT	15	rh	Output State 0 _B LTCKOUT output line is 0. 1 _B LTCKOUT output line is 1.
GBYP	16	rw	Global Bypass 0 _B M3O/M2O lines are affected by M1I/M0I lines. 1 _B M3O/M2O lines are affected by M3I/M2I lines.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GPTA0_LTCCTRk (k = 00-62)

GPTA0 Local Timer Cell Control Register k [Compare Mode]

 $(200_H + k \cdot 8_H)$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															G BYP
r															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT	OIA	OCM		CEN		SLL	ILM	EOA	BYP	SOH	SOL	REN	OSM	MOD	
rh	rw	rw		rh		rh	rw	rwh	rw	rw	rw	rw	rw	rw	

Field	Bits	Type	Description
MOD	[1:0]	rw	Mode Control Bits 00 _B LTCK operates in Capture Mode. 01 _B LTCK operates in Compare Mode. 10 _B LTCK operates in Free-Running Timer Mode. 11 _B LTCK operates in reset Timer Mode.
OSM	2	rw	One Shot Mode Enable 0 _B LTCK is continuously enabled. 1 _B LTCK is enabled for one event only.
REN	3	rw	Request Enable 0 _B Service request is disabled. 1 _B Service request SQSk is activated when a <ul style="list-style-type: none"> - capture event has occurred - compare event has occurred - timer overflow has happened depending on the operation mode selected by bit field MOD.
SOL	4	rw	Compare Mode: Select Output Low 0 _B Compare is deactivated or on high level. 1 _B Compare operation is enabled by a low level on select input SI ¹⁾ .
SOH	5	rw	Compare Mode: Select Output High 0 _B Compare is deactivated or on high level. 1 _B Compare operation is enabled by a high level on select input SI ¹⁾ .

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
BYP	6	rw	Bypass 0_B M1O/M0O lines are affected either by M1I/M0I lines or by OCM1/OCM0 bits. 1_B M1O/M0O lines are affected only by M1I/M0I lines. This bit is cleared if mode is switched to Timer Mode. OCM2 must be set in any case to enable reaction on M1I/M0I change.
EOA	7	rwh	Enable On Action 0_B LTCK is enabled for local events. 1_B LTCK is disabled for local events. On an event on the communication link via M0I/M1I lines, EOA will be cleared and local events will be enabled. EOA is bit protected (see Section 23.4.2). EOA is cleared if mode is switched to Timer Mode.
ILM	8	rw	Input Line Mode 0_B Input line is operating in Edge Sensitive Mode. 1_B Input line is operating in Level Sensitive Mode. In case of full speed GPTA®v5 module clock selection as input clock, Level Sensitive Mode must be selected. In this case the Edge Sensitive Mode will not produce any event.
SLL	9	rh	Select Line Level 0_B Current state of select input SI is 0. 1_B Current state of select input SI is 1.
CEN	10	rh	Cell Enable 0_B LTCK is currently disabled for local events. 1_B LTCK is currently enabled for local events.
OCM	[13:11]	rw	Output Control Mode Select 000_B Current state of LTCKOUT output line is hold 001_B Current state of LTCKOUT output line is toggled by an internal LTCK event otherwise hold 010_B LTCKOUT output line is forced to 0 by an internal LTCK event otherwise hold 011_B LTCKOUT output line is forced to 1 by an internal LTCK event otherwise hold $1XX_B$ LTCKOUT output line state is affected by an internal LTCK event and/or by an operation occurred in an adjacent LTCK cell (reported by M1I/M0I interface lines).

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
OIA	14	rw	Output Immediate Action 0_B No immediate action required. 1_B Action defined by bit field OCM must be performed immediately. OIA is always read as 0.
OUT	15	rh	Output State 0_B LTCKOUT output line is 0. 1_B LTCKOUT output line is 1.
GBYP	16	rw	Global Bypass 0_B M3O/M2O lines are affected by M1I/M0I lines. 1_B M3O/M2O lines are affected by M3I/M2I lines.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

1) To enable Compare Mode in all cases, SOL and SOH bits must be set to 1.

General Purpose Timer Array (GPTA®v5)

GPTA0_LTCCTR63

GPTA0 Local Timer Cell Control Register 63(3F8_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUT		0			CEN	0	ILM		0	FED	RED	REN	OSM	BRM	
rh		r			rh	r	rw		r	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
BRM	0	rw	Bit Reversal Mode Control 0 _B Compare uses normal sequence of local input data bus (YI) bits. 1 _B Compare uses reversed sequence of local input data bus (YI) bits.
OSM	1	rw	One Shot Mode Enable for Shadow Register Copy 0 _B Shadow register copy is continuously enabled. 1 _B Shadow register copy is enabled for one event only.
REN	[3:2]	rw	Request Enable 00 _B Service request SQT63 is disabled. 01 _B Service request SQT63 is generated when a compare event has occurred. 10 _B Service request SQT63 is generated when a shadow register copy event has occurred. 11 _B Reserved.
RED	4	rw	Rising Edge Select for Shadow Register Copy 0 _B Shadow register copy is not triggered by a rising edge on the LTC63IN input line. 1 _B Shadow register copy is triggered by a rising edge on the LTC63IN input line.
FED	5	rw	Falling Edge Select for Shadow Register Copy 0 _B Shadow register copy is not triggered by a falling edge on the LTC63IN input line. 1 _B Shadow register copy is triggered by a falling edge on the LTC63IN input line.

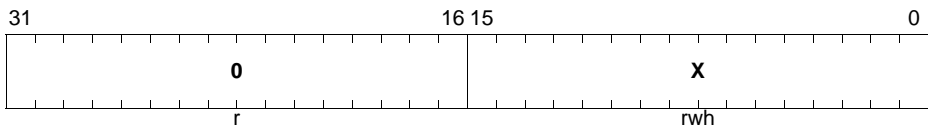
General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
ILM	8	rw	Shadow Register Copy Input Line Mode 0 _B LTC63IN is operating in Edge Sensitive Mode. 1 _B LTC63IN is operating in Level Sensitive Mode.
CEN	10	rh	Enable for Shadow Register Copy 0 _B Shadow register copy is currently disabled. 1 _B Shadow register copy is currently enabled.
OUT	15	rh	Output State 0 _B LTC63OUT output line is 0. 1 _B LTC63OUT output line is 1.
0	[7:6], 9, [14:11], [31:16]	r	Reserved Read as 0; should be written with 0.

GPTA0_LTCXRk (k = 00-62)

GPTA0 Local Timer Cell X Register k(204_H+k*8_H)

Reset Value: 0000 0000_H

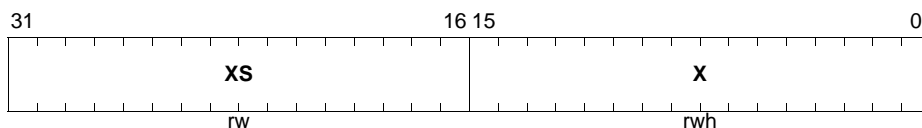


Field	Bits	Type	Description
X	[15:0]	rwh	Local Timer Data Register Value
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GPTA0_LTCXR63

GPTA0 Local Timer Cell X Register 63(3FC_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
X	[15:0]	rwh	Compare Register Value Software write operations has priority above a simultaneous hardware update.
XS	[31:16]	rw	Shadow Register Value

General Purpose Timer Array (GPTA®v5)

23.4.10 Multiplexer Control Registers

These registers are not directly accessible and can be written and read only via the multiplexer register array FIFO (see [Page 23-121](#)).

I/O Sharing Block Registers

The three registers MRACTL, MRADIN, and MRADOUT are used to write data to and read data from the GTCA Multiplexer Register Array FIFO. The Multiplexer Register Array FIFO controls the operation of the Input/Output Line Sharing Block (see).

The Multiplexer Register Array Control register controls the operation of the Multiplexer Register Array FIFO.

GPTA0_MRACTL

GPTA0 Multiplexer Register Array Control Register

(038_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										0			FIFO FUL L	WCR ES	MA EN
r		r								r			r	w	rw

Field	Bits	Type	Description
MAEN	0	rw	Multiplexer Array Enable Bit field MAEN enables/disables the programming and the interconnections of the multiplexer array. 0 _B Multiplexer array is disabled; all cell inputs are driven with 0, GPTA®v5 I/O lines (pins) are disconnected and FIFO writing is enabled. 1 _B Multiplexer array is enabled; all cell and I/O line interconnections are established as previously programmed and FIFO writing is disabled.

General Purpose Timer Array (GPTA®v5)

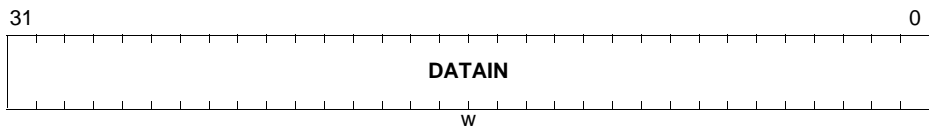
Field	Bits	Type	Description
WCRES	1	w	Write Count Reset Writing WCRES with 1 while the array is disabled (MAEN = 0), resets the write cycle counter to zero and the FIFO written sequentially (initialized). WCRES is always read as 0.
FIFOFULL	2	r	FIFO Full Status 0 _B FIFO not completely written (write access to MRADIN allowed). 1 _B FIFO completely written (write access to MRADIN ignored). Must be re-enabled via WCRES before array can be re-initialized.
FIFOFILLCNT	[13:8]	r	FIFO Fill Count This bit field shows the current contents of the write cycle counter.
0	[7:3], [31:14]	r	Reserved Read as 0; should be written with 0.

The Multiplexer Register Array Data In register is used to **write** data to the Multiplexer Register Array FIFO. The Multiplexer Register Array Data Out register is used to **read** data from the Multiplexer Register Array FIFO.

GPTA0_MRADIN

GPTA0 Multiplexer Register Array Data In Register

(03C_H)

Reset Value: 0000 0000_H


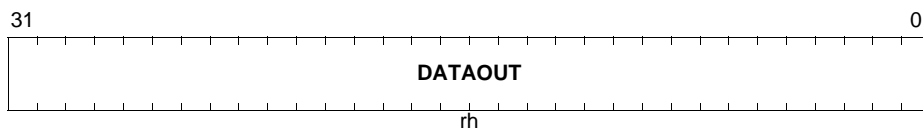
Field	Bits	Type	Description
DATAIN	[31:0]	w	FIFO Write Data This register contains the FIFO write data as defined for the Output Multiplexer Control Registers and the Input Multiplexer Control Registers.

General Purpose Timer Array (GPTA®v5)

GPTA0_MRADOUT

GPTA0 Multiplexer Register Array Data Out Register

(040_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
DATAOUT	[31:0]	rh	FIFO Read Data This register contains the FIFO read data as assigned for the Output Multiplexer Control Registers and the Input Multiplexer Control Registers.

Note: For correct operation, the MRADIN and MRADIN registers must be always read or written 32-bit wide. 8-bit and 16-bit accesses are ignored without any bus error!

General Purpose Timer Array (GPTA[®]v5)

Output Multiplexer Control Registers

Two registers, OMCRL and OMCRH, are assigned to each I/O Group IOG[6:0] and each Output Group OG[6:0]. OMCRL[6:0]/OMCRH[6:0] are assigned to IOG[6:0] and OMCRL[13:7]/OMCRH[13:7] are assigned to OG[6:0].

OMCRL controls the connections of group pins 0 to 3. OMCRH controls the connections of group pins 4 to 7.

GPTA0_OMCRLg (g = 0-13)

GPTA0 Output Multiplexer Control Register for Lower Half of Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	OMG3		0	OML3		0	OMG2		0	OML2		0	OML2		
r	rw		r	rw		r	rw		r	rw		r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	OMG1		0	OML1		0	OMG0		0	OML0		0	OML0		
r	rw		r	rw		r	rw		r	rw		r	rw		

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
OML0, OML1, OML2, OML3	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a OMG that can be selected by bit field OMGn for OMG output n. 000 _B OMG input IN0 selected 001 _B OMG input IN1 selected 010 _B OMG input IN2 selected 011 _B OMG input IN3 selected 100 _B OMG input IN4 selected 101 _B OMG input IN5 selected 110 _B OMG input IN6 selected 111 _B OMG input IN7 selected
OMG0, OMG1, OMG2, OMG3	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the OMGng which is connected to input n of I/O Group g or Output group g-7. X00 _B OMG0g selected X01 _B OMG1g selected X10 _B OMG2g selected All other combinations are reserved. If a reserved combination of OMGn value is selected, the corresponding OMG output is forced to 0 level. For compatibility reasons, OMGn[2] = 0 should be used (as value for X) for OMGn bit field programming.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GPTA0_OMCRHg (g = 0-13)

Output Multiplexer Control Register for Upper Half of Pin Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	OMG7			0	OML7			0	OMG6			0	OML6		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	OMG5			0	OML5			0	OMG4			0	OML4		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
OML4, OML5, OML6, OML7	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a OMG that can be selected by bit field OMGn for OMG output n. 000 _B OMG input IN0 selected 001 _B OMG input IN1 selected 010 _B OMG input IN2 selected 011 _B OMG input IN3 selected 100 _B OMG input IN4 selected 101 _B OMG input IN5 selected 110 _B OMG input IN6 selected 111 _B OMG input IN7 selected
OMG4, OMG5, OMG6, OMG7	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the OMGng which is connected to input n of I/O Group g or Output group g-7. X00 _B OMG0g selected X01 _B OMG1g selected X10 _B OMG2g selected All other combinations are reserved. If a reserved combination of OMGn value is selected, the corresponding OMG output is forced to 0 level. For compatibility reasons, OMGn[2] = 0 should be used (as value for X) for OMGn bit field programming.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

On-Chip Trigger and Gating Signal Multiplexer Control Registers

OTMCR controls the connections of I/O output group signals to the Trigger and Gating Signals TRIGgn

GPTA0_OTMCRg (g = 0-1)

GPTA0 On-Chip Trigger and Gating Multiplexer Control Register of Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	OTM7			0	OTM6			0	OTM5			0	OTM4		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	OTM3			0	OTM2			0	OTM1			0	OTM0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
OTMn, (n=0...7)	[4 x (n + 4):4 x n]	rw	Multiplexer Line Selection This bit field selects the input line of a OMG that can be selected by bit field OMGn for OMG output n. 000 _B OTMG input IN0 selected 001 _B OTMG input IN1 selected 010 _B OTMG input IN2 selected 011 _B OTMG input IN3 selected 100 _B OTMG input IN4 selected 101 _B OTMG input IN5 selected 110 _B OTMG input IN6 selected 111 _B OTMG input IN7 selected
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA®v5)

GTC Input Multiplexer Control Registers

Two registers, GIMCRL and GIMCRH, are assigned to each GTCG[3:0]. GIMCRL controls the connections of cells 0 to 3 in a GTC Group. GIMCRH controls the connections of cells 4 to 7 in a GTC Group.

Note: These registers are not directly accessible and can be written and read only via the multiplexer register array FIFO (see [Section 23.3.4.6](#)).

GPTA0_GIMCRLg (g = 0-3)

GPTA0 Input Multiplexer Control Register for Lower Half of GTC Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GIM EN3		GIMG3		0	GIML3		GIM EN2		GIMG2		0	GIML2			
r		rw		r	rw		r		rw		r	rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GIM EN1		GIMG1		0	GIML1		GIM EN0		GIMG0		0	GIML0			
rw		rw		r	rw		rw		rw		r	rw			

Field	Bits	Type	Description
GIML0, GIML1, GIML2, GIML3	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a GIMG that can be selected by bit field GIMGn for GIMG output n. 000 _B GIMG input IN0 selected 001 _B GIMG input IN1 selected 010 _B GIMG input IN2 selected 011 _B GIMG input IN3 selected 100 _B GIMG input IN4 selected 101 _B GIMG input IN5 selected 110 _B GIMG input IN6 selected 111 _B GIMG input IN7 selected

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
GIMG0, GIMG1, GIMG2, GIMG3	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the GIMGn which is connected to input n of GTC group g. 000 _B GIMG0g selected 001 _B GIMG1g selected (reserved for g = 3) 010 _B GIMG2g selected 011 _B GIMG3g selected 100 _B GIMG4g selected All other combinations are reserved.
GIMEN0, GIMEN1, GIMEN2, GIMEN3	7, 15, 23, 31	rw	Enable Multiplexer Connection 0 _B Input n is not connected to any line. 1 _B Input n is connected to the line defined by GIMLn and GIMGn.
0	3, 11, 19, 27	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_GIMCRHg (g = 0-3)

GPTA0 Input Multiplexer Control Register for Upper Half of GTC Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GIMEN7	GIMG7			0	GIML7			GIMEN6	GIMG6			0	GIML6		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GIMEN5	GIMG5			0	GIML5			GIMEN4	GIMG4			0	GIML4		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
GIML4, GIML5, GIML6, GIML7	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a GIMG that can be selected by bit field GIMGn for GIMG output n. 000 _B GIMG input IN0 selected 001 _B GIMG input IN1 selected 010 _B GIMG input IN2 selected 011 _B GIMG input IN3 selected 100 _B GIMG input IN4 selected 101 _B GIMG input IN5 selected 110 _B GIMG input IN6 selected 111 _B GIMG input IN7 selected
GIMG4, GIMG5, GIMG6, GIMG7	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the GIMGng which is connected to input n of GTC group g. 000 _B GIMG0g selected 001 _B GIMG1g selected (reserved for g = 3) 010 _B GIMG2g selected 011 _B GIMG3g selected 100 _B GIMG4g selected All other combinations are reserved.
GIMEN4, GIMEN5, GIMEN6, GIMEN7	7, 15, 23, 31	rw	Enable Multiplexer Connection 0 _B Input n is not connected to any line. 1 _B Input n is connected to the line defined by GIMLn and GIMGn.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
0	3, 11, 19, 27	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

LTC Input Multiplexer Control Registers

Two registers, LIMCRL and LIMCRH, are assigned to each LTC group. LIMCRL controls the connections of LTC group cells with index 0 to 3. LIMCRH controls the connections of LTC group cells with index 4 to 7.

Note: These registers are not directly accessible and can be written and read only via the multiplexer register array FIFO (see [Section 23.3.4.6](#)).

GPTA0_LIMCRLg (g = 0-7)

GPTA0 Input Multiplexer Control Register for Lower Half of LTC Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LIM EN3	LIMG3			0	LIML3			LIM EN2	LIMG2			0	LIML2		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LIM EN1	LIMG1			0	LIML1			LIM EN0	LIMG0			0	LIML0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
LIML0, LIML1, LIML2, LIML3	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a LIMG that can be selected by bit field LIMGn for LIMG output n. 000 _B LIMG input IN0 selected 001 _B LIMG input IN1 selected 010 _B LIMG input IN2 selected 011 _B LIMG input IN3 selected 100 _B LIMG input IN4 selected 101 _B LIMG input IN5 selected 110 _B LIMG input IN6 selected 111 _B LIMG input IN7 selected

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
LIMG0, LIMG1, LIMG2, LIMG3	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the LIMGn which is connected to input n of LTC group g. 000 _B LIMG0g selected 001 _B LIMG1g selected (reserved for g = 3) 010 _B LIMG2g selected 011 _B LIMG3g selected 100 _B LIMG4g selected All other combinations are reserved.
LIMEN0, LIMEN1, LIMEN2, LIMEN3	7, 15, 23, 31	rw	Enable Multiplexer Connection 0 _B Input n is not connected to any line. 1 _B Input n is connected to the line defined by LIMLn and LIMGn.
0	3, 11, 19, 27	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_LIMCRHg (g = 0-7)

GPTA0 Input Multiplexer Control Register for Upper Half of LTC Group g

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LIM EN7	LIMG7		0	LIML7		LIM EN6	LIMG6		0	LIML6					
r	rw		r	rw		r	rw		r	rw		r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LIM EN5	LIMG5		0	LIML5		LIM EN4	LIMG4		0	LIML4					
r	rw		r	rw		r	rw		r	rw		r	rw		

Field	Bits	Type	Description
LIML4, LIML5, LIML6, LIML7	[2:0], [10:8], [18:16], [26:24]	rw	Multiplexer Line Selection This bit field selects the input line of a LIMG that can be selected by bit field LIMGn for LIMG output n. 000 _B LIMG input IN0 selected 001 _B LIMG input IN1 selected 010 _B LIMG input IN2 selected 011 _B LIMG input IN3 selected 100 _B LIMG input IN4 selected 101 _B LIMG input IN5 selected 110 _B LIMG input IN6 selected 111 _B LIMG input IN7 selected
LIMG4, LIMG5, LIMG6, LIMG7	[6:4], [14:12], [22:20], [30:28]	rw	Multiplexer Group Selection This bit field determines the LIMGng which is connected to input n of LTC group g. 000 _B LIMG0g selected 001 _B LIMG1g selected (reserved for g = 3) 010 _B LIMG2g selected 011 _B LIMG3g selected 100 _B LIMG4g selected All other combinations are reserved.
LIMEN4, LIMEN5, LIMEN6, LIMEN7	7, 15, 23, 31	rw	Enable Multiplexer Connection 0 _B Input n is not connected to any line. 1 _B Input n is connected to the line defined by LIMLn and LIMGn.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
0	3, 11, 19, 27	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
PLL	12	rwh ¹⁾	Counter Service Request State for PLL 0 _B No service is requested. 1 _B Service is requested because the counter for the number remaining output pulses decremented to 0.
GT00	13	rwh ¹⁾	GT0 Timer Service Request State 0 _B No service is requested. 1 _B Service is requested due to a GT0 timer overflow.
GT01	14	rwh ¹⁾	GT1 Timer Service Request State 0 _B No service is requested. 1 _B Service is requested due to a GT1 timer overflow.
0	[31:15]	r	Reserved Read as 0; should be written with 0.

1) Writing an one to a set bit clears the bit. All other write operations have no effect.

2) k = 0-3; k = 0 refers to DCM00R, DCM00F, or DCM00C; k = 1 refers to DCM01R, DCM01F, or DCM01C; k = 2 refers to DCM02R, DCM02F, or DCM02C; k = 3 refers to DCM03R, DCM03F, or DCM03C.

General Purpose Timer Array (GPTA®v5)

GPTA0_SRSS0

GPTA0 Service Request State Set Register 0

(014_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	GT 01	GT 00	PLL	DCM 03C	DCM 03F	DCM 03R	DCM 02C	DCM 02F	DCM 02R	DCM 01C	DCM 01F	DCM 01R	DCM 00C	DCM 00F	DCM 00R
r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
DCM00R, DCM01R, DCM02R, DCM03R	0, 3, 6, 9	rwh ¹⁾	DCMk²⁾ Rising Edge Event Service Request State 0 _B No service is requested. 1 _B Service is requested due to a rising edge detected on DCMk input signal line.
DCM00F, DCM01F, DCM02F, DCM03F	1, 4, 7, 10	rwh ¹⁾	DCMk²⁾ Falling Edge Event Service Request State 0 _B No service is requested. 1 _B Service is requested due to a falling edge detected on DCMk input signal line.
DCM00C, DCM01C, DCM02C, DCM03C	2, 5, 8, 11	rwh ¹⁾	DCMk²⁾ Compare Event Service Request State 0 _B No service is requested. 1 _B Service is requested due to a compare event occurred in DCMk cell.
PLL	12	rwh ¹⁾	Counter Service Request State for PLL 0 _B No service is requested 1 _B Service is requested because the counter for the number remaining output pulses decremented to 0.
GT00	13	rwh ¹⁾	GT0 Timer Service Request State 0 _B No service is requested. 1 _B Service is requested due to a GT0 timer overflow.
GT01	14	rwh ¹⁾	GT1 Timer Service Request State 0 _B No service is requested. 1 _B Service is requested due to a GT1 timer overflow.

General Purpose Timer Array (GPTA®v5)

Field	Bits	Type	Description
0	[31:15]	r	Reserved Read as 0; should be written with 0.

- 1) Writing a one to a cleared bit sets the bit. All other write operations have no effect.
- 2) k = 0-3; k = 0 refers to DCM00R, DCM00F, or DCM00C; k = 1 refers to DCM01R, DCM01F, or DCM01C; k = 2 refers to DCM02R, DCM02F, or DCM02C; k = 3 refers to DCM03R, DCM03F, or DCM03C.

GPTA0_SRSC1

GPTA0 Service Request State Clear Register 1

(018_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC	GTC
15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
GTck (k = 00-31)	k	rwh ¹⁾	GTck Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a capture or compare event occurred in GTck.

- 1) Writing an one to a set bit clears the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_SRSS1

GPTA0 Service Request State Set Register 1

(01C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GTC 31	GTC 30	GTC 29	GTC 28	GTC 27	GTC 26	GTC 25	GTC 24	GTC 23	GTC 22	GTC 21	GTC 20	GTC 19	GTC 18	GTC 17	GTC 16
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GTC 15	GTC 14	GTC 13	GTC 12	GTC 11	GTC 10	GTC 09	GTC 08	GTC 07	GTC 06	GTC 05	GTC 04	GTC 03	GTC 02	GTC 01	GTC 00
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
GTck (k = 00-31)	k	rwh ¹⁾	GTck Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a capture or compare event occurred in GTck.

1) Writing a one to a cleared bit sets the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA[®]v5)

GPTA0_SRSC2

GPTA0 Service Request State Clear Register 2

(020_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LTC 31	LTC 30	LTC 29	LTC 28	LTC 27	LTC 26	LTC 25	LTC 24	LTC 23	LTC 22	LTC 21	LTC 20	LTC 19	LTC 18	LTC 17	LTC 16
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LTC 15	LTC 14	LTC 13	LTC 12	LTC 11	LTC 10	LTC 09	LTC 08	LTC 07	LTC 06	LTC 05	LTC 04	LTC 03	LTC 02	LTC 01	LTC 00
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
LTCk (k = 00-31)	k	rwh ¹⁾	LTCk Timer/Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a timer overflow, capture, or compare event that occurred in LTCk.

1) Writing an one to a set bit clears the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA®v5)

GPTA0_SRSS2

GPTA0 Service Request State Set Register 2

(024_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LTC 31	LTC 30	LTC 29	LTC 28	LTC 27	LTC 26	LTC 25	LTC 24	LTC 23	LTC 22	LTC 21	LTC 20	LTC 19	LTC 18	LTC 17	LTC 16
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LTC 15	LTC 14	LTC 13	LTC 12	LTC 11	LTC 10	LTC 09	LTC 08	LTC 07	LTC 06	LTC 05	LTC 04	LTC 03	LTC 02	LTC 01	LTC 00
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
LTCk (k = 00-31)	k	rwh ¹⁾	LTCk Timer/Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a timer overflow, capture, or compare event that occurred in LTCk.

1) Writing a one to a cleared bit sets the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA®v5)

GPTA0_SRSC3

GPTA0 Service Request State Clear Register 3

(028_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LTC 63	LTC 62	LTC 61	LTC 60	LTC 59	LTC 58	LTC 57	LTC 56	LTC 55	LTC 54	LTC 53	LTC 52	LTC 51	LTC 50	LTC 49	LTC 48
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LTC 47	LTC 46	LTC 45	LTC 44	LTC 43	LTC 42	LTC 41	LTC 40	LTC 39	LTC 38	LTC 37	LTC 36	LTC 35	LTC 34	LTC 33	LTC 32
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
LTCk (k = 32-63)	k-32	rwh ¹⁾	LTCk Timer/Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a timer overflow, capture, or compare event that occurred in LTCk.

1) Writing an one to a set bit clears the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA®v5)

GPTA0_SRSS3

GPTA0 Service Request State Set Register 3

(02C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LTC 63	LTC 62	LTC 61	LTC 60	LTC 59	LTC 58	LTC 57	LTC 56	LTC 55	LTC 54	LTC 53	LTC 52	LTC 51	LTC 50	LTC 49	LTC 48
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LTC 47	LTC 46	LTC 45	LTC 44	LTC 43	LTC 42	LTC 41	LTC 40	LTC 39	LTC 38	LTC 37	LTC 36	LTC 35	LTC 34	LTC 33	LTC 32
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
LTCk (k = 32-63)	k-32	rwh ¹⁾	LTCk Timer/Capture/Compare Service Request State 0 _B No service is requested. 1 _B Service is requested due to a timer overflow, capture, or compare event that occurred in LTCk.

1) Writing a one to a cleared bit sets the bit. All other write operations have no effect.

General Purpose Timer Array (GPTA[®]v5)

Node Redirection Register

The Service Request Node Redirection Register allows that GTC service requests of GTCs with an odd index number k can be individually redirected via register SRNR to a service request group that is assigned mainly to four LTCs. More details are provided on [Page 23-124](#).

GPTA0_SRNR

GPTA0 Service Request Node Redirection Register

(030_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GTC 31R	GTC 29R	GTC 27R	GTC 25R	GTC 23R	GTC 21R	GTC 19R	GTC 17R	GTC 15R	GTC 13R	GTC 11R	GTC 09R	GTC 07R	GTC 05R	GTC 03R	GTC 01R
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
GTC01R, GTC03R, GTC05R, GTC07R, GTC09R, GTC11R, GTC13R, GTC15R, GTC17R, GTC19R, GTC21R, GTC23R, GTC25R, GTC27R, GTC29R, GTC31R	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	rw	Global Timer Cell k Redirection 0 _B No redirection of GTC service requests. 1 _B Redirection of GTC service request to LTC service request groups (see Page 23-124).
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

23.5 GPTA[®]v5 Module Implementation

This section describes the GPTA[®]v5 interfaces as implemented in TC1728 with the clock control, port and Micro Second Channel connections, interrupt control, and address decoding.

23.5.1 Interconnections of GPTA0 Units

The following items are described in this section:

- GPTA[®]v5 module (kernel) external registers
- Port control and connections
 - I/O port line assignment
 - I/O function selection
 - Pad driver characteristics selection
 - Emergency control of GPTA[®]v5 outputs
- On-chip connections
 - Clock bus connections
 - MSC controller connections
 - FADC connections
 - MultiCAN, SCU, and DMA connections
 - SCU connections (ADC, DMA)
- Module clock generation
- Interrupt registers
- GPTA[®]v5 address map

Figure 23-81 shows the TC1728 specific implementation details and interconnections of the units GPTA0. The units are supplied by clock control and address decoding logic.

Additional connections are described in the following sections.

General Purpose Timer Array (GPTA®v5)

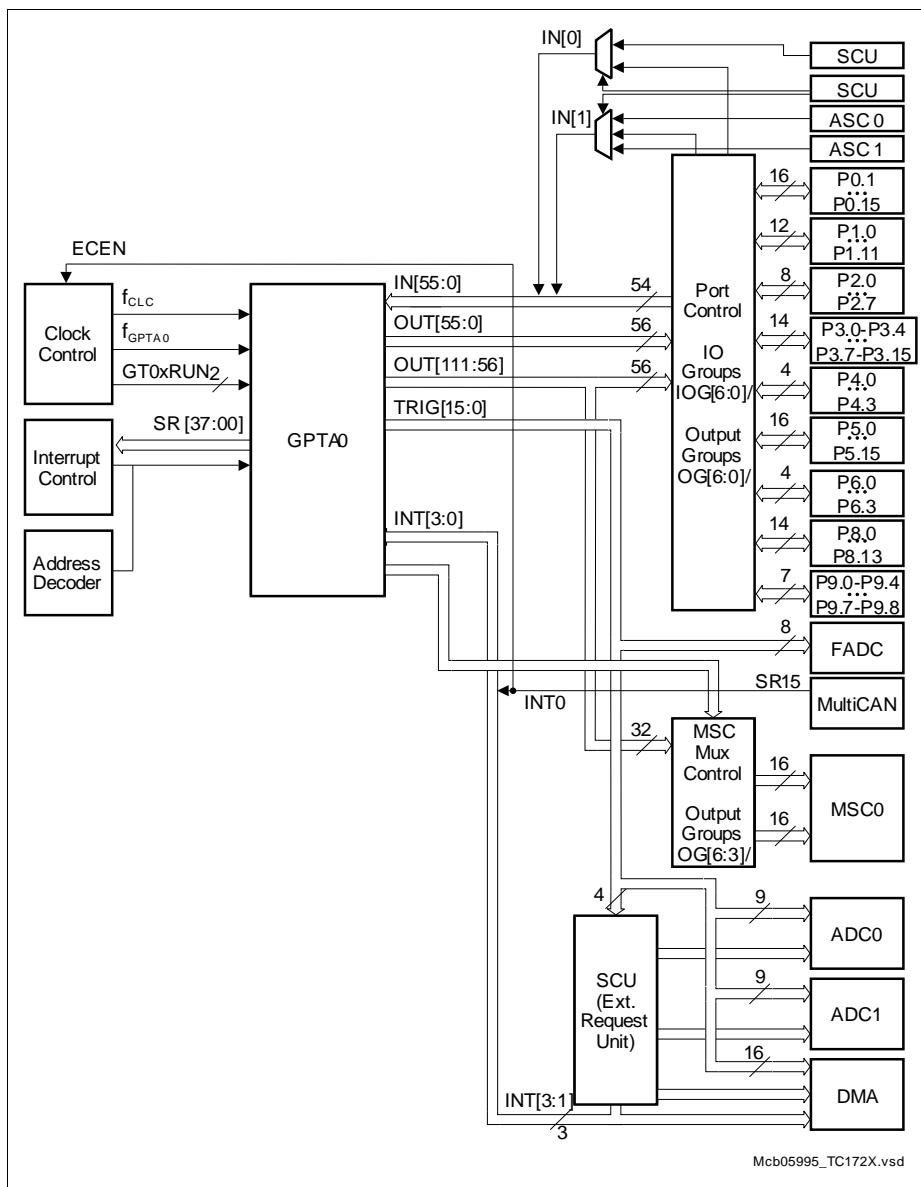


Figure 23-81 Block Diagram of GPTA®v5 Implementation

General Purpose Timer Array (GPTA[®]v5)

23.5.2 GPTA[®]v5 Module External Registers

Figure 23-82 summarizes the GPTA[®]v5 module related external registers that are required for GPTA0 programming. These registers are referenced and (some of it) described in detail in the following sub-sections.

Clock Control Registers	Port Control Registers	Port Control Registers	Interrupt Registers
GPTA0_CLC	P0_IOCRRk 1)	P0_ESR	GPTA0_SRCK 5)
GPTA0_FDR	P1_IOCRRk 2)	P1_ESR	LTCA2_SRCK 6)
GPTA0_EDCTR	P2_IOCRRk 3)	P2_ESR	
GPTA0_DBGCTR	P3_IOCRRk 1)	P3_ESR	
	P4_IOCRRk 4)	P4_ESR	
	P5_IOCRRk 1)	P5_ESR	
	P6_IOCRRk 4)	P6_ESR	
	P8_IOCRRk 1)	P8_ESR	
	P9_IOCRRk 2)	P9_ESR	
	P0_PDR		
	P1_PDR		
	P2_PDR		
	P3_PDR		
	P4_PDR		
	P5_PDR		
	P6_PDR		
	P8_PDR		
	P9_PDR		
Module Identification Registers			
GPTA0_ID			

1) k = 0, 4, 8, 12
2) k = 0, 4, 8
3) k = 0, 4
4) k = 0
5) k = 00-37
6) k = 00-07

Register_TC172X.vsd

Figure 23-82 GPTA[®]v5 Implementation-Specific Special Function Registers

23.5.3 Port Control and Connections

This section describes the I/O connections of the GPTA0 unit.

23.5.3.1 I/O Port Line Assignment

In the TC1728, the seven I/O groups and seven output groups of GPTA0 with their input lines IN[55:0] and output lines OUT[111:0] are assigned to 8-bit port groups as shown in **Figure 23-83**. Within an 8-bit I/O group, the IN/OUT line with lowest index number is assigned to the port line with the lowest index number. The remaining lines are assigned linearly with increasing index numbers. For example, is assigned to IN13/OUT13. In the TC1728, the four I/O groups

General Purpose Timer Array (GPTA®v5)

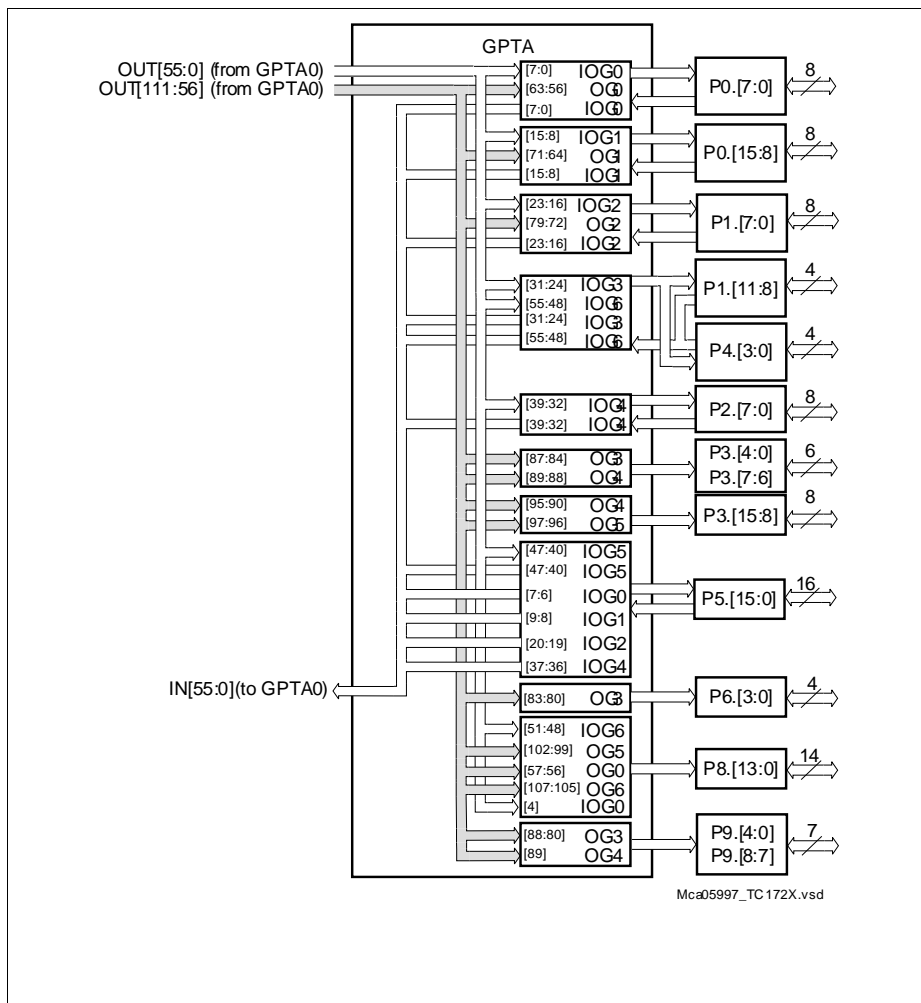


Figure 23-83 I/O Port Line Assignment

The interconnections between the GPTA0 unit and the port I/O lines are controlled in the port logics. The following port control operations selections must be executed:

- Input/output function selection (IOCR registers)
- Pad driver characteristics selection for outputs (PDR registers)

General Purpose Timer Array (GPTA[®]v5)**23.5.3.2 Input/Output Function Selection**

shows the GPTA0 I/O lines mapping to the ports. Note that GPTA0 input /IN0 (see [Page 23-241](#)) and GPTA0 input /IN1 (see [Page 23-242](#)) has special connections.

General Purpose Timer Array (GPTA[®]v5)

Table 23-20 IOCR Assignment for GPTA[®]v5 Port Lines PG-LQFP-176

Port	Port Lines for GPTA [®] v5	GPTA0 I/O Lines		Controlled by IOCR Register
		Input	Output	
Port 0	P0.[3:0]	IN[3:0] ¹⁾	OUT[3:0] OUT[59:56]	P0_IOCR0
	P0.[7:4]	IN[7:4]	OUT[7:4] OUT[63:60]	P0_IOCR4
	P0.[11:8]	IN[11:8]	OUT[11:8] OUT[67:64]	P0_IOCR8
	P0.[15:12]	IN[15:12]	OUT[15:12] OUT[71:68]	P0_IOCR12
Port 1	P1.[3:0]	IN[19:16]	OUT[19:16] OUT[75:72]	P1_IOCR0
	P1.[7:4]	IN[23:20]	OUT[23:20] OUT[79:76]	P1_IOCR4
	P1.[11:8]	IN[27:24] IN[51:48]	OUT[27:24] OUT[51:48]	P1_IOCR8
Port 2	P2.[3:0]	IN[35:32]	OUT[35:32]	P2_IOCR0
	P2.[7:4]	IN[39:36]	OUT[39:36]	P2_IOCR4
Port 3	P3.[3:0]		OUT[87:84]	P3_IOCR0
	P3.[7:4]		OUT[89:88]	P3_IOCR4
	P3.[11:8]		OUT[93:90]	P3_IOCR4
	P3.[15:12]		OUT[97:94]	P3_IOCR4
Port 4	P4.[3:0]	IN[31:28] IN[55:52]	OUT[31:28] OUT[55:52]	P4_IOCR0
Port 5	P5.[3:0]	IN[43:40]	OUT[43:40]	P5_IOCR0
	P5.[7:4]	IN[47:44]	OUT[47:44]	P5_IOCR4
	P5.[11:8]		OUT[9:6]	P5_IOCR8
	P5.[15:12]		OUT[20:19] OUT[37:36]	P5_IOCR12
Port 6	P6.[3:0]		OUT[83:80]	P6_IOCR0

General Purpose Timer Array (GPTA[®]v5)

Table 23-20 IOCR Assignment for GPTA[®]v5 Port Lines (cont'd) PG-LQFP-176

Port	Port Lines for GPTA [®] v5	GPTA0 I/O Lines		Controlled by IOCR Register
		Input	Output	
Port 8	P8.[3:0]		OUT[51:48]	P8_IOCR0
	P8.[7:4]		OUT[52] OUT[102:100]	P8_IOCR4
	P8.[11:8]		OUT[57:56] OUT[106:105]	P8_IOCR8
	P8.[13:12]		OUT[107] OUT[4]	P8_IOCR12
Port 9	P9.[3:0]		OUT[83:80]	P9_IOCR0
	P9.[7:4]		OUT[84] OUT[87]	P9_IOCR4
	P9.[8]		OUT[88]	P9_IOCR8

1) There is a special connection provided for GPTA0 input line IN0 (see [Page 23-241](#)) and GPTA0 input line IN1 (see [Page 23-242](#)).

A port line that is programmed as input can be used by the GPTA0 or other units simultaneously as input.

Port lines selected as GPTA0 output are forced to a 0 level if the related multiplexer array in the I/O Line Sharing Block is disabled or if a reserved combination of an OMGN value is selected. Therefore, no glitches and spikes can occur during the programming of the related multiplexer array.

23.5.3.3 Emergency Control of GPTA[®]v5 Output Ports Lines

Port lines connected to GPTA0 unit output pins can be selectively switched into an Emergency Mode. In this mode, GPTA0 unit output pins react immediately to an active input signal and drive a logic level that has been programmed in the port output register. As a result, in Emergency Mode a GPTA0 unit output pin drives a predefined value instead of the corresponding logic level that is provided on the related GPTA0 unit output line.

All GPTA[®]v5 pins at Port 0, Port 1, Port 2, Port 3, Port 4 are connected to one common emergency stop signal that is generated in the System Control Unit of the TC1728. More details about the generation of this emergency stop signal are described in the “System Control Unit” chapter of the TC1728 System Units User's Manual.

The emergency stop signal always controls 8-bit groups of port lines. The enable function is controlled for each pin by bits ENy (y = number of port line) which are located in the Px_ESR (x = port number) registers. When the emergency stop signal generated

General Purpose Timer Array (GPTA®v5)

in the SCU becomes active and bit Px_ESR.ENy set, output line Px.y is set to the value of register Px_OUT.Py (emergency enabled). Output Px.y is not affected by the emergency stop signal when bit Px_OUT.Py is reset (emergency disabled).

When the emergency stop signal is released, Pin x.y is switched back to the previously selected GPTA®v5 output function without reprogramming the related port registers.

Table 23-21 Emergency Control for GPTA®v5 Port Output Lines

Port	ESR Register	ESR Enable Bits	GPTA®v5 Output Lines
Port 0	P0_ESR	EN[15:0]	OUT[15:0] / OUT[71:56]
Port 1	P1_ESR	EN[11:0]	OUT[27:16] / OUT[51:48] / OUT[79:72]
Port 2	P2_ESR	EN[7:0]	OUT[39:32]
Port 3	P3_ESR	EN[15:0]	OUT[97:84]
Port 4	P4_ESR	EN[3:0]	OUT[31:28] / OUT[55:52]
Port 5	P5_ESR	EN[7:0]	OUT[47:40]
Port 6	P6_ESR	EN[3:0]	OUT[83:80]
Port 8	P8_ESR	EN[14:0]	OUT[4] / OUT[52:48] / OUT[57:56] / OUT[102:100] / OUT[107:105]
Port 9	P9_ESR	EN[8:0]	OUT[89:80]

General Purpose Timer Array (GPTA®v5)

23.5.4 On-Chip Connections

This section describes all on-chip interconnections of the GPTA0 units except the connections to I/O ports (see [Section 23.5.3](#)).

23.5.4.1 MSC Controller Connections

The MSC interfaces (MSC0) provide a serial communication link typically used to connect power switches or other peripheral devices. [Figure 23-84](#) shows the interconnections among the MSC0 module and the GPTA®v5 units.

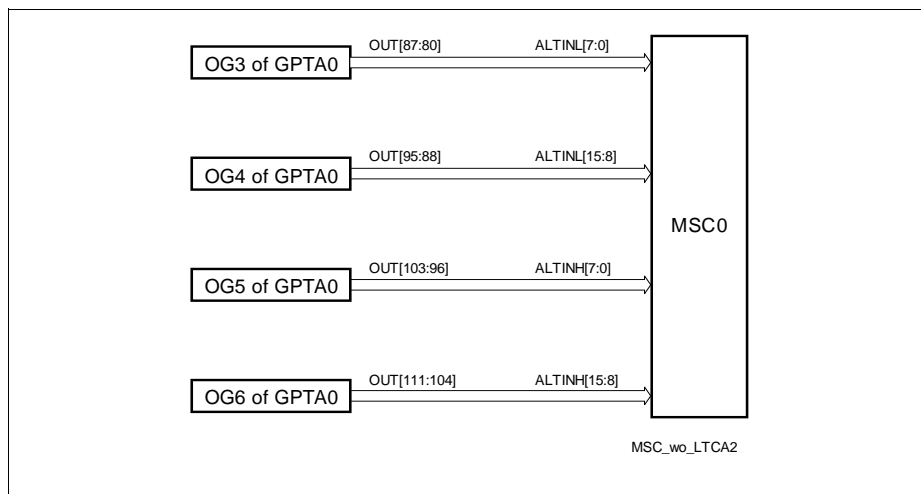


Figure 23-84 GPTA®v5-to-MSC Multiplexer

The multiplexer selection is controlled by four multiplexer control registers that are logically assigned to the GPTA0 unit address range (but described in this section).

[Table 23-22](#) shows the GPTA®v5-to-MSC interconnection assignment.

Note: [Table 23-22](#) also shows the assignment of the GPTA0/GPTA1/LTCA2 unit's seven OGx output group lines OGx.y to the output signals OUT[111:56].

Table 23-22 GPTA0 to MSC0 Interconnection Assignment

MSC0 Input Line	Assigned GPTA0 Output Line	MSC0 Input Line	Assigned GPTA0 Output Line
ALTINL.0	OUT80 / OG3.0	ALTINH.0	OUT96 / OG5.0
ALTINL.1	OUT81 / OG3.1	ALTINH.1	OUT97 / OG5.1

General Purpose Timer Array (GPTA[®]v5)

Table 23-22 GPTA0 to MSC0 Interconnection Assignment (cont'd)

MSC0 Input Line	Assigned GPTA0 Output Line	MSC0 Input Line	Assigned GPTA0 Output Line
ALTINL.2	OUT82 / OG3.2	ALTINH.2	OUT98 / OG5.2
ALTINL.3	OUT83 / OG3.3	ALTINH.3	OUT99 / OG5.3
ALTINL.4	OUT84 / OG3.4	ALTINH.4	OUT100 / OG5.4
ALTINL.5	OUT85 / OG3.5	ALTINH.5	OUT101 / OG5.5
ALTINL.6	OUT86 / OG3.6	ALTINH.6	OUT102 / OG5.6
ALTINL.7	OUT87 / OG3.7	ALTINH.7	OUT103 / OG5.7
ALTINL.8	OUT88 / OG4.0	ALTINH.8	OUT104 / OG6.0
ALTINL.9	OUT89 / OG4.1	ALTINH.9	OUT105 / OG6.1
ALTINL.10	OUT90 / OG4.2	ALTINH.10	OUT106 / OG6.2
ALTINL.11	OUT91 / OG4.3	ALTINH.11	OUT107 / OG6.3
ALTINL.12	OUT92 / OG4.4	ALTINH.12	OUT108 / OG6.4
ALTINL.13	OUT93 / OG4.5	ALTINH.13	OUT109 / OG6.5
ALTINL.14	OUT94 / OG4.6	ALTINH.14	OUT110 / OG6.6
ALTINL.15	OUT95 / OG4.7	ALTINH.15	OUT111 / OG6.7

GPTA[®]v5-to-MSC Multiplexer Control Registers

The following registers are required for GPTA[®]v5-to-MSC multiplexer control:

- **GPTA0_MMCTR00** controls the interconnections of GPTA[®]v5 Units to the MSC0 ALTINL[15:0] inputs.
- **GPTA0_MMCTR01** controls the interconnections of GPTA[®]v5 Units to the MSC0 ALTINH[15:0] inputs. MSC1 ALTINL[15:8] inputs and MSC1 ALTINH[7:0] inputs.

For each of the ALTINL/ALTINH inputs of the MSC, the 2-bit bit fields in these registers determine which unit output is selected.

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GPTA0_MMXCTR00

GPTA-to-MSC Multiplexer Control Register 00 (700_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0																	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MUXn (n = 0-15)	[2*n+1:2*n]	rw	Multiplexer Control for MSC0 Inputs ALTINL.n) 00 _B GPTA0 output OUT[80+n] selected and connected to MSC0 ALTINL.n 01 _B Reserved 10 _B Reserved 11 _B Reserved

GPTA0_MMXCTR01

GPTA-to-MSC Multiplexer Control Register 01 (704_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	MUX	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0																	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MUXn (n = 0-15)	[2*n+1:2*n]	rw	Multiplexer Control for MSC0 Inputs ALTINH.n) 00 _B GPTA0 output OUT[96+n] selected and connected to MSC0 ALTINH.n 01 _B Reserved 10 _B Reserved 11 _B Reserved

General Purpose Timer Array (GPTA[®]v5)

System Control Unit

The SCU contains the external request unit (ERU), which is especially responsible for controlling requests coming from the MSC modules, port pins, or from the GPTA0 unit and passing these request to AD converters, DMA controller, or interrupt nodes.

MultiCAN Connections

The MultiCAN controller has the following connections to the GPTA0 unit:

- MultiCAN service request output SR15 is connected to the INT0 input of GPTA0.
- GPTA0 output line OUT5 is connected to the external time trigger input ECTT3 of the MultiCAN module.

DMA Controller

As shown in [Figure 23-85](#), eight GPTA0 on-chip trigger and gating output lines are connected as trigger input signals to the DMA request inputs. Furthermore the external request unit generates four DMA request output signals (IOUT[3:0]) that can be activated via port pins, the MSC clock outputs, or the four GPTA[®]v5 output lines. Three of these four DMA request output signals are connected to the GPTA0 internal inputs INT[3:1]. These connections allow, for example, GTC or LTC events in the GPTA[®]v5 units to be triggered by a request coming from a port pin or from the MSC clock.

ADC Connections

As shown in [Figure 23-85](#), for each ADC nine GPTA0 on-chip trigger and gating output lines are connected as trigger input signals or gating input signals to the channel trigger logic of the ADC. Thus dedicated GPTA0 outputs can generate trigger events or act as gating signals for ADC channels. Furthermore the external request unit generates two ADC conversion trigger signals (IOUT[3:2]) and two ADC conversion gating signals (PDOUT[3:2]) that can be activated each via port pins, the MSC clock outputs, or two GPTA[®]v5 output lines.

FADC Connections

As shown in [Figure 23-85](#), eight GPTA0 on-chip trigger and gating output lines are connected as trigger input signals or gating input signals to the channel trigger logic of the FADC. Thus dedicated GPTA0 outputs can generate trigger events or act as gating signals for FADC channels.

Port Connections of Input IN0

The common input line IN0 of the GPTA0 unit is connected to the output of a 2-to-1 multiplexer. This multiplexer is controlled by bit field SCU_EXTCON.GPTAINSEL and allows the common GPTA0 input IN0 to be connected to one out of two input lines. This

General Purpose Timer Array (GPTA[®]v5)

feature especially allows the number of clock of the PLL (to determine clock stability) to be measured by GTs (Global Timers) or FPC0 (Filter and Prescaler Cell) of the GPTA0.

Table 23-23 GPTA0 Input Line IN0 Connections

SCU_EXTCON. GPTAINSEL	GPTA0 Input IN0 Connected to
00 _B	P0.0 / IN0 (default after reset)
01 _B	SCU: EXTCLK0

Port Connections of Input IN1

The common input line IN1 of the GPTA0 unit is connected to the output of a 4-to-1 multiplexer. This multiplexer is controlled by bit field SCU_SYSCON.GPTAIS and allows the common GPTA0 input IN1 to be connected to one out of four port input lines. This feature especially allows the baud rates of an ASC0 or ASC1 receiver input signal to be measured by timers of the GPTA0.

Table 23-24 GPTA0 Input Line IN1 Connections

SCU_SYSCON. GPTAIS	GPTA0 Input IN1 Connected to
00 _B	P0.1 / IN1 (default after reset)
01 _B	P3.0 / ASC0: RXD0A
10 _B	P3.12 ASC0: RXD0B
11 _B	P3.14 / ASC1: RXD1B

23.5.5 Module Clock Generation

clock generation circuitry is responsible for the enable/disable control, the clock frequency adjustment, and the debug clock control. The circuitry includes the following registers:

- **Clock Control Register GPTA0_CLC** (see [Page 23-245](#)), responsible for the generation of the control clock f_{CLC} that is used by each of the units.
- **Fractional Divider Register GPTA0_FDR** (see [Page 23-246](#)), responsible for the frequency control of the module timer clock f_{GPTA} .
- **Clock Enable/Disable Control Register GPTA0_EDCTR** (see [Page 23-248](#)), responsible for the enable/disable control of the different units as clocks f_{GPTA0} , and for the run control for the Global Timers in GPTA0.
- **Debug Clock Control Register GPTA0_DBGCTR** (see [Page 23-249](#)), responsible for the module timer clock control in Debug Mode.

Note: Registers GPTA0_CLC, GPTA0_FDR, GPTA0_EDCTR and GPTA0_DBGCTR are located in the address space of GPTA0.

General Purpose Timer Array (GPTA®v5)

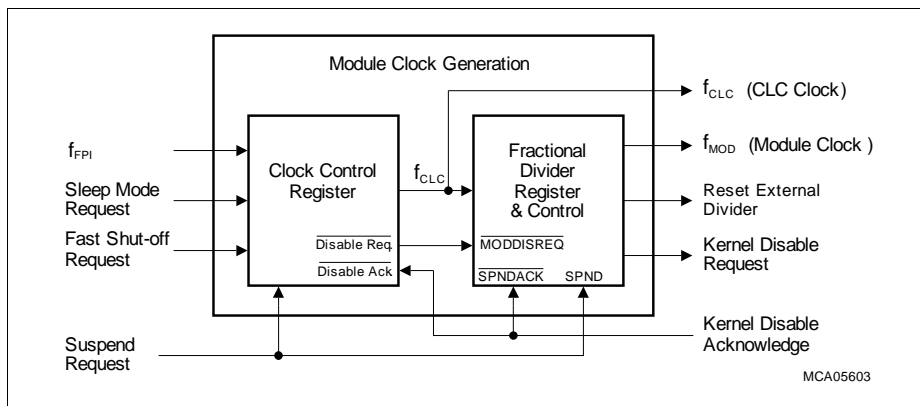


Figure 23-86 Details on Module Clock Generation

The GPTA®v5 module control clock f_{CLC} is used inside the GPTA®v5 module kernels for control purposes such as clocking of control logic and register operations. The frequency of f_{CLC} is identical to the clock frequency f_{FPI} . The clock control registers GPTA0_CLC make it possible to enable/disable f_{CLC} under certain conditions.

The separate GPTA®v5 unit clocks f_{GPTA0} are used inside the GPTA®v5 units as input clocks for the timers. All unit clocks have the same frequency as f_{GPTA} (as selected through register GPTA0_FDR) and can be enabled/disabled separately each through register GPTA0_ECDTR.

Note: If f_{GPTA0} are disabled by the enable bits in register GPTA0_ECDTR, f_{CLC} keeps running. In this case, that means that register accesses to the GPTA®v5 units are possible.

The frequency of f_{GPTA} is defined by:

$$f_{GPTA} = f_{FPI} \times \frac{1}{n} \text{ with } n = 1024 - \text{FDR.STEP or} \quad (23.6)$$

$$f_{GPTA} = f_{FPI} \times \frac{n}{1024} \text{ with } n = 0-1023 \quad (23.7)$$

Note: The upper formula applies to normal divider mode of the fractional divider (GPTA0_FDR.DM = 01_B). The lower formula applies to fractional divider mode (GPTA0_FDR.DM = 10_B).

The debug clock control register additionally makes it possible to control the timer clocks f_{GPTA0} for debug purposes on basis of a clock counter.

General Purpose Timer Array (GPTA[®]v5)

If the debug clock feature is enabled (GPTA0_DBGCTR.DBGCEN = 1) and bit GPTA0_DBGCTR.DBGCST is set, the timer clocks f_{GPTA0} will be activated in parallel for as many clock cycles as have been programmed into bit field GPTA0_DBGCTR.CLKCNT. When the debug clock feature becomes enabled, bit field CLKCNT counts down and stops counting at 0000_H. Bit DBGCST is again reset by hardware after the programmed number of clock pulses has been issued. This feature makes it possible to single step the GPTA[®]v5 units with a programmable timer clock granularity.

Note: The GPTA[®]v5 module is disabled after reset. In general, after reset, the GPTA[®]v5 module control clock f_{CLC} must be switched on (writing to register GPTA0_CLC) before the frequency of the GPTA[®]v5 module timer clock f_{GPTA} is defined (writing to register GPTA0_FDR).

General Purpose Timer Array (GPTA®v5)

23.5.5.2 Fractional Divider Register

The fractional divider makes it possible to generate a GPTA®v5 module clock from an input clock using a programmable divider. The fractional divider divides the input clock f_{CLC} either by the factor $1/n$ or by a fraction of $n/1024$ for any value of n from 0 to 1023, and outputs the clock signal, f_{GPTA} . The fractional divider is controlled by the FDR register.

The fractional divider register controls the clock frequency of the GPTA®v5 module timer clock f_{GPTA} . The clock frequency of f_{GPTA0} is identical to the one of f_{GPTA} .

GPTA0_FDR

GPTA Fractional Divider Register (00C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS CLK	EN HW	SUS REQ	SUS ACK	0		RESULT									
rw	rw	rh	rh	r		rh									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM		SC		SM	0	STEP									
rw		rw		rw	r	rw									

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value Reload or addition value for RESULT.
SM	11	rw	Suspend Mode SM selects between granted or immediate suspend mode.
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in suspend mode.
DM	[15:14]	rw	Divider Mode This bit field selects normal divider mode, fractional divider mode, and off-state.
RESULT	[25:16]	rh	Result Value Bit field for the addition result.
SUSACK	28	rh	Suspend Mode Acknowledge Indicates state of SPNDACK signal.

General Purpose Timer Array (GPTA[®]v5)

Field	Bits	Type	Description
SUSREQ	29	rh	Suspend Mode Request Indicates state of SPND signal.
ENHW	30	rw	Enable Hardware Clock Control Controls operation of ECEN input and DISCLK bit.
DISCLK	31	rwh	Disable Clock Hardware controlled disable for f_{OUT} signal.
0	10, [27:26]	r	Reserved Read as 0; should be written with 0.

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The clock enable/disable control register controls two functions: clock enable/disable control for each Global Timer in the GPTA0 units and enable/disable control for the GPTA®v5 unit clocks, separately for each clock f_{GPTA0} .

GPTA0_EDCTR

GPTA Clock Enable/Disable Control Register

(400_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								G0	0				GT	GT	
r								EN	r				01	00	
													RUN	RUN	

Field	Bits	Type	Description
GT00RUN	0	rw	GPTA0 Global Timer 0 Run Control 0 _B GPTA0 Global Timer 0 clock is stopped. 1 _B GPTA0 Global Timer 0 clock is started/running.
GT01RUN	1	rw	GPTA0 Global Timer 1 Run Control 0 _B GPTA0 Global Timer 1 clock is stopped. 1 _B GPTA0 Global Timer 1 clock is started/running.
G0EN	8	rw	GPTA0 Timer Clock Enable 0 _B GPTA0 timer clock f_{GPTA0} is disabled. 1 _B GPTA0 timer clock f_{GPTA0} is enabled.
0	[7:2], 9, 10, [31:11]	r	Reserved Read as 0; should be written with 0.

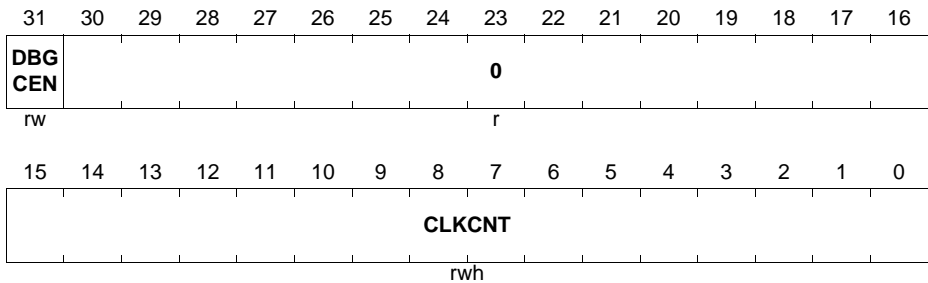
General Purpose Timer Array (GPTA[®]v5)

The debug clock control register makes it possible to control the GPTA[®]v5 unit clocks f_{GPTA0} for debug purposes on the basis of a clock counter.

GPTA0_DBGCTR

GPTA Debug Clock Control Register (004_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CLKCNT	[15:0]	rwh	Debug Clock Count This bit field determines the number of clock pulses to be issued when the debug clock feature is enabled (DBG CEN = 1). CLKCNT counts down to 0000 _H and stops when the debug clock feature is enabled.
DBG CEN	31	rw	Debug Clock Enable 0 _B The debug clock feature is disabled. The GPTA [®] v5 unit clocks are always enabled. 1 _B The debug clock feature is enabled. If a non-zero value is written to bit field CLKCNT the related number of clock pulses is issued at f_{GPTA0} .
0	[30:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Array (GPTA[®]v5)

23.5.6 Limits of Cascading GTCs and LTCs

As shown on [Page 23-57](#) and [Page 23-69](#), a maximum of 32 GTCs and a maximum of 64 LTCs can be cascaded. In the TC1728, however cascading of GTCs and LTCs is limited under certain conditions.

If the LTCs are running with the maximum GPTA[®]v5 unit clock of $f_{\text{GPTA}} = f_{\text{FPI}} = 90 \text{ MHz}$, a maximum of 16 GTCs and 16 LTCs can be connected together. If the GPTA[®]v5 unit clock f_{GPTA} is reduced, the number of LTCs that can be cascaded increases accordingly. Only the integer part of the divider ratio as selected by the GPTA0_FDR fractional divider register determines the maximum number of cascaded GTCs and LTCs.

Table 23-25 Limits of Cascading GTCs and LTCs

f_{FPI}	Selected Clock Divider Ratio ¹⁾	Max. Number of Cascaded GTCs/LTCs
90 MHz	$1 \leq f_{\text{FPI}}/f_{\text{GPTA}} < 2$	16 GTCs, 16 LTCs
	$2 \leq f_{\text{FPI}}/f_{\text{GPTA}} < 3$	no limits for GTCs, 32 LTCs
	$3 \leq f_{\text{FPI}}/f_{\text{GPTA}} < 4$	no limits for GTCs, 48 LTCs
	$4 \leq f_{\text{FPI}}/f_{\text{GPTA}}$	no limits for GTCs and LTCs
45 MHz	$1 \leq f_{\text{FPI}}/f_{\text{GPTA}} < 2$	no limits for GTCs, 32 LTCs
	$2 \leq f_{\text{FPI}}/f_{\text{GPTA}}$	no limits for GTCs and LTCs

1) Selected by the GPTA0_FDR fractional divider register.

General Purpose Timer Array (GPTA®v5)

23.5.7 Interrupt Registers

Each of the service request outputs of the GPTA0 units is able to generate an interrupt and is controlled by an interrupt service request control register GPTA_SRCk. Therefore, the following interrupt service request control registers are available:

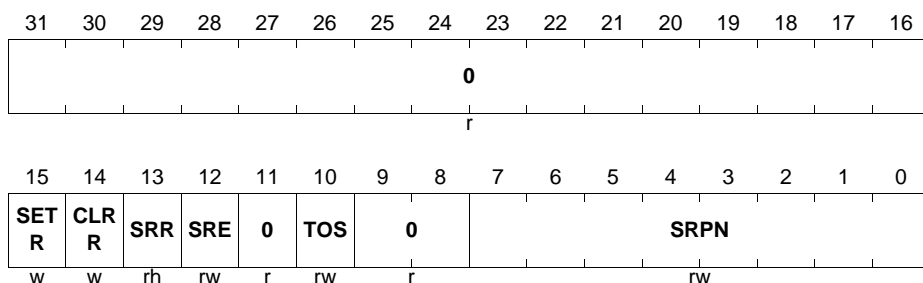
- GPTA0: GPTA0_SRC[37:00]

GPTA0_SRCk (k = 00-37)

GPTA0 Interrupt Service Request Control Register k

(7FC_H-k*4_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Note: Additional details on service request nodes and the service request control registers are described in the Interrupt chapter of the TC1728 User's Manual System Units part (Volume 1).

23.5.8 GPTA Register Address Map

The GPTA0 register map shown in [Figure 23-87](#).

General Purpose Timer Array (GPTA®v5)

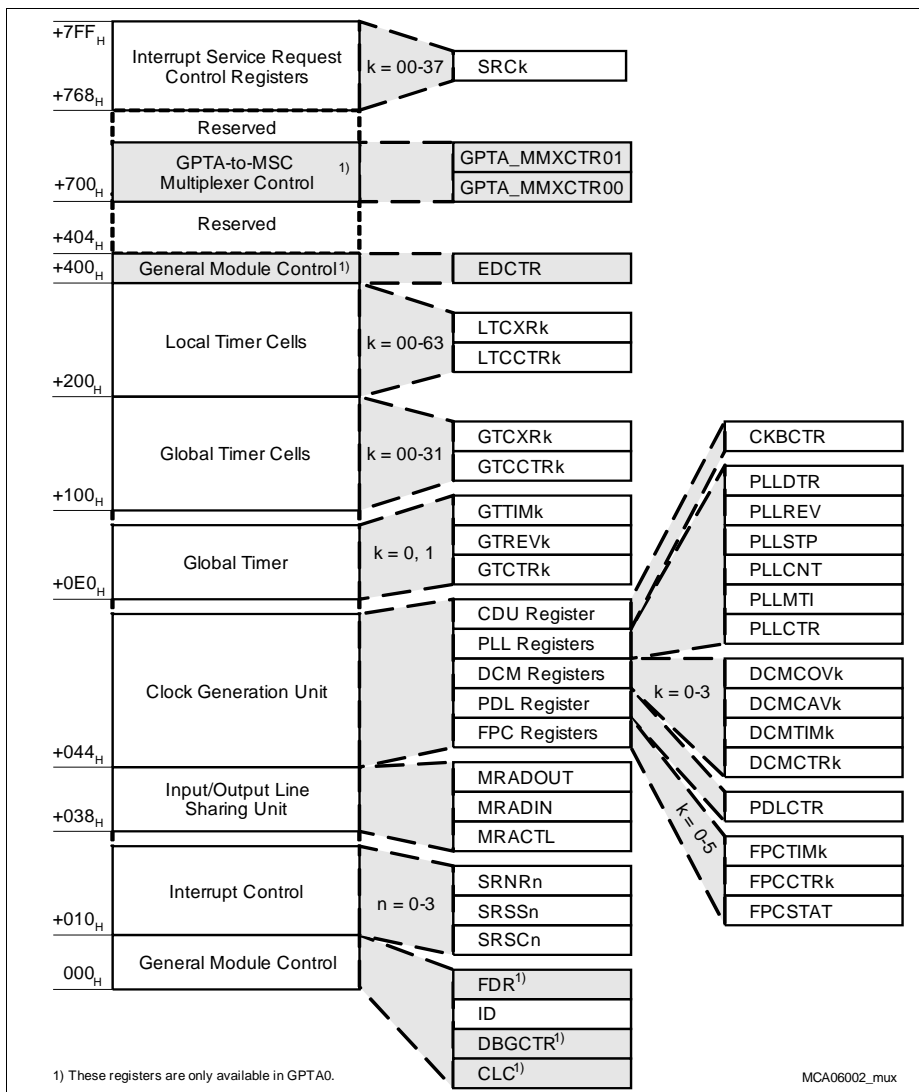


Figure 23-87 GPTA0 Register Map

24 Capture/Compare Unit 6 (CCU6)

The CCU6 is a high-resolution 16-bit capture and compare unit with application specific modes, mainly for AC drive control. Special operating modes support the control of Brushless DC-motors using Hall sensors or Back-EMF detection. Furthermore, block commutation and control mechanisms for multi-phase machines are supported.

It also supports inputs to start several timers synchronously, an important feature in devices with several CCU6 modules.

This chapter is structured as follows:

- Introduction (see [Section 24.1](#))
including register overview (see [Section 24.1.3](#))
- Operating T12 (see [Section 24.2](#))
including T12-related registers (see [Section 24.2.8](#))
and capture/compare control registers (see [Section 24.2.9](#))
- Operating T13 (see [Section 24.3](#))
including T13-related registers (see [Section 24.3.6](#))
- Synchronous start feature (see [Section 24.4](#))
- Trap handling (see [Section 24.5](#))
- Multi-Channel mode (see [Section 24.6](#))
- Hall sensor mode (see [Section 24.7](#))
- Modulation control registers (see [Section 24.8](#))
- Interrupt handling (see [Section 24.9](#))
including interrupt registers (see [Section 24.9.2](#))
- General module operation (see [Section 24.10](#))
including general registers (see [Section 24.10.4](#))
- Module implementation (see [Section 24.11](#))

24.1 Introduction

The CCU6 unit is made up of a Timer T12 Block with three capture/compare channels and a Timer T13 Block with one compare channel. The T12 channels can independently generate PWM signals or accept capture triggers, or they can jointly generate control signal patterns to drive AC-motors or inverters.

A rich set of status bits, synchronized updating of parameter values via shadow registers, and flexible generation of interrupt request signals provide means for efficient software-control.

*Note: The capture/compare module itself is named CCU6 (capture/compare unit 6).
A capture/compare channel inside this module is named CC6x.*

24.1.1 Feature Set Overview

This section gives an overview over the different building blocks and their main features.

Timer 12 Block Features

- Three capture/compare channels, each channel can be used either as capture or as compare channel
- Generation of a three-phase PWM supported (six outputs, individual signals for high-side and low-side switches)
- 16-bit resolution, maximum count frequency = peripheral clock
- Dead-time control for each channel to avoid short-circuits in the power stage
- Concurrent update of T12 registers
- Center-aligned and edge-aligned PWM can be generated
- Single-shot mode supported
- Start can be controlled by external events
- Capability of counting external events
- Many interrupt request sources
- Hysteresis-like control mode

Timer 13 Block Features

- One independent compare channel with one output
- 16-bit resolution, maximum count frequency = peripheral clock
- Concurrent update of T13 registers
- Can be synchronized to T12
- Interrupt generation at period-match and compare-match
- Single-shot mode supported
- Start can be controlled by external events
- Capability of counting external events

Additional Specific Functions

- Block commutation for Brushless DC-drives implemented
- Position detection via Hall-sensor pattern
- Noise filter supported for position input signals
- Automatic rotational speed measurement and commutation control for block commutation
- Integrated error handling
- Fast emergency stop without CPU load via external signal ($\overline{\text{CTRAP}}$)
- Control modes for multi-channel AC-drives
- Output levels can be selected and adapted to the power stage

Capture/Compare Unit 6 (CCU6)

24.1.2 Block Diagram

The Timer T12 can operate in capture and/or compare mode for its three channels. The modes can also be combined (e.g. a channel operates in compare mode, whereas another channel operates in capture mode). The Timer T13 can operate in compare mode only. The multi-channel control unit generates output patterns which can be modulated by T12 and/or T13. The modulation sources can be selected and combined for the signal modulation.

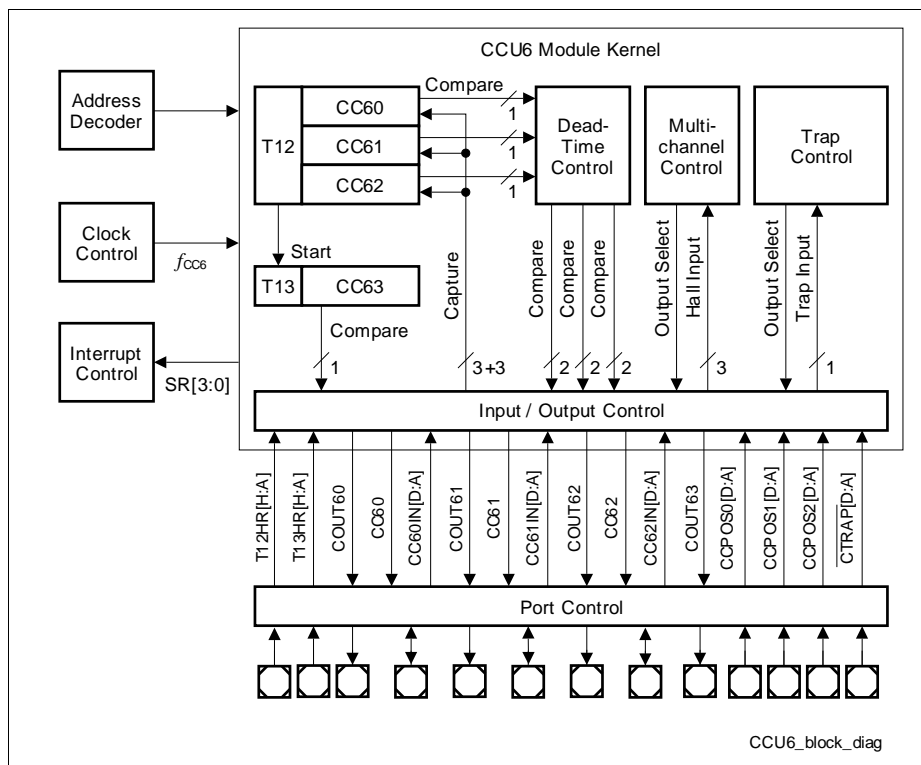


Figure 24-1 CCU6 Block Diagram

Capture/Compare Unit 6 (CCU6)

24.1.3 CCU6 Kernel Registers

For the generation of the overall register table, the prefix “CCU6x_” has to be added to the register names in this table to identify the registers of different CCU6 modules that are implemented. In this naming convention, x indicates the module number.

Table 24-1 shows all registers required for programming of a CCU6 module. It summarizes the CCU6 kernel registers and defines their offset addresses.

CCU6 Kernel Register Overview

T12 related Registers	Cap/Com Control Registers	Interrupt Status/ Control Registers	General Registers
T12	CMPSTAT	IS	LI
T12PR	CMPMODIF	ISS	IMON
T12DTC	T12MSEL	ISR	KSCFG
CC60R	TCTR0	INP	KSCSR
CC60SR	TCTR2	IEN	MCFG
CC61R	TCTR4		PISEL2
CC61SR			PISEL0
CC62R			
CC62SR			
	Modulation Control Registers	Identification Register	
	MODCTR	ID	
	TRPCTR		
	PSLR		
	MCMCTR		
	MCMOUTS		
	MCMOUT		
T13			
T13PR			
CC63R			
CC63SR			

CCU6_regs

Figure 24-2 CCU6 Registers

Note: In the case of a write access to addresses inside the address range (that is covered by the same chip select signal), but that are not the addresses explicitly mentioned for the module, the write access is not taken into account for the module. The same principle is valid for read accesses. In case of a read access to another address, the module does not react.

Capture/Compare Unit 6 (CCU6)

Note: The exact register address is given by the relative address of the register (given in [Table 24-1](#)) plus the kernel base address (given in [Table 24-14](#)) of the kernel.

Table 24-1 CCU6 Module Registers

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Reset	Page
			Read	Write			
General Registers							
ID	Module Identification Register	08 _H	U, SV	U, SV	0000 54XX _H	Class 3	24-118
PISEL0	Port Input Select Register 0	10 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-119
PISEL2	Port Input Select Register 2	14 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-121
KSCFG	Kernel State Configuration Register	18 _H	U, SV	U,SV	0000 0000 _H	Class3/ Class 1, see Section 2 4.10.4.3	24-124
KSCSR	Kernel State Control Sensitivity Register	1C _H	U, SV	U,SV	0000 0000 _H	Class 3	24-127
MCFG	Module Configuration Register	04 _H	U, SV	U,SV	0000 0007 _H	Class 3	24-128
IMON	Input Monitoring Register	98 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-130
LI	Lost Indicator Register	9C _H	U, SV	U, SV	0000 0000 _H	Class 3	24-133
SRCx x = 0 - 3	Service Request Control Registers	FC _H - x * 4 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-112

Capture/Compare Unit 6 (CCU6)

Table 24-1 CCU6 Module Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Reset	Page
			Read	Write			

Timer T12 related Registers

T12	Timer 12 Counter Register	20 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-35
T12PR	Timer 12 Period Register	24 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-36
T12DTC	Dead-Time Control Register for Timer T12	28 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-39
CC60R	Capture/Compare Register Channel CC60	30 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-37
CC61R	Capture/Compare Register Channel CC61	34 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-37
CC62R	Capture/Compare Register Channel CC62	38 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-37
CC60SR	Capture/Compare Shadow Register Channel CC60	40 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-38
CC61SR	Capture/Compare Shadow Register Channel CC61	44 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-38

Capture/Compare Unit 6 (CCU6)

Table 24-1 CCU6 Module Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Reset	Page
			Read	Write			
CC62SR	Capture/Compare Shadow Register Channel CC62	48 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-38

Capture/Compare Control Registers

CMPSTAT	Compare State Register	60 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-41
CMPMODIF	Compare State Modification Register	64 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-44
T12MSEL	T12 Capture/Compare Mode Select Register	68 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-45
TCTR0	Timer Control Register 0	70 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-46
TCTR2	Timer Control Register 2	74 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-50
TCTR4	Timer Control Register 4	78 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-53

Timer T13 related Registers

T13	Timer 13 Counter Register	50 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-68
T13PR	Timer 13 Period Register	54 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-69

Capture/Compare Unit 6 (CCU6)

Table 24-1 CCU6 Module Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Reset	Page
			Read	Write			
CC63R	Compare Register for Timer 13	58 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-70
CC63SR	Compare Shadow Register for Timer 13	5C _H	U, SV	U, SV	0000 0000 _H	Class 3	24-71

Modulation Control Registers

MODCTR	Modulation Control Register	80 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-85
TRPCTR	Trap Control Register	84 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-87
PSLR	Passive State Level Register	88 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-90
MCMOUTS	Multi-Channel Mode Output Shadow Register	8C _H	U, SV	U, SV	0000 0000 _H	Class 3	24-94
MCMOUT	Multi-Channel Mode Output Register	90 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-95
MCMCTR	Multi-Channel Mode Control Register	94 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-91

Interrupt Status and Node Registers

Capture/Compare Unit 6 (CCU6)

Table 24-1 CCU6 Module Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Reset	Page
			Read	Write			
IS	Interrupt Status Register	A0 _H	U, SV	U,SV	0000 0000 _H	Class 3	24-100
ISS	Interrupt Status Set Register	A4 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-103
ISR	Interrupt Status Reset Register	A8 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-105
INP	Interrupt Node Pointer Register	AC _H	U, SV	U, SV	0000 3940 _H	Class 3	24-110
IEN	Interrupt Node Pointer Register	B0 _H	U, SV	U, SV	0000 0000 _H	Class 3	24-107

24.2 Operating Timer T12

The timer T12 block is the main unit to generate the 3-phase PWM signals. A 16-bit counter is connected to 3 channel registers via comparators, that generate a signal when the counter contents match one of the channel register contents. A variety of control functions facilitate the adaptation of the T12 structure to different application needs. Besides the 3-phase PWM generation, the T12 block offers options for individual compare and capture functions, as well as dead-time control and hysteresis-like compare mode.

This section provides information about:

- T12 overview (see [Section 24.2.1](#))
- Counting scheme (see [Section 24.2.2](#))
- Compare modes (see [Section 24.2.3](#))
- Compare mode output path (see [Section 24.2.4](#))
- Capture modes (see [Section 24.2.5](#))
- Shadow transfer (see [Section 24.2.6](#))
- T12 operating mode selection (see [Section 24.2.7](#))
- T12 register description (see [Section 24.2.8](#))

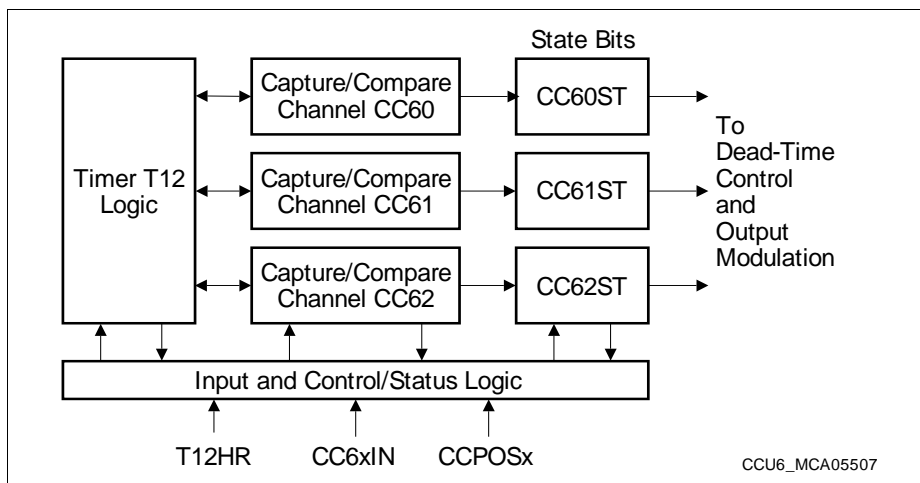


Figure 24-3 Overview Diagram of the Timer T12 Block

Capture/Compare Unit 6 (CCU6)

'down' after it has reached the period value (please note that in this mode, T12 exceeds the period value by one before counting down). In both cases, signal T12_PM (T12 Period Match) is generated. The Period Register receives a new period value from its Shadow Period Register.

A read access to T12PR delivers the current period value at the comparator, whereas a write access targets the Shadow Period Register to prepare another period value. The transfer of a new period value from the Shadow Period Register into the Period Register (see [Section 24.2.6](#)) is controlled via the 'T12 Shadow Transfer' control signal, T12_ST. The generation of this signal depends on the operating mode and on the shadow transfer enable bit STE12. Providing a shadow register for the period value as well as for other values related to the generation of the PWM signal allows a concurrent update by software for all relevant parameters.

Two further signals indicate whether the counter contents are equal to 0000_H (T12_ZM = zero match) or 0001_H (T12_OM = one match). These signals control the counting and switching behavior of T12.

The basic operating mode of T12, either Edge-Aligned mode ([Figure 24-5](#)) or Center-Aligned mode ([Figure 24-6](#)), is selected via bit CTM. A Single-Shot control bit, T12SSC, enables an automatic stop of the timer when the current counting period is finished (see [Figure 24-7](#) and [Figure 24-8](#)).

The start or stop of T12 is controlled by the Run bit T12R that can be modified by bits in register [TCTR4](#). The run bit can be set/cleared by software via the associated set/clear bits T12RS or T12RR, it can be set by a selectable edge of the input signal T12HR ([TCTR2.T12RSEL](#)), or it is cleared by hardware according to preselected conditions.

The timer T12 run bit T12R must not be set while the applied T12 period value is zero. Timer T12 can be cleared via control bit T12RES. Setting this write-only bit does only clear the timer contents, but has no further effects, for example, it does not stop the timer.

The generation of the T12 shadow transfer control signal, T12_ST, is enabled via bit STE12. This bit can be set or reset by software indirectly through its associated set/clear control bits T12STR and T12STD.

While Timer T12 is running, write accesses to the count register T12 are not taken into account. If T12 is stopped and the Dead-Time counters are 0, write actions to register T12 are immediately taken into account.

24.2.2 T12 Counting Scheme

This section describes the clocking and counting capabilities of T12.

24.2.2.1 Clock Selection

In **Timer Mode** (**PISEL2.ISCNT12** = 00_B), the input clock f_{T12} of Timer T12 is derived from the internal module clock f_{CC6} through a programmable prescaler and an optional 1/256 divider. The resulting prescaler factors are listed in **Table 24-2**. The prescaler of T12 is cleared while T12 is not running (**TCTR0.T12R** = 0) to ensure reproducible timings and delays.

Table 24-2 Timer T12 Input Frequency Options

T12CLK	Resulting Input Clock f_{T12} Prescaler Off (T12PRE = 0)	Resulting Input Clock f_{T12} Prescaler On (T12PRE = 1)
000 _B	f_{CC6}	$f_{CC6} / 256$
001 _B	$f_{CC6} / 2$	$f_{CC6} / 512$
010 _B	$f_{CC6} / 4$	$f_{CC6} / 1024$
011 _B	$f_{CC6} / 8$	$f_{CC6} / 2048$
100 _B	$f_{CC6} / 16$	$f_{CC6} / 4096$
101 _B	$f_{CC6} / 32$	$f_{CC6} / 8192$
110 _B	$f_{CC6} / 64$	$f_{CC6} / 16384$
111 _B	$f_{CC6} / 128$	$f_{CC6} / 32768$

In **Counter Mode**, timer T12 counts one step:

- If a 1 is written to **TCTR4.T12CNT** and **PISEL2.ISCNT12** = 01_B
- If a rising edge of input signal T12HR is detected and **PISEL2.ISCNT12** = 10_B
- If a falling edge of input signal T12HR is detected and **PISEL2.ISCNT12** = 11_B

24.2.2.2 Edge-Aligned / Center-Aligned Mode

In **Edge-Aligned Mode** (CTM = 0), timer T12 is always counting upwards (CDIR = 0). When reaching the value given by the period register (period-match T12_PM), the value of T12 is cleared with the next counting step (saw tooth shape).

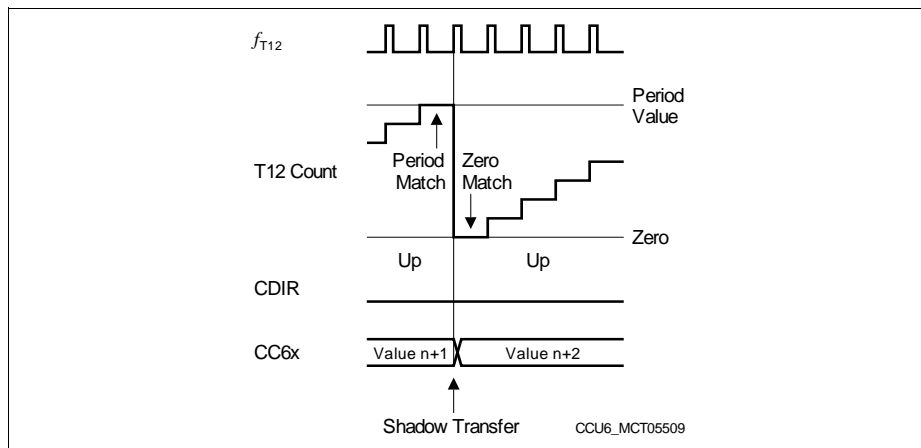


Figure 24-5 T12 Operation in Edge-Aligned Mode

As a result, in Edge-Aligned mode, the timer period is given by:

$$T12_{PER} = \langle \text{Period-Value} \rangle + 1; \text{ in } T12 \text{ clocks } (f_{T12}) \quad (24.1)$$

In **Center-Aligned Mode** (CTM = 1), timer T12 is counting upwards or downwards (triangular shape). When reaching the value given by the period register (period-match T12_PM) while counting upwards (CDIR = 0), the counting direction control bit CDIR is changed to downwards (CDIR = 1) with the next counting step.

When reaching the value 0001_H (one-match T12_OM) while counting downwards, the counting direction control bit CDIR is changed to upwards with the next counting step.

As a result, in Center-Aligned mode, the timer period is given by:

$$T12_{PER} = (\langle \text{Period-Value} \rangle + 1) \times 2; \text{ in } T12 \text{ clocks } (f_{T12}) \quad (24.2)$$

- With the next clock event of f_{T12} the count direction is set to counting up (CDIR = 0) when the counter reaches 0001_H while counting down.
- With the next clock event of f_{T12} the count direction is set to counting down (CDIR = 1) when the Period-Match is detected while counting up.
- With the next clock event of f_{T12} the counter counts up while CDIR = 0 and it counts down while CDIR = 1.

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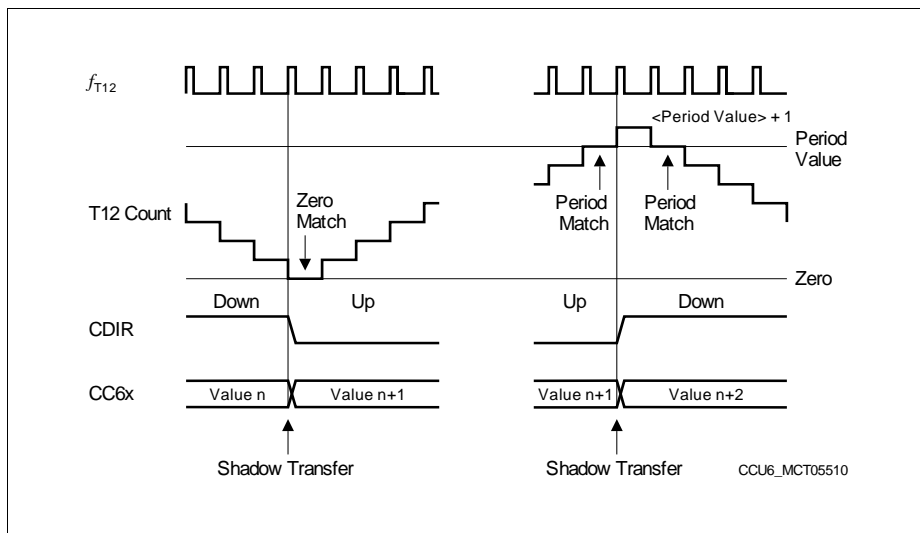


Figure 24-6 T12 Operation in Center-Aligned Mode

Note: Bit CDIR changes with the next timer clock event after the one-match or the period-match. Therefore, the timer continues counting in the previous direction for one cycle before actually changing its direction (see [Figure 24-6](#)).

24.2.2.3 Single-Shot Mode

In Single-Shot Mode, the timer run bit T12R is cleared by hardware. If bit T12SSC = 1, the timer T12 will stop when the current timer period is finished.

In Edge-Aligned mode, T12R is cleared when the timer becomes zero after having reached the period value (see [Figure 24-7](#)).

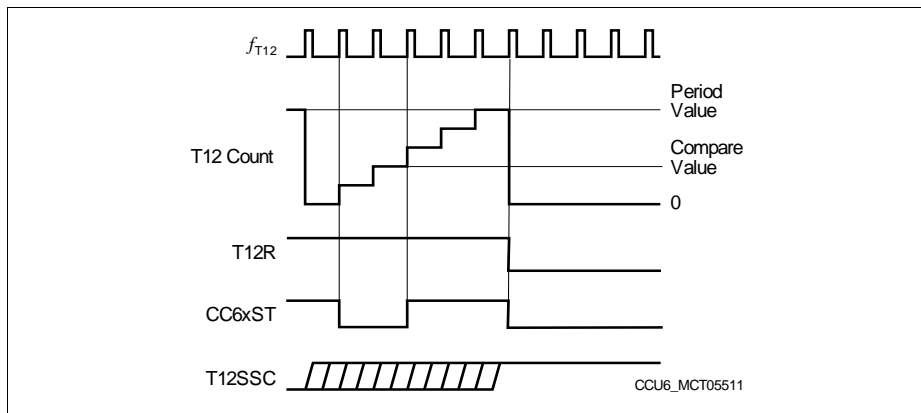


Figure 24-7 Single-Shot Operation in Edge-Aligned Mode

In Center-Aligned mode, the period is finished when the timer has counted down to zero (one clock cycle after the one-match while counting down, see [Figure 24-8](#)).

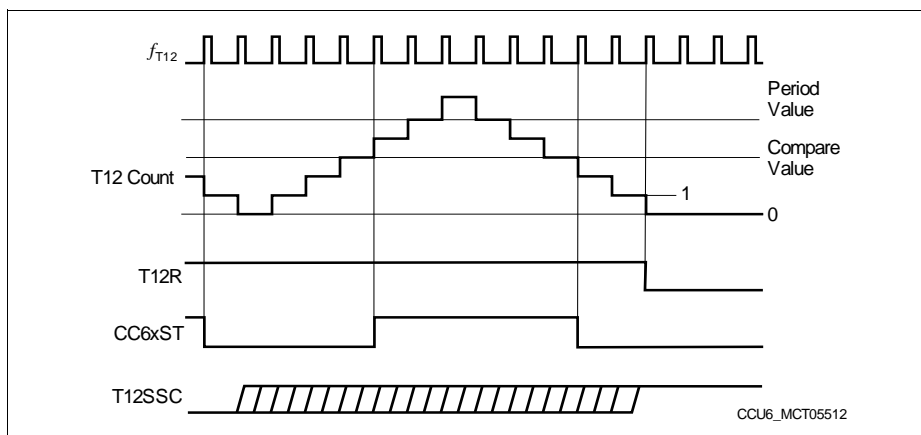


Figure 24-8 Single-Shot Operation in Center-Aligned Mode

24.2.3 T12 Compare Mode

Associated with Timer T12 are three individual capture/compare channels, that can perform compare or capture operations with regard to the contents of the T12 counter. The capture functions are explained in [Section 24.2.5](#).

24.2.3.1 Compare Channels

In Compare Mode (see [Figure 24-9](#)), the three individual compare channels CC60, CC61, and CC62 can generate a three-phase PWM pattern.

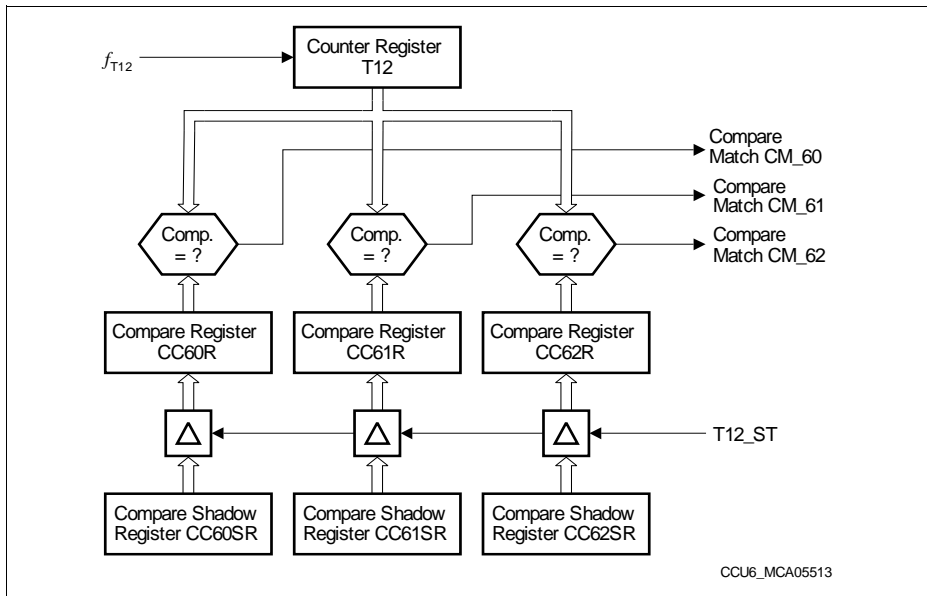


Figure 24-9 T12 Channel Comparators

Each compare channel is connected to the T12 counter register via its individual equal-to comparator, generating a match signal when the contents of the counter matches the contents of the associated compare register. Each channel consists of the comparator and a double register structure - the actual compare register CC6xR, feeding the comparator, and an associated shadow register CC6xSR, that is preloaded by software and transferred into the compare register when signal T12 shadow transfer, T12_ST, gets active. Providing a shadow register for the compare value as well as for other values related to the generation of the PWM signal facilitates a concurrent update by software for all relevant parameters of a three-phase PWM.

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In addition, each state bit can be set or cleared by software via the appropriate set and reset bits in register **CMPMODIF**, MCC6xS and MCC6xR. The input signals CCPOSx are used in hysteresis-like compare mode, whereas in normal compare mode, these inputs are ignored.

Note: In Hall Sensor, single shot or capture modes, additional/different rules are taken into account (see related sections).

A compare interrupt event CC6x_R is signaled when a compare match is detected while counting upwards, whereas the compare interrupt event CC6x_F is signaled when a compare match is detected while counting down. The actual setting of a State Bit has no influence on the interrupt generation in compare mode.

A modification of a State Bit CC6xST by the switching rule logic due to a compare action is only possible while Timer T12 is running ($T12R = 1$). If this is the case, the following switching rules apply for setting and clearing the State Bits in Compare Mode (illustrated in [Figure 24-11](#) and [Figure 24-12](#)):

A State Bit **CC6xST** is set to 1:

- with the next T12 clock (f_{T12}) after a compare-match when T12 is counting up (i.e., when the counter is incremented above the compare value);
- with the next T12 clock (f_{T12}) after a zero-match AND a parallel compare-match when T12 is counting up.

A State Bit **CC6xST** is cleared to 0:

- with the next T12 clock (f_{T12}) after a compare-match when T12 is counting down (i.e., when the counter is decremented below the compare value in center-aligned mode);
- with the next T12 clock (f_{T12}) after a zero-match AND NO parallel compare-match when T12 is counting up.

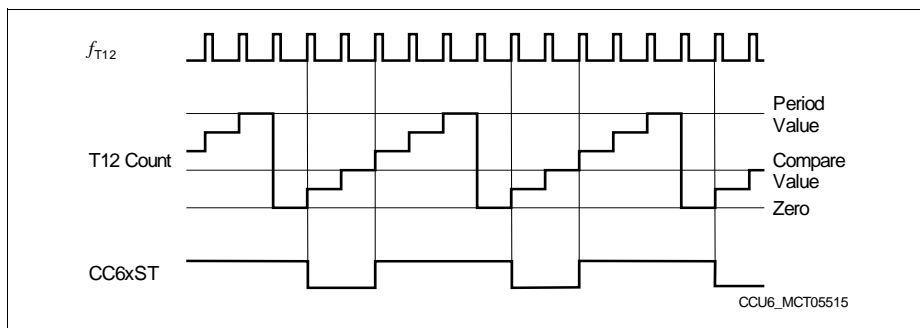


Figure 24-11 Compare Operation, Edge-Aligned Mode

[Figure 24-13](#) illustrates some more examples for compare waveforms. It is important to note that in these examples, it is assumed that some of the compare values are changed

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while the timer is running. This change is performed via a software preload of the Shadow Register, CC6xSR. The value is transferred to the actual Compare Register CC6xR with the T12 Shadow Transfer signal, T12_ST, that is assumed to be enabled.

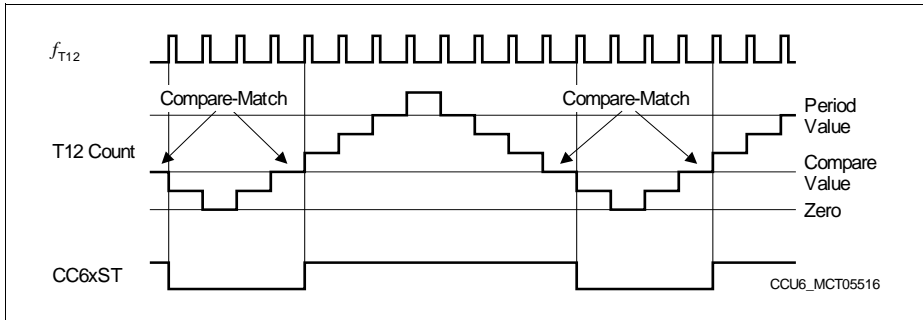


Figure 24-12 Compare Operation, Center-Aligned Mode

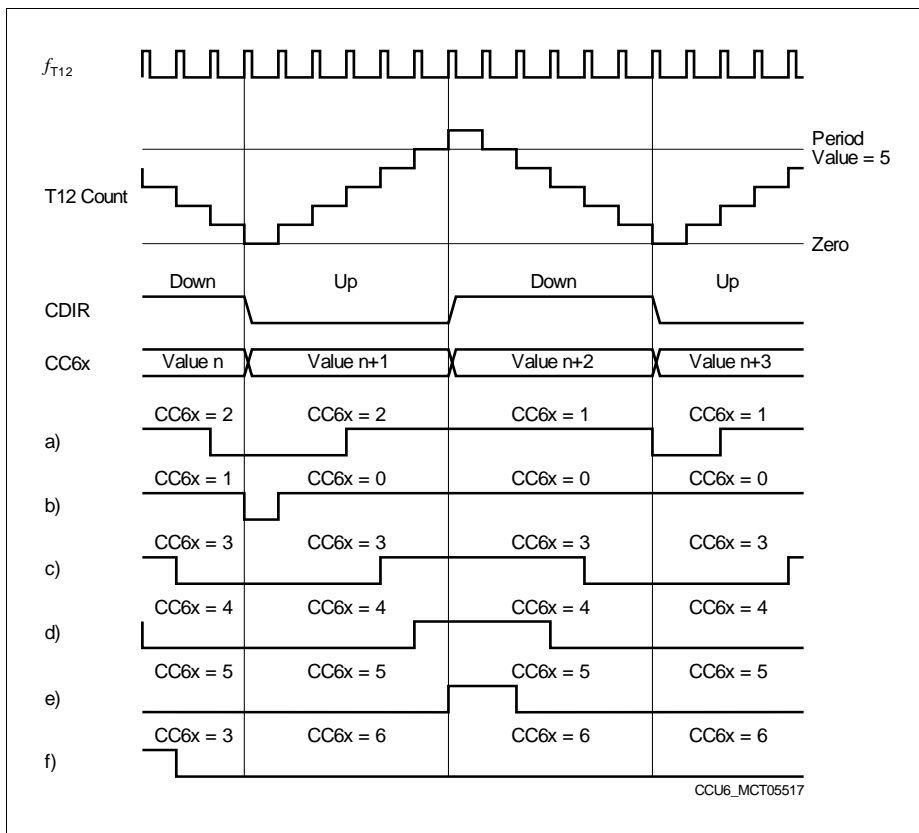


Figure 24-13 Compare Waveform Examples

Example b) illustrates the transition to a duty cycle of 100%. First, a compare value of 0001_H is used, then changed to 0000_H . Please note that a low pulse with the length of one T12 clock is still produced in the cycle where the new value 0000_H is in effect; this pulse originates from the previous value 0001_H . In the following timer cycles, the State Bit CC6xST remains at 1, producing a 100% duty cycle signal. In this case, the compare rule 'zero-match AND compare-match' is in effect.

Example f) shows the transition to a duty cycle of 0%. The new compare value is set to $\langle \text{Period-Value} \rangle + 1$, and the State Bit CC6ST remains cleared.

Figure 24-14 illustrates an example for the waveforms of all three channels. With the appropriate dead-time control and output modulation, a very efficient 3-phase PWM signal can be generated.

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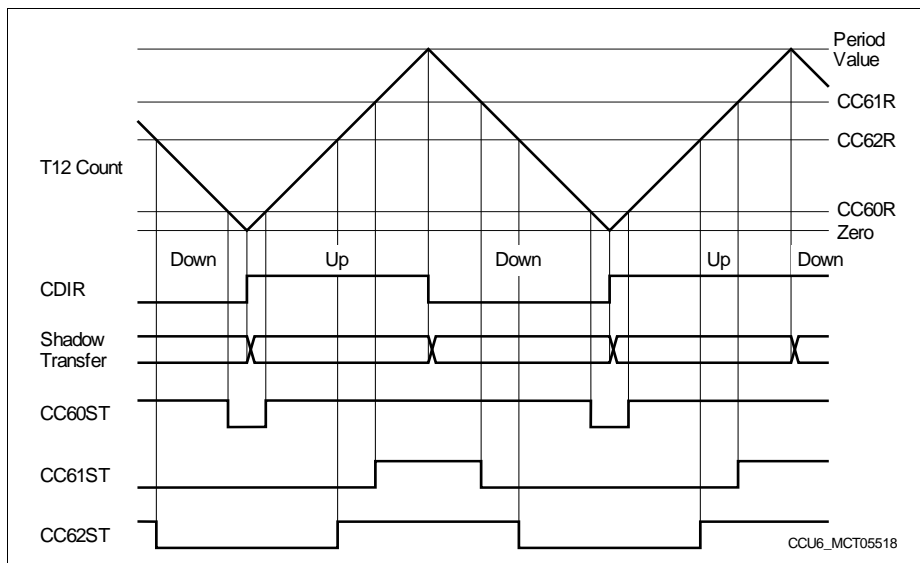


Figure 24-14 Three-Channel Compare Waveforms

24.2.3.3 Hysteresis-Like Control Mode

The hysteresis-like control mode (**T12MSEL**.MSEL6x = 1001_B) offers the possibility to switch off the PWM output if the input CCPOSx becomes 0 by clearing the State Bit CC6xST. This can be used as a simple motor control feature by using a comparator indicating, e.g., overcurrent. While CCPOSx = 0, the PWM outputs of the corresponding channel are driving their passive levels, because the setting of bit CC6xST is only possible while CCPOSx = 1.

As long as input CCPOSx is 0, the corresponding State Bit is held 0. When CCPOSx is at high level, the outputs can be in active state and are determined by bit CC6xST (see **Figure 24-10** for the state bit logic and **Figure 24-15** for the output paths).

The CCPOSx inputs are evaluated with f_{CC6} .

This mode can be used to introduce a timing-related behavior to a hysteresis controller. A standard hysteresis controller detects if a value exceeds a limit and switches its output according to the compare result. Depending on the operating conditions, the switching frequency and the duty cycle are not fixed, but change permanently.

If (outer) time-related control loops based on a hysteresis controller in an inner loop should be implemented, the outer loops show a better behavior if they are synchronized to the inner loops. Therefore, the hysteresis-like mode can be used, that combines timer-related switching with a hysteresis controller behavior. For example, in this mode, an output can be switched on according to a fixed time base, but it is switched off as soon as a falling edge is detected at input CCPOSx.

This mode can also be used for standard PWM with overcurrent protection. As long as there is no low level signal at pin CCPOSx, the output signals are generated in the normal manner as described in the previous sections. Only if input CCPOSx shows a low level, e.g. due to the detection of overcurrent, the outputs are shut off to avoid harmful stress to the system.

24.2.4 Compare Mode Output Path

Figure 24-15 gives an overview on the signal path from a channel State Bit to its output pin in its simplest form. As illustrated, a user has a variety of controls to determine the desired output signal switching behavior in relation to the current state of the State Bit, CC6xST. Please refer to [Section 24.2.4.3](#) for details on the output modulation.

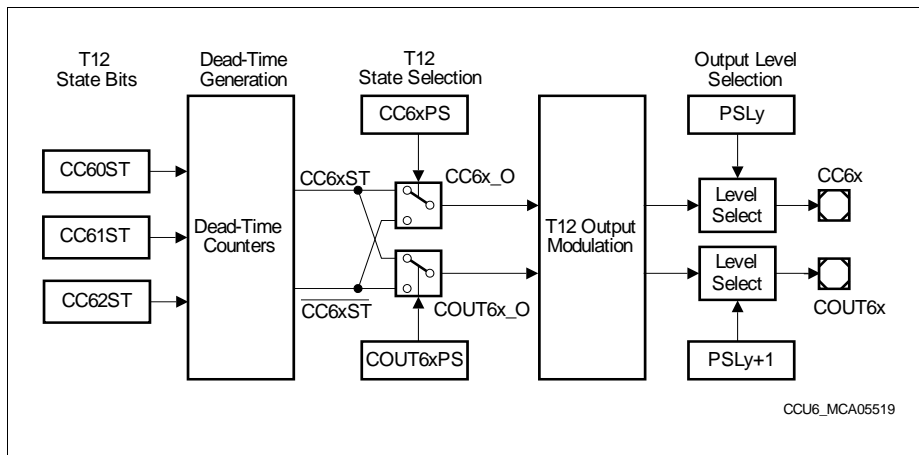


Figure 24-15 Compare Mode Simplified Output Path Diagram

The output path is based on signals that are defined as active or passive. The terms active and passive are not related to output levels, but to internal actions. This mainly applies for the modulation, where T12 and T13 signals are combined with the multi-channel signals and the trap function. The Output level Selection allows the user to define the output level at the output pin for the passive state (inverted level for the active state). It is recommended to configure this block in a way that an external power switch is switched off while the CCU6 delivers an output signal in the passive state.

24.2.4.1 Dead-Time Generation

The generation of (complementary) signals for the high-side and the low-side switches of one power inverter phase is based on the same compare channel. For example, if the high-side switch should be active while the T12 counter value is above the compare value (State Bit = 1), then the low-side switch should be active while the counter value is below the compare value (State Bit = 0).

In most cases, the switching behavior of the connected power switches is not symmetrical concerning the switch-on and switch-off times. A general problem arises if the time for switch-on is smaller than the time for switch-off of the power device. In this case, a short-circuit can occur in the inverter bridge leg, which may damage the complete system. In order to solve this problem by HW, this capture/compare unit

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contains a programmable Dead-Time Generation Block, that delays the passive to active edge of the switching signals by a programmable time (the active to passive edge is not delayed).

The Dead-Time Generation Block, illustrated in [Figure 24-16](#), is built in a similar way for all three channels of T12. It is controlled by bits in register **T12DTC**. Any change of a CC6xST State Bit activates the corresponding Dead-Time Counter, that is clocked with the same input clock as T12 (f_{T12}). The length of the dead-time can be programmed by bit field DTM. This value is identical for all three channels. Writing **TCTR4.DTRES = 1** sets all dead-times to passive.

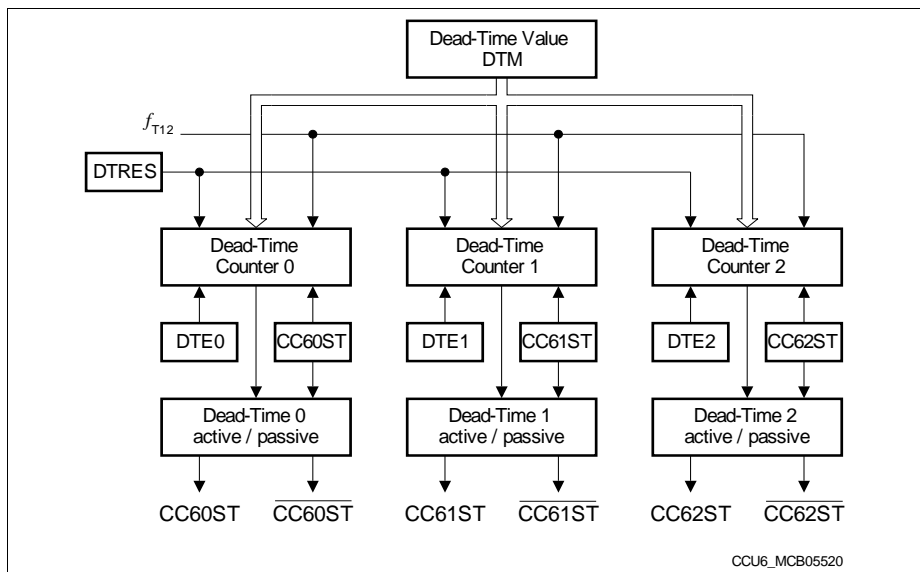


Figure 24-16 Dead-Time Generation Block Diagram

Each of the three dead-time counters has its individual dead-time enable bit, DTE_x. An enabled dead-time counter generates a dead-time delaying the passive-to-active edge of the channel output signal. The change in a State Bit CC6xST is not taken into account while the dead-time generation of this channel is currently in progress (active). This avoids an unintentional additional dead-time if a State Bit CC6xST changes too early. A disabled dead-time counter is always considered as passive and does not delay any edge of CC6xST.

Based on the State Bits CC6xST, the Dead-Time Generation Block outputs a direct signal CC6xST and an inverted signal $\overline{\text{CC6xST}}$ for each compare channel, each masked with the effect of the related Dead-Time Counters (waveforms illustrated in [Figure 24-17](#)).

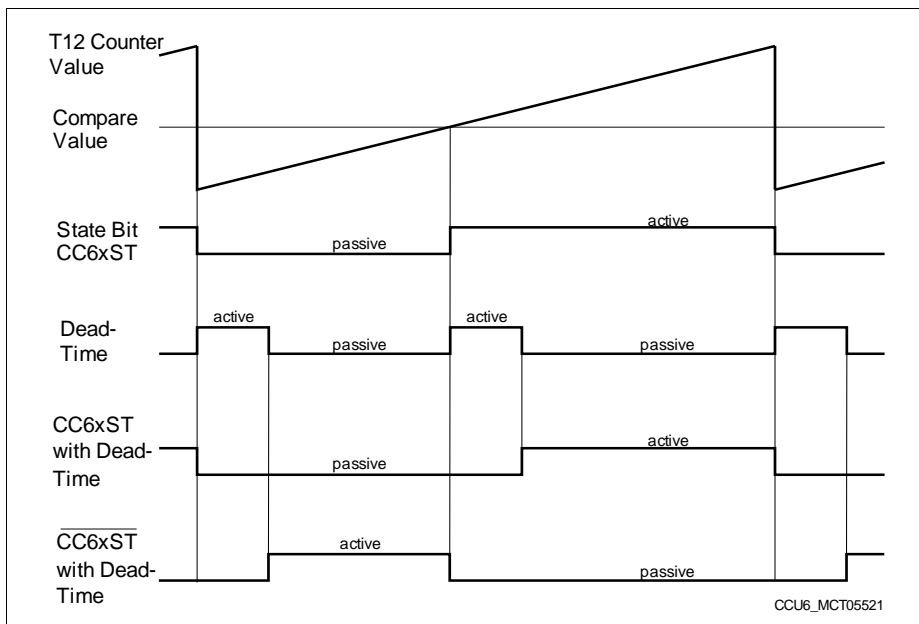


Figure 24-17 Dead-Time Generation Waveforms

24.2.4.2 State Selection

To support a wide range of power switches and drivers, the state selection offers the flexibility to define when an output can be active and can be modulated, especially useful for **complementary or multi-phase PWM** signals.

The state selection is based on the signals $\overline{\text{CC6xST}}$ and $\overline{\text{CC6xST}}$ delivered by the dead-time generator (see [Figure 24-15](#)). Both signals are never active at the same time, but can be passive at the same time. This happens during the dead-time of each compare channel after a change of the corresponding State Bit CC6xST .

The user can select independently for each output signal CC6xO and COUT6xO if it should be active before or after the compare value has been reached (see register [CMPSTAT](#)). With this selection, the active (conducting) phases of complementary power switches in a power inverter bridge leg can be positioned with respect to the compare value (e.g. signal CC6xO can be active before, whereas COUT6xO can be active after the compare value is reached). Like this, the output modulation, the trap logic and the output level selection can be programmed independently for each output signal, although two output signals are referring to the same compare channel.

24.2.4.3 Output Modulation and Level Selection

The last block of the data path is the Output Modulation block. Here, all the modulation sources and the trap functionality are combined and control the actual level of the output pins (controlled by the modulation enable bits T1xMODENy and MCMEN in register **MODCTR**). The following signal sources can be combined here **for each T12 output signal** (see **Figure 24-18** for compare channel CC60):

- A **T12 related compare signal** CC6x_O (for outputs CC6x) or COUT6x_O (for outputs COUT6x) delivered by the T12 block (state selection with dead-time) with an individual enable bit T12MODENy per output signal (y = 0, 2, 4 for outputs CC6x and y = 1, 3, 5 for outputs COUT6x)
- The **T13 related compare signal** CC63_O delivered by the T13 state selection with an individual enable bit T13MODENy per output signal (y = 0, 2, 4 for outputs CC6x and y = 1, 3, 5 for outputs COUT6x)
- A **multi-channel output signal** MCMPy (y = 0, 2, 4 for outputs CC6x and y = 1, 3, 5 for outputs COUT6x) with a common enable bit MCMEN
- The **trap state** TRPS with an individual enable bit TRPENy per output signal (y = 0, 2, 4 for outputs CC6x and y = 1, 3, 5 for outputs COUT6x)

If one of the modulation input signals CC6x_O/COUT6x_O, CC63_O, or MCMPy of an output modulation block is enabled and is at passive state, the modulated is also in passive state, regardless of the state of the other signals that are enabled. Only if all enabled signals are in active state the modulated output shows an active state. If no modulation input is enabled, the output is in passive state.

If the Trap State is active (TRPS = 1), then the outputs that are enabled for the trap signal (by TRPENy = 1) are set to the passive state.

The output of each of the modulation control blocks is connected to a level select block that is configured by register **PSLR**. It offers the option to determine the actual output level of a pin, depending on the state of the output line (decoupling of active/passive state and output polarity) as specified by the Passive State Select bit PSLy. If the modulated output signal is in the passive state, the level specified directly by PSLy is output. If it is in the active state, the inverted level of PSLy is output. This allows the user to adapt the polarity of an active output signal to the connected circuitry.

The PSLy bits have shadow registers to allow for updates without undesired pulses on the output lines. The bits related to CC6x and COUT6x (x = 0, 1, 2) are updated with the T12 shadow transfer signal (T12_ST). A read action returns the actually used values, whereas a write action targets the shadow bits. Providing a shadow register for the PSL value as well as for other values related to the generation of the PWM signal facilitates a concurrent update by software for all relevant parameters.

Figure 24-18 shows the output modulation structure for compare channel CC60 (output signals CC60 and COUT60). A similar structure is implemented for the other two compare channels CC61 and CC62.

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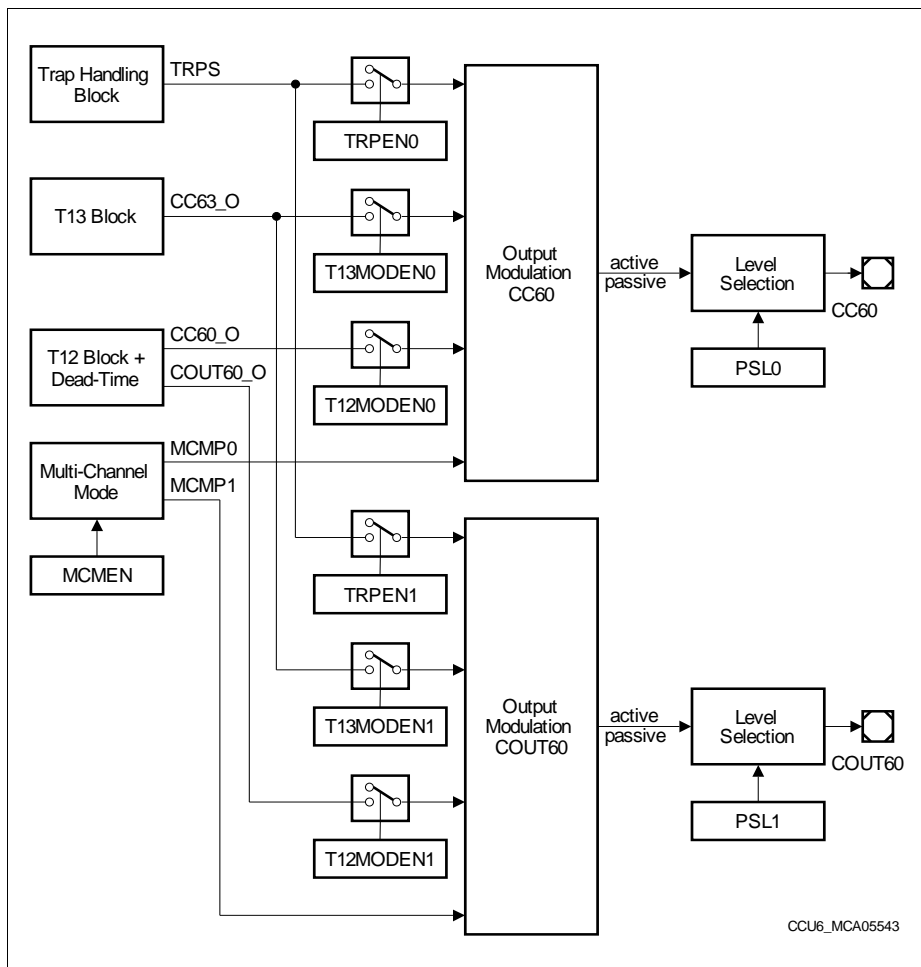


Figure 24-18 Output Modulation for Compare Channel CC60

24.2.5 T12 Capture Modes

Each of the three channels of the T12 Block can also be used to capture T12 time information in response to an external signal CC6xIN.

In capture mode, the interrupt event CC6x_R is detected when a rising edge is detected at the input CC6xIN, whereas the interrupt event CC6x_F is detected when a falling edge is detected.

There are a number of different modes for capture operation. In all modes, both of the registers of a channel are used. The selection of the capture modes is done via the **T12MSEL**. MSEL6x bit fields and can be selected individually for each of the channels.

Table 24-3 Capture Modes Overview

MSEL6x	Mode	Signal	Active Edge	CC6nSR Stored in	T12 Stored in
0100 _B	1	CC6xIN	Rising	–	CC6xR
		CC6xIN	Falling	–	CC6xSR
0101 _B	2	CC6xIN	Rising	CC6xR	CC6xSR
0110 _B	3	CC6xIN	Falling	CC6xR	CC6xSR
0111 _B	4	CC6xIN	Any	CC6xR	CC6xSR

Figure 24-19 illustrates **Capture Mode 1**. When a rising edge (0-to-1 transition) is detected at the corresponding input signal CC6xIN, the current contents of Timer T12 are captured into register CC6xR. When a falling edge (1-to-0 transition) is detected at the input signal CC6xIN, the contents of Timer T12 are captured into register CC6xSR.

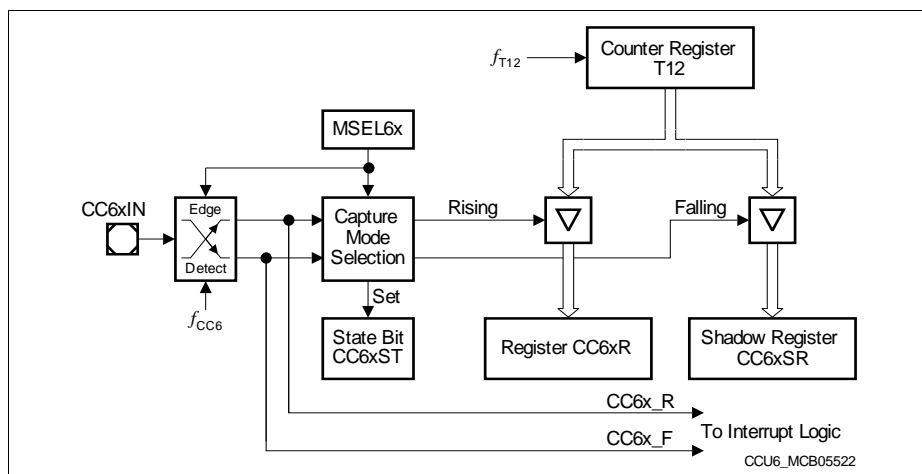


Figure 24-19 Capture Mode 1 Block Diagram

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Capture Modes 2, 3 and 4 are shown in **Figure 24-20**. They differ only in the active edge causing the capture operation. In each of the three modes, when the selected edge is detected at the corresponding input signal CC6xIN, the current contents of the shadow register CC6xSR are transferred into register CC6xR, and the current Timer T12 contents are captured in register CC6xSR (simultaneous transfer). The active edge is a rising edge of CC6xIN for Capture Mode 2, a falling edge for Mode 3, and both, a rising or a falling edge for Capture Mode 4, as shown in **Table 24-3**. These capture modes are very useful in cases where there is little time between two consecutive edges of the input signal.

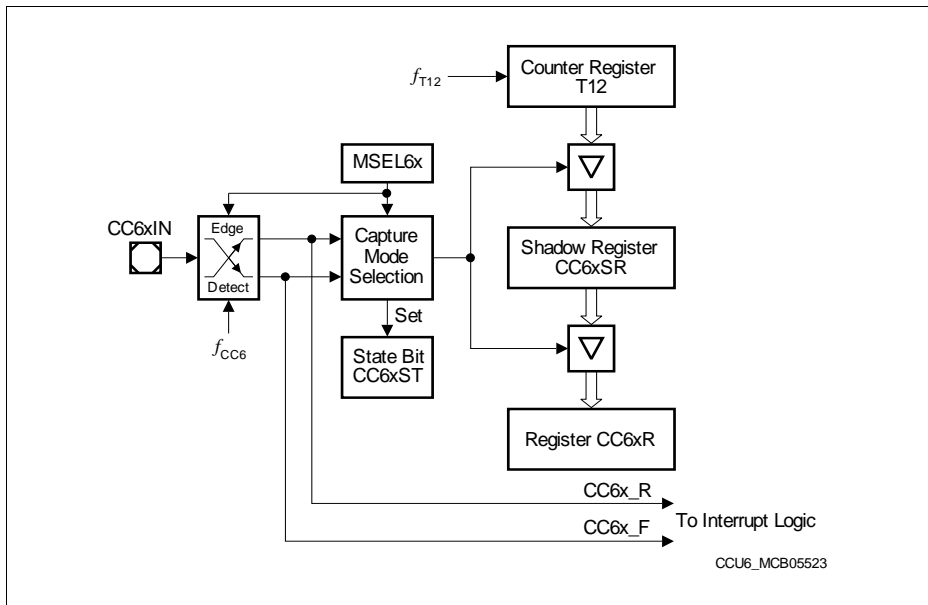


Figure 24-20 Capture Modes 2, 3 and 4 Block Diagram

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Five further capture modes are called **Multi-Input Capture Modes**, as they use two different external inputs, signal CC6xIN and signal CCPOSx.

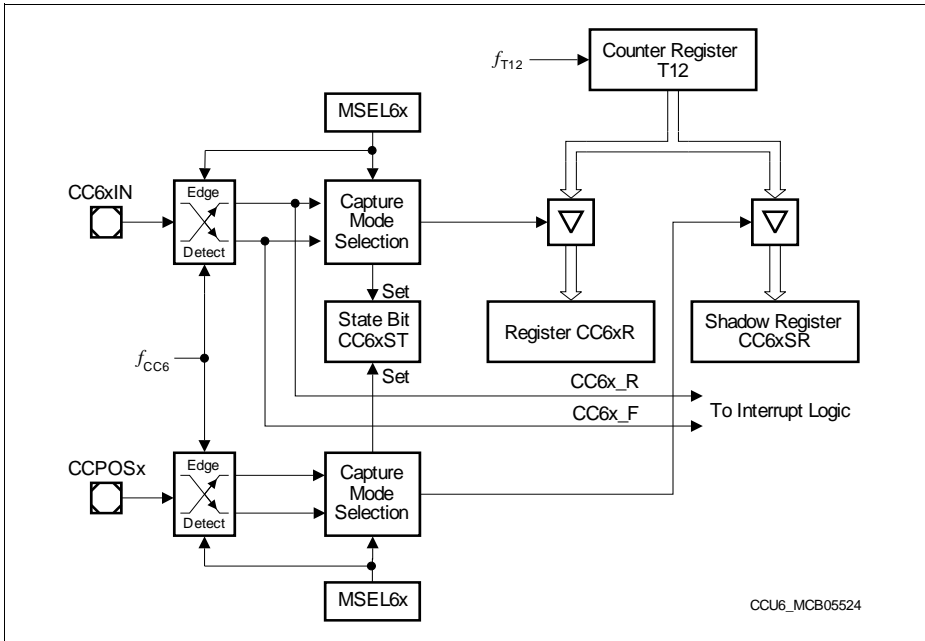


Figure 24-21 Multi-Input Capture Modes Block Diagram

In each of these modes, the current T12 contents are captured in register CC6xR in response to a selected event at signal CC6xIN, and in register CC6xSR in response to a selected event at signal CCPOSx. The possible events can be opposite input transitions, or the same transitions, or any transition at the two inputs. The different options are detailed in [Table 24-4](#).

In each of the various capture modes, the Channel State Bit, CC6xST, is set to 1 when the selected capture trigger event at signal CC6xIN or CCPOSx has occurred. The State Bit is not cleared by hardware, but can be cleared by software.

In addition, appropriate signal lines to the interrupt logic are activated, that can generate an interrupt request to the CPU. Regardless of the selected active edge, all edges detected at signal CC6xIN can lead to the activation of the appropriate interrupt request line (see also [Section 24.9](#)).

Table 24-4 Multi-Input Capture Modes Overview

MSEL6x	Mode	Signal	Active Edge	T12 Stored in
1010 _B	5	CC6xIN	Rising	CC6xR
		CCPOSx	Falling	CC6xSR
1011 _B	6	CC6xIN	Falling	CC6xR
		CCPOSx	Rising	CC6xSR
1100 _B	7	CC6xIN	Rising	CC6xR
		CCPOSx	Rising	CC6xSR
1101 _B	8	CC6xIN	Falling	CC6xR
		CCPOSx	Falling	CC6xSR
1110 _B	9	CC6xIN	Any	CC6xR
		CCPOSx	Any	CC6xSR
1111 _B	–	reserved (no capture or compare action)		

24.2.6 T12 Shadow Register Transfer

A special shadow transfer signal (T12_ST) can be generated to facilitate updating the period and compare values of the compare channels CC60, CC61, and CC62 synchronously to the operation of T12. Providing a shadow register for values defining one PWM period facilitates a concurrent update by software for all relevant parameters. The next PWM period can run with a new set of parameters. The generation of this signal is requested by software via bit **TCTR0.STE12** (set by writing 1 to the write-only bit **TCTR4.T12STR**, cleared by writing 1 to the write-only bit **TCTR4.T12STD**).

Figure 24-22 shows the shadow register structure and the shadow transfer signals, as well as on the read/write accessibility of the various registers.

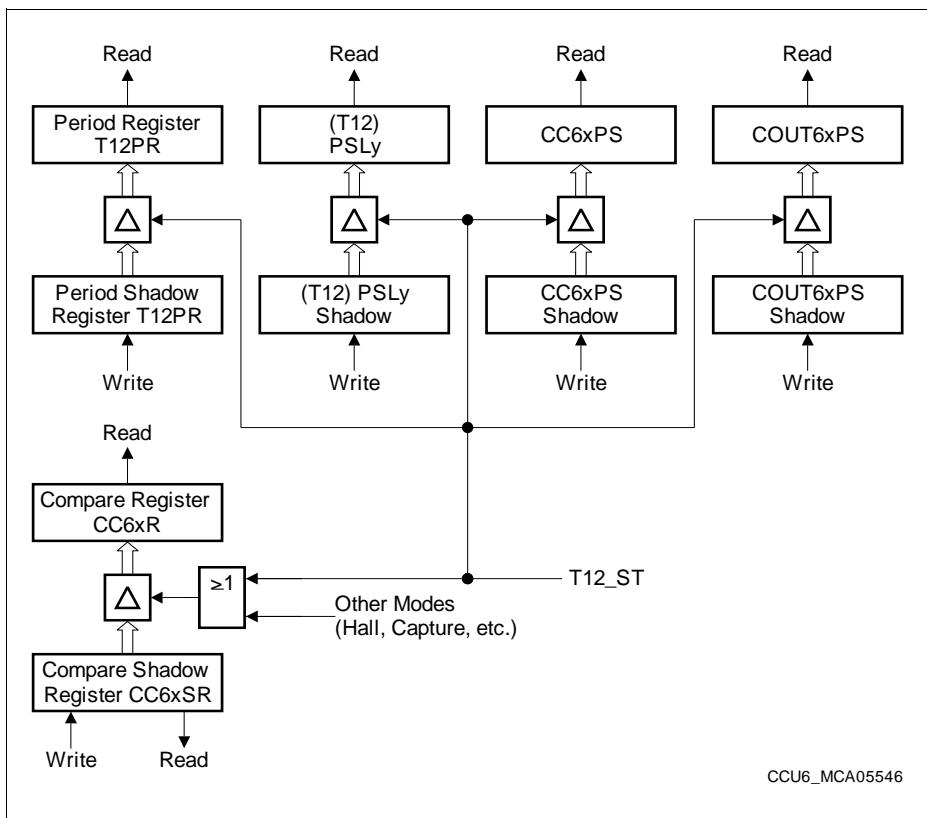


Figure 24-22 T12 Shadow Register Overview

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A T12 shadow register transfer takes place (T12_ST active):

- while timer T12 is not running (T12R = 0), or
- STE12 = 1 and a Period-Match is detected while counting up, or
- STE12 = 1 and a One-Match is detected while counting down

When signal T12_ST is active, a shadow register transfer is triggered with the next cycle of the T12 clock. Bit STE12 is automatically cleared with the shadow register transfer.

24.2.7 Timer T12 Operating Mode Selection

The operating mode for the T12 channels are defined by the bit fields **T12MSEL**.MSEL6x.

Table 24-5 T12 Capture/Compare Modes Overview

MSEL6x	Selected Operating Mode
0000 _B , 1111 _B	Capture/Compare modes switched off
0001 _B , 0010 _B , 0011 _B	Compare mode, see Section 24.2.3 same behavior for all three codings
01XX _B	Double-Register Capture modes, see Section 24.2.5
1000 _B	Hall Sensor Mode, see Section 24.7 In order to properly enable this mode, all three MSEL6x fields have to be programmed to Hall Sensor mode.
1001 _B	Hysteresis-like compare mode, see Section 24.2.3.3
1010 _B , 1011 _B , 1100 _B , 1101 _B , 1110 _B	Multi-Input Capture modes, see Section 24.2.5

The clocking and counting scheme of the timers are controlled by the timer control registers **TCTR0** and **TCTR2**. Specific actions are triggered by write operations to register **TCTR4**.

24.2.8 T12 related Registers

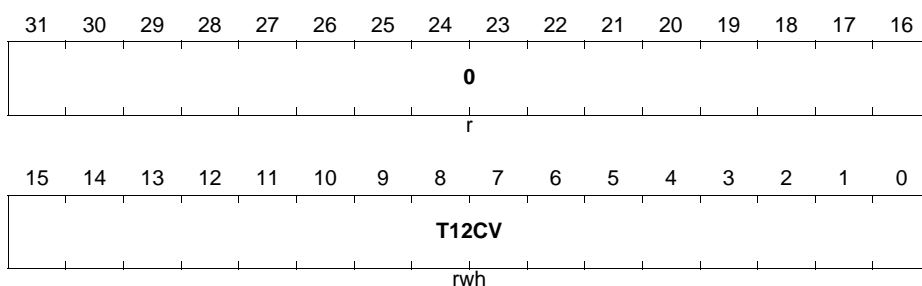
24.2.8.1 T12 Counter Register

Register T12 represents the counting value of timer T12. It can only be written while the timer T12 is stopped. Write actions while T12 is running are not taken into account. Register T12 can always be read by SW.

In edge-aligned mode, T12 only counts up, whereas in center-aligned mode, T12 can count up and down.

T12

Timer T12 Counter Register (20_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
T12CV	[15:0]	rwh	Timer 12 Counter Value This register represents the 16-bit counter value of Timer12.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Note: While timer T12 is stopped, the internal clock divider is reset in order to ensure reproducible timings and delays.

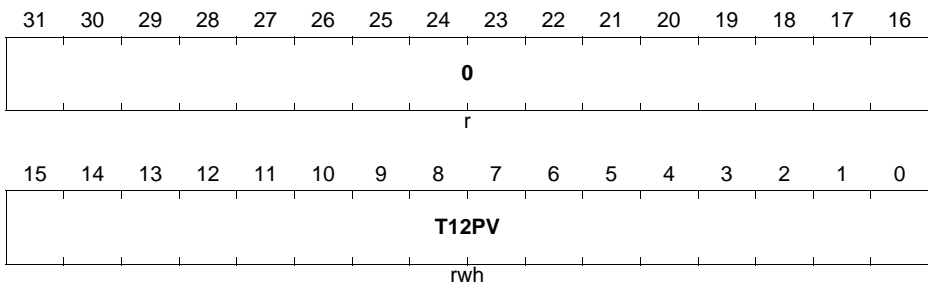
24.2.8.2 Period Register

Register T12PR contains the period value for timer T12. The period value is compared to the actual counter value of T12 and the resulting counter actions depend on the defined counting rules. This register has a shadow register and the shadow transfer is controlled by bit STE12. A read action by SW delivers the value that is currently used for the compare action, whereas the write action targets a shadow register. The shadow register structure allows a concurrent update of all T12-related values.

T12PR

Timer 12 Period Register

(24_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
T12PV	[15:0]	rwh	T12 Period Value The value T12PV defines the counter value for T12 leading to a period-match. When reaching this value, the timerT12 is set to zero (edge-aligned mode) or changes its count direction to down counting (center-aligned mode).
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

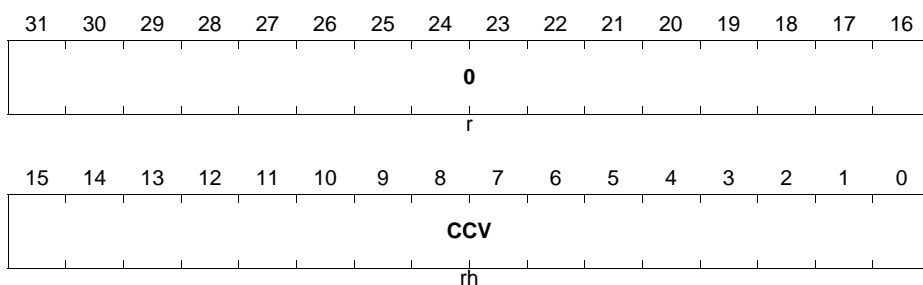
24.2.8.3 Capture/Compare Registers

In compare mode, the registers CC6xR (x = 0 - 2) are the actual compare registers for T12. The values stored in CC6xR are compared (all three channels in parallel) to the counter value of T12. In capture mode, the current value of the T12 counter register is captured by registers CC6xR if the corresponding capture event is detected.

CC6xR (x = 0-2)

Capture/Compare Register for Channel CC6x

 $(30_H + 4 \cdot x)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CCV	[15:0]	rh	Capture/Compare Value In compare mode, the bit fields CCV contain the values, that are compared to the T12 counter value. In capture mode, the captured value of T12 can be read from these registers.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

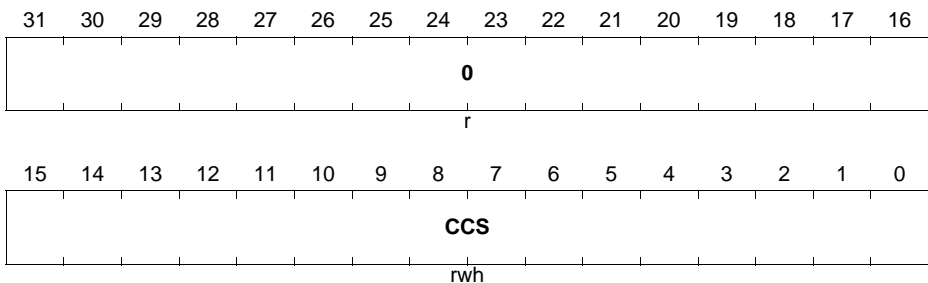
24.2.8.4 Capture/Compare Shadow Registers

The registers CC6xR can only be read by SW, the modification of the value is done by a shadow register transfer from register CC6xSR. The corresponding shadow registers CC6xSR can be read and written by SW. In capture mode, the value of the T12 counter register can also be captured by registers CC6xSR if the selected capture event is detected (depending on the selected capture mode).

CC6xSR (x=0-2)

Capture/Compare Shadow Reg. for Channel CC6x

 $(40_H + 4 \cdot x)$

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CCS	[15:0]	rwh	Shadow Register for Channel x Capture/Compare Value In compare mode, the bit fields contents of CCS are transferred to the bit fields CCV for the corresponding channel during a shadow transfer. In capture mode, the captured value of T12 can be read from these registers.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Note: The shadow registers can also be written by SW in capture mode. In this case, the HW capture event wins over the SW write if both happen in the same cycle (the SW write is discarded).

Capture/Compare Unit 6 (CCU6)

24.2.8.5 Dead-time Control Register

Register T12DTC controls the dead-time generation for the timer T12 compare channels. Each channel can be independently enabled/disabled for dead-time generation. If enabled, the transition from passive state to active state is delayed by the value defined by bit field DTM.

The dead time counters are clocked with the same frequency as T12.

This structure allows symmetrical dead-time generation in center-aligned and in edge-aligned PWM mode. A duty cycle of 50% leads to CC6x, COUT6x switched on for: $0.5 \cdot \text{period} - \text{dead time}$.

Note: The dead-time counters are not reset by bit T12RES, but by bit DTRES.

T12DTC

Dead-Time Control Register for Timer12

(28_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	DTR 2	DTR 1	DTR 0	0	DTE 2	DTE 1	DTE 0	DTM							
r	rh	rh	rh	r	rw	rw	rw	rw							

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
DTM	[7:0]	rw	Dead-Time Bit field DTM determines the programmable delay between switching from the passive state to the active state of the selected outputs. The switching from the active state to the passive state is not delayed.
DTE2, DTE1, DTE0	10, 9, 8	rw	Dead Time Enable Bits Bits DTE0..DTE2 enable and disable the dead time generation for each compare channel (0, 1, 2) of timer T12. 0_B Dead-Time Counter x is disabled. The corresponding outputs switch from the passive state to the active state (according to the actual compare status) without any delay. 1_B Dead-Time Counter x is enabled. The corresponding outputs switch from the passive state to the active state (according to the compare status) with the delay programmed in bit field DTM.
DTR2, DTR1, DTR0	14, 13, 12	rh	Dead Time Run Indication Bits Bits DTR0..DTR2 indicate the status of the dead time generation for each compare channel (0, 1, 2) of timer T12. 0_B Dead-Time Counter x is currently in the passive state. 1_B Dead-Time Counter x is currently in the active state.
0	11, [31:15]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.2.9 Capture/Compare Control Registers

24.2.9.1 Channel State Bits

The Compare State Register CMPSTAT contains status bits monitoring the current capture and compare state and control bits defining the active/passive state of the compare channels.

CMPSTAT

Compare State Register

(60_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T13 IM	C OUT 63PS	C OUT 62PS	CC 62PS	C OUT 61PS	CC 61PS	C OUT 60PS	CC 60PS	0	CC 63ST	CC POS 62	CC POS 61	CC POS 60	CC 62ST	CC 61ST	CC 60ST
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	r	rh	rh	rh	rh	rh	rh	rh

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
CC60ST, CC61ST, CC62ST, CC63ST 1)	0, 1, 2, 6	rh	Capture/Compare State Bits Bits CC6xST monitor the state of the capture/compare channels. Bits CC6xST (x = 0, 1, 2) are related to T12, bit CC63ST is related to T13. 0 _B In compare mode, the timer count is less than the compare value. In capture mode, the selected edge has not yet been detected since the bit has been cleared by SW the last time. 1 _B In compare mode, the counter value is greater than or equal to the compare value. In capture mode, the selected edge has been detected.
CCPOS60, CCPOS61, CCPOS62	3, 4, 5	rh	Sampled Hall Pattern Bits Bits CCPOS6x (x = 0, 1, 2) are indicating the value of the input Hall pattern that has been compared to the current and expected value. The value is sampled when the event HCRDY (Hall Compare Ready) occurs. 0 _B The input CCPOSx has been sampled as 0. 1 _B The input CCPOSx has been sampled as 1.
CC60PS, CC61PS, CC62PS, COUT60PS, COUT61PS, COUT62PS, COUT63PS 2)	8, 10, 12, 9, 11, 13, 14	rwh	Passive State Select for Compare Outputs Bits CC6xPS, COUT6xPS select the state of the corresponding compare channel, that is considered to be the passive state. During the passive state, the passive level (defined in register PSLR) is driven by the output pin. Bits CC6xPS, COUT6xPS (x = 0, 1, 2) are related to T12, bit CC63PS is related to T13. 0 _B The corresponding compare signal is in passive state while CC6xST is 0. 1 _B The corresponding compare signal is in passive state while CC6xST is 1. In capture mode, these bits are not used.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T13IM³⁾	15	rwh	T13 Inverted Modulation Bit T13IM inverts the T13 signal for the modulation of the CC6x and COUT6x (x = 0, 1, 2) signals. 0 _B T13 output CC63_O is equal to <u>CC63ST</u> . 1 _B T13 output CC63_O is equal to <u>CC63ST</u> .
0	7, [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

- 1) These bits are set and cleared according to the T12, T13 switching rules
- 2) These bits have shadow bits and are updated in parallel to the capture/compare registers of T12, T13 respectively. A read action targets the actually used values, whereas a write action targets the shadow bits.
- 3) This bit has a shadow bit and is updated in parallel to the compare and period registers of T13. A read action targets the actually used values, whereas a write action targets the shadow bit.

Capture/Compare Unit 6 (CCU6)

The Compare Status Modification Register CMPMODIF provides software-control (independent set and clear conditions) for the channel state bits CC6xST. This feature enables the user to individually change the status of the output lines by software, for example when the corresponding compare timer is stopped.

CMPMODIF

Compare State Modification Register

(64_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	MCC 63R		0		MCC 62R	MCC 61R	MCC 60R	0	MCC 63S		0		MCC 62S	MCC 61S	MCC 60S
r	w		r		w	w	w	r	w		r		w	w	w

Field	Bits	Type	Description
MCC60S, MCC61S, MCC62S, MCC63S, MCC60R, MCC61R, MCC62R, MCC63R	0, 1, 2, 7, 8, 9, 10, 14	w	Capture/Compare Status Modification Bits These bits are used to bits to set (MCC6xS) or to clear (MCC6xR) the corresponding bits CC6xST by SW. This feature allows the user to individually change the status of the output lines by SW, e.g. when the corresponding compare timer is stopped. This allows a bit manipulation of CC6xST-bits by a single data write action. The following functionality of a write access to bits concerning the same capture/compare state bit is provided: [MCC6xR, MCC6xS] = 00 _B Bit CC6xST is not changed. 01 _B Bit CC6xST is set. 10 _B Bit CC6xST is cleared. 11 _B reserved
0	[5:3], 7, [13:11], [31:15]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.2.9.2 T12 Mode Control Register

Register T12MSEL contains control bits to select the capture/compare functionality of the three channels of Timer T12.

T12MSEL

T12 Mode Select Register

(68_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D BYP	HSYNC			MSEL62				MSEL61				MSEL60			
rw	rw			rw				rw				rw			

Field	Bits	Type	Description
MSEL60, MSEL61, MSEL62	[3:0], [7:4], [11:8]	rw	Capture/Compare Mode Selection These bit fields select the operating mode of the three T12 capture/compare channels. Each channel (x = 0, 1, 2) can be programmed individually for one of these modes (except for Hall Sensor Mode). Coding see Table 24-5 .
HSYNC	[14:12]	rw	Hall Synchronization Bit field HSYNC defines the source for the sampling of the Hall input pattern and the comparison to the current and the expected Hall pattern bit fields. Coding see Table 24-11 .
DBYP	15	rw	Delay Bypass DBYP controls whether the source signal for the sampling of the Hall input pattern (selected by HSYNC) is delayed by the Dead-Time Counter 0. 0 _B The bypass is not active. Dead-Time Counter 0 is generating a delay after the source signal becomes active. 1 _B The bypass is active. Dead-Time Counter 0 is not used for a delay.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.2.9.3 Timer Control Registers

Register TCTR0 controls the basic functionality of both timers, T12 and T13.

Note: A write action to the bit fields T12CLK or T12PRE is only taken into account while the timer T12 is not running (T12R=0). A write action to the bit fields T13CLK or T13PRE is only taken into account while the timer T13 is not running (T13R=0).

TCTR0

Timer Control Register 0

(70_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	STE 13	T13R	T13 PRE	T13CLK		CTM	CDIR	STE 12	T12R	T12 PRE	T12CLK				
r	rh	rh	rw	rw		rw	rh	rh	rh	rw	rw				

Field	Bits	Type	Description
T12CLK	[2:0]	rw	Timer T12 Input Clock Select Selects the input clock for timer T12 that is derived from the peripheral clock according to the equation $f_{T12} = f_{CC6} / 2^{<T12CLK>}$. 000 _B $f_{T12} = f_{CC6}$ 001 _B $f_{T12} = f_{CC6} / 2$ 010 _B $f_{T12} = f_{CC6} / 4$ 011 _B $f_{T12} = f_{CC6} / 8$ 100 _B $f_{T12} = f_{CC6} / 16$ 101 _B $f_{T12} = f_{CC6} / 32$ 110 _B $f_{T12} = f_{CC6} / 64$ 111 _B $f_{T12} = f_{CC6} / 128$
T12PRE	3	rw	Timer T12 Prescaler Bit In order to support higher clock frequencies, an additional prescaler factor of 1/256 can be enabled for the prescaler for T12. 0 _B The additional prescaler for T12 is disabled. 1 _B The additional prescaler for T12 is enabled.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T12R	4	rh	Timer T12 Run Bit¹⁾ T12R starts and stops timer T12. It is set/cleared by SW by setting bits T12RR or T12RS or it is cleared by HW according to the function defined by bit field T12SSC. 0 _B Timer T12 is stopped. 1 _B Timer T12 is running.
STE12	5	rh	Timer T12 Shadow Transfer Enable Bit STE12 enables or disables the shadow transfer of the T12 period value, the compare values and passive state select bits and levels from their shadow registers to the actual registers if a T12 shadow transfer event is detected. Bit STE12 is cleared by hardware after the shadow transfer. A T12 shadow transfer event is a period-match while counting up or a one-match while counting down. 0 _B The shadow register transfer is disabled. 1 _B The shadow register transfer is enabled.
CDIR	6	rh	Count Direction of Timer T12 This bit is set/cleared according to the counting rules of T12. 0 _B T12 counts up. 1 _B T12 counts down.
CTM	7	rw	T12 Operating Mode 0 _B Edge-aligned Mode: T12 always counts up and continues counting from zero after reaching the period value. 1 _B Center-aligned Mode: T12 counts down after detecting a period-match and counts up after detecting a one-match.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T13CLK	[10:8]	rw	Timer T13 Input Clock Select Selects the input clock for timer T13 that is derived from the peripheral clock according to the equation $f_{T13} = f_{CC6} / 2^{<T13CLK>}$. 000 _B $f_{T13} = f_{CC6}$ 001 _B $f_{T13} = f_{CC6} / 2$ 010 _B $f_{T13} = f_{CC6} / 4$ 011 _B $f_{T13} = f_{CC6} / 8$ 100 _B $f_{T13} = f_{CC6} / 16$ 101 _B $f_{T13} = f_{CC6} / 32$ 110 _B $f_{T13} = f_{CC6} / 64$ 111 _B $f_{T13} = f_{CC6} / 128$
T13PRE	11	rw	Timer T13 Prescaler Bit In order to support higher clock frequencies, an additional prescaler factor of 1/256 can be enabled for the prescaler for T13. 0 _B The additional prescaler for T13 is disabled. 1 _B The additional prescaler for T13 is enabled.
T13R	12	rh	Timer T13 Run Bit²⁾ T13R starts and stops timer T13. It is set/cleared by SW by setting bits T13RR or T13RS or it is set/cleared by HW according to the function defined by bit fields T13SSC, T13TEC and T13TED. 0 _B Timer T13 is stopped. 1 _B Timer T13 is running.
STE13	13	rh	Timer T13 Shadow Transfer Enable Bit STE13 enables or disables the shadow transfer of the T13 period value, the compare value and passive state select bit and level from their shadow registers to the actual registers if a T13 shadow transfer event is detected. Bit STE13 is cleared by hardware after the shadow transfer. A T13 shadow transfer event is a period-match. 0 _B The shadow register transfer is disabled. 1 _B The shadow register transfer is enabled.
0	[31:14]	r	Reserved; Returns 0 if read; should be written with 0.

1) A concurrent set/clear action on T12R (from T12SSC, T12RR or T12RS) will have no effect. The bit T12R will remain unchanged.

Capture/Compare Unit 6 (CCU6)

- 2) A concurrent set/cleared action on T13R (from T13SSC, T13TEC, T13RR or T13RS) will have no effect. The bit T12R will remain unchanged.

Capture/Compare Unit 6 (CCU6)

Register TCTR2 controls the single-shot and the synchronization functionality of both timers T12 and T13. Both timers can run in single-shot mode. In this mode they stop their counting sequence automatically after one counting period with a count value of zero. The single-shot mode and the synchronization feature of T13 to T12 allow the generation of events with a programmable delay after well-defined PWM actions of T12.

TCTR2

Timer Control Register 2

(74_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				T13 RSEL		T12 RSEL		0	T13 TED		T13 TEC		T13 SSC	T12 SSC	
r				rw		rw		r	rw		rw		rw	rw	

Field	Bits	Type	Description
T12SSC	0	rw	Timer T12 Single Shot Control This bit controls the single shot-mode of T12. 0 _B The single-shot mode is disabled, no HW action on T12R. 1 _B The single shot mode is enabled, the bit T12R is cleared by HW if - T12 reaches its period value in edge-aligned mode - T12 reaches the value 1 while down counting in center-aligned mode. In parallel to the clear action of bit T12R, the bits CC6xST (x=0, 1, 2) are cleared.
T13SSC	1	rw	Timer T13 Single Shot Control This bit controls the single shot-mode of T13. 0 _B No HW action on T13R 1 _B The single-shot mode is enabled, the bit T13R is cleared by HW if T13 reaches its period value. In parallel to the clear action of bit T13R, the bit CC63ST is cleared.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T13TEC	[4:2]	rw	T13 Trigger Event Control Bit field T13TEC selects the trigger event to start T13 (automatic set of T13R for synchronization to T12 compare signals) according to following combinations: 000 _B no action 001 _B set T13R on a T12 compare event on channel 0 010 _B set T13R on a T12 compare event on channel 1 011 _B set T13R on a T12 compare event on channel 2 100 _B set T13R on any T12 compare event (ch. 0, 1, 2) 101 _B set T13R upon a period-match of T12 110 _B set T13R upon a zero-match of T12 (while counting up) 111 _B set T13R on any edge of inputs CCPOSx
T13TED	[6:5]	rw	Timer T13 Trigger Event Direction¹⁾ Bit field T13TED delivers additional information to control the automatic set of bit T13R in the case that the trigger action defined by T13TEC is detected. 00 _B reserved, no action 01 _B while T12 is counting up 10 _B while T12 is counting down 11 _B independent on the count direction of T12
T12RSEL	[9:8]	rw	Timer T12 External Run Selection Bit field T12RSEL defines the event of signal T12HR that can set the run bit T12R by HW. 00 _B The external setting of T12R is disabled. 01 _B Bit T12R is set if a rising edge of signal T12HR is detected. 10 _B Bit T12R is set if a falling edge of signal T12HR is detected. 11 _B Bit T12R is set if an edge of signal T12HR is detected.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T13RSEL	[11:10]	rw	Timer T13 External Run Selection Bit field T13RSEL defines the event of signal T13HR that can set the run bit T13R by HW. 00 _B The external setting of T13R is disabled. 01 _B Bit T13R is set if a rising edge of signal T13HR is detected. 10 _B Bit T13R is set if a falling edge of signal T13HR is detected. 11 _B Bit T13R is set if an edge of signal T13HR is detected.
0	7, [31:12]	r	Reserved; Returns 0 if read; should be written with 0;

1) Example:

If the timer T13 is intended to start at any compare event on T12 (T13TEC=100) the trigger event direction can be programmed to

- counting up >> a T12 channel 0, 1, 2 compare match triggers T13R only while T12 is counting up
- counting down >> a T12 channel 0, 1, 2 compare match triggers T13R only while T12 is counting down
- independent from bit CDIR >> each T12 channel 0, 1, 2 compare match triggers T13R

The timer count direction is taken from the value of bit CDIR. As a result, if T12 is running in edge-aligned mode (counting up only), T13 can only be started automatically if bit field T13TED=01 or 11.

Capture/Compare Unit 6 (CCU6)

Register TCTR4 provides software-control (independent set and clear conditions) for the run bits T12R and T13R. Furthermore, the timers can be reset (while running) and bits STE12 and STE13 can be controlled by software. Reading these bits always returns 0.

TCTR4

Timer Control Register 4

(78_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T13 STD	T13 STR	T13 CNT	0	T13 RES	T13 RS	T13 RR	T12 STD	T12 STR	T12 CNT	0	DT RES	T12 RES	T12 RS	T12 RR	
w	w	w	r	w	w	w	w	w	w	w	r	w	w	w	w

Field	Bits	Type	Description
T12RR	0	w	Timer T12 Run Reset Setting this bit clears the T12R bit. 0 _B T12R is not influenced. 1 _B T12R is cleared, T12 stops counting.
T12RS	1	w	Timer T12 Run Set Setting this bit sets the T12R bit. 0 _B T12R is not influenced. 1 _B T12R is set, T12 starts counting.
T12RES	2	w	Timer T12 Reset 0 _B No effect on T12. 1 _B The T12 counter register is cleared to zero. The switching of the output signals is according to the switching rules. Setting of T12RES has no impact on bit T12R.
DTRES	3	w	Dead-Time Counter Reset 0 _B No effect on the dead-time counters. 1 _B The three dead-time counter channels are cleared to zero.
T12CNT	5	w	Timer T12 Count Event 0 _B No action 1 _B If enabled (PISEL2), timer T12 counts one step.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T12STR	6	w	Timer T12 Shadow Transfer Request 0 _B No action 1 _B STE12 is set, enabling the shadow transfer.
T12STD	7	w	Timer T12 Shadow Transfer Disable 0 _B No action 1 _B STE12 is cleared without triggering the shadow transfer.
T13RR	8	w	Timer T13 Run Reset Setting this bit clears the T13R bit. 0 _B T13R is not influenced. 1 _B T13R is cleared, T13 stops counting.
T13RS	9	w	Timer T13 Run Set Setting this bit sets the T13R bit. 0 _B T13R is not influenced. 1 _B T13R is set, T13 starts counting.
T13RES	10	w	Timer T13 Reset 0 _B No effect on T13. 1 _B The T13 counter register is cleared to zero. The switching of the output signals is according to the switching rules. Setting of T13RES has no impact on bit T13R.
T13CNT	13	w	Timer T13 Count Event 0 _B No action 1 _B If enabled (PISEL2), timer T13 counts one step.
T13STR	14	w	Timer T13 Shadow Transfer Request 0 _B No action 1 _B STE13 is set, enabling the shadow transfer.
T13STD	15	w	Timer T13 Shadow Transfer Disable 0 _B No action 1 _B STE13 is cleared without triggering the shadow transfer.
0	4, [12:11], [31:16]	r	reserved; returns 0 if read; should be written with 0;

Note: A simultaneous write of a 1 to bits that set and clear the same bit will trigger no action. The corresponding bit will remain unchanged.

24.3 Operating Timer T13

Timer T13 is implemented similarly to Timer T12, but only with one channel in compare mode. A 16-bit up-counter is connected to a channel register via a comparator, that generates a signal when the counter contents match the contents of the channel register. A variety of control functions facilitate the adaptation of the T13 structure to different application needs. In addition, T13 can be started synchronously to timer T12 events.

This section provides information about:

- T13 overview (see [Section 24.3.1](#))
- Counting scheme (see [Section 24.3.2](#))
- Compare mode (see [Section 24.3.3](#))
- Compare output path (see [Section 24.3.4](#))
- Shadow register transfer (see [Section 24.3.5](#))
- T13 counter register description (see [Section 24.3.6](#))

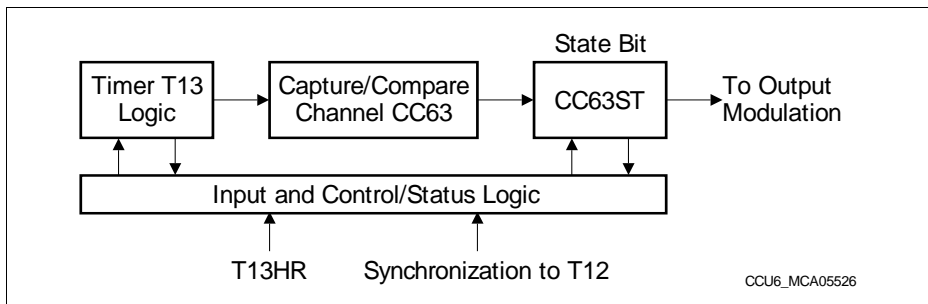


Figure 24-23 Overview Diagram of the Timer T13 Block

24.3.1 T13 Overview

Figure 24-24 shows a detailed block diagram of Timer T13. The functions of the timer T12 block are controlled by bits in registers **TCTR0**, **TCTR2**, and **PISEL2**.

Timer T13 receives its input clock, f_{T13} , from the module clock f_{CC6} via a programmable prescaler and an optional 1/256 divider or from an input signal T13HR. T13 can only count up (similar to the Edge-Aligned mode of T12).

Via a comparator, the timer T13 Counter Register **T13** is connected to the Period Register **T13PR**. This register determines the maximum count value for T13. When T13 reaches the period value, signal T13_PM (T13 Period Match) is generated and T13 is cleared to 0000_H with the next T13 clock edge. The Period Register receives a new period value from its Shadow Period Register, T13PS, that is loaded via software. The transfer of a new period value from the shadow register into T13PR is controlled via the 'T13 Shadow Transfer' control signal, T13_ST. The generation of this signal depends on the associated control bit STE13. Providing a shadow register for the period value as

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well as for other values related to the generation of the PWM signal facilitates a concurrent update by software for all relevant parameters (refer to [Table 24.3.5](#)).

Another signal indicates whether the counter contents are equal to 0000_H (T13_ZM).

A Single-Shot control bit, T13SSC, enables an automatic stop of the timer when the current counting period is finished (see [Figure 24-26](#)).

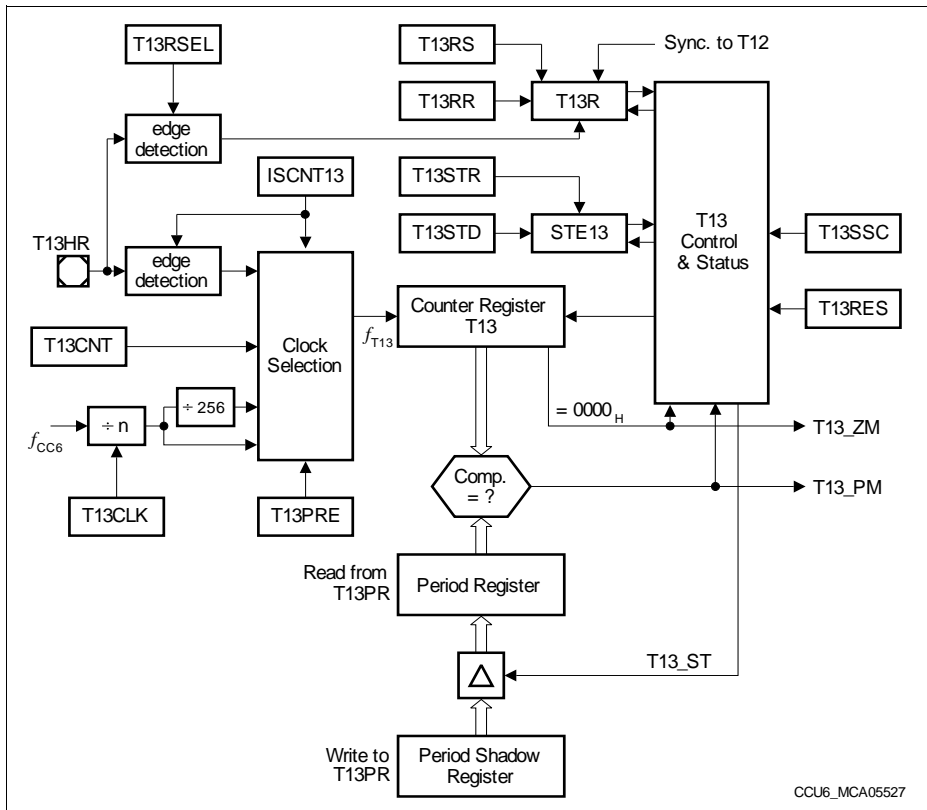


Figure 24-24 T13 Counter Logic and Period Comparators

The start or stop of T13 is controlled by the Run bit, T13R. This control bit can be set by software via the associated set/clear bits T13RS or T13RR in register [TCTR4](#), or it is cleared by hardware according to preselected conditions (single-shot mode).

The timer T13 run bit T13R must not be set while the applied T13 period value is zero. Bit T13R can be set automatically if an event of T12 is detected to synchronize T13 timings to T12 events, e.g. to generate a programmable delay via T13 after an edge of a T12 compare channel before triggering an AD conversion (T13 can trigger ADC

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conversions).

Timer T13 can be cleared to 0000_H via control bit T13RES. Setting this write-only bit only clears the timer contents, but has no further effects, e.g., it does not stop the timer.

The generation of the T13 shadow transfer control signal, T13_ST, is enabled via bit STE13. This bit can be set or cleared by software indirectly through its associated set/reset control bits T13STR and T13STD.

Two bit fields, T13TEC and T13TED, control the synchronization of T13 to Timer T12 events. T13TEC selects the trigger event, while T13TED determines for which T12 count direction the trigger should be active.

While Timer T13 is running, write accesses to the count register T13 are not taken into account. If T13 is stopped, write actions to register T13 are immediately taken into account.

Note: The T13 Period Register and its associated shadow register are located at the same physical address. A write access to this address targets the Shadow Register, while a read access reads from the actual period register.

24.3.2 T13 Counting Scheme

This section describes the clocking and the counting capabilities of T13.

24.3.2.1 Clock Selection

In **Timer Mode** (**PISEL2**.ISCNT13 = 00_B), the input clock f_{T13} of Timer T13 is derived from the internal module clock f_{CC6} through a programmable prescaler and an optional 1/256 divider. The resulting prescaler factors are listed in **Table 24-6**. The prescaler of T13 is cleared while T13 is not running (**TCTR0**.T13R = 0) to ensure reproducible timings and delays.

Table 24-6 Timer T13 Input Clock Options

T13CLK	Resulting Input Clock f_{T13} Prescaler Off (T13PRE = 0)	Resulting Input Clock f_{T13} Prescaler On (T13PRE = 1)
000 _B	f_{CC6}	$f_{CC6} / 256$
001 _B	$f_{CC6} / 2$	$f_{CC6} / 512$
010 _B	$f_{CC6} / 4$	$f_{CC6} / 1024$
011 _B	$f_{CC6} / 8$	$f_{CC6} / 2048$
100 _B	$f_{CC6} / 16$	$f_{CC6} / 4096$
101 _B	$f_{CC6} / 32$	$f_{CC6} / 8192$
110 _B	$f_{CC6} / 64$	$f_{CC6} / 16384$
111 _B	$f_{CC6} / 128$	$f_{CC6} / 32768$

In **Counter Mode**, timer T13 counts one step:

- If a 1 is written to **TCTR4**.T13CNT and **PISEL2**.ISCNT13 = 01_B
- If a rising edge of input signal T13HR is detected and **PISEL2**.ISCNT13 = 10_B
- If a falling edge of input signal T13HR is detected and **PISEL2**.ISCNT13 = 11_B

24.3.2.2 T13 Counting

The period of the timer is determined by the value in the period Register T13PR according to the following formula:

$$T13_{PER} = \langle \text{Period-Value} \rangle + 1; \text{ in } T13 \text{ clocks } (f_{T13}) \quad (24.3)$$

Timer T13 can only count up, comparable to the Edge-Aligned mode of T12. This leads to very simple 'counting rule' for the T13 counter:

- The counter is cleared with the next T13 clock edge if a Period-Match is detected. The counting direction is always upwards.

The behavior of T13 is illustrated in [Figure 24-25](#).

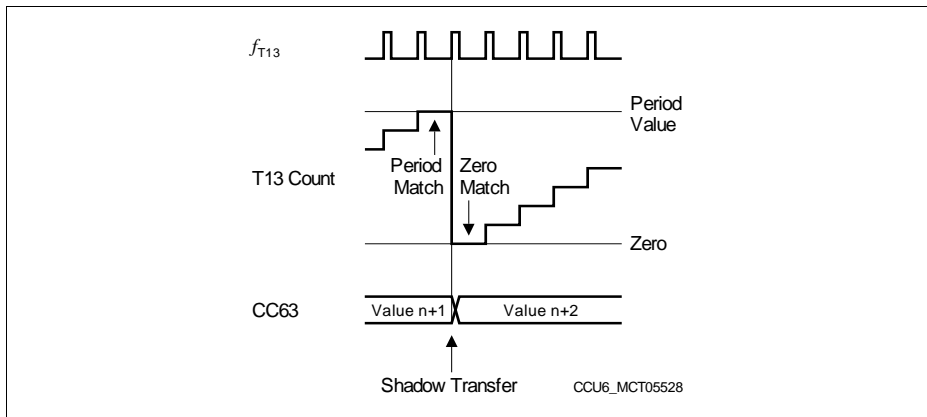


Figure 24-25 T13 Counting Sequence

24.3.2.3 Single-Shot Mode

In Single-Shot Mode, the timer run bit T13R is cleared by hardware. If bit T13SSC = 1, the timer T13 will stop when the current timer period is finished.

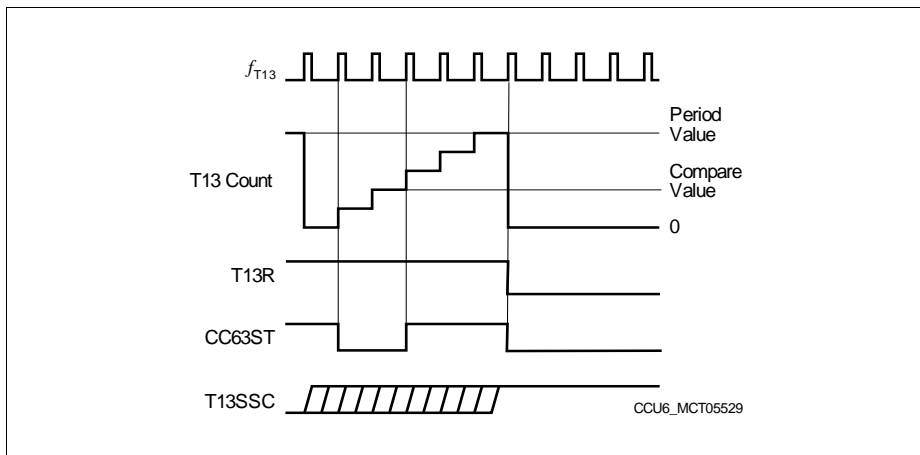


Figure 24-26 Single-Shot Operation of Timer T13

24.3.2.4 Synchronization to T12

Timer T13 can be synchronized to a T12 event. Bit fields T13TEC and T13TED select the event that is used to start Timer T13. The selected event sets bit T13R via HW, and T13 starts counting. Combined with the Single-Shot mode, this feature can be used to generate a programmable delay after a T12 event.

Figure 24-27 shows an example for the synchronization of T13 to a T12 event. Here, the selected event is a compare-match (compare value = 2) while counting up. The clocks of T12 and T13 can be different (other prescaler factor); the figure shows an example in which T13 is clocked with half the frequency of T12.

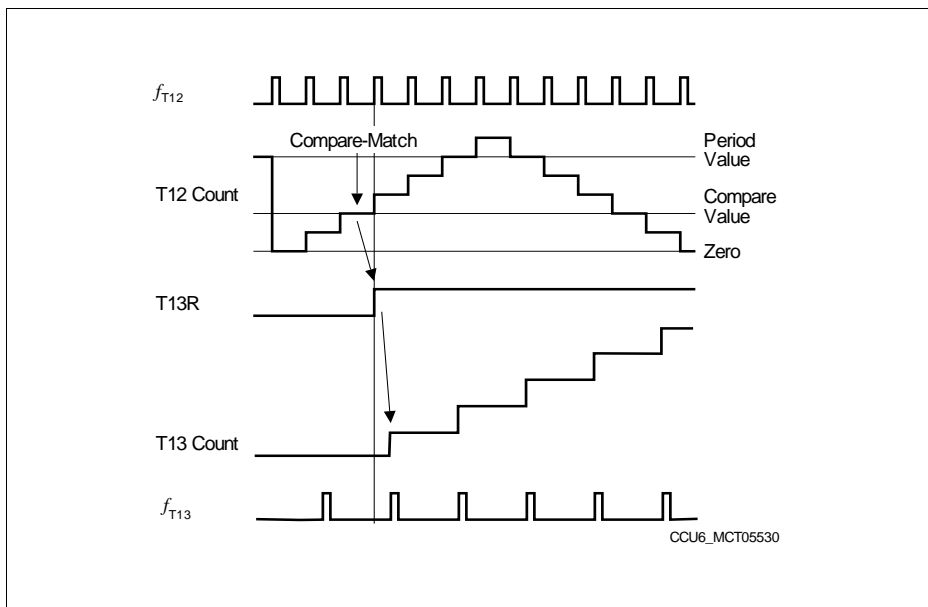


Figure 24-27 Synchronization of T13 to T12 Compare Match

Bit field T13TEC selects the trigger event to start T13 (automatic set of T13R for synchronization to T12 compare signals) according to the combinations shown in [Table 24-7](#). Bit field T13TED additionally specifies for which count direction of T12 the selected trigger event should be regarded (see [Table 24-8](#)).

Table 24-7 T12 Trigger Event Selection

T13TEC	Selected Event
000 _B	None
001 _B	T12 Compare Event on Channel 0 (CM_CC60)
010 _B	T12 Compare Event on Channel 1 (CM_CC61)
011 _B	T12 Compare Event on Channel 2 (CM_CC62)
100 _B	T12 Compare Event on any Channel (0, 1, 2)
101 _B	T12 Period-Match (T12_PM)
110 _B	T12 Zero-Match while counting up (T12_ZM and CDIR = 0)
111 _B	Any Hall State Change

Table 24-8 T12 Trigger Event Additional Specifier

T13TED	Selected Event Specifier
00 _B	Reserved, no action
01 _B	Selected event is active while T12 is counting up (CDIR = 0)
10 _B	Selected event is active while T12 is counting down (CDIR = 1)
11 _B	Selected event is active independently of the count direction of T12

24.3.3 T13 Compare Mode

Associated with Timer T13 is one compare channel, that can perform compare operations with regard to the contents of the T13 counter.

Figure 24-23 gives an overview on the T13 channel in Compare Mode. The channel is connected to the T13 counter register via an equal-to comparator, generating a compare match signal when the contents of the counter matches the contents of the compare register.

The channel consists of the comparator and a double register structure - the actual compare register, **CC63R**, feeding the comparator, and an associated shadow register, **CC63SR**, that is preloaded by software and transferred into the compare register when signal T13 shadow transfer, T13_ST, gets active. Providing a shadow register for the compare value as well as for other values related to the generation of the PWM signal facilitates a concurrent update by software for all relevant parameters.

Associated with the channel is a State Bit, **CMPSTAT.CC63ST**, holding the status of the compare operation. **Figure 24-28** gives an overview on the logic for the State Bit.

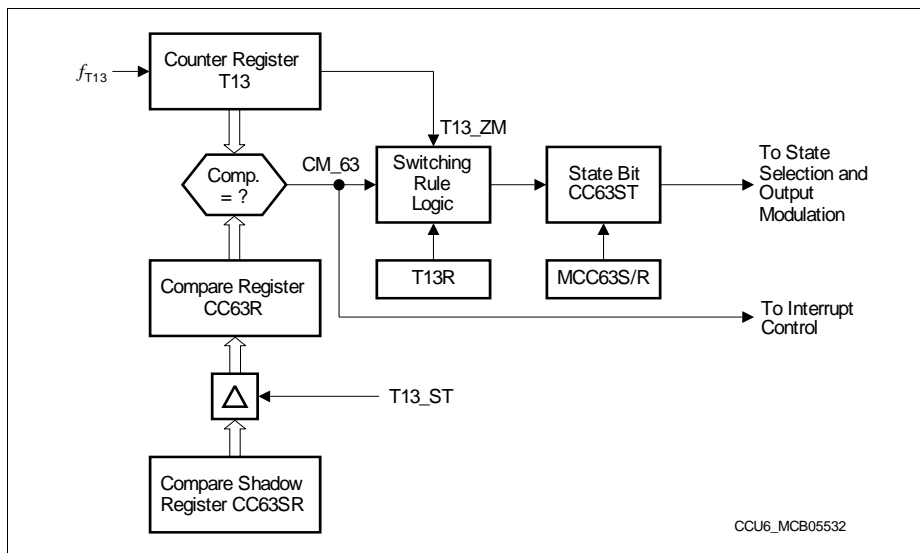


Figure 24-28 T13 State Bit Block Diagram

A compare interrupt event CM_63 is signaled when a compare match is detected. The actual setting of a State Bit has no influence on the interrupt generation.

The inputs to the switching rule logic for the CC63ST bit are the timer run bit (T13R), the timer zero-match signal (T13_ZM), and the actual individual compare-match signal CM_63. In addition, the state bit can be set or cleared by software via bits MCC63S and

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MCC63R in register **CMPMODIF**.

A modification of the State Bit CC63ST by hardware is only possible while Timer T13 is running ($T13R = 1$). If this is the case, the following switching rules apply for setting and resetting the State Bit in Compare Mode:

State Bit **CC63ST** is **set** to 1

- with the next T13 clock (f_{T13}) after a compare-match (T13 is always counting up) (i.e., when the counter is incremented above the compare value);
- with the next T13 clock (f_{T13}) after a zero-match AND a parallel compare-match.

State Bit **CC63ST** is **cleared** to 0

- with the next T13 clock (f_{T13}) after a zero-match AND NO parallel compare-match.

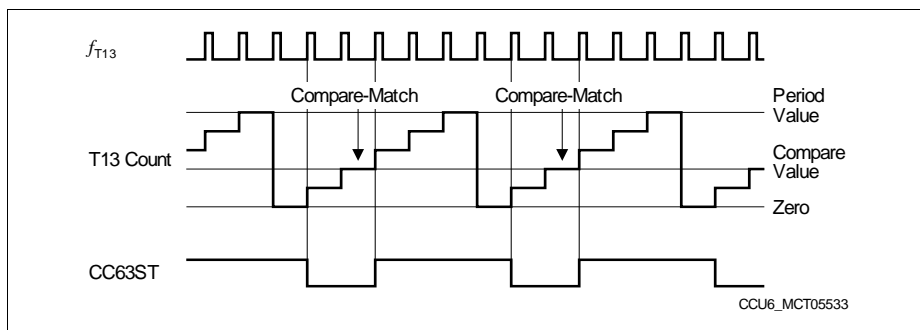


Figure 24-29 T13 Compare Operation

24.3.4 Compare Mode Output Path

Figure 24-30 gives an overview on the signal path from the channel State Bit CC63ST to its output pin COUT63. As illustrated, a user can determine the desired output behavior in relation to the current state of CC63ST. Please refer to [Section 24.2.4.3](#) for detailed information on the output modulation for T12 signals.

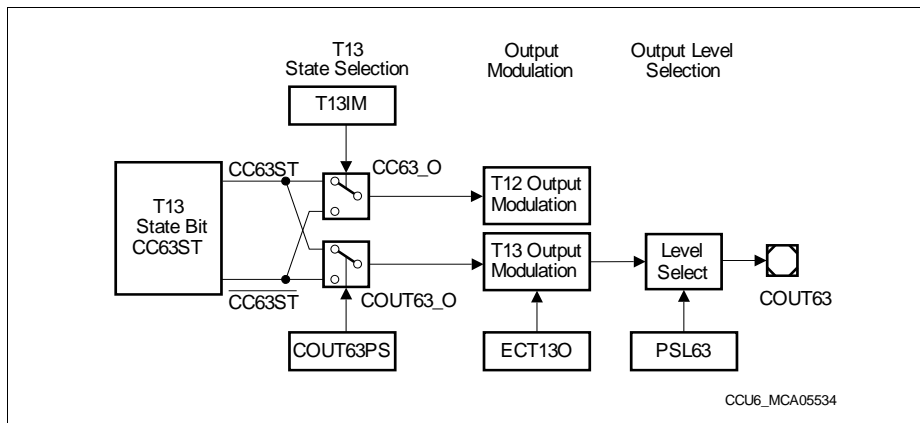


Figure 24-30 Channel 63 Output Path

The output line COUT63_O can generate a T13 PWM at the output pin COUT63. The signal CC63_O can be used to modulate the T12-related output signals with a T13 PWM. In order to decouple COUT63 from the internal modulation, the compare state leading to an active signal can be selected independently by bits T13IM and COUT63PS.

The last block of the data path is the Output Modulation block. Here, the modulation source T13 and the trap functionality are combined and control the actual level of the output pin COUT63 (see [Figure 24-31](#)):

- The **T13 related compare signal** COUT63_O delivered by the T13 state selection with the enable bit **MODCTR.ECT13O**
- The **trap state** TRPS with an individual enable bit **TRPCTR.TRPEN13**

If the modulation input signal COUT63_O is enabled (ECT13O = 1) and is at passive state, the modulated is also in passive state. If the modulation input is not enabled, the output is in passive state.

If the Trap State is active (TRPS = 1), then the output enabled for the trap signal (by TRPEN13 = 1) is set to the passive state.

The output of the modulation control block is connected to a level select block. It offers the option to determine the actual output level of a pin, depending on the state of the output line (decoupling of active/passive state and output polarity) as specified by the Passive State Select bit **PSLR.PSL63**. If the modulated output signal is in the passive

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state, the level specified directly by PSL63 is output. If it is in the active state, the inverted level of PSL63 is output. This allows the user to adapt the polarity of an active output signal to the connected circuitry.

The PSL63 bit has a shadow register to allow for updates with the T13 shadow transfer signal (T13_ST) without undesired pulses on the output lines. A read action returns the actually used value, whereas a write action targets the shadow bit. Providing a shadow register for the PSL value as well as for other values related to the generation of the PWM signal facilitates a concurrent update by software for all relevant parameters.

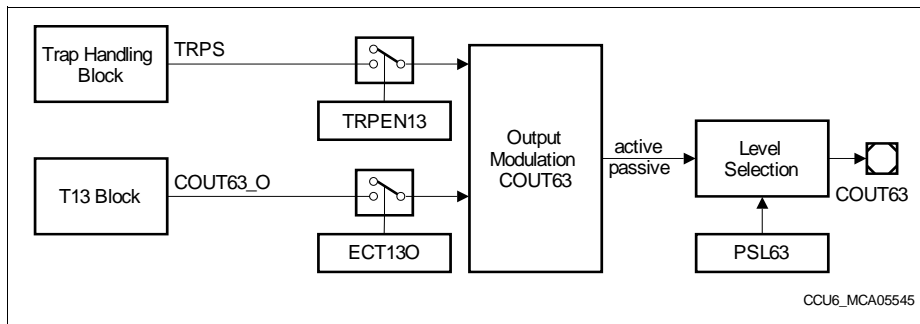


Figure 24-31 T13 Output Modulation

24.3.5 T13 Shadow Register Transfer

A special shadow transfer signal (T13_ST) can be generated to facilitate updating the period and compare values of the compare channel CC63 synchronously to the operation of T13. Providing a shadow register for values defining one PWM period facilitates a concurrent update by software for all relevant parameters. The next PWM period can run with a new set of parameters. The generation of this signal is requested by software via bit **TCTR0.STE13** (set by writing 1 to the write-only bit **TCTR4.T13STR**, cleared by writing 1 to the write-only bit **TCTR4.T13STD**).

When signal T13_ST is active, a shadow register transfer is triggered with the next cycle of the T13 clock. Bit STE13 is automatically cleared with the shadow register transfer.

A T13 shadow register transfer takes place (T13_ST active):

- while timer T13 is not running (T13R = 0), or
- STE13 = 1 and a Period-Match is detected while T13R = 1

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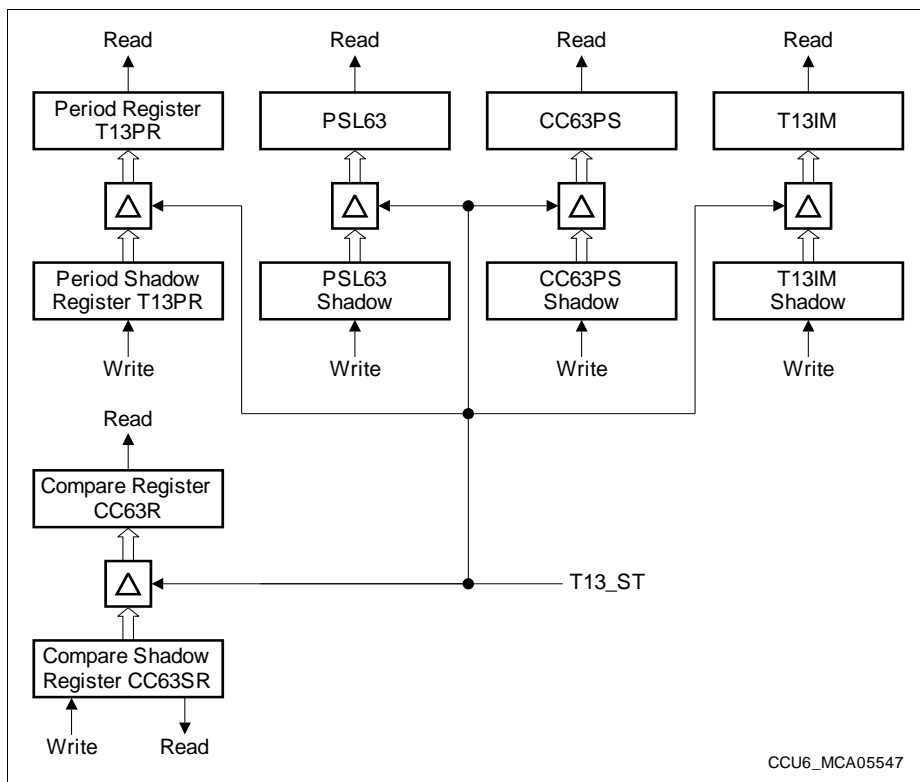


Figure 24-32 T13 Shadow Register Overview

24.3.6 T13 related Registers

24.3.6.1 T13 Counter Register

The generation of the patterns for a single channel pulse width modulation (PWM) is based on timer T13. The registers related to timer T13 can be concurrently updated (with well-defined conditions) in order to ensure consistency of the PWM signal. T13 can be synchronized to several timer T12 events.

Timer T13 only supports compare mode on its compare channel CC63.

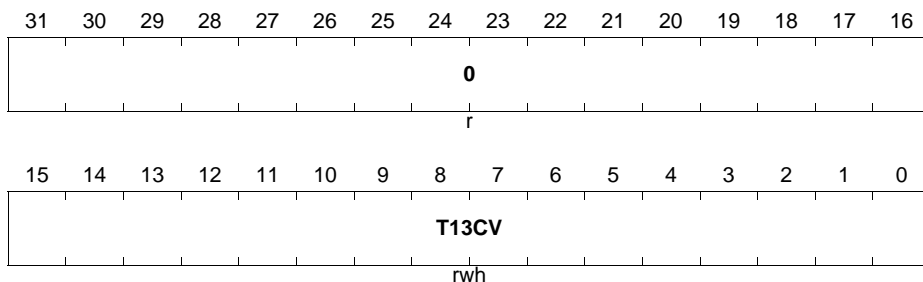
Register T13 represents the counting value of timer T13. It can only be written while the timer T13 is stopped. Write actions while T13 is running are not taken into account. Register T13 can always be read by SW.

Timer T13 only supports edge-aligned mode (counting up).

T13

Timer T13 Counter Register

(50_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
T13CV	[15:0]	rwh	Timer 13 Counter Value This register represents the 16-bit counter value of Timer13.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Note: While timer T13 is stopped, the internal clock divider is reset in order to ensure reproducible timings and delays.

Capture/Compare Unit 6 (CCU6)

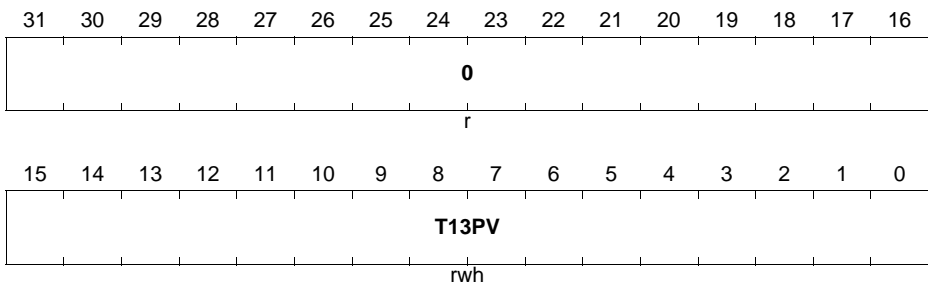
24.3.6.2 Period Register

Register T13PR contains the period value for timer T13. The period value is compared to the actual counter value of T13 and the resulting counter actions depend on the defined counting rules. This register has a shadow register and the shadow transfer is controlled by bit STE13. A read action by SW delivers the value currently used for the compare action, whereas the write action targets a shadow register. The shadow register structure allows a concurrent update of all T13-related values.

T13PR

Timer 13 Period Register

(54_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
T13PV	[15:0]	rwh	T13 Period Value The value T13PV defines the counter value for T13 leading to a period-match. When reaching this value, the timer T13 is set to zero.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

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24.3.6.3 Compare Register

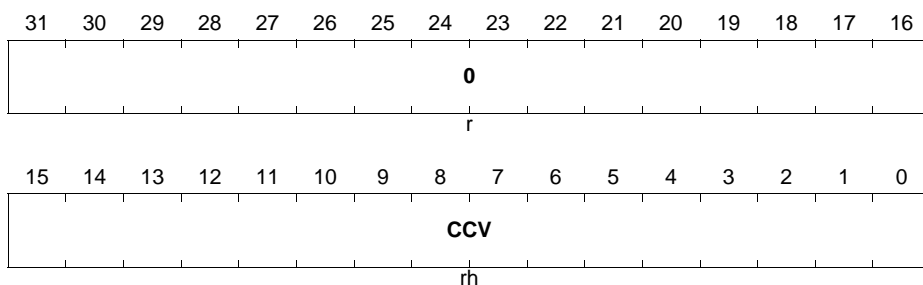
Registers CC63R is the actual compare register for T13. The values stored in CC63R is compared to the counter value of T13. The State Bit CC63ST is located in register **CMPSTAT**.

CC63R

Compare Register for T13

(58_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CCV	[15:0]	rh	Channel CC63 Compare Value The bit field CCV contains the value, that is compared to the T13 counter value.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

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24.3.6.4 Compare Shadow Register

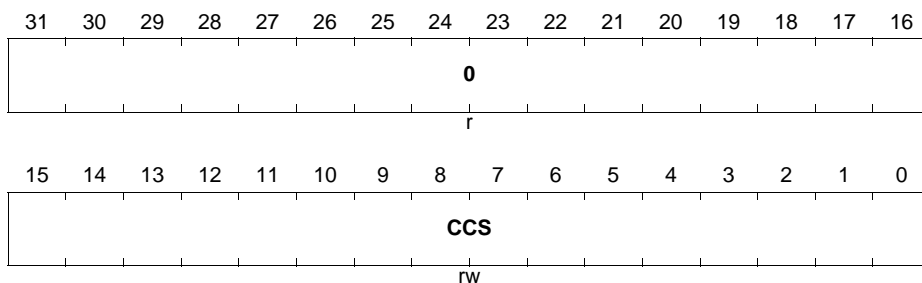
The register CC63R can only be read by SW, the modification of the value is done by a shadow register transfer from register CC63SR. The corresponding shadow register CC63SR can be read and written by SW.

CC63SR

Compare Shadow Register for T13

(5C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CCS	[15:0]	rw	Shadow Register for Channel CC63 Compare Value The bit field contents of CCS is transferred to the bit field CCV during a shadow transfer.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

24.4 Synchronous Start Feature

The T12 and T13 timers can be started synchronously through the T12HR and T13HR inputs of all CCU6x kernels.

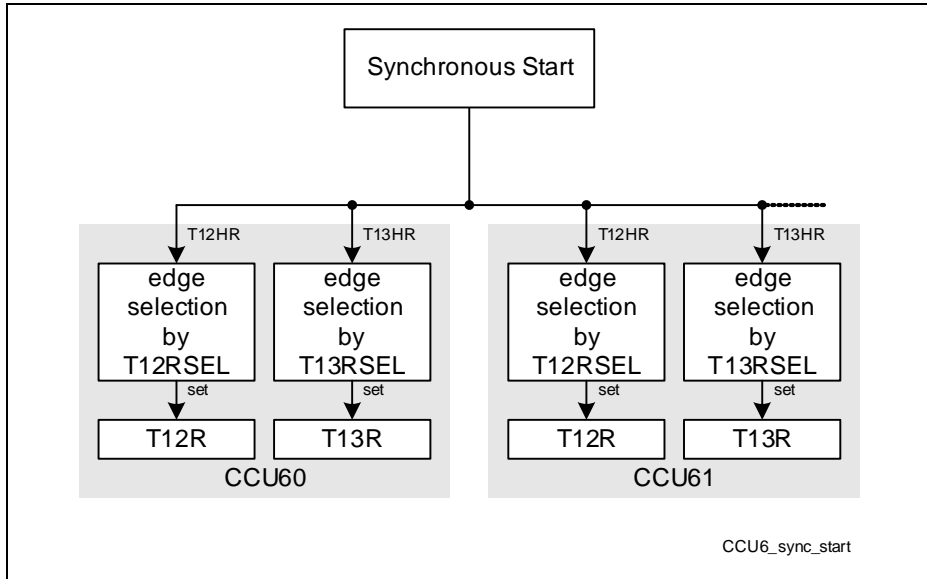


Figure 24-33 Synchronization Concept

24.5 Trap Handling

The trap functionality permits the PWM outputs to react on the state of the input signal $\overline{\text{CTRAP}}$. This functionality can be used to switch off the power devices if the trap input becomes active (e.g. to perform an emergency stop). The trap handling and the effect on the output modulation are controlled by the bits in the trap control register **TRPCTR**. The trap flags TRPF and TRPS are located in register **IS** and can be set/cleared by SW by writing to registers **ISS** and **ISR**.

Figure 24-34 gives an overview on the trap function.

The Trap Flag TRPF monitors the trap input and initiates the entry into the Trap State. The Trap State Bit TRPS determines the effect on the outputs and controls the exit of the Trap State.

When a trap condition is detected ($\overline{\text{CTRAP}} = 0$) and the input is enabled ($\text{TRPPEN} = 1$), both, the Trap Flag TRPF and the Trap State Bit TRPS, are set to 1 (trap state active). The output of the Trap State Bit TRPS leads to the Output Modulation Blocks (for T12 and for T13) and can there deactivate the outputs (set them to the passive state). Individual enable control bits for each of the six T12-related outputs and the T13-related output facilitate a flexible adaptation to the application needs.

There are a number of different ways to exit the Trap State. This offers SW the option to select the best operation for the application. Exiting the Trap State can be done either immediately when the trap condition is removed ($\text{CTRAP} = 1$ or $\text{TRPPEN} = 0$), or under software control, or synchronously to the PWM generated by either Timer T12 or Timer T13.

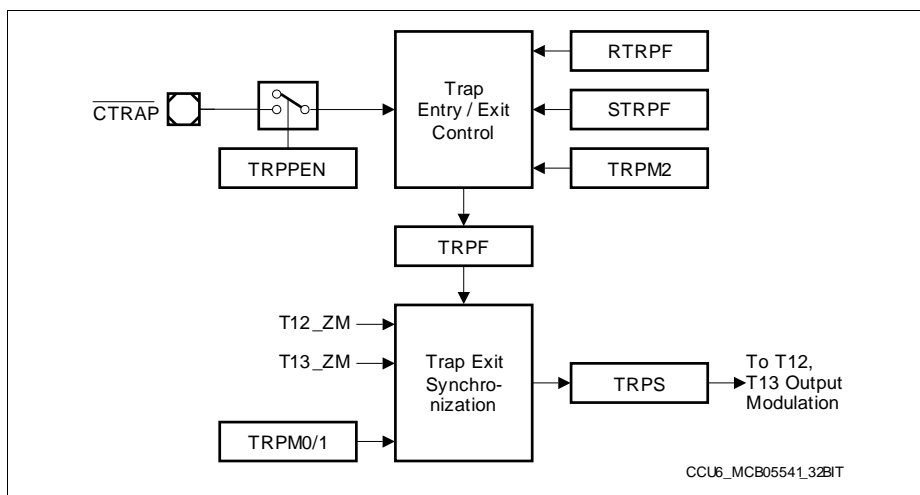


Figure 24-34 Trap Logic Block Diagram

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Clearing of TRPF is controlled by the mode control bit TRPM2. If $TRPM2 = 0$, TRPF is automatically cleared by HW when CTRAP returns to the inactive level ($CTRAP = 1$) or if the trap input is disabled ($TRPPEN = 0$). When $TRPM2 = 1$, TRPF must be reset by SW after CTRAP has become inactive.

Clearing of TRPS is controlled by the mode control bits TRPM1 and TRPM0 (located in the Trap Control Register TRPCTR). A reset of TRPS terminates the Trap State and returns to normal operation. There are three options selected by TRPM1 and TRPM0. One is that the Trap State is left immediately when the Trap Flag TRPF is cleared, without any synchronization to timers T12 or T13. The other two options facilitate the synchronization of the termination of the Trap State to the count periods of either Timer T12 or Timer T13. **Figure 24-35** gives an overview on the associated operation.

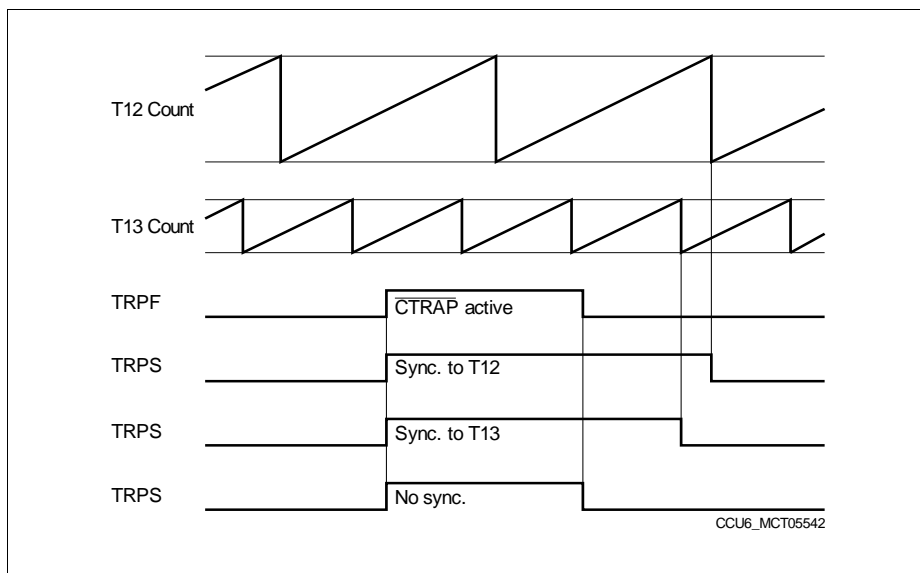


Figure 24-35 Trap State Synchronization (with $TRPM2 = 0$)

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(the event is not necessarily synchronous to the modulating PWM), and is cleared when the transfer takes place. This flag can be monitored by software to check for the status of this logic block. If the shadow transfer from MCMPS to MCMP takes place, bit **IS.STR** becomes set and an interrupt can be generated.

In addition to the Multi-Channel shadow transfer event MCM_ST, the shadow transfers for T12 (T12_ST) and T13 (T13_ST) can be generated to allow concurrent updates of applied duty cycles for T12 and/or T13 modulation and Multi-Channel patterns.

If it is explicitly desired, the update takes place immediately with the occurrence of the selected event when the direct synchronization mode is selected. The update can also be requested by software by writing to bit field MCMPS with the shadow transfer request bit STRMCM = 1. The option to trigger an update by SW is possible for all settings of SWSSEL.

By using the direct mode and bit STRMCM = 1, the update takes place completely under software control.

Table 24-9 Multi-Channel Mode Switching Event Selection

SWSSEL	Selected Event (see register MCMCTR)
000 _B	No automatic event detection
001 _B	Correct Hall Event (CM_CHE) detected at input signals CCPOSx without additional delay
010 _B	T13 Period-Match (T13_PM)
011 _B	T12 One-Match while counting down (T12_OM and CDIR = 1)
100 _B	T12 Compare Channel 1 Event while counting up (CM_61 and CDIR = 0) to support the phase delay function by CC61 for block commutation mode.
101 _B	T12 Period-Match while counting up (T12_PM and CDIR = 0)
110 _B , 111 _B	Reserved, no action

Table 24-10 Multi-Channel Mode Switching Synchronization

SWSYN	Synchronization Event (see register MCMCTR)
00 _B	Direct Mode: the trigger event directly causes the shadow transfer
01 _B	T13 Zero-Match (T13_ZM), the MCM shadow transfer is synchronized to a T13 PWM
10 _B	T12 Zero-Match (T12_ZM), the MCM shadow transfer is synchronized to a T12 PWM
11 _B	Reserved, no action

24.7 Hall Sensor Mode

For Brushless DC-Motors in block commutation mode, the Multi-Channel Mode has been introduced to provide efficient means for switching pattern generation. These patterns need to be output in relation to the angular position of the motor. For this, usually Hall sensors or Back-EMF sensing are used to determine the angular rotor position. The CCU6 provides three inputs, CCPOS0, CCPOS1, and CCPOS2, that can be used as inputs for the Hall sensors or the Back-EMF detection signals.

There is a strong correlation between the motor position and the output modulation pattern. When a certain position of the motor has been reached, indicated by the sampled Hall sensor inputs (the Hall pattern), the next, pre-determined Multi-Channel Modulation pattern has to be output. Because of different machine types, the modulation pattern for driving the motor can vary. Therefore, it is wishful to have a wide flexibility in defining the correlation between the Hall pattern and the corresponding Modulation pattern. Furthermore, a hardware mechanism significantly reduces the CPU for block-commutation.

The CCU6 offers the flexibility by having a register containing the currently assumed Hall pattern (CURH), the next expected Hall pattern (EXPH) and the corresponding output pattern (MCMP). A new Modulation pattern is output when the sampled Hall inputs match the expected ones (EXPH). To detect the next rotation phase (segment for block commutation), the CCU6 monitors the Hall inputs for changes. When the next expected Hall pattern is detected, the next corresponding Modulation pattern is output.

To increase for noise immunity (to a certain extend), the CCU6 offers the possibility to introduce a sampling delay for the Hall inputs. Some changes of the Hall inputs are not leading to the expected Hall pattern, because they are only short spikes due to noise. The Hall pattern compare logic compares the Hall inputs to the next expected pattern and also to the currently assumed pattern to filter out spikes.

For the Hall and Modulation output patterns, a double-register structure is implemented. While register **MCMOUT** holds the actually used values, its shadow register **MCMOUTS** can be loaded by software from a pre-defined table, holding the appropriate Hall and Modulation patterns for the given motor control.

A transfer from the shadow register into register MCMOUT can take place when a correct Hall pattern change is detected. Software can then load the next values into register MCMOUTS. It is also possible by software to force a transfer from MCMOUTS into MCMOUT.

Note: The Hall input signals CCPOSx and the CURH and EXPH bit fields are arranged in the following order:

CCPOS0 corresponds to CURH.0 (LSB) and EXPH.0 (LSB)

CCPOS1 corresponds to CURH.1 and EXPH.1

CCPOS2 corresponds to CURH.2 (MSB) and EXPH.2 (MSB)

24.7.1 Hall Pattern Evaluation

The Hall sensor inputs CCPOSx can be permanently monitored via an edge detection block (with the module clock f_{CC6}). In order to suppress spikes on the Hall inputs due to noise in rugged inverter environment, two optional noise filtering methods are supported by the Hall logic (both methods can be combined).

- Noise filtering with delay:
For this function, the mode control bit fields MSEL6x for all T12 compare channels must be programmed to 1000_B and DBYP = 0. The selected event triggers Dead-Time Counter 0 to generate a programmable delay (defined by bit field DTM). When the delay has elapsed, the evaluation signal HCRDY becomes activated.
Output modulation with T12 PWM signals is not possible in this mode.
- Noise filtering by synchronization to PWM:
The Hall inputs are not permanently monitored by the edge detection block, but samples are taken only at defined points in time during a PWM period. This can be used to sample the Hall inputs when the switching noise (due to PWM) does not disturb the Hall input signals.

If neither the delay function of Dead-Time Counter 0 is not used for the Hall pattern evaluation nor the Hall mode for Brushless DC-Drive control is enabled, the timer T12 block is available for PWM generation and output modulation.

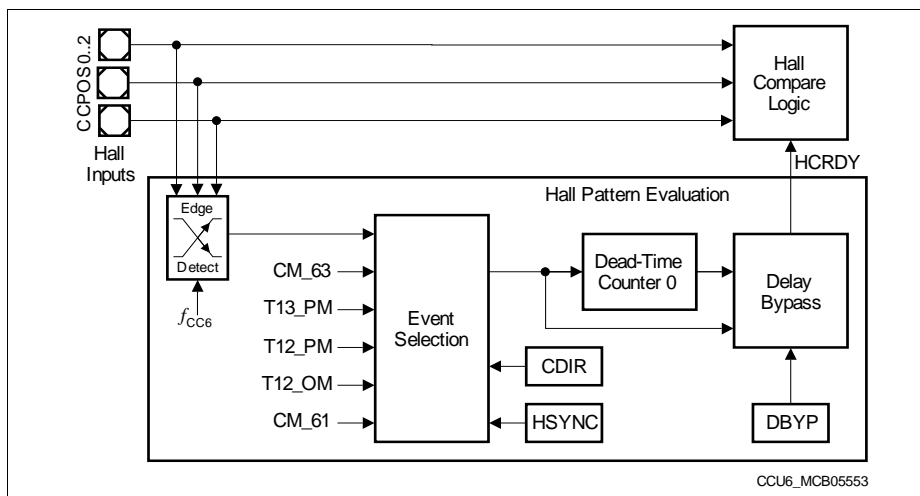


Figure 24-37 Hall Pattern Evaluation

If the evaluation signal HCRDY (Hall Compare Ready, see [Figure 24-38](#)) becomes activated, the Hall inputs are sampled and the Hall compare logic starts the evaluation of the Hall inputs.

Capture/Compare Unit 6 (CCU6)

Figure 24-37 illustrates the events for Hall pattern evaluation and the noise filter logic, **Table 24-11** summarizes the selectable trigger input signals.

Table 24-11 Hall Sensor Mode Trigger Event Selection

HSYNC	Selected Event (see register T12MSEL)
000 _B	Any edge at any of the inputs CCPOSx, independent from any PWM signal (permanent check).
001 _B	A T13 Compare-Match (CM_63).
010 _B	A T13 Period-Match (T13_PM).
011 _B	Hall sampling triggered by HW sources is switched off.
100 _B	A T12 Period-Match while counting up (T12_PM and CDIR = 0).
101 _B	A T12 One-Match while counting down (T12_OM and CDIR = 1).
110 _B	A T12 Compare-Match of compare channel CC61 while counting up (CM_61 and CDIR = 0).
111 _B	A T12 Compare-Match of compare channel CC61 while counting down (CM_61 and CDIR = 1).

24.7.2 Hall Pattern Compare Logic

Figure 24-38 gives an overview on the double-register structure and the pattern compare logic. Software writes the next modulation pattern (MCMPS) and the corresponding current (CURHS) and expected (EXPHS) Hall patterns into the shadow register MCMOUTS. Register MCMOUT holds the actually used values CURH and EXPH. The modulation pattern MCMP is provided to the T12 Output Modulation block. The current (CURH) and expected (EXPH) Hall patterns are compared to the sampled Hall sensor inputs (visible in register **CMPSTAT**). Sampling of the inputs and the evaluation of the comparator outputs is triggered by the evaluation signal HCRDY (Hall Compare Ready), that is detailed in the next section.

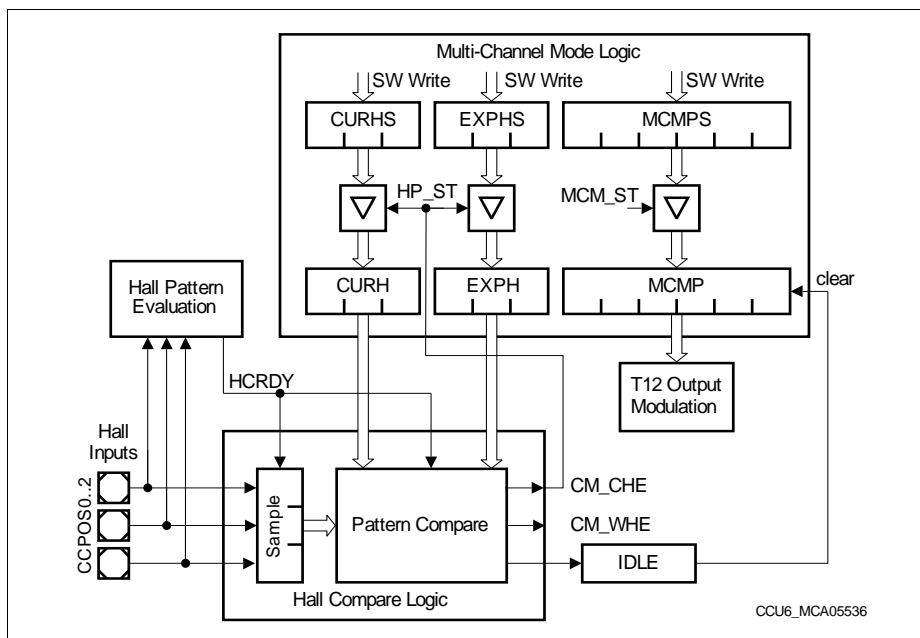


Figure 24-38 Hall Pattern Compare Logic

- If the sampled Hall pattern matches the value programmed in CURH, the detected transition was a spike (no Hall event) and no further actions are necessary.
- If the sampled Hall pattern matches the value programmed in EXPH, the detected transition was the expected event (correct Hall event CM_CHE) and the MCMP value has to change.
- If the sampled Hall pattern matches neither CURH nor EXPH, the transition was due to a major error (wrong Hall event CM_CWE) and can lead to an emergency shut down (IDLE).

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At every correct Hall event (CM_CHE), the next Hall patterns are transferred from the shadow register MCMOUTS into MCMOUT (Hall pattern shadow transfer HP_ST), and a new Hall pattern with its corresponding output pattern can be loaded (e.g. from a predefined table in memory) by software into MCMOUTS. For the Modulation patterns, signal MCM_ST is used to trigger the transfer.

Loading this shadow register can also be done by writing MCMOUTS.STRHP = 1 (for EXPH and CURH) or MCMOUTS.STRMCMP = 1 (for MCMP).

24.7.3 Hall Mode Flags

Depending on the Hall pattern compare operation, a number of flags are set in order to indicate the status of the module and to trigger further actions and interrupt requests.

Flag **IS.CHE** (Correct Hall Event) is set by signal CM_CHE when the sampled Hall pattern matches the expected one (EXPH). This flag can also be set by SW by setting bit **ISS.SCHE** = 1. If enabled by bit **IEN.ENCHE** = 1, the set signal for CHE can also generate an interrupt request to the CPU. Bit field **INP.INPCHE** defines which service request output becomes activated in case of an interrupt request. To clear flag CHE, SW needs to write **ISR.RCHE** = 1.

Flag **IS.WHE** indicates a Wrong Hall Event. Its handling for flag setting and resetting as well as interrupt request generation are similar to the mechanism for flag CHE.

The implementation of flag STR is done in the same way as for CHE and WHE. This flag is set by HW by the shadow transfer signal MCM_ST (see also [Figure 24-36](#)).

Please note that for flags CHE, WHE, and STR, the interrupt request generation is triggered by the set signal for the flag. That means, a request can be generated even if the flag is already set. There is no need to clear the flag in order to enable further interrupt requests.

The implementation for the IDLE flag is different. It is set by HW through signal CM_WHE if enabled by bit ENIDLE. Software can also set the flag via bit SIDLE. As long as bit IDLE is set, the modulation pattern field MCMP is cleared to force the outputs to the passive state. Flag IDLE must be cleared by software by writing RIDLE = 1 in order to return to normal operation. To fully restart from IDLE mode, the transfer requests for the bit fields in register MCMOUTS to register MCMOUT have to be initiated by software via bits STRMCM and STRHP in register MCMOUTS. In this way, the release from IDLE mode is under software control, but can be performed synchronously to the PWM signal.

Capture/Compare Unit 6 (CCU6)

24.7.4 Hall Mode for Brushless DC-Motor Control

The CCU6 provides a mode for the Timer T12 Block especially targeted for convenient control of block commutation patterns for Brushless DC-Motors. This mode is selected by setting all **T12MSEL**.MSEL6x bit fields of the three T12 Channels to 1000_B.

In this mode, illustrated in **Figure 24-40**, channel CC60 is placed in capture mode to measure the time elapsed between the last two correct Hall events, channel CC61 in compare mode to provide a programmable phase delay between the Hall event and the application of a new PWM output pattern, and channel CC62 also in compare mode as first time-out criterion. A second time-out criterion can be built by the T12 period match event.

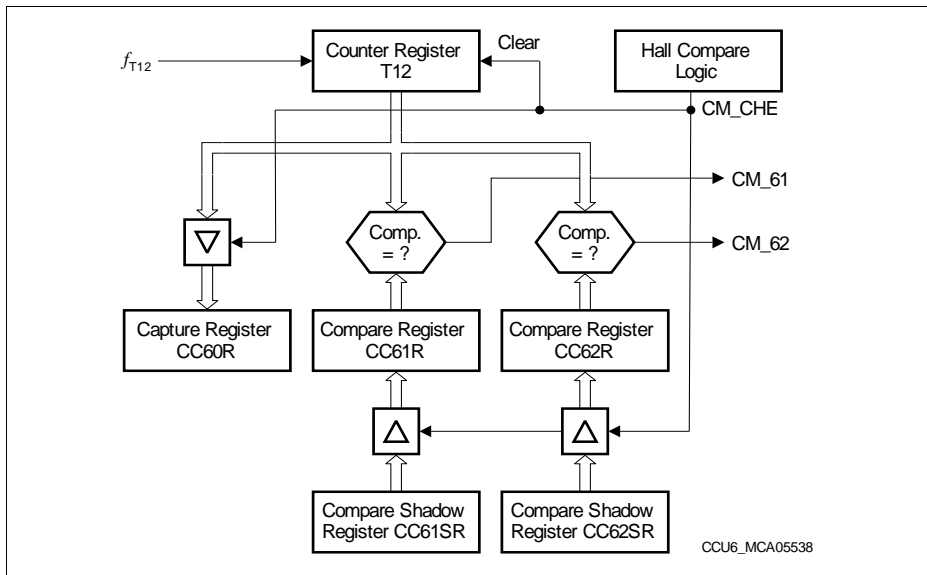


Figure 24-40 T12 Block in Hall Sensor Mode

The signal CM_CHE from the Hall compare logic is used to transfer the new compare values from the shadow registers CC6xSR into the actual compare registers CC6xR, performs the shadow transfer for the T12 period register, to capture the current T12 contents into register CC60R, and to clear T12.

Note: In this mode, the shadow transfer signal T12_ST is not generated. Not all shadow bits, such as the PSLy bits, will be transferred to their main registers. To program the main registers, SW needs to write to these registers while Timer T12 is stopped. In this case, a SW write actualizes both registers.

Capture/Compare Unit 6 (CCU6)

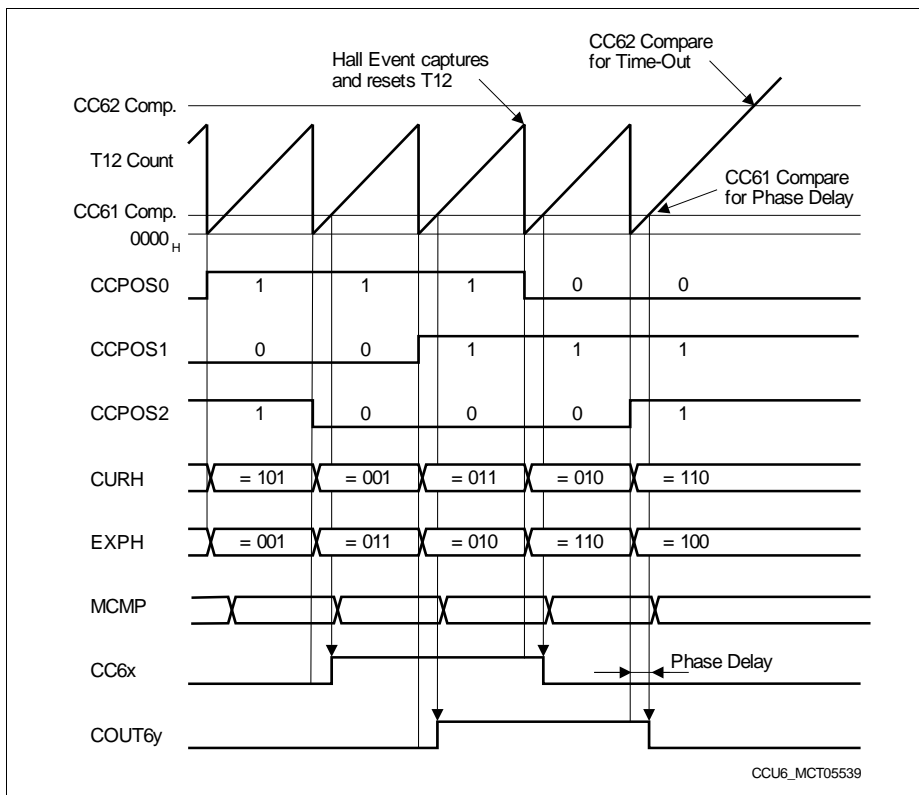


Figure 24-41 Brushless DC-Motor Control Example (all MSEL6x = 1000_B)

After the detection of an expected Hall pattern (CM_CHE active), the T12 count value is captured into channel CC60 (representing the actual rotor speed by measuring the elapsed time between the last two correct Hall events), and T12 is reset. When the timer reaches the compare value in channel CC61, the next multi-channel state is switched by triggering the shadow transfer of bit field MCMP (if enabled in bit field **SWEN**). This trigger event can be combined with the synchronization of the next multi-channel state to the PWM source (to avoid spikes on the output lines, see [Section 24.6](#)). This compare function of channel CC61 can be used as a phase delay from the position sensor input signals to the switching of the output signals, that is necessary if a sensorless back-EMF technique or Hall sensors are used. The compare value in channel CC62 can be used as a time-out trigger (interrupt), indicating that the actual motor speed is far below the desired destination value. An abnormal load change can be detected with this feature and PWM generation can be disabled.

24.8 Modulation Control Registers

24.8.1 Modulation Control

This register contains bits enabling the modulation of the corresponding output signal by PWM pattern generated by the timers T12 and T13. Furthermore, the multi-channel mode can be enabled as additional modulation source for the output signals.

MODCTR

Modulation Control Register

(80_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ECT 130	0	T13MODEN						MCM EN	0	T12MODEN					
rw	r	rw						rw	r	rw					

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T12MODEN	[5:0]	rw	<p>T12 Modulation Enable</p> <p>These bits enable the modulation of the corresponding output signal by a PWM pattern generated by timer T12.</p> <p>T12MODEN0 = MODCTR.0 for output CC60</p> <p>T12MODEN1 = MODCTR.1 for output COUT60</p> <p>T12MODEN2 = MODCTR.2 for output CC61</p> <p>T12MODEN3 = MODCTR.3 for output COUT61</p> <p>T12MODEN4 = MODCTR.4 for output CC62</p> <p>T12MODEN5 = MODCTR.5 for output COUT62</p> <p>0_B The modulation of the corresponding output signal by a T12 PWM pattern is disabled.</p> <p>1_B The modulation of the corresponding output signal by a T12 PWM pattern is enabled.</p>
MCMEN	7	rw	<p>Multi-Channel Mode Enable</p> <p>0_B The modulation of the corresponding output signal by a multi-channel pattern according to bit field MCMOUT is disabled.</p> <p>1_B The modulation of the corresponding output signal by a multi-channel pattern according to bit field MCMOUT is enabled.</p>
T13MODEN	[13:8]	rw	<p>T13 Modulation Enable</p> <p>These bits enable the modulation of the corresponding output signal by the PWM pattern CC63_O generated by timer T13.</p> <p>T13MODEN0 = MODCTR.8 for output CC60</p> <p>T13MODEN1 = MODCTR.9 for output COUT60</p> <p>T13MODEN2 = MODCTR.10 for output CC61</p> <p>T13MODEN3 = MODCTR.11 for output COUT61</p> <p>T13MODEN4 = MODCTR.12 for output CC62</p> <p>T13MODEN5 = MODCTR.13 for output COUT62</p> <p>0_B The modulation of the corresponding output signal by a T13 PWM pattern is disabled.</p> <p>1_B The modulation of the corresponding output signal by a T13 PWM pattern is enabled.</p>

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ECT130	15	rw	Enable Compare Timer T13 Output 0_B The output COUT63 is in the passive state. 1_B The output COUT63 is enabled for the PWM signal generated by T13.
0	6, 14, [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

24.8.2 Trap Control Register

The register TRPCTR controls the trap functionality. It contains independent enable bits for each output signal and control bits to select the behavior in case of a trap condition. The trap condition is a low level on the \overline{CTRAP} input pin, that is monitored (inverted level) by bit IS.TRPF. While TRPF=1 (trap input active), the trap state bit IS.TRPS is set to 1.

TRPCTR

Trap Control Register

(84_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TRP PEN	TRP EN 13	TRPEN						0				TRP M2	TRP M1	TRP M0	
rw	rw	rw						r				rw	rw	rw	

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
TRPM1, TRPM0	1, 0	rw	Trap Mode Control Bits 1, 0 These two bits define the behavior of the selected outputs when leaving the trap state after the trap condition has become inactive again. A synchronization to the timer driving the PWM pattern avoids unintended pulses when leaving the trap state. The combination [TRPM1, TRPM0] leads to: 00 _B The trap state is left (return to normal operation) after TRPF has become 0 again when a zero-match of T12 (while counting up) is detected (synchronization to T12). 01 _B The trap state is left (return to normal operation) after TRPF has become 0 again when a zero-match of T13 is detected (synchronization to T13). 10 _B reserved 11 _B The trap state is left (return to normal operation) immediately after TRPF has become 0 again without any synchronization to T12 or T13.
TRPM2	2	rw	Trap Mode Control Bit 2 This bit defines how the trap flag TRPF can be cleared after the trap input condition ($\overline{\text{CTRAP}} = 0$ and $\overline{\text{TRPPEN}} = 1$) is no longer valid (either by $\overline{\text{CTRAP}} = 1$ or by $\overline{\text{TRPPEN}} = 0$). 0 _B Automatic Mode: Bit TRPF is cleared by HW if the trap input condition is no longer valid. 1 _B Manual Mode: Bit TRPF stays 0 after the trap input condition is no longer valid. It has to be cleared by SW by writing $\text{ISR.RTRPF} = 1$.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
TRPEN	[13:8]	rw	Trap Enable Control Setting a bit enables the trap functionality for the following corresponding output signals: TRPEN0 = TRPCTR.8 for output CC60 TRPEN1 = TRPCTR.9 for output COUT60 TRPEN2 = TRPCTR.10 for output CC61 TRPEN3 = TRPCTR.11 for output COUT61 TRPEN4 = TRPCTR.12 for output CC62 TRPEN5 = TRPCTR.13 for output COUT62 0 _B The trap functionality of the corresponding output signal is disabled. The output state is independent from bit IS.TRPS. 1 _B The trap functionality of the corresponding output signal is enabled. The output state is set to the passive while IS.TRPS=1.
TRPEN13	14	rw	Trap Enable Control for Timer T13 0 _B The trap functionality for output COUT63 is disabled. The output state is independent from bit IS.TRPS. 1 _B The trap functionality for output COUT63 is enabled. The output state is set to the passive while IS.TRPS=1.
TRPPEN	15	rw	Trap Pin Enable This bit enables the input (pin) function for the trap generation. An interrupt can only be generated if a falling edge is detected at pin CTRAP while TRPPEN = 1. 0 _B The CCU6 trap functionality based on the input CTRAP is disabled. A CCU6 trap can only be generated by SW by setting bit TRPF. 1 _B The CCU6 trap functionality based on the input CTRAP is enabled. A CCU6 trap can be generated by SW by setting bit TRPF or by CTRAP=0.
0	[7:3], [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

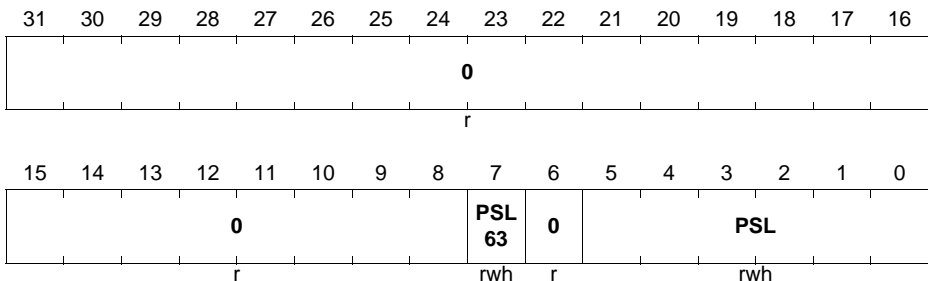
24.8.3 Passive State Level Register

Register PSLR defines the passive state level of the PWM outputs of the module. The passive state level is the value that is driven during the passive state of the output. During the active state, the corresponding output pin drives the active state level, that is the inverted passive state level. The passive state level permits to adapt the driven output levels to the driver polarity (inverted, not inverted) of the connected power stage. The bits in this register have shadow bit fields to permit a concurrent update of all PWM-related parameters (bit field PSL is updated with T12_ST, whereas PSL63 is updated with T13_ST). The actually used values can be read (attribute "rh"), whereas the shadow bits can only be written (attribute "w").

PSLR

Passive State Level Register

(88_H)

Reset Value: 0000 0000_H


Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
PSL	[5:0]	rwh	Compare Outputs Passive State Level These bits define the passive level driven by the module outputs during the passive state. PSL0 = PSLR.0 for output CC60 PSL1 = PSLR.1 for output COUT60 PSL2 = PSLR.2 for output CC61 PSL3 = PSLR.3 for output COUT61 PSL4 = PSLR.4 for output CC62 PSL5 = PSLR.5 for output COUT62 0 _B The passive level is 0. 1 _B The passive level is 1.
PSL63	7	rwh	Passive State Level of Output COUT63 This bit defines the passive level driven by the module output COUT63 during the passive state. 0 _B The passive level is 0. 1 _B The passive level is 1.
0	6, [31:8]	r	Reserved; Returns 0 if read; should be written with 0.

24.8.4 Multi-Channel Mode Registers

Register MCMCTR contains control bits for the multi-channel functionality.

MCMCTR

Multi-Channel Mode Control Register

(94_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0					STE 13U	STE 12D	STE 12U	0		SWSYN		0	SWSEL		
r					rw	rw	rw	r		rw		r	rw		

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
SWSEL	[2:0]	rw	<p>Switching Selection</p> <p>Bit field SWSEL selects one of the following trigger request sources (next multi-channel event) for the shadow transfer MCM_ST from MCMP5 to MCMP. The trigger request is stored in the reminder flag R until the shadow transfer is done and flag R is cleared automatically with the shadow transfer. The shadow transfer takes place synchronously with an event selected in bit field SWSYN.</p> <p>000_B No trigger request will be generated 001_B Correct Hall pattern detected (CM_CHE) 010_B T13 period-match detected (while counting up) 011_B T12 one-match (while counting down) 100_B T12 channel 1 compare-match detected (phase delay function) 101_B T12 period match detected (while counting up) 110_B reserved, no trigger request will be generated 111_B reserved, no trigger request will be generated</p>
SWSYN	[5:4]	rw	<p>Switching Synchronization</p> <p>Bit field SWSYN defines the synchronization mechanism of the shadow transfer event MCM_ST if it has been requested before (flag R set by an event selected by SWSEL) and if MCMEN = 1. This feature permits the synchronization of the outputs to the PWM source, that is used for modulation (T12 or T13).</p> <p>00_B Direct; the trigger event immediately leads to the shadow transfer 01_B A T13 zero-match triggers the shadow transfer 10_B A T12 zero-match (while counting up) triggers the shadow transfer 11_B reserved; no action</p>
STE12U	8	rw	<p>Shadow Transfer Enable for T12 Upcounting</p> <p>This bit enables the shadow transfer T12_ST if flag MCMOUT.R is set or becomes set while a T12 period match is detected while counting up.</p> <p>0_B No action 1_B The T12_ST shadow transfer mechanism is enabled if MCMEN = 1.</p>

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
STE12D	9	rw	Shadow Transfer Enable for T12 Downcounting This bit enables the shadow transfer T12_ST if flag MCMOUT.R is set or becomes set while a T12 one match is detected while counting down. 0 _B No action 1 _B The T12_ST shadow transfer mechanism is enabled if MCMEN = 1.
STE13U	10	rw	Shadow Transfer Enable for T13 Upcounting This bit enables the shadow transfer T13_ST if flag MCMOUT.R is set or becomes set while a T13 period match is detected. 0 _B No action 1 _B The T13_ST shadow transfer mechanism is enabled if MCMEN = 1.
0	3, [7:6], [31:11]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

Register MCMOUTS contains bits used as pattern input for the multi-channel mode and the Hall mode. This register is a shadow register (that can be read and written) for register MCMOUT, indicating the currently active signals.

MCMOUTS

Multi-Channel Mode Output Shadow Register

(8C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STR HP	0		CURHS			EXPHS		STR MCM	0				MCMPs		
w	r		rw			rw		w	r				rw		

Field	Bits	Type	Description
MCMPs	[5:0]	rw	Multi-Channel PWM Pattern Shadow Bit field MCMPs is the shadow bit field for bit field MCMP. The multi-channel shadow transfer is triggered by MCM_ST according to the transfer conditions defined by register MCMCTR.
STRMCM	7	w	Shadow Transfer Request for MCMPs Writing STRMCM = 1 leads to an immediate activation of MCM_ST to update bit field MCMP by the value of MCMPs. When read, this bit always delivers 0. 0 _B No action. 1 _B Bit field MCMP is updated.
EXPHS	[10:8]	rw	Expected Hall Pattern Shadow Bit field EXPHS is the shadow bit field for bit field EXPH. The shadow transfer takes place when a correct Hall event is detected (CM_CHE).
CURHS	[13:11]	rw	Current Hall Pattern Shadow Bit field CURHS is the shadow bit field for bit field CURH. The shadow transfer takes place when a correct Hall event is detected (CM_CHE).

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
STRHP	15	w	Shadow Transfer Request for the Hall Pattern Writing STRHP = 1 leads to an immediate activation of HP_ST to update bit fields EXPH and CURH by EXPHS and CURHS. When read, this bit always delivers 0. 0 _B No action. 1 _B Bit fields EXPH and CURH are updated.
0	6, 14 [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

MCMOUT

Multi-Channel Mode Output Register

(90_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		CURH			EXPH			0	R	MCMP					
r		rh			rh			r	rh	rh					

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
MCMP	[5:0]	rh	<p>Multi-Channel PWM Pattern</p> <p>Bit field MCMP defines the output pattern for the multi-channel mode. If this mode is enabled by MODCTR.MCMEN = 1, the output state of all T12 related PWM outputs can be modified. This bit field is 0 while IS.IDLE = 1.</p> <p>MCMP0 = MCMOUT.0 for output CC60 MCMP1 = MCMOUT.1 for output COUT60 MCMP2 = MCMOUT.2 for output CC61 MCMP3 = MCMOUT.3 for output COUT61 MCMP4 = MCMOUT.4 for output CC62 MCMP5 = MCMOUT.5 for output COUT62</p> <p>0_B The output is set to the passive state. A PWM generated by T12 or T13 are not taken into account.</p> <p>1_B The output can be in the active state, depending on the enabled PWM modulation signals generated by T12, T13 and the trap state.</p>
R	6	rh	<p>Reminder Flag</p> <p>This flag indicates that the shadow transfer from MCMP5 to MCMP has been requested by the selected trigger source. It is cleared when the shadow transfer takes place or while MCMEN=0.</p> <p>0_B A shadow transfer MCM_ST is not requested.</p> <p>1_B A shadow transfer MCM_ST is requested, but has not yet been executed, because the selected synchronization condition has not yet occurred.</p>
EXPH	[10:8]	rh	<p>Expected Hall Pattern</p> <p>Bit field EXPH is updated by a shadow transfer HP_ST from bit field EXPHS.</p> <p>If HCRDY = 1, EXPH is compared to the sampled CCPOSx inputs in order to detect the occurrence of the next desired (=expected) hall pattern or a wrong pattern. If the sampled hall pattern at the hall input pins is equal to bit field EXPH, a correct Hall event has been detected (CM_CHE).</p>

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
CURH	[13:11]	rh	Current Hall Pattern Bit field CURH is updated by a shadow transfer HP_ST from bit field CURHS. If HCRDY = 1, CURH is compared to the sampled CCPOSx inputs in order to detect a spike. If the sampled Hall pattern at the Hall input pins is equal to bit field CURH, no Hall event has been detected. If the sampled Hall input pattern is neither equal to CURH nor equal to EXPH, the Hall event was not the desired one and may be due to a fatal error (e.g. blocked rotor, etc.). In this case, a wrong Hall event has been detected (CM_WHE).
0	7, [31:14]	r	Reserved; Returns 0 if read; should be written with 0.

24.9 Interrupt Handling

This section describes the interrupt handling of the CCU6 module.

24.9.1 Interrupt Structure

The HW interrupt event or the SW setting of the corresponding interrupt set bit (in register ISS) sets the event indication flags (in register IS) and can trigger the interrupt generation. The interrupt pulse is generated independently from the interrupt status flag in register IS (it is not necessary to clear the related status bit to be able to generate another interrupt). The interrupt flag can be cleared by SW by writing to the corresponding bit in register ISR.

If enabled by the related interrupt enable bit in register IEN, an interrupt pulse can be generated on one of the four service request outputs (SR0 to SR3) of the module. If more than one interrupt source is connected to the same interrupt node pointer (in register INP), the requests are logically OR-combined to one common service request output (see [Figure 24-42](#)).

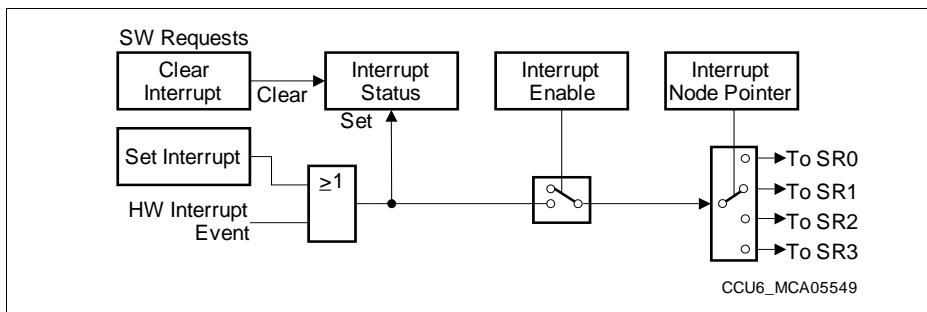


Figure 24-42 General Interrupt Structure

The available interrupt events in the CCU6 are shown in [Figure 24-43](#).

Capture/Compare Unit 6 (CCU6)

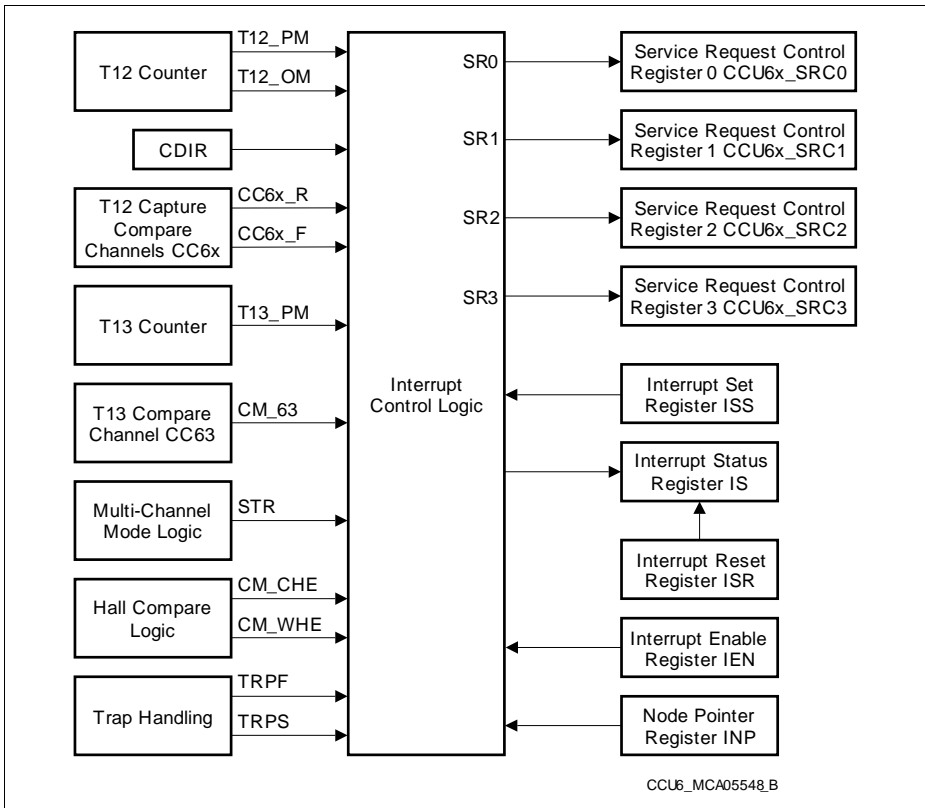


Figure 24-43 Interrupt Sources and Events

24.9.2 Interrupt Registers

24.9.2.1 Interrupt Status Register

Register IS contains the individual interrupt request bits. This register can only be read, write actions have no impact on the contents of this register. The SW can set or clear the bits individually by writing to the registers ISS (to set the bits) or to register ISR (to clear the bits).

The interrupt generation is independent from the value of the bits in register IS, e.g. the interrupt will be generated (if enabled) even if the corresponding bit is already set. The trigger for an interrupt generation is the detection of a set condition (by HW or SW) for the corresponding bit in register IS.

In compare mode (and hall mode), the timer-related interrupts are only generated while the timer is running ($T1xR=1$). In capture mode, the capture interrupts are also generated while the timer T12 is stopped.

Note: Not all bits in register IS can generate an interrupt. Other status bits have been added, that have a similar structure for their set and clear actions. It is recommended that SW checks the interrupt bits bit-wisely (instead of common OR over the bits).

IS															
Interrupt Status Register															
(A0 _H)															
Reset Value: 0000 0000 _H															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STR	IDLE	WHE	CHE	TRP S	TRP F	T13 PM	T13 CM	T12 PM	T12 OM	ICC 62F	ICC 62R	ICC 61F	ICC 61R	ICC 60F	ICC 60R
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ICC60R, ICC61R, ICC62R	0, 2, 4	rh	Capture, Compare-Match Rising Edge Flag This bit indicates that event CC6x_R has been detected. This event occurs in compare mode when a compare-match is detected while T12 is counting up (CM_6x and CDIR = 0) and in capture mode when a rising edge is detected at the related input CC6xIN. 0 _B The event has not yet been detected. 1 _B The event has been detected.
ICC60F, ICC61F, ICC62F	1, 3, 5	rh	Capture, Compare-Match Falling Edge Flag This bit indicates that event CC6x_F has been detected. This event occurs in compare mode when a compare-match is detected while T12 is counting down (CM_6x and CDIR = 1) and in capture mode when a falling edge is detected at the related input CC6xIN. 0 _B The event has not yet been detected. 1 _B The event has been detected.
T12OM	6	rh	Timer T12 One-Match Flag This bit indicates that a timer T12 one-match while counting down (T12_OM and CDIR = 1) has been detected. 0 _B The event has not yet been detected. 1 _B The event has been detected.
T12PM	7	rh	Timer T12 Period-Match Flag This bit indicates that a timer T12 period-match while counting up (T12_PM and CDIR = 0) has been detected. 0 _B The event has not yet been detected. 1 _B The event has been detected.
T13CM	8	rh	Timer T13 Compare-Match Flag This bit indicates that a timer T13 compare-match (CM_63) has been detected. 0 _B The event has not yet been detected. 1 _B The event has been detected.
T13PM	9	rh	Timer T13 Period-Match Flag This bit indicates that a timer T13 period-match (T13_PM) has been detected. 0 _B The event has not yet been detected. 1 _B The event has been detected.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
TRPF	10	rh	Trap Flag This bit indicates if a trap condition (input $\overline{\text{CTRAP}}$ = 0 or by SW) is / has been detected. If TRPM2= 0, it becomes cleared automatically if $\overline{\text{CTRAP}}$ = 1 or TRPPEN = 0, whereas if TRPM2 = 1, it has to be cleared by writing RTRPF = 1. 0_B The trap condition has not been detected. 1_B The trap condition is / has been detected.
TRPS	11	rh	Trap State¹⁾ This bit indicates the actual trap state. It is set if TRPF = 1 and becomes cleared according to the mode selected in register TRPCTR. 0_B The trap state is not active. 1_B The trap state is active.
CHE	12	rh	Correct Hall Event This bit indicates that a correct Hall event (CM_CHE) has been detected. 0_B The event has not yet been detected. 1_B The event has been detected.
WHE	13	rh	Wrong Hall Event This bit indicates that a wrong Hall event (CM_WHE) has been detected. 0_B The event has not yet been detected. 1_B The event has been detected.
IDLE	14	rh	IDLE State If enabled by ENIDLE = 1, this bit is set together with bit WHE and it has to be cleared by SW. 0_B No action. 1_B Bit field MCMP is cleared, the selected outputs are set to passive state.
STR	15	rh	Multi-Channel Mode Shadow Transfer Request This bit indicates that a shadow transfer from MCMPS to MCMP (MCM_ST) has taken place. 0_B The event has not yet been detected. 1_B The event has been detected.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ST13PM	9	w	Set Timer T13 Period-Match Flag 0 _B No action 1 _B Bit T13PM will be set.
STRPF	10	w	Set Trap Flag 0 _B No action 1 _B Bits TRPF and TRPS will be set.
SWHC	11	w	Software Hall Compare 0 _B No action 1 _B The Hall compare action is triggered.
SCHE	12	w	Set Correct Hall Event Flag 0 _B No action 1 _B Bit CHE will be set.
SWHE	13	w	Set Wrong Hall Event Flag 0 _B No action 1 _B Bit WHE will be set.
SIDLE	14	w	Set IDLE Flag 0 _B No action 1 _B Bit IDLE will be set.
SSSTR	15	w	Set STR Flag 0 _B No action 1 _B Bit STR will be set.
0	[31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
RTRPF	10	w	Reset Trap Flag 0 _B No action 1 _B Bit TRPF will be cleared (not taken into account while input $\overline{\text{CTRAP}}=0$ and TRPPEN=1.
RCHE	12	w	Reset Correct Hall Event Flag 0 _B No action 1 _B Bit CHE will be cleared.
RWHE	13	w	Reset Wrong Hall Event Flag 1 _B No action 0 _B Bit WHE will be cleared.
RIDLE	14	w	Reset IDLE Flag 0 _B No action 1 _B Bit IDLE will be cleared.
RSTR	15	w	Reset STR Flag 0 _B No action 1 _B Bit STR will be cleared.
0	11, [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.9.2.4 Interrupt Enable Register

Register IEN contains the interrupt enable bits and a control bit to enable the automatic idle function in the case of a wrong hall pattern.

IEN

Interrupt Enable Register

(B0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN STR	EN IDLE	EN WHE	EN CHE	0	EN TRP F	EN T13 PM	EN T13 CM	EN T12 PM	EN T12 OM	EN CC 62F	EN CC 62R	EN CC 61F	EN CC 61R	EN CC 60F	EN CC 60R
rw	rw	rw	rw	r	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ENCC60R, ENCC61R, ENCC62R	0, 2, 4	rw	Capture, Compare-Match Rising Edge Interrupt Enable for Channel CC6x 0 _B No interrupt will be generated if the set condition for bit CC6xR in register IS occurs. 1 _B An interrupt will be generated if the set condition for bit CC6xR in register IS occurs. The service request output that will be activated is selected by bit field INPCC6x.
ENCC60F, ENCC61F, ENCC62F	1, 3, 5	rw	Capture, Compare-Match Falling Edge Interrupt Enable for Channel CC6x 0 _B No interrupt will be generated if the set condition for bit CC6xF in register IS occurs. 1 _B An interrupt will be generated if the set condition for bit CC6xF in register IS occurs. The service request output that will be activated is selected by bit field INPCC6x.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ENT12OM	6	rw	Enable Interrupt for T12 One-Match 0_B No interrupt will be generated if the set condition for bit T12OM in register IS occurs. 1_B An interrupt will be generated if the set condition for bit T12OM in register IS occurs. The service request output that will be activated is selected by bit field INPT12.
ENT12PM	7	rw	Enable Interrupt for T12 Period-Match 0_B No interrupt will be generated if the set condition for bit T12PM in register IS occurs. 1_B An interrupt will be generated if the set condition for bit T12PM in register IS occurs. The service request output that will be activated is selected by bit field INPT12.
ENT13CM	8	rw	Enable Interrupt for T13 Compare-Match 0_B No interrupt will be generated if the set condition for bit T13CM in register IS occurs. 1_B An interrupt will be generated if the set condition for bit T13CM in register IS occurs. The service request output that will be activated is selected by bit field INPT13.
ENT13PM	9	rw	Enable Interrupt for T13 Period-Match 0_B No interrupt will be generated if the set condition for bit T13PM in register IS occurs. 1_B An interrupt will be generated if the set condition for bit T13PM in register IS occurs. The service request output that will be activated is selected by bit field INPT13.
ENTRPF	10	rw	Enable Interrupt for Trap Flag 0_B No interrupt will be generated if the set condition for bit TRPF in register IS occurs. 1_B An interrupt will be generated if the set condition for bit TRPF in register IS occurs. The service request output that will be activated is selected by bit field INPERR.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ENCHE	12	rw	Enable Interrupt for Correct Hall Event 0_B No interrupt will be generated if the set condition for bit CHE in register IS occurs. 1_B An interrupt will be generated if the set condition for bit CHE in register IS occurs. The service request output that will be activated is selected by bit field INPCHE.
ENWHE	13	rw	Enable Interrupt for Wrong Hall Event 0_B No interrupt will be generated if the set condition for bit WHE in register IS occurs. 1_B An interrupt will be generated if the set condition for bit WHE in register IS occurs. The service request output that will be activated is selected by bit field INPERR.
ENIDLE	14	rw	Enable Idle This bit enables the automatic entering of the idle state (bit IDLE will be set) after a wrong hall event has been detected (bit WHE is set). During the idle state, the bit field MCMP is automatically cleared. 0_B The bit IDLE is not automatically set when a wrong hall event is detected. 1_B The bit IDLE is automatically set when a wrong hall event is detected.
ENSTR	15	rw	Enable Multi-Channel Mode Shadow Transfer Interrupt 0_B No interrupt will be generated if the set condition for bit STR in register IS occurs. 1_B An interrupt will be generated if the set condition for bit STR in register IS occurs. The service request output that will be activated is selected by bit field INPCHE.
0	11, [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

24.9.2.5 Interrupt Node Pointer Register

Register INP contains the interrupt node pointers allowing a flexible interrupt handling. These bit fields define which service request output will be activated if the corresponding interrupt event occurs and the interrupt generation for this event is enabled.

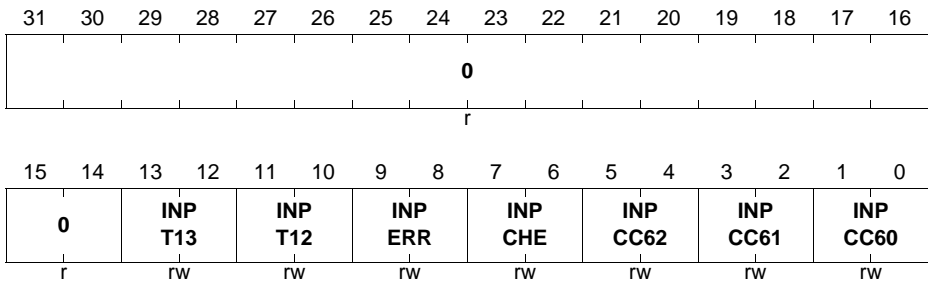
Capture/Compare Unit 6 (CCU6)

INP

Interrupt Node Pointer Register

(AC_H)

Reset Value: 0000 3940_H



Field	Bits	Type	Description
INPCC60, INPCC61, INPCC62	[1:0], [3:2], [5:4]	rw	Interrupt Node Pointer for Channel CC6x Interrupts This bit field defines the service request output activated due to a set condition for bit CC6xR (if enabled by bit ENCC6xR) or for bit CC6xF (if enabled by bit ENCC6xF). 00 _B Service request output SR0 is selected. 01 _B Service request output SR1 is selected. 10 _B Service request output SR2 is selected. 11 _B Service request output SR3 is selected.
INPCHE	[7:6]	rw	Interrupt Node Pointer for the CHE Interrupt This bit field defines the service request output activated due to a set condition for bit CHE (if enabled by bit ENCHE) or for bit STR (if enabled by bit ENSTR). Coding see INPCC6x.
INPERR	[9:8]	rw	Interrupt Node Pointer for Error Interrupts This bit field defines the service request output activated due to a set condition for bit TRPF (if enabled by bit ENTRPF) or for bit WHE (if enabled by bit ENWHE). Coding see INPCC6x.
INPT12	[11:10]	rw	Interrupt Node Pointer for Timer12 Interrupts This bit field defines the service request output activated due to a set condition for bit T12OM (if enabled by bit ENT12OM) or for bit T12PM (if enabled by bit ENT12PM). Coding see INPCC6x.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
INPT13	[13:12]	rw	Interrupt Node Pointer for Timer13 Interrupt This bit field defines the service request output activated due to a set condition for bit T13CM (if enabled by bit ENT13CM) or for bit T13PM (if enabled by bit ENT13PM). Coding see INPCC6x.
0	[31:14]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.9.3 Service Request Control Registers

Each CC6x kernel has four service request outputs which are connected to four Service Request Nodes (SRN). Each SRN contains a Service Request Control Register.

CCU60_SRCx (x = 0-3)

CCU60 Service Request Control Register

(FC_H-x*4)

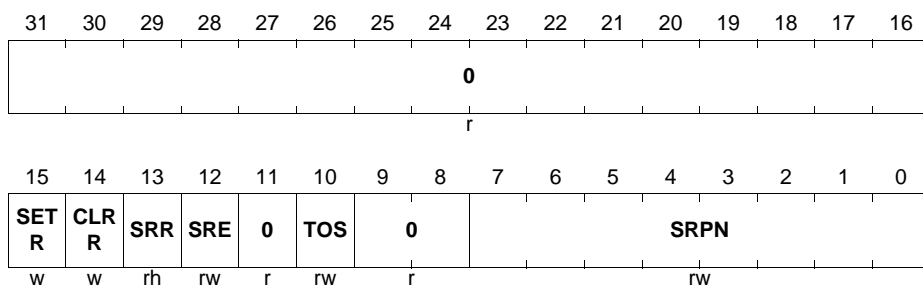
Reset Value: 0000 0000_H

CCU61_SRCx (x = 0-3)

CCU61 Service Request Control Register

(FC_H-x*4)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

24.10 General Module Operation

This section provides information about the:

- Configuration of the behavior of the different device operating modes (see mode control description in [Section 24.10.1](#))
- Input selection (see [Section 24.10.2](#))
- General register description (see [Section 24.10.4](#))

24.10.1 Mode Control

The mode control concept for system control tasks, such as power saving, or suspend request for debugging, allows to program the module behavior under different device operating conditions. The behavior of a CCU6 kernel can be programmed for each of the device operating modes, that are requested by the global state control part of the SCU. Therefore, a CCU6 module provides a kernel state configuration register **KSCFG** defining the behavior in the following device operating modes:

- **Normal operation:**
This operating mode is the default operating mode when neither a suspend request nor a clock-off request are pending. The module clock is not switched off and the CCU6 registers can be read or written. The kernel behavior is defined by KSCFG.NOMCFG.
- **Suspend mode:**
This operating mode is requested when a suspend request (issued by a debugger through OCDS) is pending in the device. The module clock is not switched off and the CCU6 registers can be read or written. The kernel behavior is defined by KSCFG.SUMCFG.
- **Clock-off mode:**
This operating mode is requested for power saving purposes. The module clock is switched off automatically when all kernels of the CCU6 module reached their specified state in a stop mode. In this case, CCU6 registers can not be accessed. The kernel behavior is defined by KSCFG.COMCFG. The clock-off mode is requested by a sleep request of the FPI bus.

The kernel distinguishes four different blocks (T12, T13, Hall logic, and trap logic). These blocks can be individually enabled for the request of stop mode 0 and stop mode 1 by the sensitivity bits **KSCSR.SBx**. If the request sensitivity is disabled, the block continues normal operation. If the request sensitivity is enabled, the block operates as specified for the selected stop mode.

The complete CCU6 acknowledge is given to the GSC when all four blocks have reached their defined end condition.

Capture/Compare Unit 6 (CCU6)

Table 24-12 CCU6 Functional Blocks

Block	Function	Sensitivity Bit
0	Timer T12: A functional enable is delivered until the specified stop condition is reached. Then, T12 stops counting and the CC6xIN input stages are frozen.	KSCSR.SB0
1	Timer T13: A functional enable is delivered until the specified stop condition is reached. Then, T13 stops counting.	KSCSR.SB1
2	Hall Logic: The hall logic is stopped immediately and the CCPOSx input stages are frozen.	KSCSR.SB2
3	Trap Logic: The trap logic is stopped immediately and the CTRAP input stage is frozen.	KSCSR.SB3

The behavior of the CCU6 kernel can be programmed for each of the device operating modes (normal operation and suspend mode). Therefore, it supports four kernel modes, as shown in [Table 24-13](#).

Table 24-13 CCU6 Kernel Behavior

Kernel Mode	Kernel Behavior	Code
run mode 0	kernel operation as specified, no impact on CCU6 operation (same behavior for run mode 0 and run mode 1)	00 _B
run mode 1		01 _B

Capture/Compare Unit 6 (CCU6)

Table 24-13 CCU6 Kernel Behavior (cont'd)

Kernel Mode	Kernel Behavior	Code
stop mode 0	<p>The sensitivity bits are taken into account for:</p> <p>T12 block: Timer T12 continues normal operation (if running) until they reach the end of the PWM period and then it stops (same stop condition as in single shot mode). When the timer stops, the CC6xIN inputs are frozen.</p> <p>T13 block: Timer T13 continues normal operation (if running) until they reach the end of the PWM period and then it stops (same stop condition as in single shot mode).</p> <p>Hall logic block: The CCPOSx input values are frozen.</p> <p>Trap logic block: The CTRAP input value is frozen.</p>	10 _B
stop mode 1	<p>The output lines enabled for the trap condition are set to their passive values (similar to a trap state). The sensitivity bits are taken into account for:</p> <p>T12 block: Timer T12 stops immediately and CC6xIN inputs are frozen.</p> <p>T13 block: Timer T13 stops.</p> <p>Hall logic block: The CCPOSx input values are frozen.</p> <p>Trap logic block: The CTRAP input value is frozen.</p>	11 _B

Generally, bit field KSCFG.NOMCFG should be configured for run mode 0 as default setting for standard operation. If a CCU6 kernel should not react to a suspend request (and to continue operation as in normal mode), bit field KSCFG.SUMCFG has to be configured with the same value as KSCFG.NOMCFG. If a CCU6 kernel should show a different behavior and stop operation when a specific stop condition is reached, the code for stop mode 0 or stop mode 1 has to be written to KSCFG.SUMCFG.

A similar mechanism applies for the clock-off mode with the possibility to program the desired behavior by bit field KSCFG.COMCFG.

Note: The stop mode selection strongly depends on the application needs and it is very unlikely that different stop modes are required in parallel in the same application. As a result, only one stop mode type (either 0 or 1) should be used in the bit fields in register KSCFG. Do not mix stop mode 0 and stop mode 1 and avoid transitions from stop mode 0 to stop mode 1 (or vice versa) for the CCU6 module.

If the module clock is disabled by KSCFG.MODEN = 0 or in clock-off mode when the stop condition is reached (in stop mode 0 or 1), the module can not be accessed by read or write operations (except register KSCFG and KSCSR that can always be accessed). As a consequence, it can not be configured.

Please note that bit KSCFG.MODEN should only be set by SW while all configuration fields are configured for run mode 0.

24.10.2 Input Selection

Each CCU6 input signal can be selected from a vector of four or eight possible inputs by programming the port input select registers **PISEL0** and **PISEL2**. This permits to adapt the pin functionality of the device to the application requirements.

The output pins for the module output signals are chosen in the ports.

Naming convention:

The input vector CC60IN[D:A] for input signal CC60IN is composed of the signals CC60INA to CC60IND.

Note: All functional inputs of the CCU6 are synchronized to f_{CC6} before they affect the module internal logic. The resulting delay of $2/f_{CC6}$ and for asynchronous signals an additional uncertainty of $1/f_{CC6}$ have to be taken into account for precise timing calculation. An edge of an input signal can only be correctly detected if the high phase and the low phase of the input signal are both longer than $1/f_{CC6}$.

Capture/Compare Unit 6 (CCU6)

24.10.3 Input Monitoring

A selected event which occurs at each CCU6 input signal can be monitored through **IMON.x**. Every input signal can be included for the detection of a lost bit event (**IMON.LBE**) if enabled through its individual lost indicator enable bits (**LI.yEN**). The lost bit event occurs if a selected event occurs again with the previous event captured (**IMON.x** remains set) and its lost indicator is enabled for at least one of the monitored input signals. The lost bit event can be enabled (**LI.LBEEN**) for an interrupt to be generated at one of the SRx line, selected through **LI.INPLBE**. The LBE output signal of the kernel can be connected to a capture input to indicate when does the lost bit event happens. See [Section 24.12](#).

The lost bit event can be used as a kind of interrupt or event watchdog to monitor if an action related to an event has been processed before a second event of the same type occurs. Like this, if a certain event is treated by an interrupt that should be monitored, the related indication flag has to be cleared by SW. If the SW has not yet cleared the flag and the event occurs again, the event is considered as being lost and another interrupt can be generated to inform the system about the loss. This can be also used to indicate that input events occur too often and the main task has not enough time to treat them.

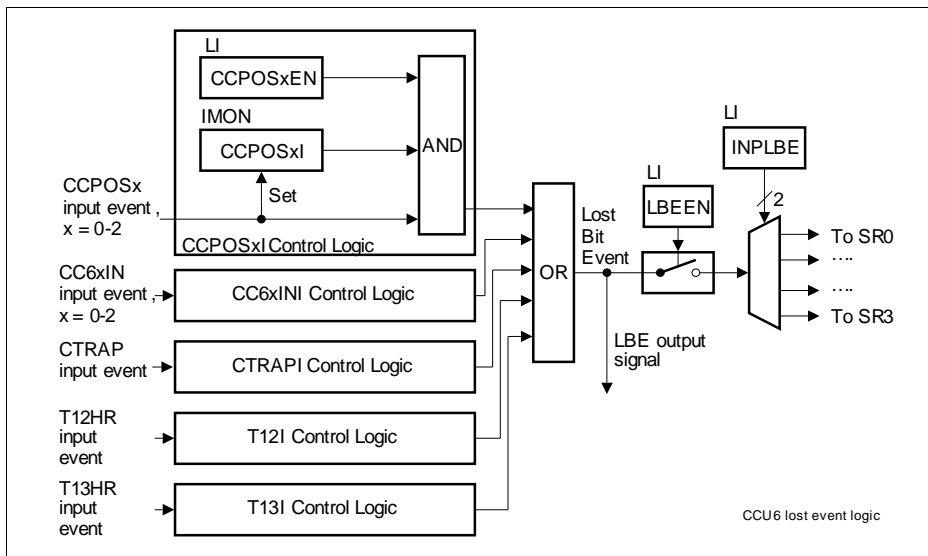


Figure 24-44 Lost Event Logic

Capture/Compare Unit 6 (CCU6)

24.10.4.2 Port Input Select Registers

Registers PISEL0 and PISEL2 contain bit fields selecting the actual input signal for the module inputs.

PISEL0

Port Input Select Register 0

(10_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IST12HR		ISPOS2		ISPOS1		ISPOS0		ISTRP		ISCC62		ISCC61		ISCC60	
rw		rw		rw		rw		rw		rw		rw		rw	

Field	Bits	Type	Description
ISCC60	[1:0]	rw	Input Select for CC60 This bit field defines the input signal used as CC60 capture input. 00 _B The signal CC60INA is selected. 01 _B The signal CC60INB is selected. 10 _B The signal CC60INC is selected. 11 _B The signal CC60IND is selected.
ISCC61	[3:2]	rw	Input Select for CC61 This bit field defines the input signal used as CC61 capture input. 00 _B The signal CC61INA is selected. 01 _B The signal CC61INB is selected. 10 _B The signal CC61INC is selected. 11 _B The signal CC61IND is selected.
ISCC62	[5:4]	rw	Input Select for CC62 This bit field defines the input signal used as CC62 capture input. 00 _B The signal CC62INA is selected. 01 _B The signal CC62INB is selected. 10 _B The signal CC62INC is selected. 11 _B The signal CC62IND is selected.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
ISTRP	[7:6]	rw	Input Select for CTRAP This bit field defines the input signal used as CTRAP input. 00 _B The signal CTRAPA is selected. 01 _B The signal CTRAPB is selected. 10 _B The signal CTRAPC is selected. 11 _B The signal CTRAPD is selected.
ISPOS0	[9:8]	rw	Input Select for CCPOS0 This bit field defines the input signal used as CCPOS0 input. 00 _B The signal CCPOS0A is selected. 01 _B The signal CCPOS0B is selected. 10 _B The signal CCPOS0C is selected. 11 _B The signal CCPOS0D is selected.
ISPOS1	[11:10]	rw	Input Select for CCPOS1 This bit field defines the input signal used as CCPOS1 input. 00 _B The signal CCPOS1A is selected. 01 _B The signal CCPOS1B is selected. 10 _B The signal CCPOS1C is selected. 11 _B The signal CCPOS1D is selected.
ISPOS2	[13:12]	rw	Input Select for CCPOS2 This bit field defines the input signal used as CCPOS2 input. 00 _B The signal CCPOS2A is selected. 01 _B The signal CCPOS2B is selected. 10 _B The signal CCPOS2C is selected. 11 _B The signal CCPOS2D is selected.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
IST12HR	[15:14]	rw	Input Select for T12HR This bit field defines the input signal used as T12HR input. 00 _B Either signal T12HRA (if T12EXT = 0) or T12HRE (if T12EXT = 1) is selected. 01 _B Either signal T12HRB (if T12EXT = 0) or T12HRF (if T12EXT = 1) is selected. 10 _B Either signal T12HRC (if T12EXT = 0) or T12HRG (if T12EXT = 1) is selected. 11 _B Either signal T12HRD (if T12EXT = 0) or T12HRH (if T12EXT = 1) is selected.
0	[31:16]	r	Reserved Returns 0 if read, should be written with 0.

PISEL2

Port Input Select Register 2

(14_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0								T13 EXT	T12 EXT	ISCNT13	ISCNT12	IST13HR			
r								rw	rw	rw	rw	rw			

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
IST13HR	[1:0]	rw	Input Select for T13HR This bit field defines the input signal used as T13HR input. 00 _B Either signal T13HRA (if T13EXT = 0) or T13HRE (if T13EXT = 1) is selected. 01 _B Either signal T13HRB (if T13EXT = 0) or T13HRF (if T13EXT = 1) is selected. 10 _B Either signal T13HRC (if T13EXT = 0) or T13HRG (if T13EXT = 1) is selected. 11 _B Either signal T13HRD (if T13EXT = 0) or T13HRH (if T13EXT = 1) is selected.
ISCNT12	[3:2]	rw	Input Select for T12 Counting Input This bit field defines the input event leading to a counting action of T12. 00 _B The T12 prescaler generates the counting events. Bit TCTR4.T12CNT is not taken into account. 01 _B Bit TCTR4.T12CNT written with 1 is a counting event. The T12 prescaler is not taken into account. 10 _B The timer T12 is counting each rising edge detected in the selected T12HR signal. 11 _B The timer T12 is counting each falling edge detected in the selected T12HR signal.
ISCNT13	[5:4]	rw	Input Select for T13 Counting Input This bit field defines the input event leading to a counting action of T13. 00 _B The T13 prescaler generates the counting events. Bit TCTR4.T13CNT is not taken into account. 01 _B Bit TCTR4.T13CNT written with 1 is a counting event. The T13 prescaler is not taken into account. 10 _B The timer T13 is counting each rising edge detected in the selected T13HR signal. 11 _B The timer T13 is counting each falling edge detected in the selected T13HR signal.
T12EXT	6	rw	Extension for T12HR Inputs This bit extends the 2-bit field IST12HR. 0 _B One of the signals T12HR[D:A] is selected. 1 _B One of the signals T12HR[H:E] is selected.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T13EXT	7	rw	Extension for T13HR Inputs This bit extends the 2-bit field IST13HR. 0 _B One of the signals T13HR[D:A] is selected. 1 _B One of the signals T13HR[H:E] is selected.
0	[31:8]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.10.4.3 Kernel State Configuration Register

The kernel state configuration register KSCFG allows the selection of the desired kernel modes for the different device operating modes.

Bit fields KSCFG.NOMCFG and KSCFG.COMCFG are reset by an application (class 3) reset. Bit field KSCFG.SUMCFG is reset by a debug (class 1) reset.

Note: The coding of the bit fields NOMCFG, SUMCFG and COMCFG are described in [Table 24-13](#).

KSCFG

Kernel State Configuration Register

(18_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BP COM	0	COMCFG	BP SUM	0	SUMCFG	BP NOM	0	NOMCFG	SUS REQ	ACK	BP MOD EN	MOD EN			
w	r	rw	w	r	rw	w	r	rw	rh	rh	w	rw			

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
MODEN	0	rw	<p>Module Enable</p> <p>This bit enables the module kernel clock and the module functionality.</p> <p>0_B The module is switched off immediately (without respecting a stop condition). It does not react on mode control actions and the module clock is switched off. The module does not react on read accesses and ignores write accesses (except to KSCFG).</p> <p>1_B The module is switched on and can operate. After writing 1 to MODEN, it is recommended to read register KSCFG to avoid pipeline effects in the control block before accessing other CCU6 registers.</p>
BPMODEN	1	w	<p>Bit Protection for MODEN</p> <p>This bit enables the write access to the bit MODEN. It always reads 0.</p> <p>0_B MODEN is not changed.</p> <p>1_B MODEN is updated with the written value.</p>
ACK	2	rh	<p>Module Acknowledge</p> <p>This bit monitors the state of the CCU6 module's acknowledge on incoming requests.</p> <p>0_B The acknowledge is not activated, because at least one of the module kernels is in a transition phase.</p> <p>1_B The acknowledge is activated, because all module kernels have reached the requested state.</p>
SUSREQ	3	rh	<p>Suspend Request</p> <p>This bit monitors the state of the CCU6 module's suspend request input, requested through OCS. The value is only valid when there is no sleep request. In the event that there is a sleep request, the value is ignored and COMCFG is considered as the kernel mode.</p> <p>0_B A suspend mode is not requested and bit field NOMCFG defines the CCU6 kernel mode.</p> <p>1_B A suspend mode is requested and bit field SUMCFG defines the CCU6 kernel mode.</p>

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
NOMCFG	[5:4]	rw	Normal Operation Mode Configuration This bit field defines the kernel mode applied in normal operation mode. 00 _B Run mode 0 is selected. 01 _B Run mode 1 is selected. 10 _B Stop mode 0 is selected. 11 _B Stop mode 1 is selected.
BPNO	7	w	Bit Protection for NOMCFG This bit enables the write access to the bit field NOMCFG. It always reads 0. 0 _B NOMCFG is not changed. 1 _B NOMCFG is updated with the written value.
SUMCFG	[9:8]	rw	Suspend Mode Configuration This bit field defines the kernel mode applied in suspend mode. Coding like NOMCFG.
BPSUM	11	w	Bit Protection for SUMCFG This bit enables the write access to the bit field SUMCFG. It always reads 0. 0 _B SUMCFG is not changed. 1 _B SUMCFG is updated with the written value.
COMCFG	[13:12]	rw	Clock Off Mode Configuration This bit field defines the kernel mode applied in clock-off mode. Coding like NOMCFG.
BPCOM	15	w	Bit Protection for COMCFG This bit enables the write access to the bit field COMCFG. It always reads 0. 0 _B COMCFG is not changed. 1 _B COMCFG is updated with the written value.
0	6, 10, 14, [31:16]	r	Reserved Returns 0 if read; should be written with 0.

Note: The bit protection bits BPxxx allow partly modification of the configuration bits with a single write operation (without the need of a read-modify-write mechanism handled by the CPU).

24.10.4.5 Module Configuration Register

The module configuration register contains bits describing the functionality that is available in the CCU6 module.

MCFG

Module Configuration Register (04_H) **Reset Value: 0000 0007_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
							0								
							r								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							0						MCM	T13	T12
r							r						r	r	r

Field	Bits	Type	Description
T12	0	r	T12 Available This bit indicates if the T12 block is available. 0 _B The T12 block is not available. A write access to T12PR is ignored. 1 _B The T12 block is available. A write access to T12PR is executed.
T13	1	r	T13 Available This bit indicates if the T13 block is available. 0 _B The T13 block is not available. A write access to T13PR is ignored. 1 _B The T13 block is available. A write access to T13PR is executed.
MCM	2	r	Multi-Channel Mode Available This bit indicates if the multi-channel mode functionality is available. 0 _B The multi-channel mode functionality is not available. A write access to MCMOUTS is ignored. 1 _B The multi-channel mode functionality is available. A write access to MCMOUTS is executed.
0	[31:3]	r	Reserved; read as 0; should be written with 0.

Capture/Compare Unit 6 (CCU6)

Note: The MCFG register can be modified only if the signal which comes from the watchdog timer mechanism allows.

Capture/Compare Unit 6 (CCU6)

24.10.4.6 Input Monitoring Register

The input monitoring register monitors the occurrence of a selected event for the input signals. If a hardware event triggers the setting of bit IMON.x and the same bit is written with 1 via software at the same time, then the corresponding bit is cleared (software overrules hardware). The lost bit event is indicated if an event is detected again at one or more input signals with its lost indicator enabled.

Note: The register is only applicable in capture modes if the edges are selected through T12MSEL.MSEL6x.

IMON

Input Monitoring Register

(98_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						T13 HRI	T12 HRI	CTR API	CC 62INI	CC 61INI	CC 60INI	CC POS 2I	CC POS 1I	CC POS 0I	LBE
r						rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
LBE	0	rwh	<p>Lost Bit Event</p> <p>This bit determines if a lost bit event has occurred. A lost bit event occurs when a selected event occurs again with the previous event captured (IMON.x remains set) and its lost indicator is enabled, for at least one of the monitored input signals. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect.</p> <p>0_B The lost bit event has not occurred. 1_B The lost bit event has occurred.</p>
CCPOSxI (x = 0 -2)	x + 1	rwh	<p>Event indication for input signal CCPOSx</p> <p>The bit determines if the selected event has occurred via an edge detection. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect.</p> <p>0_B A selected event has not occurred. 1_B Edge detection indicates a selected event has occurred.</p> <p><i>Note: The dedicated edge is indicated for a selected event if Hysteretic-like Control or Capture modes are initialised in T12MSEL.MSEL6x. If these modes are not selected, then all edges will be indicated as an event for the inputs.</i></p>
CC6xINI (x = 0 -2)	x + 4	rwh	<p>Event indication for input signal CC6xIN</p> <p>The bit determines if the selected event has occurred via an edge detection. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect.</p> <p>0_B A selected event has not occurred. 1_B Edge detection indicates a selected event has occurred.</p>
CTRAPI	7	rwh	<p>Event indication for input signal CTRAP</p> <p>The bit determines if the selected event has occurred via an edge detection. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect.</p> <p>0_B An event has not occurred. 1_B Edge detection indicates an event has occurred.</p>

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
T12HRI	8	rwh	Event indication for input signal T12HR The bit determines if the selected event has occurred via an edge detection. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect. 0 _B An event has not occurred. 1 _B Edge detection indicates an event has occurred.
T13HRI	9	rwh	Event indication for input signal T13HR The bit determines if the selected event has occurred via an edge detection. The bit can be cleared by writing a 1 to the same bit position, while writing a 0 has no effect. 0 _B An event has not occurred. 1 _B Edge detection indicates an event has occurred.
0	[31:10]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
CTRAPEN	7	rw	Lost Indicator Enable for input signal CTRAP This bit determines if the monitored event at the input signal is enabled for the detection of a lost bit event. 0 _B Input signal is disabled for a lost bit event detection. 1 _B Input signal is enabled for a lost bit event detection.
T12HREN	8	rw	Lost Indicator Enable for input signal T12HR This bit determines if the monitored event at the input signal is enabled for the detection of a lost bit event. 0 _B Input signal is disabled for a lost bit event detection. 1 _B Input signal is enabled for a lost bit event detection.
T13HREN	9	rw	Lost Indicator Enable for input signal T13HR This bit determines if the monitored event at the input signal is enabled for the detection of a lost bit event. 0 _B Input signal is disabled for a lost bit event detection. 1 _B Input signal is enabled for a lost bit event detection.
LBEN	13	rw	Interrupt Enable for Lost Bit Event This bit determines if a SRx line is activated if lost bit event is detected. 0 _B Lost bit event is disabled for the activation of a SRx line. 1 _B Lost bit event is enabled for the activation of a SRx line.
INPLBE	[15:14]	rw	Interrupt Node Pointer for lost bit event This bit field defines which service request output line is selected to output an lost event alert for an enabled lost bit event. 00 _B Service request output SR0 is selected. 01 _B Service request output SR1 is selected. 10 _B Service request output SR2 is selected. 11 _B Service request output SR3 is selected.
0	0, [12:10], [31:16]	r	Reserved; Returns 0 if read; should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.11 Implementation

This chapter describes the implementation of the CCU6 modules in the TC1728 device.

- Address map (see [Section 24.11.1](#))
- Module output select (see [Section 24.11.2](#))
- Synchronous start (see [Section 24.11.3](#))
- Digital Connections (see [Section 24.12](#))

24.11.1 Address Map

There are two CCU6 kernels in the TC1728, namely CCU60 to CCU61. The CCU6061 module consists of CCU60 and CCU61 kernels .

Table 24-14 Registers Address Space

Module	Base Address	End Address	Note
CCU60	F000 3000 _H	F000 30FF _H	CCU6061 : consists of CCU60 and CCU61 kernels
CCU61	F000 3100 _H	F000 31FF _H	CCU6061 : consists of CCU60 and CCU61 kernels

Table 24-15 Registers Overview - CCU6 Module Registers

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Reset Value	Page
			Read	Write		
CCU6061 Module Registers (only available in the address range of CCU60)						
CCU60_MO SEL	CCU60 Module Output Select Register	0C _H	U, SV	U, SV	0000 0000 _H	24-136

24.11.1.1 Module Registers

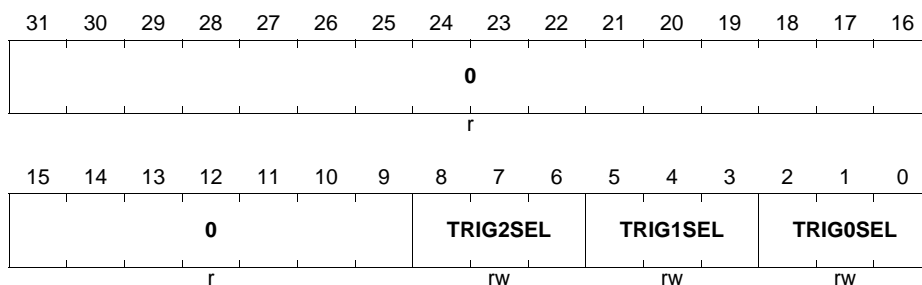
Module Output Select Register

MOSEL contains bit fields to select the output signal from the CCU6061 for the trigger signals to the ADCx modules.

CCU60_MOSEL

CCU60 Module Output Select Register(0C_H)

Reset Value: 0000 0000_H



Capture/Compare Unit 6 (CCU6)

Field	Bits	Type	Description
TRIG0SEL	[2:0]	rw	Output Trigger Select for CCU6061 TRIG0 This bit field defines the output signal from the module pair used as the trigger signal to ADCx inputs. 000 _B The signal CCU60_COUT63 is selected. 001 _B The signal CCU61_COUT63 is selected. 010 _B The signal CCU60_CC60 is selected. 011 _B The signal CCU61_CC60 is selected. 100 _B The signal CCU60_SR1 is selected. 101 _B The signal CCU61_SR1 is selected. 110 _B The signal CCU60_SR3 is selected. 111 _B The signal CCU61_SR3 is selected.
TRIG1SEL	[5:3]	rw	Output Trigger Select for CCU6061 TRIG1 This bit field defines the output signal from the module pair used as the trigger signal to ADCx inputs. 000 _B The signal CCU60_COUT63 is selected. 001 _B The signal CCU61_COUT63 is selected. 010 _B The signal CCU60_CC61 is selected. 011 _B The signal CCU61_CC61 is selected. 100 _B The signal CCU60_SR1 is selected. 101 _B The signal CCU61_SR1 is selected. 110 _B The signal CCU60_SR3 is selected. 111 _B The signal CCU61_SR3 is selected.
TRIG2SEL	[8:6]	rw	Output Trigger Select for CCU6061 TRIG2 This bit field defines the output signal from the module pair used as the trigger signal to ADCx inputs. 000 _B The signal CCU60_COUT63 is selected. 001 _B The signal CCU61_COUT63 is selected. 010 _B The signal CCU60_CC62 is selected. 011 _B The signal CCU61_CC62 is selected. 100 _B The signal CCU60_SR1 is selected. 101 _B The signal CCU61_SR1 is selected. 110 _B The signal CCU60_SR3 is selected. 111 _B The signal CCU61_SR3 is selected.
0	[31:9]	r	Reserved Returns 0 if read, should be written with 0.

Capture/Compare Unit 6 (CCU6)

24.11.2 Module Output Select

For CCU6061 module, there are 3 trigger signals which are selectable from the output signals from CCU60 and CCU61 kernels.

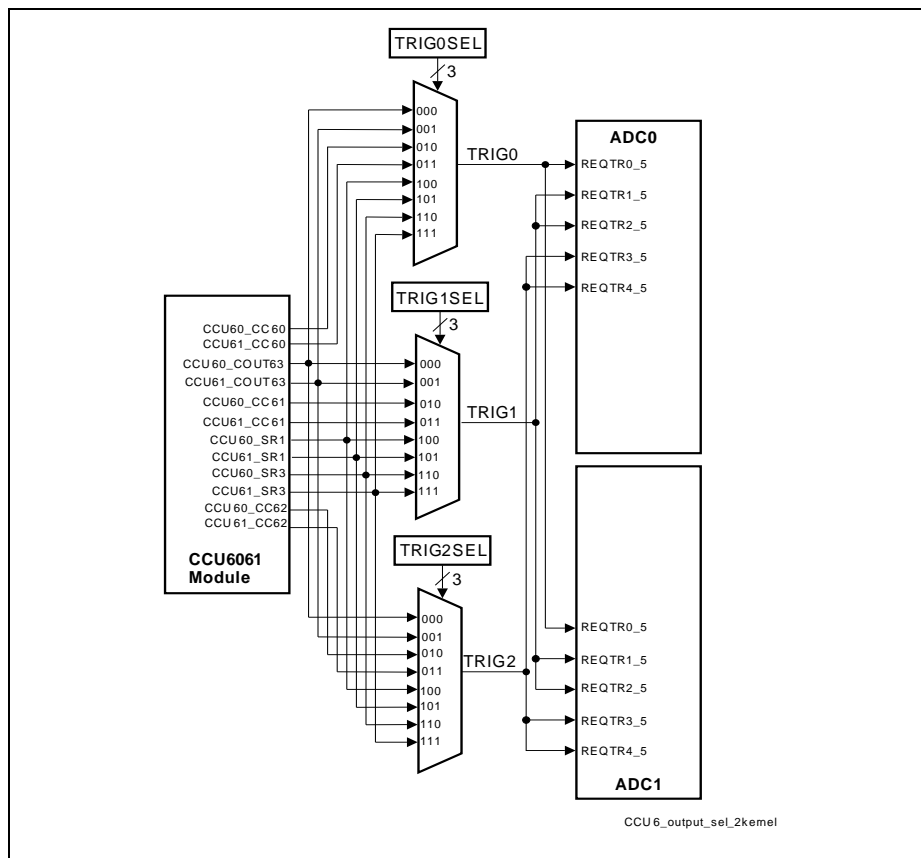


Figure 24-45 Output select trigger

24.11.3 Synchronous Start

Synchronous start of the capture/compare timers are supported by control bits SYSCON.CCTRIG0 in the SCU module. Bit SYSCON.CCTRIG0 is connected to the T12HR and T13HR for CCU60 and CCU61 kernels.

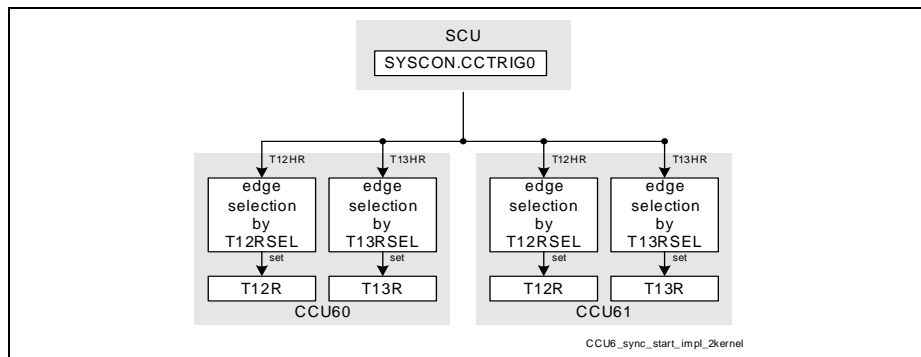


Figure 24-46 Synchronization Concept in TC1728

Capture/Compare Unit 6 (CCU6)

24.12 Digital Connections

The following tables show the digital connections of the CCU6x modules with other modules or pins in the TC1728 device.

Each input signal can be selected among 4 or 8 possible input lines, e.g. the input vector for input signal CC60IN is composed of CC60IN[D:A], whereas the input vectors for T12HR and T13HR are composed of T12HR[H:A] and T13HR[H:A]. The following sections refer to the interface signals.

Note: All functional inputs of the CCU6 are synchronized to f_{CC6} before they can affect the module internal logic. The resulting delay of $2/f_{CC6}$ and an uncertainty of $1/f_{CC6}$ have to be taken into account for precise timing calculation.

An edge of an input signal can only be correctly detected if both, the high phase and the low phase of the input signal are each longer than $1/f_{CC6}$.

24.12.1 Connections of CCU60

This table describes the module interconnections of CCU60.

Table 24-16 CCU60 Digital Connections in TC1728

Signal	from/to Module	I/O to CCU60	Can be used to/as
CC60INA	P0.0	I	input signals for capture event on channel CC60
CC60INB	P2.5	I	
CC60INC	P8.5	I	
CC60IND	CCU61_LBE	I	
CC61INA	P5.8	I	input signals for capture event on channel CC61
CC61INB	P2.2	I	
CC61INC	P8.3	I	
CC61IND	CAN_SR14	I	

Capture/Compare Unit 6 (CCU6)

Table 24-16 CCU60 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CCU60	Can be used to/as
CC62INA	P5.0	I	input signals for capture event on channel CC62
CC62INB	P2.0	I	
CC62INC	P8.7	I	
CC62IND	GPT120_T6OFL	I	
CTRAPA	P2.13	I	input signals for CTRAP
CTRAPB	P0.12	I	
CTRAPC	CCU60_CTRAPA AND CCU60_CTRAPB	I	
CTRAPD	SCU_ERU_PDOUT 0	I	
CCPOS0A	P5.12	I	input signals for CCPOS0
CCPOS0B	CCU61_SR2	I	
CCPOS0C	P8.0	I	
CCPOS0D	0	I	
			edge detection off
CCPOS1A	P5.13	I	input signals for CCPOS1
CCPOS1B	ADC_SR2	I	
CCPOS1C	P8.1	I	
CCPOS1D	0	I	
			edge detection off

Capture/Compare Unit 6 (CCU6)
Table 24-16 CCU60 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CCU60	Can be used to/as
CCPOS2A	P5.14	I	input signals for CCPOS2
CCPOS2B	0	I	
CCPOS2C	P8.2	I	
CCPOS2D	0	I	
			edge detection off
T12HRA	CCTRIG0	I	input signals for T12HR
T12HRB	P2.1	I	
T12HRC	P2.3	I	
T12HRD	GPTA_TRIG00	I	
T12HRE	P4.3	I	
T12HRF	GPT120_T6OFL	I	
T12HRG	CCU61_SR2	I	
T12HRH	0	I	
T13HRA	CCTRIG0	I	input signals for T13HR
T13HRB	P4.2	I	
T13HRC	P2.3	I	
T13HRD	GPTA_TRIG00	I	
T13HRE	P1.1	I	
T13HRF	GPT120_T6OFL	I	
T13HRG	CCU61_SR2	I	
T13HRH	CCU60_SR1	I	

Capture/Compare Unit 6 (CCU6)

Table 24-16 CCU60 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CCU60	Can be used to/as
CC60	P0.0	O	compare outputs of channel CC60
	P9.7	O	
COUT60	P0.1	O	
	P9.8	O	
CC61	P0.14	O	compare outputs of channel CC61
	P5.8	O	
COUT61	P0.15	O	
	P5.10	O	
CC62	P5.0	O	compare outputs of channel CC62
	P9.4	O	
COUT62	P5.2	O	
	P9.3	O	
COUT63	P5.11	O	compare output of channel CC63
	P9.2	O	
LBE	CCU61_CC60IND	O	lost bit event output
T12_ZM	–	O	T12 zero match
T13_PM	–	O	T13 period match
MCM_ST	–	O	MCM shadow transfer
SR0	DMA CHm1_REQ13, m = 0, 1	O	DMA triggers
SR1	CCU60_T13HRH, ERU_OGU01	O	T13 count trigger, Output Gating Unit trigger
	ADC0_REQTRx_5, ADC1_REQTRx_5, x=0,1,2,3,4		ADC0 and ADC1 trigger capability, pls see CCU60_MOSEL for the respective trigger select to the request trigger/gating inputs of the ADC0/1.

Capture/Compare Unit 6 (CCU6)

Table 24-16 CCU60 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CCU60	Can be used to/as
SR2	CCU61_CCPOS0B, CCU61_T12HRG, CCU61_T13HRG	O	CCU61 triggers
SR3	ADC0_REQTRx_5, ADC1_REQTRx_5, x=0,1,2,3,4	O	ADC0 and ADC1 trigger capability, pls see CCU60_MOSEL for the respective trigger select to the request trigger/gating inputs of the ADC0/1.

Capture/Compare Unit 6 (CCU6)

24.12.2 Connections of CCU61

This table describes the module interconnections of CCU61.

Table 24-17 CCU61 Digital Connections in TC1728

Signal	from/to Module	I/O to CC61	Can be used to/as
CC60INA	P2.5	I	input signals for capture event on channel CC60
CC60INB	P0.0	I	
CC60INC	P9.7	I	
CC60IND	CCU60_LBE	I	
CC61INA	P2.2	I	input signals for capture event on channel CC61
CC61INB	P5.8	I	
CC61INC	P0.14	I	
CC61IND	0	I	
CC62INA	P2.0	I	input signals for capture event on channel CC62
CC62INB	P5.0	I	
CC62INC	P9.4	I	
CC62IND	GPT121_T6OFL	I	

Capture/Compare Unit 6 (CCU6)

Table 24-17 CCU61 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CC61	Can be used to/as
CTRAPA	P4.3	I	input signals for CTRAP
CTRAPB	P1.1	I	
CTRAPC	CCU61_CTRAPA AND CCU61_CTRAPB	I	
CTRAPD	SCU_ERU_PDOUT 1	I	
CCPOS0A	P2.1	I	input signals for CCPOS0
CCPOS0B	CCU60_SR2	I	
CCPOS0C	P1.11	I	
CCPOS0D	0	I	
			edge detection off
CCPOS1A	P4.2	I	input signals for CCPOS1
CCPOS1B	ADC_SR2	I	
CCPOS1C	P1.9	I	
CCPOS1D	0	I	
			edge detection off
CCPOS2A	P2.3	I	input signals for CCPOS2
CCPOS2B	0	I	
CCPOS2C	P1.8	I	
CCPOS2D	0	I	
			edge detection off

Capture/Compare Unit 6 (CCU6)

Table 24-17 CCU61 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CC61	Can be used to/as
T12HRA	CCTRIG0	I	input signals for T12HR
T12HRB	P5.12	I	
T12HRC	P5.14	I	
T12HRD	GPTA_TRIG00	I	
T12HRE	P2.13	I	
T12HRF	GPT121_T6OFL	I	
T12HRG	CCU60_SR2	I	
T12HRH	0	I	
T13HRA	CCTRIG0	I	input signals for T13HR
T13HRB	P5.13	I	
T13HRC	P5.14	I	
T13HRD	GPTA_TRIG00	I	
T13HRE	P0.12	I	
T13HRF	GPT121_T6OFL	I	
T13HRG	CCU60_SR2	I	
T13HRH	CCU61_SR1	I	
CC60	P2.5	O	compare outputs of channel CC60
	P8.5	O	
COUT60	P2.7	O	
	P8.13	O	

Capture/Compare Unit 6 (CCU6)

Table 24-17 CCU61 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CC61	Can be used to/as
CC61	P2.2	O	compare outputs of channel CC61
	P8.3		
COUT61	P1.4	O	
	P8.6		
CC62	P2.0	O	compare outputs of channel CC62
	P8.7		
COUT62	P2.6	O	
	P8.4	O	
COUT63	P1.3	O	compare output of channel CC63
	P2.4	O	
LBE	CCU60_CC60IND	O	lost bit event output
T12_ZM	–	O	T12 zero match
T13_PM	–	O	T13 period match
MCM_ST	–	O	MCM shadow transfer
SR0	DMA CHm5_REQ13, m = 0, 1	O	DMA triggers
SR1	CCU61_T13HRH, ERU_OGU11	O	T13 count trigger, Output Gating Unit trigger
	ADC0_REQTRx_5, ADC1_REQTRx_5,x =0,1,2,3,4		ADC0 and ADC1 trigger capability, pls see CCU60 MOSEL for the respective trigger select to the request trigger/gating inputs of the ADC0/1.

Capture/Compare Unit 6 (CCU6)

Table 24-17 CCU61 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to CC61	Can be used to/as
SR2	CCU60_CCPOS0B, CCU60_T12HRG, CCU60_T13HRG	O	CCU60 triggers
SR3	ADC0_REQTRx_5, ADC1_REQTRx_5, x=0,1,2,3,4	O	ADC0 and ADC1 trigger capability, pls see CCU60_MOSEL for the respective trigger select to the request trigger/gating inputs of the ADC0/1.

25 General Purpose Timer Units (GPT12)

The General Purpose Timer Unit blocks GPT1 and GPT2 have very flexible multifunctional timer structures which may be used for timing, event counting, pulse width measurement, pulse generation, frequency multiplication, and other purposes.

They incorporate five 16-bit timers that are grouped into the two timer blocks GPT1 and GPT2. Each timer in each block may operate independently in a number of different modes such as Gated Timer or Counter Mode, or may be concatenated with another timer of the same block. Each block has alternate input/output functions and specific interrupts associated with it.

Note: Input signals can be selected from several sources by register PISEL.

Block GPT1 contains three timers/counters: The core timer T3 and the two auxiliary timers T2 and T4. The maximum resolution is $f_{\text{GPT}}/4$. The auxiliary timers of GPT1 may optionally be configured as reload or capture registers for the core timer. These registers are listed in [Section 25.1.6](#).

The following list summarizes the supported features:

- $f_{\text{GPT}}/4$ maximum resolution
- 3 independent timers/counters
- Timers/counters can be concatenated
- 4 operating modes:
 - Timer Mode
 - Gated Timer Mode
 - Counter Mode
 - Incremental Interface Mode
- Reload and Capture functionality
- Separate interrupts

Block GPT2 contains two timers/counters: The core timer T6 and the auxiliary timer T5. The maximum resolution is $f_{\text{GPT}}/2$. An additional Capture/Reload register (CAPREL) supports capture and reload operation with extended functionality. These registers are listed in [Section 25.2.7](#).

The following list summarizes the supported features:

- $f_{\text{GPT}}/2$ maximum resolution
- 2 independent timers/counters
- Timers/counters can be concatenated
- 3 operating modes:
 - Timer Mode
 - Gated Timer Mode
 - Counter Mode
- Extended capture/reload functions via 16-bit capture/reload register CAPREL
- Separate interrupts

General Purpose Timer Units (GPT12)

25.1 Timer Block GPT1

All three timers of block GPT1 (T2, T3, T4) can run in one of 4 basic modes: Timer Mode, Gated Timer Mode, Counter Mode, or Incremental Interface Mode. All timers can count up or down. Each timer of GPT1 is controlled by a separate control register TxCON.

Each timer has an input pin TxIN (alternate pin function) associated with it, which serves as the gate control in Gated Timer Mode, or as the count input in Counter Mode. The count direction (up/down) may be programmed via software or may be dynamically altered by a signal at the External Up/Down control input TxEUD (alternate pin function). An overflow/underflow of core timer T3 is indicated by the Output Toggle Latch T3OTL, whose state may be output on the associated pin T3OUT (alternate pin function). The auxiliary timers T2 and T4 may additionally be concatenated with the core timer T3 (through T3OTL) or may be used as capture or reload registers for the core timer T3.

The current contents of each timer can be read or modified by the CPU by accessing the corresponding timer count registers T2, T3, or T4. When any of the timer registers is written to by the CPU in the state immediately preceding a timer increment, decrement, reload, or capture operation, the CPU write operation has priority in order to guarantee correct results.

The interrupts of GPT1 are controlled through the Service Request Control Registers SRC0, SRC1, and SRC2.

Note: The timing requirements for external input signals can be found in [Section 25.1.5](#), [Section 25.5](#) summarizes the module interface signals, including pins.

General Purpose Timer Units (GPT12)

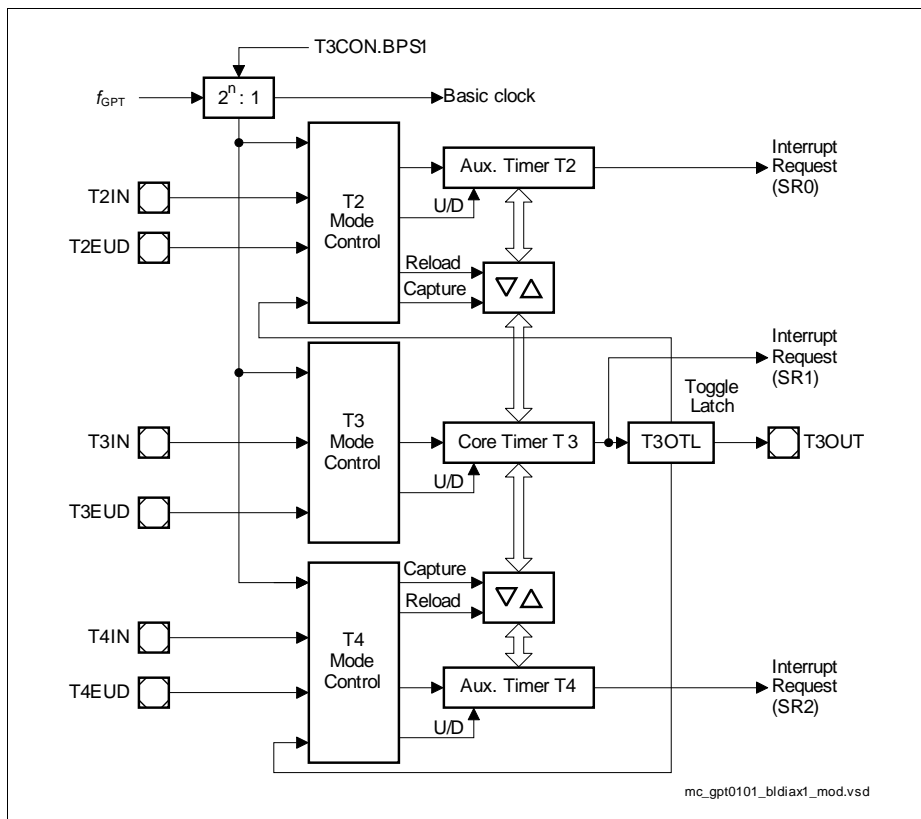


Figure 25-1 GPT1 Block Diagram

General Purpose Timer Units (GPT12)

25.1.1 GPT1 Core Timer T3 Control

The current contents of the core timer T3 are reflected by its count register T3. This register can also be written to by the CPU, for example, to set the initial start value.

The core timer T3 is configured and controlled via its control register T3CON.

T3CON

Timer T3 Control Register

(14_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T3 R DIR	T3 CH DIR	T3E DGE	BPS1		T3 OTL	T3 OE	T3 UDE	T3 UD	T3 R	T3M			T3I		
rh	rwh	rwh	rw		rwh	rw	rw	rw	rw	rw			rw		

Field	Bits	Type	Description
T3I	[2:0]	rw	Timer T3 Input Parameter Selection Depends on the operating mode, see respective sections for encoding: Table 25-8 for Timer Mode and Gated Timer Mode Table 25-2 for Counter Mode Table 25-3 for Incremental Interface Mode
T3M	[5:3]	rw	Timer T3 Mode Control 000 _B Timer Mode 001 _B Counter Mode 010 _B Gated Timer Mode with gate active low 011 _B Gated Timer Mode with gate active high 100 _B Reserved. Do not use this combination 101 _B Reserved. Do not use this combination 110 _B Incremental Interface Mode (Rotation Detection Mode) 111 _B Incremental Interface Mode (Edge Detection Mode)
T3R	6	rw	Timer T3 Run Bit 0 _B Timer T3 stops 1 _B Timer T3 runs

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
T3UD	7	rw	Timer T3 Up/Down Control¹⁾ 0_B Timer T3 counts up 1_B Timer T3 counts down <i>Note: This bit only controls count direction of T3 if bit T3UDE = 0.</i>
T3UDE	8	rw	Timer T3 External Up/Down Enable¹⁾ 0_B Count direction is controlled by bit T3UD; input T3EUD is disconnected 1_B Count direction is controlled by input T3EUD
T3OE	9	rw	Overflow/Underflow Output Enable 0_B Alternate Output Function Disabled 1_B State of T3 toggle latch is output on pin T3OUT
T3OTL	10	rwh	Timer T3 Overflow Toggle Latch Toggles on each overflow/underflow of T3. Can be set or cleared by software (see separate description)
BPS1	[12:11]	rw	GPT1 Block Prescaler Control Selects the basic clock for block GPT1 (see also Section 25.1.5) 00_B $f_{GPT}/8$ 01_B $f_{GPT}/4$ 10_B $f_{GPT}/32$ 11_B $f_{GPT}/16$
T3EDGE	13	rwh	Timer T3 Edge Detection Flag The bit is set each time a count edge is detected. T3EDGE must be cleared by software. 0_B No count edge was detected 1_B A count edge was detected
T3CHDIR	14	rwh	Timer T3 Count Direction Change Flag This bit is set each time the count direction of timer T3 changes. T3CHDIR must be cleared by software. 0_B No change of count direction was detected 1_B A change of count direction was detected
T3RDIR	15	rh	Timer T3 Rotation Direction Flag 0_B Timer T3 counts up 1_B Timer T3 counts down
0	[31:16]	r	Reserved Read as 0; should be written with 0.

1) See [Table 25-1](#) for encoding of bits T3UD and T3UDE.

General Purpose Timer Units (GPT12)

Timer T3 Run Control

The core timer T3 can be started or stopped by software through bit T3R (Timer T3 Run Bit). This bit is relevant in all operating modes of T3. Setting bit T3R will start the timer, clearing bit T3R stops the timer.

In Gated Timer Mode, the timer will only run if T3R = 1 and the gate is active (high or low, as programmed).

Note: When bit T2RC or T4RC in timer control register T2CON or T4CON is set, bit T3R will also control (start and stop) the auxiliary timer(s) T2 and/or T4.

Count Direction Control

The count direction of the GPT1 timers (core timer and auxiliary timers) can be controlled either by software or by the external input pin TxEUD (Timer Tx External Up/Down Control Input). These options are selected by bits TxUD and TxUDE in the respective control register TxCON. When the up/down control is provided by software (bit TxUDE = 0), the count direction can be altered by setting or clearing bit TxUD. When bit TxUDE = 1, pin TxEUD is selected to be the controlling source of the count direction. However, bit TxUD can still be used to reverse the actual count direction, as shown in [Table 25-1](#). The count direction can be changed regardless of whether or not the timer is running.

Note: When pin TxEUD is used as external count direction control input, it must be configured as input.

Table 25-1 GPT1 Timer Count Direction Control

Pin TxEUD	Bit TxUDE	Bit TxUD	Count Direction	Bit TxRDIR
X	0	0	Count Up	0
X	0	1	Count Down	1
0	1	0	Count Up	0
1	1	0	Count Down	1
0	1	1	Count Down	1
1	1	1	Count Up	0

General Purpose Timer Units (GPT12)

Timer T3 Output Toggle Latch

The overflow/underflow signal of timer T3 is connected to a block named 'Toggle Latch', shown in the timer mode diagrams. **Figure 25-2** illustrates the details of this block. An overflow or underflow of T3 will clock two latches: The first latch represents bit T3OTL in control register T3CON. The second latch is an internal latch toggled by T3OTL's output. Both latch outputs are connected to the input control blocks of the auxiliary timers T2 and T4. The output level of the shadow latch will match the output level of T3OTL, but is delayed by one clock cycle. When the T3OTL value changes, this will result in a temporarily different output level from T3OTL and the shadow latch, which can trigger the selected count event in T2 and/or T4.

When software writes to T3OTL, both latches are set or cleared simultaneously. In this case, both signals to the auxiliary timers carry the same level and no edge will be detected. Bit T3OE (overflow/underflow output enable) in register T3CON enables the state of T3OTL to be monitored via an external pin T3OUT. When T3OTL is linked to an external port pin (must be configured as output), T3OUT can be used to control external HW. If T3OE = 1, pin T3OUT outputs the state of T3OTL. If T3OE = 0, pin T3OUT outputs a high level (as long as the T3OUT alternate function is selected for the port pin).

The trigger signals can serve as an input for the counter function or as a trigger source for the reload function of the auxiliary timers T2 and T4.

As can be seen from **Figure 25-2**, when latch T3OTL is modified by software to determine the state of the output line, also the internal shadow latch is set or cleared accordingly. Therefore, no trigger condition is detected by T2/T4 in this case.

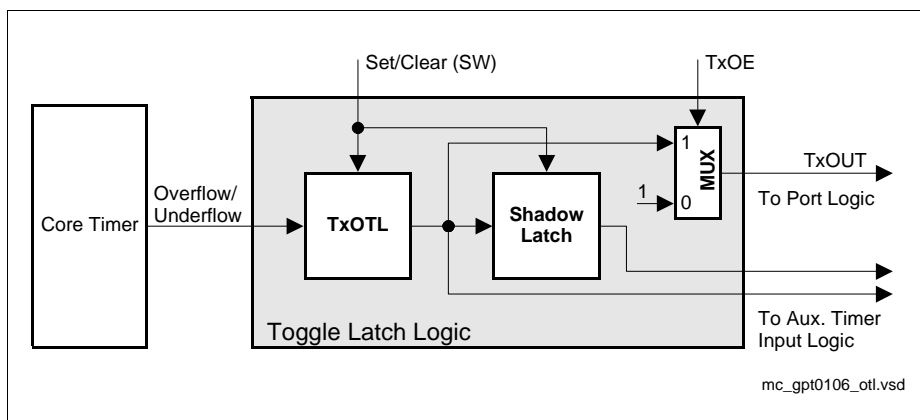


Figure 25-2 Block Diagram of the Toggle Latch Logic of Core Timer T3 (x = 3)

General Purpose Timer Units (GPT12)

25.1.2 GPT1 Core Timer T3 Operating Modes

Timer T3 can operate in one of several modes.

Timer T3 in Timer Mode

Timer Mode for the core timer T3 is selected by setting bitfield T3M in register T3CON to 000_B. In Timer Mode, T3 is clocked with the module's input clock f_{GPT} divided by two programmable prescalers controlled by bitfields BPS1 and T3I in register T3CON. Please see [Section 25.1.5](#) for details on the input clock options.

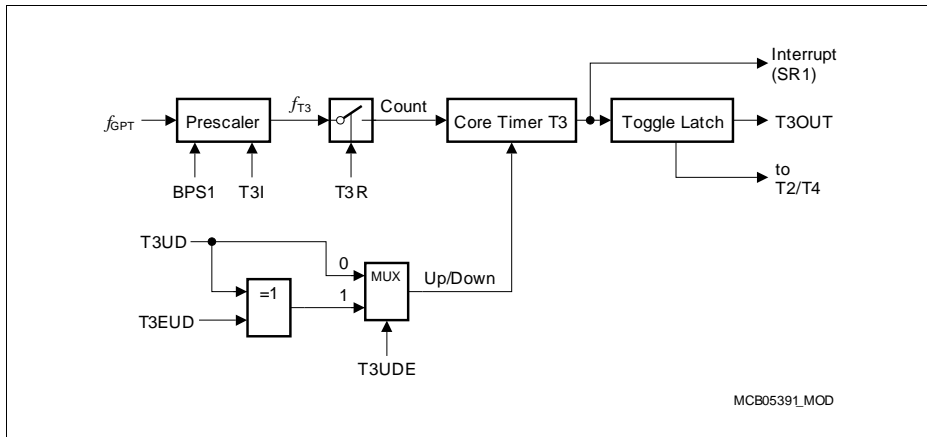


Figure 25-3 Block Diagram of Core Timer T3 in Timer Mode

General Purpose Timer Units (GPT12)

Timer T3 in Gated Timer Mode

Gated Timer Mode for the core timer T3 is selected by setting bitfield T3M in register T3CON to 010_B or 011_B. Bit T3M.0 (T3CON.3) selects the active level of the gate input. The same options for the input frequency are available in Gated Timer Mode as in Timer Mode (see [Section 25.1.5](#)). However, the input clock to the timer in this mode is gated by the external input pin T3IN (Timer T3 External Input).

To enable this operation, the associated pin T3IN must be configured as input.

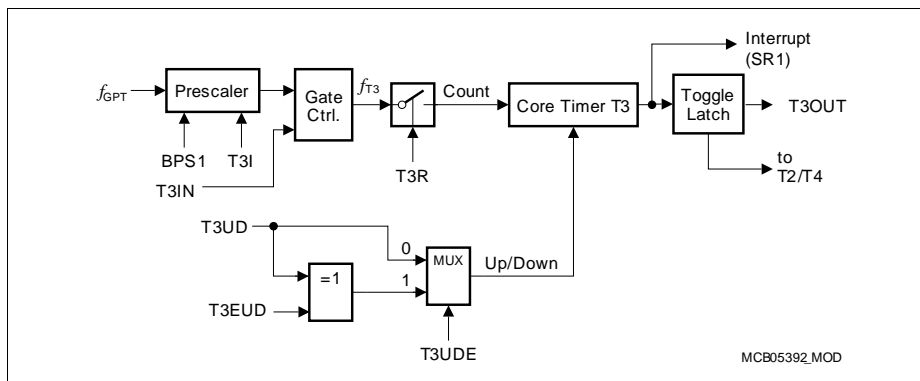


Figure 25-4 Block Diagram of Core Timer T3 in Gated Timer Mode

If T3M = 010_B, the timer is enabled when T3IN shows a low level. A high level at this line stops the timer. If T3M = 011_B, line T3IN must have a high level in order to enable the timer. Additionally, the timer can be turned on or off by software using bit T3R. The timer will only run if T3R is 1 and the gate is active. It will stop if either T3R is 0 or the gate is inactive.

Note: A transition of the gate signal at pin T3IN does not cause a service request via SRC1.

General Purpose Timer Units (GPT12)

Timer T3 in Counter Mode

Counter Mode for the core timer T3 is selected by setting bitfield T3M in register T3CON to 001_B . In Counter Mode, timer T3 is clocked by a transition at the external input pin T3IN. The event causing an increment or decrement of the timer can be a positive, a negative, or both a positive and a negative transition at this line. Bitfield T3I in control register T3CON selects the triggering transition (see [Table 25-2](#)).

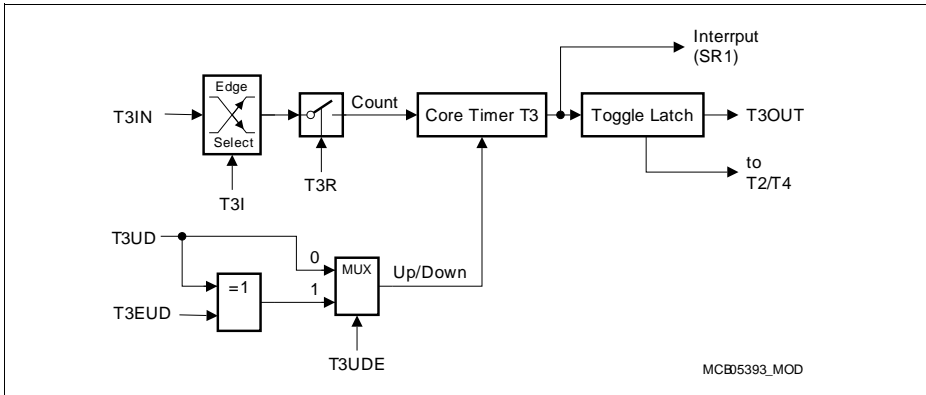


Figure 25-5 Block Diagram of Core Timer T3 in Counter Mode

Table 25-2 GPT1 Core Timer T3 (Counter Mode) Input Edge Selection

T3I	Triggering Edge for Counter Increment/Decrement
000_B	None. Counter T3 is disabled
001_B	Positive transition (rising edge) on T3IN
010_B	Negative transition (falling edge) on T3IN
011_B	Any transition (rising or falling edge) on T3IN
$1XX_B$	Reserved. Do not use this combination

For Counter Mode operation, pin T3IN must be configured as input. The maximum input frequency allowed in Counter Mode depends on the selected prescaler value. To ensure that a transition of the count input signal applied to T3IN is recognized correctly, its level must be held high or low for a minimum number of module clock cycles before it changes. This information can be found in [Section 25.1.5](#).

General Purpose Timer Units (GPT12)

Timer T3 in Incremental Interface Mode

Incremental Interface Mode for the core timer T3 is selected by setting bitfield T3M in register T3CON to 110_B or 111_B. In Incremental Interface Mode, the two inputs associated with core timer T3 (T3IN, T3EUD) are used to interface to an incremental encoder. T3 is clocked by each transition on one or both of the external input pins to provide 2-fold or 4-fold resolution of the encoder input.

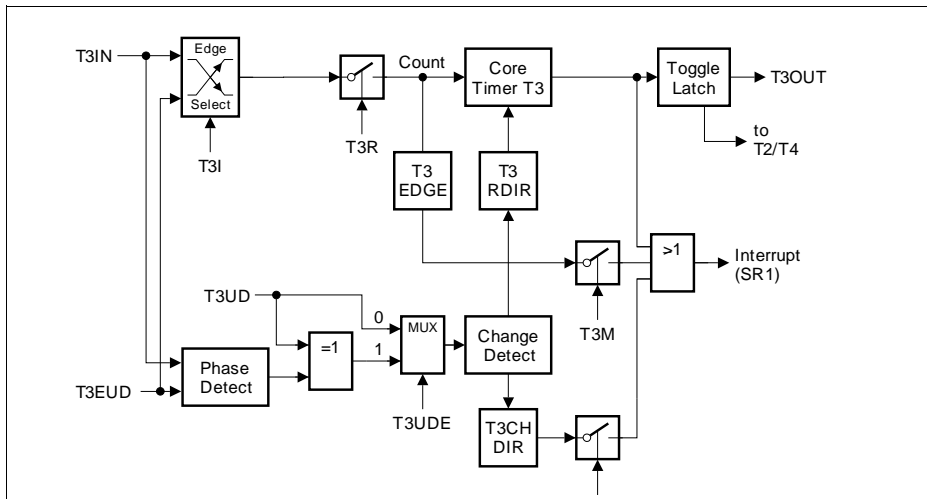


Figure 25-6 Block Diagram of Core Timer T3 in Incremental Interface Mode

Bitfield T3I in control register T3CON selects the triggering transitions (see [Table 25-3](#)). The sequence of the transitions of the two input signals is evaluated and generates count pulses as well as the direction signal. So T3 is modified automatically according to the speed and the direction of the incremental encoder and, therefore, its contents always represent the encoder's current position.

The service request generation can be selected: In Rotation Detection Mode (T3M = 110_B), a service request is generated each time the count direction of T3 changes. In Edge Detection Mode (T3M = 111_B), a service request is generated each time a count edge for T3 is detected. Count direction, changes in the count direction, and count requests are monitored by status bits T3RDIR, T3CHDIR, and T3EDGE in register T3CON.

General Purpose Timer Units (GPT12)

Table 25-3 Core Timer T3 (Incremental Interface Mode) Input Edge Selection

T3I	Triggering Edge for Counter Increment/Decrement
000 _B	None. Counter T3 stops.
001 _B	Any transition (rising or falling edge) on T3IN.
010 _B	Any transition (rising or falling edge) on T3EUD.
011 _B	Any transition (rising or falling edge) on any T3 input (T3IN or T3EUD).
1XX _B	Reserved. Do not use this combination.

The incremental encoder can be connected directly to the TC1728 without external interface logic. In a standard system, however, comparators will be employed to convert the encoder's differential outputs (such as A, \bar{A}) to digital signals (such as A). This greatly increases noise immunity.

Note: The third encoder output T0, that indicates the mechanical zero position, may be connected to an external interrupt input and trigger a reset of timer T3.

If input T4IN is available, T0 can be connected there and clear T3 automatically without requiring an interrupt.

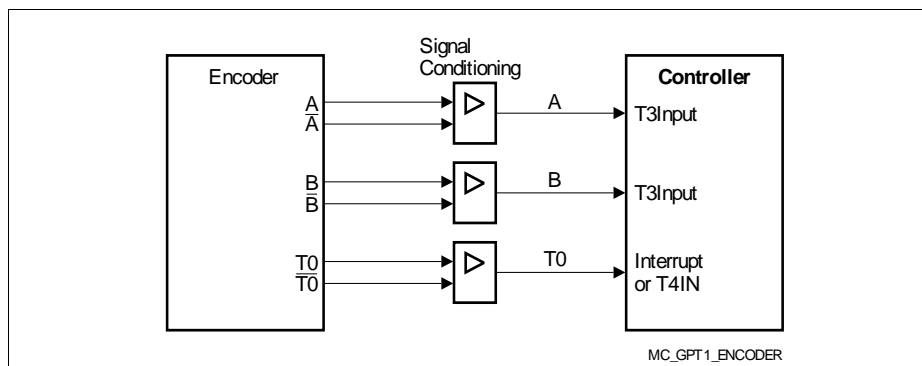


Figure 25-7 Connection of the Encoder to the TC1728

For Incremental Interface Mode operation, the following conditions must be met:

- Bitfield T3M must be 110_B or 111_B.
- Both pins T3IN and T3EUD must be configured as input.
- Pin T4IN must be configured as input, if used for T0.
- Bit T3UDE must be 1 to enable automatic external direction control.

The maximum count frequency allowed in Incremental Interface Mode depends on the selected prescaler value. To ensure that a transition of any input signal is recognized

General Purpose Timer Units (GPT12)

correctly, its level must be held high or low for a minimum number of module clock cycles before it changes. This information can be found in [Section 25.1.5](#).

As in Incremental Interface Mode two input signals with a 90° phase shift are evaluated, their maximum input frequency can be half the maximum count frequency.

In Incremental Interface Mode, the count direction is automatically derived from the sequence in which the input signals change, which corresponds to the rotation direction of the connected sensor. [Table 25-4](#) summarizes the possible combinations.

Table 25-4 GPT1 Core Timer T3 (Incremental Interface Mode) Count Direction

Level on Respective other Input	T3IN Input		T3EUD Input	
	Rising ↑	Falling ↓	Rising ↑	Falling ↓
High	Down	Up	Up	Down
Low	Up	Down	Down	Up

[Figure 25-8](#) and [Figure 25-9](#) give examples of T3's operation, visualizing count signal generation and direction control. They also show how input jitter is compensated, which might occur if the sensor rests near to one of its switching points.

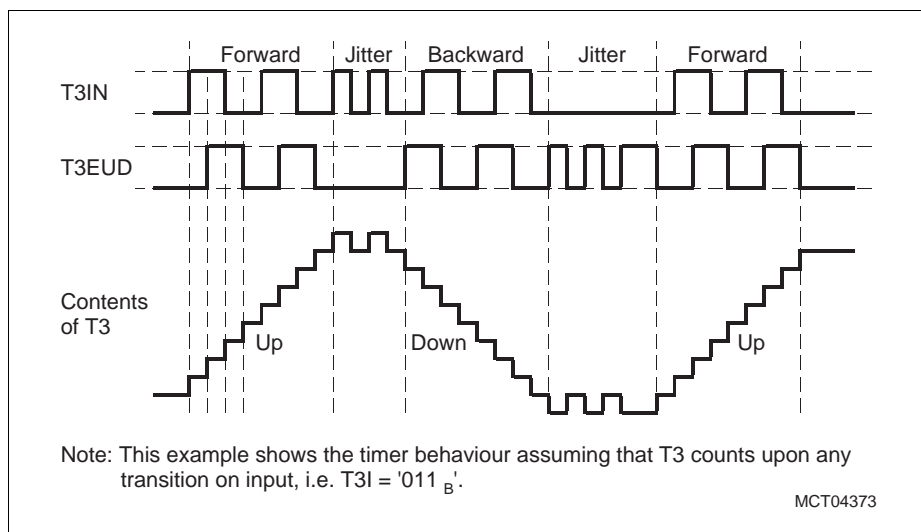


Figure 25-8 Evaluation of Incremental Encoder Signals, 2 Count Inputs

General Purpose Timer Units (GPT12)

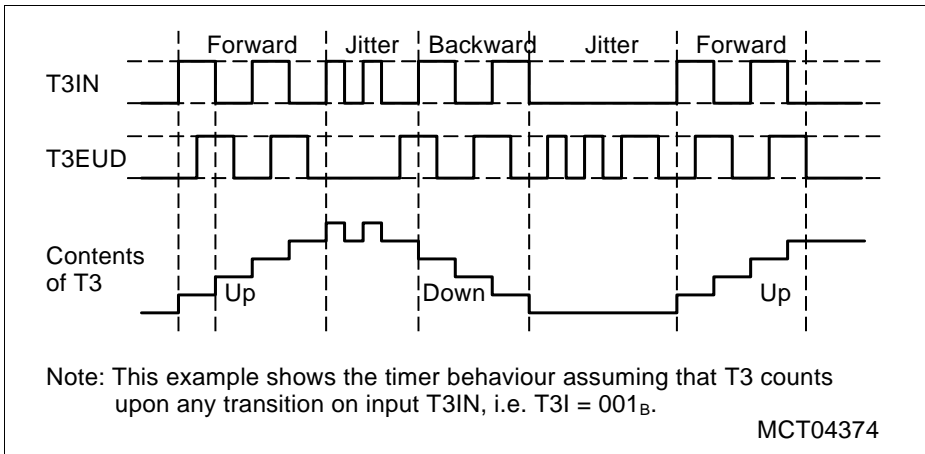


Figure 25-9 Evaluation of Incremental Encoder Signals, 1 Count Input

Note: Timer T3 operating in Incremental Interface Mode automatically provides information on the sensor's current position. Dynamic information (speed, acceleration, deceleration) may be obtained by measuring the incoming signal periods (see [“Combined Capture Modes” on Page 25-60](#)).

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
T2M	[5:3]	rw	Timer T2 Mode Control (Basic Operating Mode) 000 _B Timer Mode 001 _B Counter Mode 010 _B Gated Timer Mode with gate active low 011 _B Gated Timer Mode with gate active high 100 _B Reload Mode 101 _B Capture Mode 110 _B Incremental Interface Mode (Rotation Detection Mode) 111 _B Incremental Interface Mode (Edge Detection Mode)
T2R	6	rw	Timer T2 Run Bit 0 _B Timer T2 stops 1 _B Timer T2 runs <i>Note: This bit only controls timer T2 if bit T2RC = 0.</i>
T2UD	7	rw	Timer T2 Up/Down Control¹⁾ 0 _B Timer T2 counts up 1 _B Timer T2 counts down <i>Note: This bit only controls count direction of T2 if bit T2UDE = 0.</i>
T2UDE	8	rw	Timer T2 External Up/Down Enable¹⁾ 0 _B Count direction is controlled by bit T2UD; input T2EUD is disconnected 1 _B Count direction is controlled by input T2EUD
T2RC	9	rw	Timer T2 Remote Control 0 _B Timer T2 is controlled by its own run bit T2R 1 _B Timer T2 is controlled by the run bit T3R of core timer T3, not by bit T2R
T2IRDIS	12	rw	Timer T2 Interrupt Disable 0 _B Interrupt generation for T2CHDIR and T2EDGE interrupts in Incremental Interface Mode is enabled 1 _B Interrupt generation for T2CHDIR and T2EDGE interrupts in Incremental Interface Mode is disabled

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
T2EDGE	13	rwh	Timer T2 Edge Detection The bit is set each time a count edge is detected. T2EDGE must be cleared by software. 0 _B No count edge was detected 1 _B A count edge was detected
T2CHDIR	14	rwh	Timer T2 Count Direction Change The bit is set each time the count direction of timer T2 changes. T2CHDIR must be cleared by software. 0 _B No change in count direction was detected 1 _B A change in count direction was detected
T2RDIR	15	rh	Timer T2 Rotation Direction 0 _B Timer T2 counts up 1 _B Timer T2 counts down
0	[11:10], [31:16]	r	Reserved Read as 0; should be written with 0.

1) See [Table 25-1](#) for encoding of bits T2UD and T2UDE.

T4CON

Timer T4 Control Register

(18_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T4 R DIR	T4 CH DIR	T4E DGE	T4 IR DIS	CLR T3 EN	CLR T2 EN	T4 RC	T4 UDE	T4 UD	T4 R	T4M			T4I		
rh	rwh	rwh	rw	rw	rw	rw	rw	rw	rw	rw			rw		

Field	Bits	Type	Description
T4I	[2:0]	rw	Timer T4 Input Parameter Selection Depends on the operating mode, see respective sections for encoding: Table 25-8 for Timer Mode and Gated Timer Mode Table 25-2 for Counter Mode Table 25-3 for Incremental Interface Mode

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
T4M	[5:3]	rw	Timer T4 Mode Control (Basic Operating Mode) 000 _B Timer Mode 001 _B Counter Mode 010 _B Gated Timer Mode with gate active low 011 _B Gated Timer Mode with gate active high 100 _B Reload Mode 101 _B Capture Mode 110 _B Incremental Interface Mode (Rotation Detection Mode) 111 _B Incremental Interface Mode (Edge Detection Mode)
T4R	6	rw	Timer T4 Run Bit 0 _B Timer T4 stops 1 _B Timer T4 runs <i>Note: This bit only controls timer T4 if bit T4RC = 0.</i>
T4UD	7	rw	Timer T4 Up/Down Control¹⁾ 0 _B Timer T4 counts up 1 _B Timer T4 counts down <i>Note: This bit only controls count direction of T4 if bit T4UDE = 0.</i>
T4UDE	8	rw	Timer T4 External Up/Down Enable¹⁾ 0 _B Count direction is controlled by bit T4UD; input T4EUD is disconnected 1 _B Count direction is controlled by input T4EUD
T4RC	9	rw	Timer T4 Remote Control 0 _B Timer T4 is controlled by its own run bit T4R 1 _B Timer T4 is controlled by the run bit T3R of core timer T3, but not by bit T4R
CLRT2EN	10	rw	Clear Timer T2 Enable Enables the automatic clearing of timer T2 upon a falling edge of the selected T4EUD input. 0 _B No effect of T4EUD on timer T2 1 _B A falling edge on T4EUD clears timer T2
CLRT3EN	11	rw	Clear Timer T3 Enable Enables the automatic clearing of timer T3 upon a falling edge of the selected T4IN input. 0 _B No effect of T4IN on timer T3 1 _B A falling edge on T4IN clears timer T3

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
T4IRDIS	12	rw	Timer T4 Interrupt Disable 0_B Interrupt generation for T4CHDIR and T4EDGE interrupts in Incremental Interface Mode is enabled 1_B Interrupt generation for T4CHDIR and T4EDGE interrupts in Incremental Interface Mode is disabled
T4EDGE	13	rwh	Timer T4 Edge Detection The bit is set each time a count edge is detected. T4EDGE has to be cleared by software. 0_B No count edge was detected 1_B A count edge was detected
T4CHDIR	14	rwh	Timer T4 Count Direction Change The bit is set each time the count direction of timer T4 changes. T4CHDIR must be cleared by software. 0_B No change in count direction was detected 1_B A change in count direction was detected
T4RDIR	15	rh	Timer T4 Rotation Direction 0_B Timer T4 counts up 1_B Timer T4 counts down
0	[31:16]	r	Reserved Read as 0; should be written with 0.

1) See [Table 25-1](#) for encoding of bits T4UD and T4UDE.

Timer T2/T4 Run Control

Each of the auxiliary timers T2 and T4 can be started or stopped by software in two different ways:

- Through the associated timer run bit (T2R or T4R). In this case it is required that the respective control bit TxRC = 0.
- Through the core timer's run bit (T3R). In this case the respective remote control bit must be set (TxRC = 1).

The selected run bit is relevant in all operating modes of T2/T4. Setting the bit will start the timer, clearing the bit stops the timer.

In Gated Timer Mode, the timer will only run if the selected run bit is set and the gate is active (high or low, as programmed).

Note: If remote control is selected T3R will start/stop timer T3 and the selected auxiliary timer(s) synchronously.

General Purpose Timer Units (GPT12)

Count Direction Control

The count direction of the GPT1 timers (core timer and auxiliary timers) is controlled in the same way, either by software or by the external input pin TxEUD. Please refer to the description in [Table 25-1](#).

Note: When pin TxEUD is used as external count direction control input, it must be configured as input.

General Purpose Timer Units (GPT12)

25.1.4 GPT1 Auxiliary Timers T2/T4 Operating Modes

The operation of the auxiliary timers in the basic operating modes is almost identical with the core timer's operation, with very few exceptions. Additionally, some combined operating modes can be selected.

Timers T2 and T4 in Timer Mode

Timer Mode for an auxiliary timer Tx is selected by setting its bitfield TxM in register TxCON to 000_B.

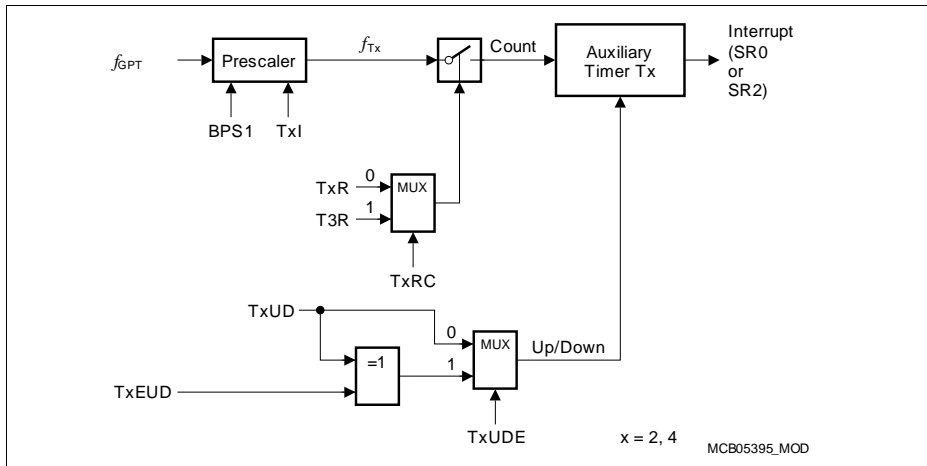


Figure 25-10 Block Diagram of an Auxiliary Timer in Timer Mode

General Purpose Timer Units (GPT12)

Timers T2 and T4 in Gated Timer Mode

Gated Timer Mode for an auxiliary timer Tx is selected by setting bitfield TxM in register TxCON to 010_B or 011_B. Bit TxM.0 (TxCON.3) selects the active level of the gate input.

Note: A transition of the gate signal at TxIN does not cause a service request. Service requests of timer T2 are handled by register SRC0 and service request of timer T4 are handled by register SRC2.

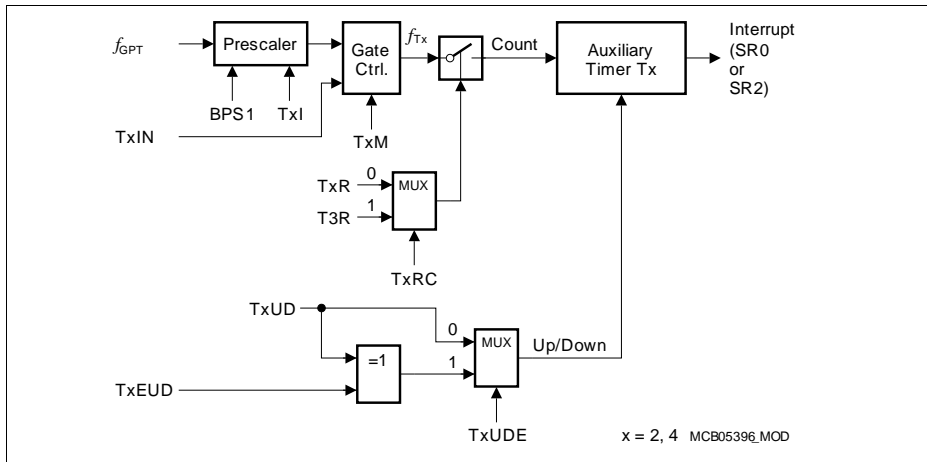


Figure 25-11 Block Diagram of an Auxiliary Timer in Gated Timer Mode

Note: There is no output toggle latch for T2 and T4.

Start/stop of an auxiliary timer can be controlled locally or remotely.

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Timers T2 and T4 in Counter Mode

Counter Mode for an auxiliary timer Tx is selected by setting bitfield TxM in register TxCON to 001_B. In Counter Mode, an auxiliary timer can be clocked either by a transition at its external input line TxIN, or by a transition of timer T3's toggle latch T3OTL. The event causing an increment or decrement of a timer can be a positive, a negative, or both a positive and a negative transition at either the respective input pin or at the toggle latch. Bitfield TxI in control register TxCON selects the triggering transition (see [Table 25-5](#)).

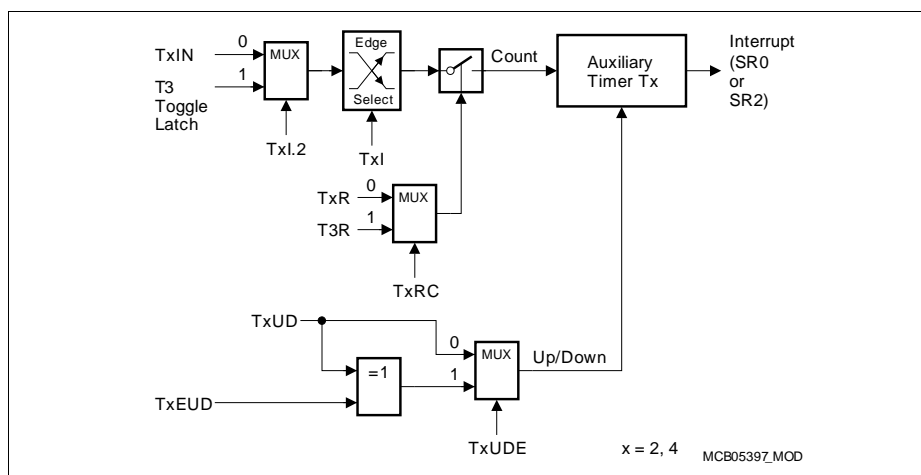


Figure 25-12 Block Diagram of an Auxiliary Timer in Counter Mode

Table 25-5 GPT1 Auxiliary Timer (Counter Mode) Input Edge Selection

T2I/T4I	Triggering Edge for Counter Increment/Decrement
X00 _B	None. Counter Tx is disabled
001 _B	Positive transition (rising edge) on TxIN
010 _B	Negative transition (falling edge) on TxIN
011 _B	Any transition (rising or falling edge) on TxIN
101 _B	Positive transition (rising edge) of T3 toggle latch T3OTL
110 _B	Negative transition (falling edge) of T3 toggle latch T3OTL
111 _B	Any transition (rising or falling edge) of T3 toggle latch T3OTL

Note: Only state transitions of T3OTL which are caused by the overflows/underflows of T3 will trigger the counter function of T2/T4. Modifications of T3OTL via software will NOT trigger the counter function of T2/T4.

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For counter operation, pin TxIN must be configured as input. The maximum input frequency allowed in Counter Mode depends on the selected prescaler value. To ensure that a transition of the count input signal applied to TxIN is recognized correctly, its level must be held high or low for a minimum number of module clock cycles before it changes. This information can be found in [Section 25.1.5](#).

Timers T2 and T4 in Incremental Interface Mode

Incremental Interface Mode for an auxiliary timer Tx is selected by setting bitfield TxM in the respective register TxCON to 110_B or 111_B. In Incremental Interface Mode, the two inputs associated with an auxiliary timer Tx (TxIN, TxEUD) are used to interface to an incremental encoder. Tx is clocked by each transition on one or both of the external input pins to provide 2-fold or 4-fold resolution of the encoder input.

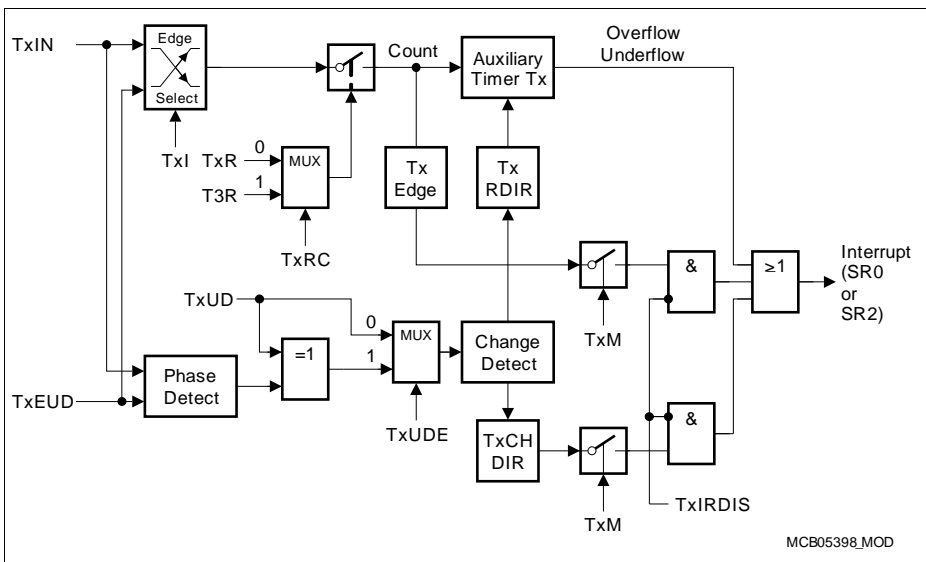


Figure 25-13 Block Diagram of an Auxiliary Timer in Incremental Interface Mode

The operation of the auxiliary timers T2 and T4 in Incremental Interface Mode and the interrupt generation are the same as described for the core timer T3. The descriptions, figures and tables apply accordingly.

Note: Timers T2 and T4 operating in Incremental Interface Mode automatically provide information on the sensor's current position. For dynamic information (speed, acceleration, deceleration) see ["Combined Capture Modes" on Page 25-60](#).

General Purpose Timer Units (GPT12)

Timer Concatenation

Using the toggle bit T3OTL as a clock source for an auxiliary timer in Counter Mode concatenates the core timer T3 with the respective auxiliary timer. This concatenation forms either a 32-bit or a 33-bit timer/counter, depending on which transition of T3OTL is selected to clock the auxiliary timer.

- **32-bit Timer/Counter:** If both a positive and a negative transition of T3OTL are used to clock the auxiliary timer, this timer is clocked on every overflow/underflow of the core timer T3. Thus, the two timers form a 32-bit timer.
- **33-bit Timer/Counter:** If either a positive or a negative transition of T3OTL is selected to clock the auxiliary timer, this timer is clocked on every second overflow/underflow of the core timer T3. This configuration forms a 33-bit timer (16-bit core timer + T3OTL + 16-bit auxiliary timer).

As long as bit T3OTL is not modified by software, it represents the state of the internal toggle latch, and can be regarded as part of the 33-bit timer.

The count directions of the two concatenated timers are not required to be the same. This offers a wide variety of different configurations.

T3, which represents the low-order part of the concatenated timer, can operate in Timer Mode, Gated Timer Mode or Counter Mode in this case.

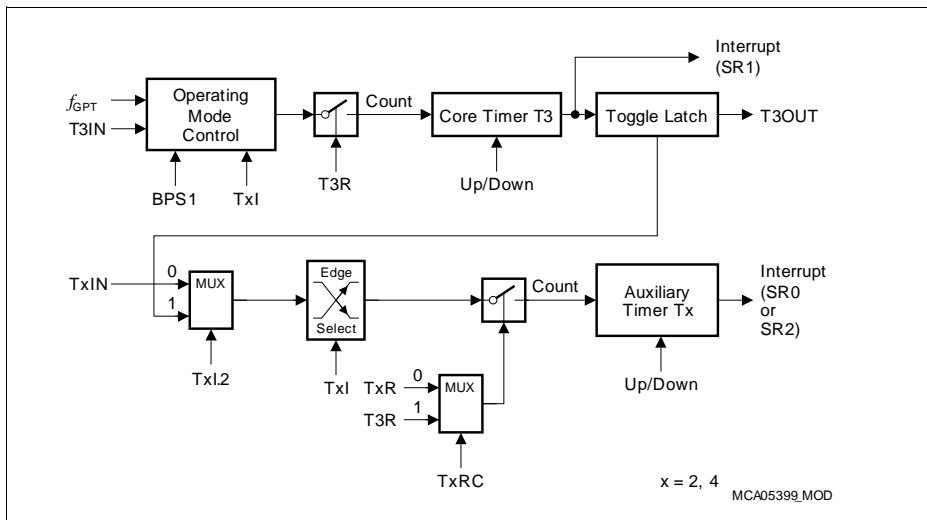


Figure 25-14 Concatenation of Core Timer T3 and an Auxiliary Timer

General Purpose Timer Units (GPT12)

When reading the low and high parts of the concatenated timer, care must be taken to obtain consistent values in particular after a timer overflow/underflow (e.g. one part may already have considered an overflow, while the other has not).

Note: This is a general issue when reading multi-word results with consecutive instructions, and not necessarily unique to the GPT12 module architecture.

The following algorithm may be used to read concatenated GPT1 timers, represented by TIMER_HIGH (for auxiliary timer, here T2) and TIMER_LOW (for core timer T3). The high part is read twice, and reading of the low part is repeated if two different values were read for the high part:

- TIMER_HIGH_TMP = T2
- TIMER_LOW = T3
- Wait two basic clock cycles (to allow increment/decrement of auxiliary timer in case of core timer overflow/underflow) - see [Table 25-6](#)
- TIMER_HIGH = T2
- If TIMER_HIGH is not equal to TIMER_HIGH_TMP then TIMER_LOW = T3

After execution of this algorithm, TIMER_HIGH and TIMER_LOW represent a consistent time stamp of the concatenated timers.

The equivalent number of system clock cycles corresponding to two basic clock cycles is shown in [Table 25-6](#).

Table 25-6 Number of System Clock Cycles to Wait for Two Basic Clock Cycles

Block Prescaler	BPS1 = 01 _B	BPS1 = 00 _B	BPS1 = 11 _B	BPS1 = 10 _B
Number of system clocks	8	16	32	64

In case the required timer resolution can be achieved with different combinations of the Block Prescaler BPS1 and the Individual Prescalers TxI (see [Table 25-8](#)), the variant with the smallest value for the Block Prescaler may be chosen to minimize the waiting time.

Timers T2 and T4 in Reload Mode

Reload Mode for an auxiliary timer Tx is selected by setting bitfield TxM in the respective register TxCON to 100_B. In Reload Mode, the core timer T3 is reloaded with the contents of an auxiliary timer register, triggered by one of two different signals. The trigger signal is selected the same way as the clock source for Counter Mode (see [Table 25-5](#)), i.e. a transition of the auxiliary timer's input TxIN or the toggle latch T3OTL may trigger the reload.

Note: When programmed for Reload Mode, the respective auxiliary timer (T2 or T4) stops independently of its run flag T2R or T4R.

The timer input pin TxIN must be configured as input if it shall trigger a reload operation.

General Purpose Timer Units (GPT12)

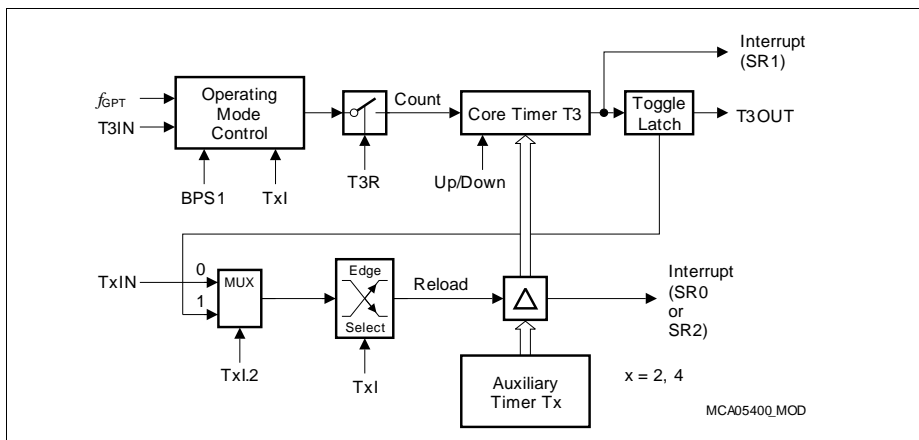


Figure 25-15 GPT1 Auxiliary Timer in Reload Mode

Upon a trigger signal, T3 is loaded with the contents of the respective timer register (T2 or T4) and the respective service request flag SRR in register SRC0 or SRC2 is set.

Note: When a T3OTL transition is selected for the trigger signal, the service request flag SRR in register SRC1 will also be set upon a trigger, indicating T3's overflow or underflow. Modifications of T3OTL via software will NOT trigger the counter function of T2/T4.

To ensure that a transition of the reload input signal applied to TxIN is recognized correctly, its level must be held high or low for a minimum number of module clock cycles, detailed in [Section 25.1.5](#).

The Reload Mode triggered by the T3 toggle latch can be used in a number of different configurations. The following functions can be performed, depending on the selected active transition:

- If both a positive and a negative transition of T3OTL are selected to trigger a reload, the core timer will be reloaded with the contents of the auxiliary timer each time it overflows or underflows. This is the standard Reload Mode (reload on overflow/underflow).
- If either a positive or a negative transition of T3OTL is selected to trigger a reload, the core timer will be reloaded with the contents of the auxiliary timer on every second overflow or underflow.
- Using this "single-transition" mode for both auxiliary timers allows to perform very flexible Pulse Width Modulation (PWM). One of the auxiliary timers is programmed to reload the core timer on a positive transition of T3OTL, the other is programmed for a reload on a negative transition of T3OTL. With this combination the core timer is alternately reloaded from the two auxiliary timers.

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Figure 25-16 shows an example for the generation of a PWM signal using the “single-transition” reload mechanism. T2 defines the high time of the PWM signal (reloaded on positive transitions) and T4 defines the low time of the PWM signal (reloaded on negative transitions). The PWM signal can be output on pin T3OUT if T3OE = 1. With this method, the high and low time of the PWM signal can be varied in a wide range.

Note: The output toggle latch T3OTL is accessible via software and may be changed, if required, to modify the PWM signal.

However, this will NOT trigger the reloading of T3.

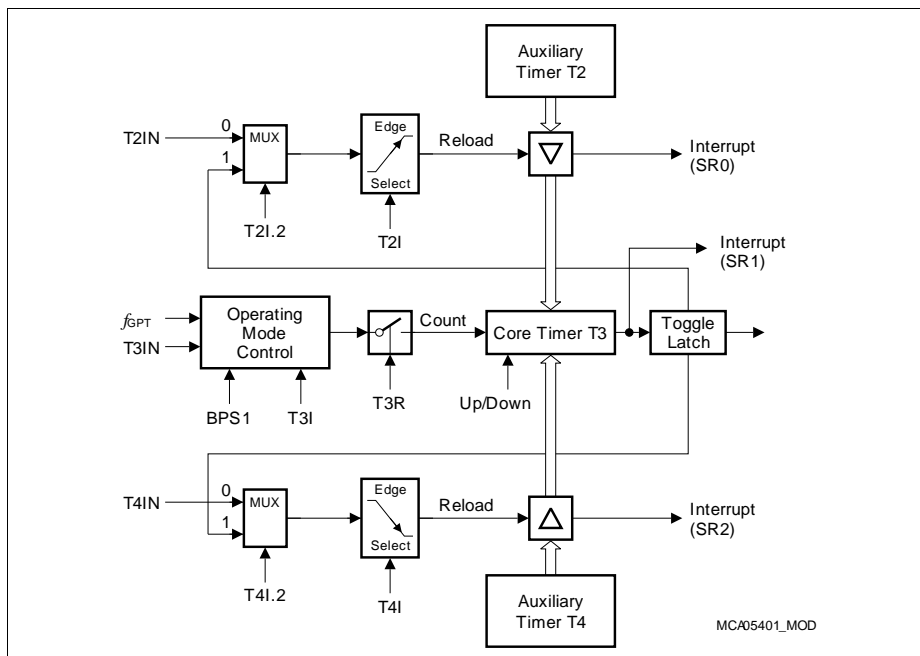


Figure 25-16 GPT1 Timer Reload Configuration for PWM Generation

Note: Although possible, selecting the same reload trigger event for both auxiliary timers should be avoided. In such a case, both reload registers would try to load the core timer at the same time. If this combination is selected, T2 is disregarded and the contents of T4 is reloaded.

The implementation of the GPT1 finite state machine may require special consideration in following cases.

In Case 1, when T2 or T4 are used to reload T3 on overflow/underflow, and T3 is read by software on the fly, the following unexpected values may be read from T3:

General Purpose Timer Units (GPT12)

- When T3 is counting up, 0000_H or 0001_H may be read from T3 directly after an overflow, although the reload value in T2/T4 is higher (0001_H may be read in particular if BPS1 = 01_B and T3I = 000_B).
- When T3 is counting down, FFFF_H or FFFE_H may be read from T3 directly after an underflow, although the reload value in T2/T4 is lower (FFFE_H may be read in particular if BPS1 = 01_B and T3I = 000_B).

Note: All timings derived from T3 in this configuration (e.g. distance between service requests, PWM waveform on T3OUT, etc.) are accurate except for the specific case described below.

Recommendation:

- When T3 counts up, and T3_value < reload value is read from T3, T3_value should be replaced with the reload value for further calculations.
- When T3 counts down, and T3_value > reload value is read from T3, T3_value should be replaced with the reload value for further calculations.

Alternatively, if the intention is to identify the overflow/underflow of T3, the T3 service request may be used.

In Case 2, when T2 is used to reload T3 in the configuration with BPS1 = 01_B and T3I = 000_B (i.e. fastest configuration/highest resolution of T3), the reload of T3 is performed with a delay of one basic clock cycle.

Recommendation:

To compensate the delay and achieve correct timing,

- increment the reload value in T2 by 1 when T3 is configured to count up,
- decrement the reload value in T2 by 1 when T3 is configured to count down.

Alternatively, use T4 instead of T2 as reload register for T3. In this configuration the reload of T3 is not delayed, i.e. the effect described above does not occur with T4.

Timers T2 and T4 in Capture Mode

Capture Mode for an auxiliary timer Tx is selected by setting bitfield TxM in the respective register TxCON to 101_B. In Capture Mode, the contents of the core timer T3 are latched into an auxiliary timer register in response to a signal transition at the respective auxiliary timer's external input pin TxIN. The capture trigger signal can be a positive, a negative, or both a positive and a negative transition.

The two least significant bits of bitfield TxI select the active transition (see [Table 25-5](#)). Bit 2 of TxI is irrelevant for Capture Mode and must be cleared (TxI.2 = 0).

Note: When programmed for Capture Mode, the respective auxiliary timer (T2 or T4) stops independently of its run flag T2R or T4R.

General Purpose Timer Units (GPT12)

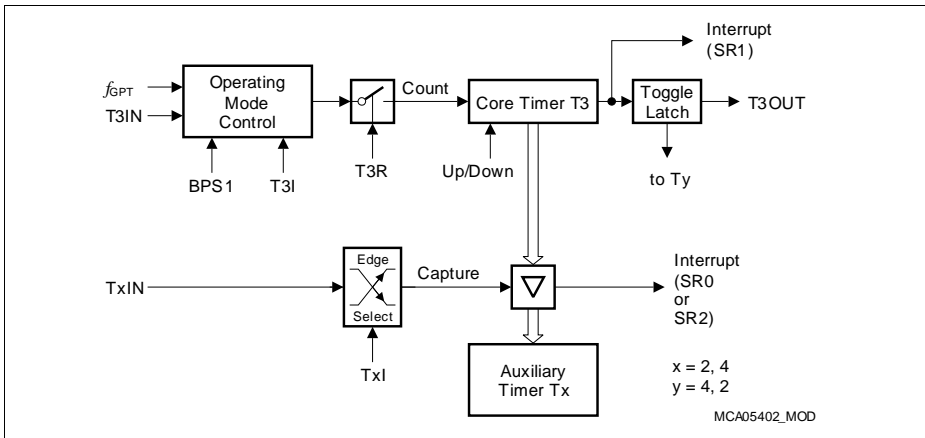


Figure 25-17 GPT1 Auxiliary Timer in Capture Mode

Upon a trigger (selected transition) at the corresponding input pin $TxIN$ the contents of the core timer are loaded into the auxiliary timer register and the associated service request flag SRR will be set.

For Capture Mode operation, the respective timer input pin $TxIN$ must be configured as input. To ensure that a transition of the capture input signal applied to $TxIN$ is recognized correctly, its level must be held high or low for a minimum number of module clock cycles, detailed in [Section 25.1.5](#).

General Purpose Timer Units (GPT12)

25.1.5 GPT1 Clock Signal Control

All actions within the timer block GPT1 are triggered by transitions of its basic clock. This basic clock is derived from the system clock by a basic block prescaler, controlled by bitfield BPS1 in register T3CON (see [Figure 25-1](#)). The count clock can be generated in two different ways:

- **Internal count clock**, derived from GPT1's basic clock via a programmable prescaler, is used for (Gated) Timer Mode.
- **External count clock**, derived from the timer's input pin(s), is used for Counter Mode.

For both ways, the basic clock determines the maximum count frequency and the timer's resolution:

Table 25-7 Basic Clock Selection for Block GPT1

Block Prescaler ¹⁾	BPS1 = 01 _B	BPS1 = 00 _B ²⁾	BPS1 = 11 _B	BPS1 = 10 _B
Prescaling Factor for GPT1: F(BPS1)	F(BPS1) = 4	F(BPS1) = 8	F(BPS1) = 16	F(BPS1) = 32
Maximum External Count Frequency	$f_{\text{GPT}}/8$	$f_{\text{GPT}}/16$	$f_{\text{GPT}}/32$	$f_{\text{GPT}}/64$
Input Signal Stable Time	$4 \times t_{\text{GPT}}$	$8 \times t_{\text{GPT}}$	$16 \times t_{\text{GPT}}$	$32 \times t_{\text{GPT}}$

1) Please note the non-linear encoding of bitfield BPS1.

2) Default after reset.

Note: The GPT1 block uses a finite state machine to control the actions. Since multiple interactions are possible between the timers (T2, T3, T4), these elements are processed sequentially. However, all actions are normally completed within one basic clock cycle. The GPT1 state machine has 8 states (4 states when BPS1 = 01_B) and processes the timers in the order T3 - T2 (all actions except capture) - T4 - T2 (capture).

Internal Count Clock Generation

In Timer Mode and Gated Timer Mode, the count clock for each GPT1 timer is derived from the GPT1 basic clock by a programmable prescaler, controlled by bitfield TxI in the respective timer's control register TxCON.

General Purpose Timer Units (GPT12)

The count frequency f_{Tx} for a timer Tx and its resolution r_{Tx} are scaled linearly with lower clock frequencies, as can be seen from the following formula:

$$f_{Tx} = \frac{f_{GPT}}{F(BPS1) \times 2^{<Tx>}} \quad r_{Tx}[\mu s] = \frac{F(BPS1) \times 2^{<Tx>}}{f_{GPT}[MHz]} \quad (25.1)$$

The effective count frequency depends on the common module clock prescaler factor F(BPS1) as well as on the individual input prescaler factor $2^{<Tx>}$. [Table 25-8](#) summarizes the resulting overall divider factors for a GPT1 timer that result from these cascaded prescalers.

Table 25-8 GPT1 Overall Prescaler Factors for Internal Count Clock

Individual Prescaler for Tx	Common Prescaler for Module Clock ¹⁾			
	BPS1 = 01 _B	BPS1 = 00 _B	BPS1 = 11 _B	BPS1 = 10 _B
Txl = 000 _B	4	8	16	32
Txl = 001 _B	8	16	32	64
Txl = 010 _B	16	32	64	128
Txl = 011 _B	32	64	128	256
Txl = 100 _B	64	128	256	512
Txl = 101 _B	128	256	512	1024
Txl = 110 _B	256	512	1024	2048
Txl = 111 _B	512	1024	2048	4096

1) Please note the non-linear encoding of bitfield BPS1.

[Table 25-9](#) lists GPT1 timer's parameters (such as count frequency, resolution, and period) resulting from the selected overall prescaler factor and the applied system frequency. Note that some numbers may be rounded.

Table 25-9 GPT1 Timer Parameters

System Clock = 10 MHz			Overall Divider Factor	System Clock = 40 MHz		
Frequency	Resolution	Period		Frequency	Resolution	Period
2.5 MHz	400 ns	26.21 ms	4	10.0 MHz	100 ns	6.55 ms
1.25 MHz	800 ns	52.43 ms	8	5.0 MHz	200 ns	13.11 ms
625.0 kHz	1.6 μs	104.9 ms	16	2.5 MHz	400 ns	26.21 ms
312.5 kHz	3.2 μs	209.7 ms	32	1.25 MHz	800 ns	52.43 ms

General Purpose Timer Units (GPT12)

Table 25-9 GPT1 Timer Parameters (cont'd)

System Clock = 10 MHz			Overall Divider Factor	System Clock = 40 MHz		
Frequency	Resolution	Period		Frequency	Resolution	Period
156.25 kHz	6.4 μ s	419.4 ms	64	625.0 kHz	1.6 μ s	104.9 ms
78.125 kHz	12.8 μ s	838.9 ms	128	312.5 kHz	3.2 μ s	209.7 ms
39.06 kHz	25.6 μ s	1.678 s	256	156.25 kHz	6.4 μ s	419.4 ms
19.53 kHz	51.2 μ s	3.355 s	512	78.125 kHz	12.8 μ s	838.9 ms
9.77 kHz	102.4 μ s	6.711 s	1024	39.06 kHz	25.6 μ s	1.678 s
4.88 kHz	204.8 μ s	13.42 s	2048	19.53 kHz	51.2 μ s	3.355 s
2.44 kHz	409.6 μ s	26.84 s	4096	9.77 kHz	102.4 μ s	6.711 s

External Count Clock Input

The external input signals of the GPT1 block are sampled with the GPT1 basic clock (see [Figure 25-1](#)). To ensure that a signal is recognized correctly, its current level (high or low) must be held active for at least one complete sampling period, before changing. A signal transition is recognized if two subsequent samples of the input signal represent different levels. Therefore, a minimum of two basic clock periods are required for the sampling of an external input signal. Thus, the maximum frequency of an input signal must not be higher than half the basic clock.

Table 25-10 summarizes the resulting requirements for external GPT1 input signals.

Table 25-10 GPT1 External Input Signal Limits

GPT1 Basic Clock = 10 MHz		Input Frequ. Factor	GPT1 Divider BPS1	Input Phase Duration	GPT1 Basic Clock = 40 MHz	
Max. Input Frequency	Min. Level Hold Time				Max. Input Frequency	Min. Level Hold Time
1.25 MHz	400 ns	$f_{\text{GPT}}/8$	01 _B	$4 \times t_{\text{GPT}}$	5.0 MHz	100 ns
625.0 kHz	800 ns	$f_{\text{GPT}}/16$	00 _B	$8 \times t_{\text{GPT}}$	2.5 MHz	200 ns
312.5 kHz	1.6 μ s	$f_{\text{GPT}}/32$	11 _B	$16 \times t_{\text{GPT}}$	1.25 MHz	400 ns
156.25 kHz	3.2 μ s	$f_{\text{GPT}}/64$	10 _B	$32 \times t_{\text{GPT}}$	625.0 kHz	800 ns

These limitations are valid for all external input signals to GPT1, including the external count signals in Counter Mode and Incremental Interface Mode, the gate input signals in Gated Timer Mode, and the external direction signals.

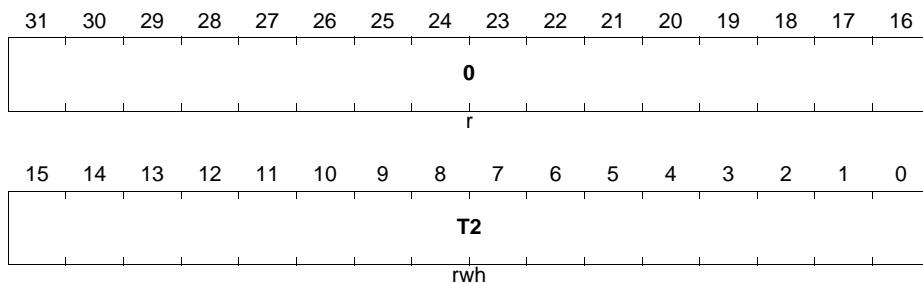
General Purpose Timer Units (GPT12)

25.1.6 GPT1 Timer Registers

T2

Timer T2 Register

(34_H)

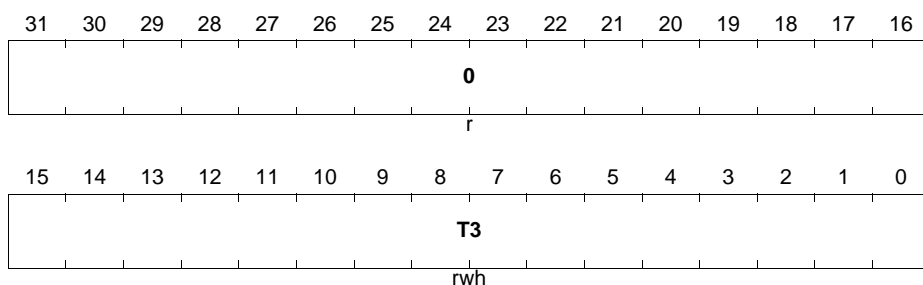
Reset Value: 0000 0000_H


Field	Bits	Type	Description
T2	[15:0]	rwh	Timer T2 Contains the current value of Timer T2.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

T3

Timer T3 Register

(38_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
T3	[15:0]	rwh	Timer T3 Contains the current value of Timer T3.

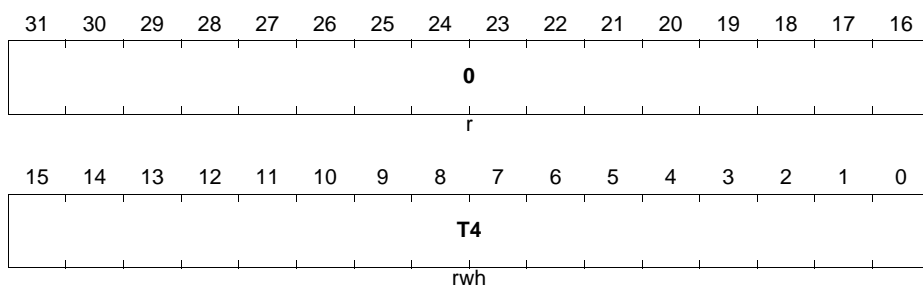
General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0; should be written with 0.

T4

Timer T4 Register

(3C_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
T4	[15:0]	rwh	Timer T4 Contains the current value of Timer T4.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

25.1.7 Interrupt Control for GPT1 Timers

When a timer overflows from $FFFF_H$ to 0000_H (when counting up), or when it underflows from 0000_H to $FFFF_H$ (when counting down), its service request flag SRR in register SRCx will be set.

Interrupts of timer T2 are connected with register SRC0.

Interrupts of timer T3 are connected with register SRC1.

Interrupts of timer T4 are connected with register SRC2.

In **Reload Mode**, upon a trigger signal, T3 is loaded with the contents of the respective timer (T2 or T4) and the respective service request flag SRR in register SRC0 or SRC1 is set.

In **Incremental Interface Mode**, the service request generation can be selected as follows:

- In Rotation Detection Mode ($T3M = 110_B$), a service request is generated each time the count direction of T3 changes.
- In Edge Detection Mode ($T3M = 111_B$), a service request is generated each time a count edge for T3 is detected.

In **Capture Mode**, upon a trigger (selected transition) at the corresponding input pin the content of the core timer T3 are loaded into the auxiliary timer register Tx and the associated service request flag SRR in register SRC0 or SRC2 will be set.

SRC0

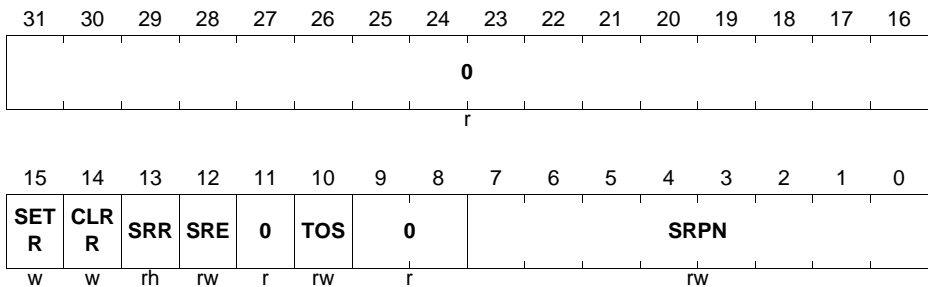
Service Request Control 0 Register (FC_H) **Reset Value: 0000 0000_H**

SRC1

Service Request Control 1 Register ($F8_H$) **Reset Value: 0000 0000_H**

SRC2

Service Request Control 2 Register ($F4_H$) **Reset Value: 0000 0000_H**



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Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority ... FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP service is initiated
SRE	12	rw	Service Request Enable 0 _B Service request is disabled 1 _B Service request is enabled
SRR	13	rh	Service Request Flag 0 _B No service request is pending 1 _B A service request is pending
CLRR	14	w	Request Clear Bit CLRR is required to clear SRR. 0 _B No action 1 _B Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 _B No action 1 _B Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

25.2 Timer Block GPT2

Both timers of block GPT2 (T5, T6) can run in one of 3 basic modes: Timer Mode, Gated Timer Mode, or Counter Mode. All timers can count up or down. Each timer of GPT2 is controlled by a separate control register TxCON.

Each timer has an input pin TxIN (alternate pin function) associated with it, which serves as the gate control in Gated Timer Mode, or as the count input in Counter Mode. The count direction (up/down) may be programmed via software or may be dynamically altered by a signal at the External Up/Down control input TxEUD (alternate pin function). An overflow/underflow of core timer T6 is indicated by the Output Toggle Latch T6OTL, whose state may be output on the associated pin T6OUT (alternate pin function). The auxiliary timer T5 may additionally be concatenated with core timer T6 (through T6OTL).

The Capture/Reload register CAPREL can be used to capture the contents of timer T5, or to reload timer T6. A special mode facilitates the use of register CAPREL for both functions at the same time. This mode allows frequency multiplication. The capture function is triggered by the input pin CAPIN, or by GPT1 timer's T3 input lines T3IN and T3EUD. The reload function is triggered by an overflow or underflow of timer T6.

The current contents of each timer can be read or modified by the CPU by accessing the corresponding timer count registers T5 or T6. When any of the timer registers is written by the CPU in the state immediately preceding a timer increment, decrement, reload, or capture operation, the CPU write operation has priority in order to guarantee correct results.

The interrupts of GPT2 are controlled through the Service Request Control Registers SRC3, SRC4, and SRC5.

Note: The timing requirements for external input signals can be found in [Section 25.2.6](#), [Section 25.5](#) summarizes the module interface signals, including pins.

General Purpose Timer Units (GPT12)

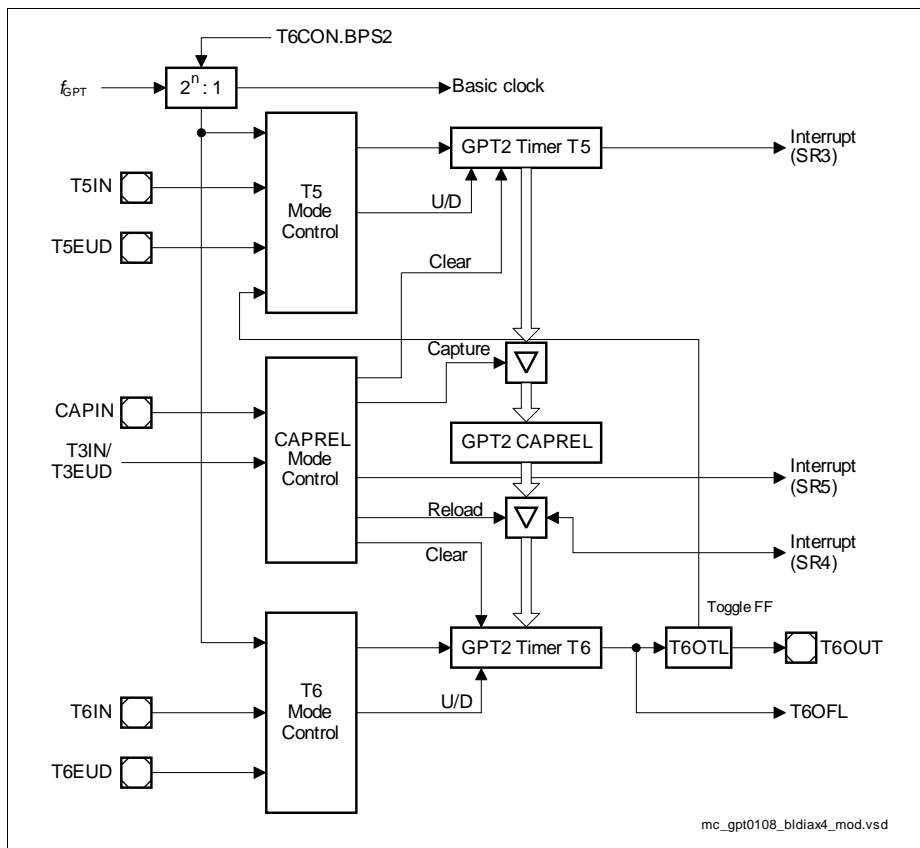


Figure 25-18 GPT2 Block Diagram

General Purpose Timer Units (GPT12)

25.2.1 GPT2 Core Timer T6 Control

The current contents of the core timer T6 are reflected by its count register T6. This register can also be written to by the CPU, for example, to set the initial start value.

The core timer T6 is configured and controlled via its control register T6CON.

T6CON

Timer T6 Control Register

(20_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T6 SR	T6 CLR	0	BPS2	T6 OTL	T6 OE	T6 UDE	T6 UD	T6 R	T6M			T6I			
rw	rw	r	rw	rwh	rw	rw	rw	rw		rw			rw		

Field	Bits	Type	Description
T6I	[2:0]	rw	Timer T6 Input Parameter Selection Depends on the operating mode, see respective sections for encoding: Table 25-17 for Timer Mode and Gated Timer Mode Table 25-12 for Counter Mode
T6M	[5:3]	rw	Timer T6 Mode Control (Basic Operating Mode) 000 _B Timer Mode 001 _B Counter Mode 010 _B Gated Timer Mode with gate active low 011 _B Gated Timer Mode with gate active high 100 _B Reserved. Do not use this combination. 101 _B Reserved. Do not use this combination. 110 _B Reserved. Do not use this combination. 111 _B Reserved. Do not use this combination.
T6R	6	rw	Timer T6 Run Bit 0 _B Timer T6 stops 1 _B Timer T6 runs

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Field	Bits	Type	Description
T6UD	7	rw	Timer T6 Up/Down Control¹⁾ 0_B Timer T6 counts up 1_B Timer T6 counts down <i>Note: This bit only controls count direction of T6 if bit T6UDE = 0.</i>
T6UDE	8	rw	Timer T6 External Up/Down Enable¹⁾ 0_B Count direction is controlled by bit T6UD; input T6EUD is disconnected 1_B Count direction is controlled by input T6EUD
T6OE	9	rw	Overflow/Underflow Output Enable 0_B Alternate Output Function Disabled 1_B State of timer T6 toggle latch is output on pin T6OUT
T6OTL	10	rwh	Timer T6 Overflow Toggle Latch Toggles on each overflow/underflow of timer T6. Can be set or cleared by software (see separate description)
BPS2	[12:11]	rw	GPT2 Block Prescaler Control Selects the basic clock for block GPT2 (see also Section 25.2.6) 00_B $f_{GPT}/4$ 01_B $f_{GPT}/2$ 10_B $f_{GPT}/16$ 11_B $f_{GPT}/8$
T6CLR	14	rw	Timer T6 Clear Enable Bit 0_B Timer T6 is not cleared on a capture event 1_B Timer T6 is cleared on a capture event
T6SR	15	rw	Timer T6 Reload Mode Enable 0_B Reload from register CAPREL Disabled 1_B Reload from register CAPREL Enabled
0	[31:16]	r	Reserved Read as 0; should be written with 0.

1) See [Table 25-11](#) for coding of bits T6UD and T6UDE

General Purpose Timer Units (GPT12)

Timer T6 Run Control

The core timer T6 can be started or stopped by software through bit T6R (timer T6 run bit). This bit is relevant in all operating modes of T6. Setting bit T6R will start the timer, clearing bit T6R stops the timer.

In Gated Timer Mode, the timer will only run if T6R = 1 and the gate is active (high or low, as programmed).

Note: When bit T5RC in timer control register T5CON is set, bit T6R will also control (start and stop) the Auxiliary Timer T5.

Count Direction Control

The count direction of the GPT2 timers (core timer and auxiliary timer) can be controlled either by software or by the external input pin TxEUD (Timer Tx External Up/Down Control Input). These options are selected by bits TxUD and TxUDE in the respective control register TxCON. When the up/down control is provided by software (bit TxUDE = 0), the count direction can be altered by setting or clearing bit TxUD. When bit TxUDE = 1, pin TxEUD is selected to be the controlling source of the count direction. However, bit TxUD can still be used to reverse the actual count direction, as shown in [Table 25-11](#). The count direction can be changed regardless of whether or not the timer is running.

Table 25-11 GPT2 Timer Count Direction Control

Pin TxEUD	Bit TxUDE	Bit TxUD	Count Direction
X	0	0	Count Up
X	0	1	Count Down
0	1	0	Count Up
1	1	0	Count Down
0	1	1	Count Down
1	1	1	Count Up

General Purpose Timer Units (GPT12)

Timer T6 Output Toggle Latch

The overflow/underflow signal of timer T6 is connected to a block named 'Toggle Latch', shown in the timer mode diagrams. **Figure 25-19** illustrates the details of this block. An overflow or underflow of T6 will clock two latches: The first latch represents bit T6OTL in control register T6CON. The second latch is an internal latch toggled by T6OTL's output. Both latch outputs are connected to the input control block of the auxiliary timer T5. The output level of the shadow latch will match the output level of T6OTL, but is delayed by one clock cycle. When the T6OTL value changes, this will result in a temporarily different output level from T6OTL and the shadow latch, which can trigger the selected count event in T5.

When software writes to T6OTL, both latches are set or cleared simultaneously. In this case, both signals to the auxiliary timers carry the same level and no edge will be detected. Bit T6OE (overflow/underflow output enable) in register T6CON enables the state of T6OTL to be monitored via an external pin T6OUT. When T6OTL is linked to an external port pin (must be configured as output), T6OUT can be used to control external HW. If T6OE = 1, pin T6OUT outputs the state of T6OTL. If T6OE = 0, pin T6OUT outputs a high level (while it selects the timer output signal).

As can be seen from **Figure 25-19**, when latch T6OTL is modified by software to determine the state of the output line, also the internal shadow latch is set or cleared accordingly. Therefore, no trigger condition is detected by T5 in this case.

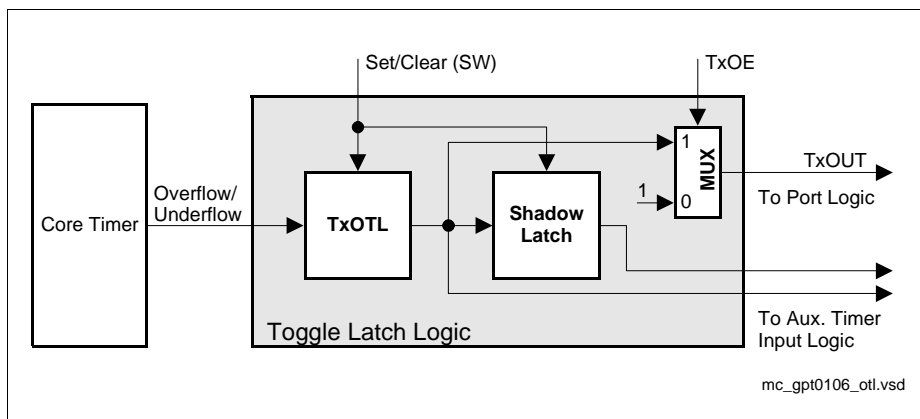


Figure 25-19 Block Diagram of the Toggle Latch Logic of Core Timer T6 (x = 6)

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Timer 6 in Gated Timer Mode

Gated Timer Mode for the core timer T6 is selected by setting bitfield T6M in register T6CON to 010_B or 011_B. Bit T6M.0 (T6CON.3) selects the active level of the gate input. The same options for the input frequency are available in Gated Timer Mode as in Timer Mode (see [Section 25.2.6](#)). However, the input clock to the timer in this mode is gated by the external input pin T6IN (Timer T6 External Input).

To enable this operation, the associated pin T6IN must be configured as input.

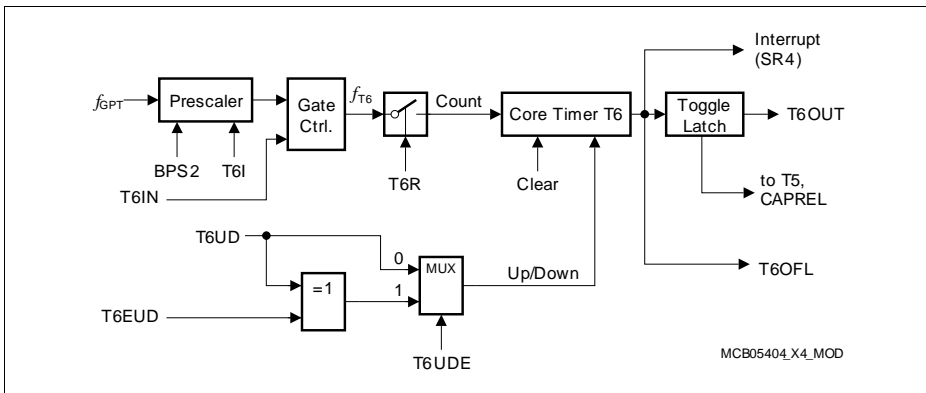


Figure 25-21 Block Diagram of Core Timer T6 in Gated Timer Mode

If T6M = 010_B, the timer is enabled when T6IN shows a low level. A high level at this line stops the timer. If T6M = 011_B, line T6IN must have a high level in order to enable the timer. Additionally, the timer can be turned on or off by software using bit T6R. The timer will only run if T6R is 1 and the gate is active. It will stop if either T6R is 0 or the gate is inactive.

Note: A transition of the gate signal at pin T6IN does not cause a service request.

General Purpose Timer Units (GPT12)

Timer 6 in Counter Mode

Counter Mode for the core timer T6 is selected by setting bitfield T6M in register T6CON to 001_B. In Counter Mode, timer T6 is clocked by a transition at the external input pin T6IN. The event causing an increment or decrement of the timer can be a positive, a negative, or both a positive and a negative transition at this line. Bitfield T6I in control register T6CON selects the triggering transition (see [Table 25-12](#)).

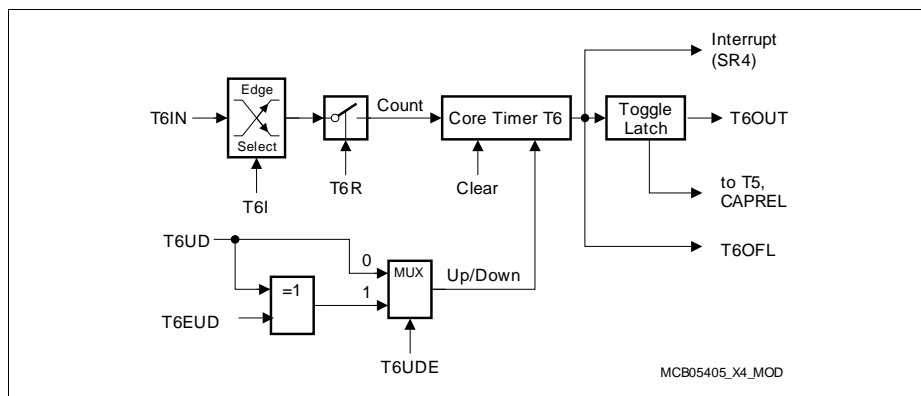


Figure 25-22 Block Diagram of Core Timer T6 in Counter Mode

Table 25-12 GPT2 Core Timer T6 (Counter Mode) Input Edge Selection

T6I	Triggering Edge for Counter Increment/Decrement
000 _B	None. Counter T6 is disabled
001 _B	Positive transition (rising edge) on T6IN
010 _B	Negative transition (falling edge) on T6IN
011 _B	Any transition (rising or falling edge) on T6IN
1XX _B	Reserved. Do not use this combination

For Counter Mode operation, pin T6IN must be configured as input. The maximum input frequency allowed in Counter Mode depends on the selected prescaler value. To ensure that a transition of the count input signal applied to T6IN is recognized correctly, its level must be held high or low for a minimum number of module clock cycles before it changes. This information can be found in [Section 25.2.6](#).

General Purpose Timer Units (GPT12)

25.2.3 GPT2 Auxiliary Timer T5 Control

Auxiliary timer T5 can be configured for Timer Mode, Gated Timer Mode, or Counter Mode with the same options for the timer frequencies and the count signal as the core timer T6. In addition to these 3 counting modes, the auxiliary timer can be concatenated with the core timer. The contents of T5 may be captured to register CAPREL upon an external or an internal trigger. The start/stop function of the auxiliary timers can be remotely controlled by the T6 run control bit. Several timers may thus be controlled synchronously.

The current contents of the auxiliary timer are reflected by its count register T5. This register can also be written to by the CPU, for example, to set the initial start value.

The individual configurations for timer T5 are determined by its control register T5CON. Some bits in this register also control the function of the CAPREL register. Note that functions which are present in all timers of block GPT2 are controlled in the same bit positions and in the same manner in each of the specific control registers.

Note: The auxiliary timer has no output toggle latch and no alternate output function.

T5CON

Timer T5 Control Register

(1C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
T5 SC	T5 CLR	CI	0	CT3	T5 RC	T5 UDE	T5 UD	T5 R	T5M			T5I			
rw	rwh	rw	rw	rw	rw	rw	rw	rw	rw	rw			rw		

Field	Bits	Type	Description
T5I	[2:0]	rw	Timer T5 Input Parameter Selection Depends on the operating mode, see respective sections for encoding: Table 25-17 for Timer Mode and Gated Timer Mode Table 25-12 for Counter Mode

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Field	Bits	Type	Description
T5M	[5:3]	rw	Timer T5 Mode Control (Basic Operating Mode) 000 _B Timer Mode 001 _B Counter Mode 010 _B Gated Timer Mode with gate active low 011 _B Gated Timer Mode with gate active high 100 _B Reserved. Do not use this combination 101 _B Reserved. Do not use this combination 110 _B Reserved. Do not use this combination 111 _B Reserved. Do not use this combination
T5R	6	rw	Timer T5 Run Bit 0 _B Timer T5 runs 1 _B Timer T5 stops <i>Note: This bit only controls timer T5 if bit T5RC = 0.</i>
T5UD	7	rw	Timer T5 Up/Down Control¹⁾ 0 _B Timer T5 counts up 1 _B Timer T5 counts down <i>Note: This bit only controls count direction of T5 if bit T5UDE = 0.</i>
T5UDE	8	rw	Timer T5 External Up/Down Enable¹⁾ 0 _B Count direction is controlled by bit T5UD; input T5EUD is disconnected 1 _B Count direction is controlled by input T5EUD
T5RC	9	rw	Timer T5 Remote Control 0 _B Timer T5 is controlled by its own run bit T5R 1 _B Timer T5 is controlled by the run bit T6R of core timer T6, not by bit T5R
CT3	10	rw	Timer T3 Capture Trigger Enable 0 _B Capture trigger from input line CAPIN 1 _B Capture trigger from T3 input lines T3IN and/or T3EUD
0	11	rw	Reserved Has to be written with 0.

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Field	Bits	Type	Description
CI	[13:12]	rw	Register CAPREL Capture Trigger Selection²⁾ 00 _B Capture disabled 01 _B Positive transition (rising edge) on CAPIN ³⁾ or any transition on T3IN 10 _B Negative transition (falling edge) on CAPIN or any transition on T3EUD 11 _B Any transition (rising or falling edge) on CAPIN or any transition on T3IN or T3EUD
T5CLR	14	rw	Timer T5 Clear Enable Bit 0 _B Timer T5 is not cleared on a capture event 1 _B Timer T5 is cleared on a capture event
T5SC	15	rw	Timer T5 Capture Mode Enable 0 _B Capture into register CAPREL disabled 1 _B Capture into register CAPREL enabled
0	5, [31:16]	r	Reserved Read as 0; should be written with 0.

1) See [Table 25-11](#) for encoding of bits T5UD and T5UDE.

2) To define the respective trigger source signal, also bit CT3 must be regarded (see [Table 25-15](#)).

3) Rising edge must be selected if capturing is triggered by the internal GPT1 read signals (see register PISEL and [“Combined Capture Modes” on Page 25-60](#)).

Timer T5 Run Control

The auxiliary timer T5 can be started or stopped by software in two different ways:

- Through the associated timer run bit (T5R). In this case it is required that the respective control bit T5RC = 0.
- Through the core timer's run bit (T6R). In this case the respective remote control bit must be set (T5RC = 1).

The selected run bit is relevant in all operating modes of T5. Setting the bit will start the timer, clearing the bit stops the timer.

In Gated Timer Mode, the timer will only run if the selected run bit is set and the gate is active (high or low, as programmed).

Note: If remote control is selected T6R will start/stop timer T6 and the auxiliary timer T5 synchronously.

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25.2.4 GPT2 Auxiliary Timer T5 Operating Modes

The operation of the auxiliary timer in the basic operating modes is almost identical with the core timer's operation, with very few exceptions. Additionally, some combined operating modes can be selected.

Timer T5 in Timer Mode

Timer Mode for the auxiliary timer T5 is selected by setting its bitfield T5M in register T5CON to 000_B.

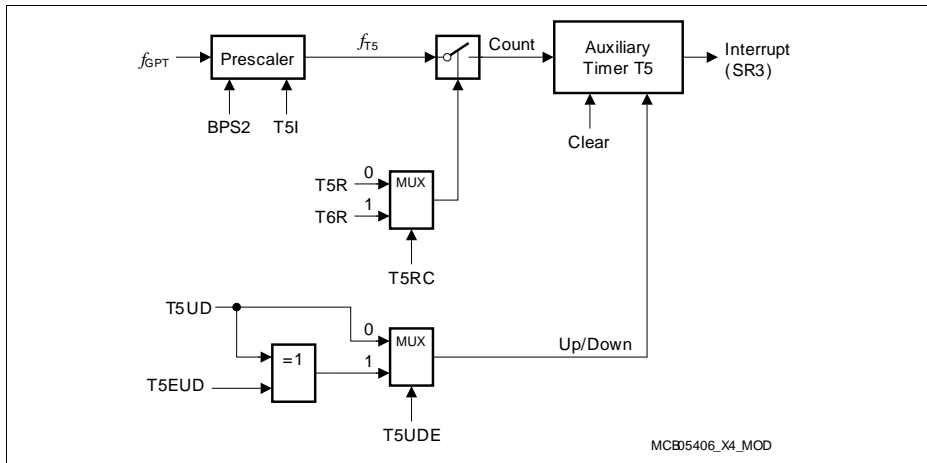


Figure 25-23 Block Diagram of Auxiliary Timer T5 in Timer Mode

General Purpose Timer Units (GPT12)

Timer T5 in Gated Timer Mode

Gated Timer Mode for the auxiliary timer T5 is selected by setting bitfield T5M in register T5CON to 010_B or 011_B. Bit T5M.0 (T5CON.3) selects the active level of the gate input.

Note: A transition of the gate signal at line T5IN does not cause a service request.

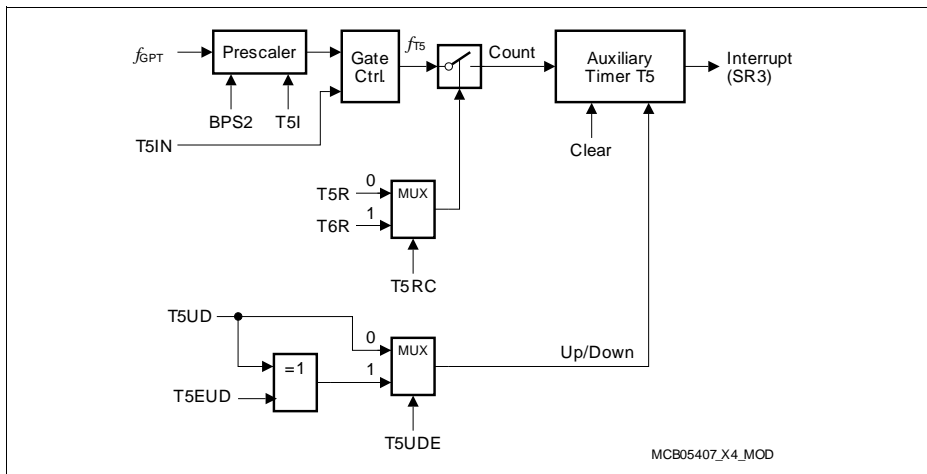


Figure 25-24 Block Diagram of Auxiliary Timer T5 in Gated Timer Mode

Note: There is no output toggle latch for T5.

Start/stop of the auxiliary timer can be controlled locally or remotely.

Timer T5 in Counter Mode

Counter Mode for auxiliary timer T5 is selected by setting bitfield T5M in register T5CON to 001_B. In Counter Mode, the auxiliary timer can be clocked either by a transition at its external input line T5IN, or by a transition of timer T6's toggle latch T6OTL. The event causing an increment or decrement of a timer can be a positive, a negative, or both a positive and a negative transition at either the respective input pin or at the toggle latch. Bitfield T5I in control register T5CON selects the triggering transition (see [Table 25-13](#)).

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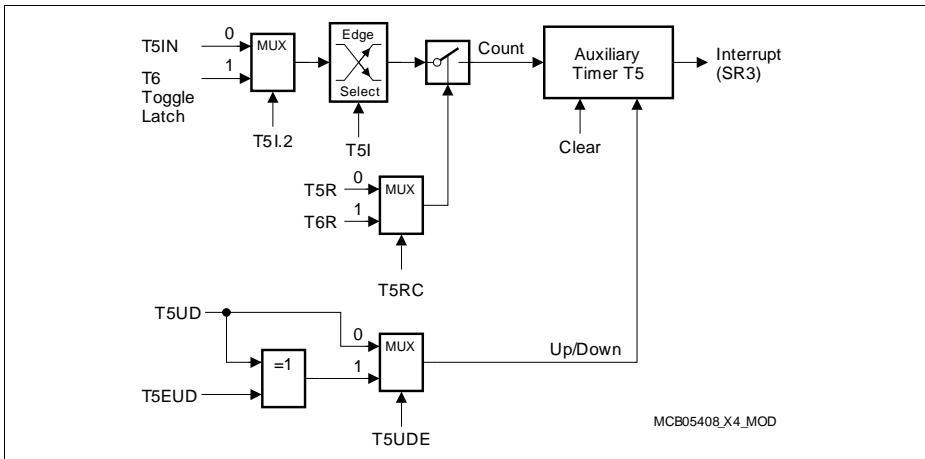


Figure 25-25 Block Diagram of Auxiliary Timer T5 in Counter Mode

Table 25-13 GPT2 Auxiliary Timer (Counter Mode) Input Edge Selection

T5I	Triggering Edge for Counter Increment/Decrement
X00 _B	None. Counter T5 is disabled
001 _B	Positive transition (rising edge) on T5IN
010 _B	Negative transition (falling edge) on T5IN
011 _B	Any transition (rising or falling edge) on T5IN
101 _B	Positive transition (rising edge) of T6 toggle latch T6OTL
110 _B	Negative transition (falling edge) of T6 toggle latch T6OTL
111 _B	Any transition (rising or falling edge) of T6 toggle latch T6OTL

Note: Only state transitions of T6OTL which are caused by the overflows/underflows of T6 will trigger the counter function of T5. Modifications of T6OTL via software will NOT trigger the counter function of T5.

For counter operation, pin T5IN must be configured as input. The maximum input frequency allowed in Counter Mode depends on the selected prescaler value. To ensure that a transition of the count input signal applied to T5IN is recognized correctly, its level must be held high or low for a minimum number of module clock cycles before it changes. This information can be found in [Section 25.2.6](#).

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Timer Concatenation

Using the toggle bit T6OTL as a clock source for the auxiliary timer in Counter Mode concatenates the core timer T6 with the auxiliary timer T5. This concatenation forms either a 32-bit or a 33-bit timer/counter, depending on which transition of T6OTL is selected to clock the auxiliary timer.

- **32-bit Timer/Counter:** If both a positive and a negative transition of T6OTL are used to clock the auxiliary timer, this timer is clocked on every overflow/underflow of the core timer T6. Thus, the two timers form a 32-bit timer.
- **33-bit Timer/Counter:** If either a positive or a negative transition of T6OTL is selected to clock the auxiliary timer, this timer is clocked on every second overflow/underflow of the core timer T6. This configuration forms a 33-bit timer (16-bit core timer + T6OTL + 16-bit auxiliary timer).

As long as bit T6OTL is not modified by software, it represents the state of the internal toggle latch, and can be regarded as part of the 33-bit timer.

The count directions of the two concatenated timers are not required to be the same. This offers a wide variety of different configurations.

T6, which represents the low-order part of the concatenated timer, can operate in Timer Mode, Gated Timer Mode or Counter Mode in this case.

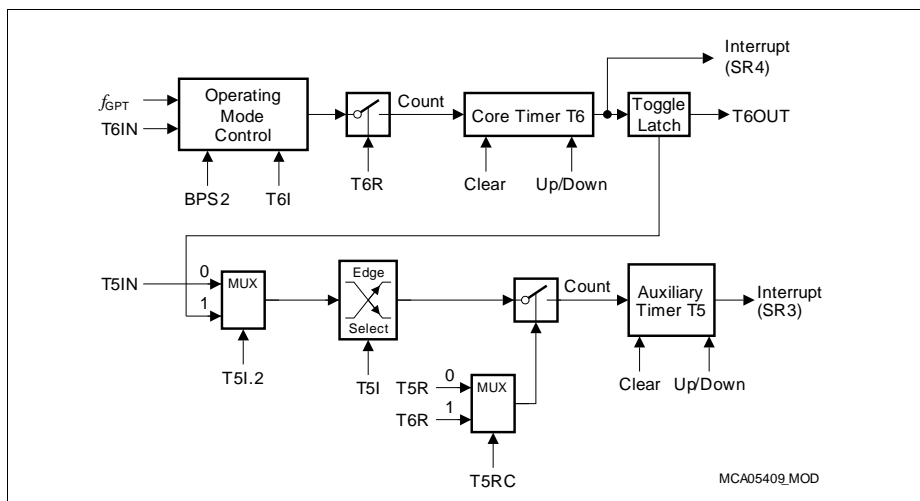


Figure 25-26 Concatenation of Core Timer T6 and Auxiliary Timer T5

When reading the low and high parts of the concatenated timer, care must be taken to obtain consistent values in particular after a timer overflow/underflow (e.g. one part may already have considered an overflow, while the other has not).

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Note: This is a general issue when reading multi-word results with consecutive instructions, and not necessarily unique to the GPT12 module architecture.

The following algorithm may be used to read concatenated GPT1 timers, represented by TIMER_HIGH (for auxiliary timer, here T5) and TIMER_LOW (for core timer T6). The high part is read twice, and reading of the low part is repeated if two different values were read for the high part:

- TIMER_HIGH_TMP = T5
- TIMER_LOW = T6
- Wait two basic clock cycles (to allow increment/decrement of auxiliary timer in case of core timer overflow/underflow) - see [Table 25-14](#)
- TIMER_HIGH = T5
- If TIMER_HIGH is not equal to TIMER_HIGH_TMP then TIMER_LOW = T6

After execution of this algorithm, TIMER_HIGH and TIMER_LOW represent a consistent time stamp of the concatenated timers.

The equivalent number of system clock cycles corresponding to two basic clock cycles is shown in [Table 25-14](#).

Table 25-14 Number of System Clock Cycles to Wait for Two Basic Clock Cycles

Block Prescaler	BPS2 = 01 _B	BPS2 = 00 _B	BPS2 = 11 _B	BPS2 = 10 _B
Number of system clocks	4	8	16	32

In case the required timer resolution can be achieved with different combinations of the Block Prescaler BPS2 and the Individual Prescalers TxI (see [Table 25-17](#)), the variant with the smallest value for the Block Prescaler may be chosen to minimize the waiting time. E.g. in order to run T6 at $f_{\text{SYS}}/512$, select BPS2 = 00_B, T6I = 111_B, and insert 8 NOPs (or other instructions) to ensure the required waiting time before reading TIMER_HIGH the second time.

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25.2.5 GPT2 Register CAPREL Operating Modes

The Capture/Reload register CAPREL can be used to capture the contents of timer T5, or to reload timer T6. A special mode facilitates the use of register CAPREL for both functions at the same time. This mode allows frequency multiplication. The capture function is triggered by the input pin CAPIN, by GPT1 timer's T3 input lines T3IN and T3EUD, or by read accesses to GPT1 timers. The reload function is triggered by an overflow or underflow of timer T6.

In addition to the capture function, the capture trigger signal can also be used to clear the contents of timers T5 and T6 individually.

The functions of register CAPREL are controlled via several bit(field)s in the timer control registers T5CON and T6CON.

Capture/Reload Register CAPREL in Capture Mode

Capture Mode for register CAPREL is selected by setting bit T5SC in control register T5CON (set bitfield CI in register T5CON to a non-zero value to select a trigger signal). In Capture Mode, the contents of the auxiliary timer T5 are latched into register CAPREL in response to a signal transition at the selected external input pin(s). Bit CT3 selects the external input line CAPIN or the input lines T3IN and/or T3EUD of GPT1 timer T3 as the source for a capture trigger. Either a positive, a negative, or both a positive and a negative transition at line CAPIN can be selected to trigger the capture function, or transitions on input T3IN or input T3EUD or both inputs, T3IN and T3EUD. The active edge is controlled by bitfield CI in register T5CON. [Table 25-15](#) summarizes these options.

Table 25-15 CAPREL Register Input Edge Selection

CT3	CI	Triggering Signal/Edge for Capture Mode
X	00 _B	None. Capture Mode is disabled.
0	01 _B	Positive transition (rising edge) on CAPIN. ¹⁾
0	10 _B	Negative transition (falling edge) on CAPIN.
0	11 _B	Any transition (rising or falling edge) on CAPIN.
1	01 _B	Any transition (rising or falling edge) on T3IN.
1	10 _B	Any transition (rising or falling edge) on T3EUD.
1	11 _B	Any transition (rising or falling edge) on T3IN or T3EUD.

1) Rising edge must be selected if capturing is triggered by the internal GPT1 read signals (see register PISEL and ["Combined Capture Modes" on Page 25-60](#)).

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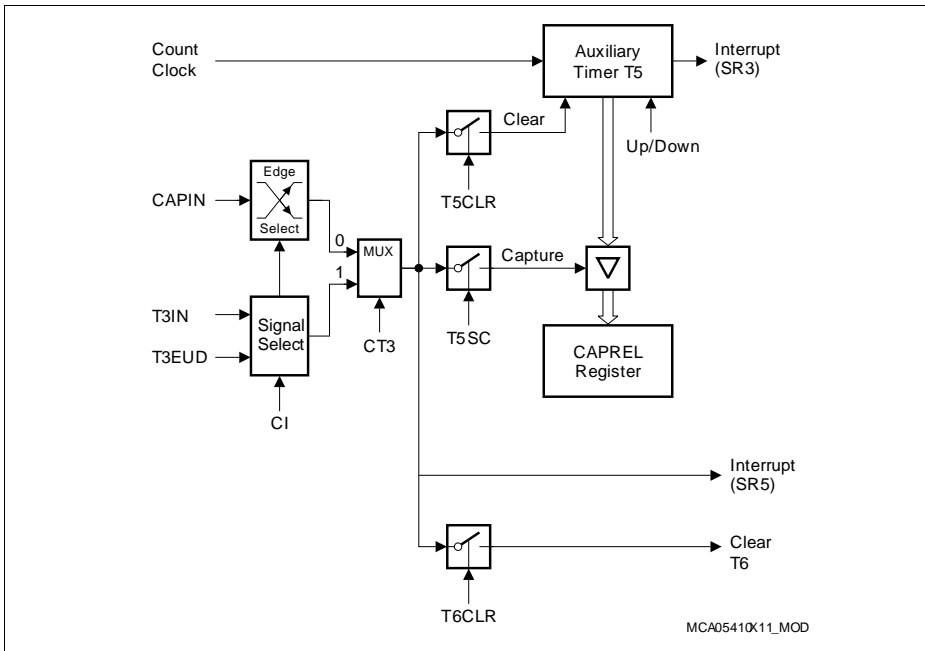


Figure 25-27 Capture/Reload Register CAPREL in Capture Mode

When a selected trigger is detected, the contents of the auxiliary timer T5 are latched into register CAPREL and the service request is activated. The same event can optionally clear timer T5 and/or timer T6. This option is enabled by bit T5CLR in register T5CON and bit T6CLR in register T6CON, respectively. If TxCLR = 0 the contents of timer Tx is not affected by a capture. If TxCLR = 1 timer Tx is cleared after the current timer T5 value has been latched into register CAPREL.

Note: Bit T5SC only controls whether or not a capture is performed. If T5SC is cleared the external input pin(s) can still be used to clear timer T5 and/or T6, or as external interrupt input(s). This interrupt is controlled by the CAPREL interrupt control register SRC5.

When capture triggers T3IN or T3EUD are enabled (CT3 = 1), register CAPREL captures the contents of T5 upon transitions of the selected input(s). These values can be used to measure T3's input signals. This is useful, for example, when T3 operates in Incremental Interface Mode, in order to derive dynamic information (speed, acceleration) from the input signals.

For Capture Mode operation, the selected pins CAPIN, T3IN, or T3EUD must be configured as input. To ensure that a transition of a trigger input signal applied to one of

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these inputs is recognized correctly, its level must be held high or low for a minimum number of module clock cycles, detailed in [Section 25.2.6](#).

Capture/Reload Register CAPREL in Reload Mode

Reload Mode for register CAPREL is selected by setting bit T6SR in control register T6CON. In Reload Mode, the core timer T6 is reloaded with the contents of register CAPREL, triggered by an overflow or underflow of T6. This will not activate the service request SRC5.SRR associated with the CAPREL register. However, a service request will be activated, indicating the overflow/underflow of T6.

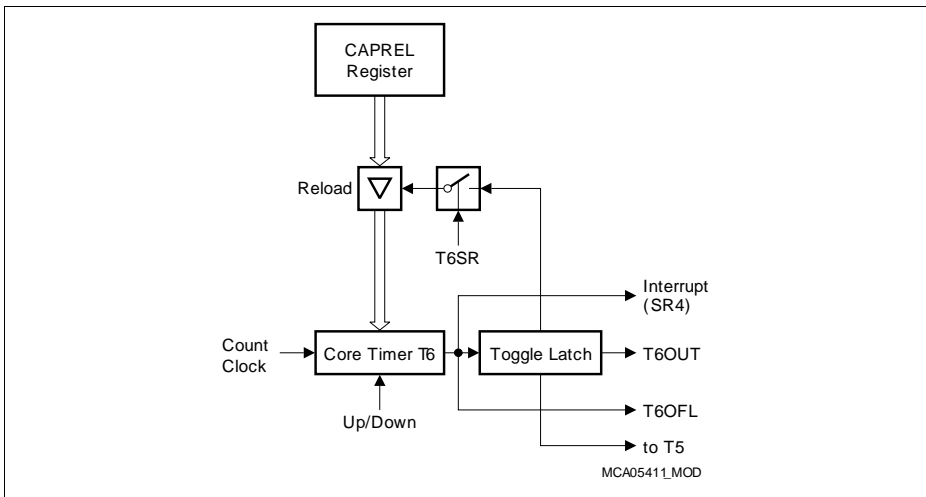


Figure 25-28 Capture/Reload Register CAPREL in Reload Mode

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Capture/Reload Register CAPREL in Capture-And-Reload Mode

Since the reload function and the capture function of register CAPREL can be enabled individually by bits T5SC and T6SR, the two functions can be enabled simultaneously by setting both bits. This feature can be used to generate an output frequency that is a multiple of the input frequency.

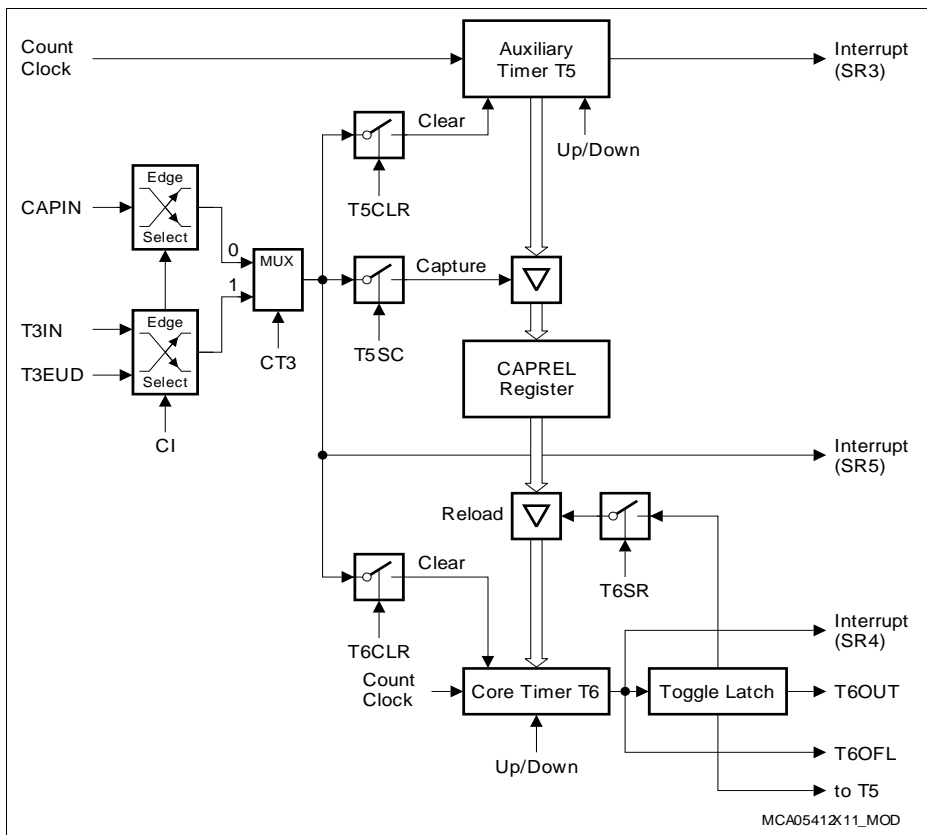


Figure 25-29 Capture/Reload Register CAPREL in Capture-And-Reload Mode

This combined mode can be used to detect consecutive external events which may occur aperiodically, but where a finer resolution, that means, more 'ticks' within the time between two external events is required.

For this purpose, the time between the external events is measured using timer T5 and the CAPREL register. Timer T5 runs in Timer Mode counting up with a frequency of e.g. $f_{GPT}/32$. The external events are applied to pin CAPIN. When an external event occurs,

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the contents of timer T5 are latched into register CAPREL and timer T5 is cleared ($T5CLR = 1$). Thus, register CAPREL always contains the correct time between two events, measured in timer T5 increments. Timer T6, which runs in Timer Mode counting down with a frequency of e.g. $f_{GPT}/4$, uses the value in register CAPREL to perform a reload on underflow. This means, the value in register CAPREL represents the time between two underflows of timer T6, now measured in timer T6 increments. Since (in this example) timer T6 runs 8 times faster than timer T5, it will underflow 8 times within the time between two external events. Thus, the underflow signal of timer T6 generates 8 'ticks'. Upon each underflow, the interrupt request SRC4.SRR will be activated and bit T6OTL will be toggled. The state of T6OTL may be output on pin T6OUT. This signal has 8 times more transitions than the signal which is applied to pin CAPIN.

Note: The underflow signal of Timer T6 can furthermore be used to clock one or more of the timers of the CAPCOM units, which gives the user the possibility to set compare events based on a finer resolution than that of the external events. This connection is accomplished via signal T6OFL.

Capture Correction

A certain deviation of the output frequency is generated by the fact that timer T5 will count actual time units (e.g. T5 running at 1 MHz will count up to the value $64_H/100_D$ for a 10 kHz input signal), while T6OTL will only toggle upon an underflow of T6 (i.e. the transition from 0000_H to $FFFF_H$). In the above mentioned example, T6 would count down from 64_H , so the underflow would occur after 101 timing ticks of T6. The actual output frequency then is 79.2 kHz, instead of the expected 80 kHz.

This deviation can be compensated for by using T6 overflows. In this case, T5 counts down and T6 counts up. Upon a signal transition on pin CAPIN, the count value in T5 is captured into CAPREL and T5 is cleared to 0000_H . In its next clock cycle, T5 underflows to $FFFF_H$, and continues to count down with the following clocks. T6 is reloaded from CAPREL upon an overflow, and continues to count up with its following clock cycles (8 times faster in the above example). In this case, T5 and T6 count the same number of steps with their respective internal count frequency.

In the above example, T5 running at 1 MHz will count down to the value $FF9C_H/-100_D$ for a 10 kHz input signal applied at CAPIN, while T6 counts up from $FF9C_H$ through $FFFF_H$ to 0000_H . So the overflow occurs after 100 timing ticks of T6, and the actual output frequency at T6OUT then is the expected 80 kHz.

However, in this case CAPREL does not directly contain the time between two CAPIN events, but rather its 2's complement. Software will have to convert this value, if it is required for the operation.

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Combined Capture Modes

For incremental interface applications in particular, several timer features can be combined to obtain dynamic information such as speed, acceleration, or deceleration. The current position itself can be obtained directly from the timer register (T2, T3, T4).

The time information to determine the dynamic parameters is generated by capturing the contents of the free-running timer T5 into register CAPREL. Two trigger sources for this event can be selected:

- Capture trigger on sensor signal transitions
- Capture trigger on position read operations

Capturing on sensor signal transitions is available for timer T3 inputs. This mode is selected by setting bit CT3 and selecting the intended signal(s) via bitfield CI in register T5CON. CAPREL then indicates the time between two selected transitions (measured in T5 counts).

Capturing on position read operations is available for timers T2, T3, and T4. This mode is selected by clearing bit CT3 and selecting the rising edge via bitfield CI in register T5CON. Bitfield ISCAPIN in register PISEL then selects either a read access from T3 or a read access from any of T2 or T3 or T4. CAPREL then indicates the time between two read accesses.

These operating modes directly support the measurement of position and rotational speed. Acceleration and deceleration can then be determined by evaluating subsequent speed measurements.

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25.2.6 GPT2 Clock Signal Control

All actions within the timer block GPT2 are triggered by transitions of its basic clock. This basic clock is derived from the system clock by a basic block prescaler, controlled by bitfield BPS2 in register T6CON (see [Figure 25-18](#)). The count clock can be generated in two different ways:

- **Internal count clock**, derived from GPT2's basic clock via a programmable prescaler, is used for (Gated) Timer Mode.
- **External count clock**, derived from the timer's input pin(s), is used for Counter Mode.

For both ways, the basic clock determines the maximum count frequency and the timer's resolution:

Table 25-16 Basic Clock Selection for Block GPT2

Block Prescaler ¹⁾	BPS2 = 01 _B	BPS2 = 00 _B ²⁾	BPS2 = 11 _B	BPS2 = 10 _B
Prescaling Factor for GPT2: F(BPS2)	F(BPS2) = 2	F(BPS2) = 4	F(BPS2) = 8	F(BPS2) = 16
Maximum External Count Frequency	$f_{\text{GPT}}/4$	$f_{\text{GPT}}/8$	$f_{\text{GPT}}/16$	$f_{\text{GPT}}/32$
Input Signal Stable Time	$2 \times t_{\text{GPT}}$	$4 \times t_{\text{GPT}}$	$8 \times t_{\text{GPT}}$	$16 \times t_{\text{GPT}}$

1) Please note the non-linear encoding of bitfield BPS2.

2) Default after reset.

Note: The GPT2 module uses a finite state machine to control the actions. Since multiple interactions are possible between the timers (T5, T6) and register CAPREL, these elements are processed sequentially. However, all actions are normally completed within one basic clock cycle. The GPT2 state machine has 4 states (2 states when BPS1 = 01_B) and processes T6 before T5.

Internal Count Clock Generation

In Timer Mode and Gated Timer Mode, the count clock for each GPT2 timer is derived from the GPT2 basic clock by a programmable prescaler, controlled by bitfield TxI in the respective timer's control register TxCON.

The count frequency f_{Tx} for a timer Tx and its resolution r_{Tx} are scaled linearly with lower clock frequencies, as can be seen from the following formula:

$$f_{\text{Tx}} = \frac{f_{\text{GPT}}}{F(\text{BPS2}) \times 2^{<\text{TxI}>}} \quad r_{\text{Tx}}[\mu\text{s}] = \frac{F(\text{BPS2}) \times 2^{<\text{TxI}>}}{f_{\text{GPT}}[\text{MHz}]} \quad (25.2)$$

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The effective count frequency depends on the common module clock prescaler factor $F(\text{BPS2})$ as well as on the individual input prescaler factor $2^{<\text{Txl}>}$. **Table 25-17** summarizes the resulting overall divider factors for a GPT2 timer that result from these cascaded prescalers.

Table 25-17 GPT2 Overall Prescaler Factors for Internal Count Clock

Individual Prescaler for Tx	Common Prescaler for Module Clock ¹⁾			
	BPS2 = 01 _B	BPS2 = 00 _B	BPS2 = 11 _B	BPS2 = 10 _B
Txl = 000 _B	2	4	8	16
Txl = 001 _B	4	8	16	32
Txl = 010 _B	8	16	32	64
Txl = 011 _B	16	32	64	128
Txl = 100 _B	32	64	128	256
Txl = 101 _B	64	128	256	512
Txl = 110 _B	128	256	512	1024
Txl = 111 _B	256	512	1024	2048

1) Please note the non-linear encoding of bitfield BPS2.

Table 25-18 lists a timer's parameters (such as count frequency, resolution, and period) resulting from the selected overall prescaler factor and the applied system frequency. Note that some numbers may be rounded.

Table 25-18 GPT2 Timer Parameters

System Clock = 10 MHz			Overall Divider Factor	System Clock = 40 MHz		
Frequency	Resolution	Period		Frequency	Resolution	Period
5.0 MHz	200 ns	13.11 ms	2	20.0 MHz	50 ns	3.28 ms
2.5 MHz	400 ns	26.21 ms	4	10.0 MHz	100 ns	6.55 ms
1.25 MHz	800 ns	52.43 ms	8	5.0 MHz	200 ns	13.11 ms
625.0 kHz	1.6 μs	104.9 ms	16	2.5 MHz	400 ns	26.21 ms
312.5 kHz	3.2 μs	209.7 ms	32	1.25 MHz	800 ns	52.43 ms
156.25 kHz	6.4 μs	419.4 ms	64	625.0 kHz	1.6 μs	104.9 ms
78.125 kHz	12.8 μs	838.9 ms	128	312.5 kHz	3.2 μs	209.7 ms
39.06 kHz	25.6 μs	1.678 s	256	156.25 kHz	6.4 μs	419.4 ms
19.53 kHz	51.2 μs	3.355 s	512	78.125 kHz	12.8 μs	838.9 ms

General Purpose Timer Units (GPT12)

Table 25-18 GPT2 Timer Parameters (cont'd)

System Clock = 10 MHz			Overall Divider Factor	System Clock = 40 MHz		
Frequency	Resolution	Period		Frequency	Resolution	Period
9.77 kHz	102.4 μ s	6.711 s	1024	39.06 kHz	25.6 μ s	1.678 s
4.88 kHz	204.8 μ s	13.42 s	2048	19.53 kHz	51.2 μ s	3.355 s

External Count Clock Input

The external input signals of the GPT2 block are sampled with the GPT2 basic clock (see [Figure 25-18](#)). To ensure that a signal is recognized correctly, its current level (high or low) must be held active for at least one complete sampling period, before changing. A signal transition is recognized if two subsequent samples of the input signal represent different levels. Therefore, a minimum of two basic clock periods are required for the sampling of an external input signal. Thus, the maximum frequency of an input signal must not be higher than half the basic clock.

[Table 25-19](#) summarizes the resulting requirements for external GPT2 input signals.

Table 25-19 GPT2 External Input Signal Limits

GPT2 Basic Clock = 10 MHz		Input Frequ. Factor	GPT2 Divider BPS2	Input Phase Duration	GPT2 Basic Clock = 40 MHz	
Max. Input Frequency	Min. Level Hold Time				Max. Input Frequency	Min. Level Hold Time
2.5 MHz	200 ns	$f_{\text{GPT}}/4$	01 _B	$2 \times t_{\text{GPT}}$	10.0 MHz	50 ns
1.25 MHz	400 ns	$f_{\text{GPT}}/8$	00 _B	$4 \times t_{\text{GPT}}$	5.0 MHz	100 ns
625.0 kHz	800 ns	$f_{\text{GPT}}/16$	11 _B	$8 \times t_{\text{GPT}}$	2.5 MHz	200 ns
312.5 kHz	1.6 μ s	$f_{\text{GPT}}/32$	10 _B	$16 \times t_{\text{GPT}}$	1.25 MHz	400 ns

These limitations are valid for all external input signals to GPT2, including the external count signals in Counter Mode and the gate input signals in Gated Timer Mode.

General Purpose Timer Units (GPT12)

25.2.7 GPT2 Timer Registers

T5

Timer T5 Register

(40_H)

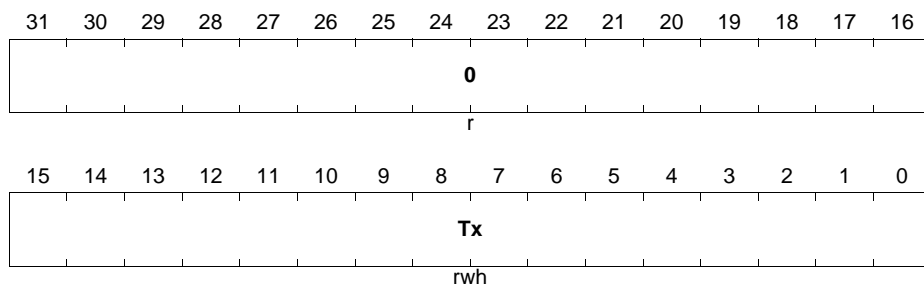
Reset Value: 0000 0000_H

T6

Timer T6 Register

(44_H)

Reset Value: 0000 0000_H



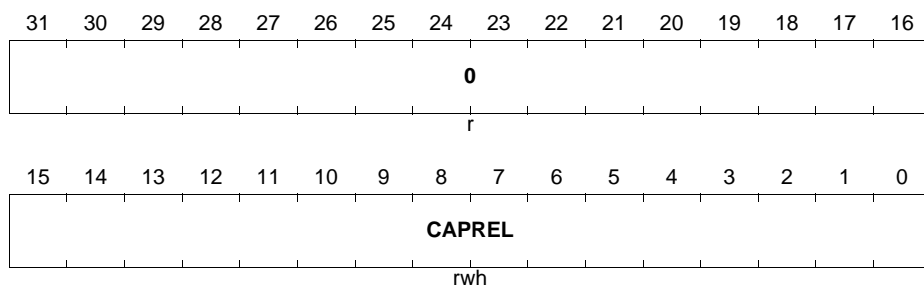
Field	Bits	Type	Description
Tx	[15:0]	rwh	Timer Tx Contains the current value of Timer Tx.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

CAPREL

Capture and Reload Register

(30_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CAPREL	[15:0]	rwh	Current reload value or Captured value

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

25.2.8 Interrupt Control for GPT2 Timers and CAPREL

When a timer overflows from $FFFF_H$ to 0000_H (when counting up), or when it underflows from 0000_H to $FFFF_H$ (when counting down), its service request flag (SRR) in register SRCx will be set. Whenever a transition according to the selection in bit field CI is detected, the service request flag SRR in register SRC5 is set.

Interrupts of timer T5 are connected with register SRC3.

Interrupts of timer T6 are connected with register SRC4.

Interrupts of the CAPREL function are connected with register SRC5.

SRC3

Service Request Control 3 Register ($F0_H$) **Reset Value: 0000 0000_H**

SRC4

Service Request Control 4 Register (EC_H) **Reset Value: 0000 0000_H**

SRC5

Service Request Control 5 Register ($E8_H$) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SET R	CLR R	SRR	SRE	0	TOS	0	SRPN								
w	w	rh	rw	r	rw	r	rw								

Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number 00 _H Service request is never serviced 01 _H Service request is on lowest priority ... FF _H Service request is on highest priority
TOS	10	rw	Type of Service Control 0 _B CPU service is initiated 1 _B PCP service is initiated
SRE	12	rw	Service Request Enable 0 _B Service request is disabled 1 _B Service request is enabled

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
SRR	13	rh	Service Request Flag 0 _B No service request is pending 1 _B A service request is pending
CLRR	14	w	Request Clear Bit CLRR is required to clear SRR. 0 _B No action 1 _B Clear SRR; bit value is not stored; read always returns 0; no action if SETR is set also.
SETR	15	w	Request Set Bit SETR is required to set SRR. 0 _B No action 1 _B Set SRR; bit value is not stored; read always returns 0; no action if CLRR is set also.
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

Field	Bits	Type	Description
IST4EUD	[9:8]	rw	Input Select for T4EUD 00 _B Signal T4EUDA is selected 01 _B Signal T4EADB is selected 10 _B Signal T4EUDC is selected 11 _B Signal T4EUDD is selected
IST5IN	10	rw	Input Select for T5IN 0 _B Signal T5INA is selected 1 _B Signal T5INB is selected
IST5EUD	11	rw	Input Select for T5EUD 0 _B Signal T5EUDA is selected 1 _B Signal T5EADB is selected
IST6IN	12	rw	Input Select for T6IN 0 _B Signal T6INA is selected 1 _B Signal T6INB is selected
IST6EUD	13	rw	Input Select for T6EUD 0 _B Signal T6EUDA is selected 1 _B Signal T6EADB is selected
ISCAPIN	[15:14]	rw	Input Select for CAPIN 00 _B Signal CAPINA is selected 01 _B Signal CAPINB is selected 10 _B Signal CAPINC (Read trigger from T3) is selected 11 _B Signal CAPIND (Read trigger from T2 or T3 or T4) is selected
0	[31:16]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

CLC

Clock Control Register

(00_H)

Reset Value: 0000 0003_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
r										rw	w	rw	rw	rh	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module. 0 _B Module disable is not requested 1 _B Module disable is requested
DISS	1	rh	Module Disable Status Bit Bit indicates the current status of the module 0 _B Module is enabled 1 _B Module is disabled
SPEN	2	rw	Module Suspend Enable Used for enabling the Suspend Mode. 0 _B Module cannot be suspended (suspend is disabled) 1 _B Module can be suspended (suspend is enabled) This bit can be written only if SBWE is set during the same write operation.
EDIS	3	rw	Sleep Mode Enable Control Used for module Sleep Mode control. 0 _B Sleep Mode request is regarded. Module is enabled to go into Sleep Mode. 1 _B Sleep Mode request is disregarded: Sleep Mode cannot be entered on a request.

General Purpose Timer Units (GPT12)

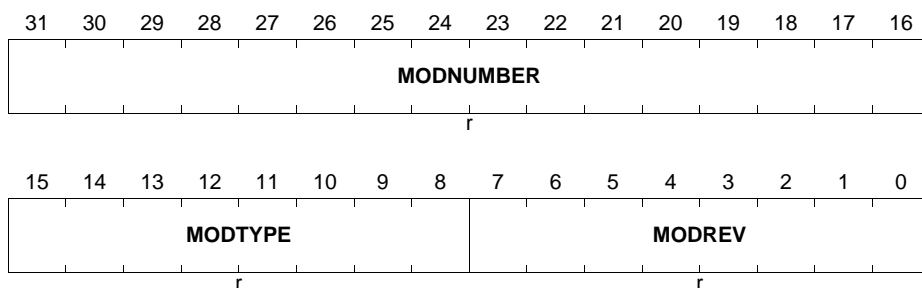
Field	Bits	Type	Description
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected. 0 _B Bits SPEN and FSOE are write-protected 1 _B Bits SPEN and FSOE are overwritten by respective value of SPEN or FSOE Reading this bit returns always 0.
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch-off in Suspend Mode. 0 _B Clock switch-off in Suspend Mode via Disable Control Feature (Secure Clock Switch Off) selected 1 _B Fast clock switch off in Suspend Mode selected This bit can be written only if SBWE is set during the same write operation.
0	[31:7]	r	Reserved Read as 0; should be written with 0.

General Purpose Timer Units (GPT12)

ID

Identification Register

(08_H)

Reset Value: 0068 C0XX_H


Field	Bits	Type	Description
MODREV	[7:0]	r	Module Revision Number This bit field indicates the revision number of the TC1728 module (01 _H = first revision).
MODTYPE	[15:8]	r	Module Type This bit field is C0 _H . It defines a 32-bit module
MODNUMBER	[31:16]	r	Module Number This bit field defines the module identification number. For the GPT12 module the module identification number is 68 _H .

General Purpose Timer Units (GPT12)

25.4 GPT12 Kernel Register Overview

Table 25-20 shows all registers which are required for programming of the GPT12E module. It summarizes the GPT12E kernel registers and the module external registers and defines their addresses and reset values.

Table 25-20 Register Overview of GPT12

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
CLC	Clock Control Register	00 _H	U, SV	SV, E	Application Reset	Page 25-70
PISEL	Port Input Select Register	04 _H	U, SV	U, SV	Application Reset	Page 25-68
ID	Identification Register	08 _H	U, SV	BE	Application Reset	Page 25-72
T2CON	Timer T2 Control Register	10 _H	U, SV	U, SV	Application Reset	Page 25-15
T3CON	Timer T3 Control Register	14 _H	U, SV	U, SV	Application Reset	Page 25-4
T4CON	Timer T4 Control Register	18 _H	U, SV	U, SV	Application Reset	Page 25-17
T5CON	Timer T5 Control Register	1C	U, SV	U, SV	Application Reset	Page 25-47
T6CON	Timer T6 Control Register	20 _H	U, SV	U, SV	Application Reset	Page 25-40
CAPREL	Capture and Reload Register	30 _H	U, SV	U, SV	Application Reset	Page 25-64
T2	Timer T2 Register	34 _H	U, SV	U, SV	Application Reset	Page 25-34
T3	Timer T3 Register	38 _H	U, SV	U, SV	Application Reset	Page 25-34
T4	Timer T4 Register	3C _H	U, SV	U, SV	Application Reset	Page 25-35
T5	Timer T5 Register	40 _H	U, SV	U, SV	Application Reset	Page 25-64
T6	Timer T6 Register	44 _H	U, SV	U, SV	Application Reset	Page 25-64

General Purpose Timer Units (GPT12)

Table 25-20 Register Overview of GPT12

Short Name	Long Name	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
SRC5	Service Request Control Register 5	E8 _H	U, SV	SV	Application Reset	Page 25-66
SRC4	Service Request Control Register 4	EC _H	U, SV	SV	Application Reset	Page 25-66
SRC3	Service Request Control Register 3	F0 _H	U, SV	SV	Application Reset	Page 25-66
SRC2	Service Request Control Register 2	F4 _H	U, SV	SV	Application Reset	Page 25-36
SRC1	Service Request Control Register 1	F8 _H	U, SV	SV	Application Reset	Page 25-36
SRC0	Service Request Control Register 0	FC _H	U, SV	SV	Application Reset	Page 25-36

- 1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

General Purpose Timer Units (GPT12)

25.5 Implementation of the GPT12 Modules

This chapter describes the implementation of the GPT12 modules in the TC1728 device.

25.5.1 Address Map

There are two GPT12 kernels in the TC1728, namely GPT120 and GPT121.

Table 25-21 Registers Address Space

Module	Base Address	End Address	Note
GPT120	F000 3400 _H	F000 34FF _H	
GPT121	F000 3500 _H	F000 35FF _H	

25.5.2 Module Connections

The following tables show the digital connections of the GPT12 modules with other modules or pins in the TC1728 device.

The GPT module is clocked with the FPI_Bus clock, so $f_{\text{GPT}} = f_{\text{FPI}}$.

Table 25-22 GPT120 Digital Connections in TC1728

Signal	from/to Module	I/O to GPT12	Can be used to/as
T2INA	P2.1	I	count input signals for timer T2
T2INB	P1.11	I	
T2EUDA	P4.2	I	direction input signals for timer T2
T2EUSB	P1.9	I	
T3INA	P5.12	I	count input signals for timer T3
T3INB	P8.0	I	
T3INC	0	I	
T3IND	0	I	
T3EUDA	P5.13	I	direction input signals for timer T3
T3EUSB	P8.1	I	
T3EUDC	0	I	
T3EUDD	0	I	
T3OUT	P1.0	O	count output signal for timer T3

General Purpose Timer Units (GPT12)
Table 25-22 GPT120 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to GPT12	Can be used to/as
T4INA	P5.14	I	count input signals for timer T4
T4INB	P8.2	I	
T4INC	0	I	
T4IND	0	I	
T4EUDA	P2.3	I	direction input signals for timer T4
T4EUSB	P1.8	I	
T4EUDC	0	I	
T4EUDD	0	I	
T5INA	0	I	count input signals for timer T5
T5INB	0	I	
T5EUDA	0	I	direction input signals for timer T5
T5EUSB	0	I	
T6INA	0	I	count input signals for timer T6
T6INB	0	I	
T6EUDA	0	I	direction input signals for timer T6
T6EUSB	0	I	
T6OUT	P2.13	O	count output signal for timer T6
T6OFL	CCU60_T12HRF CCU60_T13HRF CCU60_CC62IND	O	over/under-flow signal from timer T6
CAPINA	0	I	input capture signals
CAPINB	P5.0	I	

Table 25-23 GPT121 Digital Connections in TC1728

Signal	from/to Module	I/O to GPT12	Can be used to/as
T2INA	P1.11	I	count input signals for timer T2
T2INB	P2.1	I	
T2EUDA	P1.9	I	direction input signals for timer T2
T2EUSB	P4.2	I	

General Purpose Timer Units (GPT12)
Table 25-23 GPT121 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to GPT12	Can be used to/as
T3INA	P8.0	I	count input signals for timer T3
T3INB	P5.12	I	
T3INC	0	I	
T3IND	0	I	
T3EUDA	P8.1	I	direction input signals for timer T3
T3EADB	P5.13	I	
T3EUDC	0	I	
T3EUDD	0	I	
T3OUT	P0.8	O	count output signal for timer T3
T4INA	P8.2	I	count input signals for timer T4
T4INB	P5.14	I	
T4INC	0	I	
T4IND	0	I	
T4EUDA	P1.8	I	direction input signals for timer T4
T4EADB	P2.3	I	
T4EUDC	0	I	
T4EUDD	0	I	
T5INA	0	I	count input signals for timer T5
T5INB	0	I	
T5EUDA	0	I	direction input signals for timer T5
T5EADB	0	I	
T6INA	0	I	count input signals for timer T6
T6INB	0	I	
T6EUDA	0	I	direction input signals for timer T6
T6EADB	0	I	
T6OUT	P0.9	O	count output signal for timer T6
T6OFL	CCU61_T12HRF CCU61_T13HRF CCU61_CC62IND	O	over/under-flow signal from timer T6

General Purpose Timer Units (GPT12)
Table 25-23 GPT121 Digital Connections in TC1728 (cont'd)

Signal	from/to Module	I/O to GPT12	Can be used to/as
CAPINA	P5.0	I	input capture signals
CAPINB	0	I	

26 Analog to Digital Converter

The **Analog to Digital Converter** module (ADC) of the TC1728 allows the conversion of analog input values into discrete digital values based on the successive approximation method. With this method, the conversion result is elaborated bit by bit, starting with the most significant bit. As a consequence, an analog to digital conversion requires a certain number of clock cycles.

This chapter is structured as follows:

- Introduction (see [Section 26.1](#))
- Operating the ADC (see [Section 26.2](#))
- Module implementation in TC1728 (see [Section 26.3](#))

26.1 Introduction

This section gives an overview about the feature set of the ADC module and introduces the general structure. It describes the:

- ADC block diagram (see [Section 26.1.1](#))
- Feature set description (see [Section 26.1.2](#))
- Abbreviations (see [Section 26.1.3](#))
- Kernel overview (see [Section 26.1.4](#))
- Conversion request handling (see [Section 26.1.5](#))
- Conversion result handling (see [Section 26.1.6](#))
- Interrupt structure (see [Section 26.1.7](#))
- Electrical models (see [Section 26.1.8](#))
- Transfer characteristics and error definitions (see [Section 26.1.9](#))

26.1.1 ADC Block Diagram

The ADC module contains 2 independent kernels (ADC0, ADC1) that can operate autonomously or can be synchronized to each other. An ADC kernel is a unit used to convert an analog input signal into a digital value and provides means for triggering conversions, data handling and storage.

With this structure, parallel conversion of up to two analog input channels is supported.

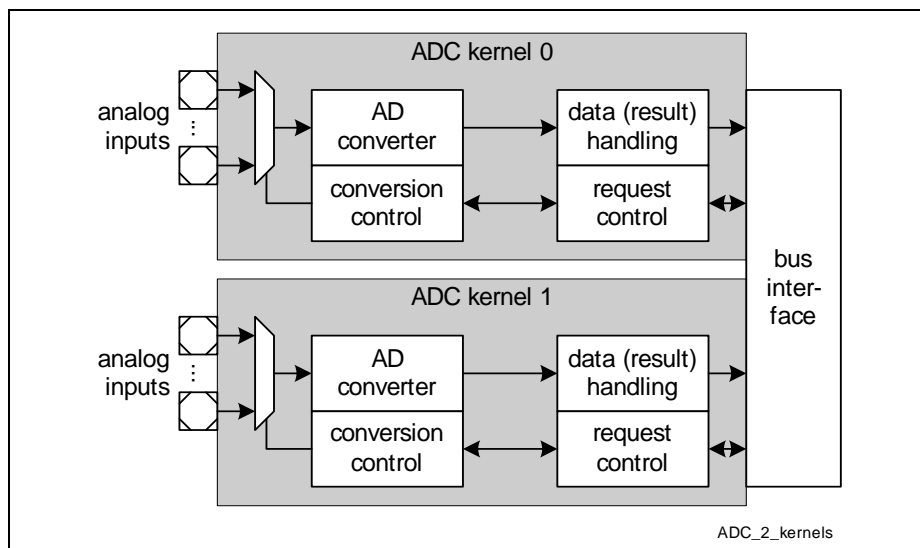


Figure 26-1 ADC Module Block Diagram

26.1.2 Feature Set

Features of each ADC kernel:

- Analog supply voltage range from 3.3 V (minimum) to 5 V (nominal) for V_{DDM}
- Input voltage range from 0 V to analog supply voltage V_{DDM}
- Input multiplexer for a maximum of 24¹⁾ possible analog input channels
- Performance for 12 bit resolution ($@f_{ADC1} = \mathbf{tbd}$ MHz):
 - conversion time less than \mathbf{tbd} μs , \mathbf{tbd} LSB_{12} TUE²⁾ @ supply voltage $V_{DDM} = 5$ V
 - conversion time about \mathbf{tbd} μs , \mathbf{tbd} LSB_{12} TUE @ supply voltage $V_{DDM} = 3.3$ V
- One standard reference input (V_{AREF}) and one alternative reference input (CH0) available
- Broken wire detection support for each input channel
- Multiplexer test support for input channels with odd channel numbers
- 5 conversion request sources for external or timer-driven events, auto-scan, programmable sequences, SW-driven conversions, etc.
- Synchronization of the ADC kernels for concurrent conversion starts and parallel sampling and measuring of analog input signals, e.g. for phase current measurements in AC drives
- Control capability for an external analog multiplexer, respecting the additional set up time
- Adjustable sampling times to accommodate output impedance of different analog signal sources (sensors, etc.)
- Possibility to cancel running conversions on demand with automatic restart
- Flexible interrupt generation (possibility of DMA support)
- Limit checking to reduce interrupt load (e.g. for temperature measurements or overload detection, only values exceeding a programmable level lead to an interrupt)
- Programmable data reduction filter, e.g. for digital anti-aliasing filtering, by adding a programmable number of conversion results
- Independent result registers (16 independent registers)
- Support of conversion result FIFO mechanism to allow a longer interrupt latency
- Support of suspend and power saving modes
- Individually programmable reference selection for each channel, e.g. to allow measurements of 3.3 V and 5 V signals in the full measurement range with the same ADC kernel (with exception of dedicated channels always referring to V_{AREF})

1) ADC1 has max of 24 channels and ADC0 has max of 16 channels.

2) This value reflects the ADC module capability in an adapted electrical environment, e.g. characterized by "clean" routing of analog and digital signals and separation of analog and digital PCB areas, low noise on analog power supply ($< 30\text{mV}$), low switching activity of digital pins near to the ADC, etc.

26.1.3 Abbreviations

The following acronyms and terms are used in the ADC chapter:

Table 26-1 Abbreviations in ADC chapter

Abbreviation	Meaning
ADC	analog to digital converter
DMA	direct memory access mechanism
DNL	differential non-linearity error
FIFO	first-in-first-out data buffer mechanism
INL	integral non-linearity error
LSB _n	finest granularity of the analog value in digital format, represented by one least significant bit of the conversion result with n bits resolution (measurement range divided in 2 ⁿ equally distributed steps)
SCU	system control unit of the device
TUE	total unadjusted error

26.1.4 ADC Kernel Overview

Each ADC kernel comprises:

- An **analog to digital converter** with a maximum of 24 analog inputs (ADC0, CH0 - CH15 and ADC1, CH16-CH39). This block selects an input signal and translates the analog voltage into a digital value.
Not all analog input channels are necessarily available in all packages, please refer to the implementation description in [Section 26.3](#).
- A **conversion control** unit defining the conversion parameters like the length of the sample phase, the resolution and the reference for each conversion. The length of the sample phase and the resolution depend on the type of sensor (or other analog sources) connected to the ADC. These values are similar for several channels and, therefore, are grouped together to form the so-called input classes. Each channel can be individually assigned to an input class to define these parameters.
The conversion control also handles the start conditions for the conversions, such as the immediate start (cancel-inject-repeat), overwrite of former results (wait-for-read), or synchronization of the ADC kernels (parallel conversions).
Additionally, an external analog multiplexer can be controlled by the output signals EMUX[2:0] of each ADC kernel.
- A **request control** unit defining which analog input channel has to be converted next. It contains 5 request sources that can trigger conversions depending on different events, such as edges of PWM or timer signals or events at port pins. Each request source can trigger either 1, up to 4, or up to 16 (ADC0) / 24 (ADC1) conversions in a sequence.
- A **result handling** unit providing 16 result registers for the conversion results. The conversion result of each analog input channel can be directed to one of the result registers to be stored there. The result handling block also supports data reduction (e.g. for digital anti-aliasing filtering) by automatically adding up to 4 conversion results before informing the CPU that new data is available.
Additionally, the results registers can be concatenated to FIFO structures to provide storage capability for more than one conversion result without overwriting previous data. This feature also helps to handle CPU latency effects.
- An **interrupt generation** unit issuing interrupt requests to the CPU depending on ADC events. The interrupt generation in the ADC kernels support different mechanisms, e.g. some interrupts can be coupled to a value range of the conversion result (limit checking), some interrupts can be used to transport conversion data to locations in memory for further treatment, and other interrupts are generated after a complete sequence of conversions.

Analog to Digital Converter

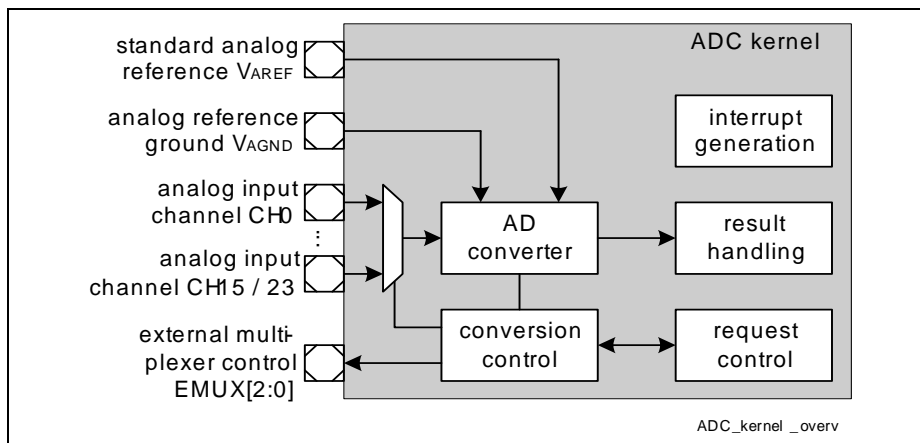


Figure 26-2 ADC Kernel Block Diagram

26.1.5 Conversion Request Unit

The conversion request unit of each ADC kernel autonomously handles the generation of conversion requests.

It contains 5 independent request sources that are connected to several modules to trigger the start of a conversion. A request source defines the analog input channel to be converted if a defined event occurs. For example, a trigger pulse from a timer unit generating a PWM signal can start the conversion of a single input channel or a programmed sequence of input channels.

Depending on the application, the request sources can be triggered by different events, either issued by other modules or under SW control. As a consequence, there can be two or more conversion requests pending at the same time. To allow the user to adapt the request source mechanism to the application needs, the trigger capability, the channel number(s) to be converted, and the priority can be individually programmed for each request source.

An arbiter block regularly scans the request sources for pending conversion requests and acts upon the conversion request with the highest priority. This conversion request is forwarded to the converter to start the conversion of the requested channel.

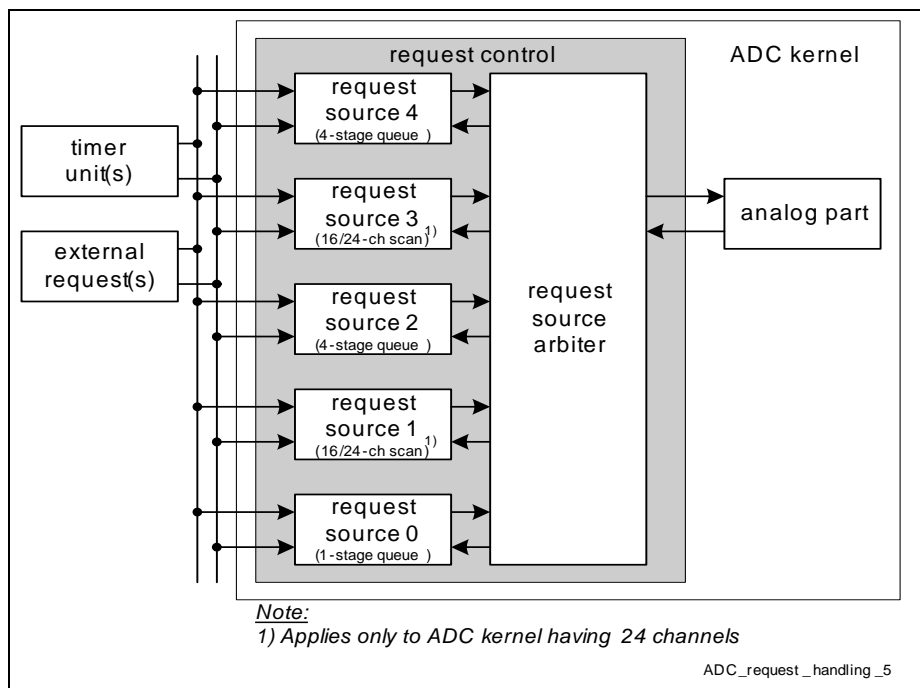


Figure 26-3 Conversion Request Unit

Analog to Digital Converter

The functional characteristics of the request sources are adapted to the most common application requirements. In all request sources, a continuous operation or a single-shot operation can be selected. For continuous operation, the programmed sequence of conversions requests are continuously issued (once started), whereas in single-shot mode, each sequence of conversion requests has to be explicitly started. The trigger for a conversion request or a sequence can be handled under SW control or can be synchronized to ADC-external events, such as timer signals or port pins. For each request source, the user can select an input signal (from 8 possible signals REQTRx_[7:0]) as trigger input REQTRx and an input signal (from 8 possible signals REQGTx_[7:0]) as gating input REQGTx.

- **Request source 0** (1-stage sequential source) can issue a conversion request for a single input channel. The channel number can directly be programmed.
This mechanism could be used for SW-controlled conversion requests or HW-triggered conversions of a single input channel. If programmed with a high priority, it can interrupt the sequences of the other request sources to inject a single conversion.
- **Request sources 1 and 3** (16(ADC0) / 24(ADC1)-channel scan sources) can issue conversion requests for a sequence of up to 24 input channels. It can be programmed which channel takes part in this sequence. The sequence always starts with the highest enabled channel number and continues towards lower channel numbers (order defined by the channel number, each channel can be converted only once per sequence).
This mechanism could be used to scan input channels permanently or on a regular time base. For example, if programmed with a low priority, some input channels can be scanned in a background task to update information that is not time-critical.
- **Request sources 2 and 4** (4-stage sequential sources) can issue a conversion request for a sequence of up to 4 input channels. The channel numbers can be freely programmed, especially multiple conversions of the same channel within the sequence are supported.
This mechanism could be used to support application-specific conversion sequences that can not be covered by the scanning mechanism of request sources 1 or 3. Especially for timing-critical sequences containing multiple conversions of the same channel, one of these request sources should be used. For example, if programmed with a medium priority, some input channels can be converted when a specified event occurs (e.g. synchronized to a PWM) while the scan of other input channels of the background task (handled by request source 1) is interrupted.

26.1.6 Conversion Result Unit

The conversion result unit comprises for each ADC kernel:

- A set of **16 result registers** for storing the conversion results. A pointer mechanism for each analog input channel distributes the conversion results to the result registers. Especially for auto-scan applications, this feature simplifies DMA use (only one DMA channel needed to transfer a complete auto-scan sequence into the device memory).
- The result registers provide **valid flags** to indicate if new data has been stored since it has been read out (new data indication).
- A **result FIFO mechanism** for conversion results handling with a “relaxed” CPU timing. Result registers not directly used as target for a conversion result can be concatenated to form a result FIFO. This structure allows to store a sequence of conversion results before the CPU has to interact.
- A **digital anti-aliasing or data reduction filter**, accumulating a programmable number of conversion results before generating a result event interrupt. This feature can be used to avoid CPU intervention on each conversion result if a certain number of conversion results are added before further treatment, especially for fast conversions sequences and averaging of results.
- A **wait-for-read mechanism** can be enabled independently for each result register to delay conversions targeting a result register that has not yet been read out.
- A **flexible interrupt generation** based on result register events. A result register event occurs if a new valid data word becomes available in a result register and can be read out. Especially when using data reduction or digital anti-aliasing filtering, the result register event indicates that the final result is available.
- **Debugger support** for ADC result registers supporting read out of ADC conversion results without changing the result status (new data indication).

26.1.7 Interrupt Structure

Each ADC kernel provides 8 independent service request output signals (ADCx_SR[7:0]) used for interrupt handling. The interrupt generation inside the ADC kernel is based on three different types of events.

- **Channel events:**

A channel event is detected if a conversion is finished and the conversion result is within a programmable value range.

This type of event can be used to check if analog input values are inside or out of a nominal operating range, especially to reduce CPU load for background tasks. This allows the user to interrupt the CPU only if the specified conversion result range is met (or not met) instead of comparing each result by SW.

- **Result events:**

A result event is detected if a new result is available in a result register and can be read out, e.g. to store the data in memory for further treatment by SW.

This type of event can be used to trigger a read action by the CPU (or DMA). Especially when using data reduction or digital anti-aliasing filtering, not all finished conversion leads to a new result. Furthermore, when using a result FIFO, a result event decouples the CPU (DMA) read out from the channel events and tolerates a higher interrupt latency. The result register structure allows to use a single DMA channel for a complete auto-scan sequence by triggering the read out by a result event (if the conversion results of all channels taking part in the auto-scan sequence target the same result register, e.g. with FIFO mechanism or with a wait-for-read condition to avoid data loss).

- **Request source events:**

A request source event is detected if a scan source has completely finished the requested conversion sequence. For a sequential source, the user can define where inside a conversion sequence a request source event is generated.

This type of event can be used to inform the CPU that a conversion sequence has reached a defined state and SW can start the treatment of the related results in a block.

Each ADC event is indicated by a dedicated flag that can be cleared by SW. An interrupt can be generated (if enabled) for each event, independently from the status of the corresponding event indication flag. This structure ensures efficient DMA handling of ADC events (the ADC event can generate an interrupt without the need to clear the indication flag). A node pointer mechanism allows the user to group interrupts events by selecting which service request output signals SRx becomes activated by which event. Each ADC event can be individually directed to one of the service request output signals to adapt easily to application needs.

Note: A conversion can lead to three interrupts, one of each type. In this case, the ADC module first triggers the request source event interrupt, then the channel event interrupt, followed by the result event interrupt (all within a few f_{ADC} clock cycles).

26.1.8 Electrical Models

Each conversion of an analog input voltage into a digital value consists of two consecutive phases. During the sample phase, the input voltage is sampled and prepared for the following conversion phase. A simplified model for the sample phase describes the input signal path, whereas a second simplified model for the conversion phase is related to the reference voltage handling.

26.1.8.1 Input Signal Path

The ADC kernel in the TC1728 is based on one switched capacitor field for measurement with a total capacity represented by C_{AIN} and a small static capacitor at each input pin. During the sample phase, the capacitor field C_{AIN} is connected to one of the analog input CHx via an input multiplexer. The multiplexer is modeled by ideal switches and series resistors R_{AIN} . Only the switch to the selected analog input is closed during the sample phase. During the conversion phase or while no conversion is running (ADC is idle), all switches are open. The voltage at the analog input channel CHx is represented by V_{AINx} .

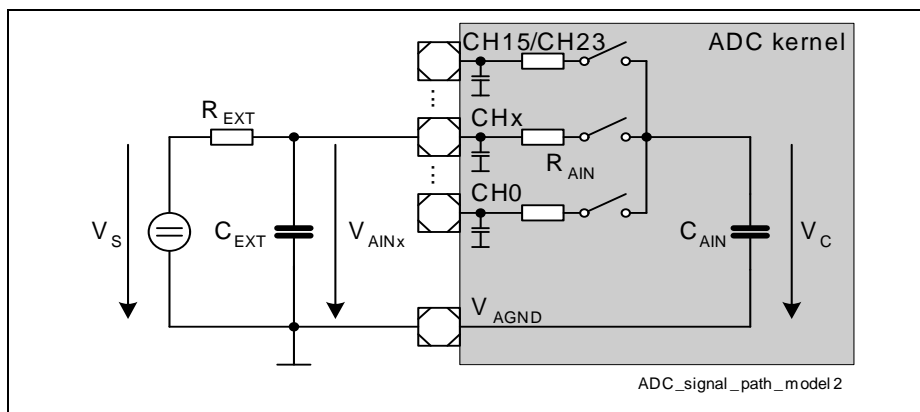


Figure 26-4 Signal Path Model

A simplified model for the analog input signal path is given in [Figure 26-4](#). An analog voltage source (value V_S) with an internal impedance of R_{EXT} delivers the analog input that should be converted.

During the sample phase the corresponding switch is closed and the capacitor field C_{AIN} is charged. Due to the low-pass behavior of the resulting RC combination, the voltage V_C to be actually converted does not immediately follow V_S . The value R_{EXT} of the analog voltage source and the desired precision of the conversion strongly define the required length of the sample phase.

To reduce the influence of R_{EXT} and to filter input noise, it is recommended to introduce

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a fast external blocking capacitor C_{EXT} at the analog input pin of the ADC. Like this, mainly C_{EXT} delivers the charge during the sample phase. This structure allows a significantly shorter sample phase than without a blocking capacitor, because the low-pass time constant defining the sample time is mainly given by the values of R_{AIN} and C_{AIN} .

Additionally, the capacitor C_{AIN} is automatically precharged to a voltage of approximately the half of the standard reference voltage V_{AREF} to minimize the average difference between V_{AINx} and V_C at the beginning of a sample phase. Due to varying parameters and parasitic effects, the precharge voltage of C_{AIN} is typically smaller than $V_{AREF} / 2$.

On the other hand, the charge redistribution between C_{EXT} and C_{AIN} leads to a voltage change of V_{AINx} during the sample phase. In order to keep this voltage change lower than 1 LSB_n, it is recommended to use an external blocking capacitor C_{EXT} in the range of at least $2^n \times C_{AIN}$.

The resulting low-pass filter of R_{EXT} and C_{EXT} should be dimensioned in a way to allow V_{AINx} to follow V_S between two sample phases of the same analog input channel.

Please note that, especially at high temperatures, the analog input structure of an ADC can lead to a leakage current and introduces an error due to a voltage drop over R_{EXT} . The ADC input leakage current increases if the input voltage level is close to the analog supply ground V_{SSM} or to the analog power supply V_{DDM} . It is recommended to use an operating range for the input voltage between approximately 3% and 97% of V_{DDM} to reduce input leakage values.

Furthermore, the leakage is influenced by an overload condition at adjacent analog inputs. During an overload condition, an input voltage exceeding the supply range is applied at an input and the built-in protection circuit limits the resulting input voltage. This leads to an overload current through the protection circuit that is translated (by a coupling factor) into an additional leakage at adjacent inputs.

26.1.8.2 Reference Path

During the conversion phase, parts of the capacitor field C_{AIN} are switched to a reference input or to V_{AGND} . The ADC kernel supports two possible reference inputs, V_{AREF} as standard reference and CH0 as alternative reference. The reference selection between both possibilities is handled individually for each analog input channel. For example, this structure allows conversions of 5 V and 3.3 V based analog input signals with the same ADC kernel.

A high accuracy of the conversion results requires a stable and noise-free reference voltage and analog supply voltages during the conversion phase. Instable voltages or noise on the supply or reference inputs lead to a reduced conversion accuracy. Please note that noise can also be introduced into the ADC module by other modules, e.g. by switching of neighboring pins. It is strongly recommended to carefully decouple analog from digital signal domains.

Due to the switching of parts of C_{AIN} , the ADC requires a dynamic current at the selected reference input. Thus, the impedance R_{AREF} of the reference voltage source V_R has to

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be low enough to supply the reference current during the conversion phase. An external blocking capacitor C_{AREF} should be used to supply the peak currents and to minimize the current delivered by the reference source.

Due to the charge redistribution between C_{AREF} and parts of C_{AIN} , the voltage V_{AREF} decreases during the conversion phase. In order to limit the error introduced by this effect to $1/2 \text{ LSB}_n$, the external blocking capacitor C_{AREF} for the reference input should be at least $2^n \times C_{AIN}$.

The reference current I_{AREF} introduces a voltage drop at R_{AREF} that should not be neglected for the calculation of the overall accuracy. The average reference current during a conversion depends on the reference voltage level and the time t_{CONV} between two conversion starts.

$$I_{AREF} = C_{AIN} \times V_{AREF} / t_{CONV}$$

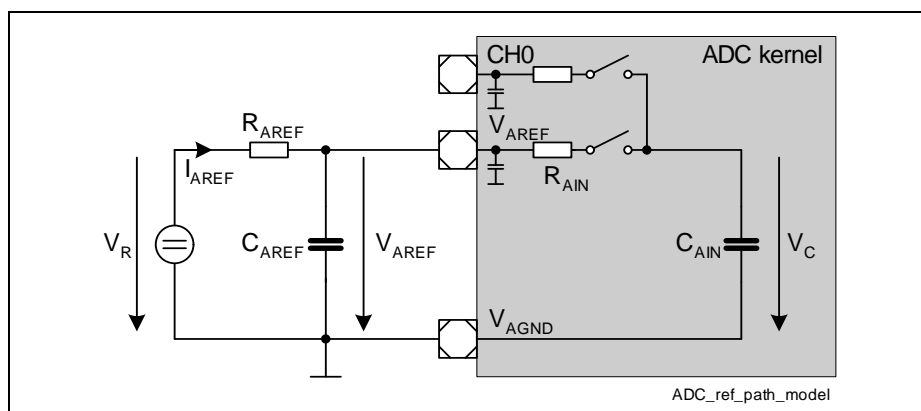


Figure 26-5 Reference Path Model

26.1.9 Transfer Characteristics and Error Definitions

The ideal transfer characteristic of the ADC translates a continuous analog input voltage into a discrete digital value out of a result range of 2^n steps for n bit resolution over a measurement range between 0 and a reference voltage. Each digital value in the available result range (from 0 to 2^n-1) represents an input voltage range that is defined by the reference voltage divided by 2^n . This range (called quantization step) represents the smallest granularity (called LSB_n) that can be handled by the ADC. Due to the discrete character of the digital result, each ADC conversion result has a system-inherent quantization uncertainty of $\pm 0.5 LSB_n$. According to the ideal transfer characteristics, the first digital transition (between the digital values 0 and 1) takes place when the analog input reaches $0.5 LSB_n$.

An analog input voltage above the reference voltage leads to a saturation of the digital result at 2^n-1 .

Deviations of the conversion result from the ideal transfer characteristics can appear:

- An **offset error** is the deviation from the ideal transfer characteristics for an input voltage close to 0. It describes the difference between $0.5 LSB_n$ and the input voltage where the first digital transition (between the values of 0 and 1) occurs.
- A **gain error** is the deviation from the ideal transfer characteristics for an input voltage close to the reference voltage. It describes the difference between the reference voltage and the input voltage where the last digital transition (between the values of 2^n-2 and 2^n-1) occurs.
- A **differential non-linearity error** (DNL) describes the variations in the analog input voltage between two adjacent digital conversion results, over the full measurement range. If each step between the digital conversion results x and $x+1$ is exactly $1 LSB_n$, the DNL value is zero. If the DNL value is lower than $1 LSB_n$, the possibility of missing codes is excluded. A missing code occurs if not all values of the possible conversion result range can be reached.
- An **integral non-linearity error** (INL) describes the maximum difference between the transfer characteristics between the first and the last point of the measurement range and the real transfer characteristics (without quantization uncertainty, offset and gain errors).
- The **total unadjusted error** (TUE) describes the maximum deviation between a real conversion result and the ideal transfer characteristics over a given measurement range. Since some of these errors noted above can compensate each other, the TUE value generally is much less than the sum of the individual errors.
The TUE also covers production process variations and internal noise effects (if switching noise is generated by the system, this generally leads to an increased TUE value).

26.2 Operating the ADC

This section describes the kernel functions and how to operate the kernel. It provides the functional descriptions and the associated register descriptions.

- Register overview (see [Section 26.2.1](#))

General module, kernel and arbiter operation:

- Enabling the ADC module for configuration of the behavior for the different device operating modes (see mode control description in [Section 26.2.2](#)).
- Enabling the converter for operation or selecting the desired power saving mode (see [Section 26.2.3](#))
- Selecting the appropriate frequency for the converter and for the request source arbiter (see [Section 26.2.4](#)).
- ADC module registers (see [Section 26.2.5](#))
- General ADC kernel registers (see [Section 26.2.6](#))
- Configuring the request source arbiter (see [Section 26.2.7](#))
- Arbiter registers (see [Section 26.2.8](#))

Request source operation:

- Scan request source handling (see [Section 26.2.9](#))
- Scan request source registers (see [Section 26.2.10](#))
- Sequential request source handling (see [Section 26.2.11](#))
- Sequential request source registers (see [Section 26.2.12](#))

Channel and result register operation:

- Configuring the channel-related functions (see [Section 26.2.13](#))
- Channel-related registers (see [Section 26.2.14](#))
- Conversion result handling (see [Section 26.2.15](#))
- Conversion request handling (see [Section 26.2.16](#))

Additional features:

- Multiplexer test support (see [Section 26.2.17](#))
- External multiplexer control (see [Section 26.2.18](#))
- Synchronization for parallel conversions (see [Section 26.2.19](#))
- Equidistant sampling (see [Section 26.2.20](#))
- Access protection (see [Section 26.2.21](#))
- Broken-wire detection (see [Section 26.2.22](#))
- Additional feature registers (see [Section 26.2.23](#))

26.2.1 Register Overview

Table 26-2 shows all registers required for programming the ADC module. It summarizes the ADC kernel registers and defines their relative addresses and the reset values. The relative addresses have to be added to the base addresses for the ADC kernels (see [Section 26.3](#)) to obtain the absolute address for each register. Each ADC kernel is located in an address window of $4 * 256$ bytes.

All registers can be accessed with 8 bit, 16 bit, or 32 bit wide accesses.

The prefix “**ADCx_**” has to be added to the register names in this table for each ADC kernel to distinguish registers of the different kernels. In this naming convention, x indicates the kernel number (e.g. ADC0_ for the ADC0 kernel and “ADC1_” for the ADC1 kernel).

The registers that are implemented only once in the ADC module are located in the address range of ADC0.

All ADC registers (including KSCFG.NOMCFG and KSCFG.COMCFG) are reset by an application reset (class 3), whereas bit field KSCFG.SUMCFG is reset by a debug reset (class 1).

Note: Register bits marked “w” always deliver 0 when read.

Access rights within the address range of an ADC kernel:

- Read or write access to defined register addresses: U, SV
- Accesses to empty addresses: reserved, BE¹⁾

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		

ADC Module Registers (only available in the address range of ADC0)

CLC	Clock Control Register	000 _H	U, SV	SV, E	Class 3	Page 26-26
KSCFG	Kernel State Configuration Register	00C _H	U, SV	SV, E	Class 3	Page 26-27
SRCx x = 0 - 5	Service Request Control Registers	3FC _H - x * 4 _H	U, SV	U, SV	Class 3	Page 26-29
SLCON	Supply Level Control Register	290 _H	U, SV	SV, E	Power-on Reset	Page 26-30

1) Read/Write access to F0101268_H - F010126C_H, F01013DC_H - F01013E4_H, F010166C_H, F0101720_H - F010173C_H - reserved, no BE.

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		

General Kernel Registers

ID	Module Identification Register	008 _H	U, SV	U, SV	Class 3	Page 26-34
RSIRx (x = 0 - 4)	Request Source x Input Register	010 _H + x * 4	U, SV	U, SV	Class 3	Page 26-31
INTR	Interrupt Activation Register	204 _H	U, SV	U, SV	Class 3	Page 26-35
GLOBCTR	Global Control Register	030 _H	U, SV	U, SV	Class 3	Page 26-36
GLOBCFG	Global Configuration Register	034 _H	U, SV	U, SV	Class 3	Page 26-39
GLOBSTR	Global Status Register	038 _H	U, SV	U, SV	Class 3	Page 26-41

Arbiter Registers

ASENR	Arbitration Slot Enable Register	03C _H	U, SV	U, SV	Class 3	Page 26-49
RSPR0	Request Source Priority Register 0	040 _H	U, SV	U, SV	Class 3	Page 26-50
RSPR4	Request Source Priority Register 4	044 _H	U, SV	U, SV	Class 3	Page 26-51

Request Source 0 Registers (available in the address range of each kernel)

QMR0	Queue 0 Mode Register	080 _H	U, SV	U, SV	Class 3	Page 26-68
QSR0	Queue 0 Status Register	084 _H	U, SV	U, SV	Class 3	Page 26-71
Q0R0	Queue 0 Register 0	088 _H	U, SV	U, SV	Class 3	Page 26-73
QBUR0	Queue 0 Backup Register	08C _H	U, SV	U, SV	Class 3	Page 26-75

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
QINR0	Queue 0 Input Register	08C _H	U, SV	U, SV	Class 3	Page 26-77

Request Source 1 Registers (available in the address range of each kernel)

CRCR1	Conversion Request 1 Control Register	090 _H	U, SV	U, SV	Class 3	Page 26-56
CRPR1	Conversion Request 1 Pending Register	094 _H	U, SV	U, SV	Class 3	Page 26-58
CRMR1	Conversion Request 1 Mode Register	098 _H	U, SV	U, SV	Class 3	Page 26-60

Request Source 2 Registers (available in the address range of each kernel)

QMR2	Queue 2 Mode Register	0A0 _H	U, SV	U, SV	Class 3	Page 26-68
QSR2	Queue 2 Status Register	0A4 _H	U, SV	U, SV	Class 3	Page 26-71
Q0R2	Queue 2 Register 0	0A8 _H	U, SV	U, SV	Class 3	Page 26-73
QBUR2	Queue 2 Backup Register	0AC _H	U, SV	U, SV	Class 3	Page 26-75
QINR2	Queue 2 Input Register	0AC _H	U, SV	U, SV	Class 3	Page 26-77

Request Source 3 Registers (available in the address range of each kernel)

CRCR3	Conversion Request 3 Control Register	0B0 _H	U, SV	U, SV	Class 3	Page 26-56
CRPR3	Conversion Request 3 Pending Register	0B4 _H	U, SV	U, SV	Class 3	Page 26-58
CRMR3	Conversion Request 3 Mode Register	0B8 _H	U, SV	U, SV	Class 3	Page 26-60

Request Source 4 Registers (available in the address range of each kernel)

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
QMR4	Queue 4 Mode Register	0C0 _H	U, SV	U, SV	Class 3	Page 26-68
QSR4	Queue 4 Status Register	0C4 _H	U, SV	U, SV	Class 3	Page 26-71
Q0R4	Queue 4 Register 0	0C8 _H	U, SV	U, SV	Class 3	Page 26-73
QBUR4	Queue 4 Backup Register	0CC _H	U, SV	U, SV	Class 3	Page 26-75
QINR4	Queue 4 Input Register	0CC _H	U, SV	U, SV	Class 3	Page 26-77

Channel Registers (available in the address range of each kernel)

CHCTR _x (x = 0 -15)	Channel x Control Register	100 _H + x * 4	U, SV	U, SV	Class 3	Page 26-84
ADC1_CH CTR _x (x = 16 -23)	Channel x Control Register	2C0 _H + x * 4	U, SV	U, SV	Class 3	Page 26-84
INPCR _x (x = 0 -3)	Input Class x Register	050 _H + x * 4	U, SV	U, SV	Class 3	Page 26-87
ALR0	Alias Register 0	210 _H	U, SV	U, SV	Class 3	Page 26-88
LCBR _x (x = 0 - 3)	Limit Check Boundary Register x	0F0 _H + x * 4	U, SV	U, SV	Class 3	Page 26-89
CHFR	Channel Flag Register	060 _H	U, SV	U, SV	Class 3	Page 26-90
CHFCR	Channel Flag Clear Register	064 _H	U, SV	U, SV	Class 3	Page 26-91
CHENPR0	Channel Event Node Pointer Register 0	068 _H	U, SV	U, SV	Class 3	Page 26-92
CHENPR8	Channel Event Node Pointer Register 8	06C _H	U, SV	U, SV	Class 3	Page 26-93
ADC1_CH ENPR16	Channel Event Node Pointer Register 16	268 _H	U, SV	U, SV	Class 3	Page 26-94

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		

Result Registers (available in the address range of each kernel)

RESR0	Result Register 0	180 _H	U, SV	U, SV	Class 3	Page 26-103
RESRx (x = 1 - 15)	Result Register x	180 _H + x * 4	U, SV	U, SV	Class 3	Page 26-106
RESRD0	Result Register 0 for Debugging	1C0 _H	U, SV	U, SV	Class 3	Page 26-103
RESRDx (x = 1 - 15)	Result Register x for Debugging	1C0 _H + x * 4	U, SV	U, SV	Class 3	Page 26-106
VFR	Valid Flag Register	200 _H	U, SV	U, SV	Class 3	Page 26-109
RCRx (x = 0 - 15)	Result Control Register x	140 _H + x * 4	U, SV	U, SV	Class 3	Page 26-110
EVFR	Event Flag Register	070 _H	U, SV	U, SV	Class 3	Page 26-112
EVFCR	Event Flag Clear Register	074 _H	U, SV	U, SV	Class 3	Page 26-114
EVNPR	Source Event Node Pointer Register	078 _H	U, SV	U, SV	Class 3	Page 26-115
RNPR0	Result Node Pointer Register 0	208 _H	U, SV	U, SV	Class 3	Page 26-116
RNPR8	Result Node Pointer Register 8	20C _H	U, SV	U, SV	Class 3	Page 26-117

Additional Feature Registers (available in the address range of each kernel)

APR	Access Protection Register	218 _H	U, SV	SV, E	Class 3	Page 26-130
EMCTR	External Multiplexer Control Register	220 _H	U, SV	U, SV	Class 3	Page 26-131
SYNCTR	Synchronization Control Register	048 _H	U, SV	U, SV	Class 3	Page 26-135

Table 26-2 Register Overview of ADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
BWDENR	Broken Wire Detection Enable Register	224 _H	U, SV	U, SV	Class 3	Page 26-137
BWDCFG R	Broken Wire Detection Configuration Register	228 _H	U, SV	U, SV	Class 3	Page 26-138

1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

26.2.2 Mode Control

The mode control concept for system control tasks, such as suspend request for debugging, allows to program the module behavior under different device operating conditions. The behavior of the ADC kernels can be programmed for each of the device operating modes. It is advantageous that the ADC kernels of an ADC module show an identical behavior regarding the device operating modes (e.g. to avoid that a non-suspended kernel waits for a suspended kernel to start a synchronized conversion). Therefore, the ADC module has a common associated register **ADC0_KSCFG** defining the behavior of all kernels of the module in the following device operating modes:

- **Normal operation:**
This operating mode is the default operating mode when no suspend request is pending. The kernel behavior is defined by KSCFG.NOMCFG.
- **Suspend mode:**
This operating mode is requested when a suspend request (issued by a debugger) is pending in the device. The kernel behavior is defined by KSCFG.SUMCFG.

For the ADC module, the following internal actions can be influenced by mode control:

- A current conversion of an analog value:
If the request control unit has found a pending conversion request, the conversion can be started. This start has to be enabled by the mode control. If the current kernel mode allows the conversion start (run modes 0 and 1), it will be executed. If the kernel mode does not allow a start (stop modes 0 and 1), the conversion is not started. The start request is not cancelled, but frozen. A “frozen” conversion is started as programmed if the kernel mode is changed to a run mode again.
- An arbiter round:
The start of a new arbiter round has to be enabled by the kernel modes. In stop mode 1, a new arbiter round will not start.

The behavior of the ADC kernels can be programmed for each of the device operating modes (normal operation, suspend mode). Therefore, the ADC kernels support four kernel modes, as shown in **Table 26-3**.

Table 26-3 ADC Kernel Behavior

Kernel Mode	Kernel Behavior	Code
run mode 0	kernel operation as specified, no impact on data transfer (same behavior for run mode 0 and run mode 1)	00 _B
run mode 1		01 _B

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Table 26-3 ADC Kernel Behavior (cont'd)

Kernel Mode	Kernel Behavior	Code
stop mode 0	A currently running AD conversion is completely finished and the result is treated. Pending conversion request to start a new conversion are not taken into account (but not deleted). They start conversions after entering a run mode as programmed. The arbiter continues as programmed.	10 _B
stop mode 1	Like stop mode 0, but the arbiter is stopped after it has finished its arbitration round.	11 _B

Generally, bit field KSCFG.NOMCFG should be configured for run mode 0 as default setting for standard operation. If the ADC kernels should not react to a suspend request (and to continue operation as in normal mode), bit field KSCFG.SUMCFG has to be configured with the same value as KSCFG.NOMCFG. If the ADC kernels should show a different behavior and stop operation when a specific stop condition is reached, the code for stop mode 0 or stop mode 1 has to be written to KSCFG.SUMCFG.

Note: The stop mode selection strongly depends on the application needs and it is very unlikely that different stop modes are required in parallel in the same application. As a result, only one stop mode type (either 0 or 1) should be used in the bit fields in register KSCFG. Do not mix stop mode 0 and stop mode 1 and avoid transitions from stop mode 0 to stop mode 1 (or vice versa) for the ADC module.

26.2.3 Module Activation and Power Saving Modes

The converter of the ADC supports specific power down modes allowing an automatic reduction of the power consumption between two conversions. The following modes are determined by bit field **GLOBSTR**.ANON:

- ANON = 00_B: **Converter switched off** (default after reset)
The complete converter is switched off and held in its reset state, conversions are not possible. To start a conversion, ANON has to be programmed to the desired mode. A maximum wake-up time of about 10 µs has to be respected before starting a conversion. Furthermore, digital logic blocks are set to their initial state.
- ANON = 01_B and 10_B: **Reserved**
These modes are reserved and must not be selected.
- ANON = 11_B: **Normal operation**
Conversions are always possible with the desired sample time. The converter stays active permanently.

26.2.4 Clocking Scheme

The different parts of an ADC kernel are driven by clock signals that are based on the clock f_{ADC} of the bus that is used to access the ADC module.

- The analog clock f_{ADCI} is used as internal clock for the converter and defines the conversion length and the sample time. It can be adjusted by programming bit field **GLOBCTR.DIVA**.
- The digital clock f_{ADCD} is used for the arbiter and defines the duration of an arbiter round. It can be adjusted by programming bit field **GLOBCTR.DIVD**.
- All other digital structures (such as interrupts, etc.) are directly driven by the module clock f_{ADC} .

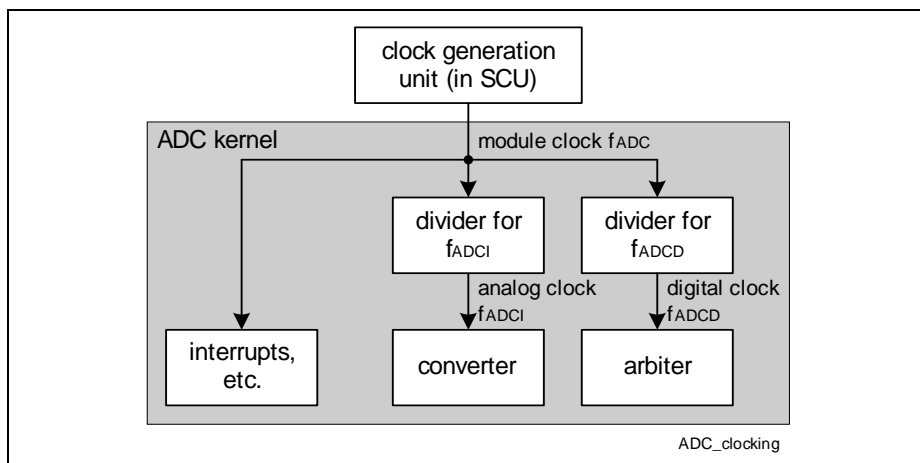


Figure 26-6 Clocking Scheme

Note: If the clock generation for the converter of the ADC falls below a minimum value or is stopped during a running conversion, the conversion result can be corrupted. For correct ADC results, the frequency of f_{ADCI} must not exceed the range indicated in the electrical characteristics chapter.

26.2.5 ADC Module Registers

26.2.5.1 Clock Control Register

The clock control register allows the programmer to control (enable/disable) the clock signals to the ADC module.

ADC0_CLC

ADC Clock Control Register

(000_H)

Reset Value: 0000 0003_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
r										rw	w	rw	rw	r	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used to switch off fast clock in Suspend Mode.
0	[31:6]	r	Reserved ; returns 0 if read; should be written with 0.

Note: After a hardware reset operation, the f_{CLC} and f_{ADC} clocks are switched off and the ADC module is disabled (DISS set).

26.2.5.2 Kernel State Configuration Register

The kernel state configuration register KSCFG allows the selection of the desired kernel modes. The ADC kernels are controlled by the same register ADC0_KSCFG.

All bits in KSCFG, except KSCFG.SUMCFG are reset by an application (class3) reset.

Bit field KSCFG.SUMCFG is reset by the debug reset.

If a module should be switched off, SW can program a stop mode in bit field NOMCFG and check for ACK = 1 afterwards.

Note: The coding of the bit fields NOMCFG, SUMCFG and COMCFG is described in Table 26-3.

ADC0_KSCFG

Kernel State Configuration Register (00C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		0		BP SUM	0	SUMCFG	BP NOM	0	NOMCFG	SUS REQ	ACK			0	
		r		w	r	rw	w	r	rw	rh	rh			r	

Field	Bits	Type	Description
ACK	2	rh	Module Acknowledge This bit monitors the state of the ADC module's acknowledge on incoming requests. 0 _B The acknowledge is not activated, because at least one of the module kernels is in a transition phase. 1 _B The acknowledge is activated, because all module kernels have reached the requested state.
SUSREQ	3	rh	Suspend Request This bit monitors the state of the ADC module's suspend request input. 0 _B A suspend mode is not requested and bit field NOMCFG defines the ADC kernel mode. 1 _B A suspend mode is requested and bit field SUMCFG defines the ADC kernel mode.

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Field	Bits	Type	Description
NOMCFG	[5:4]	rw	Normal Operation Mode Configuration This bit field defines the kernel mode applied in normal operation mode. 00 _B Run mode 0 is selected. 01 _B Run mode 1 is selected. 10 _B Stop mode 0 is selected. 11 _B Stop mode 1 is selected.
BPNOM	7	w	Bit Protection for NOMCFG This bit enables the write access to the bit field NOMCFG. It always reads 0. 0 _B The bit field NOMCFG is not changed. 1 _B The bit field NOMCFG is updated with the written value.
SUMCFG	[9:8]	rw	Suspend Mode Configuration This bit field defines the kernel mode applied in suspend mode. Coding like NOMCFG.
BPSUM	11	w	Bit Protection for SUMCFG This bit enables the write access to the bit field SUMCFG. It always reads 0. 0 _B The bit field SUMCFG is not changed. 1 _B The bit field SUMCFG is updated with the written value.
0	[1:0], 6, 10, [31:12]	r	Reserved Read as 0; should be written with 0.

26.2.5.3 Service Request Control Registers

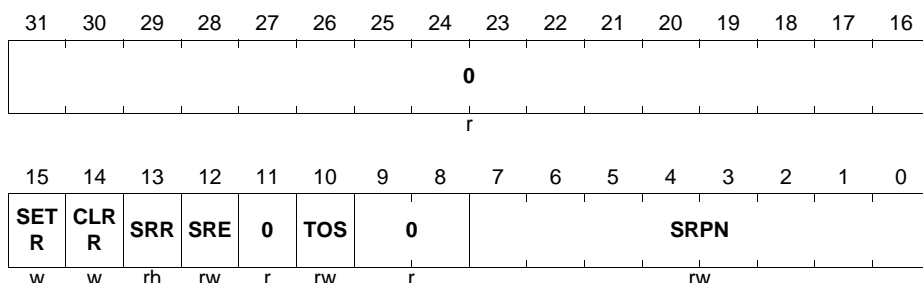
The service request control registers of the ADC module are located in the address range of ADC0.

ADC0_SRCx (x = 0-5)

ADC Service Request Control Register x

($3FC_H - x \cdot 4$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0; should be written with 0.

Note: Additional details on service request nodes and the service request control registers are described in the TC1728 System Units part (Volume 1).

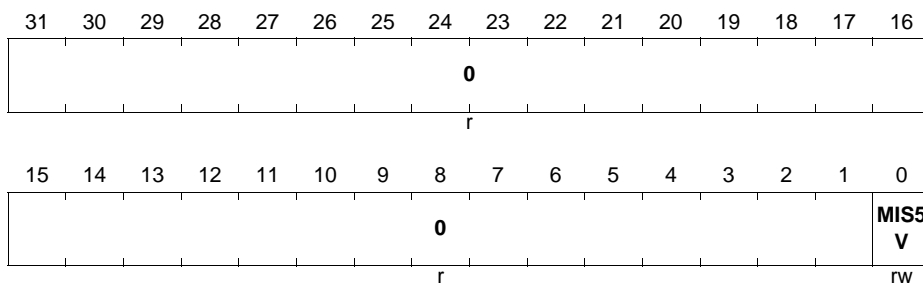
26.2.5.4 Supply Level Control Register

The SLCON register is used to control the power supply to the ADC module. When an external 5V supply is present at Vddm, bit 0 of SLCON register has to be set to 0. And when no 5V supply is present at Vddm, bit 0 of SLCON register has to be set to 1.

ADC0_SLCON

Supply Level Control Register

(290_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
MIS5V	0	rw	5V Supply Missing This bit field controls the power supply to the ADC. 0 _B 5V supply is available on Vddm. 1 _B 5V supply is not available on Vddm.
0	[31:1]	r	Reserved Read as 0; should be written with 0.

26.2.6 General ADC Kernel Registers

26.2.6.1 Request Source Input Registers

The setting of the request source input registers selects the desired input signal for the gating and trigger signals of the request sources. The status of the selected inputs is monitored. Additionally, the edge sensitivity for the trigger signal and the timer mode for equidistant sampling can be enabled/disabled.

The actual connections depending on the device implementation, please refer to the implementation description in [Section 26.3](#) for details.

Note: Signals from a synchronous domain can of course be connected to inputs with a synchronization stage. The additional synchronization delay of two ADC module clock cycles and an additional uncertainty of one ADC module clock cycle for asynchronous signals have to be taken into account when using a synchronization stage.

RSIRx (x = 0 - 4)

Request Source x Input Register ($010_H + x * 4$)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TRI	0	R EN	F EN	0	TRSEL		GTI		0	TM EN	0	GTSEL			
rh	r	rw	rw	r	rw		rh		r	rw	r	rw			

Field	Bits	Type	Description
GTSEL	[2:0]	rw	Input Selection for REQGT of Source x This bit field defines the input signal used for request gating in request source x. The inputs selected by codes 0XX _H are considered as synchronous to the ADC module. The inputs selected by codes 1XX _H are considered as asynchronous to the ADC module. 000 _B The input signal REQGTx_0 is selected. 001 _B The input signal REQGTx_1 is selected. 010 _B The input signal REQGTx_2 is selected. 011 _B The input signal REQGTx_3 is selected. 100 _B The input signal REQGTx_4 is selected. 101 _B The input signal REQGTx_5 is selected. 110 _B The input signal REQGTx_6 is selected. 111 _B The input signal REQGTx_7 is selected.
TMEN	4	rw	Timer Mode Enable of Source x This bit enables the timer mode for equidistant sampling for request source x. 0 _B The timer mode is disabled. The standard gating mechanism can be used. 1 _B The timer mode for equidistant sampling is enabled. The standard gating mechanism has to be disabled.
GTI	7	rh	Gating Input of Source x This flag monitors the status of the selected gating signal REQGTx for request source x. 0 _B The selected gating signal is 0. 1 _B The selected gating signal is 1.

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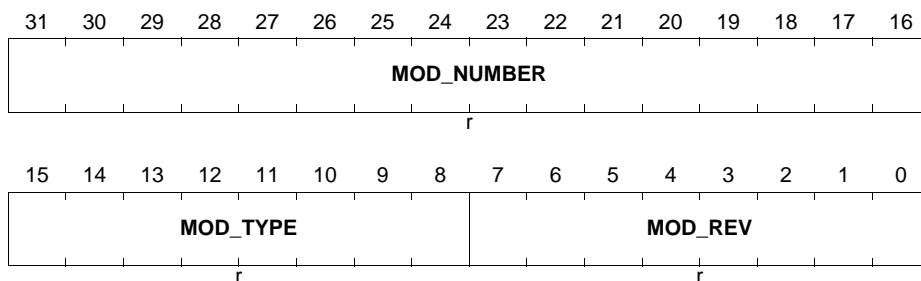
Field	Bits	Type	Description
TRSEL	[10:8]	rw	Input Selection for REQTR of Source x This bit field defines the input signal used for request triggering in request source x. The inputs selected by codes 0XX _H are considered as synchronous to the ADC module. The inputs selected by codes 1XX _H are considered as asynchronous to the ADC module. 000 _B The input signal REQTRx_0 is selected. 001 _B The input signal REQTRx_1 is selected. 010 _B The input signal REQTRx_2 is selected. 011 _B The input signal REQTRx_3 is selected. 100 _B The input signal REQTRx_4 is selected. 101 _B The input signal REQTRx_5 is selected. 110 _B The input signal REQTRx_6 is selected. 111 _B The input signal REQTRx_7 is selected.
FEN	12	rw	Falling Edge Enable of Source x This bit enables the request trigger for falling edges of the selected REQTRx signal for request source x. 0 _B The request trigger with a falling edge is disabled. 1 _B The request trigger with a falling edge is enabled.
REN	13	rw	Rising Edge Enable of Source x This bit enables the request trigger for rising edges of the selected REQTRx signal for request source x. 0 _B The request trigger with a rising edge is disabled. 1 _B The request trigger with a rising edge is enabled.
TRI	15	rh	Trigger Input of Source x This flag monitors the status of the selected trigger signal REQTRx for request source x. 0 _B The selected trigger signal is 0. 1 _B The selected trigger signal is 1.
0	3, [6:5], 11, 14, [31:16]	r	Reserved Read as 0; should be written with 0.

26.2.6.2 Module Identification Register

ID

Module Identification Register

(008_H)

Reset Value: 005A C0XX_H


Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision This bit field indicates the revision number of the module implementation (depending on the design step). The given value of 00 _H is a placeholder for the actual number. Bits [3:0] refer to the version of the digital part and bits [7:4] indicate the version of the analog part (anid).
MOD_TYPE	[15:8]	r	Module Type
MOD_NUMBER	[31:16]	r	Module Number

26.2.6.4 Global Control

The global control register contains bits to control the arbiter timing and the general enable function for the analog part.

GLOBCTR

Global Control Register

(030_H)

Reset Value: 0000 00FF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARB M	0			ARBRND		ANON		DIVD		DIVA					
rw	rw			rw		rw		rw		rw					

Field	Bits	Type	Description
DIVA	[5:0]	rw	Divider Factor for Analog Internal Clock This bit field defines the number of f_{ADC} clock cycles to generate the f_{ADCI} clock for the converter (used as internal base for the conversions and the sample time calculation). The minimum divider is 4. 00 _H $f_{ADCI} = f_{ADC} / 4$ 01 _H $f_{ADCI} = f_{ADC} / 4$ 02 _H $f_{ADCI} = f_{ADC} / 4$ 03 _H $f_{ADCI} = f_{ADC} / 4$ 04 _H $f_{ADCI} = f_{ADC} / 4$ 05 _H $f_{ADCI} = f_{ADC} / 5$ 06 _H $f_{ADCI} = f_{ADC} / 6$ 07 _H $f_{ADCI} = f_{ADC} / 7$... 3F _H $f_{ADCI} = f_{ADC} / 63$

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Field	Bits	Type	Description
DIVD	[7:6]	rw	Divider Factor for Digital Arbiter Clock This bit field defines the number of f_{ADC} clock cycles within each arbitration slot (each arbitration slots last one periods of f_{ADCD}). It is recommended to use the default setting 00_B to obtain the minimum arbiter reaction time. $00_B \quad f_{ADCD} = f_{ADC}$ $01_B \quad f_{ADCD} = f_{ADC} / 2$ $10_B \quad f_{ADCD} = f_{ADC} / 3$ $11_B \quad f_{ADCD} = f_{ADC} / 4$
ANON	[9:8]	rw	Analog Part Switched On This bit field defines the setting of bit field GLOBSTR .ANON (bit description see there) if this kernel is the synchronization master or without synchronization feature. For a synchronization slave, this bit field is not taken into account.
ARBRND	[11:10]	rw	Arbitration Round Length This bit field defines the number of arbitration slots per arbitration round (arbitration round length = t_{ARB}). 00_B An arbitration round contains 4 arbitration slots ($t_{ARB} = 4 / f_{ADCD}$). 01_B An arbitration round contains 8 arbitration slots ($t_{ARB} = 8 / f_{ADCD}$). 10_B An arbitration round contains 16 arbitration slots ($t_{ARB} = 16 / f_{ADCD}$). 11_B An arbitration round contains 20 arbitration slots ($t_{ARB} = 20 / f_{ADCD}$).
0	[14:12]	rw	Reserved This bit field is reserved for future use and has to be written with 000_B .

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Field	Bits	Type	Description
ARBM	15	rw	Arbitration Mode This bit field defines whether the arbiter runs permanently or only while at least one conversion request is pending. 0_B The arbiter runs permanently. This setting has to be chosen in a synchronization slave (see Section 26.2.19) and for equidistant sampling using the signal ARBCNT (see Section 26.2.20). 1_B The arbiter only runs if at least one conversion request of an enabled request source is pending. This setting leads to a reproducible latency from an incoming request to the conversion start if the converter is idle. Synchronized conversions are not supported.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

26.2.6.5 Global Configuration

The global configuration register configures the general ADC kernel setting.

GLOBCFG

Global Configuration Register

(034_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MTM EN	0				MTMCH			0	DP CAL	SU CAL	MTM 7			0	
rw	r				rw			r	rw	rw	rw			r	

Field	Bits	Type	Description
MTM7	4	rw	Multiplexer Test Mode for Channel 7 This bit enables/disables the multiplexer test mode for the input channel 7, see Section 26.2.17 . This feature is independent of the current mode of the ADC (ANON, selected channel for conversion). 0 _B The multiplexer test mode is disabled. The analog input CH7 can be used for normal measurements. 1 _B The multiplexer test mode is enabled. The analog input CH7 is internally connected to ground via voltage divider based on an additional resistor. ¹⁾
SUCAL	5	rw	Start-Up Calibration The transition from 0 to 1 of this bit starts the start-up calibration phase of the analog part. This should be done after reset before starting the first conversion to reduce analog errors. During the calibration phase (indicated by GLOBSTR.CAL = 1), conversions must not be started. It can take a few f _{ADC} clock cycles before bit CAL is set after a rising edge of SUCAL. 0 _B Start-up calibration can be started. 1 _B Start-up calibration has been started.

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Field	Bits	Type	Description
DPCAL	6	rw	Disable Post Calibration This bit enables/disables the automatic post calibration of the analog part. 0_B The automatic post calibration is enabled. 1_B The automatic post calibration is disabled.
MTMCH	[12:8]	rw	Multiplexer Test Mode Channel This bit field defines the input channel number that can be enabled for multiplexer test mode in addition to channel CH7 (a value of 00001_B defines channel CH1, 00011_B channel CH3, 00101_B channel 5, etc.). The multiplexer test mode is enabled for the selected selected input if $MTMEN = 1$.
MTMEN	15	rw	Multiplexer Test Mode Enable This bit enables the multiplexer test mode for the channel number selected by MTMCH. If an even channel number is selected, this bit is internally considered as 0. 0_B The multiplexer test mode for the selected input channel is disabled. This analog input can be used for normal measurements. 1_B The multiplexer test mode for the selected input channel is enabled. This analog input CH7 is internally connected to ground via voltage divider based on an additional resistor. ¹⁾
0	[3:0], 7 [14:13], [31:16]	r	Reserved Read as 0; should be written with 0.

1) Please refer to the AC/DC chapter for the value of the grounding resistor and its current capability.

26.2.6.6 Global Status

The status control register contains bits indicating the current status of a conversion.

GLOBSTR

Global Status Register

(038_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		CSRC			SYN RUN	ANON		CHNR				CAL	SAM PLE	BU SY	
r		rh			rh	rh		rh				rh	rh	rh	

Field	Bits	Type	Description
BUSY	0	rh	Analog Part Busy This bit indicates that a conversion is currently active. 0 _B The analog part is idle. 1 _B A conversion is currently active.
SAMPLE	1	rh	Sample Phase This bit indicates that an analog input signal is currently sampled. 0 _B The analog part is not in the sampling phase. 1 _B The analog part is in the sampling phase.
CAL	2	rh	Calibration Phase This bit indicates that the analog part is in the startup calibration phase. 0 _B The analog part is not in the calibration phase. 1 _B The analog part is in the calibration phase.
CHNR	[7:3]	rh	Channel Number This bit field indicates which analog input channel is currently converted. This information is updated when a new conversion is started. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).

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Field	Bits	Type	Description
ANON	[9:8]	rh	<p>Analog Part Switched On</p> <p>This bit field defines the operation mode of the converter. It monitors either bit field GLOBCTR.ANON of the same ADC kernel (in master mode or without synchronization feature) or bit field GLOBCTR.ANON of the ADC kernel selected as synchronization master for this kernel (in slave mode). This ensures that all kernels of a synchronization group can be controlled with a single write operation to bit field GLOBCTR of the synchronization master.</p> <p>00_B The analog part is switched off and conversions are not possible. To achieve a minimal power consumption, the internal analog circuitry is in its power-down state and the generation of f_{ADCI} and f_{ADCD} is stopped (counters set to an initial value). Furthermore, the arbiter finishes its current arbitration round (if running) and then remains in the idle state.</p> <p>01_B reserved, do not use 10_B reserved, do not use 11_B The analog part of the ADC module is switched on and conversions are possible.</p>
SYNRUN	10	rh	<p>Synchronous Conversion Running</p> <p>This bit indicates that a synchronous (= parallel) conversion is currently running.</p> <p>0_B There is no synchronous conversion running (either there is no conversion currently running or a parallel conversion has not been requested). A running conversion can be cancelled and repeated in case of a new incoming conversion request with higher priority.</p> <p>1_B A synchronous conversion is running. This conversion can not be cancelled while running. Higher priority requests can trigger conversions only after the end of the currently running synchronous conversion.</p>

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Field	Bits	Type	Description
CSRC	[13:11]	rh	<p>Currently Converted Request Source</p> <p>This bit field indicates the arbitration slot number of the current conversion (if BUSY = 1, a conversion is still running) or of the last conversion (if BUSY = 0, no conversion is running). This bit field is updated with each conversion start.</p> <p>000_B The channel requested by the request source of arbitration slot 0 is (has been) converted.</p> <p>001_B The channel requested by the request source of arbitration slot 1 is (has been) converted.</p> <p>...</p> <p>110_B The channel requested by the request source of arbitration slot 6 is (has been) converted.</p> <p>111_B The channel requested by a synchronous injection is (has been) converted.</p>
0	[31:14]	r	<p>Reserved</p> <p>Read as 0; should be written with 0.</p>

26.2.7 Request Source Arbiter

The request source arbiter evaluates which analog input channel has to be converted. Therefore, it regularly polls the request sources one after the other for pending conversion requests. The polling sequence is based on time slots with programmable length, called arbitration slots. If a request source is disabled or if no request source is available for an arbitration slot, the slot is considered as being empty and has no influence on the evaluation of the arbitration winner. After reset, all request sources are disabled and have to be enabled by bits in register **ASENR** to take part in the arbitration process.

The number of arbitration slots forming an arbitration round can be programmed to obtain a similar arbiter timing for different devices, even if the number of available request sources differs from one device to another. At the end of each arbitration round, the arbiter has determined the request source with the highest priority and a pending conversion request. This arbitration result is stored as arbitration winner for further actions. If a conversion is started in an arbitration round, this arbitration round does not deliver an arbitration winner.

In the TC1728, the following request sources are available:

- **Request source 0** in arbitration slot 0: **1-stage sequential source**
This request source can issue a conversion request for a single input channel.
- **Request source 1** in arbitration slot 1: **16(ADC0) / 24(ADC1)-channel scan source**
This request source can issue a conversion request sequence of up to 24 input channels in a defined order.
- **Request source 2** in arbitration slot 2: **4-stage sequential source**
This request source can issue a conversion request sequence of up to 4 input channels in a freely programmable order.
- **Request source 3** in arbitration slot 3: **16(ADC0) / 24(ADC1)-channel scan source**
This request source can issue a conversion request sequence of up to 24 input channels in a defined order.
- **Request source 4** in arbitration slot 4: **4-stage sequential source**
This request source can issue a conversion request sequence of up to 4 input channels in a freely programmable order.
- Last arbitration slot of the arbitration round: **Synchronization source**
In this slot, the arbiter checks for a synchronized request from another ADC kernel and does not evaluate any internal request source. A request for a synchronized conversion is always handled with the highest priority in a synchronization slave kernel (pending requests from other sources are not considered).

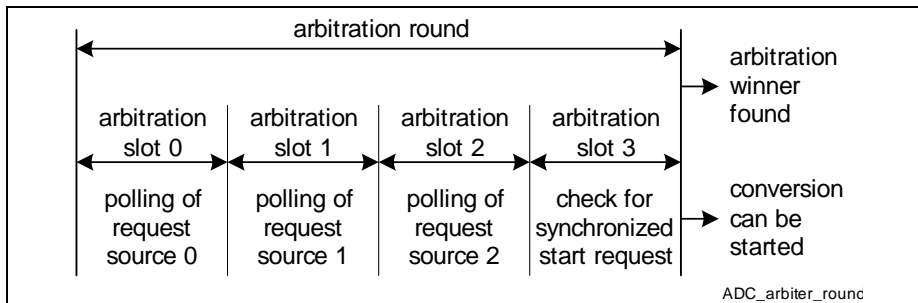


Figure 26-7 Arbitration Round with 4 Arbitration Slots

The period t_{ARB} of an arbitration round is given by:

$$t_{ARB} = N \times (\text{GLOBCTR.DIVD} + 1) / f_{ADC}$$

with N being 4, 8, 16, or 20 as defined by **GLOBCTR.ARBND**

The period of the arbitration round introduces a timing granularity to detect an incoming conversion request signal and the earliest point to start the related conversion. This granularity can introduce a jitter of maximum one arbitration round. The jitter can be reduced by minimizing the period of an arbitration round (numbers of arbitration slots and their length).

To achieve a reproducible reaction time (constant delay without jitter) between the trigger event of a conversion request (e.g. by a timer unit or due to an external event) and the start of the related conversion, mainly the following two options exist. For both options, the converter has to be idle and other conversion requests must not be pending for at least one arbiter round before the trigger event occurs:

- If bit **GLOBCTR.ARB** = 0, the **arbiter runs permanently**. In this mode, synchronized conversions of more than one ADC kernel are possible. The trigger for the conversion triggers has to be generated synchronously to the arbiter timing. Incoming triggers should have exactly n-times the granularity of the arbiter ($n = 1, 2, 3, \dots$). In order to allow some flexibility, the duration of an arbitration slot can be programmed in cycles of f_{ADC} .
- If bit **GLOBCTR.ARB** = 1, the **arbiter stops after an arbitration round** when no conversion request have been found pending any more. The arbiter is started again if at least one enabled request source indicates a pending conversion request. The trigger of a conversion request does need not to be synchronous to the arbiter timing. In this mode, parallel conversions are not possible for synchronization slave kernels.

26.2.7.1 Request Source Priority

Each request source has an individually programmable priority to be able to adapt to different applications (see registers **RSPR0**, **RSPR4**). The priorities define the order the request sources are handled by the arbiter if two or more request sources indicate

pending conversion requests at the same time.

Starting with request source 0, the arbiter checks if an enabled request source has a pending request for a conversion. The arbitration winner is the request source with a pending conversion request and the highest priority that has been found first in an arbitration round.

26.2.7.2 Conversion Start Modes

To start the requested conversion of the arbitration winner, the following aspects are automatically taken into consideration by the arbiter:

- If the converter is currently idle (no conversion running), the conversion of the arbitration winner is started immediately.
- If a conversion is currently running, the arbitration winner is compared to the priority of the currently running conversion. In the case that the current conversion has the same or a higher priority, it is completed. Then, the conversion of the arbitration winner is started.
- If a conversion is currently running, the arbitration winner is compared to the priority of the currently running conversion. In the case that the current conversion has the lower priority and the arbiter winner has been programmed for **wait-for-start mode**, the currently running conversion is completed. Then, the conversion of the arbitration winner is started.

This mode can be used if the timing requirement for the higher priority conversions allow a jitter (between t_3 and t_4 in [Figure 26-8](#)) in the range of a running conversion.

- If a conversion is currently running, the arbitration winner is compared to the priority of the currently running conversion. In the case that the current conversion has the lower priority and the arbiter winner has been programmed for **cancel-inject-repeat mode**, the current conversion is aborted immediately if a new request with a higher priority has been found, unless both requests target the same result register with wait-for-read active (see [Section 26.2.15.2](#)). The conversion of the arbitration winner is started after the abort action. The aborted conversion request is restored in the request source that has requested the aborted conversion. As a consequence, it takes part again in the next arbitration round.

Please note that the abort mechanism can take between 1 and $3 f_{\text{ADCI}}$ cycles, depending on the state of the current conversion.

This mode can be used if higher priority conversions only tolerate a small jitter (between t_8 and t_9 in [Figure 26-8](#)).

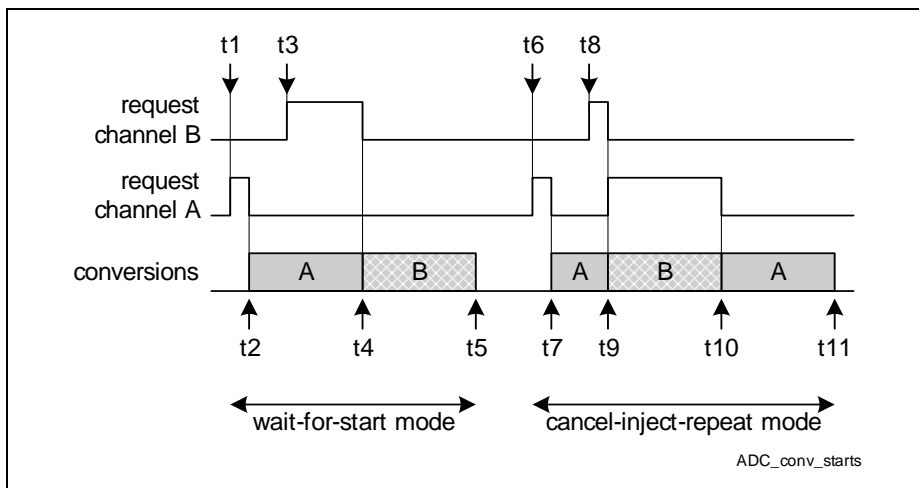


Figure 26-8 Conversion Start Modes

The conversion start mode can be individually programmed for each request source by bits in registers **RSPR0** and **RSPR4** and is applied to all channels requested by the source. **Figure 26-8** shows the influence of both conversion start modes on the conversion sequence if two request sources generate conversion requests. In this example, channel A is issued by a request source with a lower priority than the request source requesting the conversion of channel B.

- t1: The trigger event for channel A occurs and a conversion request is activated.
- t2: At the end of the arbitration round, channel A is determined as arbitration winner, the conversion of channel A is started. With the start of the conversion, the related conversion request is cleared.
- t3: The trigger event for channel B occurs and a conversion request is activated. In wait-for-read mode, the currently running conversion of channel A is finished normally.
- t4: After the conversion of channel A is finished, the conversion of channel B is started. With the start of the conversion, the related conversion request is cleared.
- t5: The conversion of channel B is finished.
- t6: The trigger event for channel A occurs and a conversion request is activated.
- t7: At the end of the arbitration round, channel A is determined as arbitration winner, the conversion of channel A is started. With the start of the conversion, the related conversion request is cleared.
- t8: The trigger event for channel B occurs and a conversion request is activated.
- t9: At the end of the arbitration round, channel B is determined as arbitration winner. In cancel-inject-repeat mode, the currently running conversion of channel A is aborted and the conversion of channel B is started. With the abort of the conversion,

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the related conversion request is set again. With the start of the conversion, the related conversion request is cleared.

- t10: The conversion of channel B is finished. In the meantime, the pending request for channel A has been identified as arbitration winner and the conversion of channel A is started. With the start of the conversion, the related conversion request is cleared.
- t11: The conversion of channel A is finished.

26.2.8 Arbiter Registers

26.2.8.1 Arbitration Slot Enable Register

The arbitration slot enable register contains bits to enable/disable the conversion request treatment in the arbitration slots.

ASENR

Arbitration Slot Enable Register

(03C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0											AS EN4	AS EN3	AS EN2	AS EN1	AS EN0
r											rw	rw	rw	rw	rw

Field	Bits	Type	Description
ASENx (x = 0-4)	x	rw	Arbitration Slot x Enable Each bit enables an arbitration slot of the arbiter round. ASEN0 enables the arbitration slot 0, ASEN1 the slot 1, etc. If an arbitration slot is disabled, it is considered as being empty. The request bits of the request sources are not modified by write actions to ASENr. 0 _B The corresponding arbitration slot is disabled and is not taken into account by the arbiter. Conversions are not requested, even for the request source(s) with pending request bit(s). 1 _B The corresponding arbitration slot is enabled. Conversions are requested for the request source(s) with pending request bit(s).
0	[31:5]	r	Reserved Read as 0; should be written with 0.

26.2.8.2 Request Source Priority Register

The request source priority registers contain bits to define the request source priority and the conversion start mode.

RSPR0

Request Source Priority Register 0 (040_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CSM 3	0	PRI0 3	CSM 2	0	PRI0 2	CSM 1	0	PRI0 1	CSM 0	0	PRI0 0	CSM 3	0	PRI0 3	CSM 2
rw	r	rw	rw	r	rw	rw	r	rw	rw	r	rw	rw	r	rw	rw

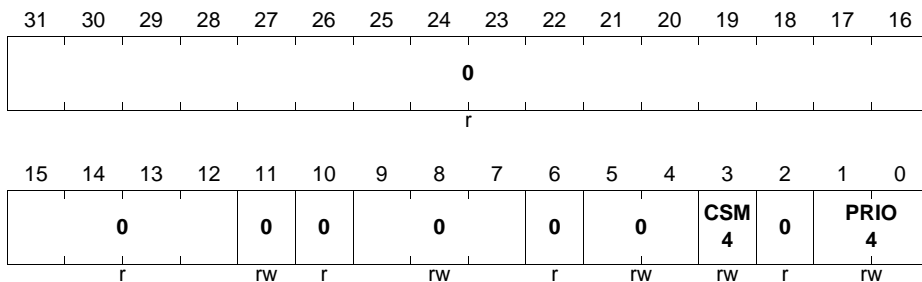
Field	Bits	Type	Description
PRI00, PRI01, PRI02, PRI03	[1:0], [5:4], [9:8], [13:12]	rw	Priority of Request Source x This bit field defines the priority of the conversion request source x, located in arbitration slot x. 00 _B Lowest priority is selected. ... 11 _B Highest priority is selected.
CSM0, CSM1, CSM2, CSM3	3, 7, 11, 15	rw	Conversion Start Mode of Request Source x This bit defines the conversion start mode of the conversion request source x, located in arbitration slot x. 0 _B The wait-for-start mode is selected. 1 _B The cancel-inject-repeat mode is selected.
0	2, 6, 10, 14, [31:16]	r	Reserved Read as 0; should be written with 0.

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RSPR4

Request Source Priority Register 4 (044_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
PRIO4	[1:0]	rw	Priority of Request Source 4 This bit field defines the priority of the conversion request source 4, located in arbitration slot 4. 00 _B Lowest priority is selected. ... 11 _B Highest priority is selected.
CSM4	3	rw	Conversion Start Mode of Request Source 4 This bit defines the conversion start mode of the conversion request source 4, located in arbitration slot 4. 0 _B The wait-for-start mode is selected. 1 _B The cancel-inject-repeat mode is selected.
0	[5:4], [9:7], 11	rw	Reserved These bits are reserved for future use and have to be written with 000 _B .
0	2, 6, 10, [31:12]	r	Reserved Read as 0; should be written with 0.

26.2.9 Scan Request Source Handling

A scan request source can issue conversion requests for a sequence of up to 24 input channels. It can be programmed individually for each input channel if it takes part in the scan sequence. The scan sequence always starts with the highest enabled channel number and continues towards lower channel numbers (order defined by the channel number, each channel can be converted only once per sequence).

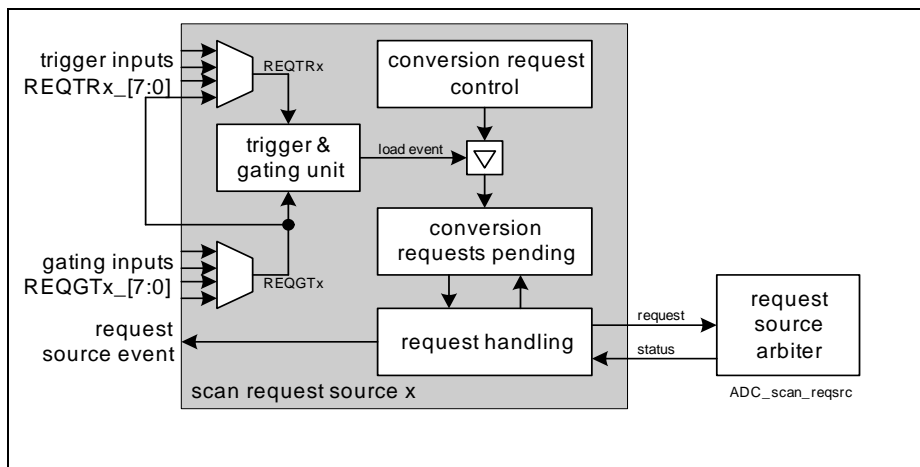


Figure 26-9 Scan Request Source

26.2.9.1 Overview

A scan request source performs the:

- **Conversion request control:**
The conversion request control defines if an analog input channel takes part in the scan sequence (see bits in registers [CRCR1](#), [CRCR3](#)). The programmed register value is kept unchanged by an ongoing scan sequence.
- **Conversion request pending:**
The pending conversion requests indicate if an input channel has to be converted in an ongoing scan sequence (see bits in registers [CRPR1](#), [CRPR3](#)). A conversion request can only be issued to the request source arbiter if at least one pending bit is set. With each conversion start that has been triggered by the scan request source, the corresponding pending bit is automatically cleared. The scan sequence is considered finished and a request source event is generated if the last conversion triggered by the scan source is finished and all pending bits have been cleared.
- **Request handling:**
The request handling blocks interfaces with the request source arbiter. It requests conversion due to pending bits in the scan sequence and handles the conversion

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status information. If a conversion triggered by the scan request source is aborted due to a conversion request from another request source with a higher priority, the corresponding pending bit is automatically set. This mechanism ensures that an aborted conversion takes part in the next arbitration round and does not get lost. The control of the scan sequence is done based on bits in registers **CRMR1**, **CRMR3**.

- Trigger and gating signal handling:
The trigger and gating unit interfaces with signals and modules outside the ADC module that can request conversions. For example, a timer unit can issue a request signal to synchronize conversions to PWM events. A load event starts a scan sequence by modifying the request pending bits according to the request control bits.

26.2.9.2 Scan Sequence Operation

To **operate a scan request source**, the following aspects should be taken into account:

- The bits in register CRCRx have to be programmed to define the channels participating in the scan sequence.
- If a trigger or gating function by external signals is desired, the gating and trigger inputs have to be defined by bit fields in the related registers **RSIRx (x = 0 - 4)**, the value of x defines the number of the arbitration slot where the scan source is connected. Also the edge selection for the trigger event is done in these registers.
- The gating mechanism has to be defined by CRMRx.ENG.
- The corresponding arbitration slot has to be enabled to accept conversion requests from the scan source (see register **ASENR**).
- The load event has to be defined by bits in CRMRx to start a scan sequence.
- If a load event occurs while CRMRx.LDM = 0, the content of CRCRx is copied to CRPRx (overwrite). This setting allows starting a new scan sequence and to “forget” remaining pending bits if a load event occurs while a scan sequence is running.
- If a load event occurs while CRMRx.LDM = 1, the content of CRCRx is bit-wisely logical OR-combined to CRPRx (no overwrite). This setting allows starting a new scan sequence without “forgetting” remaining pending bits if a load event occurs while a scan sequence is running.

To **start a scan sequence**, the following mechanisms are supported to generate a load event:

- An external trigger signal can be selected to start a scan sequence controlled by HW by an external module or signal, e.g. a timer unit or an input pin. The trigger feature is enabled by CRMRx.ENTR = 1. The load event is generated if the selected edge is detected at the selected trigger input REQTRx. The edge selection is done in register RSIRx.
- A load event is generated under SW control by writing CRMRx.LDEV = 1. This mechanism starts a scan sequence without modifying the bits in register CRCRx. A data write action to CRCRx does not lead to a load event (first prepare the channel control, then start the sequence).

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- If SW writes data to register CRPRx, the written data is stored in register CRCRx and a load event is generated automatically. This mechanism starts a scan sequence with the channels defined by the written data (the sequence is defined and started with a single data write action, e.g. under DMA control).
- A load event is generated each time a scan sequence has finished and the request source event occurs if bit CRMRx.SCAN = 1. This setting leads to a permanent repetition of the scan sequence.

To **stop or abort an ongoing scan sequence**, the following mechanisms are supported:

- An external gating signal can be selected to stop and to continue a scan sequence at any point in time controlled by an external module or signal, e.g. a timer unit or an input pin. The gating feature can be enabled and the polarity of the gating signal REQGTx can be selected by CRMRx.ENGT. The gating mechanism does not modify the contents of the conversion pending bits, but only prevents the request handling block from issuing conversion requests to the arbiter.
- The arbiter can be disabled by SW for this arbiter slot by clearing the corresponding bit **ASENR**.ASENx. This mechanism does not modify the contents of the conversion pending bits, but only prevents the arbiter from accepting requests from the request handling block.
- The pending request bits can be cleared by writing bit CRMRx.CLRPND = 1. It is recommended to stop the scan sequence before clearing the pending bits.

26.2.9.3 Request Source Event and Interrupt

A request source event of a scan source occurs if the last conversion of a scan sequence is finished (all pending bits = 0). A request source event interrupt can be generated based on a request source event according to the structure shown in **Figure 26-10**. If a request source event is detected, it sets the corresponding indication flag in register **EVFR**. These flags can also be set by writing a 1 to the corresponding bit position, whereas writing 0 has no effect. Additionally, a gated event flag **EVFR**.GFSx indicates that a request source interrupt has been activated. The indication flags can be cleared by SW by writing a 1 to the corresponding bit position in register **EVFCR**.

The service request output ADCy_SRx that is selected by the request source event interrupt node pointer bit fields in register **EVNPR** becomes activated each time the related request source event is detected and the interrupt generation is enabled for this event in registers **CRCR1** (for request source 1) or **CRCR3** (for request source 3).

A service request output can be activated under SW control by writing **INTR**.SISRx.

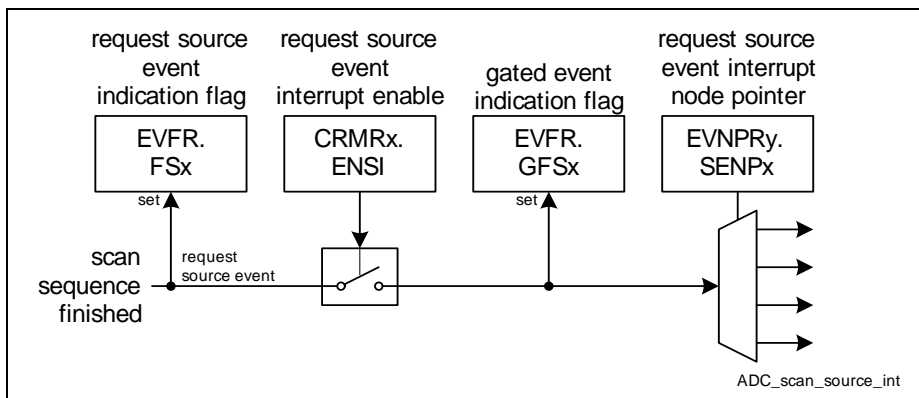


Figure 26-10 Interrupt Generation of a Scan Request Source

26.2.10 Scan Request Source Registers

26.2.10.1 Conversion Request Control Registers

These registers contain the control and status bits of a scan request source. In the TC1728, two scan sources are available (sources 1 and 3). The index describes the number of the arbitration slot where the request source is taking part in the arbitration.

The conversion request control reent one clock cycle later.

CRCR1

Conversion Request 1 Control Register

(090_H)

Reset Value: 0000 0000_H

CRCR3

Conversion Request 3 Control Register

(0B0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
			0					CH 23	CH 22	CH 21	CH 20	CH 19	CH 18	CH 17	CH 16
			r					rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CH 15	CH 14	CH 13	CH 12	CH 11	CH 10	CH 9	CH 8	CH 7	CH 6	CH 5	CH 4	CH 3	CH 2	CH 1	CH 0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
CHx (x = 0-23)	x	rwh	Channel Bit x Each bit corresponds to one analog input channel, the channel number CHx is defined by the bit position x in this register. ADC0 kernel has 16 channels, CH0-CH15, while ADC1 kernel has 24 channels, CH0-CH23. The corresponding bit x in the conversion request pending register will be overwritten by this bit (LDM = 0) or bit-wisely OR-combined with this bit (LDM = 1) when the load event occurs. 0 _B The analog channel CHx will not be requested for conversion by this request source. 1 _B The analog channel CHx will be requested for conversion by this request source.

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Field	Bits	Type	Description
0	[31:24]	r	Reserved Read as 0; should be written with 0.

26.2.10.2 Conversion Request Pending Registers

The conversion request pending register contains the bits that are requesting a conversion of the corresponding analog channel.

A read operation to CRPRx delivers the pending bits (attribute “rh”). A write operation to CRPRx leads to a data write to the bits in CRCRx with an automatic load event generation (additional attribute “w”).

CRPR1

Conversion Request 1 Pending Register

(094_H)

Reset Value: 0000 0000_H

CRPR3

Conversion Request 3 Pending Register

(0B4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								CHP 23	CHP 22	CHP 21	CHP 20	CHP 19	CHP 18	CHP 17	CHP 16
r								rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CHP 15	CHP 14	CHP 13	CHP 12	CHP 11	CHP 10	CHP 9	CHP 8	CHP 7	CHP 6	CHP 5	CHP 4	CHP 3	CHP 2	CHP 1	CHP 0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
CHPx (x = 0-23)	x	rwh	Channel Pending Bit x <u>Write view:</u> A write to this address targets the bits in register CRCR1 (for CRPR1) or CRCR3 (for CRPR3). <u>Read view:</u> Each bit corresponds to one analog channel, the channel number CHx is defined by the bit position in the register. ADC0 kernel has 16 channels, CH0-CH15, while ADC1 kernel has 24 channels, CH0-CH23. 0 _B The analog channel CHx is not requested for conversion by this request source. 1 _B The analog channel CHx is requested for conversion by this request source.

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Field	Bits	Type	Description
0	[31:24]	r	Reserved Read as 0; should be written with 0.

26.2.10.3 Conversion Request Mode Registers

The conversion request mode registers contain bits to configure the desired operating mode of the scan request sources.

CRMR1

Conversion Request 1 Mode Register

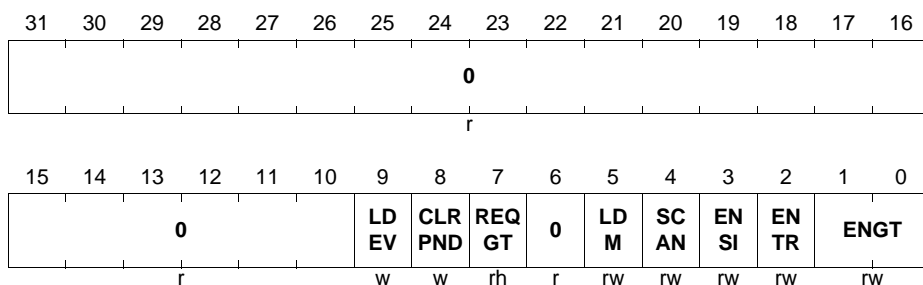
(098_H)

Reset Value: 0000 0000_H

CRMR3

Conversion Request 3 Mode Register

(0B8_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
ENGT	[1:0]	rw	Enable Gate This bit field enables the gating functionality for the request source. 00 _B The request source does not issue conversion requests. 01 _B The request source issues conversion requests if at least one pending bit is set. 10 _B The request source issues conversion requests if at least one pending bit is set and the selected gating signal REQGTx = 1. 11 _B The request source issues conversion requests if at least one pending bit is set and the selected gating signal REQGTx = 0.

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Field	Bits	Type	Description
ENTR	2	rw	Enable External Trigger This bit enables the external trigger possibility. If enabled, the load event takes place if the selected edge is detected at the external trigger input REQTRx. 0 _B The external trigger is disabled. 1 _B The external trigger is enabled.
ENSI	3	rw	Enable Source Interrupt This bit enables the request source interrupt generation if a request source event occurs (last pending conversion is finished). 0 _B The request source interrupt is disabled. 1 _B The request source interrupt is enabled.
SCAN	4	rw	Autoscan Enable This bit enables a permanent scan functionality. If enabled, the load event is automatically generated if a request source event occurs. 0 _B The permanent scan functionality is disabled. 1 _B The permanent scan functionality is enabled.
LDM	5	rw	Load Event Mode This bit defines the transfer mechanism triggered by the load event. 0 _B With the load event, the value of register CRCRx is copied to the pending register CRPRx (overwrite). 1 _B With the load event, the value of register CRCRx is bit-wisely logical OR combined to the pending register CRPRx.
REQGT	7	rh	Request Gate Level This bit monitors the level at the REQGTx input. 0 _B The level is 0. 1 _B The level is 1.
CLRPND	8	w	Clear Pending Bits 0 _B No action. 1 _B The bits in register CRPRx are cleared.
LDEV	9	w	Generate Load Event 0 _B No action. 1 _B A load event is generated.

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Field	Bits	Type	Description
0	6, [31:10]	r	Reserved Read as 0; should be written with 0.

26.2.11 Sequential Request Source Handling

Sequential request sources have been introduced to allow short conversion sequences with freely programmable channel numbers (contrary to a scan request source with a fixed conversion order for the enabled channels). Two versions of the sequential sources are available in each ADC kernel:

- Request sources in arbitration slots 2 and 4:
These request sources can handle a sequence of up to 4 input channels (4-stage queue for 4 entries). This mechanism could be used to support application-specific conversion sequences, especially for timing-critical sequences containing multiple conversions of the same channel.
- Request source in arbitration slot 0:
This request source can handle a single input channel (1-stage queue for 1 entry). This mechanism could be used for SW-controlled conversion requests or HW-triggered conversions of a single input channel (to “inject” a single conversion into a running sequence).

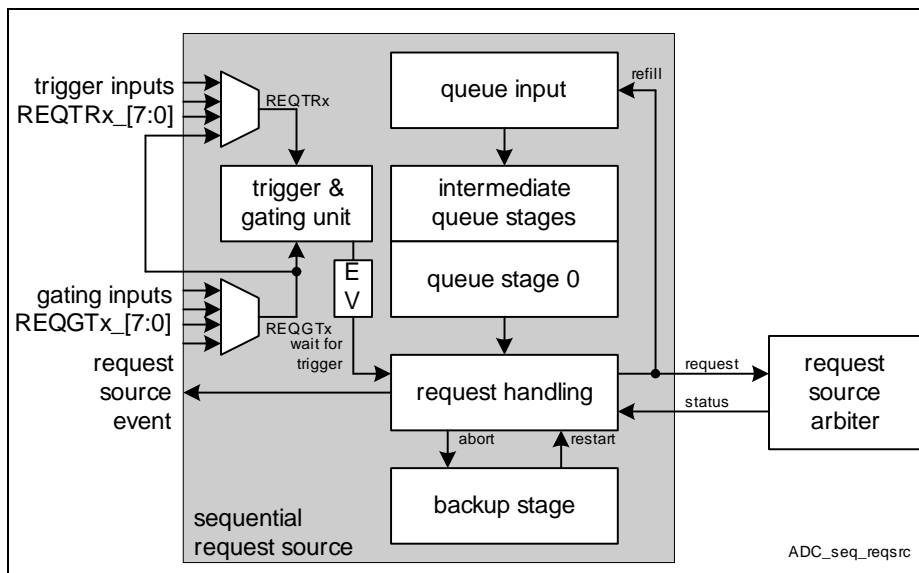


Figure 26-11 Sequential Request Source

The internal structure and the handling of the sequential sources is similar for both versions. The programmed sequence is stored in a queue buffer (based on a FIFO mechanism) with at least one queue stage (stage 0) and a backup stage for aborted conversions. The only difference between both versions is given by the number of intermediate queue stages for storing the sequence. The request source in arbitration

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slot 0 does not provide intermediate queue stages (1-stage queue with only queue stage 0), whereas the ones in arbitration slots 2 and 4 provides 3 intermediate queue stages in addition to queue stage 0 (leading to a 4-stage queue each).

26.2.11.1 Overview

A sequential request source performs the:

- Queue input:
The queue input represents the programming interface where the sequence is defined (see [QINR0](#), [QINR2](#), [QINR4](#)). It does not provide any buffer capability, but handles the filling of the queue buffer (queue stage 0 plus optional intermediate queue stages) by writing data to it. The contents of the queue stages can not be directly modified by program, except by the command for flushing the complete queue.
The queue input also handles the refill mechanism, an automatic re-insertion of a started conversion from queue stage 0 (including the control parameters) as new queue input. This feature allows a single setup (by SW) of a conversion sequence and multiple repetitions of the same sequence without the need to re-program it each time. A conversion sequence is repeated if all queue entries of the sequence are setup for refill mode.
- Queue stage 0:
The contents of this queue stage defines which channel will be requested next for a conversion (see [QOR0](#), [QOR2](#), [QOR4](#)). It also defines if the request should be triggered by an external event or if the requested conversion should follow the previous one as soon as possible. It also enables the request source interrupt generation after the conversion.
The contents of this queue stage is cleared when the requested conversion is started and the next queue entry can be handled (if available).
- Queue backup stage:
The queue backup stage is used to store the request control parameters when a conversion requested by this request source is aborted. A validation bit indicates that the aborted conversion has to be requested next (before the current contents of queue stage 0) to maintain the original sequence (see [QBUR0](#), [QBUR2](#), [QBUR4](#)).
- Request handling:
The request handling block interfaces with the request source arbiter. It requests a conversion due to a valid information in queue stage 0 and handles the conversion status information. The control of the queue sequence is done based on bits in registers [QMR0](#), [QMR2](#), and [QMR4](#) (for the arbitration slot x).
- Trigger and gating signal handling:
The trigger and gating unit interfaces with signals and modules outside the ADC module that can request conversions. For example, a timer unit can issue a request signal to synchronize conversions to PWM events. A trigger event can start a conversion request for the entry in queue stage 0 (see [QMR0](#), [QMR2](#), [QMR4](#)). An

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event flag QSRx.EV indicates that a trigger event has been detected (selected edge of selected trigger input signal REQTRx if enabled by QMRx.ENTR or write action with QMRx.TREV = 1). This bit is cleared with each conversion start requested by this source or by writing bits CEV = 1, FLUSH = 1, or CLRV = 1.

26.2.11.2 Sequential Source Operation

To **operate a sequential request source**, the following aspects should be taken into account:

- The sequence has to be initialized by writing to the queue input **QINR0** (for arbitration slot 0), **QINR2** (for arbitration slot 2), or **QINR4** (for arbitration slot 4) when using the refill mechanism. Each write access corresponds to one conversion request. The desired sequence should be completely initialized before enabling the request source, because with enabled refill feature, write accesses by SW to QINRx are not allowed.
- If a trigger or gating function by external signals is desired, the gating and trigger inputs have to be defined by bit fields in the related registers **RSIRx (x = 0 - 4)**, the value of x defines the number of the arbitration slot where the request source is connected. Also the edge selection for the trigger event is done in these registers.
- The gating mechanism has to be defined by QMRx.ENGTT.
- The corresponding arbitration slot has to be enabled to accept conversion requests from the sequential source (see register **ASENR**).

To **start a sequence** of a sequential request source, the following mechanisms are supported:

- An external trigger signal can be selected to start a scan sequence controlled by HW by an external module or signal, e.g. a timer unit or an input pin. The trigger feature is enabled by QMRx.ENTR = 1. The trigger event is generated if the selected edge is detected at the selected trigger input.
- A trigger event is generated under SW control by writing QMRx.TREV = 1. This mechanism starts a request if queue stage 0 contains valid data (or the queue backup stage respectively).
- A write operation to a queue input leads to a (new) valid queue entry. If the queue is empty (no valid entry), the written data arrives in queue stage 0 and starts a conversion request (if enabled by QMRx.ENGTT and without waiting for an external trigger). If the refill mechanism is used, the queue inputs must not be written while the queue is running. Write operations to a completely filled queue are ignored.

To **stop or abort an ongoing sequence** of a sequential request source, the following mechanisms are supported:

- An external gating signal can be selected to stop and to continue a sequence at any point in time controlled by an external module or signal, e.g. a timer unit or an input pin. The gating feature can be enabled and the polarity of the gating signal REQGTx can be selected by QMRx.ENGTT. The gating mechanism does not modify the queue

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entries, but only prevents the request handling block from issuing conversion requests to the arbiter.

- The arbiter can be disabled by SW for this arbiter slot by clearing the corresponding bit **ASENR.ASENx**. This mechanism does not modify the queue entries, but only prevents the arbiter from accepting requests from the request handling block.
- The next pending queue entry is cleared by writing bit **QMRx.CLRV** = 1. It is recommended to stop the sequence before clearing a queue entry (**ENGT** = 00_B). If the queue backup stage contains a valid entry, this one is cleared, otherwise a valid entry in queue register 0 is cleared.
- All queue entries are cleared by writing bit **QMRx.FLUSH** = 1. It is recommended to stop the sequence before clearing queue entries.

26.2.11.3 Request Source Event and Interrupt

A request source event occurs when a conversion that has been requested by this source is completely finished. The interrupt enable bits are located in the queue 0 register (if this has not been a repeated start after an abort) or in the queue backup register (if this has been a repeated start after an abort), e.g. see **QOR0** for request source 0) or in the queue backup register (if this has been a repeated start after an abort, e.g. see **QBUR0** for request source 0).

A request source event interrupt can be generated based on a request source event according to the structure shown in **Figure 26-12**. If a request source event is detected, it sets the corresponding indication flag in register **EVFR**. These flags can also be set by writing a 1 to the corresponding bit position, whereas writing 0 has no effect. The indication flags can be cleared by SW by writing a 1 to the corresponding bit position in register **EVFCR**.

The service request output **ADCy_SRx** that is selected by the request source event interrupt node pointer bit fields in register **EVNPR** becomes activated each time the related request source event is detected.

A service request output can be activated under SW control by writing **INTR.SISRx**.

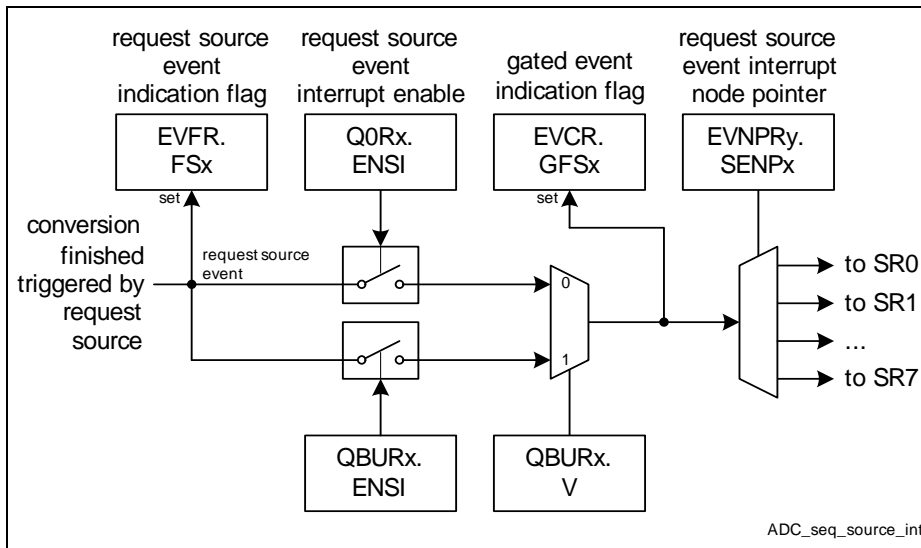


Figure 26-12 Interrupt Generation of a Sequential Request Source

26.2.12 Sequential Source Registers

26.2.12.1 Queue Mode Registers

These registers contain the control and status bits of a sequential source. The index describes the number of the arbitration slot where the request source is taking part in the arbitration.

*Note: Before SW modifies the queue content by QMRx.CLRV or QMRx.FLUSH, all HW actions related to this queue have to be finished. Therefore, the arbitration slot has to be disabled and SW has to wait for at least two arbitration rounds (to be sure that this request source can no longer be an arbitration winner). Then, it has to check **GLOBSTR.CRSC** and **GLOBSTR.BUSY** to be sure that a conversion triggered by this request source is no longer running. Then SW can read QBURx and Q0Rx and can start modification of the queue content.*

QMR0

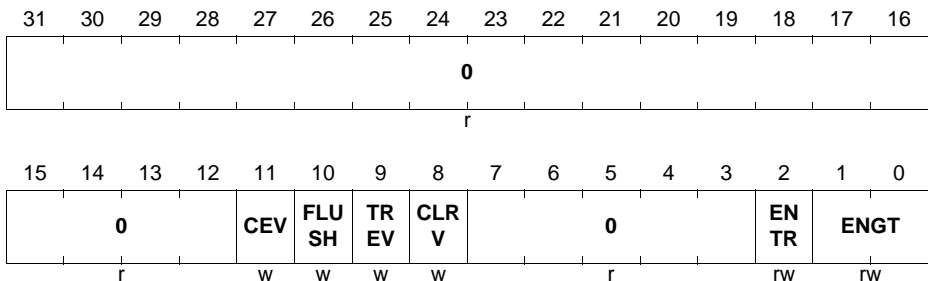
Queue 0 Mode Register (080_H) Reset Value: 0000 0000_H

QMR2

Queue 2 Mode Register (0A0_H) Reset Value: 0000 0000_H

QMR4

Queue 4 Mode Register (0C0_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
ENGT	[1:0]	rw	Enable Gate This bit field enables the gating functionality for the request source. 00 _B The request source does not issue conversion requests. 01 _B The request source issues conversion requests if a valid conversion request is pending in the queue 0 register or in the backup register. 10 _B The request source issues conversion requests if a valid conversion request is pending in the queue 0 register or in the backup register and the selected gating signal REQGTx = 1. 11 _B The request source issues conversion requests if a valid conversion request is pending in the queue 0 register or in the backup register and the selected gating signal REQGTx = 0.
ENTR	2	rw	Enable External Trigger This bit enables the external trigger possibility. 0 _B The external trigger is disabled and the trigger event is not generated. 1 _B The external trigger is enabled and a trigger event is generated if the selected edge is detected at the selected trigger input signal for REQTRx.
CLRv	8	w	Clear V Bit 0 _B No action. 1 _B The next pending valid queue entry in the sequence and the event flag EV are cleared. If there is a valid entry in the queue backup register (QBURx.V = 1), this entry is cleared, otherwise the entry in queue register 0 is cleared.

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Field	Bits	Type	Description
TREV	9	w	Trigger Event 0 _B No action. 1 _B A trigger event is generated by SW. If the a valid entry in the request source waits for a trigger event, a conversion request is started.
FLUSH	10	w	Flush Queue 0 _B No action. 1 _B All entries in the queue (including the backup stage) and the event flag EV are cleared. The queue contains no more valid entry.
CEV	11	w	Clear Event Flag 0 _B No action. 1 _B Bit EV is cleared.
0	[7:3], [31:12]	r	Reserved Read as 0; should be written with 0.

26.2.12.2 Queue Status Registers

The queue status registers contain bits indicating the status of the sequential source. The filling level and the empty information refer to the queue intermediate stages (if available) and to the queue register 0. An aborted conversion stored in the backup stage is not indicated by these bits (therefore, see QBURx.V).

QSR0

Queue 0 Status Register

(084_H)

Reset Value: 0000 0020_H

QSR2

Queue 2 Status Register

(0A4_H)

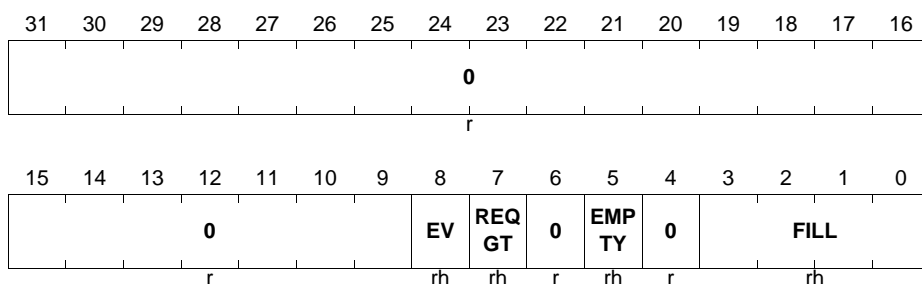
Reset Value: 0000 0020_H

QSR4

Queue 4 Status Register

(0C4_H)

Reset Value: 0000 0020_H



Field	Bits	Type	Description
FILL	[3:0]	rh	Filling Level¹⁾ This bit field indicates how many queue entries are valid in the sequential source. It is incremented each time a new entry is written to QINRx or by an enabled refill mechanism. It is decremented each time a requested conversion has been started. A new entry is ignored if the filling level has reached its maximum value. 00 _B EMPTY = 1: There is no valid entry in the queue. EMPTY = 0: There is 1 valid entries in the queue. 01 _B There are 2 valid entries in the queue. 10 _B There are 3 valid entries in the queue. 11 _B There are 4 valid entries in the queue.

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Field	Bits	Type	Description
EMPTY	5	rh	Queue Empty This bit indicates if the sequential source contains valid entries. 0_B There are FILL+1 valid entries in the queue. 1_B There are no valid entries (queue is empty).
REQGT	7	rh	Request Gate Level This bit monitors the level at the REQGTx input. 0_B The level is 0. 1_B The level is 1.
EV	8	rh	Event Detected This bit indicates that an event has been detected while at least one valid entry has been in the queue (queue register 0 or backup stage). Once set, this bit is cleared automatically when the requested conversion is started. 0_B A trigger event has not been detected. 1_B A trigger event has been detected.
0	4, 6, [31:9]	r	Reserved Read as 0; should be written with 0.

1) This bit field is always 00_B for the 1-stage queue in arbitration slot 0.

26.2.12.3 Queue 0 Registers

The queue x registers 0 monitor the status of the current sequential request (queue stage 0).

Q0R0

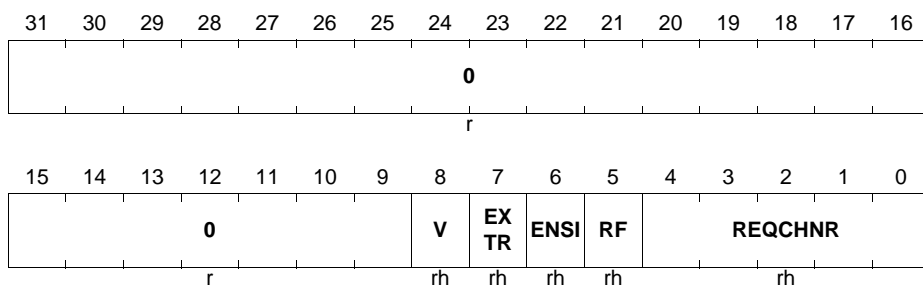
Queue 0 Register 0 (088_H) Reset Value: 0000 0000_H

Q0R2

Queue 2 Register 0 (0A8_H) Reset Value: 0000 0000_H

Q0R4

Queue 4 Register 0 (0C8_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
REQCHNR	[4:0]	rh	Request Channel Number This bit field indicates the channel number that will be or is currently requested. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
RF	5	rh	Refill This bit indicates if the pending request is discarded after the conversion start or if it is automatically refilled into the queue input of the request queue. 0 _B The request is discarded after the conversion start. 1 _B The request is refilled into the queue after the conversion start.

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Field	Bits	Type	Description
ENSI	6	rh	Enable Source Interrupt This bit indicates if a request source interrupt is generated when the conversion is finished. 0_B The request source interrupt generation is disabled. 1_B The request source interrupt generation is enabled.
EXTR	7	rh	External Trigger This bit indicates if a valid queue entry immediately leads to a conversion request or if the request handler waits for a trigger event. 0_B The request handler does not wait for a trigger event. 1_B The request handler waits for a trigger event.
V	8	rh	Request Channel Number Valid This bit indicates if the queue register 0 contains a valid queue entry. 0_B The queue entry is not valid and does not lead to a conversion request. 1_B The queue entry is valid and leads to a conversion request.
0	[31:9]	r	Reserved Read as 0; should be written with 0.

26.2.12.4 Queue Backup Registers

The queue backup registers monitor the status of an aborted sequential request.

The registers QBURx and QINRx share the same register address. A read operation at this register address will deliver the “rh” bits of register QBURx. A write operation to this address will target register QINRx.

QBUR0

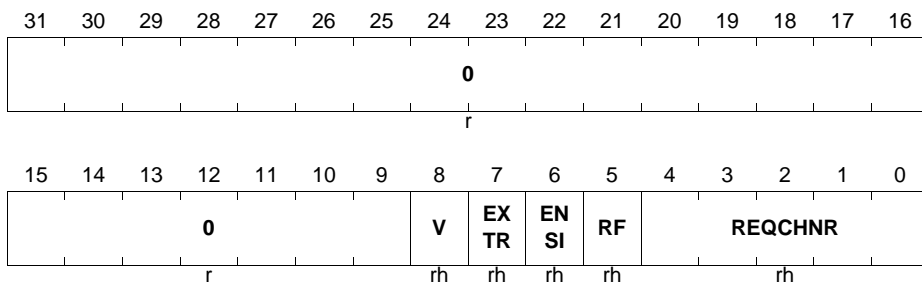
Queue 0 Backup Register (08C_H) Reset Value: 0000 0000_H

QBUR2

Queue 2 Backup Register (0AC_H) Reset Value: 0000 0000_H

QBUR4

Queue 4 Backup Register (0CC_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
REQCHNR	[4:0]	rh	Request Channel Number This bit field contains the channel number of an aborted conversion that has been requested by this request source. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
RF	5	rh	Refill This bit contains the refill bit of an aborted conversion that has been requested by this request source.
ENSI	6	rh	Enable Source Interrupt This bit contains the request source event interrupt enable bit of an aborted conversion that has been requested by this request source.

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Field	Bits	Type	Description
EXTR	7	rh	External Trigger This bit contains the external trigger bit of an aborted conversion that has been requested by this request source.
V	8	rh	Request Channel Number Valid This bit indicates if the entry in the queue backup register is valid (REQCHNR, RF, TR and ENSI are valid). Bit V is set if a running conversion that has been requested by this request source is aborted. It is cleared when the repeated conversion is started. 0_B The backup register does not contain a valid entry. 1_B The backup register contains a valid entry. It will be requested before a valid entry in queue register 0 will be requested.
0	[31:9]	r	Reserved Read as 0; should be written with 0.

26.2.12.5 Queue Input Registers

The queue input registers are the entry registers for sequential requests for each sequential source (queue).

The registers QBURx and QINRx share the same register address. A read operation at this register address will deliver the “rh” bits of register QBURx. A write operation to this address will target the “w” bits in register QINRx.

QINR0

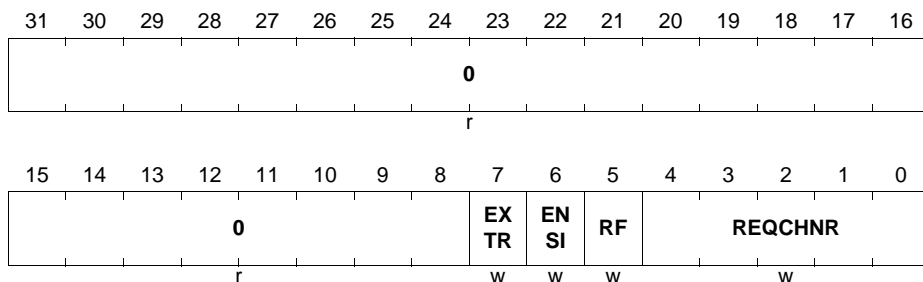
Queue 0 Input Register (08C_H) Reset Value: 0000 0000_H

QINR2

Queue 2 Input Register (0AC_H) Reset Value: 0000 0000_H

QINR4

Queue 4 Input Register (0CC_H) Reset Value: 0000 0000_H



Field	Bits	Type	Description
REQCHNR	[4:0]	w	Request Channel Number This bit field defines the requested channel number. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
RF	5	w	Refill This bit defines the refill functionality for this queue entry. 0 _B The content of this queue entry is not entered again in QINRx when the related conversion is started. 1 _B The content of this queue entry is automatically entered again in QINRx when the related conversion is started.

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Field	Bits	Type	Description
ENSI	6	w	Enable Source Interrupt This bit defines the request source event interrupt functionality. 0_B A request source event interrupt is not generated if the related conversion is finished. 1_B A request source event interrupt is generated if the related conversion is finished.
EXTR	7	w	External Trigger This bit defines the external trigger functionality. 0_B A valid queue entry immediately leads to a conversion request. 1_B A valid queue entry waits for a trigger event to occur before issuing a conversion request.
0	[31:8]	r	Reserved Read as 0; should be written with 0.

26.2.13 Channel-Related Functions

The channel control unit defines the conversion settings, that can be programmed individually for each analog input channel. Therefore, a channel control register **CHCTR_x** (**x = 0 - 15**), for (ADC0, ADC1) and **ADC1_CHCTR_x** (**x = 16 - 23**), for ADC1, is associated to each analog input channel CH_x. After the arbiter has determined the channel to be converted, the defined settings are applied to the AD converter, comprising information about:

- **Conversion parameters:**
Bit field ICLSEL defines which input class is taken into account for the conversion (see [Section 26.2.13.1](#)).
- **Reference selection:**
Bit field REFSEL defines which reference input is used for the conversion (see [Section 26.2.13.2](#))
- **Channel event handling:**
Bit fields LCC, BNDASEL, and BNDBSEL define which boundaries are used for limit checking (see [Section 26.2.13.4](#)) and which channel event leads to a channel event interrupt (see [Section 26.2.13.5](#)).
- **Synchronous conversion request:**
Bit SYNC defines if the channel triggers a synchronized conversion (see [Section 26.2.19](#)).
- **Alias feature:**
In addition to the general channel control, the ADC kernel supports a mechanism (named alias feature, see [Section 26.2.13.3](#)) to redirect a conversion request to another channel number.

26.2.13.1 Input Classes

An input class defines the length of the sample phase and the resolution of the conversion. In most applications, the characteristics of the input circuitries (RC input low-pass filter and impedance of the signal source) are quite similar for several analog input signals, leading to similar timings for the sample phase of these channels. As a consequence, input channels with similar parameters can be grouped together to form an input class.

All channels with the same ICLSEL setting belong to the same input class and have the same sample phase length and resolution. In the TC1728, 4 input classes are supported. Registers **INPCR_x** (**x = 0 - 3**) can be programmed to adjust the sample time and the resolution to the application requirements independently for each input class.

The default setting of these registers lead to the minimum sample phase length of $2 f_{\text{ADC1}}$ cycles and conversions with 10 bits resolution. If this default setting fits to the application requirements, bit fields **CHCTR_x** (**x = 0 - 15**), for (ADC0, ADC1) and **ADC1_CHCTR_x** (**x = 16 - 23**), for ADC1. ICLSEL and registers **INPCR_x** (**x = 0 - 3**) need not to be changed.

26.2.13.2 Reference Selection

The conversion result of the ADC is always referring to a reference voltage. The maximum digital result value (full scale) is obtained if the analog input voltage equals the reference voltage. In order to support more than one measurement range with full scale digital representation, the user can select between the standard reference input V_{AREF} and an alternative reference input at the analog input channel CH0 for each ADC kernel. The reference selection can be individually programmed for each input channel.

This feature can be used to connect 5 V based sensors and 3.3 V based sensors to the same ADC kernel. In this case, one set of input channels refers to the standard reference input, whereas the other one refers to the voltage level at input CH0.

Please note that the smallest granularity 1 LSB_n for n bit resolution refers to the selected reference voltage. The granularity becomes very small if a low reference voltage is applied, and as a consequence, the resulting TUE increases due to noise effects. Therefore it is recommended to avoid small reference voltages.

26.2.13.3 Alias Feature

The ADC kernel provides an alias feature, allowing a re-direction of conversion requests for channels CH0 or CH1 to other channel numbers. This feature can be used to measure the same input channel and to store the conversion results in two different result registers.

- The same signal can be measured twice without the need to read out the conversion result to avoid data loss. This allows triggering both conversions quickly one after the other and being independent from CPU interrupt latency.
- The sensor signal is connected to only one input channel (instead of two analog inputs). This saves input pins in low-cost applications and only the leakage of one input has to be considered in the error calculation.
- Even if the analog input CH0 is used as alternative reference (see [Figure 26-13](#)), the internal trigger and data handling features for channel CH0 can be used.
- The channel settings for both conversions can be different (boundary values, interrupts, etc.).
- If a sequential conversion request source has been set up, a conversion request for channels CH0 or CH1 can be easily directed to other input channels without flushing the queue.

In typical low-cost AC-drive applications, only one common current sensor is used to determine the phase currents. Depending on the applied PWM pattern, the measured value has different meanings and the sample points have to be precisely located in the PWM period. [Figure 26-13](#) shows an example where the sensor signal is connected to one input channel (CHx) but two conversions are triggered for two different channels (CHx and CH0). With the alias feature, a conversion request for CH0 leads to a conversion of the analog input CHx instead of CH0, but taking into account the settings for CH0. Although the same analog input (CHx) has been measured, the conversion

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results can be stored and read out from the result registers RESRx (conversion triggered for CHx) and RESRy (conversion triggered for CH0). Additionally, different interrupts or limit boundaries can be selected, enabled or disabled.

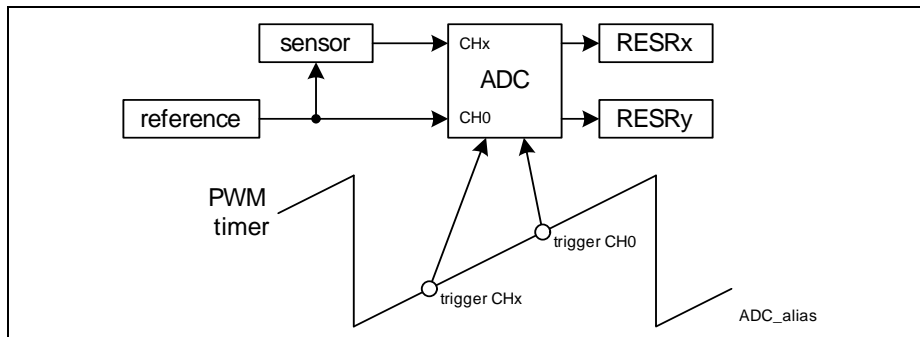


Figure 26-13 Alias Feature

26.2.13.4 Limit Checking

The limit checking mechanism automatically compares each conversion result to two boundary values (boundaries A and B). For each channel, the user can select these boundaries from a set of 4 programmable values (**LCBR0** to **LCBR3**).

With this structure, the conversion result range is split into three areas:

- Area I: The conversion result is below or equal to both boundaries.
- Area II: The conversion result is above one boundary and below or equal to the other boundary.
- Area III: The conversion result is above both boundaries.

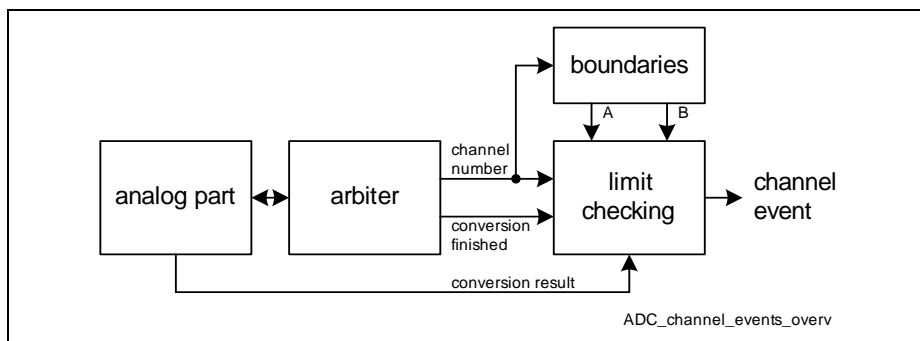


Figure 26-14 Channel Event Generation

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Bit field LCC in the channel control register defines the condition to generate a channel event, leading to a channel event interrupt:

- LCC = 000_B: No trigger, the channel event generation is disabled.
- LCC = 001_B: A channel event is generated if the conversion result is not in area I.
- LCC = 010_B: A channel event is generated if the conversion result is not in area II.
- LCC = 011_B: A channel event is generated if the conversion result is not in area III.
- LCC = 100_B: A channel event is always generated (regardless of the boundaries).
- LCC = 101_B: A channel event is generated if the conversion result is in area I.
- LCC = 110_B: A channel event is generated if the conversion result is in area II.
- LCC = 111_B: A channel event is generated if the conversion result is in area III.

Figure 26-15 shows an example for limit checking where channel events are generated only if the conversion results are not in the normal operating range defined by area II (LCC = 010_B).

Typical applications for limit checking are temperature monitoring or overcurrent sensing. As long as the measured temperature value is below a boundary value, the CPU does not need to be informed. In this case, a channel event should be generated only if the conversion result is in area III (LCC = 111_B) to indicate an over-temperature condition. If the conversion of the analog temperature input signal is part of an auto-scan sequence autonomously triggered on a regular time base, the CPU load for the temperature monitoring is zero until the over-temperature condition is detected.

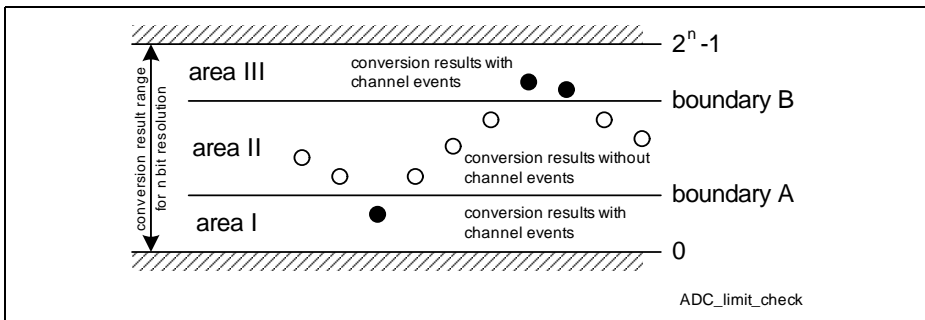


Figure 26-15 Limit Checking

Note: It is also possible to select the same boundary register for boundaries A and B. In this case, the conversion result range is split into two ranges (area II is empty).

26.2.14 Channel-Related Registers

26.2.14.1 Channel Control Registers

The channel control registers contain bits to select the targeted result register, to control the limit check mechanism and to select an input class.

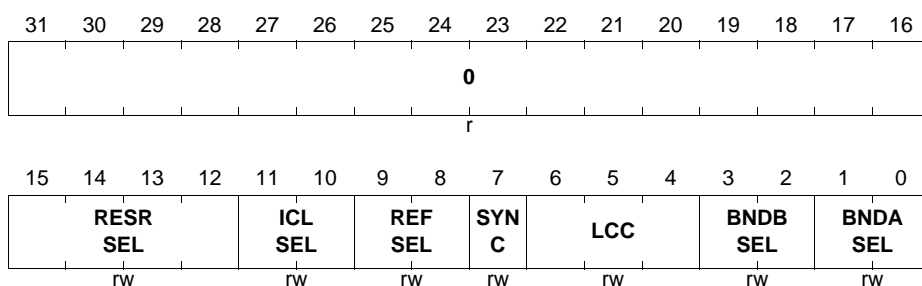
The channel control register 0 defines the settings for the input channel 0, etc.

CHCTR_x (x = 0 - 15)

Channel x Control Register ($100_H + x * 4$) **Reset Value: 0000 0000_H**

ADC1_CHCTR_x (x = 16 - 23)

Channel x Control Register ($2C0_H + x * 4$) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
BNDASEL	[1:0]	rw	Boundary A Selection This bit field defines which boundary will be taken as boundary A for the limit checking. 00 _B The value given by LCBR0 is selected. 01 _B The value given by LCBR1 is selected. 10 _B The value given by LCBR2 is selected. 11 _B The value given by LCBR3 is selected.
BNDBSEL	[3:2]	rw	Boundary B Selection This bit field defines which boundary will be taken as boundary B for the limit checking. 00 _B The value given by LCBR0 is selected. 01 _B The value given by LCBR1 is selected. 10 _B The value given by LCBR2 is selected. 11 _B The value given by LCBR3 is selected.

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Field	Bits	Type	Description
LCC	[6:4]	rw	Limit Check Control This bit field defines the behavior of the limit checking mechanism. Please refer to the coding in Section 26.2.13.4 on Page 26-81 .
SYNC	7	rw	Synchronization Request This bit defines if a conversion request for this channel leads to a synchronized (parallel) conversion with other ADC kernels. This bit is only taken into account if the ADC kernel is a potential conversion master (SYNCTR .STSEL = 00), otherwise it is considered to be 0. 0 _B This channel does not request a synchronized conversion. 1 _B This channel requests a synchronized conversion if the ADC kernel is a potential synchronization master.
REFSEL	[9:8]	rw	Reference Input Selection This bit field defines the reference source for this channel. 00 _B The standard reference input V_{AREF} is selected. 01 _B The alternative reference input CH0 is selected. 10 _B reserved, do not use 11 _B reserved, do not use
ICLSEL	[11:10]	rw	Input Class Selection These bits are used to select the input class. 00 _B The input class 0 is selected. 01 _B The input class 1 is selected. 10 _B The input class 2 is selected. 11 _B The input class 3 is selected.
RESRSEL	[15:12]	rw	Result Register Selection This bit field defines which result register will be the target of a conversion of this channel. 0 _H Result register 0 is selected. 1 _H Result register 1 is selected. ... F _H Result register 15 is selected.

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Field	Bits	Type	Description
0	[31:16]	r	Reserved Read as 0; should be written with 0.

26.2.14.2 Input Class Registers

The input class registers contain bits to control the sample time and the resolution for each input class.

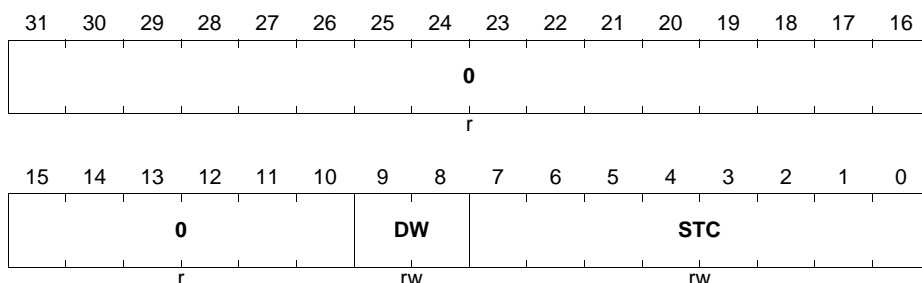
The input class register 0 defines the settings for the input class 0, etc.

INPCR_x (x = 0 - 3)

Input Class Register x

(050_H + x * 4)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
STC	[7:0]	rw	Sample Time Control This bit field defines the additional length of the sample phase, given in analog clock cycles f_{ADCI} . A minimum sample phase of 2 analog clock cycles is extended by the programmed value. sample phase length = $(2 + \text{STC}) / f_{\text{ADCI}}$
DW	[9:8]	rw	Data Width This bit field defines how many bits are converted for the result. The MSBs of conversion results with different DW settings are left aligned in the result bit fields. Bit positions that are not converted are 0. 00 _B The result is 10 bits wide. 01 _B The result is 12 bits wide. 10 _B The result is 8 bits wide. 11 _B reserved
0	[31:10]	r	Reserved Read as 0; should be written with 0.

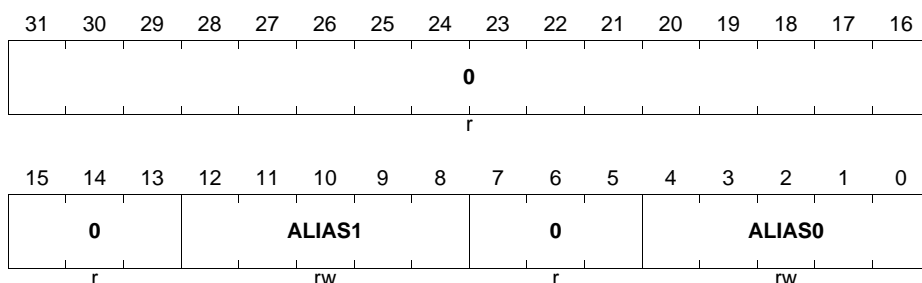
26.2.14.3 Alias Register

The alias register contains bits to change a requested channel number from CH0 and CH1 to another channel number, see also [Section 26.2.13.3](#). The programmed alias channel number is replacing the internally requested number for analog input multiplexer (of the converter). The internally requested channel number is taken into account for all other internal actions and the synchronization request.

ALR0

Alias Register 0

(210_H)

Reset Value: 0000 0100_H


Field	Bits	Type	Description
ALIAS0	[4:0]	rw	Alias Value for CH0 Conversion Requests The channel indicated in this bit field is converted instead of channel CH0. The conversion is done with the settings defined for channel CH0. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
ALIAS1	[12:8]	rw	Alias Value for CH1 Conversion Requests The channel indicated in this bit field is converted instead of channel CH1. The conversion is done with the settings defined for channel CH1. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
0	[7:5], [31:13]	r	Reserved Read as 0; should be written with 0.

26.2.14.4 Limit Check Boundary Registers

The bit fields in these registers define compare value (boundary) for the limit checking unit. The reset values of the boundaries are defined as 10%, 90%, 33% and 66% of the complete result range (the MSB located at bit position 11) of each conversion.

LCBR0

Limit Check Boundary Register 0 (0F0_H) **Reset Value: 0000 0198_H**

LCBR1

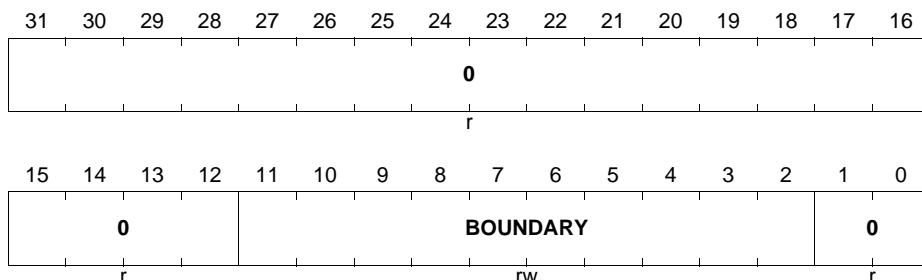
Limit Check Boundary Register 1 (0F4_H) **Reset Value: 0000 0E64_H**

LCBR2

Limit Check Boundary Register 2 (0F8_H) **Reset Value: 0000 0554_H**

LCBR3

Limit Check Boundary Register 3 (0FC_H) **Reset Value: 0000 0AA8_H**



Field	Bits	Type	Description
BOUNDARY	[11:2]	rw	Boundary for Limit Checking This bit field contains the value for the limit checking unit that is compared to the actual conversion result. The result of the limit check is used for the generation of the channel event, see Section 26.2.13.4 .
0	[1:0], [31:12]	r	Reserved Read as 0; should be written with 0.

26.2.14.5 Channel Flag Register

The channel event indication flag register CHFR monitors the detected channel events.

CHFR

Channel Flag Register

(060_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								F	F	F	F	F	F	F	F
								C23	C22	C21	C20	C19	C18	C17	C16
r								rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	C0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
FCx (x = 0 - 23)	x	rwh	Event Flag for Channel x Flag FCx indicates that a channel event for channel x has been detected. ADC0 kernel has 16 channels, CH0-CH15 thus FC0-FC15 is valid, while ADC1 kernel has 24 channels, CH0-CH23 and FC0-FC23 is valid. Writing a 0 has no effect, whereas writing a 1 sets the written bit position without generating an interrupt. Bit FCx is cleared by writing CHFCR.CFCx = 1. 0 _B A channel x event has not occurred. 1 _B A channel x event has occurred.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

26.2.14.6 Channel Flag Clear Register

Writing a 1 to a bit position in register CHFCR clears the corresponding channel flag in register CHFR. If a hardware event triggers the setting of bit CHFR.x and software writes CHFCR.x = 1, bit CHFR.x is cleared (software overrules hardware).

CHFCR

Channel Flag Clear Register

(064_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								CF C23	CF C22	CF C21	CF C20	CF C19	CF C18	CF C17	CF C16
								w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CF C15	CF C14	CF C13	CF C12	CF C11	CF C10	CF C9	CF C8	CF C7	CF C6	CF C5	CF C4	CF C3	CF C2	CF C1	CF C0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
CFCx (x = 0 - 23)	x	w	Clear Event Flag for Channel x ADC0 kernel has 16 channels, CH0-CH15 thus CFC0-CFC15 is valid, while ADC1 kernel has 24 channels, CH0-CH23 and CFC0-CFC23 is valid. 0 _B No action. 1 _B Bit CHFR.FCx is cleared.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

26.2.14.7 Channel Event Node Pointer Registers

The bit fields in these registers define the service request output ADCy_SR[7:0] that is activated if a channel event occurs and the interrupt generation is enabled for this channel.

CHENPR0

Channel Event Node Pointer Register 0

(068_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	CHENP7			0	CHENP6			0	CHENP5			0	CHENP4		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CHENP3			0	CHENP2			0	CHENP1			0	CHENP0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
CHENP0, CHENP1, CHENP2, CHENP3, CHENP4, CHENP5, CHENP6, CHENP7	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Node Pointer for Channel x This bit field defines which service request output becomes activated if the channel x event of kernel ADCy occurs while enabled by CHCTRx (x = 0 - 15).LCC. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

CHENPR8

Channel Event Node Pointer Register 8

(06C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	CHENP15			0	CHENP14			0	CHENP13			0	CHENP12		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CHENP11			0	CHENP10			0	CHENP9			0	CHENP8		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
CHENP8, CHENP9, CHENP10, CHENP11, CHENP12, CHENP13, CHENP14, CHENP15	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Node Pointer for Channel x This bit field defines which service request output becomes activated if the channel x event of kernel ADCy occurs while enabled by CHCTRx (x = 0 - 15) .LCC. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

ADC1_CHENPR16

Channel Event Node Pointer Register 16

(268_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	CHENP23			0	CHENP22			0	CHENP21			0	CHENP20		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CHENP19			0	CHENP18			0	CHENP17			0	CHENP16		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
CHENP16, CHENP17, CHENP18, CHENP19, CHENP20, CHENP21, CHENP22, CHENP23	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Node Pointer for Channel x This bit field defines which service request output becomes activated if the channel x event of kernel ADCy occurs while enabled by ADC1_CHCTR_x (x = 16 - 23).LCC. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

26.2.15 Conversion Result Handling

The result generation part handles the:

- Storage of the conversion results (see [Section 26.2.15.1](#))
- Wait-for-read mode (see [Section 26.2.15.2](#))
- Result event interrupts (see [Section 26.2.15.3](#))
- Result FIFO buffer (see [Section 26.2.15.4](#))
- Data reduction or anti-aliasing filtering (see [Section 26.2.15.5](#))

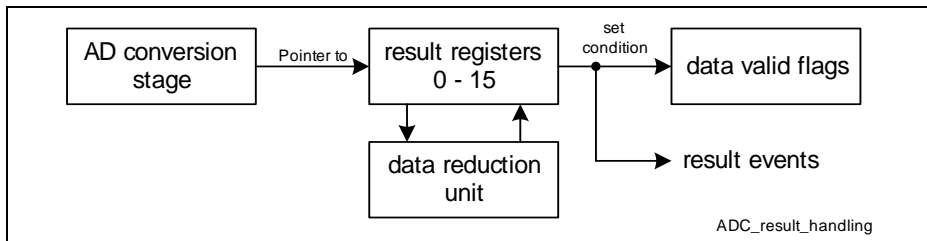


Figure 26-17 Conversion Result Handling

26.2.15.1 Storage of Conversion Results

For each analog input channel, the associated channel control register **CHCTR_x** (**x = 0 - 15**) for (ADC0, ADC1) and **ADC1_CHCTR_x** (**x = 16 - 23**) for ADC1 contains a pointer bit field (RESRSEL) defining the result register to store the conversion result of this channel. This structure allows the user to direct conversion results of different channels to one or more result registers. Depending on the application needs (data reduction, auto-scan, alias feature, result FIFO, etc.), the user can distribute the conversion results to minimize CPU load or to be more tolerant against interrupt latency.

An individual data valid flag **VFR.VF_x** for each result register indicates that “new” valid data has been stored in the corresponding result register and can be read out.

Due to different result handling mechanisms, the conversion result can be represented in different ways:

- **Data reduction filter disabled:**
The conversion result is maximum 12 bits wide with the MSB of the conversion result being always at bit position 11 and the remaining LSBs filled with 0.
The data valid flag is set and a result event occurs each time a new conversion result is stored in the result register.
It is possible to share a result register among several analog input channels.
- **Data reduction filter enabled:**
The conversion result is maximum 12 bits wide with the MSB of the conversion result being always at bit position 11 and the remaining LSBs filled with 0. The additional bits [13:12] show the MSBs of the data accumulation.

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The data valid flag is set and a result event occurs each time a data reduction sequence is finished and the final result is available in the result register.

In order to support a wait-for-read and FIFO buffer features, the valid flag has to be cleared automatically when SW does a read access or the result is transferred into another FIFO element (if result FIFO buffering is enabled).

This behavior is contradictory to debugging requirements. For debugging, it has to be possible to introduce read or write commands into the normal program flow, e.g. to monitor conversion results. If a debugger reads out a result register, it would change the status of the conversion result from valid = "new" (not yet read out) to "old" (already read out). This would have an undesired impact on the application.

Therefore, the read views with "D" deliver the same value as the read views without "D", but without clearing the valid bit. As a result, a debugger using read views with "D" can monitor the conversion results without influencing their status for the application.

To allow debugger accesses without the risk of data sequence corruption, two different result register read views are supported. The read views refer to the same result register contents, but show a different behavior according to the address that has been read:

- Standard read view **RESR0** and **RESRx (x = 1 - 15)**:
A read action clears the corresponding valid bit.
- Read view **RESRD0** and **RESRDx (x = 1 - 15)** for debugger:
A read action does not clear the corresponding valid bit.

26.2.15.2 Wait-for-Read Mode

The wait-for-read mode is a feature of a result register allowing the CPU (or DMA) to treat each conversion result independently without the risk of data loss. Data loss could occur if the CPU does not read a conversion result from a result register before a new result overwrites the previous one.

Especially for auto-scan conversion sequences (or other sequences with “relaxed” timing requirements), the wait-for-read offers the possibility to request a conversion sequence according to an event (HW or SW), but to start a new conversion according to the CPU capability to read the formerly converted result.

If wait-for-read mode is enabled for a result register by setting bit WFR in register **RCRx (x = 0 - 15)**, a request source does not generate a conversion request while the targeted result register contains valid data (indicated by the valid flag VFx = 1) or if a currently running conversion targets the same result register.

A new conversion request is generated only after the targeted result register has been read out.

If two request sources target the same result register with wait-for-read selected, a lower priority request started before the higher priority source has requested its conversion can not be interrupted by the higher priority request. If a higher priority request targets a different result register, the lower priority conversion can be cancelled and repeated afterwards.

26.2.15.3 Result Event Interrupts

A result event interrupt can be generated based on a result event according to the structure shown in [Figure 26-18](#). If a result event is detected, it sets the corresponding indication flag in register [EVFR](#). These flags can also be set by writing a 1 to the corresponding bit position, whereas writing 0 has no effect. The indication flags can be cleared by SW by writing a 1 to the corresponding bit position in register [EVFCR](#).

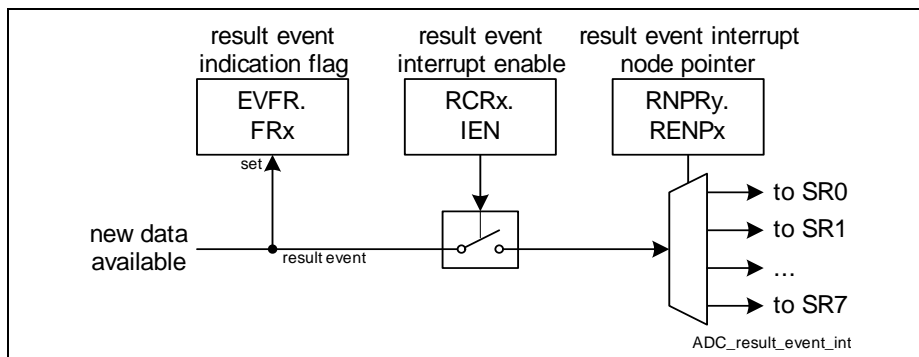


Figure 26-18 Result Event Interrupt Generation

The service request output $ADCy_SRx$ that is selected by the result event interrupt node pointer bit fields in registers [RNPR0](#) or [RNPR8](#) issues an interrupt each time the related result event is detected.

A service request output can be activated under SW control by writing [INTR.SISRx](#).

26.2.15.4 Result FIFO Buffer

If a result register is not used as direct target for a conversion result, it can be concatenated with other result registers of the same ADC kernel to form a result FIFO buffer (first-in-first-out buffer mechanism). This allows to store measurement results and to read them out later with a “relaxed” CPU access timing. It is possible to set up more than one FIFO buffer structure with the available result registers.

A FIFO structure can be built by at least two “neighbor” result registers with the indices x and $z = x+1$, where result register z represents the input and result register x represents the output of the FIFO buffer. The conversion result has to be delivered by the converter stage to the FIFO input, whereas the buffered data has to be read out from the FIFO output.

The FIFO buffer function can be enabled by setting bit FEN in registers **RCRx** ($x = 0 - 15$).

In the example shown in **Figure 26-19**, the result registers have been configured to form two FIFO buffers with two buffer stages (result registers 0/1 and 6/7, respectively), one FIFO buffer with three buffer stages (result registers 2/3/4), whereas result register 5 is used as “normal” result register without additional FIFO buffer functionality.

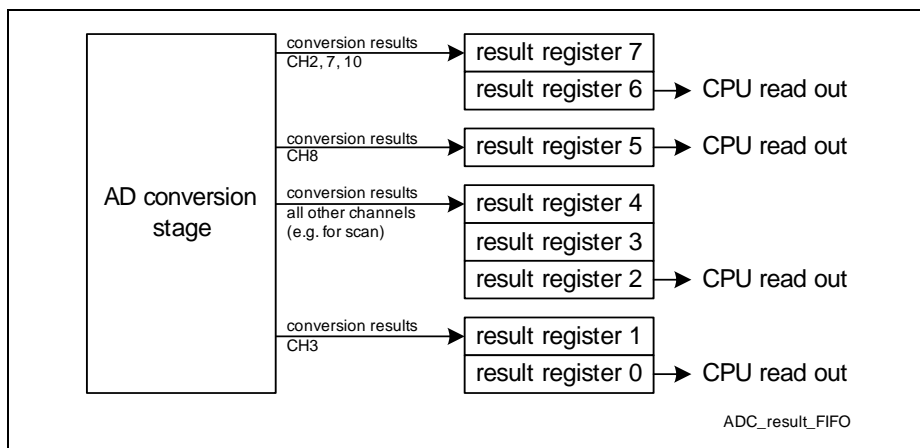


Figure 26-19 Result FIFO Buffers

If more than two result neighbor registers are concatenated to a FIFO buffer (from result register z to result register x , with $z > x$), the one with the highest index (z) is always the input and the one with the lowest index (x) is always the output. All intermediate result registers y ($x < y < z$) are used as intermediate FIFO stages without data input or data output functionality.

Result register features for each FIFO buffer:

- Result register z (**FIFO buffer input**):
This result register can be enabled for data reduction. The wait-for-read mode is supported to avoid data loss if the FIFO is full. Result event interrupt generation is not supported. Must not be read at a read view modifying the valid bit.
- Result register y (**intermediate buffer stage**):
This/these result register(s) must not be enabled neither for wait-for-read mode, nor for data reduction. Result event interrupt generation is not supported. Must not be read at a read view modifying the valid bit, nor be the target of a conversion result.
- Result register x (**FIFO buffer output**):
This result register can be enabled for result event interrupt generation to inform the CPU that new data can be read out from this register location. Data reduction and wait-for-read are not supported and have to be disabled. Must not be the target of a conversion result.
If enabled, a result interrupt is generated for each data word in the FIFO.

26.2.15.5 Data Reduction Filter

The data reduction filter can be used as digital filter for anti-aliasing or decimation purposes. It can accumulate a maximum of 4 conversion results to generate a final result.

Each result register can be individually enabled for data reduction. The feature is controlled by bit field DRCTR in registers **RCRx (x = 0 - 15)**. The actual status is given by bit field DRC (data reduction counter) in the related result register.

Conversion delivering results to other result registers do not influence the data reduction filter of result register x. As a consequence, other channels can be converted between two conversions targeting result register x.

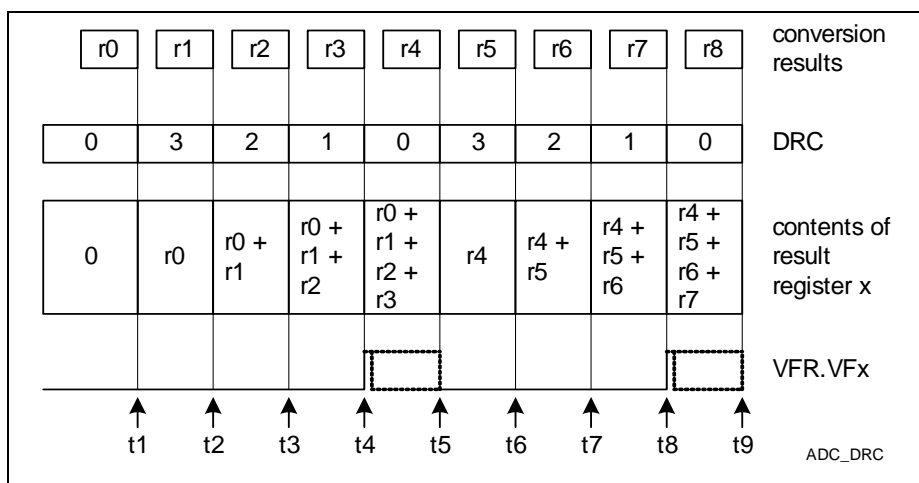


Figure 26-20 Data Reduction Filter

In the example given in **Figure 26-20**, a data reduction sequence of 4 accumulated conversion results is shown. The data reduction is based on three rules:

- Each time bit field DRC is 0 and a conversion targeting result register x is completed (t1, t5, t9), the contents of bit field RCRx.DRCTR is loaded into bit field DRC and the conversion result is stored in result register x.
- Each time bit field DRC is not 0 and a conversion targeting result register x is completed (t2, t3, t4 for the first final result and t6, t7, t8 for the next one), bit field DRC is decremented by 1 and the conversion result is added to the value already stored in result register x.
- Each time bit field DRC is 0 after decrementing or after loading it with RCRx.DRCTR = 0 (t4 for the first final result and t8 for the next one), the valid bit for the result register x becomes set and a result register event occurs.

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The final result of a data reduction sequence has to be read out from result register x before the next data reduction sequence starts (interval between t4 and t5, or t8 and t9 respectively). With the read out of the final result from this register, the valid flag is automatically cleared.

If this interval is too short, it is recommended to associate a second result register z to result register x by enabling the result FIFO mechanism for result register x, see [Figure 26-21](#) ($z = x + 1$). In this case, result register x is loaded with the final result elaborated by result register z when a data reduction sequence is finished. The final result has to be read out from result register x before the next data reduction sequence is finished (interval between t4 and t8).

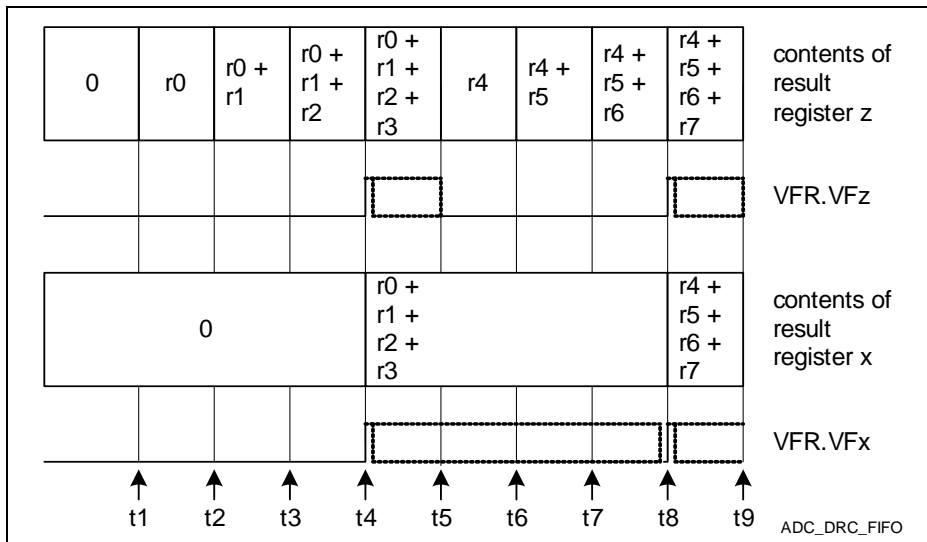


Figure 26-21 Data Reduction Filter with Result FIFO

26.2.16 Conversion Result-Related Registers

26.2.16.1 Result Register 0

The result registers deliver the conversion results and associated information.

Additionally to this information, result register RESR0 also indicates the setting of an external analog multiplexer. The conversion results of the channel used with an external multiplexer have to be directed to RESR0 in order to indicate the multiplexer setting used during the conversion. If this information is not necessary, the conversion result can be directed to any other result register.

The valid flag VF indicates that a result register contains updated data and can be used to poll for new data. The valid flag of a result register is cleared automatically if at least the low byte of register RESR0 is read, whereas it is left unchanged when reading RESRD0.

RESR0

Result Register 0

(180_H)

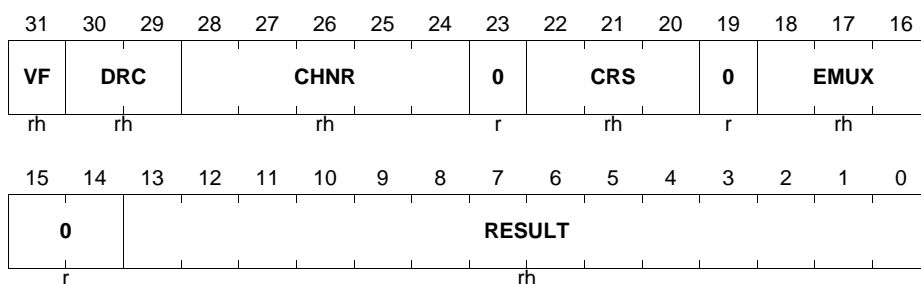
Reset Value: 0000 0000_H

RESRD0

Result Register 0 for Debugging

(1C0_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RESULT	[13:0]	rh	Conversion Result This bit field contains the conversion result, or respectively, the result of the data reduction filter.
EMUX	[18:16]	rh	External Multiplexer Setting This bit field indicates the external multiplexer setting leading to the result stored in bit field RESULT.

Analog to Digital Converter

Field	Bits	Type	Description
CRS	[22:20]	rh	Converted Request Source This bit field indicates the request source that has requested the conversion leading to the result stored in bit field RESULT. 000 _B The conversion was requested by source 0. 001 _B The conversion was requested by source 1. 010 _B The conversion was requested by source 2. 011 _B The conversion was requested by source 3. 100 _B The conversion was requested by source 4. else reserved
CHNR	[28:24]	rh	Channel Number This bit field contains the channel number of the latest register update. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).
DRC	[30:29]	rh	Data Reduction Counter This bit field indicates how many conversion results have still to be accumulated to generate the final result for data reduction. The valid flag is automatically set when this bit field becomes 0. It can be cleared by SW by writing a 1 to the related bit position in register VFR. 00 _B The final result is available in the result register. The valid flag is automatically set when this bit field is set to 0. 01 _B 1 more conversion result has to be added to obtain the final result in the result register. 10 _B 2 more conversion results have to be added to obtain the final result in the result register. 11 _B 3 more conversion results have to be added to obtain the final result in the result register.
VF	31	rh	Valid Flag This bit indicates that bit field RESULT has been updated with valid data since it has been read out. It is another view of the corresponding bit in register VFR. 0 _B The result register has not been updated. 1 _B The result register has been updated.

Analog to Digital Converter

Field	Bits	Type	Description
0	[15:14], 19, 23	r	Reserved Read as 0; should be written with 0.

26.2.16.2 Result Registers 1 to 15

The result registers deliver the conversion results and associated information.

The valid flag VF indicates that the result register contain updated data and can be used to poll for new data. The valid flag of a result register is cleared automatically if at least the low byte of register RESRx is read, whereas it is left unchanged when reading RESRDx.

RESRx (x = 1 - 15)

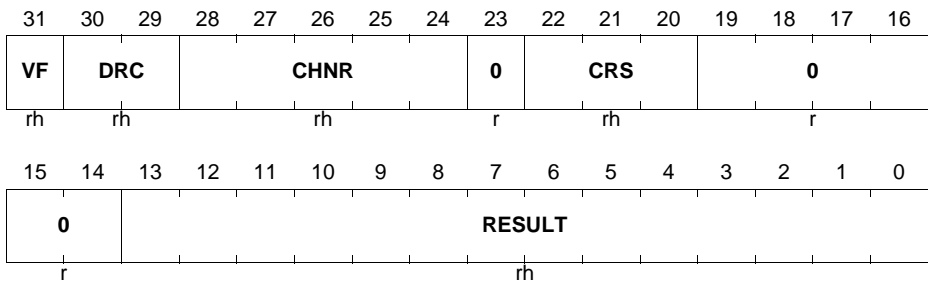
Result Register x (180_H + x * 4)

Reset Value: 0000 0000_H

RESRDx (x = 1 - 15)

Result Register x for Debugging (1C0_H + x * 4)

Reset Value: 0000 0000_H



Analog to Digital Converter

Field	Bits	Type	Description
RESULT	[13:0]	rh	Conversion Result This bit field contains the conversion result, or respectively, the result of the data reduction filter.
CRS	[22:20]	rh	Converted Request Source This bit field indicates the request source that has requested the conversion leading to the result stored in bit field RESULT. 000 _B The conversion was requested by source 0. 001 _B The conversion was requested by source 1. 010 _B The conversion was requested by source 2. 011 _B The conversion was requested by source 3. 100 _B The conversion was requested by source 4. else reserved
CHNR	[28:24]	rh	Channel Number This bit field contains the channel number of the latest register update. ADC0 kernel has 16 channels, CH0-CH15 (i.e 00 _H to 0F _H), while ADC1 kernel has 24 channels, CH0-CH23 (i.e 00 _H to 17 _H).

Analog to Digital Converter

Field	Bits	Type	Description
DRC	[30:29]	rh	<p>Data Reduction Counter</p> <p>This bit field indicates how many conversion results have still to be accumulated to generate the final result for data reduction. The valid flag is automatically set and a result event is generated when this bit field becomes 0 (by decrementing or by reload).</p> <p>Bit field DRC is cleared by writing the related VFR.VFx = 1.</p> <p>00_B The final result is available in the result register.</p> <p>01_B 1 more conversion result has to be added to obtain the final result in the result register.</p> <p>10_B 2 more conversion results have to be added to obtain the final result in the result register.</p> <p>11_B 3 more conversion results have to be added to obtain the final result in the result register.</p>
VF	31	rh	<p>Valid Flag</p> <p>This bit indicates that bit field RESULT has been updated with valid data since it has been read out. It is another view of the corresponding bit in register VFR.</p> <p>0_B The result register has not been updated.</p> <p>1_B The result register has been updated.</p>
0	[19:14], 23	r	<p>Reserved</p> <p>Read as 0; should be written with 0.</p>

26.2.16.3 Valid Flag Register

The valid flag register contains the flags indicating that the corresponding result register contents are valid (valid = “new” = not read out).

These bits are another (condensed) view of the valid flags in the result registers.

VFR

Valid Flag Register

(200_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VF 15	VF 14	VF 13	VF 12	VF 11	VF 10	VF 9	VF 8	VF 7	VF 6	VF 5	VF 4	VF 3	VF 2	VF 1	VF 0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

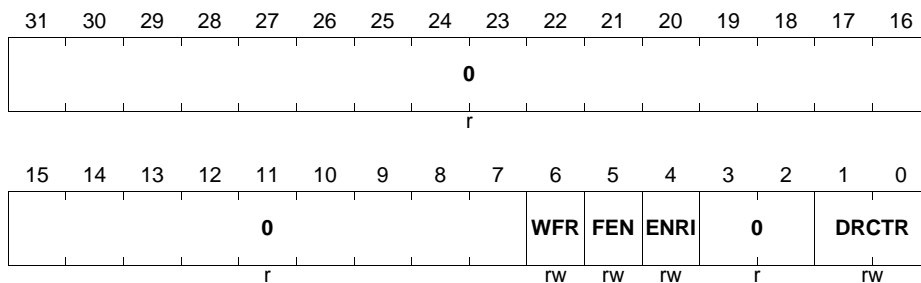
Field	Bits	Type	Description
VFx (x = 0 - 15)	x	rwh	Valid Flag for Result Register x This bit indicates that the contents of the result register x is valid. Writing a 0 has no effect, whereas writing a 1 clears the written bit position and the bit field DRC in the related result register. If a hardware event triggers the setting of a bit VFx and SW writes a 1 to the same bit position, the bit VFx is cleared (software overrules hardware). 0 _B The result register x does not contain valid data. Either this register has been read out or no data has been moved to it. 1 _B The result register x contains valid data that has not yet been read out.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

26.2.16.4 Result Control Registers

The result control registers contain bits to control the behavior of the result registers and to monitor their status. Result register x is controlled by result control register x.

RCRx (x = 0 - 15)

Result Control Register x $(140_H + x * 4)$ Reset Value: 0000 0000_H



Field	Bits	Type	Description
DRCTR	[1:0]	rw	Data Reduction Control This bit field defines how many conversion results are accumulated for data reduction (see Section 26.2.15.5). It defines the reload value for bit field DRC. 00 _B The data reduction filter is disabled. The reload value for DRC is 0, so no accumulation is done. 01 _B The data reduction filter is enabled. The reload value for DRC is 1, so the accumulation is done over 2 conversions. 10 _B The data reduction filter is enabled. The reload value for DRC is 2, so the accumulation is done over 3 conversions. 11 _B The data reduction filter is enabled. The reload value for DRC is 3, so the accumulation is done over 4 conversions.
ENRI	4	rw	Enable Result Interrupt This bit enables the result event interrupt if a result event is detected for result register x. 0 _B The result event interrupt is disabled. 1 _B The result event interrupt is enabled.

Analog to Digital Converter

Field	Bits	Type	Description
FEN	5	rw	FIFO Enable This bit enables the FIFO functionality for result register x, see Section 26.2.15.4 . 0 _B The FIFO functionality is disabled. 1 _B The FIFO functionality is enabled.
WFR	6	rw	Wait-for-Read Mode This bit enables the wait-for-read mode for result register x. 0 _B The wait-for-read mode is disabled. 1 _B The wait-for-read mode is enabled.
0	[3:2], [31:7]	r	Reserved Read as 0; should be written with 0.

26.2.16.5 Event Flag Register

The event flag register contains flags related to request source events and result register events.

EVFR

Event Flag Register

(070_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0			GF S4	GF S3	GF S2	GF S1	GF S0	0			F S4	F S3	F S2	F S1	F S0
r			rh	rh	rh	rh	rh	r			rwh	rwh	rwh	rwh	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
F R15	F R14	F R13	F R12	F R11	F R10	F R9	F R8	F R7	F R6	F R5	F R4	F R3	F R2	F R1	F R0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
FRx (x = 0 - 15)	x	rwh	Event Flag for Result Register x Flag FRx indicates that a result event of result register x has been detected. Writing a 0 has no effect, whereas writing a 1 sets the written bit position without generating an interrupt. Bit FRx is cleared by writing EVFCR.CFRx = 1. 0 _B An event of result register x has not yet been detected. 1 _B An event of result register x has been detected.
FSx (x = 0 - 4)	x + 16	rwh	Event Flag for Request Source x Flag FSx indicates that a request source event of request source x has been detected. Writing a 0 has no effect, whereas writing a 1 sets the written bit position without generating an interrupt. Bit FSx is cleared by writing EVFCR.CFSx = 1. 0 _B An event of request source x has not yet been detected. 1 _B An event of request source x has been detected.

Analog to Digital Converter

Field	Bits	Type	Description
GFSx (x = 0 - 4)	x + 24	rh	Gated Event Flag for Request Source x Flag GFSx indicates that a request source event of request source x has been detected while the related interrupt was enabled. Writing to this bit position has no effect. Bit GFSx is cleared by writing EVFCR.CFSx = 1. 0 _B An event of request source x has not yet been detected or the related interrupt was not enabled. 1 _B An event of request source x has been detected while the related event interrupt was enabled.
0	[23:21], [31:29]	r	Reserved Read as 0; should be written with 0.

26.2.16.6 Event Flag Clear Register

Writing a 1 to a bit position in register EVFCR clears the corresponding event flag in register EVFR. If a hardware event triggers the setting of bit EVFR.x and software writes EVFCR.x = 1, bit EVFR.x is cleared (software overrides hardware).

EVFCR

Event Flag Clear Register

(074_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
					0						CF S4	CF S3	CF S2	CF S1	CF S0
					r						w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CF R15	CF R14	CF R13	CF R12	CF R11	CF R10	CF R9	CF R8	CF R7	CF R6	CF R5	CF R4	CF R3	CF R2	CF R1	CF R0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
CFR_x (x = 0 - 15)	x	w	Clear Event Flag for Result Register x 0 _B No action. 1 _B Bit EVFR.FR _x is cleared.
CFS_x (x = 0 - 4)	x + 16	w	Clear Event Flag for Source x 0 _B No action. 1 _B Bits EVFR.FS _x and EVFR.GFS _x are cleared.
0	[31:21]	r	Reserved Read as 0; should be written with 0.

26.2.16.7 Event Node Pointer Registers

The bit fields in these registers define the service request output ADCy_SR[7:0] that is activated if a request source event or a result register event occurs and the interrupt generation is enabled for this event.

EVNPR

Event Node Pointer Register

(078_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													SEN4		
r													rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	SEN3		0	SEN2		0	SEN1		0	SEN0					
r	rw		r	rw		r	rw		r	rw					

Field	Bits	Type	Description
SEN0, SEN1, SEN2, SEN3, SEN4	[2:0], [6:4], [10:8], [14:12], [18:16]	rw	Node Pointer for Request Source x This bit field defines which service request output becomes activated if the request source x event of kernel ADCy occurs while the interrupt generation is enabled for this event. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, [31:19]	r	Reserved Read as 0; should be written with 0.

Analog to Digital Converter

RNPR0

Result Node Pointer Register 0

(208_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	RENp7			0	RENp6			0	RENp5			0	RENp4		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	RENp3			0	RENp2			0	RENp1			0	RENp0		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
RENp0, RENp1, RENp2, RENp3, RENp4, RENp5, RENp6, RENp7	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Node Pointer for Result Register x This bit field defines which service request output becomes activated if the result register x event of kernel ADCy occurs while the interrupt generation is enabled for this event. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

Analog to Digital Converter

RNPR8

Result Node Pointer Register 8

(20C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	RENp15			0	RENp14			0	RENp13			0	RENp12		
r	rw			r	rw			r	rw			r	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	RENp11			0	RENp10			0	RENp9			0	RENp8		
r	rw			r	rw			r	rw			r	rw		

Field	Bits	Type	Description
RENp8, RENp9, RENp10, RENp11, RENp12, RENp13, RENp14, RENp15	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Node Pointer for Result Register x This bit field defines which service request output becomes activated if the result register x event of kernel ADCy occurs while the interrupt generation is enabled for this event. 000 _B ADCy_SR0 is selected. 001 _B ADCy_SR1 is selected. ... 111 _B ADCy_SR7 is selected.
0	3, 7, 11, 15, 19, 23, 27, 31	r	Reserved Read as 0; should be written with 0.

26.2.17 Multiplexer Test Support

A specific multiplexer test mode has been implemented for the analog input CH7 that can be enabled during run time by the user to check the connection to the sensor.

- **Multiplexer test mode disabled** (**GLOBCFG.MTM7** = 0):
The switch for the voltage divider and static load R_{MTM7} is open. The analog input CH7 can be used for normal measurements.
- **Multiplexer test mode enabled** (**GLOBCFG.MTM7** = 1):
The switch for the voltage divider and static load R_{MTM7} is closed. The analog input CH7 is loaded by a resulting resistance and the measured voltage is reduced by a voltage divider.
Please refer to the AC/DC chapter for the value of the resulting grounding resistor and its current capability.

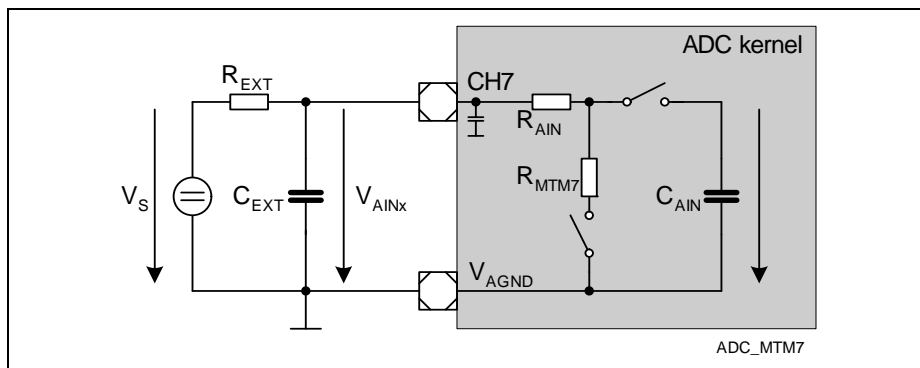


Figure 26-22 Multiplexer Test Mode for CH7

In addition to the multiplexer test support for channel CH7 based on bit MTM7, one out of input channels listed below can also be enabled for the same function. The additional channel number is selected by bit field **GLOBCFG.MTMCH** and the test mode becomes enabled for this channel if **GLOBCFG.MTMEN** = 1.

The following channels can be selected for the additional multiplexer test mode support: CH1, CH3, CH5, CH7, CH9, CH11, CH13, CH15, CH17, CH19, CH21, CH23

The channels with an even channel number do not support this test mode, even if their channel number is selected and **MTMEN** = 1.

The multiplexer test mode for input channel CH7 can be activated by both mechanisms.

26.2.18 External Multiplexer Control

If an application requires more analog inputs channels than available on the TC1728, the ADC kernel supports an extension of analog channels by adding an external analog multiplexer. Three output signals EMUX[2:0] are delivered by each ADC kernel to control the settings of an external analog multiplexer. They can be used to extend the number of analog input channels by adding an external 1-out-of-8 multiplexer.

The external multiplexer control behavior is defined by the bits in register **EMCTR**.

The current setting of EMUX[2:0] is given by bit field EMUX. If another extended input channel should be converted, bit field SETEMUX has to be programmed to the desired value or the scan function has to be enabled. The SETEMUX value is automatically applied with the start of the next conversion of the related analog ADC input channel.

In the example shown in **Figure 26-23** and in the description below, the analog input CH7 has been extended, leading to additional analog inputs named CH70 to CH77. The channel number where the external multiplexer is connected to is defined by bit field EMUXCHNR.

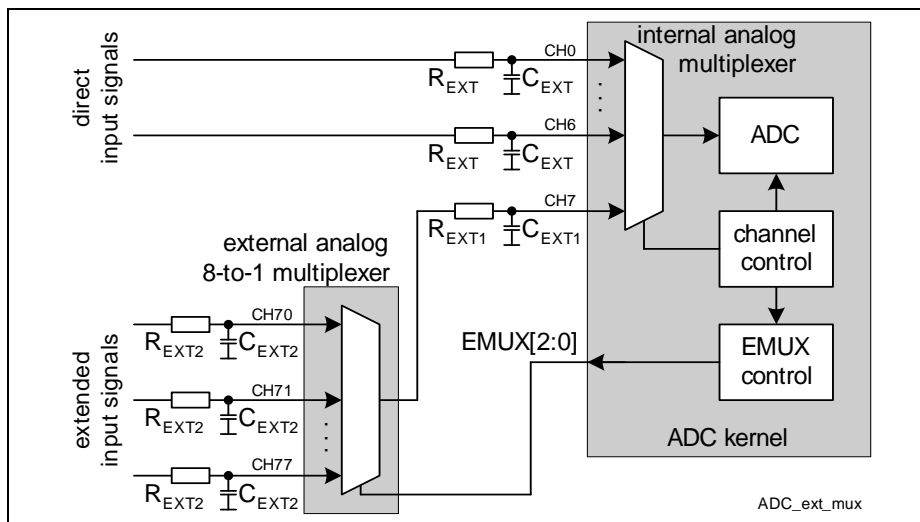


Figure 26-23 External Analog Multiplexer

If the external multiplexer is located far from the ADC analog input, it is recommended to introduce an RC filter R_{EXT1} - C_{EXT1} directly at the analog input CH7 of the ADC. If needed for signal filtering, local RC filters R_{EXT2} - C_{EXT2} can be optionally added at the inputs of the external analog multiplexer.

If the external multiplexer is located close to the analog ADC input, the components R_{EXT1} and C_{EXT1} are not necessarily needed. In this case it is strongly recommended to

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introduce RC filters (R_{EXT2} , C_{EXT2}) at the multiplexer inputs.

Please note that each RC filter limits the bandwidth of the analog input signal.

The RC filters used with an external multiplexer may lead to another impedance “seen” by the ADC analog input CH7 than for the other (direct) analog inputs. The adaptation of the sample phase length can be done by using a different input class with a different value for the sample phase extension. This value can be adapted to execute conversions with an EMUX[2:0] setting that has changed a sufficiently long time before the conversion of CH7 starts. “A sufficiently long time before” signifies that signal transitions at the analog ADC input due to changing multiplexer setting are finished and the input signal is stable enough.

After changing the EMUX[2:0] setting of the external multiplexer, an additional settling time has to elapse before the switched analog signal is stable and can be measured. To compensate for this settling time, an alternative sample phase length (instead of the one given by the input class) is automatically applied for the first conversion of CH7 after EMUX[2:0] has changed. The alternative sample phase length can be programmed by bit field **EMCTR.EMSAMPLE**. If the first conversion of CH7 after the EMUX[2:0] setting has changed is aborted due to a higher priority request, the repeated conversion of CH7 also uses the value of EMSAMPLE. The settling time is considered to be finished after the complete conversion of CH7.

The external multiplexer control block supports different modes, that are programmed by the bits in register **EMCTR**:

- **SW control** without any HW interaction (EMUXEN = 0):
The automatic control of the external multiplexer setting and of the sampling time is disabled. Bit field EMUX is permanently updated with the value of SETEMUX. The changes of EMUX are related to write actions to SETEMUX and not to conversion timing. The setting of EMSAMPLE is not taken into account. It is recommended to write the start value of the first scan sequence to SETEMUX while EMUXEN = 0.
- **HW control without scan** (EMUXEN = 1, SCANEN = 0):
The update of EMUX with the value of SETEMUX happens with each conversion start of the channel selected by EMUXCHNR. For the first conversion with a new EMUX value, the setting of EMSAMPLE is applied.
- **HW control with single-input scan** (EMUXEN = 1, SCANEN = 1, TROEN = 0):
The update of EMUX with a new value happens after each conversion of the channel selected by EMUXCHNR. For each update, EMUX is automatically decremented by 1. If EMUX = 0, it is reloaded with the value of SETEMUX for the next update. For each conversion of the selected channel, the setting of EMSAMPLE is applied. With this setting, an autoscan sequence requesting the conversion of the channel defined by EMUXCHNR leads to one conversion of the channel connected to the external multiplexer. As a result, for each completed auto scan sequence, another EMUX setting is applied.

Assuming inputs 1, 2, 70, 71, and 72 being selected for scan, the following sequence will be executed: 1, 2, 72, 1, 2, 71, 1, 2, 70, 1, 2, 72, 1, 2, 71, 1, 2, 70, 1, 2, 72, ...

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- **HW control with multi-input scan** (EMUXEN = 1, SCANEN = 1, TROEN = 1):

The update of EMUX with a new value happens after each conversion of the channel selected by EMUXCHNR. For each update, EMUX is automatically decremented by 1. If EMUX = 0, it is reloaded with the value of SETEMUX for the next update. For each conversion of the selected channel, the setting of EMSAMPLE is applied.

With enabled trigger option, the external multiplexer control block triggers a new conversion request each time a conversion is started of the channel defined by EMUXCHNR while EMUX > 0.

In a scan request source, the corresponding pending bit becomes set, whereas in a sequential request source, the content of the backup stage becomes valid (V bit of backup stage becomes set).

With this setting, all external multiplexer inputs are scanned during a single autoscan sequence, starting with the channel indicated by SETEMUX (same update rate of all channels of this sequence).

Assuming inputs 1, 2, 70, 71, and 72 being selected for scan, the following sequence will be executed: 1, 2, 72, 71, 70, 1, 2, 72, 71, 70, 1, 2, 72, 71, 70, 1, 2, 72, ...

26.2.19 Synchronized Conversions for Parallel Sampling

The independent ADC kernels implemented in the TC1728 can be synchronized for simultaneous (parallel) measurements of analog input channels. While no parallel conversion is requested, the kernels can work independently.

The synchronization mechanism for parallel conversions ensures that the sample phases of the related channel start simultaneously. Different values for the resolution and the sample phase length of each kernel for a parallel conversion are supported.

A parallel conversion can be requested individually for each input channel (also several channels can be enabled for parallel conversions). In the example shown in the figure below, input channels CH3 of the ADC kernels ADC0 and ADC1 are converted synchronously, whereas other input channels do not lead to parallel conversions.

This leads to the following structure:

- A **synchronization master** ADC kernel can request a conversion of an analog channel. If this channel is selected for a synchronized conversion, it is also requested in the connected slave ADC kernel(s).
- A **synchronization slave** ADC kernel reacts to incoming synchronized conversion requests from its master. While no incoming master requests are active, the slave kernel can convert its own requests.
- All ADC kernels in an ADC module being similar, each kernel can be set up to be a synchronization master or a synchronization slave (depending on the application needs, such as trigger capability of request sources).
- A synchronization master can synchronize several slave kernels, whereas a slave kernel can only be synchronized to one master kernel.

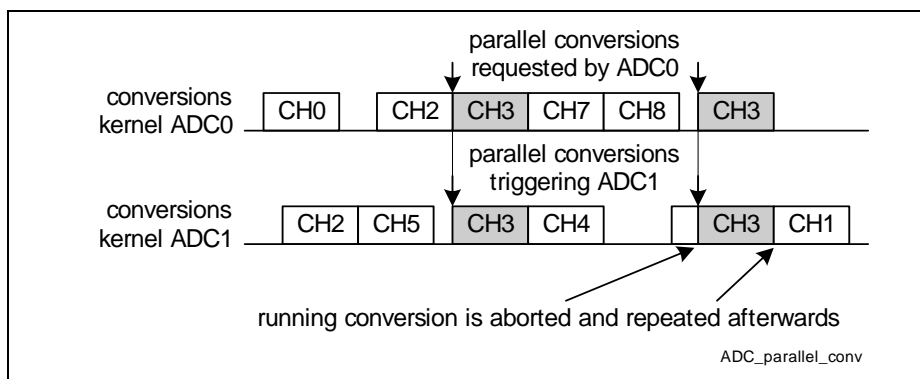


Figure 26-24 Parallel Conversions

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The term “conversion group” has been introduced to define the kernel behavior allowing parallel sampling:

- Kernels in the same conversion group can execute parallel conversions.
- A conversion group contains at least 1 ADC kernel and can contain a maximum of all ADC kernels of the ADC module.
- Each conversion group contains exactly one synchronization master kernel that issues a parallel conversion request and defines the internal frequencies f_{ADCI} and f_{ADCD} and the channel number for a parallel conversion of the conversion group.
- All other kernels in a conversion group are synchronization slaves and have to be programmed with the same values of **GLOBCTR.DIVA**, **DIVD** and **ARBRND** as the synchronization master.
- If there is no need for parallel conversions, each kernel can be considered to form an own conversion group with only an ADC kernel as synchronization master, but without any synchronization slave.
- The channel number and the synchronization request are issued by the synchronization master to the kernels in the same synchronization group if a conversion is requested with **CHCTR_x (x = 0 - 15)**. **SYNC = 1** for (ADC0, ADC1) and **ADC1_CHCTR_x (x = 16 - 23)** for ADC1 and in the synchronization master kernel. Synchronization slaves can not issue synchronization requests.
- Once started, a parallel conversion can not be aborted.
- A parallel conversion request is always handled with highest priority and cancel-inject-repeat mode in a synchronization slave (see **Section 26.2.7.2**).
- Bit **GLOBCTR.ARB** has to be 0 for synchronization slaves.
- The wait-for-read mode is supported for the master kernel, whereas the setting is ignored in the slave kernels (previous results may be overwritten).

The synchronization request issuing mechanism of the master to the slave kernels is based on bit field **GLOBSTR.ANON**. The information given by **GLOBCTR.ANON** is distributed by the synchronization master to all kernels in the conversion group (the bit fields **SYNCTR.STSEL** of all kernels must be programmed in a way that all kernels refer to the same information). In addition to the **ANON** information, the master delivers the requested channel number to the slave (not explicitly shown in **Figure 26-25**).

The start of the converters of all kernels of a conversion group is based on signals indicating when a kernel is ready and can start the sample phase of a parallel conversion. Bit **SYNCTR.EVALRx** defines if a kernel has to wait for the other kernel(s) (to allow parallel conversions) or can start without waiting (no parallel conversions possible). To support parallel conversions, all ready signals of the kernels of a conversion group have to be considered.

The alias feature is independent of synchronized conversions. All kernels of a conversion group request the same channel number (defined by the master), but can convert analog signals from different inputs. The requested channel number can be redirected by its alias setting. E.g., if the channel number requested in a conversion group is channel CH0, but for a kernel, an alternative reference is connected to this input,

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the actually converted analog input can be changed to any value. This can be done by programming bit field ALIAS0 accordingly.

Note: A parallel conversion in a slave ADC should not target a result register that is already used for data reduction of other channels.

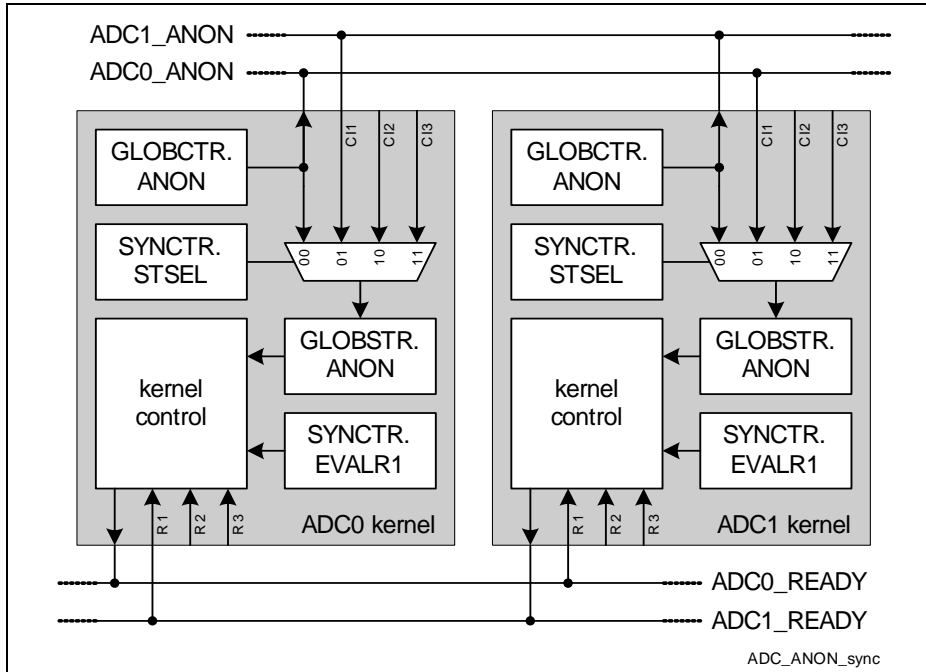


Figure 26-25 Synchronization via ANON and Ready Signals

The connections of the ADCx_ANON and ADCx_READY signals, as well as the programming hints for register EMCTR are described in the implementation chapter, see [Section 26.3](#).

26.2.20 Equidistant Sampling

Each ADC kernel supports equidistant sampling of one (or more) analog input channels, e.g. for audio purposes or digital filters.

Therefore, each request source can be programmed to take part in the arbitration round and to win the arbitration (depending on the programmed priority levels), but without starting the conversion immediately. The exact start point of the conversion is given by a control signal (generated outside the ADC module, e.g. by a timer module) that is selected as trigger input REQTRx of request source x. Equidistant sampling is ensured if the REQTRx signal is generated synchronously to the arbiter timing, mainly for the arbiter. Each ADC kernel provides an output ARBCNT, that is activated once per arbitration round to count the arbiter cycles as timing base for the equidistant sampling by a timer located outside the ADC module.

A requested equidistant conversion can start its sampling phase if the converter is idle and the arbiter has decided which channel to convert. To ensure that the converter is idle, the arbiter decides which channel to convert (winner of the arbitration round), but it waits for the timer control signal to really start the measurement (preface time). If the request source selected for equidistant sampling has been programmed with the highest priority, no other request source can disturb the equidistant sampling.

The interpretation of the trigger signal REQTRx for equidistant sampling is enabled by selecting timer mode in the corresponding request source input register (RSIRx.TMEN = 1). The frequency of signal REQTRx defines the sampling rate and its high time defines the length of the preface time interval where the corresponding request source takes part in the arbitration. During the preface time, the currently running conversion can be finished. It has to be programmed to a value allowing the converter to become idle.

If signal ARBCNT is used as counting input signal for a timer, the arbiter has to be programmed to run permanently (GLOBCTR.ARBM = 0). If the timer has an independent time base, the arbiter can be stopped while no requests are pending. The preface time has to be longer than one arbitration round.

Depending on the request source requesting equidistant sampling, one or more channels can be converted one after the other. The order of the requested channels being fixed by the request source, the equidistant sampling is also supported for several channels. It is also possible to do equidistant sampling for more than one request source in parallel if the preface times and the equidistant conversions do not overlap.

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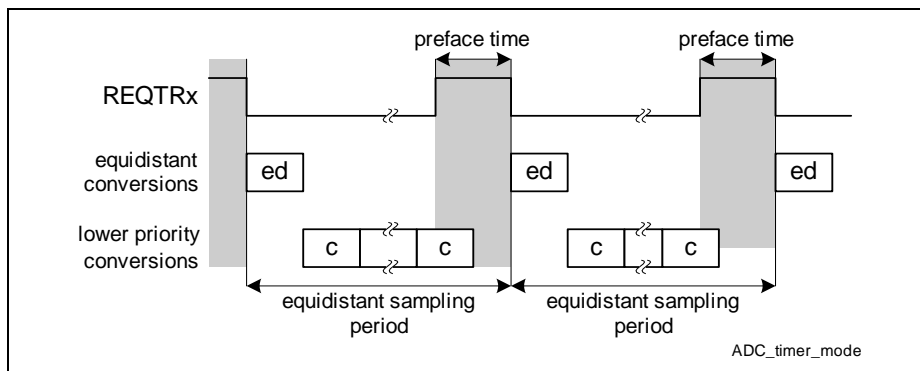


Figure 26-26 Timer Mode for Equidistant Sampling

26.2.21 Access Protection

An access protection scheme has been implemented to avoid unintended modification of some ADC control registers. It can be enabled by bits in register **APR** that itself is protected by the ENDINIT mechanism.

If the access protection is enabled for a group of registers and a write access occurs to one of them, the write access is discarded, the targeted register is not modified, the written data is ignored and the error flag ACCERR is set.

The protected ADC registers are located in one of the following register groups (registers not listed below can not be protected):

- Register group 0:
GLOBCTR
- Register group 1:
GLOBCFG, EMCTR, RSIRx (x = 0 - 4), ALR0
- Register group 2:
ASENR, RSPR0, RSPR4, INPCRx (x = 0 - 3), SYNCTR
- Register group 3:
CHCTRx (x = 0 - 15), ADC1_CHCTRx (x = 16 - 23)
- Register group 4:
RCRx (x = 0 - 15), VFR, LCBR0, LCBR1, LCBR2, LCBR3
- Register group 5:
**CHENPR0, CHENPR8, EVNPR, RNPR0, RNPR8, INTR, CHFR, EVFR
ADC1_CHENPR16**

26.2.22 Broken Wire Detection

To support self-test in safety-critical applications, each ADC kernel provides a broken wire detection mechanism to check the connection of sensors or other voltage sources to the analog inputs of the ADC kernels.

This mechanism allows to prepare the capacitor field C_{AIN} before starting the sample phase and the conversion phase. A preparation phase is added to each conversion of an input channel with **BWDENR.ENx = 1** (the broken wire detection can be individually enabled for each input channel CH0 to CH15/24).

An analog to digital conversion consists of the following phases:

- **Optional preparation phase:**

If a channel is enabled for broken wire detection, the capacitor field C_{AIN} is connected to the analog input CHx defined by **BWDCFGR.CHP** before the sample phase starts. The preparation phase length is identical to the sample phase length for this conversion.

If a channel is disabled for broken wire detection, the preparation phase is omitted (default setting).

- **Sample phase:**

During this phase, the capacitor field C_{AIN} is connected to one of the analog inputs CHx via an input multiplexer (see [Section 26.1.8.1](#)). The request sources and the arbiter define which analog input has the highest priority.

- **Conversion phase:**

During this phase, the capacitor field C_{AIN} is not connected to an analog input and the analog to digital conversion takes place. At the end of this phase, C_{AIN} is loaded to about $V_{AREF}/2$.

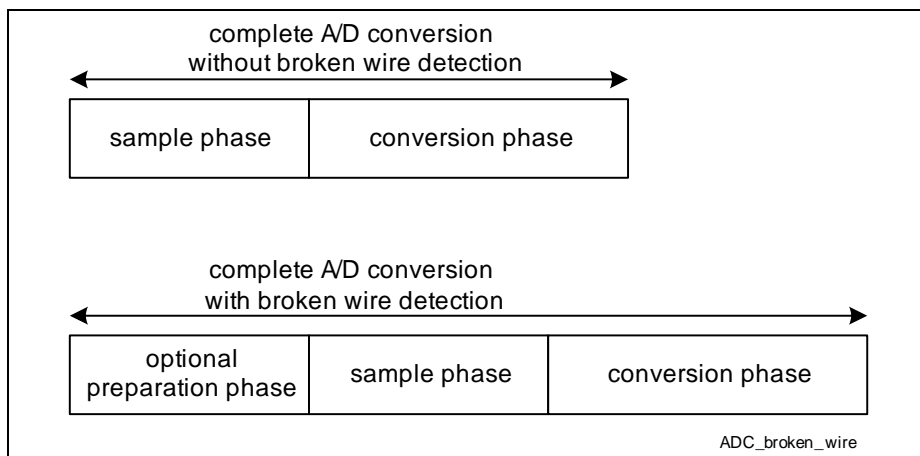


Figure 26-27 Broken Wire Detection

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The broken wire detection mechanism allows to apply a voltage outside the expected measurement value range of the connected sensor. If the actual digital conversion result is located outside the expected measurement range (e.g. by using limit checking) with enabled broken wire detection, a defective connection has been detected. It is recommended to ensure enough margin between the voltage applied during the preparation phase and the sensors output range to minimize the effects of parasitics and leakage.

Input channels CH30 (V_{AGND}) and CH31 (V_{AREF}) have been especially introduced to allow the selection of the maximum or the minimum voltage of the measurement range.

Note: The length of the complete analog to digital conversion is increased by the length of the preparation phase if the broken wire detection is enabled. This influences the timing of conversion sequences.

The preparation phase is introduced as additional presample phase (same behavior as the standard sampling phase, but with the possibility to select a different channel number). The analog part provides additional inputs for the channel number to be used during the presample phase and an enable line. The channel number is directly connected to BWDCFGR.CHP, whereas the enable line corresponds to the BWDENR.ENx bit for the arbitration winner CH x. The analog part expects these values at the beginning of the conversion (like all other signals) and automatically handles the insertion of the presample phase (handled like two consecutive sample phases with different channel numbers (but same length) before starting the conversion phase).

26.2.23 Additional Feature Registers

26.2.23.1 Access Protection Register

The access protection register APR contains bits to enable/disable modification of ADC control/configuration registers by write accesses. Register APR itself is protected by the ENDINIT mechanism.

APR

Access Protection Register (218_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								0							
								r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ACC ERR										RG5	RG4	RG3	RG2	RG1	RG0
rwh										rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
RGx (x = 0 - 5)	x	rw	Register Group x This bit enables/disables write accesses to registers of register group x. 0 _B Write actions to register group x are enabled and can modify the register contents. 1 _B Write actions to register group x are disabled and do not modify the register contents.
ACCERR	15	rwh	Access Error This flag indicates a violation of the access protection mechanism for the ADC kernel. It can be cleared by writing 1 to this bit position. Writing 0 has no effect. 0 _B A write access to a protected register group has not been detected. 1 _B A write access to a protected register group has been detected and discarded.
0	[31:16], [14:6]	r	Reserved Read as 0; should be written with 0.

26.2.23.2 External Multiplexer Control

The external multiplexer control register defines the settings of the external analog multiplexer.

EMCTR

External Multiplexer Control Register (220_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								EMUXEN	SCANEN	TROEN	EMUXCHNR				
r								rw	rw	rw	rw				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EMSAMPLE								0	EMUX		0	SETEMUX			
rw								r	rh		r	rw			

Field	Bits	Type	Description
SETEMUX	[2:0]	rw	Setting of External Multiplexer If the external multiplexer control is disabled, EMUX is loaded with the SETEMUX value. If enabled, the following two options are available: <u>Scan Mode disabled:</u> This bit field defines the input of the external multiplexer that will be selected for the next conversion of the channel selected by EMUXCHNR. Bit field EMUX will be updated by SETEMUX at the beginning of the next conversion of this channel. <u>Scan Mode enabled:</u> This bit field defines the start value of the scan of the external multiplexer inputs. The scan starts with the programmed input down to input 0. Bit field EMUX is updated by SETEMUX at the end of the conversion of this channel if EMUX = 0.

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Field	Bits	Type	Description
EMUX	[6:4]	rh	<p>Current Setting for External Multiplexer</p> <p>This bit field defines the input of the external multiplexer selected for conversion. Its value is available at the output lines EMUX[2:0].</p> <p>If the external multiplexer control is disabled, EMUX is loaded with the SETEMUX value. If enabled, the following two options are available:</p> <p><u>Scan Mode disabled:</u></p> <p>This bit field becomes updated by SETEMUX at the beginning of the conversion of the channel selected by EMUXCHNR.</p> <p><u>Scan Mode enabled:</u></p> <p>This bit field is decremented by 1 at the end of the conversion of the channel selected by EMUXCHNR. After reaching 0, it is reloaded with the value of bit field SETEMUX.</p>
EMSAMPLE	[15:8]	rw	<p>External Multiplexer Sampling Time</p> <p>This bit field defines the alternative sample phase length in the case the external multiplexer setting has changed with the start of a conversion with enabled external multiplexer (the value given by the selected input class is not taken into account).</p> <p>A minimum sample phase of 2 analog clock cycles is extended by the programmed value.</p> <p>sample phase length = $(2 + \text{EMSAMPLE}) / f_{\text{ADCI}}$</p>
EMUXCHNR	[20:16]	rw	<p>Channel Number for External Multiplexer</p> <p>If external multiplexer control is enabled (EMUXEN = 1), this bit field defines the analog ADC input channel connected to the external analog multiplexer. EMUXCHNR [20:16] applies for ADC kernel having 24channels, while EMUXCHNR [19:16] applies for ADC kernel having 16channels.</p>

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Field	Bits	Type	Description
TROEN	21	rw	<p>Trigger Option Enable</p> <p>This bit selects the scan mode behavior of the external multiplexer (if enabled). Description see Section 26.2.18.</p> <p>0_B Single-input scan is selected. The trigger option is disabled (no automatic trigger of more conversions of CHx).</p> <p>1_B Multi-input scan is selected. The trigger option is enabled leading to an automatic scan through the externally connected multiplexer inputs by automatically triggering additional conversions of CHx until EMUX = 0.</p>
SCANEN	22	rw	<p>Scan Enable</p> <p>This bit enables/disables the automatic scan of the inputs of the external multiplexer for conversions of the channel selected by bit field EMUXCHNR (taken into account only if EMUXEN=1).</p> <p>0_B The scan mode is disabled. Bit field EMUX is updated by bit field SETEMUX at the beginning of a conversion of the selected channel. If bit EMUX is changed, the value of EMSAMPLE is applied.</p> <p>1_B The scan mode is enabled. Bit field EMUX is decremented by 1 for each conversion of the selected channel. After reaching 0, bit field EMUX is updated by bit field SETEMUX. The value of EMSAMPLE is always applied for the selected channel.</p> <p>It is recommended to write the start value of the first scan sequence to SETEMUX while EMUXEN=0.</p>

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Field	Bits	Type	Description
EMUXEN	23	rw	External Multiplexer Control Enable This bit enables/disables the automatic control of the external multiplexer. 0_B The external multiplexer control by HW is disabled. Bit field EMUX is immediately updated under SW control by writing to SETEMUX. The settings of SCANEN and TROEN are ignored. 1_B The external multiplexer control is enabled. The update of EMUX is under HW control respecting the conversion timings.
0	3, 7, [31:24]	r	Reserved Read as 0; should be written with 0.

26.2.23.3 Synchronization Control Register

The synchronization control register contains bits controlling the synchronization between several kernels for parallel conversions. The programming of register SYNCTR in the kernels of a conversion group has to be done while the bit fields **GLOBCTR**.ANON = 00_B in all ADC kernels of the conversion group. Bit field **GLOBCTR**.ANON of the synchronization master can be set to 11_B afterwards.

The bits EVALRx are only taken into account if a synchronized, parallel conversion is requested by a master. This ensures that the conversions of the ADC kernels of the same synchronization group are started at the same time for parallel sampling (although a kernel might be idle, the master and all its connected slaves have to wait for all of them being ready).

SYNCTR

Synchronization Control Register (048_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16		
0																	
r																	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
0								EVA LR3		EVA LR2		EVA LR1		0		STSEL	
r								rw		rw		rw		r		rw	

Field	Bits	Type	Description
STSEL	[1:0]	rw	Start Selection This bit field controls the synchronization mechanism of the ADC kernel. 00 _B The kernel is a synchronization master. The kernels own bit field GLOBCTR.ANON is taken into account. 01 _B The kernel is a synchronization slave. The control information at input CI1 is taken into account instead. 10 _B The kernel is a synchronization slave. The control information at input CI2 is taken into account instead. 11 _B reserved, do not use (kernel is switched off)

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Field	Bits	Type	Description
EVALR1	4	rw	<p>Evaluate Ready Input R1</p> <p>This bit defines if a kernel is considered to be part of a synchronization group. Parallel conversions can only be started if the synchronization master and all slaves of the conversion group indicate that they are ready to start a parallel conversion.</p> <p>0_B The ready input R1 is not considered for the start of a parallel conversion of this conversion group.</p> <p>1_B The ready input R1 is considered for the start of a parallel conversion of this conversion group.</p>
EVALR2	5	rw	<p>Evaluate Ready Input R2</p> <p>This bit defines if a kernel is considered to be part of a synchronization group. Parallel conversions can only be started if the synchronization master and all slaves of the conversion group indicate that they are ready to start a parallel conversion.</p> <p>0_B The ready input R2 is not considered for the start of a parallel conversion of this conversion group.</p> <p>1_B The ready input R2 is considered for the start of a parallel conversion of this conversion group.</p>
EVALR3	6	rw	<p>Evaluate Ready Input R3</p> <p>This bit defines if a kernel is considered to be part of a synchronization group. Parallel conversions can only be started if the synchronization master and all slaves of the conversion group indicate that they are ready to start a parallel conversion.</p> <p>0_B The ready input R3 is not considered for the start of a parallel conversion of this conversion group.</p> <p>1_B The ready input R3 is considered for the start of a parallel conversion of this conversion group.</p>
0	[3:2], [31:7]	r	<p>Reserved</p> <p>Read as 0; should be written with 0.</p>

26.2.23.4 Broken Wire Detection Enable Register

The broken wire detection enable register defines if a channel is enabled for broken wire detection by introducing an additional preparation phase to the sample phase (see [Section 26.2.22](#)). The channel number refers to the arbitration winner (can be directed to another input by the alias feature).

BWDENR

Broken Wire Detection Enable Register

(224_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
								EN 23	EN 22	EN 21	EN 20	EN 19	EN 18	EN 17	EN 16
								r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EN 15	EN 14	EN 13	EN 12	EN 11	EN 10	EN 9	EN 8	EN 7	EN 6	EN 5	EN 4	EN 3	EN 2	EN 1	EN 0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Field	Bits	Type	Description
ENx (x=0-23)	x	rw	Broken Wire Detection Enable for Channel CHx This bit defines if the broken wire detection is enabled for CHx. ADC0 kernel has 16 channels, CH0-CH15, thus EN0-EN15 is valid, while ADC1 kernel has 24 channels, CH0-CH23 and EN0-EN23 is valid. 0 _B The broken wire detection is disabled. 1 _B The broken wire detection is enabled.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

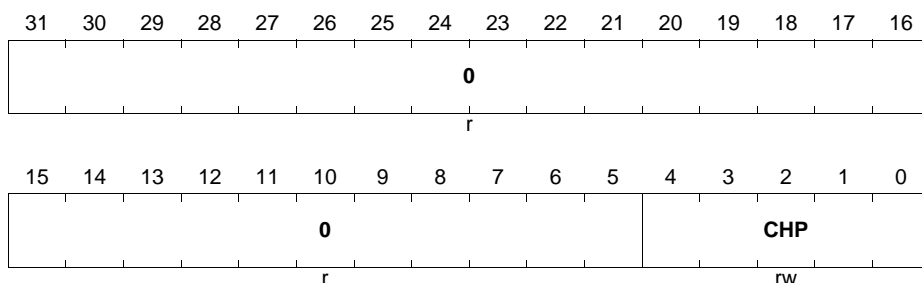
26.2.23.5 Broken Wire Detection Configuration Register

The broken wire detection configuration register defines which channel number is used for the additional preparation phase.

BWDCFGR

Broken Wire Detection Configuration Register

(228_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
CHP	[4:0]	rw	Channel Number for Preparation Phase This bit field defines which input channel is used for the preparation phase for the broken wire detection.
0	[15:5]	r	Reserved returns 0 if read; should be written with 0;

26.3 Implementation

This chapter describes the implementation of the ADC kernels in the TC1728 device. It contains the following sections:

- Request sources (see [Section 26.3.1](#))
- Address map (see [Section 26.3.2](#))
- Connections to modules and pins (see [Section 26.3.3](#))

26.3.1 Request Sources in TC1728

In each ADC kernel 5 request sources are implemented. They are numbered source 0 to source 4, with source x being evaluated in arbitration slot x. Each request source has the possibility to select one trigger input REQTRx out of a vector REQTRx_[7:0] and one gating input REQGTx out of a vector REQGTx_[7:0]. Each input vector contains 8 possible input signals, but not all of them are necessarily connected.

- Source 0: 1-stage sequential source
- Source 1: Parallel source for up to 24 channels
- Source 2: 4-stage sequential source
- Source 3: Parallel source for up to 24 channels
- Source 4: 4-stage sequential source

26.3.2 Address Map

The common KSCFG register of the ADC module can be accessed in the address range of kernel ADC0. The corresponding address in the range of kernel ADC1 is not used and delivers a dummy value when read.

The ADC kernels are available at the following base addresses:

Table 26-4 Registers Address Space

Module	Base Address	End Address	Note
ADC0	F010 1000 _H	F010 13FF _H	
ADC1	F010 1400 _H	F010 17FF _H	

Table 26-5 Registers Overview

Register Short Name	Register Long Name	Offset Address	Page Number
please refer to register table in Section 26.2.1		H	

26.3.3 ADC Module Connections

In addition to the standard signals of the interface between the analog and the digital parts, some side band signals have been introduced.

The ADC module consists of two ADC kernels. All kernels support the feature set listed above and share a common ADC0_KSCFG register. The kernels can be synchronized to each other for parallel sampling.

The channels CH4, CH5, CH6, and CH7 of ADC0 and the channels CH0 of all ADC kernels are always converted referring to the V_{AREF} input of the corresponding ADC kernel. For these channels, the programmed alternative reference selection is not taken into account. All other channels are converted with respect to the selected reference.

26.3.3.1 ADC0 Connections

Signals of the ADC module referring to the kernel of ADC0 are generally named with the prefix ADC0_.

The kernel ADC0 has its own reference inputs $ADC0_V_{AGND}$ and $ADC0_V_{AREF}$. Depending on the package, these lines can be available as independent pins for high pin count packages or can be combined with the corresponding inputs of the other kernels for low pin count packages.

The respective voltage supply lines of all ADC analog parts are connected together.

Table 26-6 ADC0 Connections to Analog Part in TC1728

ADC0 Signal of Analog Part	from/to Module or Pin	Input or Output	Can be used to/as
V_{DDM}	V_{DDM}	I	analog power supply 3.3V - 5V
V_{DDA}	V_{DDA}	I	analog power supply for comparator,
V_{SSM}	V_{SSM}	I	analog power ground
V_{AREF}	V_{AREF}	I	positive analog reference, in 176 pin package combined with $ADC1_V_{AREF}$
V_{AGND}	V_{AGND}	I	negative analog reference, combined with other kernel
CH0	AN0	I	analog input channel 0
CH1	AN1	I	analog input channel 1
CH2	AN2	I	analog input channel 2
CH3	AN3	I	analog input channel 3
CH4	AN4	I	analog input channel 4
CH5	AN5	I	analog input channel 5
CH6	AN6	I	analog input channel 6
CH7	AN7	I	analog input channel 7
CH8	AN8	I	analog input channel 8
CH9	AN9	I	analog input channel 9
CH10	AN10	I	analog input channel 10
CH11	AN11	I	analog input channel 11
CH12	AN12	I	analog input channel 12
CH13	AN13	I	analog input channel 13

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Table 26-6 ADC0 Connections to Analog Part in TC1728 (cont'd)

ADC0 Signal of Analog Part	from/to Module or Pin	Input or Output	Can be used to/as
CH14	AN14	I	analog input channel 14
CH15	AN15	I	analog input channel 15

The following table shows the digital connections of the ADC0 kernel with other modules or pins in the TC1728 device. Signals of the ADC module referring to the kernel of ADC0 are named with the prefix ADC0_.

Table 26-7 ADC0 Connections of Digital Part in TC1728

ADC0 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
-----------------------------	-----------------------	-------------------------------	-------------------

Kernel Signals

ARBCNT	-	O	Counting signal for arbiter rounds
EMUXTR	-	O	Trigger output for scanning the external multiplexer inputs
EMUX0	see port chapter	O	control of external analog multiplexer(s)
EMUX1	see port chapter		
EMUX2	see port chapter		

Request Source 0

REQGT0_0	TRIG10	I	GPTA
REQGT0_1	TRIG12	I	GPTA
REQGT0_2	TRIG14	I	GPTA
REQGT0_3	PDOUT2	I	ERU
REQGT0_4	REQ0	I (s)	P3.10
REQGT0_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT0_6	0	I (s)	not (yet) connected
REQGT0_7		I (s)	
REQTR0_0	TRIG00	I	GPTA
REQTR0_1	IOOUT2	I	ERU
REQTR0_2	0	I	not (yet) connected

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Table 26-7 ADC0 Connections of Digital Part in TC1728 (cont'd)

ADC0 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR0_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR0_4	REQ1	I (s)	P3.11
REQTR0_5	CCU6061_TRIG0	I (s)	CCU6061
REQTR0_6	ADC0_REQGT0	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR0_7	ADC0_SR7	I (s)	service request output 7 of ADC0
REQTR0	-	O	selected trigger signal for source 0 (used as REQTRS for source 0)
REQGT0	ADC0_REQTR0_6	O	selected gating signal for source 0

Request Source 1

REQGT1_0	TRIG10	I	GPTA
REQGT1_1	TRIG12	I	GPTA
REQGT1_2	TRIG14	I	GPTA
REQGT1_3	PDOUT3	I	ERU
REQGT1_4	REQ0	I (s)	P3.10
REQGT1_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT1_6	0	I (s)	not (yet) connected
REQGT1_7		I (s)	
REQTR1_0	TRIG03	I	GPTA
REQTR1_1	IOOUT3	I	ERU
REQTR1_2	TRIG16	I	GPTA
REQTR1_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR1_4	REQ1	I (s)	P3.11
REQTR1_5	CCU6061_TRIG1	I (s)	CCU6061
REQTR1_6	ADC0_REQGT1	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR1_7	ADC0_SR7	I (s)	service request output 7 of ADC0

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Table 26-7 ADC0 Connections of Digital Part in TC1728 (cont'd)

ADC0 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR1	-	O	selected trigger signal for source 1 (used as REQTRS for source 1)
REQGT1	ADC0_REQTR1_6	O	selected gating signal for source 1

Request Source 2

REQGT2_0	TRIG10	I	GPTA
REQGT2_1	TRIG12	I	GPTA
REQGT2_2	TRIG14	I	GPTA
REQGT2_3	PDOUT3	I	ERU
REQGT2_4	REQ4	I (s)	P0.14
REQGT2_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT2_6	0	I (s)	not (yet) connected
REQGT2_7		I (s)	
REQTR2_0	TRIG04	I	GPTA
REQTR2_1	IOUT3	I	ERU
REQTR2_2	TRIG16	I	GPTA
REQTR2_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR2_4	REQ5	I (s)	P0.15
REQTR2_5	CCU6061_TRIG1	I (s)	CCU6061
REQTR2_6	ADC0_REQGT2	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR2_7	ADC0_SR7	I (s)	service request output 7 of ADC0
REQTR2	-	O	selected trigger signal for source 2 (used as REQTRS for source 2)
REQGT2	ADC0_REQTR2_6	O	selected gating signal for source 2

Request Source 3

REQGT3_0	TRIG10	I	GPTA
REQGT3_1	TRIG12	I	GPTA
REQGT3_2	TRIG14	I	GPTA

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Table 26-7 ADC0 Connections of Digital Part in TC1728 (cont'd)

ADC0 Signal of Digital Part	from/to Module or Pin	Input¹⁾ or Output	Can be used to/as
REQGT3_3	PDOUT2	I	ERU
REQGT3_4	REQ4	I (s)	P0.14
REQGT3_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT3_6	0	I (s)	not (yet) connected
REQGT3_7		I (s)	
REQTR3_0	TRIG07	I	GPTA
REQTR3_1	IOOUT2	I	ERU
REQTR3_2	TRIG16	I	GPTA
REQTR3_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR3_4	REQ5	I (s)	P0.15
REQTR3_5	CCU6061_TRIG2	I (s)	CCU6061
REQTR3_6	ADC0_REQGT3	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR3_7	ADC0_SR7	I (s)	service request output 7 of ADC0
REQTR3	-	O	selected trigger signal for source 3 (used as REQTRS for source 3)
REQGT3	ADC0_REQTR3_6	O	selected gating signal for source 3

Request Source 4

REQGT4_0	TRIG10	I	GPTA
REQGT4_1	TRIG12	I	GPTA
REQGT4_2	TRIG14	I	GPTA
REQGT4_3	PDOUT2	I	ERU
REQGT4_4	REQ0	I (s)	P3.10
REQGT4_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT4_6	0	I (s)	not (yet) connected
REQGT4_7		I (s)	
REQTR4_0	TRIG11	I	GPTA

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Table 26-7 ADC0 Connections of Digital Part in TC1728 (cont'd)

ADC0 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR4_1	IOUT2	I	ERU
REQTR4_2	0	I	not (yet) connected
REQTR4_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR4_4	0	I (s)	reserved
REQTR4_5	CCU6061_TRIG2	I (s)	CCU6061
REQTR4_6	ADC0_REQGT4	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR4_7	ADC0_SR7	I (s)	service request output 7 of ADC0
REQTR4	-	O	selected trigger signal for source 4 (used as REQTRS for source 4)
REQGT4	ADC0_REQTR4_6	O	selected gating signal for source 4

1) In case of input signals, the lines marked "I" don't contain synchronization stages, whereas the lines marked "I (s)" contain synchronization stages (so they can directly handle asynchronous input signals). A signal connected to an input line marked "I" has to be delivered from a block located in the same clock domain as the ADC (the signal has to be synchronous to the ADC clock domain).

26.3.3.2 ADC1 Connections

Signals of the ADC module referring to the kernel of ADC1 are named with the prefix ADC1_.

The kernel ADC1 has its own reference inputs ADC1_ V_{AGND} and ADC1_ V_{AREF} . Depending on the package, these lines can be available as independent pins for high pin count packages or can be combined with the corresponding inputs of the other kernels for low pin count packages.

The respective voltage supply lines of the ADC analog parts are connected together.

Table 26-8 ADC1 Connections of Analog Part in TC1728

ADC1 Signal of Analog Part	from/to Module or Pin	Input or Output	Can be used to/as
V_{DDM}	V_{DDM}	I	analog power supply 3.3V - 5V
V_{DDA}	V_{DDA}	I	analog power supply for comparator,
V_{SSM}	V_{SSM}	I	analog power ground
V_{AREF}	V_{AREF}	I	positive analog reference, in 176 pin package combined with ADC0_ V_{AREF}
V_{AGND}	V_{AGND}	I	negative analog reference, combined with other kernel
CH0	AN16	I	analog input channel 16, overlaid with digital input
CH1	AN17	I	analog input channel 17, overlaid with digital input
CH2	AN18	I	analog input channel 18, overlaid with digital input
CH3	AN19	I	analog input channel 19, overlaid with digital input
CH4	AN20	I	analog input channel 20, overlaid with digital input
CH5	AN21	I	analog input channel 21, overlaid with digital input
CH6	AN22	I	analog input channel 22, overlaid with digital input
CH7	AN23	I	analog input channel 23, overlaid with digital input

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Table 26-8 ADC1 Connections of Analog Part in TC1728 (cont'd)

ADC1 Signal of Analog Part	from/to Module or Pin	Input or Output	Can be used to/as
CH8	AN24	I	analog input channel 24, overlaid with digital input
CH9	AN25	I	analog input channel 25, overlaid with digital input
CH10	AN26	I	analog input channel 26, overlaid with digital input
CH11	AN27	I	analog input channel 27, overlaid with digital input
CH12	AN28	I	analog input channel 28, overlaid with digital input
CH13	AN29	I	analog input channel 29, overlaid with digital input
CH14	AN30	I	analog input channel 30, overlaid with digital input
CH15	AN31	I	analog input channel 31, overlaid with digital input
CH16	AN32	I	analog input channel 32, overlaid with FADC_FAIN0P
CH17	AN33	I	analog input channel 33, overlaid with FADC_FAIN0N
CH18	AN34	I	analog input channel 34, overlaid with FADC_FAIN1P
CH19	AN35	I	analog input channel 35, overlaid with FADC_FAIN1N
CH20	AN36	I	analog input channel 36, overlaid with digital input
CH21	AN37	I	analog input channel 37, overlaid with digital input
CH22	AN38	I	analog input channel 38, overlaid with digital input
CH23	AN39	I	analog input channel 39, overlaid with digital input

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The following table shows the digital connections of the ADC1 kernel with other modules or pins in the TC1728 device. Output signals of the ADC module referring to the kernel of ADC1 are named with the prefix ADC1_.

Table 26-9 ADC1 Connections of Digital Part in TC1728

ADC1 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
Kernel Signals			
ARBCNT	-	O	Counting signal for arbiter rounds
EMUXTR	-	O	Trigger output for scanning the external multiplexer inputs
EMUX0	see port chapter	O	control of external analog multiplexer(s)
EMUX1	see port chapter		
EMUX2	see port chapter		
Request Source 0			
REQGT0_0	TRIG10	I	GPTA
REQGT0_1	TRIG12	I	GPTA
REQGT0_2	TRIG14	I	GPTA
REQGT0_3	PDOUT2	I	ERU
REQGT0_4	REQ4	I (s)	P0.14
REQGT0_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT0_6	ADC0_SR7	I (s)	ADC1 trigger by ADC0
REQGT0_7		I (s)	
REQTR0_0	TRIG00	I	GPTA
REQTR0_1	IOOUT2	I	ERU
REQTR0_2	0	I	not (yet) connected
REQTR0_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR0_4	REQ5	I (s)	P0.15
REQTR0_5	CCU6061_TRIG0	I (s)	CCU6061
REQTR0_6	ADC1_REQGT0	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR0_7	ADC1_SR7	I (s)	service request output 7 of ADC1

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Table 26-9 ADC1 Connections of Digital Part in TC1728 (cont'd)

ADC1 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR0	-	O	selected trigger signal for source 0 (used as REQTRS for source 0)
REQGT0	ADC1_REQTR0_6	O	selected gating signal for source 0

Request Source 1

REQGT1_0	TRIG10	I	GPTA
REQGT1_1	TRIG12	I	GPTA
REQGT1_2	TRIG14	I	GPTA
REQGT1_3	PDOUT3	I	ERU
REQGT1_4	REQ4	I (s)	P0.14
REQGT1_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT1_6	ADC0_SR7	I (s)	ADC1 trigger by ADC0
REQGT1_7		I (s)	
REQTR1_0	TRIG05	I	GPTA
REQTR1_1	IOUT3	I	ERU
REQTR1_2	TRIG16	I	GPTA
REQTR1_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR1_4	REQ5	I (s)	P0.15
REQTR1_5	CCU6061_TRIG1	I (s)	CCU6061
REQTR1_6	ADC1_REQGT1	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR1_7	ADC1_SR7	I (s)	service request output 7 of ADC1
REQTR1	-	O	selected trigger signal for source 1 (used as REQTRS for source 1)
REQGT1	ADC1_REQTR1_6	O	selected gating signal for source 1

Request Source 2

REQGT2_0	TRIG10	I	GPTA
REQGT2_1	TRIG12	I	GPTA
REQGT2_2	TRIG14	I	GPTA

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Table 26-9 ADC1 Connections of Digital Part in TC1728 (cont'd)

ADC1 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQGT2_3	PDOUT3	I	ERU
REQGT2_4	REQ0	I (s)	P3.10
REQGT2_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT2_6	ADC0_SR7	I (s)	ADC1 trigger by ADC0
REQGT2_7		I (s)	
REQTR2_0	TRIG06	I	GPTA
REQTR2_1	IOOUT3	I	ERU
REQTR2_2	TRIG16	I	GPTA
REQTR2_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR2_4	REQ1	I (s)	P3.11
REQTR2_5	CCU6061_TRIG1	I (s)	CCU6061
REQTR2_6	ADC1_REQGT2	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR2_7	ADC1_SR7	I (s)	service request output 7 of ADC1
REQTR2	-	O	selected trigger signal for source 2 (used as REQTRS for source 2)
REQGT2	ADC1_REQTR2_6	O	selected gating signal for source 2

Request Source 3

REQGT3_0	TRIG10	I	GPTA
REQGT3_1	TRIG12	I	GPTA
REQGT3_2	TRIG14	I	GPTA
REQGT3_3	PDOUT2	I	ERU
REQGT3_4	REQ0	I (s)	P3.10
REQGT3_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT3_6	ADC0_SR7	I (s)	ADC1 trigger by ADC0
REQGT3_7		I (s)	
REQTR3_0	TRIG01	I	GPTA

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Table 26-9 ADC1 Connections of Digital Part in TC1728 (cont'd)

ADC1 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR3_1	IOUT2	I	ERU
REQTR3_2	TRIG16	I	GPTA
REQTR3_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR3_4	REQ1	I (s)	P3.11
REQTR3_5	CCU6061_TRIG2	I (s)	CCU6061
REQTR3_6	ADC1_REQGT3	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR3_7	ADC1_SR7	I (s)	service request output 7 of ADC1
REQTR3	-	O	selected trigger signal for source 3 (used as REQTRS for source 3)
REQGT3	ADC1_REQTR3_6	O	selected gating signal for source 3

Request Source 4

REQGT4_0	TRIG10	I	GPTA
REQGT4_1	TRIG12	I	GPTA
REQGT4_2	TRIG14	I	GPTA
REQGT4_3	PDOUT3	I	ERU
REQGT4_4	REQ0	I (s)	P3.10
REQGT4_5	IRQ1	I (s)	STM (do not use for gating, but for triggering)
REQGT4_6	ADC0_SR7	I (s)	ADC1 trigger by ADC0
REQGT4_7		I (s)	
REQTR4_0	TRIG13	I	GPTA
REQTR4_1	IOUT3	I	ERU
REQTR4_2	0	I	not (yet) connected
REQTR4_3	ADC_SR6	I	common service request output 6 of ADC module
REQTR4_4	0	I (s)	reserved
REQTR4_5	CCU6061_TRIG2	I (s)	CCU6061

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Table 26-9 ADC1 Connections of Digital Part in TC1728 (cont'd)

ADC1 Signal of Digital Part	from/to Module or Pin	Input ¹⁾ or Output	Can be used to/as
REQTR4_6	ADC1_REQGT4	I (s)	extend input selection for triggering by using gating inputs (with ENGT = 0X)
REQTR4_7	ADC1_SR7	I (s)	service request output 7 of ADC1
REQTR4	-	O	selected trigger signal for source 4 (used as REQTRS for source 4)
REQGT4	ADC1_REQTR4_6	O	selected gating signal for source 4

1) In case of input signals, the lines marked "I" don't contain synchronization stages, whereas the lines marked "I (s)" contain synchronization stages (so they can directly handle asynchronous input signals). A signal connected to an input line marked "I" has to be delivered from a block located in the same clock domain as the ADC (the signal has to be synchronous to the ADC clock domain).

26.3.3.3 Service Request Connections

Each ADC kernel provides the service request output lines ADCy_SR[7:0]. The ADC module's service request outputs ADC_SR[11:0] are generated based on these lines according to the following table. If a line ADCy_SRx can be activated by more than one ADC kernel, the corresponding request lines of the ADC kernels are logical OR-combinations of the kernel outputs.

The wiring of the ADC_SRx signals to the DMA channels is given in the DMA chapter. The signal ADCy_SR7 of each ADC kernel is available as input for the request sources for this kernel. Additionally, ADC0_SR7 is connected to ADC1 inputs.

The common signal ADC_SR6 is available as input for the request sources of all kernels.

Note: The ADC2 kernel is not implemented in the TC1728, but will be available in bigger devices, such as TC1797. The following table indicates the service request connections for this case to allow a common approach for the interrupt generation.

Table 26-10 ADC Module Service Request Generation

Module Service Request Output	from ADC0 Kernel	from ADC1 Kernel	from ADC2 Kernel ¹⁾	Service Request Node ²⁾
ADC_SR0	ADC0_SR0	ADC1_SR0	-	ADC0_SRC0
ADC_SR1	ADC0_SR1	ADC1_SR1	-	ADC0_SRC1
ADC_SR2	ADC0_SR2	ADC1_SR2	-	ADC0_SRC2
ADC_SR3	ADC0_SR3	ADC1_SR3	-	ADC0_SRC3
ADC_SR4	ADC0_SR4	ADC1_SR4	ADC2_SR4	ADC0_SRC4
ADC_SR5	ADC0_SR5	ADC1_SR5	ADC2_SR5	ADC0_SRC5
ADC_SR6	ADC0_SR6	ADC1_SR6	ADC2_SR6	-
ADC_SR7	ADC0_SR7	ADC1_SR7	ADC2_SR7	-
ADC_SR8	-	-	ADC2_SR0	ADC0_SRC6
ADC_SR9	-	-	ADC2_SR1	ADC0_SRC7
ADC_SR10	-	-	ADC2_SR2	ADC0_SRC8
ADC_SR11	-	-	ADC2_SR3	-

1) Not available in TC1728, ADC2_SR[7:0] lines are considered always inactive in this device.

2) The service request nodes ADC0_SRC[8:6] are not available in TC1728.

26.3.3.4 Kernel Synchronization

The independent ADC kernels of the ADC module can be synchronized to each other by selecting the corresponding connections. The table below shows the setting of the bits in the synchronization control registers in the ADC to allow synchronization. A kernel can operate completely autonomously if it is configured as master ADC. A slave ADC can be synchronized by the selected master ADC.

Note: A master ADC can synchronize several slave ADCs, whereas a slave ADC can only be synchronized by one master ADC.

Table 26-11 SYNCTR Setting for Kernel Synchronization

Operating Mode	SYNCTR. EVALR3	SYNCTR. EVALR2	SYNCTR. EVALR1	SYNCTR. STSEL
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ADC0 Kernel (values to be programmed to ADC0_SYNCTR)

no sync	0	0	0	00 _B
master of ADC1	0	0	1	00 _B
slave of ADC1	0	0	1	01 _B

ADC1 Kernel (values to be programmed to ADC1_SYNCTR)

no sync	0	0	0	00 _B
master of ADC0	0	0	1	00 _B
slave of ADC0	0	0	1	01 _B

27 Fast Analog to Digital Converter (FADC)

The TC1728 contains a fast analog to digital converter (FADC) with differential input channels, thus allowing sampling of high frequency signals. For slow and mid-range frequency signals, an anti-aliasing filter by data reduction is implemented to avoid expensive external filters.

- Functional description of the FADC Kernel (see [Section 27.2](#))
- FADC kernel register descriptions (see [Section 27.3](#))
- TC1728 implementation-specific details and registers of the FADC module, including on-chip interconnections, service request control, address decoding, and clock control (see [Section 27.4](#))

Note: The FADC Kernel register names described in [Section 27.3](#) are referenced in the TC1728 User's Manual by the module name prefix "FADC_" for the FADC interface.

Fast Analog to Digital Converter (FADC)

27.1 FADC Short Description

General Features

- Extreme fast conversion, 21 cycles of f_{FADC} clock (191 ns @ $f_{\text{FADC}} = 110$ MHz)
- 10-bit A/D conversion (higher resolution can be achieved by averaging of consecutive conversions in digital data reduction filter)
- Successive approximation conversion method
- Two differential input channels with impedance control overlaid with ADC1 inputs
- Each differential input channel can also be used as single-ended input
- Offset calibration support for each channel
- Programmable gain of 1, 2, 4, or 8 for each channel
- Free-running (Channel Timers) or triggered conversion modes
- Trigger and gating control for external signals
- Built-in Channel Timers for internal triggering
- Channel timer request periods independently selectable for each channel
- Selectable, programmable digital anti-aliasing and data reduction filter block with four independent filter units

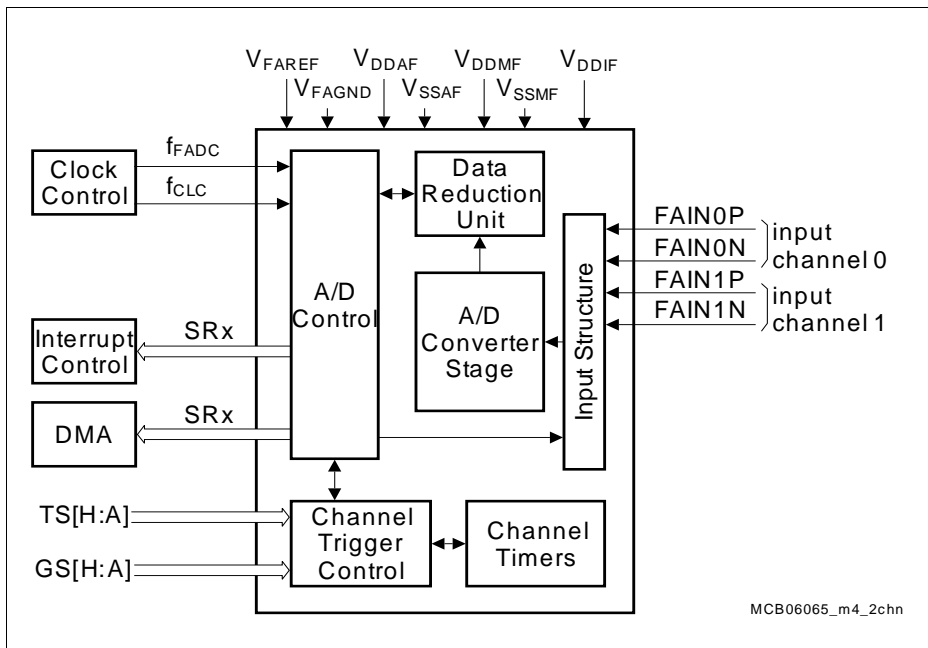


Figure 27-1 Block Diagram of the FADC Module with 2 Input Channels

As shown in [Figure 27-1](#), the main FADC functional blocks are:

Fast Analog to Digital Converter (FADC)

- An Input Structure containing the differential inputs and impedance control.
- An A/D Converter Stage responsible for the analog-to-digital conversion including an input multiplexer to select between the channel amplifiers
- A Data Reduction Unit containing programmable anti-aliasing and data reduction filters
- A Channel Trigger Control block determining the trigger and gating conditions for the FADC channels
- A Channel Timer for each channel to independently trigger the conversions
- An A/D Control block responsible for the overall FADC functionality

The analog block of the FADC in the TC1728 contains:

- A differential analog input stage for each input channel to select the input impedance (differential or single-ended measurement) and to decouple the FADC input signal from the pins. It is supplied by V_{DDIF} / V_{SSMF} (3.3 V - 5 V).
The V_{DDIF} supply does not appear as supply pin in the pin list, because it is internally connected to the V_{DDM} supply of the ADC that is sharing the FADC input pins.
- A channel amplifier with a settling time of about 5 μ s if its configuration is changed by SW (changing between unused, differential, single-ended N, or single-ended P mode). It is supplied by V_{DDMF} / V_{SSMF} (3.3 V) connected to an internal voltage regulator in the ADC.
- FADC input channels 0 and 1 are overlaid with ADC1 input signals (AN32, AN33, AN34, AN35).
Input levels on enabled FADC inputs must not exceed V_{DDMF} , whereas those of disabled FADC inputs must not exceed V_{DDIF} .
- A 10-bit analog converter stage supplied by V_{DDAF} / V_{SSAF} (1.3V), connected to an internal voltage regulator. The inputs for the FADC reference voltage (3.3 V max.) and the FADC reference ground V_{FAREF} / V_{FAGND} are connected to an internal voltage reference.

Fast Analog to Digital Converter (FADC)

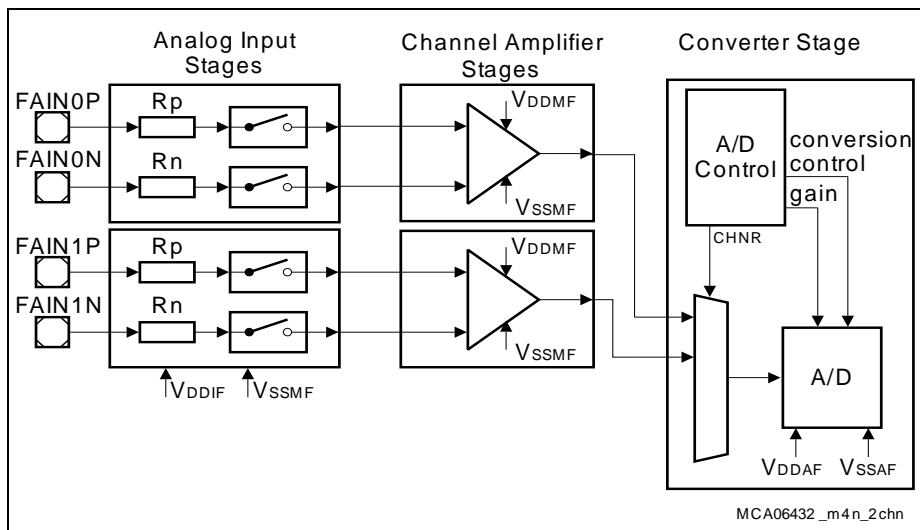


Figure 27-2 FADC Input Structure in TC1728

Note: The analog voltages of the FADC have to be stable and noise-free to ensure a high quality of the conversions.

Fast Analog to Digital Converter (FADC)

27.2 FADC Kernel Description

The FADC kernel description covers the following items:

- Analog input stage configurations (see [Section 27.2.1](#))
- Conversion timing (see [Section 27.2.3](#))
- Channel triggers (see [Section 27.2.4](#))
- Channel timers (see [Section 27.2.5](#))
- Conversion control (see [Section 27.2.6](#))
- Data reduction unit (see [Section 27.2.7](#))
- Neighbor channel trigger (see [Section 27.2.8](#))
- Offset calibration (see [Section 27.2.9](#))
- Interrupt generation (see [Section 27.2.10](#))

27.2.1 Analog Input Stage Configurations

The analog input stage makes it possible to control the input impedance by selecting different configurations independently for each FADC channel x. These combinations are shown in [Figure 27-3](#).

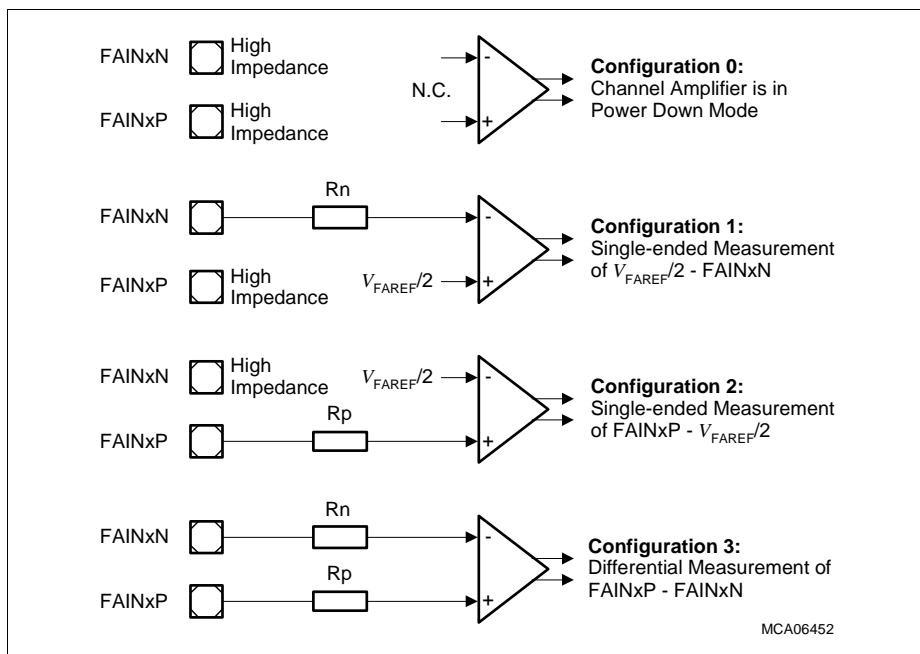


Figure 27-3 Analog Input Stage Configurations

Fast Analog to Digital Converter (FADC)

Note: Due to the temperature characteristics of offset and gain of the internal amplifiers a TUE (total unadjusted error) cannot be specified. The input impedance for R_p and R_n is defined in the TC1728 Data Sheet.

Note: The analog input lines of the FADC can also be used as input lines for other ADCs. If both (regular ADC and FADC) are connected to the same pin at the same time, the input impedances of the analog inputs must be taken into account in order to minimize signal distortions and measurement errors.

Configuration 0: Channel Not Used ($ACRx.ENP = ACRx.ENN = 0$)

FADC channel x inputs $FAINxP$ and $FAINxN$ are in a high impedance state. The channel amplifier of the analog input stage is in power-down mode if both connected input channels are switched off for measurements.

Configuration 1: Single-ended of $FAINxN$ ($ACRx.ENP = 0$ and $ACRx.ENN = 1$)

This configuration enables the single-ended measurement mode for $V_{VAREF}/2 - FAINxN$: The positive analog input $FAINxP$ is disconnected is in a high impedance state. The negative analog input $FAINxN$ is connected to the channel amplifier (input impedance is determined by R_n). The positive input of the channel amplifier is connected to $V_{FAREF}/2$ (1.65 V with $V_{FAREF} = 3.3$ V). If the voltage at the negative input $FAINxN$ varies, the FADC will deliver conversion results as follows (gain = 1 selected by $ACRx.GAIN = 00_B$):

- $FAINxN = 0$ V: FADC conversion result is 768
- $FAINxN = 3.3$ V: FADC conversion result is 256

To cover the full range of the measurement result in this single-ended measurement mode, a gain of 2 must be selected ($ACRx.GAIN = 01_B$). With gain = 2, the FADC will deliver conversion results as follows:

- $FAINxN = 0$ V: FADC conversion result is 1023
- $FAINxN = 3.3$ V: FADC conversion result is 0

The voltage at the disconnected positive analog input $FAINxP$ has no influence on the conversion result.

Configuration 2: Single-ended of $FAINxP$ ($ACRx.ENP = 1$ and $ACRx.ENN = 0$)

This configuration enables the single-ended measurement mode for $FAINxP - V_{VAREF}/2$. The negative analog input $FAINxN$ is disconnected and in a high impedance state. The positive analog input $FAINxP$ is connected to the channel amplifier (input impedance is determined by R_p). The negative input of the channel amplifier is connected to $V_{FAREF}/2$ (1.65 V with $V_{FAREF} = 3.3$ V). If the voltage at the positive input $FAINxP$ varies, the FADC will deliver conversion results as follows (gain = 1 selected by $ACRx.GAIN = 00_B$):

- $FAINxP = 0$ V: FADC conversion result is 256
- $FAINxP = 3.3$ V: FADC conversion result is 768

Fast Analog to Digital Converter (FADC)

To cover the full range of the measurement result in this single-ended measurement mode, a gain of 2 must be selected ($ACRx.GAIN = 01_B$). With gain = 2, the FADC will deliver conversion results as follows:

- $FAINxP = 0\text{ V}$: FADC conversion result is 0
- $FAINxP = 3.3\text{ V}$: FADC conversion result is 1023

The voltage at the disconnected negative analog input $FAINxN$ has no influence on the conversion result.

Configuration 3: Differential Measurement ($ACRx.ENP = ACRx.ENN = 1$)

This configuration enables the differential measurement mode for $FAINxP$ - $FAINxN$. Both analog inputs, $FAINx.N$ and $FAINxP$, are connected to the channel amplifier inputs. Their impedances are determined by R_n and R_p . The full measurement range is available.

27.2.2 Result Representation

The conversion result for FADC channel x is given by the following equations:

$$\text{Conversion Result } V_{Mx} = GAIN_x \times ((V_{FAINxP} - V_{FAREFM}) + (V_{FAREFM} - V_{FAINxN})) \quad (27.1)$$

with $V_{FAREFM} = V_{FAGND} + (V_{FAREF} - V_{FAGND})/2$

The absolute value of the result V_{Mx} is limited to V_{FAREF} . The mapping of the conversion result V_{Mx} to the result $RCHx.ADRES$ is as follows:

$$\begin{aligned} V_{Mx} &= -V_{FAREF} && \text{leads to } RCHx.ADRES = 0 \\ V_{Mx} &= 0 && \text{leads to } RCHx.ADRES = 512 \\ V_{Mx} &= +V_{FAREF} && \text{leads to } RCHx.ADRES = 1023 \end{aligned}$$

For single-ended measurements, the following values are taken into account:

- if $ENP_x = 0$ then $V_{FAINxP} = V_{FAREFM}$
- if $ENN_x = 0$ then $V_{FAINxN} = V_{FAREFM}$

Note: In Multiplexer Test Mode ($GCR.MUXTM = 1$), the channel amplifiers are disconnected from the converter stage. The measured conversion result in multiplexer test mode is 512 plus/minus the offset of the converter stage.

27.2.3 Conversion Timing

The conversion time of the FADC is determined by the frequency of clock f_{FADC} . The conversion time including sampling, converting, and storing of the conversion result takes 21 periods of f_{FADC} .

27.2.4 Channel Triggers

As shown [Figure 27-4](#), the trigger behavior of an FADC channel x is determined by its channel x trigger control logic. An FADC channel x can be triggered by three trigger sources:

- External trigger source input signal, selectable from an input vector TS[H:A]
- Internal channel x timer trigger signal
- Internal neighbor channel trigger signal

If one of these trigger sources is selected, becomes active, and the gating logic is programmed to enable trigger signals (signal ECHTIMx set), the conversion request flag CRFx becomes set indicating a valid request for FADC channel x.

The gating source input and gating mode selection logic generate an enable signal for channel x timer that determines whether any of the three conversion trigger signal sources is allowed to set the channel x conversion request flag CRFx. It can select an input signal from the input vector GS[H:A].

The control logic does the following tasks, independently in each of the FADC channels:

- Gating source input selection (CFGRx.GSEL)
- Gating mode selection (CFGRx.GM)
- Trigger source input selection (CFGRx.TSEL)
- Trigger mode selection (CFGRx.TM)
- Channel timer request generation
- Conversion request flag set/clear

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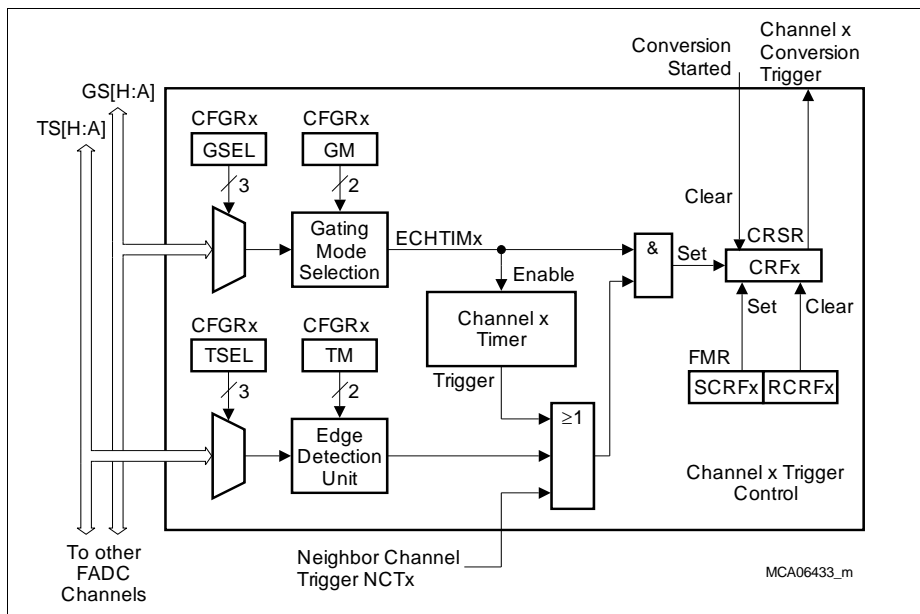


Figure 27-4 Channel Trigger Control Logic

Table 27-1 describes the possible gating modes (enabled, disabled, active gating source input polarity) of an FADC channel.

Table 27-1 Gating Modes

CFGRx.GM	Gating Mode
00 _B	Conversion requests are disabled and Channel Timer is stopped. Bit CRSR.CRFx never becomes set (by hardware).
01 _B	Conversion requests and Channel Timer are always enabled. Bit CRSR.CRFx becomes set by hardware with each active trigger signal.
10 _B	When gating source input GS _n = 1 (as selected by CFGRx.GSEL), the Channel Timer is enabled and the conversion request bit CRSR.CRFx becomes set by hardware with each active trigger signal.
11 _B	When gating source input GS _n = 0 (as selected by CFGRx.GSEL), the Channel Timer is enabled and the conversion request bit CRSR.CRFx becomes set by hardware with each active trigger signal.

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An edge detection unit determines which edge of the trigger source input signal (as selected by CFGRx.TSEL) is generating a conversion request trigger signal. Rising, falling or both edges can be selected for trigger signal generation.

Table 27-2 Trigger Modes

CFGRx.TM	Trigger Mode
00 _B	No trigger signal generated.
01 _B	A conversion request trigger signal is generated on a rising edge of trigger source input TS _n (selected by CFGRx.TSEL).
10 _B	A conversion request trigger signal is generated on a falling edge of trigger source input TS _n (selected by CFGRx.TSEL).
11 _B	A conversion request trigger signal is generated on a rising or falling edge of trigger source input TS _n (selected by CFGRx.TSEL).

The Conversion Request Flag CRSR.CRF_x is cleared by hardware when the conversion of channel x is started. Bit CRF_x can be also set or cleared by software via bits in the Flag Modification Register FMR. Writing a 1 to FMR.SCRF sets CRF_x. Writing a 1 to FMR.RCRF clears CRF_x (independently of FMR.SCRF).

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27.2.5 Channel Timer

Each of the FADC channels contains an 8-bit Channel Timer that can be used to generate periodic conversion requests. The Channel Timer is built up by a decrementing counter that is reloaded with a programmable value. When the Channel Timer reaches zero while running, a Channel Timer trigger event is generated and the Channel Timer is reloaded with the reload value $CFGRx.CTREL$ when the requested conversion is started. With the start of the A/D conversion, request bit $CRSR.CRFx$ is cleared. Note that the request flag is set by a timer trigger event only if the gating condition is met (signal $ECHTIMx$ in [Figure 27-4](#) set).

A clock divider, fed by the module clock f_{FADC} and common for all Channel Timers, generates several clock signals with different periods. Bit field $CFGRx.CTF$ selects whether or not the channel x timer clock f_{CTx} is enabled and, if enabled, determines the frequency of channel x timer input clock f_{CTx} .

While the Channel Timer is disabled ($CFGRx.CTM = 00_B$) or if the gating condition is not met (gating line $ECHTIMx$ delivers 0), the channel x timer value is set to 04_H . This value ensures a fast conversion trigger after the gating becomes enabled, but prevents unintended conversion starts in case of short pulses (bouncing) at the gating input.

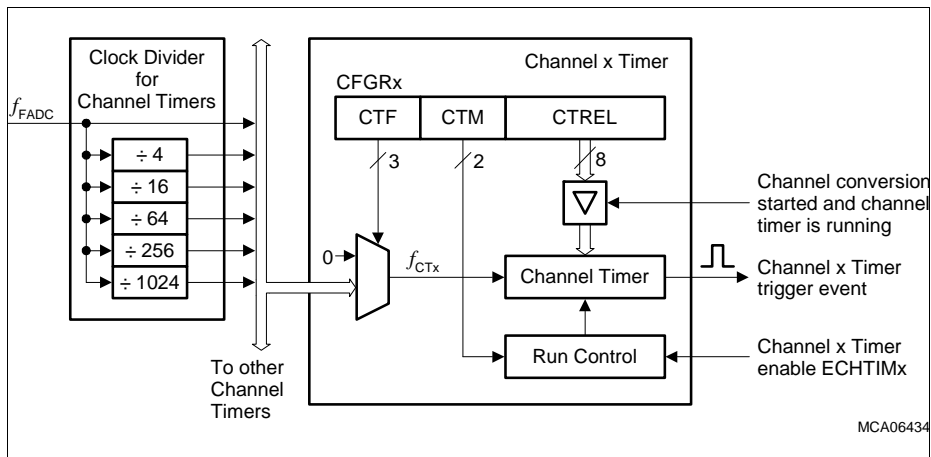


Figure 27-5 Channel Timer Block Diagram

Due to the common divider, the first event at the trigger output of $CHTIMx$ after the start has a maximum jitter of one clock cycle of the selected channel x timer clock f_{CTx} .

A Channel x Timer input clock pulse at f_{CTx} is ignored if it occurs in the f_{FADC} clock cycle directly after the Channel x Timer has reached 0. If there is at least one f_{FADC} clock cycle between two Channel x Timer input clock pulses, all Channel x Timer input clock pulses

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are taken into account. This leads to a Channel x Timer reload value (CFGRx.CTREL) whose definition depends on the ratio of f_{FADC} / f_{CTx} :

$f_{FADC} / f_{CTx} = 1$ Channel x timer divide factor = CTREL + 2

$1 < f_{FADC} / f_{CTx} < 2$ Not recommended to be used!

$2 \leq f_{FADC} / f_{CTx}$ Channel x timer divide factor = CTREL + 1

In case of a f_{FADC} / f_{CTx} ratio between 1 and 2, a mixture of both divide factor definitions occurs depending on the divider ratio as programmed by the fractional divider value. Therefore, it is recommended that this ratio should not be used.

27.2.6 Conversion Control

A conversion is started when at least one of the CRSR.CRFx bits is set. A running conversion cannot be aborted and is indicated by the busy flag CRSR.BSYx set. The corresponding bit CRSR.CRFx is reset by hardware when the conversion starts.

27.2.6.1 Static Channel Priority

If more than one conversion request flag CRSR.CRFx (x = 0-1) is set, the channels are converted according to a priority scheme as defined by the bit field GCR.CRPRIO (without respecting the status of the current filter sequences).

Table 27-3 Static Channel Request Priority

Priority	GCR.CRPRIO			
	00 _B	01 _B	10 _B	11 _B
High	Channel 0	Channel 1	Channel 0	Channel 0
Low	Channel 1	Channel 0	Channel 1	Channel 1

27.2.6.2 Dynamic Priority Assignment

If dynamic priority assignment is enabled (GCR.DPAEN = 1), a channel that has the only active gate signal (signal ECHTIMx in [Figure 27-4](#)) among the four channels gets the highest priority (GCR.CRPRIO is set to the number of the channel). If more than one channel gating signal is active, GCR.CRPRIO is not changed automatically. In this case, it can be changed by software.

27.2.6.3 Clock Generation

The FADC module is provided with two clock signals: f_{CLC} and f_{FADC} . Clock f_{CLC} is used inside the FADC kernel for control purposes such as clocking of control logic, register

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operations, trigger detection, or filter calculation.

The clock rate of f_{FADC} is programmable. It is used inside the FADC kernel for the Channel Timers and other internal timings.

27.2.6.4 Suspend Mode Behavior

When a suspend/idle mode request is generated for the FADC module via the fractional divider, a currently running conversion is completely finished (not aborted) and, if selected, a filter calculation still takes place. Thereafter, no new conversion will be started and the state of the FADC module is frozen until the suspend/idle mode request is released again. If enabled, the related interrupts are signaled.

If suspend mode is needed, it is recommended to use the suspend control by the fractional divider and not by the CLC register.

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27.2.6.5 Alias Feature

The alias feature is mainly meant for emulation purposes and does not need to be used in standard applications. It allows a reassignment of the channel to be converted with respect to the channel number that has been requested for conversion. This feature can be used to redirect conversion requests to other input channels without changing the request SW. For example, a SW from TC1766 (with only the two input channels 0 and 1), can be adapted to either channels 0 and 1. Especially when emulating several different devices with a common emulation chip, the channel reassignment allows compatible SW usage with different channel wiring to pins.

The setting of the input stages (incl. calibration information) is defined by register ACRx of the input channel that is requested (no alias-mapping). I.e. the ACRx register of the actually converted channel is used as it is permanently connected to its channel. The result handling (incl. interrupts) also refers to the requested channel number. The alias feature is only taken into account as channel number for the conversion start.

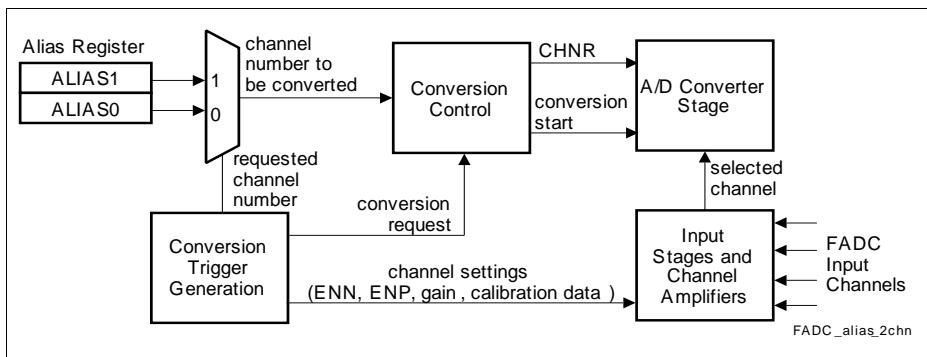


Figure 27-6 Alias Feature

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27.2.7 Data Reduction Unit

A Data Reduction Unit is implemented in the FADC that operates as anti-aliasing filter. This unit allows the number of conversion data requests that are issued to the CPU or other bus masters to be reduced by adding multiple conversion results according to a certain algorithm and presenting it to the CPU or other bus masters with a reduced conversion request rate.

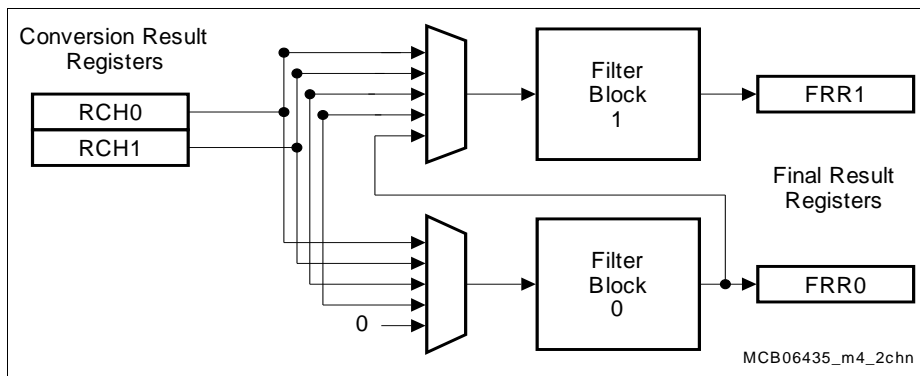


Figure 27-7 TC1728 FADC Filter Blocks

The Data Reduction Unit contains two filter blocks. Each filter block allows selection of its input data source. The input data sources are the conversion result registers of the two A/D converter channels.

Filter blocks can also be concatenated (block 0 and block 1 can be concatenated). When the result of a filter operation is stored in one of the final result registers, a service request can be generated. Each filter block basically contains adder logic and intermediate storage registers that allow support for typical digital filter operations such as moving average calculations with intermediate results.

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27.2.7.1 Filter Block Structure

The filter block consists of an adder and several result registers for calculating filter output data from the filter input data. For filter n , the Current Result Register CRR_n is used for adding up conversion results. After a programmable number of conversion results have been added, the contents of CRR_n are stored as intermediate result in the Intermediate Result Register IRR_{1n} . The three intermediate result registers operate like a pipeline. Before IRR_{1n} is overwritten, IRR_{2n} is transferred to IRR_{3n} , and IRR_{1n} is transferred to IRR_{2n} . The Final Result Register FRR_n stores the sum that is built by the contents of the current result register and the intermediate result registers.

All result registers of the filter block can be read at any time. Please note that only one intermediate result register is available in filter block 1 (IRR_{11}).

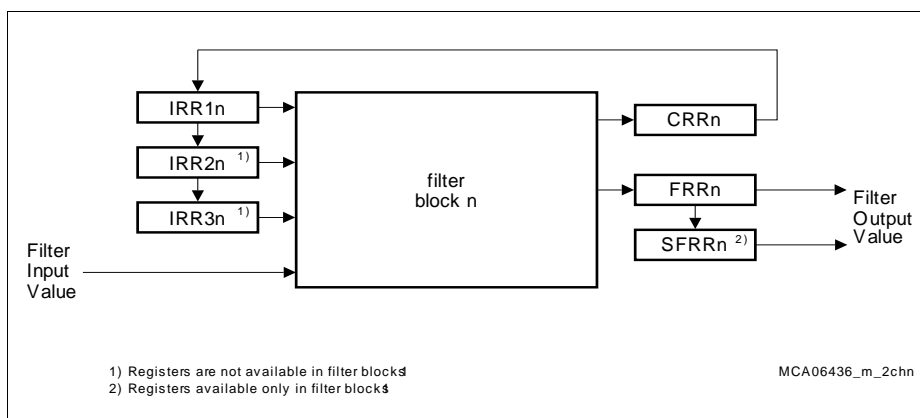


Figure 27-8 Filter Block Structure

27.2.7.2 Filter Block Operation

A filter block can be used for data-reduction or anti-aliasing filtering of the conversion results (n indicates the number of the filter block). It performs a combination of data reduction by adding and a moving average operation.

- A continuous A/D conversion is running on channel x .
- The filter input selection is set to channel x ($FCR_n.INSEL = 100_B + x$).
- The addition length is controlled by $FCR_n.ADDL$ defining how many conversion results are added to build one intermediate result (intermediate cycle).
- The moving average length is controlled by $FCR_n.MAVL$ defining how many intermediate results are taken into account for a moving average to build the final result (final result cycle).

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Intermediate Result Calculation

Each incoming conversion result is added to the content of CRRn until the programmed number of conversion results have been summed up in CRRn. At that point, CRRn contains a new intermediate result and the calculation of the next final result value by moving average is started. Then CRRn is cleared automatically after the final result cycle to be prepared for the first conversion result for the next intermediate cycle.

Before the filter operation of continuous conversion results of channel x is started, the filter block n has to be cleared (writing GCR.RSTFn = 1) after programming the filter control bit fields.

Final Result Calculation

The calculation of a final result is started when an intermediate cycle has been finished. The new intermediate result (stored in CRRn) and the contents of the intermediate registers IRRnx are added to build the final result in FRRn. The number of intermediate results taking part in the moving average operation to build the final result is programmable, the maximum is given by:

- Filter block 0: $FRR0 := CRR0 + IRR10 + IRR20 + IRR30$
- Filter block 1: $FRR1 := CRR1 + IRR11$

At the end of the final result cycle, the contents of IRR2n are transferred into IRR3n, then the contents of IRR1n into IRR2n, then the contents of CRRn into IRR10 (for filter blocks 0). The former contents of IRR3n are lost.

Bit field FCRn.MAVL determines the number of intermediate results that are used for the final result calculation. For filter blocks 1, only two bit combinations are valid and the intermediate result registers IRR2n and 3n are not available and handled as if they were 0.

Each update of a result register FRRn with a new final result value generates a filter block n service request.

27.2.7.3 Filter Concatenation

Filter block 1 allow filter concatenation to support more filter stages. Filter 1 can be programmed to use the result value of filter 0.

Filter blocks 0 operate with the following parameters:

- Intermediate results are calculated based on the conversion results of one of the input channels ($FCRn.INSEL = 1XX_B$).
- An intermediate cycle can contain a maximum of 8 conversion results.
- A final result cycle can contain a maximum of 4 intermediate results.

Filter blocks 1 operate with the following parameters:

- Intermediate results are based on the final results of filter block 0 (for filter block 1) . Filter block concatenation is enabled by $FCRn.INSEL = 010_B$.

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- An intermediate cycle can contain a maximum of 8 conversion results.
- A final result cycle can contain a maximum of 2 intermediate results.

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27.2.7.4 Width of Result Registers

The additions executed in filter 0 and filter 1 together with the possible maximum values of the filter parameters determine the width of the current, intermediate, and final result registers.

In addition to the final result registers FRR1 and FRR3 with 20 bit width, another view is available that is shifted by 5 bit positions to the right, given by registers SFRR1 and SFRR3. This allows a representation of the data within a 16 bit word for further digital data handling.

Table 27-4 Data Width of Result Registers

Register Long Name	Register Short Name	Result Width
Filter 0 Current Result Register	CRR0	13-bit
Filter 0 Intermediate Result Register 1	IRR10	
Filter 0 Intermediate Result Register 2	IRR20	
Filter 0 Intermediate Result Register 3	IRR30	
Filter 0 Final Result Register	FRR0	15-bit
Filter 1 Current Result Register	CRR1	18-bit
Filter 1 Intermediate Result Register 1	IRR11	
Filter 1 Final Result Register	FRR1	20-bit
Filter 1 Shifted Final Result Register	SFRR1	15-bit

27.2.8 Neighbor Channel Trigger

The neighbor channel trigger feature allows the concatenation of channel conversions. This means that the start of a conversion for one channel can generate multiple channel trigger requests for the other channels. A channel conversion request flag of a neighbor channel becomes only set by a neighbor channel trigger request if the gating condition (gating mode selection output at high level in [Figure 27-4](#)) in the corresponding neighbor channel is valid.

All neighbor channel trigger enable bits EN_{xy} are located in the Neighbor Channel Trigger Register NCTR. Index “x” indicates the number of the channel that starts a neighbor channel trigger. Index “y” is the number of the neighbor channel to be triggered.

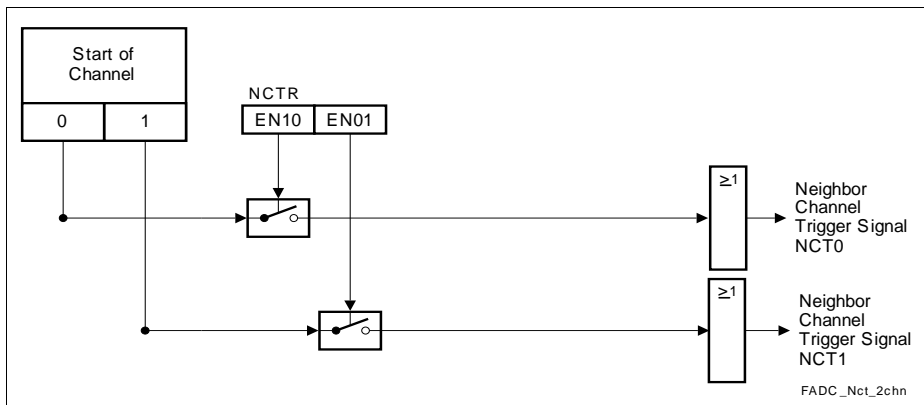


Figure 27-9 Neighbor Channel Trigger

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27.2.9 Calibration

The calibration is used to minimize the error of the FADC conversion results independently for each channel. The output of each channel amplifier can be adjusted to deliver a minimum offset value for zero input voltage difference. The channel which is calibrated is selected by GCR.CALCH. The calibration mode is selected by GCR.CALMODE. During the calibration process of a channel, the other channels can be used in normal conversion mode without restrictions.

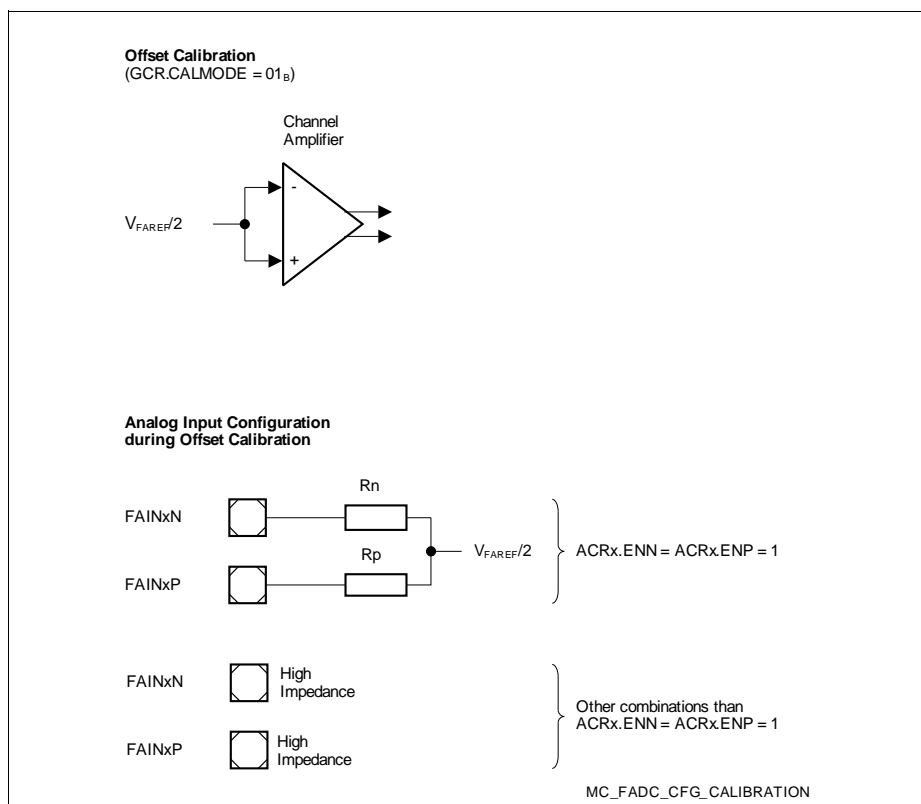


Figure 27-10 Analog Input and Channel Amplifier Configuration at Calibration

Figure 27-10 shows the channel amplifier configuration as well as the analog input pin configurations that are selected during offset and gain calibration. Note that in the calibration modes, the impedance of the analog inputs depends on the settings of the ENN and ENP bits of the corresponding Channel x Analog Control Register ACRx.

Fast Analog to Digital Converter (FADC)**27.2.9.1 Offset Calibration**

When offset calibration is selected ($\text{GCR.CALMODE} = 01_{\text{B}}$), the channel amplifier inputs of the selected channel are both connected to $V_{\text{FAREF}}/2$. After enabling a channel amplifier for offset calibration, a delay of minimum 5 μs must be respected before starting a conversion for this channel. The conversion result must be compared by software with the tolerated offset value (a conversion result with zero offset is equal to 512). If the conversion result exceeds the tolerated range, bit field ACRx.CALOFF (with x specifying the calibrated channel) can be adjusted and a new conversion can be started. The calibration process is finished when the conversion result is in the tolerated offset range. After switching back to normal mode for channel x, a delay of minimum 5 μs must be respected before starting a new conversion for this channel.

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27.2.10 Interrupt Generation

A flexible service request control structure is implemented in the FADC. The FADC provides the channel conversion request sources and the filter block request sources, that can be programmed to generate one of four service request output signals SR[3:0]. The service request compressor also makes it possible to assign more than one service request source to one service request output.

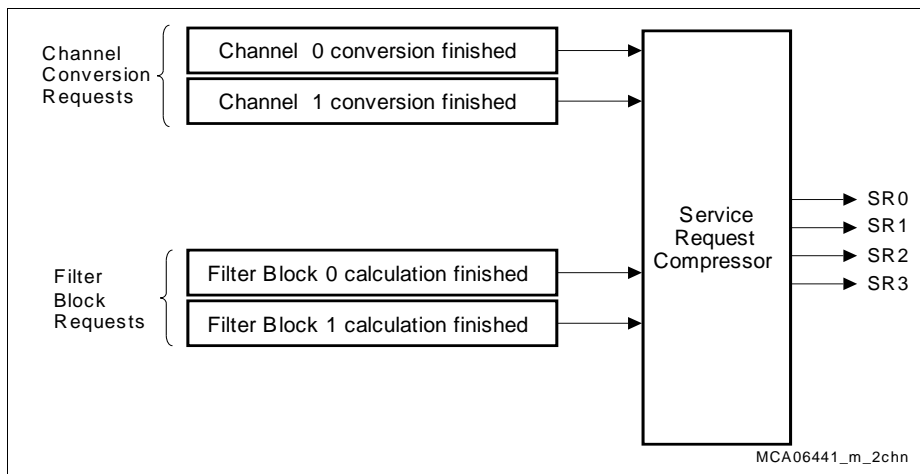


Figure 27-11 Service Request Configuration

All service requests are controlled by an identical control logic. This control logic as shown in [Figure 27-12](#) provides the following functionality:

- Service Request Flag
- Set/Clear Request Flag Control Bits
- Service Request Enable Bit
- Service Request Node Pointer

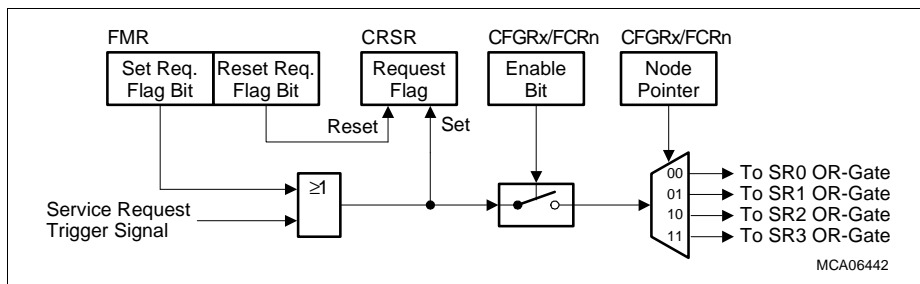


Figure 27-12 Service Request Control Logic

Fast Analog to Digital Converter (FADC)

The request flag is always set by hardware when the corresponding request event occurs. It can also be set or cleared by software when writing a 1 to the corresponding set/clear request flag bit in the Flag Modification Register FMR. Finally, a service request event is directed to one of the four service request output lines SR[3:0] when the corresponding service request enable bit IEN is set. The service request node pointer determines which of the service request output lines SR[3:0] becomes activated.

Table 27-5 lists the six service request sources of the FADC Module with its related control and status flags/bits.

Table 27-5 Service Request Control/Status Bits/Flags

Service Request Source	Request Flag	Enable Bit	Set Request Bit / Clear Request Bit	Service Request Node Pointer
Channel x Conversion Request (x = 0-1)	CRSR.IRQx	CFGRx.IEN	FMR.SIRQx / FMR.RIRQx	CFGRx.INP
Filter Block n Request (n = 0-1)	CRSR.IRQFn	FCRn.IEN	FMR.SIRQFn / FMR.RIRQFn	FCRn.INP

In the service request compressor logic shown in **Figure 27-13**, the inputs of one SRx OR-gate are connected to all demultiplexer outputs with identical INP node pointer value. Therefore, one service request event can be only assigned to one of the four service request outputs, but one service request output can be used by multiple service request events.

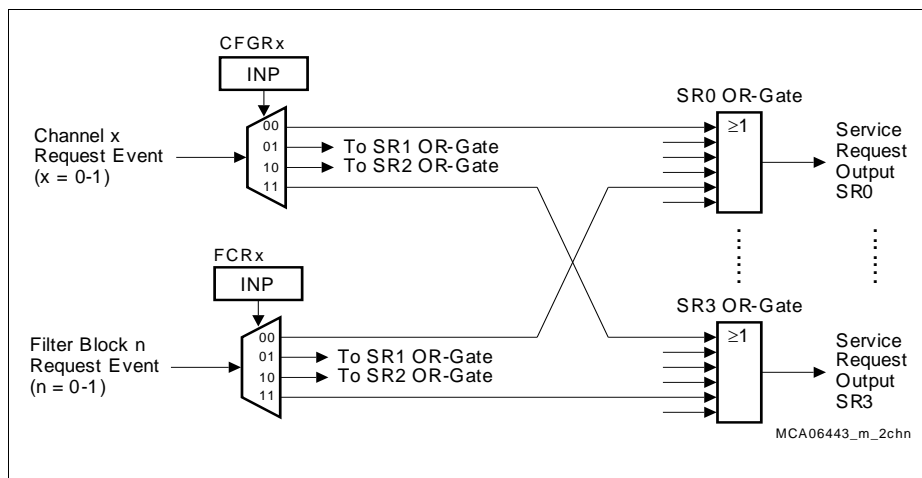


Figure 27-13 Service Request Compressor Logic

Fast Analog to Digital Converter (FADC)

Depending on the implementation of the FADC Module in a specific micro controller, the service request output signals SR[3:0] can either be connected to an interrupt node (controlled by a service request control register) or can be used as DMA request input of a DMA controller unit. The TC1728 specific request output connections are described in the FADC implementation chapter.

Fast Analog to Digital Converter (FADC)

27.3 FADC Register Description

This section describes the kernel registers of the FADC module. All FADC kernel register names described in this section will be referenced in other parts of the TC1728 User's Manual by the module name prefix "FADC_".

All registers can be accessed with 8-bit, 16-bit, or 32-bit read or write operations.

System Registers	Channel Registers	Filter Registers
CLC	CFGR0	FCR0
FDR	ACR0	CRR0
SRCx	RCH0	IRR10
		IRR20
		IRR30
		FRR0
Global Registers	CFGR1	
	ACR1	
	RCH1	
CRSR		FCR1
FMR		CRR1
NCTR		IRR11
GCR		FRR1
ALR		SFRR1

MCA06444_m4_2chn

Figure 27-14 FADC Kernel Registers

Access rights within the address range of an FADC kernel:

- Read access to defined register addresses: U, SV
- Write access to defined register addresses: U, SV
- Accesses to empty addresses: reserved, BE¹⁾

1) Read/Write access to F0100428_H - F010042C_H, F0100438_H - F010043C_H, F0100448_H - F010044C_H, F01004A0_H - F01004B4_H, F01004C0_H - F01004C8_H, F01004D4_H - F01004D8_H - reserved, no BE

Fast Analog to Digital Converter (FADC)

Table 27-6 Register Overview of FADC

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		

FADC Module Registers

CLC	Clock Control Register	000 _H	U, SV	SV, E	Class 3	Page 27-29
FDR	Fractional Divider Register	00C _H	U, SV	SV, E	Class 3	Page 27-30
ID	Module Identification Register	008 _H	U, SV	U, SV	Class 3	Page 27-32
SRCx x = 0 - 3	Service Request Control Registers	0FC _H - x * 4 _H	U, SV	U, SV	Class 3	Page 27-33

Global Registers

CRSR	Conversion Request Status Register	010 _H	U, SV	U, SV	Class 3	Page 27-34
FMR	Flag Modification Register	014 _H	U, SV	U, SV	Class 3	Page 27-36
NCTR	Neighbor Channel Trigger Register	018 _H	U, SV	U, SV	Class 3	Page 27-38
GCR	Global Control Register	01C _H	U, SV	U, SV	Class 3	Page 27-39
reserved	no BE, has to be written with 0	050 _H				
ALR	Alias Register	054 _H	U, SV	SV, E	Class 3	Page 27-42

Channel Registers

CFGRx	Channel x Configuration Register (x = 0-1)	020 _H + (x × 4)	U, SV	U, SV	Class 3	Page 27-43
ACRx	Channel x Analog Control Reg. (x = 0-1)	030 _H + (x × 4)	U, SV	U, SV	Class 3	Page 27-47
RCHx	Channel x Conversion Result Register (x = 0-1)	040 _H + (x × 4)	U, SV	U, SV	Class 3	Page 27-49

Fast Analog to Digital Converter (FADC)

Table 27-6 Register Overview of FADC (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Reset	Description See
			Read	Write		
Filter 0 Registers						
FCR0	Filter 0 Control Register	060 _H	U, SV	U, SV	Class 3	Page 27-50
CRR0	Filter 0 Current Result Register	064 _H	U, SV	U, SV	Class 3	Page 27-53
IRR10	Filter 0 Intermediate Result Register 1	068 _H	U, SV	U, SV	Class 3	Page 27-55
IRR20	Filter 0 Intermediate Result Register 2	06C _H	U, SV	U, SV	Class 3	Page 27-55
IRR30	Filter 0 Intermediate Result Register 3	070 _H	U, SV	U, SV	Class 3	Page 27-55
FRR0	Filter 0 Final Result Register	074 _H	U, SV	U, SV	Class 3	Page 27-56

Filter 1 Registers

FCR1	Filter 1 Control Register	080 _H	U, SV	U, SV	Class 3	Page 27-50
CRR1	Filter 1 Current Result Register	084 _H	U, SV	U, SV	Class 3	Page 27-53
IRR11	Filter 1 Intermediate Result Register 1	088 _H	U, SV	U, SV	Class 3	Page 27-55
FRR1	Filter 1 Final Result Register	094 _H	U, SV	U, SV	Class 3	Page 27-56
SFRR1	Filter 1 Shifted Final Result Register	098 _H	U, SV	U, SV	Class 3	Page 27-57

- 1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

Fast Analog to Digital Converter (FADC)

27.3.1 System Registers

27.3.1.1 Clock Control Register

The Clock Control Register allows the programmer to control (enable/disable) the clock signal f_{CLC} under certain conditions. After a reset operation, the FADC module is disabled and its module clock signal f_{CLC} is switched off.

CLC

Clock Control Register

(000_H)

Reset Value: 0000 0003_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0										FS OE	SB WE	E DIS	SP EN	DIS S	DIS R
r										rw	w	rw	rw	r	rw

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module.
DISS	1	r	Module Disable Status Bit Bit indicates the current status of the module.
SPEN	2	rw	Module Suspend Enable for OCDS Used to enable the suspend mode.
EDIS	3	rw	Sleep Mode Enable Control Used to control module's sleep mode.
SBWE	4	w	Module Suspend Bit Write Enable for OCDS Determines whether SPEN and FSOE are write-protected.
FSOE	5	rw	Fast Switch Off Enable Used for fast clock switch off in Suspend Mode.
0	[31:6]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.1.2 Fractional Divider Register

The Fractional Divider Register allows the programmer to control the clock rate of the module clock f_{FADC} .

FDR

Fractional Divider Register

(00C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DIS CLK	EN HW	SUS REQ	SUS ACK	0		RESULT									
rw	rw	rh	rh	r		rh									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DM		SC		SM	FDIS	STEP									
rw		rw		rw	rw	rw									

Field	Bits	Type	Description
STEP	[9:0]	rw	Step Value Reload or addition value for RESULT.
FDIS	10	rw	Freeze Disable This bit controls the freeze function for this module. 0 _B Module operates on corrected clock, with reduced modulation jitter 1 _B Module operates on uncorrected clock with full modulation jitter
SM	11	rw	Suspend Mode SM selects between granted or immediate suspend mode.
SC	[13:12]	rw	Suspend Control This bit field determines the behavior of the fractional divider in suspend mode.
DM	[15:14]	rw	Divider Mode This bit field selects normal divider mode, fractional divider mode, and off-state.
RESULT	[25:16]	rh	Result Value Bit field for the addition result.
SUSACK	28	rh	Suspend Mode Acknowledge Indicates state of SPNDACK signal.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
SUSREQ	29	rh	Suspend Mode Request Indicates state of SPND signal.
ENHW	30	rw	Enable Hardware Clock Control Controls operation of ECEN input and DISCLK bit. Should be always written with 0.
DISCLK	31	rwh	Disable Clock Hardware controlled disable for f_{FADC} signal.
0	10, [27:26]	r	Reserved Read as 0. Should be written with 0.

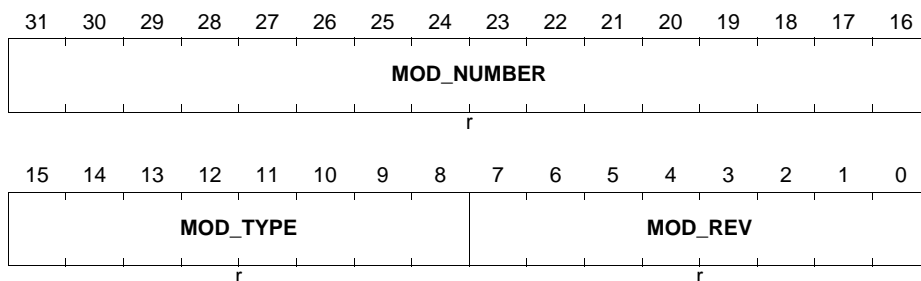
Fast Analog to Digital Converter (FADC)

27.3.1.3 Module Identification Register

The register table can be found on [Page 27-26](#).

ID

Module Identification Register (008_H) **Reset Value: 0027 C000_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision This bit field indicates the revision number of the module implementation (depending on the design step). The given value of 00 _H is a placeholder for the actual number. Bits [3:0] refer to the version of the digital part and bits [7:4] indicate the version of the analog part (anid).
MOD_TYPE	[15:8]	r	Module Type
MOD_NUMBER	[31:16]	r	Module Number

Fast Analog to Digital Converter (FADC)

27.3.1.4 Service Request Control Registers

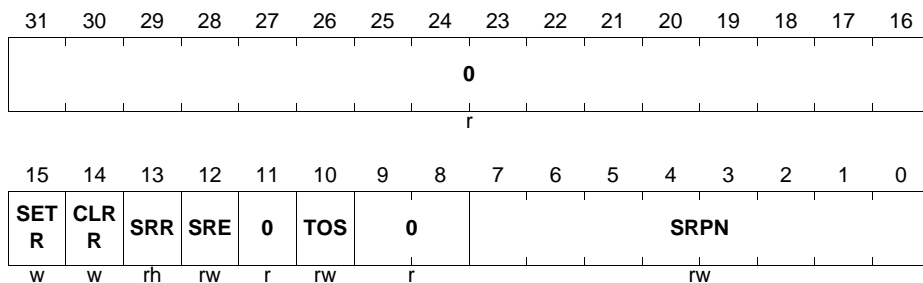
Each of the interrupts of the FADC is controlled by a service request control register.

SRCx (x = 0-3)

Service Request Control Register x

($0FC_H - x \cdot 4_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRPN	[7:0]	rw	Service Request Priority Number
TOS	10	rw	Type of Service Control
SRE	12	rw	Service Request Enable
SRR	13	rh	Service Request Flag
CLRR	14	w	Request Clear Bit
SETR	15	w	Request Set Bit
0	[9:8], 11, [31:16]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.2 Global Registers

27.3.2.1 Conversion Request Status Register

The Conversion Request Status Register CRSR contains the flags for monitoring the state of pending conversions and the interrupt request flags.

CRSR

Conversion Request Status Register (010_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0										IRQ F1	IRQ F0	0		IRQ 1	IRQ 0
r										rh	rh	r		rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						BSY 1	BSY 0	0						CRF 1	CRF 0
r						rh	rh	r						rh	rh

Field	Bits	Type	Description
CRFx (x = 0-1)	x	rh	Conversion Request Flag This bit monitors whether a conversion request is pending for channel x. CRFx is set by hardware when a trigger event is detected while the gating condition delivers 1. CRFx is automatically cleared by hardware when a conversion of the channel x is started. 0 _B A conversion of channel x has not been requested. 1 _B A conversion of channel x has been requested. Bits CRFx can be set/cleared by software via bits FMR.RCRFx and FMR.SCRFx. If a set and a clear condition for CRFx occur simultaneously (generated by hardware and/or software), the clear condition always wins.

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Field	Bits	Type	Description
BSYx (x = 0-1)	8 + x	rh	Busy Flag This bit indicates if a conversion is currently running for channel x. 0 _B A conversion is not running. 1 _B A conversion is running.
IRQx (x = 0-1)	16 + x	rh	Interrupt Request Flag This bit indicates that a conversion of channel x has been finished since it has been cleared by software. Interrupt requests can also be generated while IRQx is still set. An interrupt can only be generated when CFGRx.IEN = 1. 0 _B A conversion has not been finished. 1 _B A conversion has been finished. Bits IRQx can be set/cleared by software via bits FMR.SIRQx and FMR.RIRQx.
IRQFn (n = 0-1)	20 + n	rh	Interrupt Request Flag for Filter n This bit indicates that a filter sequence of filter n has been finished (new final result is available) since it has been cleared by software. Interrupt requests can also be generated while IRQ is still set. An interrupt can only be generated when FCRn.IEN = 1. 0 _B A filter sequence has not been finished. 1 _B A filter sequence has been finished. Bits IRQFn can be set/cleared by software via bits FMR.SIRQFn and FMR.RIRQFn.
0	[7:2], [15:10], [19:18], [31:22]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.2.2 Flag Modification Register

The bits of the Flag Modification Register FMR allow the flags of the conversion request status register to be set/cleared by software.

If a clear and set request are issued at the same time, the target flag is cleared. It is recommended to avoid writing both bit positions (for set and for clear) of the same target bit with 1 within the same write operation.

FMR

Flag Modification Register

(014_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0		S IRQ F1	S IRQ F0	0		S IRQ 1	S IRQ 0	0		R IRQ F1	R IRQ F0	0		R IRQ 1	R IRQ 0
r		w	w	r		w	w	r		w	w	r		w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						S CRF 1	S CRF 0	0						R CRF 1	R CRF 0
r						w	w	r						w	w

Field	Bits	Type	Description
RCRFx (x = 0-1)	x	w	Clear Conversion Request Flag This bit allows bit CRSR.CRFx to be cleared by software. 0 _B No operation 1 _B Bit CRSR.CRFx is cleared.
SCRFx (x = 0-1)	8 + x	w	Set Conversion Request Flag This bit allows bit CRSR.CRFx to be set by software. 0 _B No operation 1 _B Bit CRSR.CRFx is set.
RIRQx (x = 0-1)	16 + x	w	Clear Interrupt Request Flag This bit allows bit CRSR.IRQx to be cleared by software. 0 _B No operation 1 _B Bit CRSR.IRQx is cleared.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
RIRQFn (n = 0-1)	20 + n	w	Clear Interrupt Request Flag for Filter n This bit allows bit CRSR.IRQFn to be cleared by software. 0 _B No operation 1 _B Bit CRSR.IRQFn is cleared.
SIRQx (x = 0-1)	24 + x	w	Set Interrupt Request Flag This bit allows bit CRSR.IRQx to be set by software. 0 _B No operation 1 _B Bit CRSR.IRQx is set and an interrupt is generated if CFGRx.IEN = 1.
SIRQFn (n = 0-1)	28 + n	w	Set Interrupt Request Flag for Filter n This bit allows bit CRSR.IRQFn to be set by software. 0 _B No operation 1 _B Bit CRSR.IRQFn is set and an interrupt is generated if FCRn.IEN = 1.
0	[7:2], [15:10], [19:18], [23:22], [27:26], [31:30]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.2.3 Neighbor Channel Trigger Register

The Neighbor Channel Trigger Register NCTR contains the enable bits for the neighbor channel trigger signal (NCTx) generation (see [Page 27-20](#)).

NCTR

Neighbor Channel Trigger Register (018_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															
r															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							EN 10	0					EN 01	0	
r							rw	r					rw	r	

Field	Bits	Type	Description
EN01	1	rw	Enable Neighbor Channel Trigger 01 This bit enables the neighbor channel trigger for channel 1 when a conversion of channel 0 is started. 0 _B No action. 1 _B A trigger will be generated.
EN10	8	rw	Enable Neighbor Channel Trigger 10 This bit enables the neighbor channel trigger for channel 0 when a conversion of channel 1 is started. 0 _B No action. 1 _B A trigger will be generated.
0	0, [7:2], [15:9], [31:16]	r	Reserved Read as 0. Should be written with 0.

Note: The hardware does not check whether the enable bits are set in such a way as to describe a loop of conversion requests (e.g. 0 triggers 2, 2 triggers 3 and 3 triggers 0, etc.). It is in the responsibility of the user to set these bits in an appropriate way.

Fast Analog to Digital Converter (FADC)

27.3.2.4 Global Control Register

The Global Control Register GCR contains bits used to reset the Channel Timers, the filters and to control global FADC settings.

GCR

Global Control Register

(01C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
					CAL CH	CALMODE		0		AN ON	MUX TM	RES WEN	DPA EN	CRPRIO	
					r	rw	rw	r		rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
					0	RST F1	RST F0	RCD			0			RCT 1	RCT 0
					r	w	w	w			r			w	w

Field	Bits	Type	Description
RCTx (x = 0-1)	x	w	Reload Channel Timer 0 _B Channel x Timer will not be changed. 1 _B Channel x Timer will be loaded with its reload value.
RCD	8	w	Reset Common Divider 0 _B The common divider will not be changed. 1 _B The common divider will be cleared.
RSTFn (n = 0-1)	9 + n	w	Reset Filter n 0 _B The contents of filter n will not be changed. 1 _B The contents of filter n will be cleared. The values of the bits in the filter registers will be cleared, except bit field CRRn.AC that is loaded with the value of FCRn.ADDL.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
CRPRIO	[17:16]	rwh	Conversion Request Priority This bit field determines the priority of the conversion requests if more than one channel is requested. If the dynamic priority assignment is enabled, the priority is automatically changed as a function of the gating inputs. The priority of the channels is: 00 _B Channel 0 before channel 1 01 _B Channel 1 before channel 0 10 _B Channel 0 before channel 1 11 _B Channel 0 before channel 1
DPAEN	18	rw	Dynamic Priority Assignment Enable If the dynamic priority assignment is enabled, the priority bit field CRPRIO is automatically changed as a function of the gating input signals. In this case, the channel that is active while the other three channels are not active gets the highest priority. 0 _B The dynamic priority assignment is disabled. 1 _B The dynamic priority assignment is enabled.
RESWEN	19	rw	Result Write Enable This bit enables a write action to the result registers RCHx (x = 0-1) of the FADC. 0 _B Write accesses to the result registers are not taken into account. The written data is discarded. 1 _B Write accesses to the result registers are taken into account. The former value of the written result register is overwritten by the write data. If a filter is sensitive to the written result register, the written value is taken as new filter input value.
MUXTM	20	rw	Multiplexer Test Mode The input multiplexer to select a channel for the conversion can be tested by opening all multiplexer inputs. In multiplexer test mode, the channel amplifiers are not connected to the converter stage. 0 _B The multiplexer test mode is disabled. 1 _B The multiplexer test mode is enabled.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
ANON	21	rw	Analog Part ON This bit enables the analog part of the FADC. This bit must be set to convert the analog input signal to a digital value. 0 _B The complete analog part is in power-down mode, the amplifiers and comparators are switched off. Conversions are not possible. 1 _B The analog part is enabled.
CALMODE	[25:24]	rw	Calibration Mode This bit field enables the calibration for offset and gain for the channel selected by CALCH. 00 _B No calibration process is running. All channels are in normal mode (default after reset). 01 _B The analog channel selected by CALCH is in offset calibration mode. The other channels are in normal mode. 10 _B Reserved 11 _B Reserved
CALCH	26	rw	Calibration Channel This bit field selects the channel for the calibration process determined by CALMODE. The setting of CALCH is only taken into account while a calibration process is running. 0 _B The analog input channel 0 is selected for a calibration process. 1 _B The analog input channel 1 is selected for a calibration process.
0	[7:2], [15:11], [23:22], [31:27]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.2.5 Alias Register

The Alias Register contains bit fields allowing a re-assignment of the requested channel number to the actually converted channel.

ALR

Alias Register

(054_H)

Reset Value: 0000 00E4_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															0
r															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0													ALIAS S1	0	ALIAS S0
r													rw	r	rw

Field	Bits	Type	Description
ALIAS0	0	rw	Alias of Channel 0 This bit field defines which channel is converted if a trigger for channel 0 occurs. 0 _B Channel 0 will be converted (default). 1 _B Channel 1 will be converted.
ALIAS1	2	rw	Alias of Channel 1 This bit field defines which channel is converted if a trigger for channel 1 occurs. 0 _B Channel 0 will be converted. 1 _B Channel 1 will be converted (default).
0	16	rw	Placeholder Bit This bit position is a placeholder for further extensions and should be written with 0.
0	[31:17], [15:3],1	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.3 Channel Registers

27.3.3.1 Channel Configuration Registers

The Channel x Configuration Register CFGRx contains the bits for the selection of the trigger source, the gating source, and other channel settings of channel x.

CFGRx (x = 0-1)

Channel x Configuration Register (020_H+x*4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IEN	0	INP	0				CTREL								
rw	r	rw	r				rw								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	CTF			CTM	TM	GM	TSEL			GSEL					
r	rw			rw	rw	rw	rw			rw			rw		

Field	Bits	Type	Description
GSEL	[2:0]	rw	Gating Selection This bit field selects the gating source input signal for channel x. 000 _B Gating source input signal GSA selected 001 _B Gating source input signal GSB selected 010 _B Gating source input signal GSC selected 011 _B Gating source input signal GSD selected 100 _B Gating source input signal GSE selected 101 _B Gating source input signal GSF selected 110 _B Gating source input signal GSG selected 111 _B Gating source input signal GSH selected

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
TSEL	[5:3]	rw	Trigger Selection This bit field selects the trigger source input signal for channel x. 000 _B Trigger source input signal TSA selected 001 _B Trigger source input signal TSB selected 010 _B Trigger source input signal TSC selected 011 _B Trigger source input signal TSD selected 100 _B Trigger source input signal TSE selected 101 _B Trigger source input signal TSF selected 110 _B Trigger source input signal TSG selected 111 _B Trigger source input signal TSH selected
GM	[7:6]	rw	Gating Mode This bit field determines the functionality of the gating (enable) signal. It determines whether and under which condition the generation of conversion requests by trigger signals is possible. 00 _B Conversion requests are disabled and the Channel Timer is stopped. CRFx never becomes set (by hardware). 01 _B Conversion requests and the Channel Timer are always enabled. CRFx becomes set by hardware with each active trigger signal. 10 _B Conversion requests and the Channel Timer are enabled only if the gating source input (as selected by CFGRx.GSEL) is at high level. 11 _B Conversion requests and the Channel Timer are enabled only if the gating source input (as selected by CFGRx.GSEL) is at low level.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
TM	[9:8]	rw	Trigger Mode This bit field enables the triggering and determines the edge of the trigger source input signal that generates a conversion trigger signal. 00 _B No conversion trigger signals are generated. Edge detection unit is switched off. 01 _B A conversion request is generated (if gating enabled) on a rising edge of a trigger source input (as selected by CFGRx.TSEL). 10 _B A conversion request is generated (if gating enabled) on a falling edge of a trigger source input (as selected by CFGRx.TSEL). 11 _B A conversion request is generated (if gating enabled) on both, rising and falling, edges of a trigger source input (as selected by CFGRx.TSEL).
CTM	[11:10]	rw	Channel Timer Mode This bit determines the operating mode of channel x timer. 00 _B Channel x timer is switched off. 01 _B Channel timer is permanently running. 10 _B Channel timer is running only if ECHTIMx = 1. 11 _B Reserved A Channel Timer trigger event is generated each time the channel x timer value reaches 00 _H . While the Channel Timer is not running (CTM = 00 _B or signal ECHTIMx = 0), the Channel Timer is loaded with 04 _H .
CTF	[14:12]	rw	Channel Timer Frequency This bit field controls the channel x timer input clock f_{CT} (enable control and frequency selection). 000 _B f_{CTx} is disabled. 001 _B f_{CTx} is enabled with frequency f_{FADC} . 010 _B f_{CTx} is enabled with frequency $f_{FADC} / 4$. 011 _B f_{CTx} is enabled with frequency $f_{FADC} / 16$. 100 _B f_{CTx} is enabled with frequency $f_{FADC} / 64$. 101 _B f_{CTx} is enabled with frequency $f_{FADC} / 256$. 110 _B f_{CTx} is enabled with frequency $f_{FADC} / 1024$. 111 _B Reserved; do not use this combination.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
CTREL	[23:16]	rw	Channel Timer Reload Value This bit field determines the reload value of the Channel Timer CHTIMx, see Section 27.2.5 . If CTREL = 0, no trigger event is generated.
INP	[29:28]	rw	Interrupt Node Pointer This bit field selects which service request output line will be activated when a conversion of channel x is finished while CFGRx.IEN is set. 00 _B Service request output SR0 is selected. 01 _B Service request output SR1 is selected. 10 _B Service request output SR2 is selected. 11 _B Service request output SR3 is selected.
IEN	31	rw	Interrupt Enable This bit enables the generation of a service request when a conversion of channel x is finished. 0 _B Channel x conversion service request generation is disabled. 1 _B Channel x conversion service request generation is enabled.
0	15, [27:24], 30	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
ENN	3	rw	Enable Negative Input This bit enables the voltage measurement on the FAINxN analog input. 0 _B Analog input FAINxN is high-impedance. The lower half of the measuring range is not available. 1 _B Analog input FAINxN line is connected to the channel amplifier. The lower half of the measuring range is available.
CALOFF[2:0]	[10:8]	rw	Calibrate Offset This bit field determines the value applied for the offset calibration for channel x. The calibrate offset value is composed by the most significant bit CALOFF3 and bit field CALOFF[2:0], resulting in a 4-bit bit field CALOFF[3:0].
CALOFF3	12	rw	
0	[7:4], 11, [14:13], [31:15]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.3.3 Conversion Result Registers

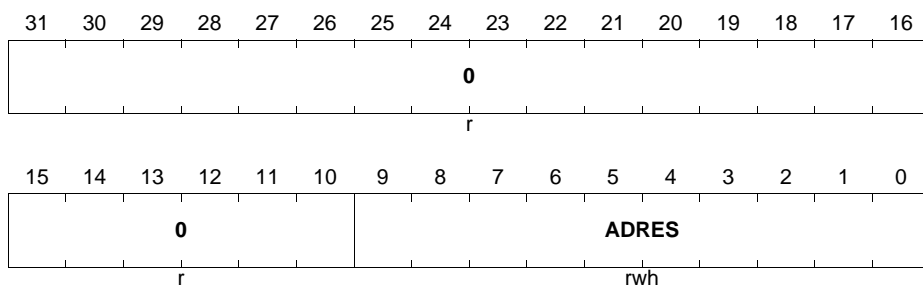
The Channel x Conversion Result Register RCHx contains the conversion result of channel x.

RCHx (x = 0-1)

Channel x Conversion Result Register

($040_H + x * 4_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
ADRES	[9:0]	rwh	AD Conversion Result This bit field contains the conversion result of channel x. ADRES can only be overwritten by software if GCR.RESWEN = 1.
0	[31:10]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
MAVL	[5:4]	rw	<p>Moving Average Length</p> <p>This bit field determines the number of intermediate results that are added up for a final result.</p> <p>00_B No moving average is selected. Each intermediate result is considered as final result value: $FRRn.FR = CRRn.CR$</p> <p>01_B A moving average of 2 values is selected. The final result is calculated by 2 values: $FRRn.FR = CRRn.CR + IRR1n.IR$</p> <p>10_B A moving average of 3 values is selected. The final result is calculated by 3 values: $FRRn.FR = CRRn.CR + IRR1n.IR + IRR2n.IR$</p> <p>11_B A moving average of 4 values is selected. The final result is calculated by 4 values: $FRRn.FR = CRRn.CR + IRR1n.IR + IRR2n.IR + IRR3n.IR$</p> <p>Bit combinations 10_B and 11_B are not available in filter blocks 1 and 3 and must not be selected there.</p>

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
INSEL	[10:8]	rw	Input Selection This bit field enables the filter block and determines which input value is taken for filter block n. For the settings 010 _B , set FORM = 00 _B . 000 _B The filter block is disabled. Intermediate and final sum calculations are not executed. The filter register values are not changed (except by a filter block reset). 001 _B Any conversion result of any channel is taken as new filter input value. 010 _B Filter block 0: filter is stopped (as 000 _B). Filter block 1: filter input value is the output value (final result) of filter block 0. Filter block 2: filter is stopped (as 000 _B). Filter block 3: filter input value is the output value (final result) of filter block 2. 011 _B Reserved 100 _B Channel 0 conversion result is taken as filter input value. 101 _B Channel 1 conversion result is taken as filter input value. 110 _B Channel 2 conversion result is taken as filter input value. 111 _B Channel 3 conversion result is taken as filter input value. <i>Note: Channel 2/3 is only applicable for FADC modules having 4 channels</i>
INP	[13:12]	rw	Interrupt Node Pointer This bit field selects which service request output line will be activated when a final result of filter block n is available while bit IEN is set. 00 _B Service request output SR0 selected 01 _B Service request output SR1 selected 10 _B Service request output SR2 selected 11 _B Service request output SR3 selected
IEN	15	rw	Interrupt Enable This bit enables the generation of a new final result service request of filter block n. 0 _B Service request generation disabled 1 _B Service request generation enabled

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
0	3, [7:6], 11, 14, [31:16]	r	Reserved Read as 0. Should be written with 0.

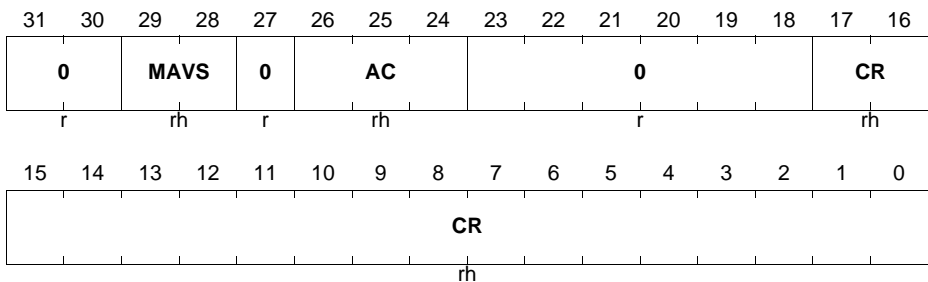
27.3.4.2 Current Result Registers

The Current Result Registers CRRn store the current result of filter n. Further, status information of filter block n can be read from CRRn.

CRRn (n = 0-1)

Filter n Current Result Register ($064_H + n * 20_H$)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CR	[17:0]	rh	Current Result This bit field (significant bits [12:0] for filter 0, [17:0] for filter 1) contains the right-aligned current result value of filter 0. CR is cleared when writing GCR.RSTFn = 1.
AC	[26:24]	rh	Addition Count This bit field indicates the number of additions of filter input values with remain to be executed before the next intermediate result register transfer occurs. AC is loaded with the value of FCRn.ADDL for a new addition sequence, also when writing GCR.RSTFn = 1.

Fast Analog to Digital Converter (FADC)

Field	Bits	Type	Description
MAVS	[29:28]	rh	Moving Average State This bit field indicates how many intermediate registers transfers remain to be executed for the generation of the next final result. MAVS = 0 indicates the end of a filter calculation operation. Since the filter calculation is executed very fast in comparison to a conversion, MAVS > 0 can be interpreted only as a kind of calculation busy flag. Therefore, it is recommended to read a valid filter result from register FRRn only when the corresponding interrupt request flag CRSR.IRQFn is set. MAVS is reset when writing GCR.RSTFn = 1.
0	[23:18], 27, [31:30]	r	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

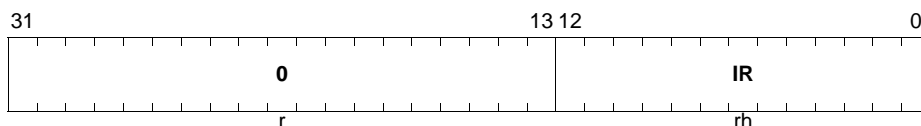
27.3.4.3 Intermediate Result Registers

The Intermediate Result Registers IRRmn hold the intermediate results y of filter n .

IRRY0 ($y = 1-3$)

Filter 0 Intermediate Result Register y

 $(064_H + y \cdot 4_H)$

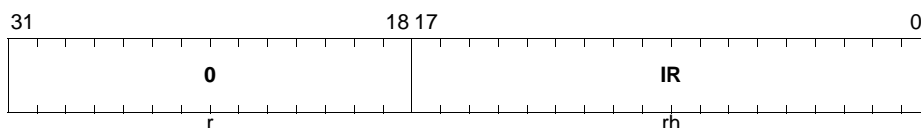
Reset Value: 0000 0000_H


Field	Bits	Type	Description
IR	[12:0]	rh	Intermediate Result This bit field contains the right-aligned intermediate result. IR is cleared when writing GCR.RSTFn = 1.
0	[31:13]	rh	Reserved Read as 0. Should be written with 0.

IRR11

Filter 1 Intermediate Result Register 1

 (088_H)

Reset Value: 0000 0000_H


Field	Bits	Type	Description
IR	[17:0]	rh	Intermediate Result This bit field contains the right-aligned intermediate result. IR is reset when writing GCR.RSTFn = 1.
0	[31:18]	rh	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.3.4.4 Final Result Registers

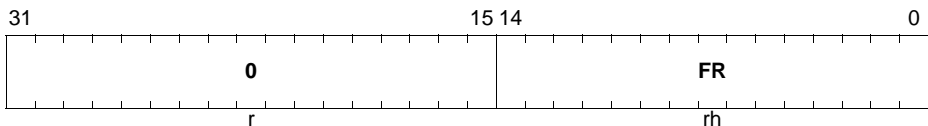
The Final Result Registers FRRn hold the final results of filter block n. The data width being different for the filter block 0 and 2 from the one from data blocks 1 and 3, two different register layouts are necessary.

FRR0

Filter 0 Final Result Register

(074_H)

Reset Value: 0000 0000_H



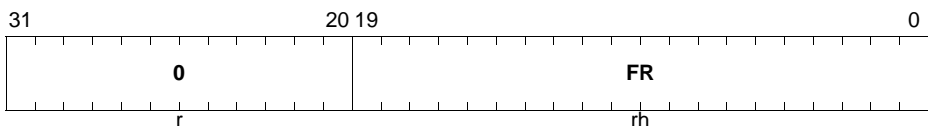
Field	Bits	Type	Description
FR	[14:0]	rh	Final Result This bit field contains the right-aligned final result. FR is cleared when writing GCR.RSTFn = 1.
0	[31:15]	rh	Reserved Read as 0. Should be written with 0.

FRR1

Filter 1 Final Result Register

(094_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
FR	[19:0]	rh	Final Result This bit field contains the right-aligned final result. FR is cleared when writing GCR.RSTFn = 1.
0	[31:20]	rh	Reserved Read as 0. Should be written with 0.

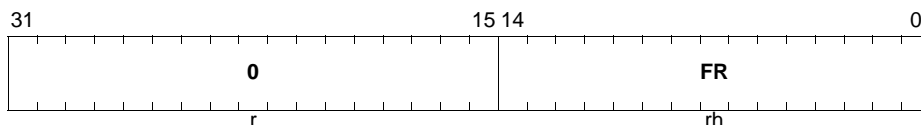
Fast Analog to Digital Converter (FADC)

The Shifted Final Result Registers SFRRn hold the final results of filter blocks 1 and 3 that are shifted right by 5 bit positions. The data representation allows the use of 16-bit data operations for further treatment.

SFRR1

Filter 1 Shifted Final Result Register (098_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
FR	[14:0]	rh	Final Result This bit field contains the right-aligned final result from the corresponding final result register FRRn shifted right by 5 bit positions. FR is cleared when writing GCR.RSTFn = 1.
0	[31:15]	rh	Reserved Read as 0. Should be written with 0.

Fast Analog to Digital Converter (FADC)

27.4 Implementation of FADC

This section describes the implementation of the FADC module in the TC1728.

27.4.1 Register Overview

All FADC kernel register names described in this section are referenced in other parts of the TC1728 User's Manual by the module name prefix "FADC_".

Table 27-7 Registers Address Space - FADC Module

Module	Base Address	End Address	Note
FADC	F010 0400 _H	F010 05FF _H	-

Table 27-8 Registers Overview

Register Short Name	Register Long Name	Offset Address	Page Number
intentionally left blank, please refer to register table in Section 27.3		H	

Fast Analog to Digital Converter (FADC)

27.4.2 Interfaces of the FADC Module

Figure 27-15 shows the TC1728 specific implementation details and interconnections of the FADC module.

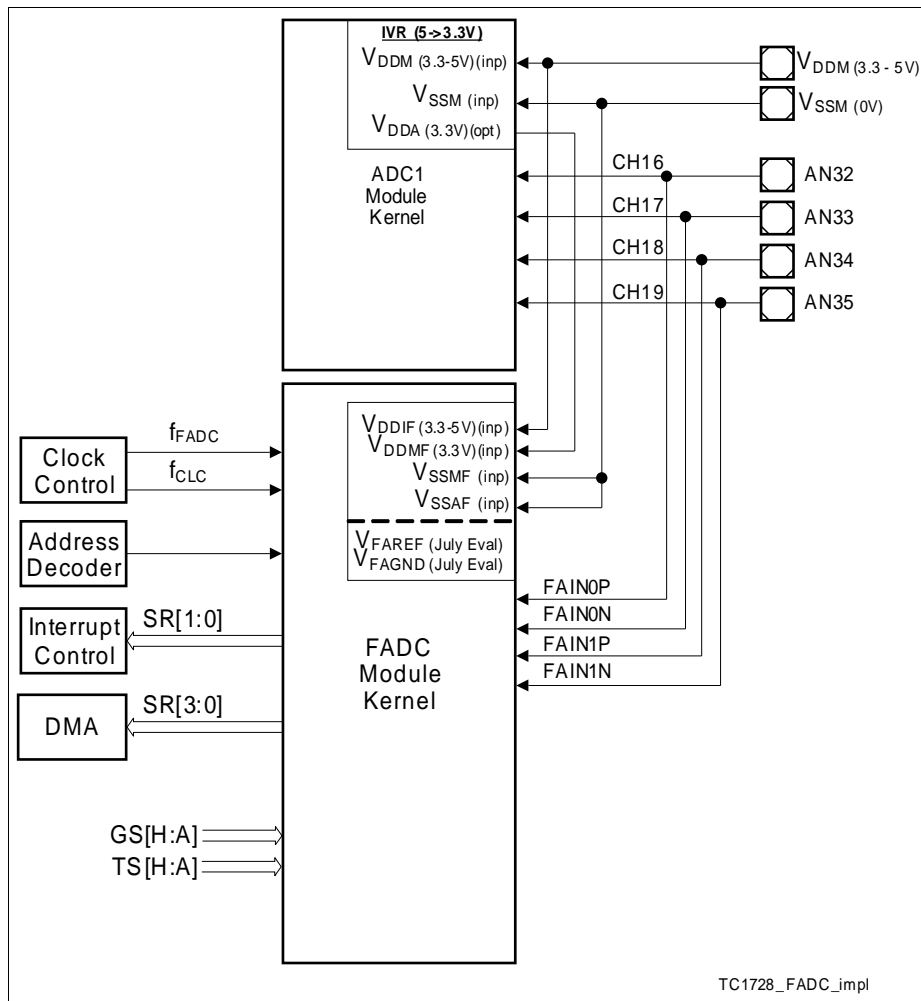


Figure 27-15 FADC Module Implementation and Interconnections

Fast Analog to Digital Converter (FADC)

27.4.3 FADC Connections

The following table shows the analog connections of the FADC kernel with other modules or pins in the TC1728 device.

Table 27-9 Connections to FADC Analog Part in TC1728

FADC Signal of Analog Part	from/to Module or Pin	Input or Output	Can be used to/as
V_{DDIF}	V_{DDM}	I	analog power supply 3 V - 5.5 V of input stage, connected to the power supply of the ADC
V_{DDMF}	V_{DDA}	I	analog power supply 3.3 V, connected to internal voltage regulator in ADC
V_{SSMF}	V_{SSMF}	I	analog power ground
V_{DDAF}	V_{DDAF}	I	analog power supply 1.3V, connected to internal voltage regulator in FADC
V_{SSAF}	V_{SSM}	I	analog power ground
V_{FAREF}	V_{FAREF}	I	positive analog reference, connected to internal reference from FADC
V_{FAGND}	V_{FAGND}	I	negative analog reference, connected to internal reference from FADC
FAIN0P	AN32	I	analog input P channel 0, overlaid with ADC1 channel 16
FAIN0N	AN33	I	analog input N channel 0, overlaid with ADC1 channel 17
FAIN1P	AN34	I	analog input P channel 1, overlaid with ADC1 channel 18
FAIN1N	AN35	I	analog input N channel 1, overlaid with ADC1 channel 19

The following table shows the digital connections of the FADC kernel with other modules or pins in the TC1728 device.

Fast Analog to Digital Converter (FADC)

Table 27-10 Connections of FADC Digital Part in TC1728

FADC Signal of Digital Part	from/to Module or Pin	Input or Output	Can be used to/as
Gating Inputs			
GSA	REQ0	I	P3.10
GSB	REQ4	I	P0.14
GSC	PDOUT2	I	ERU
GSD	PDOUT3	I	ERU
GSE	TRIG11	I	GPTA
GSF	TRIG13	I	GPTA
GSG	TRIG15	I	GPTA
GSH	TRIG17	I	GPTA
Trigger Inputs			
TSA	REQ1	I	P3.11
TSB	REQ5	I	P0.15
TSC	IOUT2	I	ERU
TSD	IOUT3	I	ERU
TSE	TRIG00	I	GPTA
TSF	TRIG02	I	GPTA
TSG	TRIG04	I	GPTA
TSH	TRIG06	I	GPTA
Others			
FADC_SR[3:0]	interrupt controller, DMA	O	service request output lines of FADC (service request)

27.4.4 Service Request Connections

The FADC kernel provides 4 service request output lines FADC_SR[3:0]. All 4 lines are connected to the DMA (for more details, refer to DMA chapter).

Fast Analog to Digital Converter (FADC)**Table 27-11 FADC Service Request Connections in TC1728**

Service Request Signal	Connected to Service Request Node
FADC_SR[0]	FADC_SRC0
FADC_SR[1]	FADC_SRC1
FADC_SR[2]	FADC_SRC2
FADC_SR[3]	FADC_SRC3

Fast Analog to Digital Converter (FADC)

27.4.5 Clock Control

The FADC module is provided with two clock signals:

- f_{CLC}
This is the module clock that is used inside the FADC kernel for control purposes such as clocking of control logic and register operations. The frequency of f_{CLC} is always identical to the system clock frequency $f_{\text{SYS}} (= f_{\text{FPI}})$. The clock control register FADC_CLC makes it possible to enable/disable f_{CLC} .
- f_{FADC}
This clock is the module clock that is used in the FADC as the clock for the channel timer and other internal timings, such as the conversion timing. The fractional divider registers FADC_FDR controls the frequency of f_{FADC} and allows it to be enabled/disabled independently of f_{CLC} .

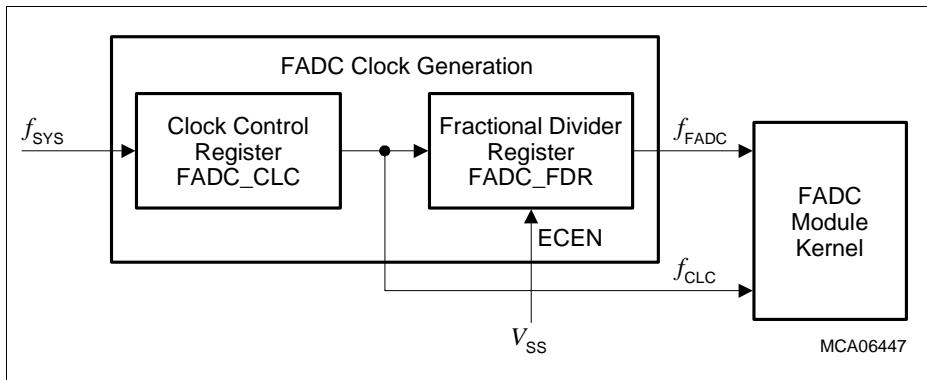


Figure 27-16 FADC Clock Generation

The following formulas define the frequency of f_{FADC} :

$$f_{\text{FADC}} = f_{\text{SYS}} \times \frac{1}{n} \quad \text{with } n = 1024 - \text{FDR.STEP} \quad (27.2)$$

$$f_{\text{FADC}} = f_{\text{SYS}} \times \frac{n}{1024} \quad \text{with } n = 0-1023 \quad (27.3)$$

Equation (27.2) is valid for FADC_FDR.DM = 01_B (normal divider mode).

Equation (27.3) is valid for FADC_FDR.DM = 10_B (fractional divider mode).

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