

XMC1200 AB-Step

Microcontroller Series
for Industrial Applications

XMC1000 Family

ARM[®] Cortex[®]-M0
32-bit processor core

Reference Manual

V1.3 2016-08

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Page	Subjects
7-4	Memory Organization chapter Corrected user readable to non-readable ROM boundary address
8-5 8-16 8-18	NVM chapter - Add description about using flash with fixed wait states - Bit field WS added to NVMCONF register - Added CONFIG1 register

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About this Document

This Reference Manual is addressed to embedded hardware and software developers. It provides the reader with detailed descriptions about the behavior of the XMC1200 series functional units and their interaction.

The manual describes the functionality of the superset device of the XMC1200 microcontroller series. For the available functionality (features) of a specific XMC1200 derivative (derivative device), please refer to the respective Data Sheet. For simplicity, the various device types are referenced by the collective term XMC1200 throughout this manual.

XMC1000 Family User Documentation

The set of user documentation includes:

- **Reference Manual**
 - describes the functionality of the superset device.
- **Data Sheets**
 - list the complete ordering information, available features and electrical characteristics of derivative devices.
- **Errata Sheets**
 - list deviations from the specifications given in the related Reference Manual or Data Sheets. Errata Sheets are provided for the superset of devices.

Attention: Please consult all parts of the documentation set to attain consolidated knowledge about your device.

Application related guidance is provided by **Users Guides** and **Application Notes**.

Please refer to <http://www.infineon.com/xmc1000> to get access to the latest versions of those documents.

Related Documentations

The following documents are referenced:

- ARM® Cortex M0
 - Technical Reference Manual
 - User Guide, Reference Material
- ARM®v6-M Architecture Reference Manual
- AMBA® 3 AHB-Lite Protocol Specification
- AMBA® 3 APB Protocol Specification

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Text Conventions

This document uses the following naming conventions:

- Functional units of the XMC1200 are given in plain UPPER CASE. For example: "The USIC0 unit supports...".
- Pins using negative logic are indicated by an overline. For example: "The $\overline{\text{WAIT}}$ input has...".
- Bit fields and bits in registers are in general referenced as "Module_RegisterName.BitField" or "Module_RegisterName.Bit". For example: "The USIC0_PCR.MCLK bit enables the...". Most of the register names contain a module name prefix, separated by an underscore character "_" from the actual register name (for example, "USIC0_PCR", where "USIC0" is the module name prefix, and "PCR" 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 "MOFCR_n" refers to multiple "MOFCR" 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. 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

Bit Function Terminology

In tables where register bits or bit fields are defined, the following conventions are used to indicate the access types.

Table 1 Bit Function Terminology

Bit Function	Description
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. If not otherwise documented the software takes priority in case of a write conflict between software and 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.

Register Access Modes

Read and write access to registers and memory locations are sometimes restricted. In memory and register access tables, the following terms are used.

Table 2 Register Access Modes

Symbol	Description
PV (SV), U	Access permitted in Privileged (Supervisor) Mode. Note: ARM® Cortex M0 processor does not support different privilege levels. Only Privileged (Supervisor) Mode is supported in XMC1000 Family. Symbol “U” and Symbol “PV” can be used to represent the access permitted in this mode.
BP	Indicates that this register can only be access when the bit protection is disabled. See detailed description of Bit Protection Scheme in the Memory Organisation chapter.

Table 2 Register Access Modes (cont'd)

Symbol	Description
32	Only 32-bit word accesses are permitted to this register/address range.
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.

Reserved Bits

Register bit fields named **Reserved** or **0** indicate unimplemented functions with the following behavior.

- 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.

Abbreviations and Acronyms

The following acronyms and terms are used in this document:

ACMP	Analog Comparator
AHB	Advanced High-performance Bus
AMBA	Advanced Microcontroller Bus Architecture
ANACTRL	Analog Control Unit
APB	Advanced Peripheral Bus
ASC	Asynchronous Serial Channel
BCCU	Brightness and Colour Control Unit
BMI	Boot Mode Index
CMSIS	Cortex Microcontroller Software Interface Standard
CPU	Central Processing Unit
CCU4	Capture Compare Unit 4
CCU8	Capture Compare Unit 8
CRC	Cyclic Redundancy Code
DCO	Digitally Controlled Oscillator
ECC	Error Correction Code

ERU	Event Request Unit
EVR	Embedded Voltage Regulator
FPU	Floating Point Unit
GPIO	General Purpose Input/Output
HMI	Human-Machine Interface
IIC	Inter Integrated Circuit (also known as I2C)
IIS	Inter-IC Sound Interface
I/O	Input / Output
JTAG	Joint Test Action Group = IEEE1149.1
LED	Light Emitting Diode
LEDTS	LED and Touch Sense Control Unit
MSB	Most Significant Bit
NC	Not Connected
NMI	Non-Maskable Interrupt
NVIC	Nested Vectored Interrupt Controller
ORC	Out of Range Comparator
PAU	Peripheral Access Unit
POSIF	Position Interface
PRNG	Pseudo Random Number Generator
ROM	Read-Only Memory
RAM	Random Access Memory
RTC	Real Time Clock
SCU	System Control Unit
SFR	Special Function Register
SHS	Sample and Hold Sequencer
SPI	Serial Peripheral Interface
SRAM	Static RAM
SR	Service Request
SSC	Synchronous Serial Channel
SSW	Start-up Software
TSE	Temperature Sensor
UART	Universal Asynchronous Receiver Transmitter

About this Document

USIC	Universal Serial Interface Channel
VADC	Versatile Analog-to-Digital Converter
WDT	Watchdog Timer

Introduction

1 Introduction

The XMC1200 series belongs to the XMC1000 Family of industrial microcontrollers based on the ARM Cortex-M0 processor core. The XMC1200 series devices are optimized for LED Lighting applications and Human-Machine interface (HMI).

Increasing complexity and demand for computing power of embedded control applications requires microcontrollers to have a significant CPU performance, integrated peripheral functionality and rapid development environment enabling short time-to-market, without compromising cost efficiency. Nonetheless the architecture of the XMC1200 microcontroller pursue successful hardware and software concepts, which have been established in Infineon microcontroller families.

1.1 Overview

The XMC1200 series devices combine the extended functionality and performance of the Cortex-M0 core with powerful on-chip peripheral subsystems and on-chip memory units. The following key features are available within the range of XMC1200 series devices:

CPU Subsystem

- CPU Core
 - High Performance 32-bit Cortex-M0 CPU
 - Most of 16-bit Thumb instruction set
 - Subset of 32-bit Thumb2 instruction set
 - High code density with 32-bit performance
 - Single cycle 32-bit hardware multiplier
 - System timer (SysTick) for Operating System support
 - Ultra low power consumption
- Nested Vectored Interrupt Controller (NVIC)
- Event Request Unit (ERU) for programmable processing of external and internal service requests

On-Chip Memories

- 8 kbytes on-chip ROM
- 16 kbytes on-chip high-speed SRAM
- up to 200 kbytes on-chip Flash program and data memory

Communication Peripherals

- Two Universal Serial Interface Channels (USIC), usable as UART, double-SPI, quad-SPI, IIC, IIS and LIN interfaces
- LED and Touch-Sense Controller (LEDTS) for Human-Machine interface

Analog Frontend Peripherals

- A/D Converters, up to 12 channels, includes 2 sample and hold stages and a fast 12-bit analog to digital converter with adjustable gain
- Up to 8 channels of out of range comparators (ORC)
- Up to 3 fast analog comparators (ACMP)
- Temperature Sensor (TSE)

Industrial Control Peripherals

- Capture/Compare Units 4 (CCU4) for use as general purpose timers
- Brightness and Colour Control Unit (BCCU), for LED color and dimming application

System Control

- Window Watchdog Timer (WDT) for safety sensitive applications
- Real Time Clock module with alarm support (RTC)
- System Control Unit (SCU) for system configuration and control
- Pseudo random number generator (PRNG), provides random data with fast generation times

Input/Output Lines With Individual Bit Controllability

- Tri-stated in input mode
- Push/pull or open drain output mode
- Configurable pad hysteresis

Debug System

- Access through the standard ARM serial wire debug (SWD) or the single pin debug (SPD) interface
- A breakpoint unit (BPU) supporting up to 4 hardware breakpoints
- A watchpoint unit (DWT) supporting up to 2 watchpoints

Packages Information

- PG-VQFN-40
- PG-VQFN-24
- PG-TSSOP-38
- PG-TSSOP-28
- PG-TSSOP-16

Note: For details about package availability for a particular derivative please check the datasheet.

1.1.1 Block Diagram

The diagram below shows the functional blocks and their basic connectivity within the XMC1200 System.

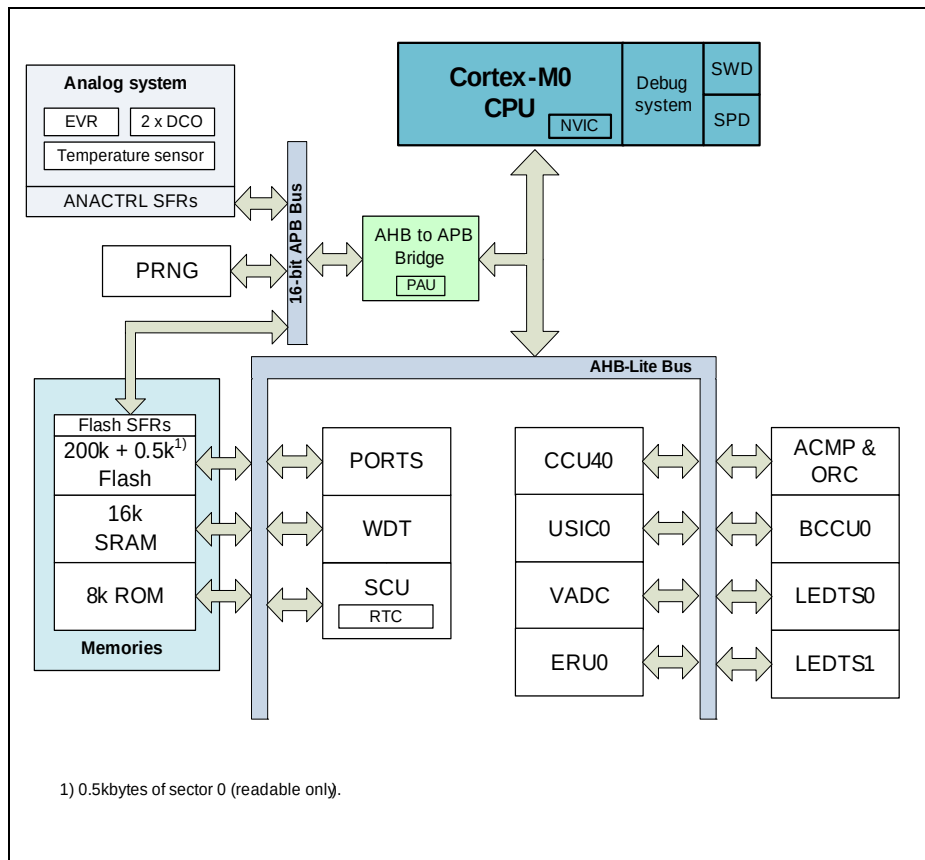


Figure 1-1 XMC1200 Functional diagram

1.2 Core Processing Units

The XMC1200 system core consists of the CPU and the memory interface blocks for memories.

1.2.1 Central Processing Unit (CPU)

The ARM Cortex-M0 processor is built on a highly area and power optimized 32-bit processor core, with a 3-stage pipeline von Neumann architecture. The processor delivers exceptional energy efficiency through a small but powerful instruction set and extensively optimized design, providing high-end processing hardware including a single cycle multiplier.

The instruction set is based on the 16-bit Thumb instruction set and includes Thumb-2 technology. This provides the exceptional performance expected of a modern 32-bit architecture, with a higher code density than other 8-bit and 16-bit microcontrollers.

1.2.2 Programmable Multiple Priority Interrupt System (NVIC)

The XMC1200 provides separate interrupt nodes that may be assigned to 4 interrupt priority levels. Most interrupt sources are connected to a dedicated interrupt node. In some cases, multi-source interrupt nodes are incorporated for efficient use of system resources. These nodes can be activated by several source requests and are controlled via interrupt subnode control registers.

1.3 System Units

The XMC1200 controllers provide a number of system resources designed around the CPU.

1.3.1 Memories

8 kbytes of ROM (ROM) memory for boot code execution and exception vector table. The ROM contains system basic initialization sequence code and is executed immediately after reset release. The Bootstrap Loaders(BSL) and User Routines are also stored in the ROM.

Up to 200 kbytes of on-chip Flash memory store code or constant data. Dynamic error correction provides high read data security for all read accesses.

16 kbytes of on-chip code RAM (SRAM) are provided to store user code or data, as well as system variables such as system stack. The SRAM is accessed via the AHB and provides zero-waitstate access for CPU code execution.

1.3.2 Watchdog Timer (WDT)

The main purpose of the Window Watchdog Timer is to improve the system integrity. WDT triggers the system reset or other corrective action like e.g. an interrupt if the main program, due to some fault condition, neglects to regularly service the watchdog. The intention is to bring the system back from the unresponsive state into normal operation.

1.3.3 Real Timer Clock (RTC)

Real-time clock (RTC) is a clock that keeps track of the current time. RTCs are present in almost any electronic device which needs to keep accurate time in a digital format for clock displays and computer systems..

1.3.4 System Control unit (SCU)

The System Control Unit (SCU) handles all system control tasks besides the debug related tasks. All functions are tightly coupled and thus, they are conveniently handled by one unit, SCU. It consists of the Power Control Unit (PCU), Reset Control Unit, Clock Control Unit (CCU) and the Miscellaneous Control Unit (GCU).

The CCU generates the Main clock (MCLK) and the fast Peripheral clock (PCLK) using the 64MHz DCO1 oscillator. The PCU has a Embedded Voltage Regulator (EVR) that is used to generate the core voltage. It also provides voltage monitoring detectors to secure system performance under critical condition (eg. brownout).

1.3.5 Pseudo Random Bit Generator (PRNG)

The pseudo random bit generator (PRNG) provides random data with fast generation times.

1.4 Peripherals Units

XMC1200 offers a set of on-chip peripherals to support industrial applications.

Universal Serial Interface Channel (USIC)

The USIC is a flexible interface module covering several serial communication protocols such as ASC, LIN, SSC, I2C, I2S. A USIC module contains two independent communication channels which can be used in parallel. A FIFO allows transmit and result buffering for relaxing real-time conditions. Multiple chip select signals are available for communication with multiple devices on the same channel.

LED and Touch Sense (LEDTS)

The LEDTS module drives LEDs and controls touch pads used in human-machine interface (HMI) applications. There are 2 kernels of the LEDTS module in this device. These 2 kernels of LEDTS can measure the capacitance of up to 16 touch pads using the relaxation oscillator (RO) topology. It can also drive up to 88 LEDs in LED matrix. Touch pads and LEDs can share pins to minimize the number of pins needed for such applications.

Analog to Digital Converter (VADC)

The Versatile Analog-to-Digital Converter module consists of an independent kernels which operate according to the successive approximation principle (SAR). The resolution is programmable from 8 to 12bit.

The kernel provides a versatile state machine allowing complex measurement sequences. The kernels can be synchronized and conversions may run completely in background. Multiple trigger events can be prioritized and allow the exact measurement of time critical signals. The result buffering and handling avoids data loss and ensures consistency. Self-test mechanisms can be used for plausibility checks.

The basic structure supports a clean software architecture where tasks may only read valid results and do not need to care for starting conversions.

Analog Comparator (ACMP) and Out of Range Comparator (ORC)

The Analog Comparator is used to compare the voltage of two analog inputs and a digital output indicating which input voltage is higher. One of the input can either be the internal reference voltage or from external pin. A low power mode is available to help to reduce the total power consumption.

A number of out-of-range on-chip comparators serve the purpose of over-voltage monitoring for analog input pins of the VADC.

Temperature Sensor (TSE)

The Temperature Sensor generates a measurement result that indicates directly the die temperature. It is also capable of generating interrupt requests when the temperature measurement crosses the selectable upper/lower threshold value.

Capture/Compare Unit 4 (CCU4)

The CCU4 peripheral is a major component for systems that need general purpose timers for signal monitoring/conditioning and Pulse Width Modulation (PWM) signal generation. Power electronic control systems like switched mode power supplies or uninterruptible power supplies can easily be implemented with the functions inside the CCU4 peripheral.

The internal modularity of CCU4 translates into a software friendly system for fast code development and portability between applications.

Brightness and Color Control Unit (BCCU)

The BCCU is a dimming control peripheral for LED lighting applications that is capable of controlling multiple LED channels. A one-bit sigma-delta bit stream is provided for every channel that determines the brightness. The brightness can be changed gradually along an exponential curve to appear natural to the human eye by using dedicated

dimming engines. The module supports color control by adjusting the relative intensity of selected channels using a linear walk scheme for smooth color changes, and it also supports high-power multi-channel LED lamps by optionally “packing” the bitstream to provide a defined ON-time at the output.

General Purpose I/O Ports (PORTS)

The Ports provide a generic and very flexible software and hardware interface for all standard digital I/Os. Each Port slice has individual interfaces for the operation as General Purpose I/O and it further provides the connectivity to the on-chip periphery and the control for the pad characteristics.

1.5 Debug Unit

The on-chip debug system based on the ARM Cortex-M0™ debug system provides a broad range of debug and emulation features built into the XMC1200. The user software running on the XMC1200 can thus be debugged within the target system environment.

The Debug unit is controlled by an external debugging tool via the debug interface. The debugger controls the Debug unit via a set of dedicated registers accessible via the debug interface. Additionally, the Debug unit can be controlled by the CPU, e.g. by a monitor program.

Multiple breakpoints can be triggered by on-chip hardware or by software. Single stepping is supported as well as the injection of arbitrary instructions and read/write access to the complete internal address space. A breakpoint trigger can be answered with a CPU-halt, a monitor call or a data transfer.

The data transferred at a watchpoint (see above) can be obtained via the debug interface for increased performance.

CPU Subsystem

2 Central Processing Unit (CPU)

XMC1200 features the ARM Cortex-M0 processor. An entry-level 32-bit ARM Cortex processor designed for a broad range of embedded applications. This CPU offers significant benefits to users, including:

- a simple architecture that is easy to learn and program
- ultra-low power, energy efficient operation
- excellent code density
- deterministic, high-performance interrupt handling
- upward compatibility with Cortex-M processor family

References to ARM Documentation

The following documents can be accessed through <http://infocenter.arm.com>

- [1] Cortex™-M0 Devices, Generic User Guide (ARM DUI 0467B)
- [2] ARMv6-M Architecture Reference Manual (ARM DDI 0419)
- [3] Cortex Microcontroller Software Interface Standard (CMSIS)

References to ARM Figures

- [4] <http://www.arm.com>

2.1 Overview

The Cortex-M0 processor is built on a highly area and power optimized 32-bit processor core, with a 3-stage pipeline von Neumann architecture. The processor delivers exceptional energy efficiency through a small but powerful instruction set and extensively optimized design, providing high-end processing hardware including a single-cycle multiplier.

The Cortex-M0 processor implements the ARMv6-M architecture, which is based on the 16-bit Thumb® instruction set and includes Thumb-2 technology. The Cortex-M0 instruction set provides exceptional performance expected of a modern 32-bit architecture, with a higher code density than other 8-bit and 16-bit microcontrollers.

The Cortex-M0 processor closely integrates a configurable NVIC, to deliver industry leading interrupt performance. The NVIC provides 4 interrupt priority levels. The tight integration of the processor core and NVIC provides fast execution of interrupt service routines (ISRs), dramatically reducing the interrupt latency. This is achieved through the hardware stacking of registers, and the ability to abandon and restart load-multiple and store-multiple operations. Interrupt handlers do not require any assembler wrapper code, removing any code overhead from the ISRs. Tail-chaining optimization also significantly reduces the overhead when switching from one ISR to another.

Central Processing Unit (CPU)

To optimize low-power designs, the NVIC integrates with the sleep modes, that include a deep sleep function that enables the entire device to be rapidly powered down.

2.1.1 Features

The CPU provides the following functionality:

- Thumb instruction set combines high code density with 32-bit performance
- integrated sleep modes for low power consumption
- fast code execution permits slower processor clock or increases sleep mode time
- single cycle 32-bit hardware multiplier
- high-performance interrupt handling for time-critical applications
- extensive debug capabilities:
 - Serial Wire Debug and Single Pin Debug reduce the number of pins required for debugging.

2.1.2 Block Diagram

The Cortex-M0 core components comprise of:

Processor Core

The CPU provides most 16-bit Thumb instruction set and subset of 32-bit Thumb2 instruction set.

Nested Vectored Interrupt Controller

The NVIC is an embedded interrupt controller that supports low latency interrupt processing.

Debug Solution

The XMC1200 implements a complete hardware debug solution.

- Single Pin Debug (SPD) or 2-pin Serial Wire Debug (SWD)
- Extensive hardware breakpoint and watchpoint options

This provides high system control and visibility of the processor and memory even in small package devices.

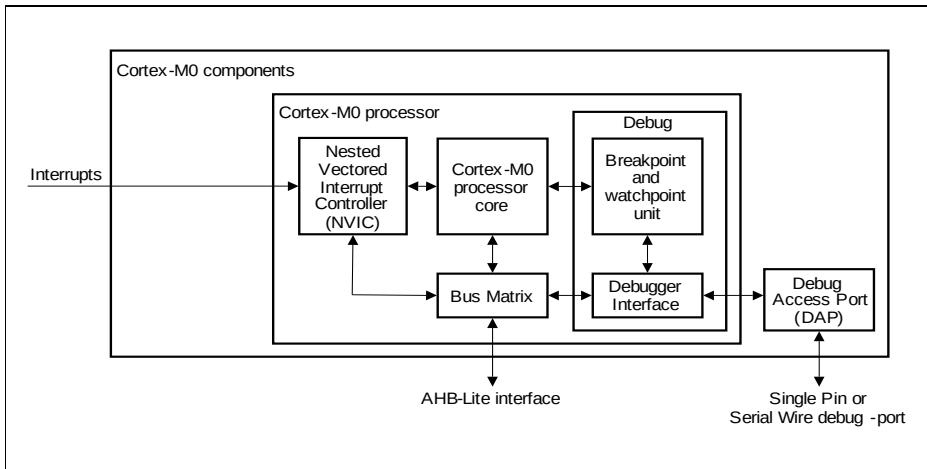


Figure 2-1 Cortex-M0 Block Diagram

System Level Interface

The Cortex-M0 processor provides a single system-level interface using AMBA® technology to provide high speed, low latency memory accesses.

2.2 Programmers Model

This section describes the Cortex-M0 programmers model. In addition to the individual core register descriptions, it contains information about the processor modes and stacks.

2.2.1 Processor Mode

The processor modes are:

- **Thread mode**
Used to execute application software. The processor enters Thread mode when it comes out of reset.
- **Handler mode**
Used to handle exceptions. The processor returns to Thread mode when it has finished all exception processing.

2.2.2 Stacks

The processor uses a full descending stack. This means the stack pointer holds the address of the last stacked item in memory. When the processor pushes a new item onto the stack, it decrements the stack pointer and then writes the item to the new memory

Central Processing Unit (CPU)

location. The processor implements two stacks, the main stack and the process stack, with a pointer for each held in independent registers, see [Stack Pointer](#).

In Thread mode, the CONTROL register controls whether the processor uses the main stack or the process stack, see [CONTROL Register](#). In Handler mode, the processor always uses the main stack. The options for processor operations are:

Table 2-1 Summary of processor mode, execution, and stack use options

Processor mode	Used to execute	Stack used
Thread	Applications	Main stack or process stack ¹⁾
Handler	Exception handlers	Main stack

1) See [CONTROL Register](#).

2.2.3 Core Registers

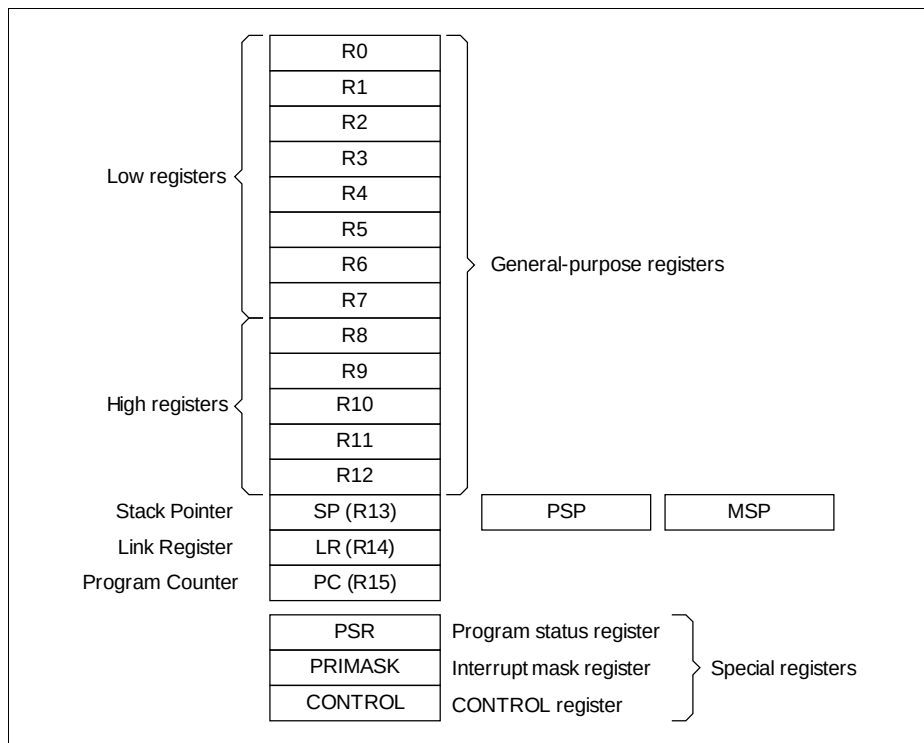


Figure 2-2 Core registers

The processor core registers are:

Table 2-2 Core register set summary

Name	Type ¹⁾	Reset value	Description
R0-R12	rw	Unknown	General-purpose registers on Page 2-6
MSP	rw	See description	Stack Pointer on Page 2-6
PSP	rw	Unknown	Stack Pointer on Page 2-6
LR	rw	Unknown	Link Register on Page 2-7
PC	rw	See description	Program Counter on Page 2-8
PSR	rw	Unknown	Program Status Register on Page 2-8

Central Processing Unit (CPU)

Table 2-2 Core register set summary (cont'd)

Name	Type ¹⁾	Reset value	Description
APSR	rw	Unknown	Application Program Status Register on Page 2-9
IPSR	r	00000000 _H	Interrupt Program Status Register on Page 2-10
EPSR	r	Unknown	Execution Program Status Register on Page 2-12
PRIMASK	rw	00000000 _H	Priority Mask Register on Page 2-13
CONTROL	rw	00000000 _H	CONTROL Register on Page 2-14

1) Describes access type during program execution in thread mode and handler mode. Debug access can differ.

General-purpose registers

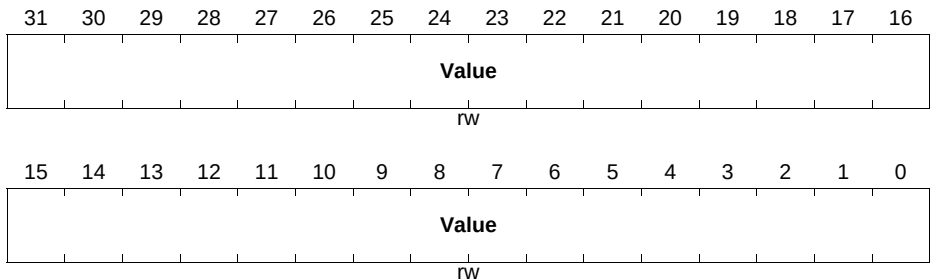
R0-R12 are 32-bit general-purpose registers for data operations.

Note: For information on how to program the core registers, please refer to the ARMv6-M Architecture Reference Manual [2].

Rx (x=0-12)

General-purpose register Rx

Reset Value: XXXXXXXX_H



Field	Bits	Type	Description
Value	[31:0]	rw	Content of Register

Stack Pointer

The Stack Pointer (SP) is register R13. In Thread mode, bit[1] of the CONTROL register indicates the stack pointer to use:

- 0 = Main Stack Pointer (MSP). This is the reset value.

Central Processing Unit (CPU)

- 1 = Process Stack Pointer (PSP).

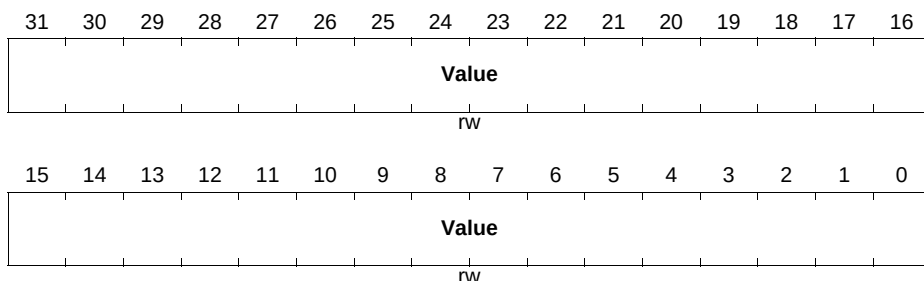
On reset, the processor loads the MSP with the value from address 00000000_H.

Note: For information on how to program the core registers, please refer to the ARMv6-M Architecture Reference Manual [2].

SP

Stack Pointer

Reset Value: 00000000_H



Field	Bits	Type	Description
Value	[31:0]	rw	Content of Register

Link Register

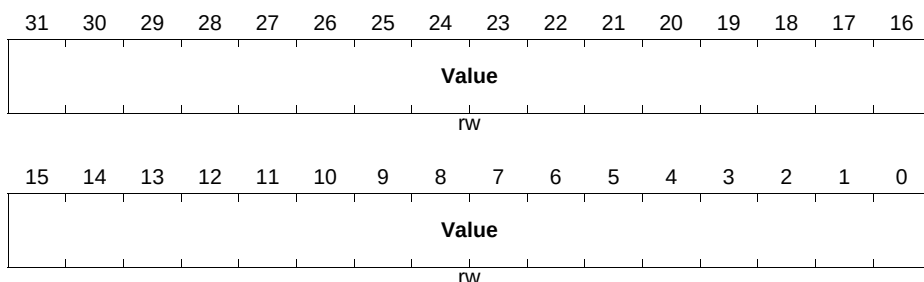
The Link Register (LR) is register R14. It stores the return information for subroutines, function calls, and exceptions. On reset, the LR value is unknown.

Note: For information on how to program the core registers, please refer to the ARMv6-M Architecture Reference Manual [2].

LR

Link Register

Reset Value: XXXXXXXX_H



Field	Bits	Type	Description
Value	[31:0]	rw	Content of Register

Program Counter

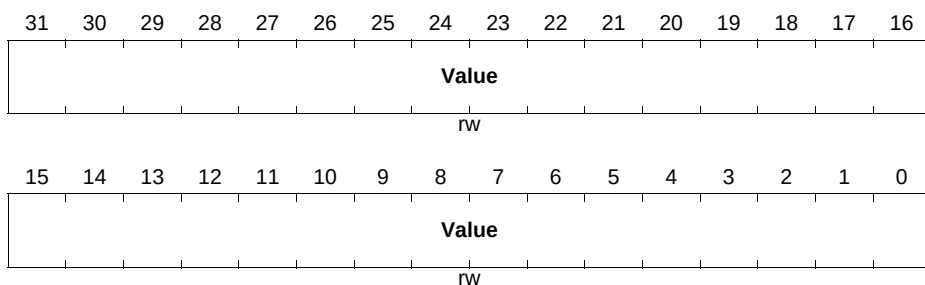
The Program Counter (PC) is register R15. It contains the current program address. On reset, the processor loads the PC with the value of the reset vector, which is at address 00000004_H. Bit [0] of the value is loaded into the EPSR T-bit at reset and must be 1.

Note: For information on how to program the core registers, please refer to the ARMv6-M Architecture Reference Manual [2].

PC

Program Counter

Reset Value: 00000004_H



Field	Bits	Type	Description
Value	[31:0]	rw	Content of Register

Program Status Register

The Program Status Register (PSR) combines:

- Application Program Status Register (APSR)
- Interrupt Program Status Register (IPSR)
- Execution Program Status Register (EPSR)

These registers are mutually exclusive bit fields in the 32-bit PSR.

Access these registers individually or as a combination of any two or all three registers, using the register name as an argument to the MSR or MRS instructions. For example:

- read all of the registers using PSR with the MRS instruction
- write to the APSR N, Z, C, and V bits using APSR with the MSR instruction

The PSR combinations and attributes are:

Table 2-3 PSR register combinations

Register	Type	Combination
PSR	rw ¹⁾²⁾	APSR, EPSR, and IPSR
IEPSR	r	EPSR and IPSR
IAPSR	rw ¹⁾	APSR and IPSR
EAPSR	rw ²⁾	APSR and EPSR

1) The processor ignores writes to the IPSR bits.

2) Reads of the EPSR bits return zero, and the processor ignores writes to the these bits

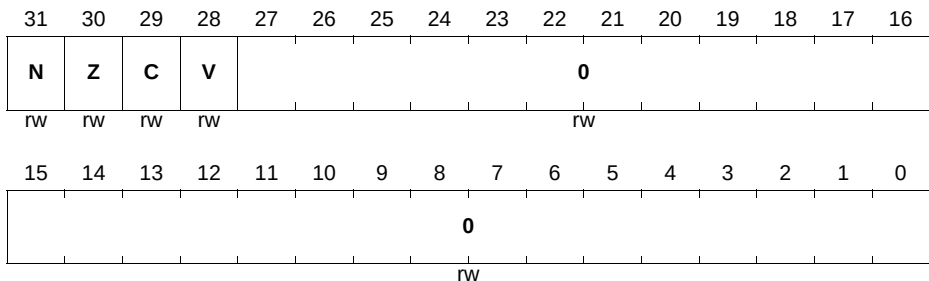
Application Program Status Register

The APSR contains the current state of the condition flags from previous instruction executions. See the register summary in [Table 2-2](#) for its attributes.

APSR

Application Program Status Register

Reset Value: XXXXXXXX_H



Field	Bits	Type	Description
N	31	rw	Negative flag
Z	30	rw	Zero flag
C	29	rw	Carry or borrow flag
V	28	rw	Overflow flag
0	[27:0]	r	Reserved

Central Processing Unit (CPU)

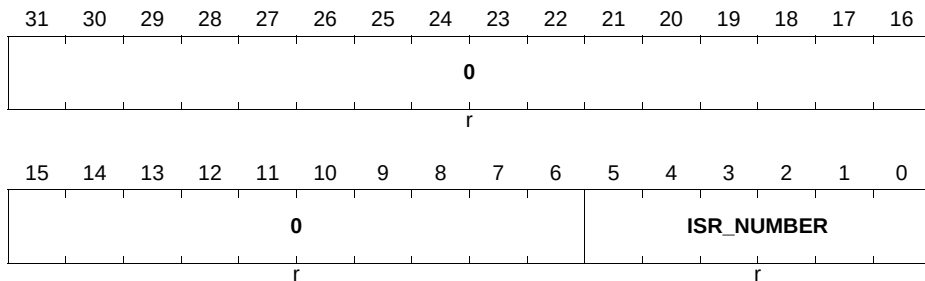
Interrupt Program Status Register

The IPSR contains the exception type number of the current Interrupt Service Routine (ISR). See the register summary in [Table 2-2](#) for its attributes.

IPSR

Interrupt Program Status Register

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[31:6]	r	Reserved

Central Processing Unit (CPU)

Field	Bits	Type	Description
ISR_NUMBER	[5:0]	r	Number of the current exception 0 _D Thread mode 1 _D Reserved 2 _D Reserved 3 _D HardFault 4 _D Reserved 5 _D Reserved 6 _D Reserved 7 _D Reserved 8 _D Reserved 9 _D Reserved 10 _D Reserved 11 _D SVCall 12 _D Reserved 13 _D Reserved 14 _D PendSV 15 _D SysTick 16 _D IRQ0 ... 47 _D IRQ31 48 _D -63 _D Reserved See Exception types in Section 2.5.2 for more information.

Execution Program Status Register

The EPSR contains the Thumb state bit.

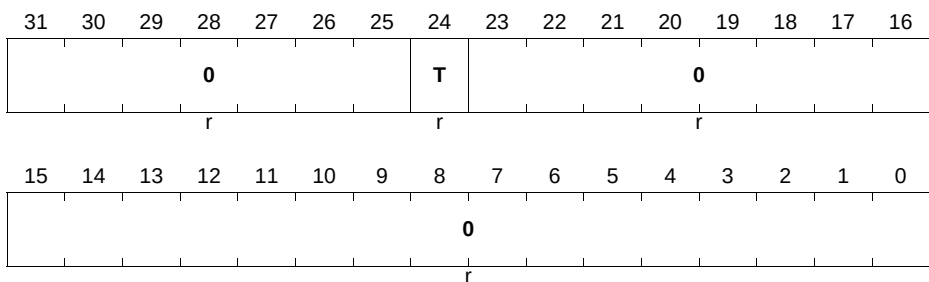
See the register summary in [Table 2-2](#) for the EPSR attributes.

Attempts to read the EPSR directly through application software using the MSR instruction always return zero. Attempts to write the EPSR using the MSR instruction in application software are ignored. Fault handlers can examine the EPSR value in the stacked PSR to determine the cause of the fault. See Exception Entry and Return in [Section 2.5.6](#).

EPSR

Execution Program Status Register

Reset Value: XXXXXXXX_H



Field	Bits	Type	Description
0	[31:25]	r	Reserved
T	24	r	Thumb state bit See Thumb state.
0	[23:0]	r	Reserved

Interruptible-restartable instructions

When an interrupt occurs during the execution of an LDM, STM, PUSH, POP instruction, the processor abandons execution of the instruction.

After servicing the interrupt, the processor restarts execution of the instruction from the beginning.

Thumb state

The Cortex-M0 processor only supports execution of instructions in Thumb state. The following can clear the T bit to 0:

- instructions BLX, BX and POP{PC}

Central Processing Unit (CPU)

- restoration from the stacked xPSR value on an exception return
- bit[0] of the vector value on an exception entry.

Attempting to execute instructions when the T bit is 0 results in a HardFault or lockup. See Lockup in [Section 2.6.1](#) for more information.

Exception mask registers

The exception mask registers disable the handling of exceptions by the processor. Disable exceptions where they might impact on timing critical tasks or code sequences requiring atomicity.

Exceptions can be disabled or re-enabled by the MSR and MRS instructions, or the CPS instruction, to change the value of PRIMASK or FAULTMASK.

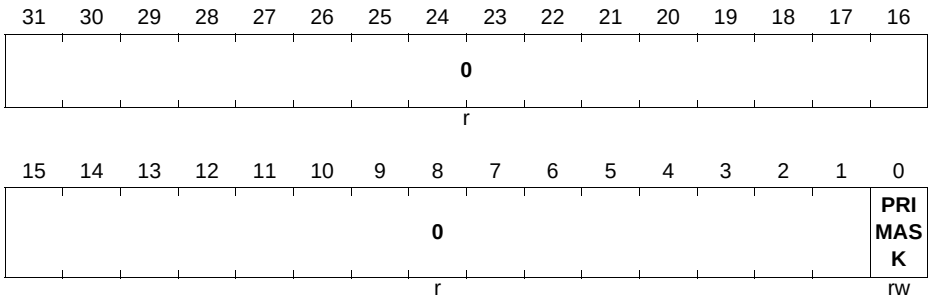
Priority Mask Register

The PRIMASK register prevents activation of all exceptions with configurable priority. See the register summary in [Table 2-2](#) for its attributes.

PRIMASK

Priority Mask Register

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[31:1]	r	Reserved
PRIMASK	0	rw	Priority Mask 0 _B No effect. 1 _B Prevents the activation of all exceptions with configurable priority.

Central Processing Unit (CPU)

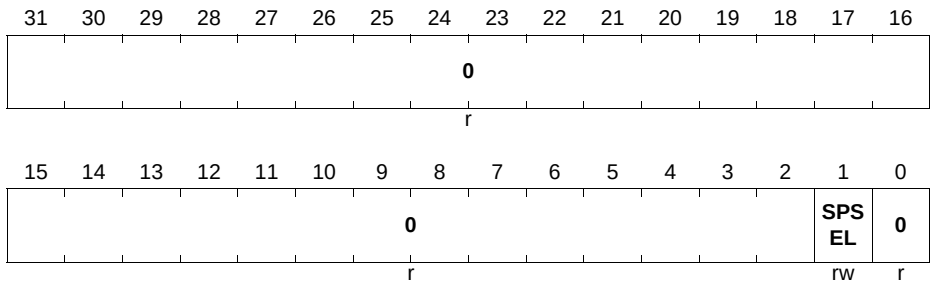
CONTROL Register

The CONTROL register controls the stack used when the processor is in Thread mode. See the register summary in [Table 2-2](#) for its attributes.

CONTROL

CONTROL Register

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[31:2]	r	Reserved
SPSEL	1	rw	Active stack pointer This bit defines the current stack. In Handler mode, this bit reads as zero and ignores writes. 0 _B MSP is the current stack pointer 1 _B PSP is the current stack pointer
0	0	r	Reserved

Handler mode always uses the MSP, so the processor ignores explicit writes to the active stack pointer bit of the CONTROL register when in Handler mode. The exception entry and return mechanisms automatically update the CONTROL register.

In an OS environment, it is recommended that threads running in Thread mode use the process stack and the kernel and exception handlers use the main stack.

By default, Thread mode uses the MSP. To switch the stack pointer used in Thread mode to the PSP, use the MSR instruction to set the Active stack pointer bit to 1.

Note: When changing the stack pointer, software must use an ISB instruction immediately after the MSR instruction. This ensures that instructions after the ISB instruction execute using the new stack pointer.

2.2.4 Exceptions and Interrupts

The Cortex-M0 processor supports interrupts and system exceptions. The processor and the NVIC prioritize and handle all exceptions. An interrupt or exception changes the normal flow of software control. The processor uses handler mode to handle all exceptions except for reset. See Exception entry on [Section 2.5.6.1](#) and Exception return on [Section 2.5.6.2](#) for more information.

The NVIC registers control interrupt handling. See Interrupt System chapter for more information.

2.2.5 Data Types

The processor:

- supports the following data types:
 - 32-bit words
 - 16-bit halfwords
 - 8-bit bytes
- manages all data memory accesses as little-endian. See Memory regions, types and attributes in [Section 2.3.1](#) for more information.

2.2.6 The Cortex Microcontroller Software Interface Standard

For a Cortex-M0 microcontroller system, the Cortex Microcontroller Software Interface Standard (CMSIS) [\[3\]](#) defines:

- a common way to:
 - access peripheral registers
 - define exception vectors
- the names of:
 - the registers of the core peripherals
 - the core exception vectors
- a device-independent interface for RTOS kernels.

The CMSIS includes address definitions and data structures for the core peripherals in the Cortex-M0 processor.

CMSIS simplifies software development by enabling the reuse of template code and the combination of CMSIS-compliant software components from various middleware vendors. Software vendors can expand the CMSIS to include their peripheral definitions and access functions for those peripherals.

This document includes the register names defined by the CMSIS, and gives short descriptions of the CMSIS functions that address the processor core and the core peripherals.

Note: This document uses the register short names defined by the CMSIS. In a few cases these differ from the architectural short names that might be used in other documents.

The following sections give more information about the CMSIS:

- Power Management Programming Hints in [Section 2.7.3](#)
- CMSIS Functions in [Section 2.2.7](#)
- Accessing CPU Registers using CMSIS in Interrupt System chapter
- NVIC programming hints in Interrupt System chapter

For additional information please refer to <http://www.onarm.com/cmsis>

2.2.7 CMSIS Functions

ISO/IEC C code cannot directly access some Cortex-M0 instructions. This section describes intrinsic functions that can generate these instructions, provided by the CMSIS and that might be provided by a C compiler. If a C compiler does not support an appropriate intrinsic function, an inline assembler may be used to access the relevant instruction.

The CMSIS provides the following intrinsic functions to generate instructions that ISO/IEC C code cannot directly access:

Table 2-4 CMSIS functions to generate some Cortex-M0 instructions

Instruction	CMSIS intrinsic function
CPSIE i	void __enable_irq (void)
CPSID i	void __disable_irq (void)
ISB	void __ISB (void)
DSB	void __DSB (void)
DMB	void __DMB (void)
NOP	void __NOP (void)
REV	uint32_t __REV (uint32_t int value)
REV16	uint32_t __REV16 (uint32_t int value)
REVSH	uint32_t __REVSH (uint32_t int value)
WFE	void __WFE (void)
WFI	void __WFI (void)

The CMSIS also provides a number of functions for accessing the special registers using MRS and MSR instructions:

Table 2-5 CMSIS functions to access the special registers

Special register	Access	CMSIS function
PRIMASK	Read	uint32_t __get_PRIMASK (void)
	Write	void __set_PRIMASK (uint32_t value)
CONTROL	Read	uint32_t __get_CONTROL (void)
	Write	void __set_CONTROL (uint32_t value)
MSP	Read	uint32_t __get_MSP (void)
	Write	void __set_MSP (uint32_t TopOfMainStack)
PSP	Read	uint32_t __get_PSP (void)
	Write	void __set_PSP (uint32_t TopOfMainStack)

Central Processing Unit (CPU)

2.3 Memory Model

This section describes the processor memory map and the behavior of memory accesses. The processor has a fixed default memory map that provides up to 4GB of addressable memory. The memory map is:

Device	511MB	0xFFFFFFFF
Private peripheral bus	1.0MB	0xE0100000 0xE00FFFFF
External device	1.0GB	0xE0000000 0xDFFFFFFF
External RAM	1.0GB	0xA0000000 0x9FFFFFFF
Peripheral	0.5GB	0x60000000 0x5FFFFFFF
SRAM	0.5GB	0x40000000 0x3FFFFFFF
Code	0.5GB	0x20000000 0x1FFFFFFF
		0x00000000

Figure 2-3 Memory map

Central Processing Unit (CPU)

The processor reserves regions of the Private peripheral bus (PPB) address range for core peripheral registers, see About the Private Peripherals in [Section 2.8.1](#).

2.3.1 Memory Regions, Types and Attributes

The memory map is split into regions. Each region has a defined memory type, and some regions have additional memory attributes. The memory type and attributes determine the behavior of accesses to the region.

The memory types are:

Normal	The processor can re-order transactions for efficiency, or perform speculative reads.
Device	The processor preserves transaction order relative to other transactions to Device or Strongly-ordered memory.
Strongly-ordered	The processor preserves transaction order relative to all other transactions.

The different ordering requirements for Device and Strongly-ordered memory mean that the memory system can buffer a write to Device memory, but must not buffer a write to Strongly-ordered memory.

The additional memory attributes include:

Execute Never (XN)	Means the processor prevents instruction accesses. A HardFault exception is generated on execution of an instruction fetched from an XN region of memory.

2.3.2 Memory System Ordering of Memory Accesses

For most memory accesses caused by explicit memory access instructions, the memory system does not guarantee that the order in which the accesses complete matches the program order of the instructions, providing any re-ordering does not affect the behavior of the instruction sequence. Normally, if correct program execution depends on two memory accesses completing in program order, software must insert a memory barrier instruction between the memory access instructions, see Software ordering of memory accesses in [Section 2.3.4](#).

However, the memory system does guarantee some ordering of accesses to Device and Strongly-ordered memory. For two memory access instructions A1 and A2, if A1 occurs before A2 in program order, the ordering of the memory accesses caused by two instructions is described in [Figure 2-4](#).

A1 \ A2	Normal access	Device access	Strongly-ordered access
Normal access	-	-	-
Device access	-	<	<
Strongly-ordered access	-	<	<

Figure 2-4 Memory system ordering

Where:

- “-” Means that the memory system does not guarantee the ordering of the accesses.
- “<” Means that accesses are observed in program order, that is, A1 is always observed before A2.

2.3.3 Behavior of Memory Accesses

The behavior of accesses to each region in the memory map is:

Table 2-6 Memory access behavior

Address range	Memory region	Memory type ¹⁾	XN ¹⁾	Description
0x00000000-0x1FFFFFFF	Code	Normal	-	Executable region for program code. Data can be placed here.
0x20000000-0x3FFFFFFF	SRAM	Normal	-	Executable region for data. Code can be placed here.
0x40000000-0x5FFFFFFF	Peripheral	Device	XN	Peripherals region.
0x60000000-0x9FFFFFFF	External RAM	Normal	-	Executable region for data.
0xA0000000-0xDFFFFFFF	External device	Device	XN	External device memory.

Table 2-6 Memory access behavior (cont'd)

Address range	Memory region	Memory type ¹⁾	XN ¹⁾	Description
0xE0000000-0xE00FFFFF	Private Peripheral Bus	Strongly-ordered	XN	This region includes the NVIC, system timer, and system control block. Only word accesses can be used in this region.
0xE0100000-0xFFFFFFFF	Device	Device	XN	Vendor specific

1) See Memory regions, types and attributes in [Section 2.3.1](#) for more information.

The Code, SRAM, and external RAM regions can hold programs.

2.3.4 Software Ordering of Memory Accesses

The order of instructions in the program flow does not always guarantee the order of the corresponding memory transactions. This is because:

- the processor can reorder some memory accesses to improve efficiency, providing this does not affect the behavior of the instruction sequence.
- memory or devices in the memory map have different wait states
- some memory accesses are buffered or speculative.

Memory system ordering of memory accesses in [Section 2.3.2](#) describes the cases where the memory system guarantees the order of memory accesses. Otherwise, if the order of memory accesses is critical, software must include memory barrier instructions to force that ordering. The processor provides the following memory barrier instructions:

DMB	The Data Memory Barrier (DMB) instruction ensures that outstanding memory transactions complete before subsequent memory transactions.
DSB	The Data Synchronization Barrier (DSB) instruction ensures that outstanding memory transactions complete before subsequent instructions execute.
ISB	The Instruction Synchronization Barrier (ISB) ensures that the effect of all completed memory transactions is recognizable by subsequent instructions.

2.3.5 Memory Endianness

The processor views memory as a linear collection of bytes numbered in ascending order from zero. For example, bytes 0-3 hold the first stored word, and bytes 4-7 hold the second stored word. [Section 2.3.5.1](#) describes how words of data are stored in memory.

2.3.5.1 Little-endian format

In little-endian format, the processor stores the least significant byte (lsbyte) of a word at the lowest-numbered byte, and the most significant byte (msbyte) at the highest-numbered byte. An example of the little-endian format is described in [Figure 2-5](#).

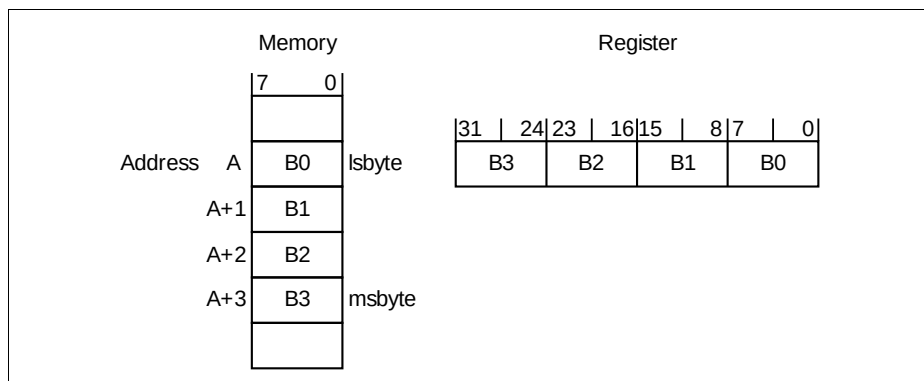


Figure 2-5 Little-endian format (Example)

2.4 Instruction Set

Table 2-7 lists the supported Cortex-M0 instructions. For more information on the instructions and operands, please refer to the Cortex™-M0 Devices, Generic User Guide available through [\[1\]](#).

Table 2-7 Cortex-M0 instructions

Mnemonic	Operands	Brief description	Flags
ADCS	{Rd,} Rn, Rm	Add with carry	N,Z,C,V
ADD{S}	{Rd,} Rn, <Rm #imm>	Add	N,Z,C,V
ADR	Rd, label	PC-relative Address to Register	-
ANDS	{Rd,} Rn, Rm	Bitwise AND	N,Z
ASRS	{Rd,} Rm, <Rs #imm>	Arithmetic Shift Right	N,Z,C
B{cc}	label	Branch {conditionally}	-
BICS	{Rd,} Rn, Rm	Bit Clear	N,Z
BKPT	#imm	Breakpoint	-
BL	label	Branch with Link	-
BLX	Rm	Branch indirect with Link	-
BX	Rm	Branch indirect	-
CMN	Rn, Rm	Compare Negative	N,Z,C,V
CMP	Rn, <Rm #imm>	Compare	N,Z,C,V
CPSID	i	Change Processor State, Disable Interrupts	-
CPSIE	i	Change Processor State, Enable Interrupts	-
DMB	-	Data Memory Barrier	-
DSB	-	Data Synchronization Barrier	-
EORS	{Rd,} Rn, Rm	Exclusive OR	N,Z
ISB	-	Instruction Synchronization Barrier	-
LDM	Rn{!}, regist	Load Multiple registers, increment after	-

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Table 2-7 Cortex-M0 instructions (cont'd)

Mnemonic	Operands	Brief description	Flags
LDR	Rt, label	Load Register from PC-relative address	-
LDR	Rt, [Rn, <Rm #imm>]	Load Register with word	-
LDRB	Rt, [Rn, <Rm #imm>]	Load Register with byte	-
LDRH	Rt, [Rn, <Rm #imm>]	Load Register with halfword	-
LDRSB	Rt, [Rn, <Rm #imm>]	Load Register with signed byte	-
LDRSH	Rt, [Rn, <Rm #imm>]	Load Register with signed halfword	-
LSLS	{Rd,} Rn, <Rs #imm>	Logical Shift Left	N,Z,C
LSRS	{Rd,} Rn, <Rs #imm>	Logical Shift Right	N,Z,C
MOV{S}	Rd, Rm	Move	N,Z
MRS	Rd, spec_reg	Move to general register from special register	-
MSR	spec_reg, Rm	Move to special register from general register	N,Z,C,V
MULS	Rd, Rn, Rm	Multiply, 32-bit result	N,Z
MVNS	Rd, Rm	Bitwise NOT	N,Z
NOP	-	No Operation	-
ORRS	{Rd,} Rn, Rm	Logical OR	N,Z
POP	reglist	Pop registers from stack	-
PUSH	reglist	Push registers onto stack	-
REV	Rd, Rm	Byte-Reverse word	-
REV16	Rd, Rm	Byte-Reverse packed halfwords	-
REVSH	Rd, Rm	Byte-Reverse signed halfword	-
RORS	{Rd,} Rn, Rs	Rotate Right	N,Z,C
RSBS	{Rd,} Rn, #0	Reverse Subtract	N,Z,C,V

Table 2-7 Cortex-M0 instructions (cont'd)

Mnemonic	Operands	Brief description	Flags
SBCS	{Rd,} Rn, Rm	Subtract with Carry	N,Z,C,V
STM	Rn!, reglist	Store Multiple registers, increment after	-
STR	Rt, [Rn, <Rm #imm>]	Store Register as word	-
STRB	Rt, [Rn, <Rm #imm>]	Store Register as byte	-
STRH	Rt, [Rn, <Rm #imm>]	Store Register as halfword	-
SUB{S}	{Rd,} Rn, <Rm #imm>	Subtract	N,Z,C,V
SVC	#imm	Supervisor Call	-
SXTB	Rd, Rm	Sign extend byte	-
SXTH	Rd, Rm	Sign extend halfword	-
TST	Rn, Rm	Logical AND based test	N,Z
UXTB	Rd, Rm	Zero extend a byte	-
UXTH	Rd, Rm	Zero extend a halfword	-
WFE	-	Wait for Event	-
WFI	-	Wait for Interrupt	-

2.4.1 Intrinsic Functions

ISO/IEC C code cannot directly access some Cortex-M0 instructions. The intrinsic functions that can generate these instructions, provided by the CMSIS and might be provided by a C compiler are described in [Section 2.2.7](#).

2.5 Exception Model

This section describes the exception model. It describes:

- Exception states ([Section 2.5.1](#))
- Exception types ([Section 2.5.2](#))
- Exception handlers ([Section 2.5.3](#))
- Vector table ([Section 2.5.4](#))
- Exception priorities ([Section 2.5.5](#))
- Exception entry and return ([Section 2.5.6](#))

2.5.1 Exception States

Each exception is in one of the following states:

Inactive	The exception is not active and not pending.
Pending	The exception is waiting to be serviced by the processor. An interrupt request from a peripheral or from software can change the state of the corresponding interrupt to pending.
Active	An exception that is being serviced by the processor but has not completed. <i>Note: An exception handler can interrupt the execution of another exception handler. In this case both exceptions are in the active state.</i>
Active and pending	The exception is being serviced by the processor and there is a pending exception from the same source.

2.5.2 Exception Types

The exception types are described in [Table 2-8](#).

Table 2-8 Exception types

Exception Types	Descriptions
Reset	Reset is invoked on power up or a warm reset. The exception model treats reset as a special form of exception. When reset is asserted, the operation of the processor stops, potentially at any point in an instruction. When reset is deasserted, execution restarts from the address provided by the reset entry in the vector table. Execution restarts in Thread mode.
HardFault	A HardFault is an exception that occurs because of an error during normal or exception processing. HardFaults have a fixed priority of -1, meaning they have higher priority than any exception with configurable priority.
SVCall	A supervisor call (SVC) is an exception that is triggered by the SVC instruction. In an OS environment, applications can use SVC instructions to access OS kernel functions and device drivers.
PendSV	PendSV is an interrupt-driven request for system-level service. In an OS environment, use PendSV for context switching when no other exception is active.
SysTick	A SysTick exception is an exception the system timer generates when it reaches zero. Software can also generate a SysTick exception. In an OS environment, the processor can use this exception as system tick.
Interrupt (IRQ)	A interrupt, or IRQ, is an exception signalled by a peripheral, or generated by a software request. All interrupts are asynchronous to instruction execution. In the system, peripherals use interrupts to communicate with the processor.

Table 2-9 Properties of the different exception types

Exception number ¹⁾	IRQ number ¹⁾	Exception type	Priority	Vector address or offset ²⁾	Activation
1	-	Reset	-3, the highest	0x00000004	Asynchronous
2	-	Reserved	-	-	-
3	-13	HardFault	-1	0x0000000C	Synchronous

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Table 2-9 Properties of the different exception types (cont'd)

Exception number ¹⁾	IRQ number ¹⁾	Exception type	Priority	Vector address or offset ²⁾	Activation
4-10	-	Reserved	-	-	-
11	-5	SVCALL	Configurable ³⁾	0x0000002C	Synchronous
12-13	-	Reserved	-	-	-
14	-2	PendSV	Configurable ³⁾	0x00000038	Asynchronous
15	-1	SysTick	Configurable ³⁾	0x0000003C	Asynchronous
16 and above	0 and above	Interrupt (IRQ)	Configurable ³⁾	0x00000040 and above ⁴⁾	Asynchronous

1) To simplify the software layer, the CMSIS only uses IRQ numbers and therefore uses negative values for exceptions other than interrupts. The IPSR returns the Exception number, see [Interrupt Program Status Register](#).

2) See Vector table in [Section 2.5.4](#) for more information.

3) See Interrupt Priority Registers in Interrupt System chapter.

4) Increasing in steps of 4.

For an asynchronous exception, other than reset, the processor can execute additional instructions between when the exception is triggered and when the processor enters the exception handler.

Software can disable the exceptions in [Table 2-9](#) which have configurable priority, see Interrupt Clear-enable Register in Interrupt System chapter.

For more information about HardFaults, see Fault handling in [Section 2.6](#).

2.5.3 Exception Handlers

The processor handles exceptions using:

Interrupt Service Routines (ISRs) Interrupts IRQ0 to IRQ31 are the exceptions handled by ISRs.

Fault handlers HardFault is the only exception handled by the fault handler.

System handlers PendSV, SVCALL, SysTick, and the HardFault are all system exceptions that are handled by system handlers.

2.5.4 Vector Table

The vector table contains the reset value of the stack pointer, and the start addresses, also called exception vectors, for all exception handlers. [Figure 2-6](#) shows the order of

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the exception vectors in the vector table. The least-significant bit of each vector must be 1, indicating that the exception handler is written in Thumb code.

Exception number	IRQ number	Offset	Vector
47	31	0x00BC	IRQ31
.	.	.	.
.	.	.	.
.	.	.	.
18	2	0x0048	IRQ2
17	1	0x0044	IRQ1
16	0	0x0040	IRQ0
15	-1	0x003C	Systick
14	-2	0x0038	PendSV
13			Reserved
12			
11	-5	0x002C	SVCall
10			
9			
8			
7			Reserved
6			
5			
4			
3	-13	0x0010	Hard fault
2		0x000C	Reserved
1			Reset
		0x0004	Initial SP value
		0x0000	

Figure 2-6 Vector table

The vector table is fixed at address 0x00000000.

2.5.4.1 Vector Table Remap

In XMC1200, the vector table is located inside the ROM. Therefore, the vector table is remapped to the SRAM based on the mapping shown in [Table 2-10](#). The user application uses these locations as entry points for the actual exception and interrupt handlers. This is done by placing the code for these handlers or having the branch instruction to the handlers there.

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For example, upon an exception entry due to IRQ0, the processor reads the intermediate handler start address 2000'0040_H (fixed in ROM) from the vector table and starts execution from there. If the actual handler is located in another address location due to size constraints, the address 2000'0040_H should trigger a load and a branch instruction to jump to this new location.

Note: The user application needs to reserve the SRAM addresses 2000'000C_H - 2000'00BF_H for the remapped vector table if all vectors are used.

Table 2-10 Remapped Vector Table

Exception Number	IRQ Number	Vector	Default Vector Address	Remapped Vector Address
-	-	Initial SP Value	0000'0000 _H	1000'1000 _H
1	-	Reset	0000'0004 _H	1000'1004 _H ¹⁾
3	-13	HardFault	0000'000C _H	2000'000C _H
11	-5	SVCall	0000'002C _H	2000'002C _H
14	-2	PendSV	0000'0038 _H	2000'0038 _H
15	-1	SysTick	0000'003C _H	2000'003C _H
16-47	0-31	IRQn (n=0-31)	0000'0040 _H + (n*4)	2000'0040 _H + (n*4)

1) The remapped reset vector address refers to the location (start of the Flash memory) that the startup software jumps to upon exiting the startup sequence in user mode.

2.5.5 Exception Priorities

Table 2-9 shows that all exceptions have an associated priority, with:

- a lower priority value indicating a higher priority
- configurable priorities for all exceptions except Reset and HardFault.

If software does not configure any priorities, then all exceptions with a configurable priority have a priority of 0. For information about configuring exception priorities see

- System Handler Priority Registers [SHPR2](#), [SHPR3](#).
- Interrupt Priority Registers in Interrupt System chapter.

Note: Configurable priority values are in the range 0-192, in steps of 64. This means that the Reset and HardFault exceptions, with fixed negative priority values, always have higher priority than any other exception.

For example, assigning a higher priority value to IRQ[0] and a lower priority value to IRQ[1] means that IRQ[1] has higher priority than IRQ[0]. If both IRQ[1] and IRQ[0] are asserted, IRQ[1] is processed before IRQ[0].

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If multiple pending exceptions have the same priority, the pending exception with the lowest exception number takes precedence. For example, if both IRQ[0] and IRQ[1] are pending and have the same priority, then IRQ[0] is processed before IRQ[1].

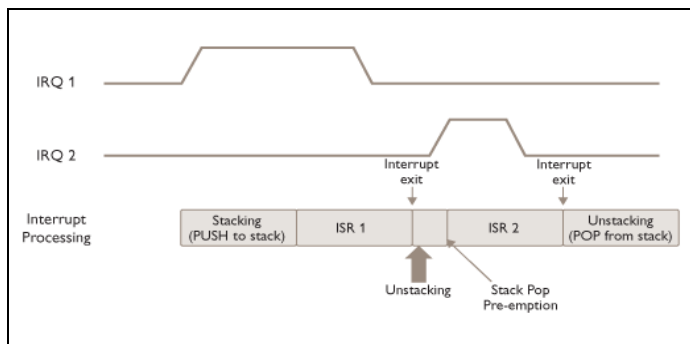
When the processor is executing an exception handler, the exception handler is preempted if a higher priority exception occurs. If an exception occurs with the same priority as the exception being handled, the handler is not preempted, irrespective of the exception number. However, the status of the new interrupt changes to pending.

2.5.6 Exception Entry and Return

Exception handling can be described using the following terms:

Preemption

When the processor is executing an exception handler, an exception can preempt the exception handler if its priority is higher than the priority of the exception being handled. When one exception preempts another, the exceptions are called nested exceptions. See Exception entry in [Section 2.5.6.1](#) for more information.



Source of figure [\[4\]](#).

Return

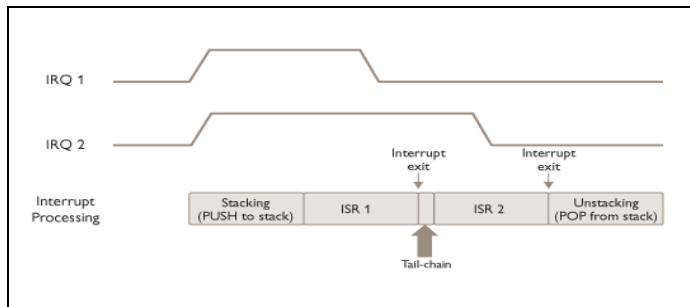
This occurs when the exception handler is completed, and:

- there is no pending exception with sufficient priority to be serviced
- the completed exception handler was not handling a late-arriving exception.

The processor pops the stack and restores the processor state to the state it had before the interrupt occurred. See Exception return in [Section 2.5.6.2](#) for more information.

Tail-chaining

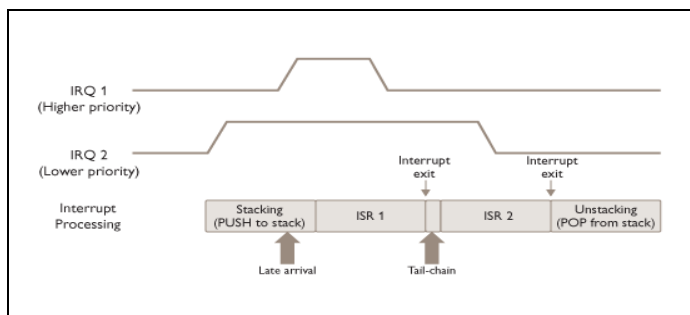
This mechanism speeds up exception servicing. On completion of an exception handler, if there is a pending exception that meets the requirements for exception entry, the stack pop is skipped and control transfers to the new exception handler.



Source of figure [4].

Late-arriving

This mechanism speeds up preemption. If a higher priority exception occurs during state saving for a previous exception, the processor switches to handle the higher priority exception and initiates the vector fetch for that exception. State saving is not affected by late arrival because the state saved is the same for both exceptions. On return from the exception handler of the late-arriving exception, the normal tail-chaining rules apply.



Source of figure [4].

2.5.6.1 Exception entry

Exception entry occurs when there is a pending exception with sufficient priority and either:

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- the processor is in Thread mode
- the new exception is of higher priority than the exception being handled, in which case the new exception preempts the original exception.

When one exception preempts another, the exceptions are nested.

Sufficient priority means the exception has greater priority than any limits set by the mask register, see [Exception mask registers](#). An exception with less priority than this is pending but is not handled by the processor.

When the processor takes an exception, unless the exception is a tail-chained or a late-arriving exception, the processor pushes information onto the current stack. This operation is referred to as stacking and the structure of eight data words is referred to as a stack frame. The stack frame contains the following information, as illustrated in [Figure 2-7](#).

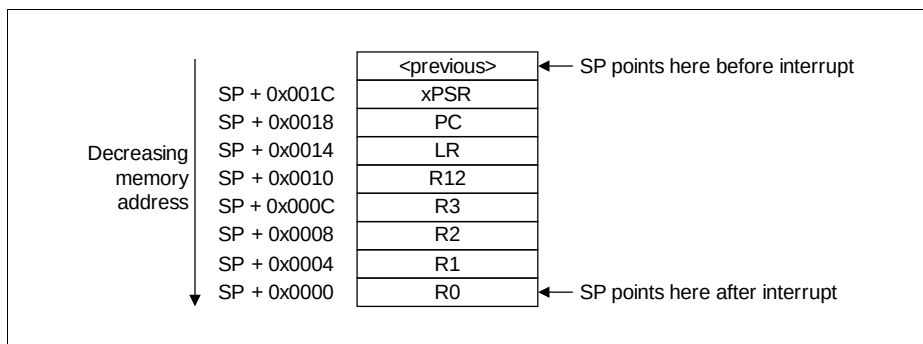


Figure 2-7 Exception stack frame

Immediately after stacking, the stack pointer indicates the lowest address in the stack frame. The stack frame is aligned to a double-word address.

The stack frame includes the return address. This is the address of the next instruction in the interrupted program. This value is restored to the PC at exception return so that the interrupted program resumes.

The processor performs a vector fetch that reads the exception handler start address from the vector table. When stacking is complete, the processor starts executing the exception handler. At the same time, the processor writes an EXC_RETURN value to the LR. This indicates which stack pointer corresponds to the stack frame and what operation mode the processor was in before the entry occurred.

If no higher priority exception occurs during exception entry, the processor starts executing the exception handler and automatically changes the status of the corresponding pending interrupt to active.

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If another higher priority exception occurs during exception entry, the processor starts executing the exception handler for this exception and does not change the pending status of the earlier exception. This is the late arrival case.

2.5.6.2 Exception return

Exception return occurs when the processor is in Handler mode and execution of one of the following instructions attempts to set the PC to an EXC_RETURN value:

- a POP instruction that loads the PC
- a BX instruction using any register.

The processor saves an EXC_RETURN value to the LR on exception entry. The exception mechanism relies on this value to detect when the processor has completed an exception handler. Bits [31:4] of an EXC_RETURN value are set to 1. When this value is loaded into the PC, the processor detects that the exception is complete, and starts the exception return sequence. Bits [3:0] of the EXC_RETURN value indicate the required return stack and processor mode. [Table 2-11](#) shows the EXC_RETURN values with description of the exception return behavior.

Table 2-11 Exception return behavior

EXC_RETURN[31:0]	Description
0xFFFFFFFF1	Return to Handler mode. Exception return gets state from the main stack. Execution uses MSP after return.
0xFFFFFFFF9	Return to Thread mode. Exception return gets state from MSP. Execution uses MSP after return.
0xFFFFFFFDD	Return to Thread mode. Exception return gets state from the PSP. Execution uses PSP after return.
All other values	Reserved.

2.6 Fault Handling

Faults are a subset of the exceptions, see Exception model in [Section 2.5](#). All faults result in the HardFault exception being taken or cause lockup if they occur in the HardFault handler. The faults are:

- execution of an SVC instruction at a priority equal or higher than SVCall
- execution of a BKPT instruction without a debugger attached
- a system-generated bus error on a load or store
- execution of an instruction from an XN memory address
- execution of an instruction from a location for which the system generates a bus fault
- a system-generated bus error on a vector fetch
- execution of an undefined instruction
- execution of an instruction when not in Thumb-State as a result of the T-bit being previously cleared to 0
- an attempted load or store to an unaligned address

Note: Only Reset can preempt the fixed priority HardFault handler. A HardFault can preempt any exception other than Reset, or another hard fault.

2.6.1 Lockup

The processor enters a lockup state if a fault occurs when executing the HardFault handlers, or if the system generates a bus error when unstacking the PSR on an exception return using the MSP. When the processor is in lockup state it does not execute any instructions. The processor remains in lockup state until one of the following occurs:

- it is reset
- it is halted by a debugger

2.7 Power Management

The Cortex-M0 processor sleep modes reduce power consumption:

- Sleep mode
- Deep sleep mode

The SLEEPDEEP bit of the SCR selects which sleep mode is used, see System Control Register [SCR](#).

This section describes the mechanisms for entering sleep mode, and the conditions for waking up from sleep mode.

2.7.1 Entering Sleep Mode

This section describes the mechanisms software can use to put the processor into sleep mode.

The system can generate spurious wakeup events, for example a debug operation wakes up the processor. Therefore software must be able to put the processor back into sleep mode after such an event. A program might have an idle loop to put the processor back to sleep mode.

Wait for interrupt

The wait for interrupt instruction, WFI, causes immediate entry to sleep mode. When the processor executes a WFI instruction it stops executing instructions and enters sleep mode.

Wait for event

The wait for event instruction, WFE, causes entry to sleep mode depending on the value of a one-bit event register. When the processor executes a WFE instruction, it checks the value of the event register:

- 0 The processor stops executing instructions and enters sleep mode.
- 1 The processor clears the register to 0 and continues executing instructions without entering sleep mode.

If the event register is 1, this indicates that the processor must not enter sleep mode on execution of a WFE instruction. Typically, this is because an external event is asserted. Software cannot access this register directly.

Sleep-on-exit

If the SLEEPONEXIT bit of the SCR is set to 1, when the processor completes the execution of an exception handler and returns to Thread mode, it immediately enters sleep mode. This mechanism is used in applications that only require the processor to run when an interrupt occurs.

2.7.2 Wakeup from Sleep Mode

The conditions for the processor to wakeup depend on the mechanism that caused it to enter sleep mode.

Wakeup from WFI or Sleep-on-exit

The following events are WFI wake-up events:

- reset event
- debug event, if debug is enabled
- exception at a priority that would preempt any currently active exceptions, if PRIMASK was set to 0

Note: If PRIMASK is set to 1, an interrupt or exception that has a higher priority than the current exception priority will cause the processor to wake up. Interrupt handler is not executed until the processor sets PRIMASK to 0. For more information about PRIMASK, see [Exception mask registers](#).

Wakeup from WFE

The following events are WFE wake-up events:

- reset event
- exception or interrupt with sufficient priority to cause exception entry
- exception or interrupt entering pending state, if SEVONPEND is set to 1 (See [SCR](#))
- debug event, if debug is enabled

Note: Wakeup by Event Register (see The Event Register in ARMv6-M Architecture Reference Manual [\[2\]](#)) is not possible in XMC1200. Nevertheless, SEV instruction will set the event register.

2.7.3 Power Management Programming Hints

ISO/IEC C cannot directly generate the WFI and WFE instructions. The CMSIS provides the following functions for these instructions:

```
void __WFE(void) // Wait for Event  
void __WFI(void) // Wait for Interrupt
```

2.8 Private Peripherals

The following sections are the reference material for the ARM Cortex-M0 core peripherals.

2.8.1 About the Private Peripherals

The address map of the Private Peripheral Bus (PPB) is:

Table 2-12 Core peripheral register regions

Address	Core peripheral	Description
0xE000E008-0xE000E00F	System Control Block	See Section 2.8.2 and Section 2.9.1
0xE000E010-0xE000E01F	System timer	See Section 2.8.3 and Section 2.9.2
0xE000E100-0xE000E4EF	Nested Vectored Interrupt Controller	See Interrupt System chapter
0xE000ED00-0xE000ED3F	System Control Block	See Section 2.8.2 and Section 2.9.1
0xE000EF00-0xE000EF03	Nested Vectored Interrupt Controller	See Interrupt System chapter

2.8.2 System control block

The System Control Block (SCB) provides system implementation information, and system control. This includes configuration, control, and reporting of the system exceptions.

2.8.2.1 System control block usage hints and tips

Ensure software uses aligned 32-bit word size transactions to access all the system control block registers.

2.8.3 System timer, SysTick

The processor has a 24-bit system timer, SysTick, that counts down from the reload value to zero, reloads, that is wraps to, the value in the SYST_RVR register on the next clock cycle, then counts down on subsequent clock cycles.

Note: When the processor is halted for debugging the counter does not decrement.

2.8.3.1 SysTick usage hints and tips

The interrupt controller clock updates the SysTick count. When processor clock is selected and the clock signal is stopped for low power mode, the SysTick counter stops. When external clock is selected, the clock continues to run in low power mode and SysTick can be used as a wakeup source.

Ensure software uses aligned word accesses to access the SysTick registers.

If the SysTick counter reload and current value are undefined at reset, the correct initialization sequence for the SysTick counter is:

1. Program reload value.
2. Clear current value.
3. Program Control and Status register.

2.9 PPB Registers

The CPU private peripherals registers base address is E000E000_H.

Table 2-13 Register Overview

Short Name	Description	Offset Address	Access Mode		Description See
			Read	Write	
System Control Space (SCS)					
CPUID	CPUID Base Register	D00 _H	PV, 32	PV, 32	Page 2-41
ICSR	Interrupt Control and State Register	D04 _H	PV, 32	PV, 32	Page 2-42
AIRCR	Application Interrupt and Reset Control Register	D0C _H	PV, 32	PV, 32	Page 2-45
SCR	System Control Register	D10 _H	PV, 32	PV, 32	Page 2-46
CCR	Configuration and Control Register	D14 _H	PV, 32	PV, 32	Page 2-48
SHPR2	System Handler Priority Register 2	D1C _H	PV, 32	PV, 32	Page 2-49
SHPR3	System Handler Priority Register 3	D20 _H	PV, 32	PV, 32	Page 2-50
SHCSR	System Handler Control and State Register	D24 _H	PV, 32	PV, 32	Page 2-51
System Timer (SysTick)					
SYST_CSR	SysTick Control and Status Register	010 _H	PV, 32	PV, 32	Page 2-52
SYST_RVR	SysTick Reload Value Register	014 _H	PV, 32	PV, 32	Page 2-54
SYST_CVR	SysTick Current Value Register	018 _H	PV, 32	PV, 32	Page 2-55
SYST_CALIB	SysTick Calibration Value Register	01C _H	PV, 32	-	Page 2-56

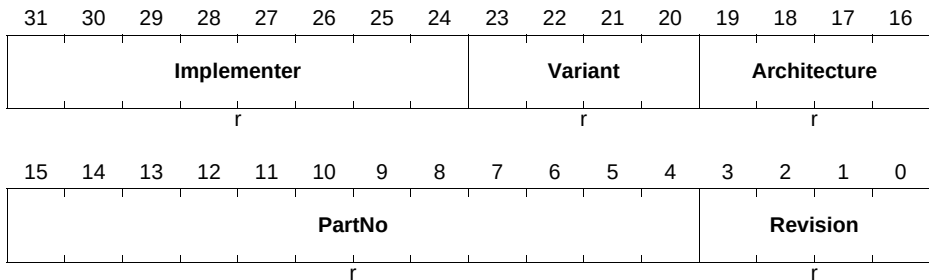
2.9.1 SCS Registers

CPUID

The CPUID register contains the processor part number, version, and implementation information.

CPUID

CPUID Base Register (E000ED00_H) **Reset Value: 410CC200_H**



Field	Bits	Type	Description
Revision	[3:0]	r	Revision Number 0 _H Patch 0
PartNo	[15:4]	r	Part Number of the Processor C20 _H Cortex-M0
Architecture	[19:16]	r	Architecture C _H ARMv6-M
Variant	[23:20]	r	Variant Number 0 _H Revision 0
Implementer	[31:24]	r	Implementer Code 41 _H ARM

Central Processing Unit (CPU)

ICSR

The ICSR:

- provides:
 - set-pending and clear-pending bits for the PendSV and SysTick exceptions
- indicates:
 - the exception number of the exception being processed
 - whether there are preempted active exceptions
 - the exception number of the highest priority pending exception
 - whether any interrupts are pending.

ICSR

Interrupt Control and State Register

(E000ED04_H)

Reset Value: 00000000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0			PEN DSV SET	PEN DSV CLR	PEN DST SET	PEN DST CLR	0		ISRP ENDI NG	0			VECTPEN DING		
r			rw	w	rw	w	r		r	r			r		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VECTPENDING				0						VECTACTIVE					
r				r						r					

Field	Bits	Type	Description
VECTACTIVE ¹⁾	[5:0]	r	Active Exception Number 00 _H Thread mode Non-zero value The exception number of the currently active exception. <i>Note: Subtract 16 from this value to obtain the CMSIS IRQ number required to index into the Interrupt Clear-Enable, Set-Enable, Clear-Pending, Set-Pending, or Priority Registers, see Interrupt Program Status Register.</i>
0	[11:6]	r	Reserved Read as 0; should be written with 0.

Central Processing Unit (CPU)

Field	Bits	Type	Description
VECTPENDING	[17:12]	r	Pending Exception Number Indicates the exception number of the highest priority pending enabled exception. 0 _H No pending exceptions Non-zero value: The exception number of the highest priority pending enabled exception.
0	[21:18]	r	Reserved Read as 0; should be written with 0.
ISRPENDING	22	r	Interrupt Pending Flag This bit sets the interrupt pending flag, excluding faults. 0 _B Interrupt not pending 1 _B Interrupt pending.
0	[24:23]	r	Reserved Read as 0; should be written with 0.
PENDSTCLR	25	w	SysTick Exception Clear-pending 0 _B No effect 1 _B removes the pending state from the SysTick exception. This bit is write-only. On a register read, this value is unknown.
PENDSTSET	26	rw	SysTick Exception Set-pending 0 _D SysTick exception is not pending 1 _D SysTick exception is pending. A write of 0 to the bit has no effect.
PENDSVCLR	27	w	PendSV Clear Pending This bit clears a pending PendSV exception. 0 _B Do not clear. 1 _B Removes pending state from PendSV exception.
PENDSVSET	28	rw	PendSV Set Pending This bit sets a pending PendSV exception or reads back the current state. 0 _B PendSV exception is not pending. 1 _B PendSV exception is pending. <i>Note: Writing 1 to this bit is the only way to set the PendSV exception state to pending.</i> A software write of 0 to the bit has no effect.

Central Processing Unit (CPU)

Field	Bits	Type	Description
0	[31:29]	r	Reserved Read as 0; should be written with 0.

1) This is the same value as IPSR bits[5:0], see [Interrupt Program Status Register](#).

Note: The result is unpredictable if:

1. Both *PENDSVSET* and *PENDSVCLR* bits are set to 1.
2. Both *PENDSTSET* and *PENDSTCLR* bits are set to 1.

AIRCR

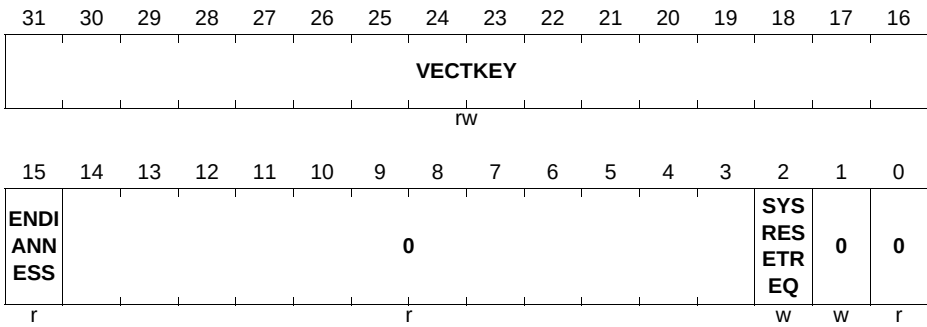
The AIRCR register provides endian status for data accesses and reset control of the system. To write to this register, you must write 0x5FA to the VECTKEY field, otherwise the processor ignores the write.

AIRCR

Application Interrupt and Reset Control Register

(E000ED0C_H)

Reset Value: FA050000_H



Field	Bits	Type	Description
0	0	r	Reserved Read as 0; should be written with 0.
0	1	w	Reserved Must be written with 0.
SYSRESETREQ	2	w	System Reset Request 0 _B No effect. 1 _B Requests a system level reset. This bit is read as 0.
0	[14:3]	r	Reserved Read as 0; should be written with 0.
ENDIANNESS	15	r	Data Endianness 0 _B Little-endian
VECTKEY	[31:16]	rw	Register Key Reads as unknown. On writes, write 0x5FA to VECTKEY, otherwise the write is ignored.

Central Processing Unit (CPU)

SCR

The SCR controls features of entry to and exit from low power state.

SCR

System Control Register

(E000ED10_H)

Reset Value: 00000000_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											SEV ONP END	0	SLE EPD EEP	SLE EPO NEXI T	0
r											rw	r	rw	rw	r

Field	Bits	Type	Description
0	0	r	Reserved Read as 0; should be written with 0.
SLEEPONEXIT	1	rw	Sleep-on-exit This bit indicates sleep-on-exit when returning from Handler mode to Thread mode. 0_B Do not sleep when returning to Thread mode. 1_B Enter sleep, or deep sleep, on return from an ISR to Thread mode. Setting this bit to 1 enables an interrupt driven application to avoid returning to an empty main application.
SLEEPDEEP	2	rw	Low Power Sleep Mode This bit controls whether the processor uses sleep or deep sleep as its low power mode. 0_B Sleep 1_B Deep sleep
0	3	r	Reserved Read as 0; should be written with 0.

Central Processing Unit (CPU)

Field	Bits	Type	Description
SEVONPEND	4	rw	Send Event on Pending bit 0_B Only enabled interrupts or events can wakeup the processor, disabled interrupts are excluded. 1_B Enabled events and all interrupts, including disabled interrupts, can wakeup the processor. When an event or interrupt enters pending state, the event signal wakes up the processor from WFE. If the processor is not waiting for an event, the event is registered and affects the next WFE.
0	[31:5]	r	Reserved Read as 0; should be written with 0.

Central Processing Unit (CPU)

CCR

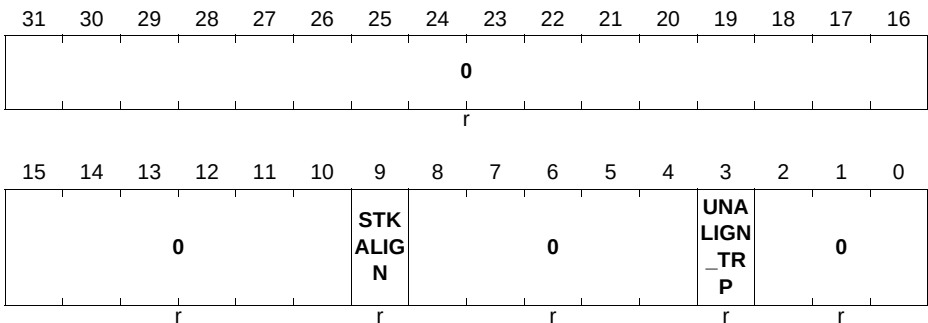
The CCR is a read-only register and it indicates some aspects of the behavior of the Cortex-M0 processor.

CCR

Configuration and Control Register

(E000ED14_H)

Reset Value: 00000208_H



Field	Bits	Type	Description
0	[2:0]	r	Reserved Read as 0; should be written with 0.
UNALIGN_TRP	3	r	Unaligned Access Traps This bit always reads as 1, indicates that all unaligned accesses generate a HardFault.
0	[8:4]	r	Reserved Read as 0; should be written with 0.
STKALIGN	9	r	Stack Alignment This bit always reads as 1, indicates 8-byte stack alignment on exception entry. On exception entry, the processor uses bit [9] of the stacked PSR to indicate the stack alignment. On return from the exception, it uses this stacked bit to restore the correct stack alignment.
0	[31:10]	r	Reserved Read as 0; should be written with 0.

System Handler Priority Registers

The SHPR2-SHPR3 registers set the priority level, 0 to 192, of the exception handlers that have configurable priority.

SHPR2-SHPR3 are word accessible. To access to the system exception priority level using CMSIS, the following CMSIS functions are used:

- `uint32_t NVIC_GetPriority(IRQn_Type IRQn)`
- `void NVIC_SetPriority(IRQn_Type IRQn, uint32_t priority)`

The system fault handlers, the priority field and register for each handler are:

Table 2-14 System fault handler priority fields

Handler	Field	Register description
SVCall	PRI_11	System Handler Priority Register 2 on Page 2-49
PendSV	PRI_14	System Handler Priority Register 3 on Page 2-50
SysTick	PRI_15	

Each PRI_N field is 8 bits wide, but the XMC1200 implements only bits [7:6] of each field, and bits [5:0] read as zero and ignore writes.

SHPR2

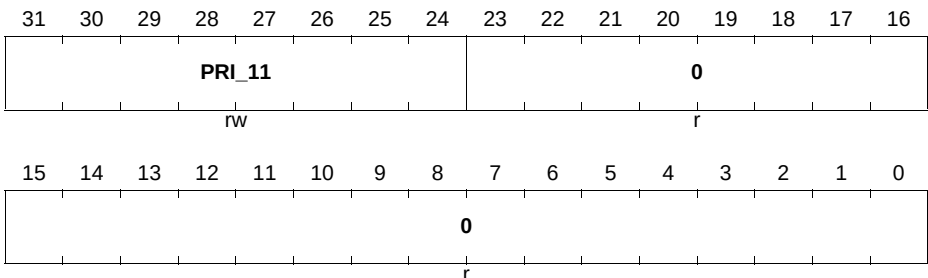
The SHPR2 register sets the priority level for the SVCall handler.

SHPR2

System Handler Priority Register 2

(E000ED1C_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[23:0]	r	Reserved Read as 0; should be written with 0.
PRI_11	[31:24]	rw	Priority of System Handler 11 SVCall.

SHPR3

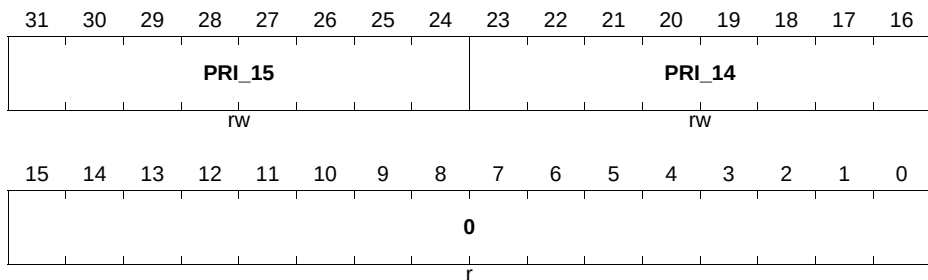
The SHPR3 register sets the priority level for the PendSV and SysTick handlers.

SHPR3

System Handler Priority Register 3

(E000ED20_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[15:0]	r	Reserved Read as 0; should be written with 0.
PRI_14	[23:16]	rw	Priority of System Handler 14 PendSV.
PRI_15	[31:24]	rw	Priority of System Handler 15 SysTick exception.

Central Processing Unit (CPU)

SHCSR

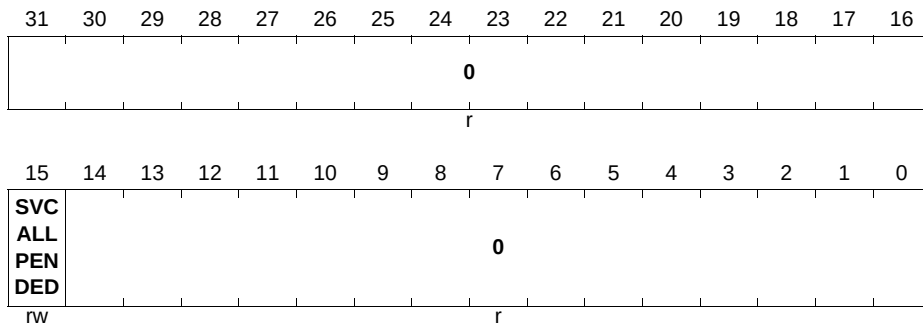
The SHCSR register controls and provides the status of system handlers.

SHCSR

System Handler Control and State Register

(E000ED24_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
0	[14:0]	r	Reserved Read as 0; should be written with 0.
SVCALLPENDE D	15	rw	SVCAll Pending bit This bit reflects the pending state on a read, and updates the pending state, to the value written, on a write. 0 _B SVCAll is not pending. 1 _B SVCAll is pending ¹⁾ .
0	[31:16]	r	Reserved Read as 0; should be written with 0.

- 1) Pending state bits are set to 1 when an exception occurs, and are cleared to 0 when an exception becomes active.

2.9.2 SysTick Registers

SYST_CSR

The SYST_CSR register enables the SysTick features.

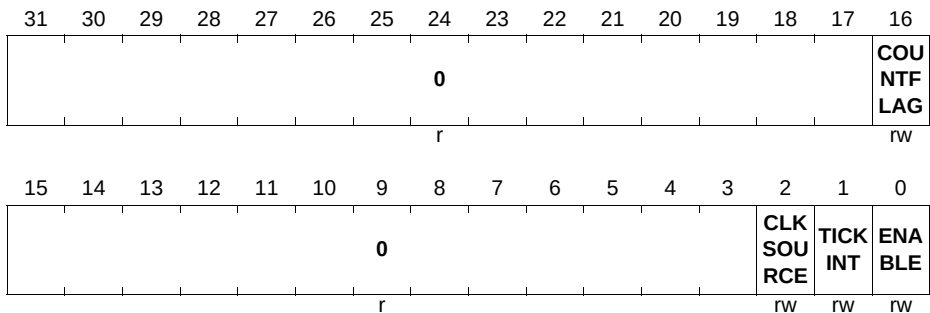
Reading SYST_CSR clears the COUNTFLAG bit to 0.

SYST_CSR

SysTick Control and Status Register

(E000E010_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
ENABLE	0	rw	Counter Enable This bit enables the counter. 0 _B Counter disabled. 1 _B Counter enabled.
TICKINT	1	rw	SysTick Exception Request This bit enables the SysTick exception request. 0 _B Counting down to zero does not assert the SysTick exception request. 1 _B Counting down to zero to assert the SysTick exception request. In software, COUNTFLAG bit can be used to determine if SysTick has counted to zero.
CLKSOURCE	2	rw	Clock Source This bit selects the SysTick timer clock source. 0 _B External clock ¹⁾ . 1 _B Processor clock.

Central Processing Unit (CPU)

Field	Bits	Type	Description
0	[15:3]	r	Reserved Read as 0; should be written with 0.
COUNTFLAG	16	rw	Counter Flag This bit returns 1 if timer counted to 0 since the last read of this register.
0	[31:17]	r	Reserved Read as 0; should be written with 0.

1) In XMC1200, the external clock refers to the on-chip 32 kHz standby clock.

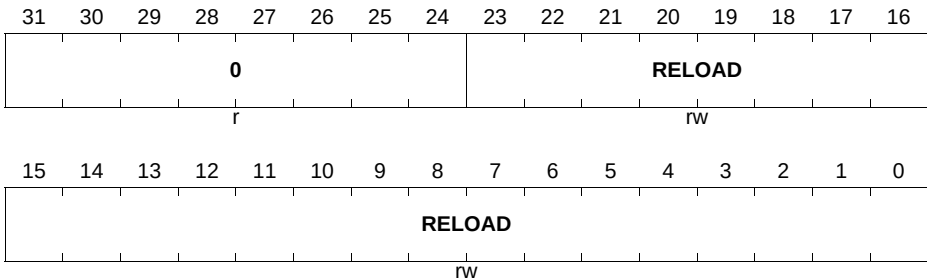
When ENABLE is set to 1, the counter loads the RELOAD value from the SYST_RVR register and then counts down. On reaching 0, it sets the COUNTFLAG to 1 and optionally asserts the SysTick depending on the value of TICKINT. It then loads the RELOAD value again, and begins counting.

SYST_RVR

The SYST_RVR register specifies the start value to load into the SYST_CVR register.

SYST_RVR

SysTick Reload Value Register (E000E014_H) **Reset Value: XXXXXXXX_H**



Field	Bits	Type	Description
RELOAD	[23:0]	rw	Reload Value This field sets the value to load into the SYST_CVR register when the counter is enabled and when it reaches 0.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

Notes on calculating the RELOAD value

1. The RELOAD value can be any value in the range 0x00000001-0x00FFFFFF. A start value of 0 is possible, but this has no effect because the SysTick exception request and COUNTFLAG are activated when counting from 1 to 0.
2. The RELOAD value is calculated according to its use. For example, to generate a multi-shot timer with a period of N processor clock cycles, use a RELOAD value of N-1. If the SysTick interrupt is required every 100 clock pulses, set RELOAD to 99.

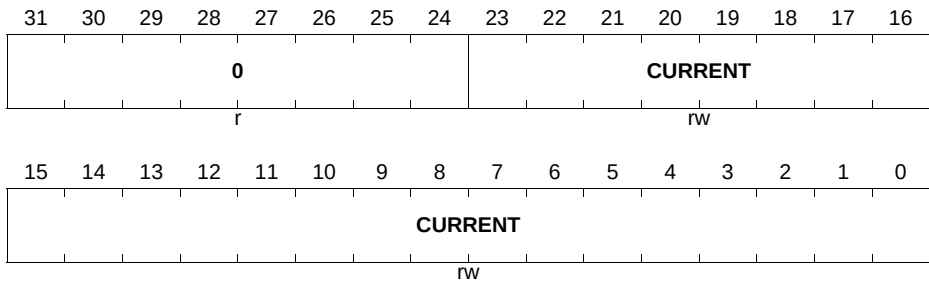
SYST_CVR

The SYST_CVR register contains the current value of the SysTick counter.

Writing to the SYST_CVR clears the register and the COUNTFLAG status bit to 0. The write does not trigger the SysTick exception logic. Reading the register returns its value at the time it is accessed.

SYST_CVR

SysTick Current Value Register (E000E018_H) **Reset Value: XXXXXXXX_H**



Field	Bits	Type	Description
CURRENT	[23:0]	rw	SysTick Counter Current Value When read, it returns the current value of the SysTick counter. A write of any value clears the field to 0, and also clears the SYST_CSR.COUNTFLAG bit to 0.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

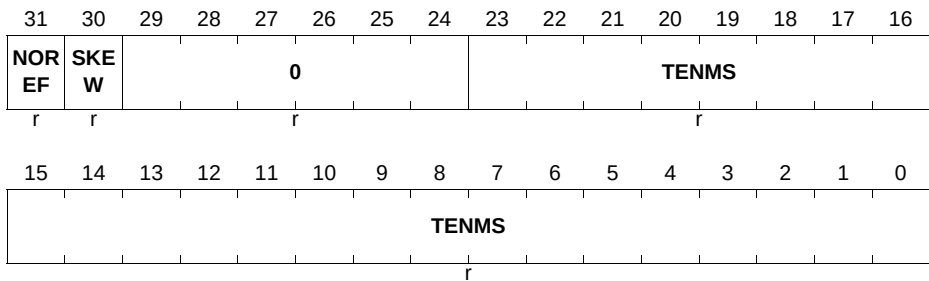
SYST_CALIB

The SYST_CALIB register indicates the SysTick calibration properties.

SYST_CALIB

SysTick Calibration Value Register(E000E01C_H)

Reset Value: 40000147_H



Field	Bits	Type	Description
TENMS	[23:0]	r	10 Milliseconds The reload value for 10ms timing is subject to system clock skew errors. The default value of TENMS is 0x000147.
0	[29:24]	r	Reserved Read as 0; should be written with 0.
SKEW	30	r	Clock Skew This bit is read as 1. It indicates that 10ms calibration value is inexact, because of the clock frequency.
NOREF	31	r	Reference Clock This bit is read as 0. It indicates that external reference clock is provided.

3 Bus System

The single master bus system in XMC1200 consists of a high-performance system bus based on the industry AMBA 3 AHB-Lite Protocol standard for memories and high-bandwidth on-chip peripherals and a narrower APB for low-bandwidth on-chip peripherals.

3.1 Bus Interfaces

This chapter describes the features for the two kinds of interfaces.

- Memory Interface
- Peripheral Interface

All on-chip modules implement Little Endian data organization.

Memory Interface

The on-chip memories are capable to accept a transfer request with each bus clock cycle.

The memory interface data bus width is 32-bit. Flash memory supports only 32-bit accesses while SRAM allows 32-bit, 16-bit and 8-bit write accesses. Read accesses to SRAM is always 32-bit wide.

Peripheral Interface

Each slave on the AHB-Lite supports 32-bit accesses. Additionally:

- USIC0 supports 8-bit and 16-bit accesses

Each slave on the APB supports only 16-bit accesses.

Note: Unaligned memory accesses to memory or peripheral slaves result in a HardFault exception.

4 Service Request Processing

A hardware pulse is called Service Request (SR) in an XMC1200 system. Service Requests are the fastest way to send trigger “messages” between connected on-chip resources.

An SR can generate any of the following requests

- Interrupt
- Peripheral action

This chapter describes the available Service Requests and the different ways to select and process them.

Table 4-1 Abbreviations

ERU	Event Request Unit
NVIC	Nested Vectored Interrupt Controller
SR	Service Request

4.1 Overview

Efficient Service Request Processing is based on the interconnect between the request sources and the request processing units. XMC1200 provides both fixed and programmable interconnect.

4.1.1 Features

The following features are provided for Service Request processing:

- Connectivity matrix between Service Requests and request processing units
 - Fixed connections
 - Programmable connections using ERU

4.1.2 Block Diagram

Figure 4-1 shows a representation of the interaction between the request sources and the request processing units.

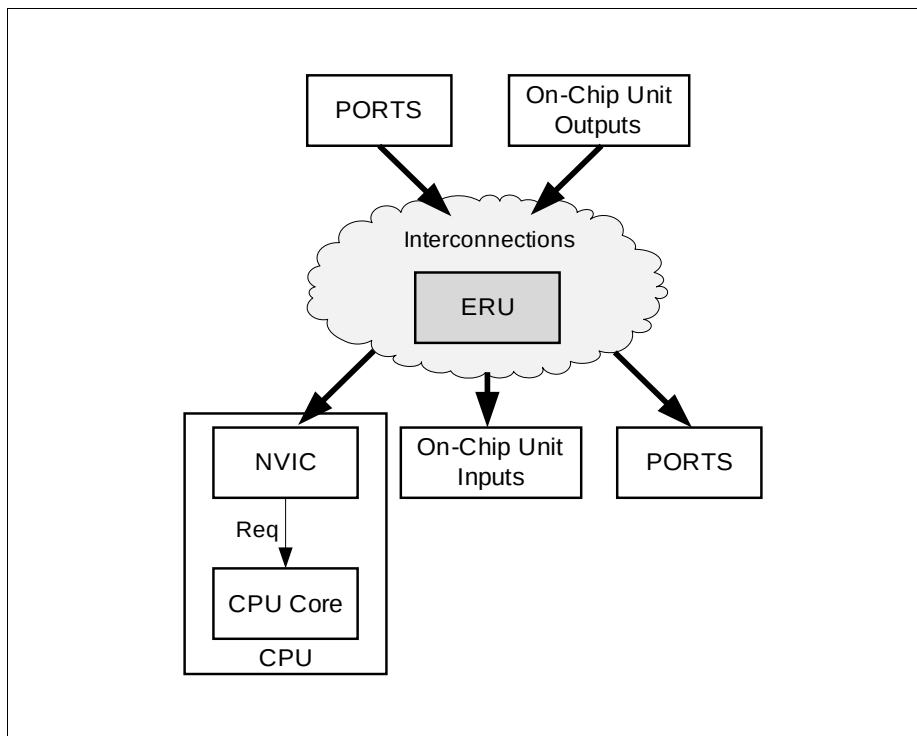


Figure 4-1 Block Diagram on Service Request Processing

4.2 Service Request Distribution

Figure 4-2 shows an example of how a service request can be distributed concurrently. To support the concurrent distribution to multiple receivers, the receiving modules are capable to enable/disable incoming requests.

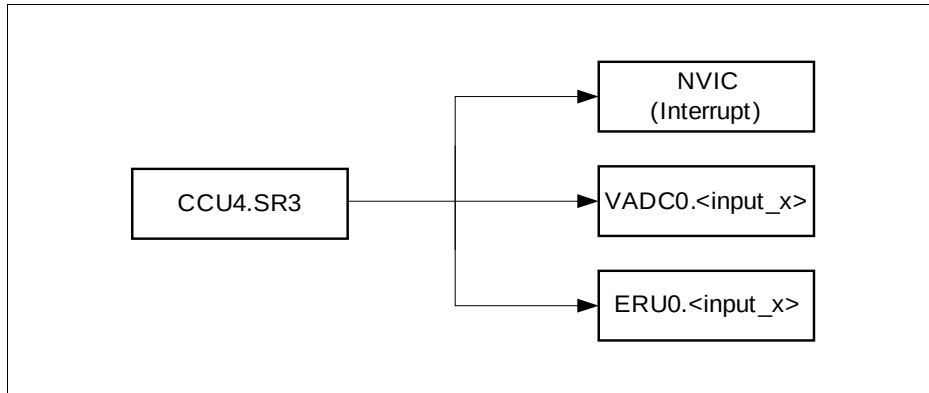


Figure 4-2 Example for Service Request Distribution

The units involved in Service Request distribution can be subdivided into

- Embedded real time services
- Interrupt services

Embedded real time services

Connectivity between On-Chip Units and PORTS is real time application and also chip package dependant. Related connectivity and availability of pins can be looked up in the

- “Interconnects” Section of the respective module(s) chapters
- “Parallel Ports” chapter and Data Sheet for PORTS
- “Event Request Unit” chapter

Interrupt services

The following table gives an overview on the number of service requests per module and how the service requests are assigned to NVIC Interrupt service provider.

Service Requests are always of type “Pulse” in XMC1200.

Table 4-2 Interrupt services per module

Modules	Request Sources	NVIC	Type
VADC	12	6	Pulse
CCU40	4	4	Pulse
USIC0	6	6	Pulse
LEDTS0-1	2	2	Pulse
BCCU0	1	1	Pulse
SCU	3	3	Pulse
ERU0	4	4	Pulse
Total	32	26	-

5 Interrupt Subsystem

The interrupt Subsystem in XMC1200 consists of the Nested Vectored Interrupt Controller (NVIC) and the respective modules' interrupt generation blocks.

Note: The CPU exception model is described in the CPU chapter.

5.1 Nested Vectored Interrupt Controller (NVIC)

The NVIC is an integral part of the Cortex M0 processor unit. Due to a tight coupling with the CPU, it provides the lowest interrupt latency and efficient processing of late arriving interrupts.

5.1.1 Features

The NVIC supports the following features:

- 32 interrupt nodes
- 4 programmable priority levels for each interrupt node
- Support for interrupt tail-chaining and late-arrival
- Software interrupt generation

5.1.2 Interrupt Node Assignment

Table 5-1 lists the service request sources per peripheral and their assignment to NVIC interrupt nodes. For calculation of the vector routine address, please refer to the section on Vector Table in the CPU chapter.

Table 5-1 Interrupt Node assignment

Service Request	Node ID	Description
SCU.SR0 - SCU.SR2	0...2	System Control SR0 is the system critical request SR1 is the common SCU request SR2 is the comparators (ACMPx and ORCx) request
ERU0.SR0 - ERU0.SR3	3...6	External Request Unit 0
NC	7...8	Reserved
USIC0.SR0 - USIC0.SR5	9...14	Universal Serial Interface Channel (Module 0)
VADC0.C0SR0 - VADC0.C0SR1	15...16	Analog to Digital Converter (Common)
VADC0.G0SR0 - VADC0.G0SR1	17...18	Analog to Digital Converter (Group 0)

Table 5-1 Interrupt Node assignment (cont'd)

Service Request	Node ID	Description
VADC0.G1SR0 - VADC0.G1SR1	19...20	Analog to Digital Converter (Group 1)
CCU40.SR0 - CCU40.SR3	21...24	Capture Compare Unit 4 (Module 0)
NC	25...28	Reserved
LEDTS0.SR0	29	LED and Touch Sense Control Unit (Module 0)
LEDTS1.SR0	30	LED and Touch Sense Control Unit (Module 1)
BCCU0.SR0	31	Brightness Control Unit (Module 0)

5.1.3 Interrupt Signal Generation

In XMC1200, all peripherals support only the generation of pulse interrupts. Pulse interrupts are also described as edge-triggered interrupts.

A pulse interrupt is an interrupt signal sampled synchronously on the rising edge of the processor clock (MCLK). To ensure the NVIC detects the interrupt, the peripheral asserts the interrupt signal for at least one MCLK clock cycle, during which the NVIC detects the pulse and latches the interrupt.

When the processor enters the ISR, it automatically removes the pending state from the interrupt, see [Hardware and software control of interrupts](#).

The processor automatically stacks its state on exception entry and unstacks this state on exception exit, with no instruction overhead. This provides low latency exception handling.

Hardware and software control of interrupts

The Cortex-M0 latches all interrupts. A peripheral interrupt becomes pending for one of the following reasons:

- the NVIC detects that the interrupt signal is active and the interrupt is not active
- the NVIC detects a rising edge on the interrupt signal
- software writes to the corresponding interrupt set-pending register bit, see Interrupt Set-pending Register NVIC_ISPR.

A pending interrupt remains pending until one of the following:

- The processor enters the ISR for the interrupt. This changes the state of the interrupt from pending to active. Then:
 - The NVIC continues to monitor the interrupt signal, and If this is pulsed the state of the interrupt changes to pending and active. In this case, when the processor returns from the ISR the state of the interrupt changes to pending, which might cause the processor to immediately re-enter the ISR.

Interrupt Subsystem

If the interrupt signal is not pulsed while the processor is in the ISR, the state of the interrupt changes to inactive when the processor returns from the ISR.

- Software writes to the corresponding interrupt clear-pending register bit.
 - The state of the interrupt changes to inactive, if the state was pending; or active, if the state was active and pending.

5.1.4 NVIC design hints and tips

An interrupt node can enter pending state even if it is disabled. Disabling an interrupt node only prevents the processor from taking interrupts from that node.

NVIC programming hints

Software uses the CPSIE i and CPSID i instructions to enable and disable interrupts. The CMSIS provides the following intrinsic functions for these instructions:

```
void __disable_irq(void) // Disable Interrupts
```

```
void __enable_irq(void) // Enable Interrupts
```

In addition, the CMSIS provides a number of functions for NVIC control, including:

Table 5-2 CMSIS functions for NVIC control

CMSIS interrupt control function	Description
void NVIC_EnableIRQ (IRQn_t IRQn)	Enable IRQn
void NVIC_DisableIRQ (IRQn_t IRQn)	Disable IRQn
uint32_t NVIC_GetPendingIRQ (IRQn_t IRQn)	Return true (1) if IRQn is pending
void NVIC_SetPendingIRQ (IRQn_t IRQn)	Set IRQn pending
void NVIC_ClearPendingIRQ (IRQn_t IRQn)	Clear IRQn pending status
void NVIC_SetPriority (IRQn_t IRQn, uint32_t priority)	Set priority for IRQn
uint32_t NVIC_GetPriority (IRQn_t IRQn)	Read priority of IRQn
void NVIC_SystemReset (void)	Reset the system

The input parameter IRQn is the IRQ number. For more information about these functions, please refer to the CMSIS documentation.

5.1.5 Accessing CPU Registers using CMSIS

CMSIS functions enable software portability between different Cortex-M profile processors. To access the NVIC registers when using CMSIS, use the following functions:

Table 5-3 CMSIS access NVIC functions

CMSIS function	Description
void NVIC_EnableIRQ (IRQn_Type IRQn) ¹⁾	Enables an interrupt or exception.
void NVIC_DisableIRQ (IRQn_Type IRQn) ¹⁾	Disables an interrupt or exception.
void NVIC_SetPendingIRQ (IRQn_Type IRQn) ¹⁾	Sets the pending status of interrupt or exception to 1.
void NVIC_ClearPendingIRQ (IRQn_Type IRQn) ¹⁾	Clears the pending status of interrupt or exception to 0.
uint32_t NVIC_GetPendingIRQ (IRQn_Type IRQn) ¹⁾	Reads the pending status of interrupt or exception. This function returns non-zero value if the pending status is set to 1.
void NVIC_SetPriority(IRQn_Type IRQn, uint32_t priority) ¹⁾	Sets the priority of an interrupt or exception with configurable priority level to 1.
uint32_t NVIC_GetPriority(IRQn_Type IRQn) ¹⁾	Reads the priority of an interrupt or exception with configurable priority level. This function return the current priority level.

1) The input parameter IRQn is the IRQ number.

5.1.6 Interrupt Priority

An interrupt node can be assigned one of four priority levels. The levels are in steps of 64, from 0 to 192, and defined in an 8-bit priority field in the Interrupt Priority Register x (IPRx). A higher level corresponds to a lower priority, so level 0 is the highest interrupt priority.

Since there are four priority fields in each IPRx register and each field corresponds to one interrupt node, altogether 8 IPRx registers (IPR0...IPR7) are needed as shown in [Figure 5-1](#).

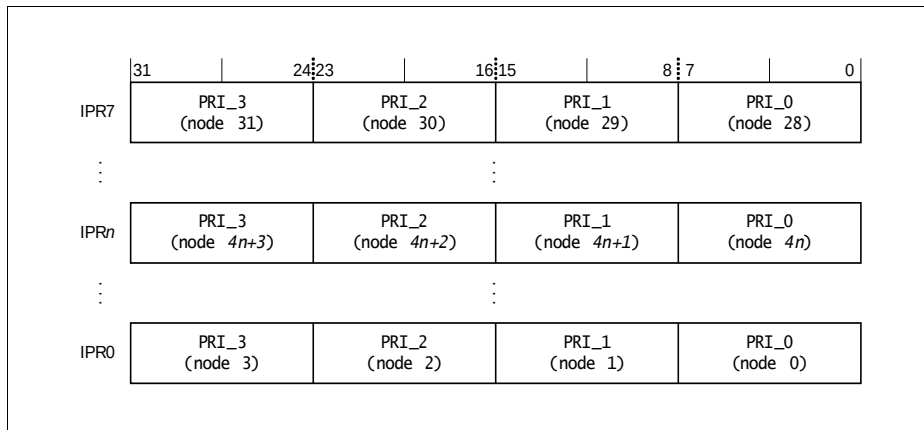


Figure 5-1 Interrupt Priority Register

The IPR number and byte offset for interrupt node m ($0 \dots 31$) can be found as follows:

- the corresponding IPR number n is given by
 $n = m \text{ DIV } 4$
- the byte offset of the required Priority field in this register is $m \text{ MOD } 4$, where:
 - byte offset 0 refers to register bits [7:0]
 - byte offset 1 refers to register bits [15:8]
 - byte offset 2 refers to register bits [23:16]
 - byte offset 3 refers to register bits [31:24]
- for example, Priority field of interrupt node 21 is located at IPR5.[15:8], since
 - $n = 21 \text{ DIV } 4 = 5$
 - byte offset = $21 \text{ MOD } 4 = 1$

Note: IPRx registers are only word-accessible.

Refer to [Table 5-2](#) for more information on the access to the interrupt node priority array, which provides the software view of the interrupt node priorities.

5.1.7 Interrupt Latency

The XMC1200 interrupt latency, defined as the time from detection of the generated pulse and latching of the interrupt by NVIC to execution of the first instruction at the interrupt handler, is typically 21 MCLK cycles as shown in [Figure 5-2](#).

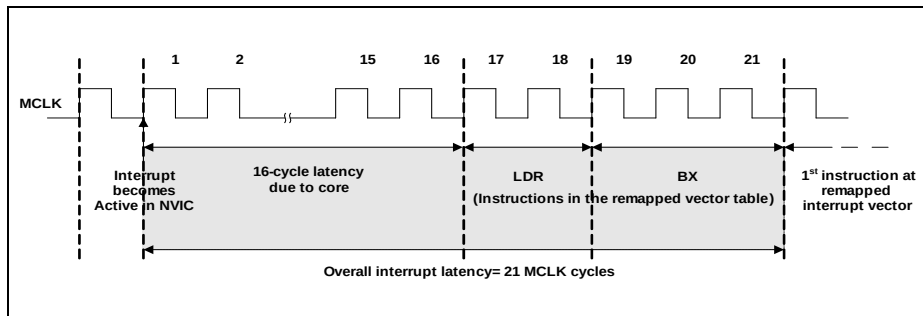


Figure 5-2 Typical XMC1200 Interrupt Latency

This assumes the following conditions:

- Interrupt generation is enabled
- No occurrence of interrupt pre-emption, late-arrival or tail-chaining
- Delays due to memory wait states are not taken into account

5.2 General Module Interrupt Structure

A module might have multiple interrupt sources. Each interrupt source has typically the following structure (see [Figure 5-3](#)):

- An interrupt source status flag
- A set bit to allow software to set the flag to 1
- A clear bit to allow software to reset the flag to 0
- An enable bit to trigger interrupt when the hardware event occurs or status flag set bit is set (i.e. software triggered interrupt)

Note: If a flag set event (due to a peripheral HW event) occurs in the same clock cycle as a flag clear event (due to SW Setting of the Clear bit), the set has higher priority over the clear.

Note: Setting of the status flag by a hardware event or software writing to status flag set bit, is independent of interrupt generation enabled/disabled. Similarly, interrupt generation is independent of the level of the status flag.

Additionally, some modules might have more interrupt sources than interrupt lines. Therefore, they include an interrupt routing management block, which maps the interrupt sources to the interrupt lines.

For further details and exceptions to the above general structure, refer to the respective module chapters. An overview of all XMC1200 interrupt sources is given at the end of the chapter.

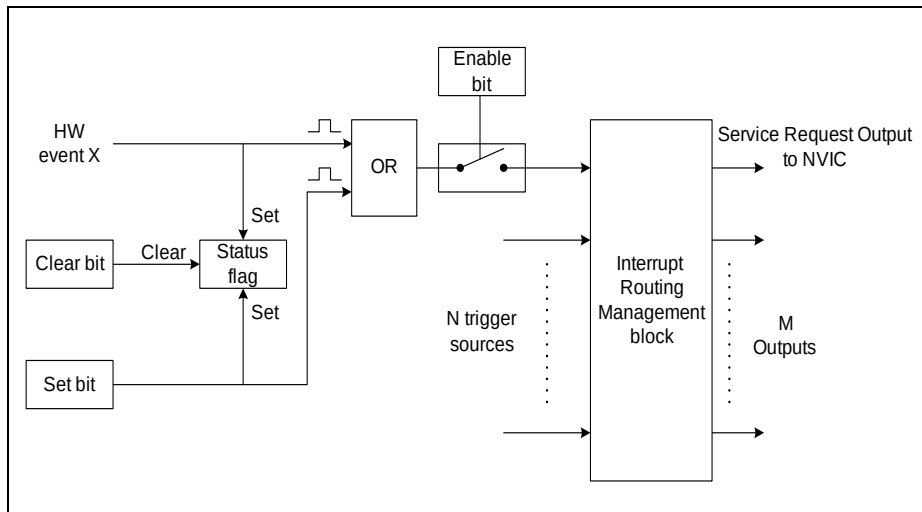


Figure 5-3 Typical Module Interrupt Structure

To enable a module HW event for interrupt generation, SW has to:

- Enable the interrupt node that is allocated to the module in the NVIC, through the NVIC_IUSER register.
- If the module has an interrupt routing management block, select an available service request output through which the interrupt will be generated to the NVIC. This is usually done by configuring an interrupt node pointer register in the module.
- Finally, set the interrupt enable bit of the module HW event for interrupt generation.

5.3 Registers

Table 5-4 Registers Address Space

Module	Base Address	End Address	Note
CPU PPB: System Control Space (SCS)	E000E000 _H	E000EFFF _H	

Registers Overview

The absolute register address is calculated by adding:
Module Base Address + Offset Address

Table 5-5 Register Overview

Short Name	Description	Offset Address	Access Mode		Description See
			Read	Write	
Nested Vectored Interrupt Controller (NVIC)					
NVIC_ISER	Interrupt Set-enable Registers	100 _H	U, PV	U, PV	Page 5-9
NVIC_ICER	Interrupt Clear-enable Registers	180 _H	U, PV	U, PV	Page 5-10
NVIC_ISPR	Interrupt Set-pending Registers	200 _H	U, PV	U, PV	Page 5-11
NVIC_ICPR	Interrupt Clear-pending Registers	280 _H	U, PV	U, PV	Page 5-12
NVIC_IPR0 - NVIC_IPR7	Interrupt Priority Registers	400 _H -41C _H	U, PV	U, PV	Page 5-13

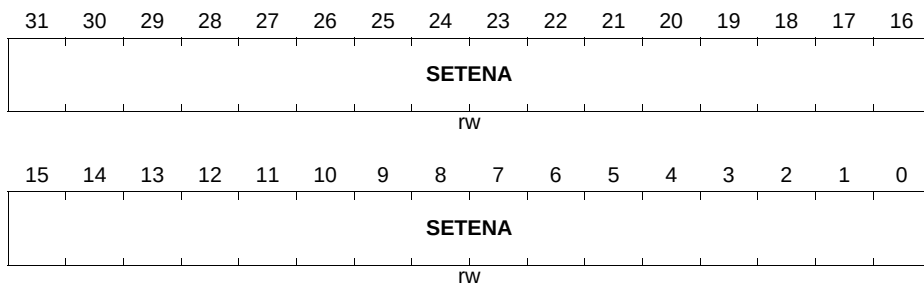
5.3.1 NVIC Registers

NVIC_ISER

The ISER register enables interrupt nodes, and shows which interrupt nodes are enabled.

NVIC_ISER

Interrupt Set-enable Register (E000E100_H) **Reset Value: 00000000_H**



Field	Bits	Type	Description
SETENA	[31:0]	rw	Interrupt Node Set-enable 0 _B Read: Interrupt node disabled. Write: No effect. 1 _B Read: Interrupt node enabled. Write: Enable interrupt node

If a pending interrupt is enabled, the NVIC activates the interrupt based on its priority. If an interrupt is not enabled, asserting its interrupt signal changes the interrupt state to pending, but the NVIC never activates the interrupt, regardless of its priority.

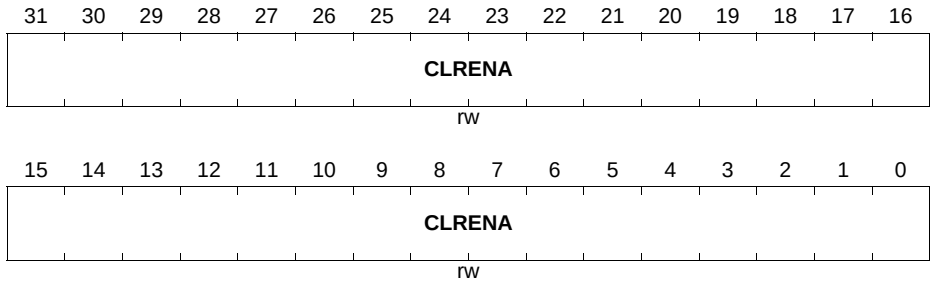
NVIC_ICER

The ICER register disables interrupt nodes, and shows which interrupt nodes are enabled.

NVIC_ICER

Interrupt Clear-enable Register (E000E180_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
CLRENA	[31:0]	rw	Interrupt Node Clear-enable 0_B Read: Interrupt node disabled. Write: No effect 1_B Read: Interrupt node enabled. Write: Disable interrupt node.

NVIC_ISPR

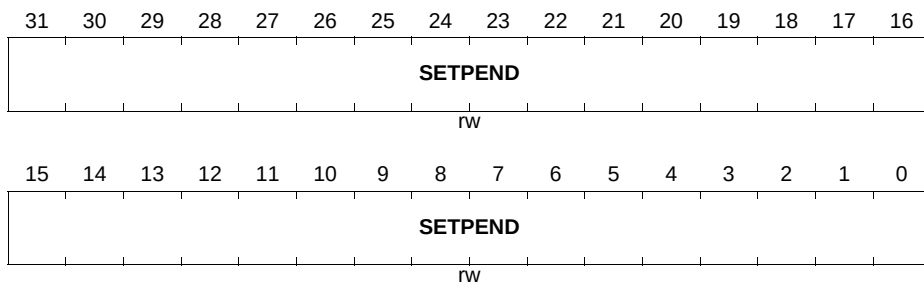
The ISPR register forces interrupt nodes into the pending state, and shows which interrupt nodes are pending.

NVIC_ISPR

Interrupt Set-pending Register

(E000E200_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
SETPEND	[31:0]	rw	Interrupt Node Set-pending 0 _B Read: Interrupt node is not pending. Write: No effect 1 _B Read: Interrupt node is pending. Write: Change interrupt state to pending.

Note: Writing 1 to the ISPR bit corresponding to:

- an interrupt node that is pending has no effect
- a disabled interrupt node sets the state of that interrupt node to pending

NVIC_ICPR

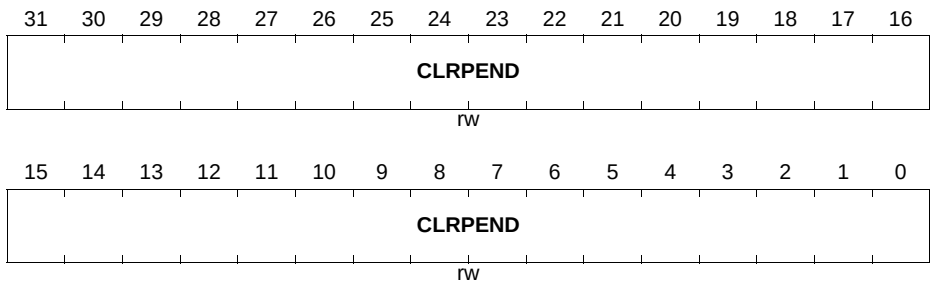
The ICPR register removes the pending state from interrupt nodes, and shows which interrupt nodes are pending.

NVIC_ICPR

Interrupt Clear-pending Register

(E000E280_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
CLRPEND	[31:0]	rw	Interrupt Node Clear-pending 0 _B Read: Interrupt node is not pending. Write: No effect. 1 _B Read: Interrupt node is pending. Write: Remove interrupt state from pending.

Note: Writing 1 to an ICPR bit does not affect the active state of the corresponding interrupt node.

NVIC_IPRx (x=0-7)

The IPR0-IPR7 registers provide a 8-bit priority field for each interrupt node. Each register holds four priority fields.

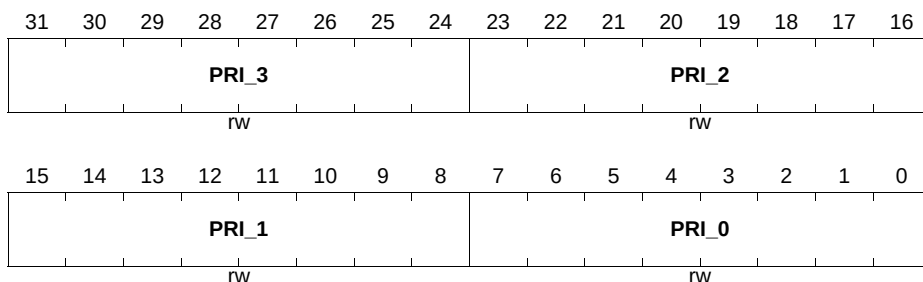
Each priority field holds a priority value, 0-192. The lower the value, the greater the priority of the corresponding interrupt node. The processor implements only bits [7:6] of each field, bits [5:0] reads as 0 and ignores writes. This means writing 255 to a priority register saves value 192 to the register.

NVIC_IPRx (x=0-7)

Interrupt Priority Register x

(E000E400_H + 4*x)

Reset Value: 00000000_H



Field	Bits	Type	Description
PRI_3	[31:24]	rw	Priority, Byte Offset 3
PRI_2	[23:16]	rw	Priority, Byte Offset 2
PRI_1	[15:8]	rw	Priority, Byte Offset 1
PRI_0	[7:0]	rw	Priority, Byte Offset 0

5.4 Interrupt Request Source Overview

An overview of all XMC1200 interrupt sources and related register bits are shown in the next few pages.

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
0	SCU.SR0	Flash double bit ECC ¹⁾	SCU_SRRAW	FLECC2I	SCU_SRMSK	FLECC2I	SCU_SRSET	FLECC2I	SCU_SRCLR	FLECC2I	-	-
			NVM_NVM STATUS	ECC2READD	-	-	-	-	NVM_NVM PROG	RSTECC	-	-
		Flash operation complete	SCU_SRRAW	FLCMPLTI	NVM_NVMCONF	INT_ON	SCU_SRSET	FLCMPLTI	SCU_SRCLR	FLCMPLTI	-	-
		SRAM parity error	SCU_SRRAW	PESRAMI	SCU_SRMSK	PESRAMI	SCU_SRSET	PESRAMI	SCU_SRCLR	PESRAMI	-	-
		USIC RAM parity error	SCU_SRRAW	PEU0I	SCU_SRMSK	PEU0I	SCU_SRSET	PEU0I	SCU_SRCLR	PEU0I	-	-
		Loss of clock	SCU_SRRAW	LOCI	SCU_SRMSK	LOCI	SCU_SRSET	LOCI	SCU_SRCLR	LOCI	-	-

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
1	SCU.SR1	Standby clock failure	SCU_SRRAW	SBYCLKFI	SCU_SRMSK	SBYCLKFI	SCU_SRSET	SBYCLKFI	SCU_SRCLR	SBYCLKFI	-	-
		VDDP pre-warning	SCU_SRRAW	VDDPI	SCU_SRMSK	VDDPI	SCU_SRSET	VDDPI	SCU_SRCLR	VDDPI	-	-
		VDDC drops below VDROPI	SCU_SRRAW	VDROPI	SCU_SRMSK	VDROPI	SCU_SRSET	VDROPI	SCU_SRCLR	VDROPI	-	-
		VDDC rises above VCLIP	SCU_SRRAW	VCLIP	SCU_SRMSK	VCLIP	SCU_SRSET	VCLIP	SCU_SRCLR	VCLIP	-	-
		DTS done	SCU_SRRAW	TSE_DONE	SCU_SRMSK	TSE_DONE	SCU_SRSET	TSE_DONE	SCU_SRCLR	TSE_DONE	-	-
		DTS compare high	SCU_SRRAW	TSE_HIGH	SCU_SRMSK	TSE_HIGH	SCU_SRSET	TSE_HIGH	SCU_SRCLR	TSE_HIGH	-	-
		DTS compare low	SCU_SRRAW	TSE_LOW	SCU_SRMSK	TSE_LOW	SCU_SRSET	TSE_LOW	SCU_SRCLR	TSE_LOW	-	-
		WDT pre-warning	SCU_SRRAW	PRWARN	SCU_SRMSK	PRWARN	SCU_SRSET	PRWARN	SCU_SRCLR	PRWARN	-	-
		RTC periodic event	SCU_SRRAW	PI	-	-	SCU_SRSET	PI	SCU_SRCLR	PI	-	-
		RTC alarm	SCU_SRRAW	AI	-	-	SCU_SRSET	AI	SCU_SRCLR	AI	-	-
		RTC CTR Mirror Register updated	SCU_SRRAW	RTC_CTR	SCU_SRMSK	RTC_CTR	SCU_SRSET	RTC_CTR	SCU_SRCLR	RTC_CTR	-	-
		RTC ATIM0 Mirror Register updated	SCU_SRRAW	RTC_ATIM0	SCU_SRMSK	RTC_ATIM0	SCU_SRSET	RTC_ATIM0	SCU_SRCLR	RTC_ATIM0	-	-
		RTC ATIM1 Mirror Register updated	SCU_SRRAW	RTC_ATIM1	SCU_SRMSK	RTC_ATIM1	SCU_SRSET	RTC_ATIM1	SCU_SRCLR	RTC_ATIM1	-	-
		RTC TIM0 Mirror Register updated	SCU_SRRAW	RTC_TIM0	SCU_SRMSK	RTC_TIM0	SCU_SRSET	RTC_TIM0	SCU_SRCLR	RTC_TIM0	-	-
		RTC TIM1 Mirror Register updated	SCU_SRRAW	RTC_TIM1	SCU_SRMSK	RTC_TIM1	SCU_SRSET	RTC_TIM1	SCU_SRCLR	RTC_TIM1	-	-

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
2	SCU.SR2	Out of range comparator x event (x=0-7)	SCU_SRRAW	ORCxl	SCU_SRMSK	ORCxl	SCU_SRSET	ORCxl	SCU_SRCLR	ORCxl	-	-
		Analog comparator x event (x=0-2)	SCU_SRRAW	ACMPxl	SCU_SRMSK	ACMPxl	SCU_SRSET	ACMPxl	SCU_SRCLR	ACMPxl	-	-
3, 4, 5, 6	ERU0.SR[3:0]	ERU0_IOUTx (x=0-3)	See section on ERU0 for details.									
7, 8	Reserved											
9, 10, 11, 12, 13, 14	USIC0_SR[5:0]	USIC: Standard receive event	USIC0_PSR	RIF	USIC0_CCR	RIEN	-	-	USIC0_PSCR	CRIF	USIC0_INPR	RINP
		USIC: Receive start event	USIC0_PSR	RSIF	USIC0_CCR	RSIEN	-	-	USIC0_PSCR	CRSIF	USIC0_INPR	TBINP
		USIC: Alternate receive event	USIC0_PSR	AIF	USIC0_CCR	AIEN	-	-	USIC0_PSCR	CAIF	USIC0_INPR	AINP
		USIC: Transmit shift event	USIC0_PSR	TSIF	USIC0_CCR	TSIEN	-	-	USIC0_PSCR	CTSIF	USIC0_INPR	TSINP
		USIC: Transmit buffer event	USIC0_PSR	TBIF	USIC0_CCR	TBIEN	-	-	USIC0_PSCR	CTBIF	USIC0_INPR	TBINP
		USIC: Data lost event	USIC0_PSR	DLIF	USIC0_CCR	DLIEN	-	-	USIC0_PSCR	CDLIF	USIC0_INPR	PINP
		USIC: BRG event	USIC0_PSR	BRGIF	USIC0_CCR	BRGIEN	-	-	USIC0_PSCR	CBRGIF	USIC0_INPR	PINP

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
9, 10, 11, 12, 13, 14	USIC0_SR[5:0]	USIC: Standard transmit buffer event	USIC0_TRBSR	STBI	USIC0_TBCTR	STBIEN	-	-	USIC0_TRBSCR	CSTBI	USIC0_TBCTR	STBINP
		USIC: Standard transmit buffer event	USIC0_TRBSR	STBT	USIC0_TBCTR	STBIEN	-	-	-	-	USIC0_TBCTR	STBINP
		USIC: Transmit Buffer error event	USIC0_TRBSR	TBERI	USIC0_TBCTR	TBERIEN	-	-	USIC0_TRBSCR	CTBERI	USIC0_TBCTR	ATBINP
		USIC: Standard receive buffer event	USIC0_TRBSR	SRBI	USIC0_RBCTR	SRBIEN	-	-	USIC0_TRBSCR	CSRBI	USIC0_RBCTR	SRBINP
		USIC: Standard receive buffer event	USIC0_TRBSR	SRBT	USIC0_RBCTR	SRBIEN	-	-	-	-	USIC0_RBCTR	SRBINP
		USIC: Alternate receive buffer event	USIC0_TRBSR	ARBI	USIC0_RBCTR	ARBIEN	-	-	USIC0_TRBSCR	CARBI	USIC0_RBCTR	ARBINP
		USIC: Receive buffer error event	USIC0_TRBSR	RBERI	USIC0_RBCTR	RBERIEN	-	-	USIC0_TRBSCR	CRBERI	USIC0_RBCTR	ARBINP
		ASC: Synchronisation break detected	USIC0_PSR	SBD	USIC0_PCR	SBDIEN	-	-	USIC0_PSCR	CSBD	USIC0_INPR	PINP
		ASC: Collision detected	USIC0_PSR	COL	USIC0_PCR	CDIEN	-	-	USIC0_PSCR	CCOL	USIC0_INPR	PINP
		ASC: Receiver noise detected	USIC0_PSR	RNS	USIC0_PCR	RNIEN	-	-	USIC0_PSCR	CRNS	USIC0_INPR	PINP
		ASC: Format error in stop bit 0	USIC0_PSR	FER0	USIC0_PCR	FEIEN	-	-	USIC0_PSCR	CFER0	USIC0_INPR	PINP
		ASC: Format error in stop bit 1	USIC0_PSR	FER1	USIC0_PCR	FEIEN	-	-	USIC0_PSCR	CFER1	USIC0_INPR	PINP
		ASC: Receive frame finished	USIC0_PSR	RFF	USIC0_PCR	FFIEN	-	-	USIC0_PSCR	CRFF	USIC0_INPR	PINP
		ASC: Transmit frame finished	USIC0_PSR	TFF	USIC0_PCR	FFIEN	-	-	USIC0_PSCR	CTFF	USIC0_INPR	PINP

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
9, 10, 11, 12, 13, 14	USIC0_SR[5:0]	SSC: MSLS event detected	USIC0_PSR	MSLSEV	USIC0_PCR	MSLSIEN	-	-	USIC0_PSCR	CMSLSEV	USIC0_INPR	PINP
		SSC: Parity error detected	USIC0_PSR	PAERR	USIC0_PCR	PARIEN	-	-	USIC0_PSCR	CPAERR	USIC0_INPR	PINP
		SSC: DX2T event detected	USIC0_PSR	DX2TEV	USIC0_PCR	DX2TIEN	-	-	USIC0_PSCR	CDX2TEV	USIC0_INPR	PINP
		IIC: Wrong TDF code detected	USIC0_PSR	WTDF	USIC0_PCR	ERRIEN	-	-	USIC0_PSCR	CWTDF	USIC0_INPR	PINP
		IIC: Start condition received	USIC0_PSR	SCR	USIC0_PCR	SCRIEN	-	-	USIC0_PSCR	CSCR	USIC0_INPR	PINP
		IIC: Repeated start condition received	USIC0_PSR	RSCR	USIC0_PCR	RSCRIEN	-	-	USIC0_PSCR	CRSCR	USIC0_INPR	PINP
		IIC: Stop condition received	USIC0_PSR	PCR	USIC0_PCR	PCRIEN	-	-	USIC0_PSCR	CPCR	USIC0_INPR	PINP
		IIC: NACK received	USIC0_PSR	NACK	USIC0_PCR	NACKIEN	-	-	USIC0_PSCR	CNACK	USIC0_INPR	PINP
		IIC: Arbitration lost	USIC0_PSR	ARL	USIC0_PCR	ARLIEN	-	-	USIC0_PSCR	CARL	USIC0_INPR	PINP
		IIC: Slave read request	USIC0_PSR	SRR	USIC0_PCR	SRRIEN	-	-	USIC0_PSCR	CSRR	USIC0_INPR	PINP
		IIC: Error detected	USIC0_PSR	ERR	USIC0_PCR	ERRIEN	-	-	USIC0_PSCR	CERR	USIC0_INPR	PINP
		IIC: ACK received	USIC0_PSR	ACK	USIC0_PCR	ACKIEN	-	-	USIC0_PSCR	CACK	USIC0_INPR	PINP
		IIS: DX2T event detected	USIC0_PSR	DX2TEV	USIC0_PCR	DX2TIEN	-	-	USIC0_PSCR	CDX2TEV	USIC0_INPR	PINP
		IIS: WA falling edge event	USIC0_PSR	WAFE	USIC0_PCR	WAFEIEN	-	-	USIC0_PSCR	CWAFE	USIC0_INPR	PINP
		IIS: WA rising edge event	USIC0_PSR	WARE	USIC0_PCR	WAREIEN	-	-	USIC0_PSCR	CWARE	USIC0_INPR	PINP
		IIS: WA generation end	USIC0_PSR	END	USIC0_PCR	ENDIEN	-	-	USIC0_PSCR	CEND	USIC0_INPR	PINP

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
15, 16,	VADC0_C0SR[1:0]	Source Event 0	VADC0_G xSEFLAG	SEV0	VADC0_G xQINR0	ENSI	VADC0_G xSEFLAG	SEV0	VADC0_G xSEFCLR	SEV0	VADC0_G xSEVNP	SEV0NP
17, 18, 19, 20	VADC0_GxSR[1:0] (x=0-1)	Source Event 1	VADC0_G xSEFLAG	SEV1	VADC0_G xASMR	ENSI	VADC0_G xSEFLAG	SEV1	VADC0_G xSEFCLR	SEV1	VADC0_G xSEVNP	SEV1NP
		Channel Event y (y=0-7)	VADC0_G xCEFLAG	CEVy	VADC0_G xCHCTry	CHEVMODE	VADC0_G xCEFLAG	CEVy	VADC0_G xCEFCLR	CEVy	VADC0_G xCEVNP	CEVyINP
		Result Event y (y=0-7)	VADC0_G xREFLAG	REVy	VADC0_G xRCRy	SRGEN	VADC0_G xREFLAG	REVy	VADC0_G xREFCLR	REVy	VADC0_G xREVNP0	REVyNP
		Result Event y (y=8-15)	VADC0_G xREFLAG	REVy	VADC0_G xRCRy	SRGEN	VADC0_G xREFLAG	REVy	VADC0_G xREFCLR	REVy	VADC0_G xREVNP1	REVyNP
		Global Source Event	VADC0_G LOBEFLAG	SEVGLB	VADC0_B RSMR	ENSI	VADC0_G LOBEFLAG	SEVGLB	VADC0_G LOBEFCLR	SEVGLBCLR	VADC0_G LOBEVNP	REV0NP
		Global Result Event	VADC0_G LOBEFLAG	REVGLB	VADC0_G LOBERCR	SRGEN	VADC0_G LOBEFLAG	REVGLB	VADC0_G LOBEFCLR	REVGLBCLR	VADC0_G LOBEVNP	SEV0NP

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
21, 22, 23, 24	CCU40_ SR[3:0]	Event 0 edge(s) information from event selector	CCU40_ CC4yINTS	E0AS	CCU40_ CC4yINTE	E0AE	CCU40_ CC4ySWS	SE0A	CCU40_ CC4ySWR	RE0A	CCU40_ CC4ySRS	E0SR
		Event 1 edge(s) information from event selector	CCU40_ CC4yINTS	E1AS	CCU40_ CC4yINTE	E1AE	CCU40_ CC4ySWS	SE1A	CCU40_ CC4ySWR	RE1A	CCU40_ CC4ySRS	E1SR
		Event 2 edge(s) information from event selector	CCU40_ CC4yINTS	E2AS	CCU40_ CC4yINTE	E2AE	CCU40_ CC4ySWS	SE2A	CCU40_ CC4ySWR	RE2A	CCU40_ CC4ySRS	E2SR
		Period Match while counting up	CCU40_ CC4yINTS	PMUS	CCU40_ CC4yINTE	PME	CCU40_ CC4ySWS	SPM	CCU40_ CC4ySWR	RPM	CCU40_ CC4ySRS	POSR
		Compare Match while counting up	CCU40_ CC4yINTS	CMUS	CCU40_ CC4yINTE	CMUE	CCU40_ CC4ySWS	SCMU	CCU40_ CC4ySWR	RCMU	CCU40_ CC4ySRS	CMSR
		Compare Match while counting down	CCU40_ CC4yINTS	CMDS	CCU40_ CC4yINTE	CMDE	CCU40_ CC4ySWS	SCMD	CCU40_ CC4ySWR	RCMD	CCU40_ CC4ySRS	CMSR
		One Match while counting down	CCU40_ CC4yINTS	OMDS	CCU40_ CC4yINTE	OME	CCU40_ CC4ySWS	SOM	CCU40_ CC4ySWR	ROM	CCU40_ CC4ySRS	POSR
		Entering Trap State	CCU40_ CC4yINTS	TRPF	CCU40_ CC4yINTE	E2AE	CCU40_ CC4ySWS	STRPF	CCU40_ CC4ySWR	RTRPF	CCU40_ CC4ySRS	E2SR
25, 26, 27, 28	Reserved											
29	LEDTS0_ SR0	Start of time slice	LEDTS0_ EVFR	TSF	LEDTS0_ GLOBCTL	ITS_EN	-	-	LEDTS0_ EVFR	CTSF	-	-
		Start of extended time frame	LEDTS0_ EVFR	TFF	LEDTS0_ GLOBCTL	ITF_EN	-	-	LEDTS0_ EVFR	CTFF	-	-
		Start of autoscan time period	LEDTS0_ EVFR	TPF	LEDTS0_ GLOBCTL	ITP_EN	-	-	LEDTS0_ EVFR	CTPF	-	-

Table 5-6 Interrupt Source Overview

IRQ	Interrupt Node	Interrupt Source	Status Flag		Interrupt Enable		Set Flag		Clear Flag		Node Pointer	
			Register	Bit	Register	Bit	Register	Bit	Register	Bit	Register	Bit
30	LEDTS1. SR1	Start of time slice	LEDTS1_ EVFR	TSF	LEDTS1_ GLOBCTL	ITS_EN	-	-	LEDTS1_ EVFR	CTSF	-	-
		Start of extended time frame	LEDTS1_ EVFR	TFF	LEDTS1_ GLOBCTL	ITF_EN	-	-	LEDTS1_ EVFR	CTFF	-	-
		Start of autoscan time period	LEDTS1_ EVFR	TPF	LEDTS1_ GLOBCTL	ITP_EN	-	-	LEDTS1_ EVFR	CTPF	-	-
31	BCCU0. SR0	Trigger 0	BCCU0_ EVFR	T0F	BCCU0_ EVIER	T0IEN	BCCU0_ EVFSR	T0FS	BCCU0_ EVFCR	T0FC	-	-
		Trigger 1	BCCU0_ EVFR	T1F	BCCU0_ EVIER	T1IEN	BCCU0_ EVFSR	T1FS	BCCU0_ EVFCR	T1FC	-	-
		FIFO Full	BCCU0_ EVFR	FF	BCCU0_ EVIER	FIEN	BCCU0_ EVFSR	FFS	BCCU0_ EVFCR	FFC	-	-
		FIFO Empty	BCCU0_ EVFR	EF	BCCU0_ EVIER	EIEN	BCCU0_ EVFSR	EFs	BCCU0_ EVFCR	EFC	-	-
		Trap	BCCU0_ EVFR	TPF	BCCU0_ EVIER	TPIEN	BCCU0_ EVFSR	TPFS	BCCU0_ EVFCR	TPFC	-	-

1) Flash ECC double bit error has two status flags, each having its own clear bit. It is sufficient to use only one of the status flag and ignore the other.

6 Event Request Unit (ERU)

As described in the Service Request Processing chapter, XMC1200 uses the Event Request Unit (ERU) to support the programmable interconnection for the processing of service requests.

6.1 Features

The ERU supports these features:

- Flexible processing of external and internal service requests
- Programmable for edge and/or level triggering
- Multiple inputs per channel
- Triggers combinable from multiple inputs
- Input and output gating

6.2 Overview

The Event Request Unit (ERU) is a versatile multiple input event detection and processing unit.

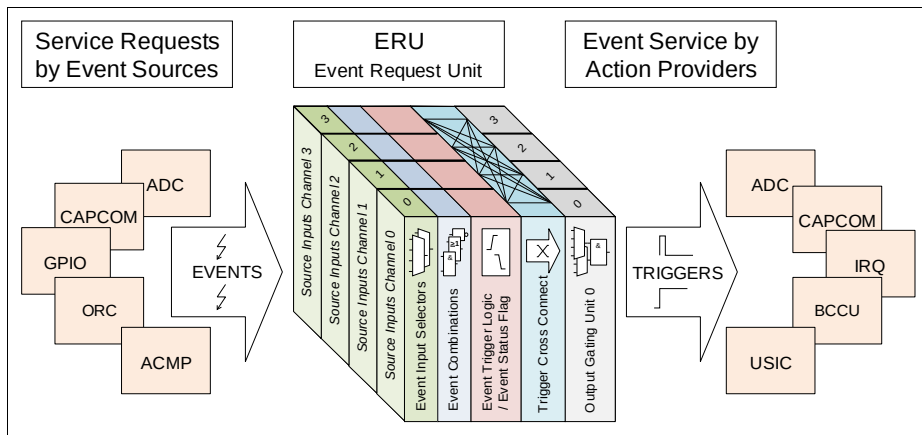


Figure 6-1 Event Request Unit Overview

Each ERU unit consists of the following blocks:

- An **Event Request Select (ERS)** unit.
 - Event Input Selectors allow the selection of one out of two inputs. For each of these two inputs, a vector of 4 possible signals is available.
 - Event Combinations allow a logical combination of two input signals to a common trigger.

Event Request Unit (ERU)

- An **Event Trigger Logic (ETL)** 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 events.
- The Trigger **Cross Connect Matrix** distributes the events and status flags to the Output Channels. Additionally, trigger signals from other modules are made available and can be combined with the local triggers.
- An **Output Gating Unit (OGU)** combines the trigger events and status information and gates the Output depending on a gating signal.

Note: An event of one Input can lead to reactions on several Outputs, or also events on several Inputs can be combined to a reaction on one Output.

6.3 Event Request Select Unit (ERS)

For each Input Channel x ($x = 0-3$), an ERS x unit handles the input selection for the associated ETL x unit. Each ERS x performs a logical combination of two signals (A_x , B_x) to provide one combined output signal ERS x O to the associated ETL x . Input A_x can be selected from 4 options of the input vector ERU_xA[3:0] and can be optionally inverted. A similar structure exists for input B_x (selection from ERU_xB[3:0]).

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

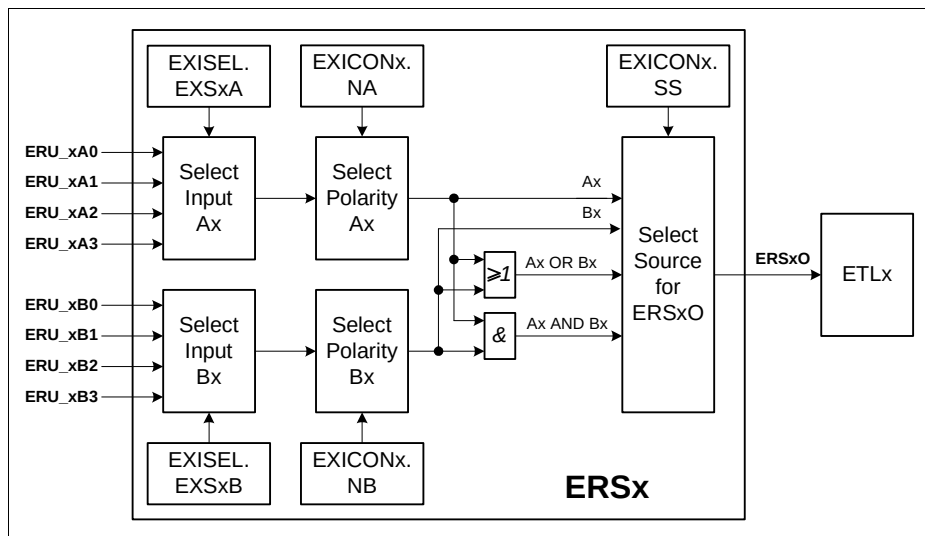


Figure 6-2 Event Request Select Unit Overview

Event Request Unit (ERU)

The ERS units are controlled via register **ERU0_EXISEL** (one register for all four ERSx units) and registers EXICONx (one register for each ERSx and associated ETLx unit, e.g. **ERU0_EXICONx (x=0-3)** for Input Channel 0).

6.4 Event Trigger Logic (ETLx)

For each Input Channel x (x = 0-3), an event trigger logic ETLx derives a trigger event and related status information from the input ERSxO. 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 of the four ETLx units has an associated EXICONx register, that controls all options of an ETLx (the register also holds control bits for the associated ERSx unit, e.g. **ERU0_EXICONx (x=0-3)** to control ERS0 and ETL0).

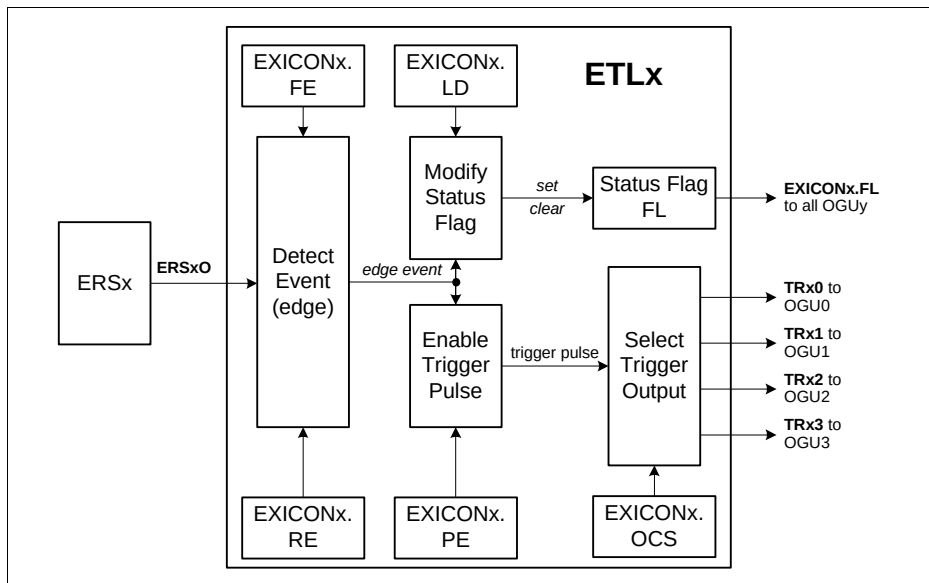


Figure 6-3 Event Trigger Logic Overview

When the selected event (edge) is detected, the status flag EXICONx.FL becomes set. This flag can also be modified by software. Two different operating modes are supported by this status flag.

It can be used as “sticky” flag, which is set by hardware when the desired event has been detected and has to be cleared by software. In this operating mode, it indicates that the event has taken place, but without indicating the actual status of the input.

Event Request Unit (ERU)

In the second operating mode, it is cleared automatically if the “opposite” event is detected. 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 (OGUy) in parallel (see [Figure 6-4](#)) to provide **pattern detection capability of all OGUy** units based on different or the same status flags.

In addition to the modification of the status flag, a trigger pulse output TRxy of ETLx can be enabled (by bit EXICONx.PE) and selected to **trigger actions in one of the OGUy** units. The target OGUy for the trigger is selected by bit field EXICON.OCS.

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

6.5 Cross Connect Matrix

The matrix shown in [Figure 6-4](#) distributes the trigger signals (TRxy) and status signals (EXICONx.FL) from the different ETLx units between the OGUy units. In addition, it receives peripheral trigger signals that can be OR-combined with the ETLx trigger signals in the OGUy units.

Event Request Unit (ERU)

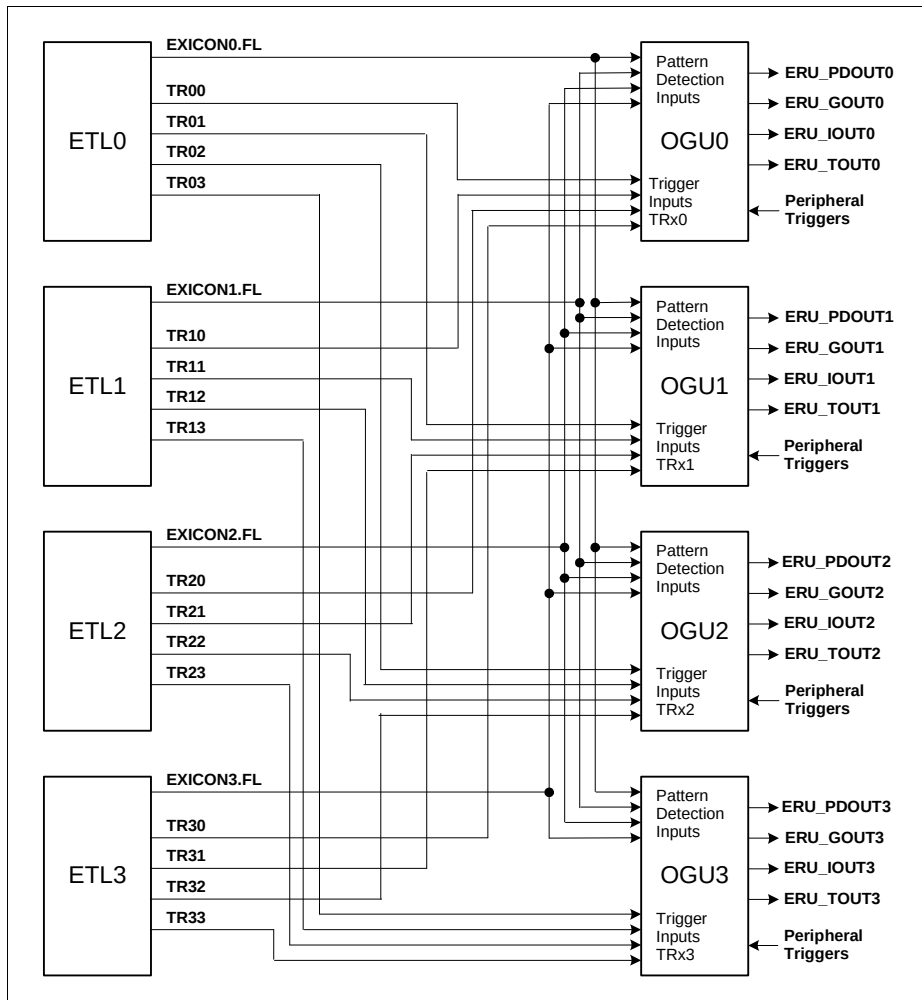


Figure 6-4 ERU Cross Connect Matrix

6.6 Output Gating Unit (OGUy)

Each OGUy (y = 0-3) unit combines the available trigger events and status flags from the Input Channels and distributes the results to the system. [Figure 6-5](#) illustrates the logic blocks within an OGUy unit. All functions of an OGUy unit are controlled by its associated

Event Request Unit (ERU)

EXOCONy register, e.g. **ERU0_EXOCONx** (x=0-3) for OGU0. 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, a selected peripheral-related trigger event, and a pattern change event (if enabled) are logically OR-combined.
- **Pattern Detection:**
The status flags EXICONx.FL 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.

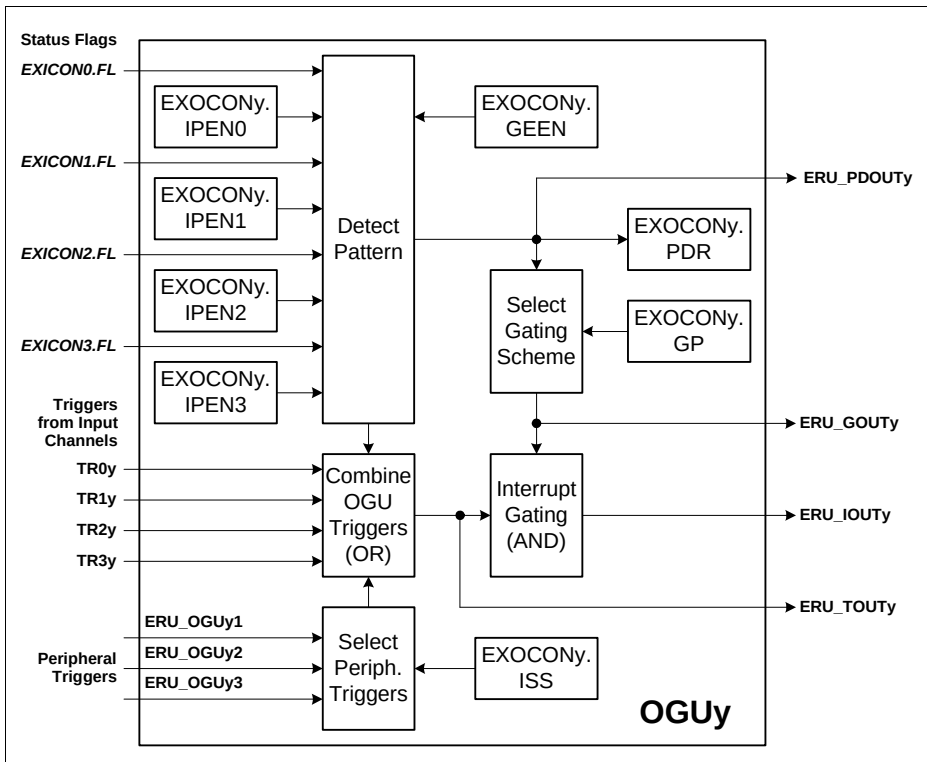


Figure 6-5 Output Gating Unit for Output Channel y

Each OGUy unit generates 4 output signals that are distributed to the system (not all of them are necessarily used):

- **ERU_PDOUTy** to directly output the pattern match information for gating purposes in other modules (pattern match = 1).

Event Request Unit (ERU)

- **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 service requests (e.g. the service request generation can be gated to allow service request activation during a certain time window).

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 (EXOCONy.IPENx) 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 ECOCONy.GEEN).

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 service request or to start an ADC conversion. This combination capability allows the generation of a service request per OGU that can be triggered by several inputs (multitude of request sources results in one reaction).

The selection is defined by the bit fields ISS in registers **ERU0_EXOCONx (x=0-3)**.

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 EXOCONy.IPENx. The pattern detection block outputs the following pattern detection results:

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

Event Request Unit (ERU)

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 EXOCONy.GEEN = 1). The pattern result change event is logically OR-combined with the other enabled trigger events to support service request generation or to trigger other module functions (e.g. in the ADC). The event is indicated when the pattern detection result changes and EXOCONy.PDR becomes updated.

The service request 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 service requests 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, service requests can be issued on a regular time base (peripheral trigger input from capture/compare unit is selected) 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 service requests ERU_IOUTy under different conditions:

- **Pattern match** (EXOCONy.GP = 10_B):
A service request is issued when a trigger event occurs while the pattern detection shows a pattern match.
- **Pattern miss** (EXOCONy.GP = 11_B):
A service request is issued when the trigger event occurs while the pattern detection shows a pattern miss.
- **Independent** of pattern detection (EXOCONy.GP = 01_B):
In this mode, each occurring trigger event leads to a service 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 service requests on trigger events).
- **No service requests** (EXOCONy.GP = 00_B, default setting)
In this mode, an occurring trigger event does not lead to a service 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 service requests on trigger events).

6.7 Power, Reset and Clock

ERU is running on the main clock, MCLK. It is consuming power in all operating modes as long as the MCLK continues to run.

6.8 Initialization and System Dependencies

Service Requests must always be enabled at the source and at the destination. Additionally it must be checked whether it is necessary to program the ERU0 process and route a request.

Enabling Peripheral SRx Outputs

- Peripherals' SRx outputs must be selectively enabled. This procedure depends on the individual peripheral. Please look up the section "Service Request Generation" within a peripheral chapter for details.
- Optionally ERU0 must be programmed to process and route the request

Enabling External Requests

- Selected PORTS must be programmed for input
- ERU0 must be programmed to process and route the external request

Note: The number of external service request inputs may be limited by the package used.

6.9 Registers

Table 6-1 Registers Address Space

Module	Base Address	End Address	Note
ERU0	4001 0600 _H	4001 06FF _H	

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 6-2 Register Overview

Short Name	Description	Offset Address	Access Mode		Description See
			Read	Write	
EXISEL	ERU External Input Control Selection	0000 _H	U, PV	U, PV	Page 6-11
EXICON0	ERU External Input Control Selection	0010 _H	U, PV	U, PV	Page 6-13
EXICON1	ERU External Input Control Selection	0014 _H	U, PV	U, PV	Page 6-13
EXICON2	ERU External Input Control Selection	0018 _H	U, PV	U, PV	Page 6-13
EXICON3	ERU External Input Control Selection	001C _H	U, PV	U, PV	Page 6-13
EXOCON0	ERU Output Control Register	0020 _H	U, PV	U, PV	Page 6-15
EXOCON1	ERU Output Control Register	0024 _H	U, PV	U, PV	Page 6-15
EXOCON2	ERU Output Control Register	0028 _H	U, PV	U, PV	Page 6-15
EXOCON3	ERU Output Control Register	002C _H	U, PV	U, PV	Page 6-15

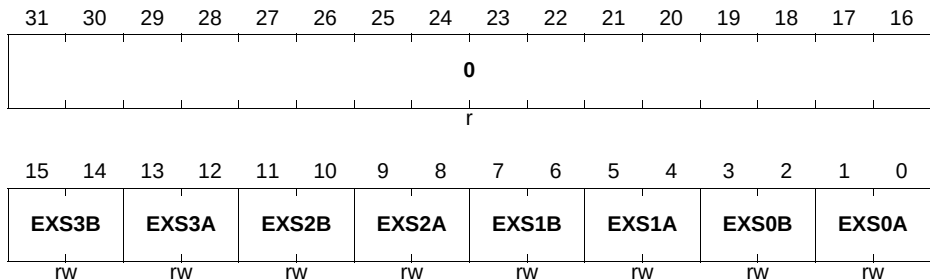
6.9.1 ERU Registers

ERU0_EXISEL

Event Input Select

(00_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
EXS0A	[1:0]	rw	Event Source Select for A0 (ERS0) This bit field defines which input is selected for A0. 00 _B Input ERU_0A0 is selected 01 _B Input ERU_0A1 is selected 10 _B Input ERU_0A2 is selected 11 _B Input ERU_0A3 is selected
EXS0B	[3:2]	rw	Event Source Select for B0 (ERS0) This bit field defines which input is selected for B0. 00 _B Input ERU_0B0 is selected 01 _B Input ERU_0B1 is selected 10 _B Input ERU_0B2 is selected 11 _B Input ERU_0B3 is selected
EXS1A	[5:4]	rw	Event Source Select for A1 (ERS1) This bit field defines which input is selected for A1. 00 _B Input ERU_1A0 is selected 01 _B Input ERU_1A1 is selected 10 _B Input ERU_1A2 is selected 11 _B Input ERU_1A3 is selected
EXS1B	[7:6]	rw	Event Source Select for B1 (ERS1) This bit field defines which input is selected for B1. 00 _B Input ERU_1B0 is selected 01 _B Input ERU_1B1 is selected 10 _B Input ERU_1B2 is selected 11 _B Input ERU_1B3 is selected

Event Request Unit (ERU)

Field	Bits	Type	Description
EXS2A	[9:8]	rw	Event Source Select for A2 (ERS2) This bit field defines which input is selected for A2. 00 _B Input ERU_2A0 is selected 01 _B Input ERU_2A1 is selected 10 _B Input ERU_2A2 is selected 11 _B Input ERU_2A3 is selected
EXS2B	[11:10]	rw	Event Source Select for B2 (ERS2) This bit field defines which input is selected for B2. 00 _B Input ERU_2B0 is selected 01 _B Input ERU_2B1 is selected 10 _B Input ERU_2B2 is selected 11 _B Input ERU_2B3 is selected
EXS3A	[13:12]	rw	Event Source Select for A3 (ERS3) This bit field defines which input is selected for A3. 00 _B Input ERU_3A0 is selected 01 _B Input ERU_3A1 is selected 10 _B Input ERU_3A2 is selected 11 _B Input ERU_3A3 is selected
EXS3B	[15:14]	rw	Event Source Select for B3 (ERS3) This bit field defines which input is selected for B3. 00 _B Input ERU_3B0 is selected 01 _B Input ERU_3B1 is selected 10 _B Input ERU_3B2 is selected 11 _B Input ERU_3B3 is selected
0	[31:16]	r	Reserved Read as 0; should be written with 0.

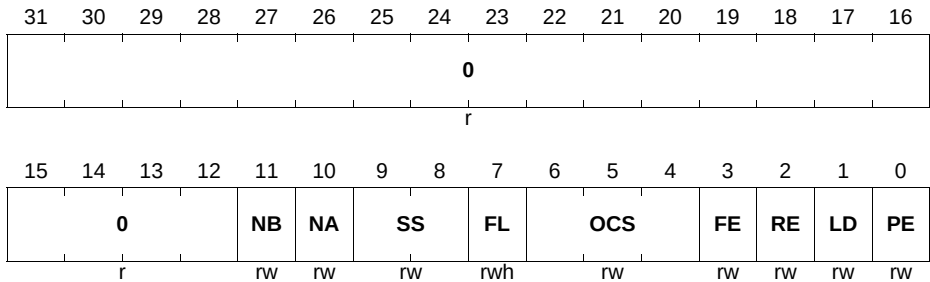
Event Request Unit (ERU)

ERU0_EXICONx (x=0-3)

Event Input Control x

(10_H + 4*x)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
PE	0	rw	Output Trigger Pulse Enable for ETLx This bit enables the generation of an output trigger pulse at TRxy when the selected edge is detected (set condition for the status flag FL). 0 _B The trigger pulse generation is disabled 1 _B The trigger pulse generation is enabled
LD	1	rw	Rebuild Level Detection for Status Flag for ETLx This bit selects if the status flag FL is used as “sticky” bit or if it rebuilds the result of a level detection. 0 _B The status flag FL is not cleared by hardware and is used as “sticky” bit. Once set, it is not influenced by any edge until it becomes cleared by software. 1 _B The status flag FL rebuilds a level detection of the desired event. It becomes automatically set with a rising edge if RE = 1 or with a falling edge if FE = 1. It becomes automatically cleared with a rising edge if RE = 0 or with a falling edge if FE = 0.
RE	2	rw	Rising Edge Detection Enable ETLx This bit enables/disables the rising edge event as edge event as set condition for the status flag FL or as possible trigger pulse for TRxy. 0 _B A rising edge is not considered as edge event 1 _B A rising edge is considered as edge event

Event Request Unit (ERU)

Field	Bits	Type	Description
FE	3	rw	Falling Edge Detection Enable ETLx This bit enables/disables the falling edge event as edge event as set condition for the status flag FL or as possible trigger pulse for TRxy. 0 _B A falling edge is not considered as edge event 1 _B A falling edge is considered as edge event
OCS	[6:4]	rw	Output Channel Select for ETLx Output Trigger Pulse This bit field defines which Output Channel OGUy is targeted by an enabled trigger pulse TRxy. 000 _B Trigger pulses are sent to OGU0 001 _B Trigger pulses are sent to OGU1 010 _B Trigger pulses are sent to OGU2 011 _B Trigger pulses are sent to OGU3 Others: Reserved, do not use this combination
FL	7	rwh	Status Flag for ETLx This bit represents the status flag that becomes set or cleared by the edge detection. 0 _B The enabled edge event has not been detected 1 _B The enabled edge event has been detected
SS	[9:8]	rw	Input Source Select for ERSx This bit field defines which logical combination is taken into account as ERSxO. 00 _B Input A without additional combination 01 _B Input B without additional combination 10 _B Input A OR input B 11 _B Input A AND input B
NA	10	rw	Input A Negation Select for ERSx This bit selects the polarity for the input A. 0 _B Input A is used directly 1 _B Input A is inverted
NB	11	rw	Input B Negation Select for ERSx This bit selects the polarity for the input B. 0 _B Input B is used directly 1 _B Input B is inverted
0	[31:12]	r	Reserved Read as 0; should be written with 0.

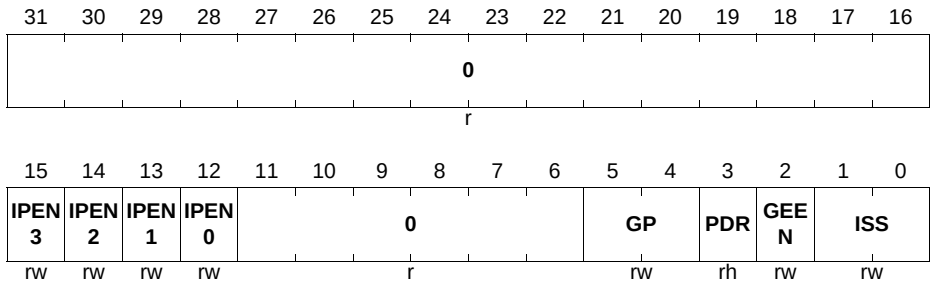
Event Request Unit (ERU)

ERU0_EXOCONx (x=0-3)

Event Output Trigger Control x

($20_H + 4 \cdot x$)

Reset Value: 0000 0008_H



Field	Bits	Type	Description
ISS	[1:0]	rw	Internal Trigger Source Selection This bit field defines which input is selected as peripheral trigger input for OGUy. 00 _B The peripheral trigger function is disabled 01 _B Input ERU_OGUy1 is selected 10 _B Input ERU_OGUy2 is selected 11 _B Input ERU_OGUy3 is selected
GEEN	2	rw	Gating Event Enable Bit GEEN enables the generation of a trigger event when the result of the pattern detection changes from match to miss or vice-versa. 0 _B The event detection is disabled 1 _B The event detection is enabled
PDR	3	rh	Pattern Detection Result Flag This bit represents the pattern detection result. 0 _B A pattern miss is detected 1 _B A pattern match is detected

Event Request Unit (ERU)

Field	Bits	Type	Description
GP	[5:4]	rw	Gating Selection for Pattern Detection Result This bit field defines the gating scheme for the service request generation (relation between the OGU output ERU_PDOUTy and ERU_GOUTy). 00 _B ERU_GOUTy is always disabled and ERU_IOUTy can not be activated 01 _B ERU_GOUTy is always enabled and ERU_IOUTy becomes activated with each activation of ERU_TOUTy 10 _B ERU_GOUTy is equal to ERU_PDOUTy and ERU_IOUTy becomes activated with an activation of ERU_TOUTy while the desired pattern is detected (pattern match PDR = 1) 11 _B ERU_GOUTy is inverted to ERU_PDOUTy and ERU_IOUTy becomes activated with an activation of ERU_TOUTy while the desired pattern is not detected (pattern miss PDR = 0)
IPENx (x = 0-3)	12+x	rw	Pattern Detection Enable for ETLx Bit IPENx defines whether the trigger event status flag EXICONx.FL of ETLx takes part in the pattern detection of OGUy. 0 _B Flag EXICONx.FL is excluded from the pattern detection 1 _B Flag EXICONx.FL is included in the pattern detection
0	[31:16] , [11:6]	r	Reserved Read as 0; should be written with 0.

6.10 Interconnects

This section describes how the ERU0 module is connected within the XMC1200 system.

Event Request Unit (ERU)

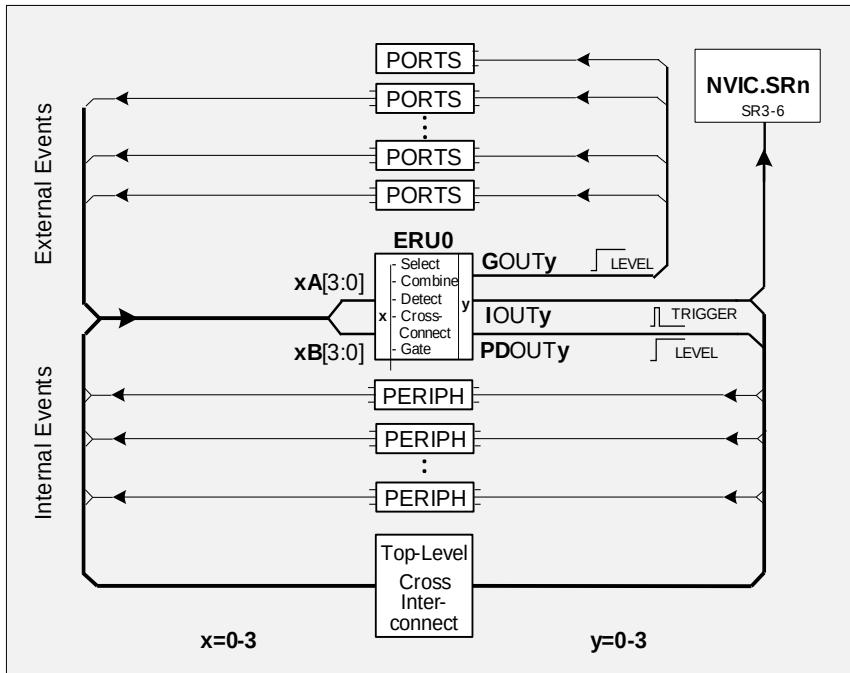


Figure 6-6 ERU Interconnects Overview

6.10.1 ERU0 Connections

The following table shows the ERU0 connections.

Table 6-3 ERU0 Pin Connections

Global Inputs/Outputs	Connected To	I/O	Description
ERU0.OA0	ACMP0.OUT	I	
ERU0.OA1	P2.4	I	
ERU0.OA2	ORC2.OUT	I	
ERU0.OA3	VADC0.G0BFLOUT0	I	from ADC boundary flag
ERU0.OB0	P2.0	I	
ERU0.OB1	P2.2	I	

Event Request Unit (ERU)
Table 6-3 ERU0 Pin Connections

Global Inputs/Outputs	Connected To	I/O	Description
ERU0.0B2	ORC0.OUT	I	
ERU0.0B3	VADC0.G1BFLOUT0	I	from ADC boundary flag
ERU0.1A0	ACMP1.OUT	I	
ERU0.1A1	P2.5	I	
ERU0.1A2	ORC3.OUT	I	
ERU0.1A3	VADC0.G0BFLOUT1	I	from ADC boundary flag
ERU0.1B0	P2.1	I	
ERU0.1B1	P2.3	I	
ERU0.1B2	ORC1.OUT	I	
ERU0.1B3	VADC0.G1BFLOUT1	I	from ADC boundary flag
ERU0.2A0	ACMP2.OUT	I	
ERU0.2A1	P2.6	I	
ERU0.2A2	ORC4.OUT	I	
ERU0.2A3	VADC0.G0BFLOUT2	I	from ADC boundary flag
ERU0.2B0	P2.10	I	
ERU0.2B1	P2.11	I	
ERU0.2B2	ORC2.OUT	I	
ERU0.2B3	VADC0.G1BFLOUT2	I	from ADC boundary flag
ERU0.3A0	ORC7.OUT	I	
ERU0.3A1	P2.7	I	
ERU0.3A2	ORC5.OUT	I	
ERU0.3A3	VADC0.G0BFLOUT3	I	from ADC boundary flag
ERU0.3B0	P2.9	I	
ERU0.3B1	P2.8	I	
ERU0.3B2	ORC6.OUT	I	
ERU0.3B3	VADC0.G1BFLOUT3	I	from ADC boundary flag
ERU0.0GU01	CCU40.SR0	I	
ERU0.0GU02	VADC0.C0SR2	I	
ERU0.0GU03	reserved	I	
ERU0.0GU11	CCU40.SR1	I	

Event Request Unit (ERU)

Table 6-3 ERU0 Pin Connections

Global Inputs/Outputs	Connected To	I/O	Description
ERU0.OGU12	VADC0.C0SR2	I	
ERU0.OGU13	reserved	I	
ERU0.OGU21	CCU40.SR2	I	
ERU0.OGU22	VADC0.C0SR3	I	
ERU0.OGU23	reserved	I	
ERU0.OGU31	CCU40.SR3	I	
ERU0.OGU32	VADC0.C0SR3	I	
ERU0.OGU33	reserved	I	
ERU0.PDOUT0	VADC0.BGREQGTO VADC0.G0REQGTO VADC0.G1REQGTO CCU40.IN1D CCU40.IN0J USIC0_CH1.HWIN0 P0.0 P2.11	O	
ERU0.GOUT0	P0.0 P2.11	O	
ERU0.TOUT0	not connected	O	
ERU0.IOUT0	NVIC.ERU0.SR0 SCU.RTC_extclk VADC0.BGREQTRM VADC0.G0REQTRM VADC0.G1REQTRM CCU40.CLKB CCU40.IN0K BCCU0.TRAPINE	O	
ERU0.PDOUT1	VADC0.BGREQGTP VADC0.G0REQGTP VADC0.G1REQGTP CCU40.IN0D CCU40.IN1J USIC0_CH1.HWIN2 P0.1 P2.10	O	

Event Request Unit (ERU)

Table 6-3 ERU0 Pin Connections

Global Inputs/Outputs	Connected To	I/O	Description
ERU0.GOUT1	P0.1 P2.10	O	
ERU0.TOUT1	not connected	O	
ERU0.IOUT1	NVIC.ERU0.SR1 VADC0.BGREQTRN VADC0.G0REQTRN VADC0.G1REQTRN CCU40.CLKC CCU40.IN1K BCCU0.TRAPINF	O	
ERU0.PDOUT2	VADC0.BGREQGTK VADC0.G0REQGTK VADC0.G1REQGTK CCU40.IN3D CCU40.IN2J P0.2 P2.1	O	
ERU0.GOUT2	P0.2 P2.1	O	
ERU0.TOUT2	not connected	O	
ERU0.IOUT2	NVIC.ERU0.SR2 VADC0.BGREQTRG VADC0.G0REQTRG VADC0.G1REQTRG CCU40.IN2K BCCU0.TRAPING	O	
ERU0.PDOUT3	VADC0.BGREQGTL VADC0.G0REQGTL VADC0.G1REQGTL CCU40.IN3J CCU40.IN2D P0.3 P2.0	O	
ERU0.GOUT3	P0.3 P2.0	O	

Table 6-3 ERU0 Pin Connections

Global Inputs/Outputs	Connected To	I/O	Description
ERU0.TOUT3	not connected	O	
ERU0.IOUT3	NVIC.ERU0.SR3 VADC0.BGREQTRH VADC0.G0REQTRH VADC0.G1REQTRH CCU40.IN3K BCCU0.TRAPINH	O	

On-Chip Memories

7 Memory Organization

This chapter provides description of the system memory organization, memory accesses and memory protection strategy.

References

[5] Cortex®-M0 User Guide, ARM DUI 0497A (ID112109)

7.1 Overview

The Memory Map in XMC1200 is based on standard ARM Cortex-M0 system memory map.

7.1.1 Features

The Memory Map implements the following features:

- Compatibility with standard ARM Cortex-M0 CPU [\[5\]](#)
- Full compatibility across entire XMC1000 Family

7.1.2 Cortex-M0 Address Space

The system memory map defines several regions. Address boundaries of each of the regions are determined by the Cortex-M0 core architecture.

Memory Organization

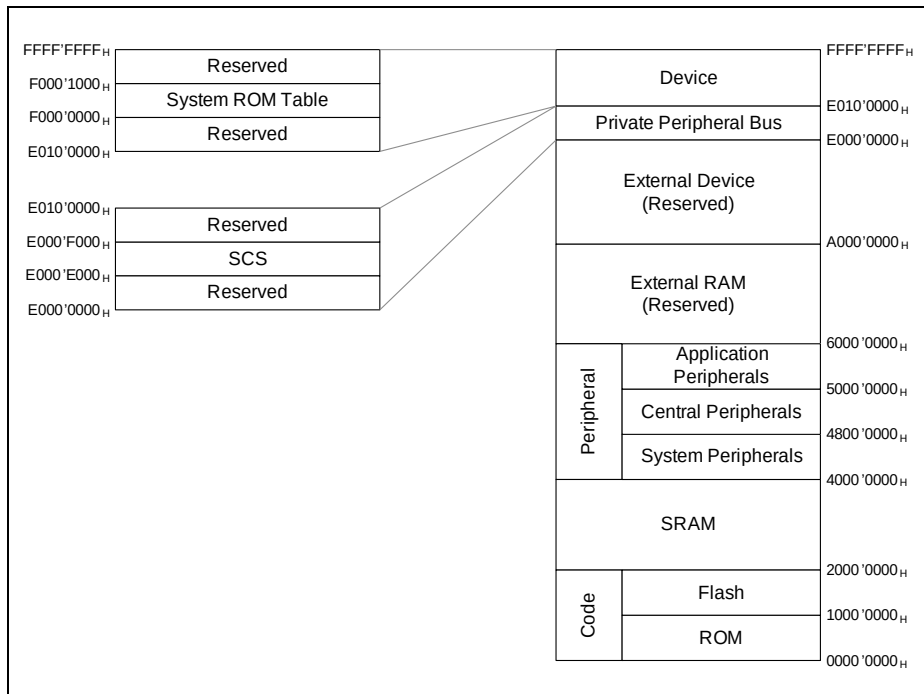


Figure 7-1 XMC1200 Address Space

7.2 Memory Regions

The XMC1200 device-specific address map contains on-chip memories and peripherals. The memory regions for XMC1200 are described in [Table 7-1](#).

Table 7-1 Memory Regions

Start (hex)	End (hex)	Size (hex)	Space name	Usage
00000000	1FFFFFFF	20000000	Code	ROM Firmware, Flash
20000000	3FFFFFFF	20000000	SRAM	Fast internal SRAM
40000000	47FFFFFF	08000000	Peripheral	System Peripherals group

Memory Organization

Table 7-1 Memory Regions (cont'd)

Start (hex)	End (hex)	Size (hex)	Space name	Usage
48000000	4FFFFFFF	08000000	Peripheral	Central Peripherals group
50000000	57FFFFFFF	08000000	Peripheral	Application Peripherals group
58000000	5FFFFFFF	08000000	Peripheral	reserved
60000000	9FFFFFFF	40000000	External SRAM	reserved
A0000000	DFFFFFFF	40000000	External Device	reserved
E0000000	E0FFFFFF	00100000	Private Peripheral Bus	CPU
E0100000	FFFFFFF	0FF00000	Vendor specific 1	reserved
F0000000	FFFFFFF	10000000	Vendor specific 2	System ROM Table

7.3 Memory Map

Table 7-2 defines detailed system memory map of XMC1200 where each individual peripheral or memory instance implement its own address spaces. For detailed register description of the system components and peripherals, please refer to respective chapters of this document.

Note: Depending on the device variant, not all peripherals and memory address ranges may be available.

Memory Organization
Table 7-2 Memory Map

Address space	Address Range	Description	Access Type ¹⁾	
			Read	Write
Code	00000000 _H - 00000BFF _H	ROM (user-readable)	U, PV	nBE
	00000C00 _H - 00001FFF _H	ROM (non-user-readable)	BE	BE
	00002000 _H - 0FFFFFFF _H	reserved	BE	BE
	10000000 _H - 10000DFF _H	Flash Sector 0 (non-user-readable)	nBE	nBE
	10000E00 _H - 10000FFF _H	Flash Sector 0 (user-readable)	U, PV	nBE
	10001000 _H - 10032FFF _H	Flash (200 Kbytes)	U, PV	U, PV
	10033000 _H - 1FFFFFFF _H	reserved	BE	BE
SRAM ²⁾	20000000 _H - 20000FFF _H	SRAM Block 0	U, PV	U, PV
	20001000 _H - 20001FFF _H	SRAM Block 1	U, PV	U, PV
	20002000 _H - 20002FFF _H	SRAM Block 2	U, PV	U, PV
	20003000 _H - 20003FFF _H	SRAM Block 3	U, PV	U, PV
	20004000 _H - 3FFFFFFF _H	reserved	BE	BE

Memory Organization

Table 7-2 Memory Map (cont'd)

Address space	Address Range	Description	Access Type ¹⁾	
			Read	Write
System Peripherals	40000000 _H - 400007FF _H	Memory Control	U, PV	U, PV
	40000800 _H - 4000FFFF _H	reserved	BE	BE
	40010000 _H - 40010FFF _H	SCU (including RTC)	U, PV	U, PV
	40011000 _H - 4001107F _H	ANACTRL	U, PV	U, PV
	40011080 _H - 4001FFFF _H	reserved	BE	BE
	40020000 _H - 4002001F _H	WDT	U, PV	U, PV
	40020020 _H - 4003FFFF _H	reserved	BE	BE

Memory Organization
Table 7-2 Memory Map (cont'd)

Address space	Address Range	Description	Access Type ¹⁾	
			Read	Write
System Peripherals (cont'd)	40040000 _H - 4004007F _H	Port 0	U, PV	U, PV
	40040080 _H - 400400FF _H	reserved	BE	BE
	40040100 _H - 4004017F _H	Port 1	U, PV	U, PV
	40040180 _H - 400401FF _H	reserved	BE	BE
	40040200 _H - 4004027F _H	Port 2	U, PV	U, PV
	40040280 _H - 4004FFFF _H	reserved	BE	BE
	40050000 _H - 400500DF _H	Flash Registers	U, PV	U, PV
	400500E0 _H - 47FFFFFF _H	reserved	BE	BE
Central Peripherals	48000000 _H - 480001FF _H	USIC0 Channel 0	U, PV	U, PV
	48000200 _H - 480003FF _H	USIC0 Channel 1	U, PV	U, PV
	48000400 _H - 480007FF _H	USIC0 RAM	nBE	BE
	48000800 _H - 4801FFFF _H	reserved	BE	BE
	48020000 _H - 4802000F _H	PRNG	U, PV	U, PV
	48020010 _H - 4802FFFF _H	reserved	BE	BE

Memory Organization

Table 7-2 Memory Map (cont'd)

Address space	Address Range	Description	Access Type ¹⁾	
			Read	Write
Central Peripherals (cont'd)	48030000 _H - 480303FF _H	VADC0 General and Global Registers	U, PV	U, PV
	48030400 _H - 480307FF _H	VADC0 Group 0	U, PV	U, PV
	48030800 _H - 48030BFF _H	VADC0 Group 1	U, PV	U, PV
	48030C00 _H - 48033FFF _H	reserved	BE	BE
	48034000 _H - 480341FF _H	SHS0	U, PV	U, PV
	48034200 _H - 4803FFFF _H	reserved	BE	BE
	48040000 _H - 480401FF _H	CCU40 CC40 and Kernel Registers	U, PV	U, PV
	48040200 _H - 480402FF _H	CCU40 CC41	U, PV	U, PV
	48040300 _H - 480403FF _H	CCU40 CC42	U, PV	U, PV
	48040400 _H - 480404FF _H	CCU40 CC43	U, PV	U, PV
	48040500 _H - 4FFFFFFF _H	reserved	BE	BE

Memory Organization
Table 7-2 Memory Map (cont'd)

Address space	Address Range	Description	Access Type ¹⁾	
			Read	Write
Application Peripherals	50000000 _H - 5001FFFF _H	reserved	BE	BE
	50020000 _H - 5002003F _H	LEDTS0	U, PV	U, PV
	50020040 _H - 500203FF _H	reserved	BE	BE
	50020400 _H - 5002043F _H	LEDTS1	U, PV	U, PV
	50020440 _H - 5002FFFF _H	reserved	BE	BE
	50030000 _H - 500301FF _H	BCCU0	U, PV	U, PV
	50030200 _H - 57FFFFFF _H	reserved	BE	BE
Peripheral	58000000 _H - 5FFFFFFF _H	reserved	BE	BE
External SRAM	60000000 _H - 9FFFFFFF _H	reserved	BE	BE
External Device	A0000000 _H - DFFFFFFF _H	reserved	BE	BE
Private Peripheral Bus	E0000000 _H - E00FFFFF _H	NVIC, System timer, System Control Block	U, PV	U, PV
Vendor specific 1	E0100000 _H - EFFFFFFF _H	reserved	BE	BE
Vendor specific 2	F0000000 _H - F0000FFF _H	System ROM Table	U, PV	nBE
	F0001000 _H - FFFFFFF _H	reserved	BE	BE

1) For address ranges taken up by peripherals, the access type for each address in the range may differ from that shown in the table. Refer to respective chapters for details.

2) The address range 2000'0000_H to 2000'01FF_H will be overwritten by start-up software during device start-up.

7.4 Memory Access

This section describes the memory accesses to the different type of memories in XMC1200.

7.4.1 Flash Memory Access

The XMC1200 provides up to 200 Kbytes of Flash memory for instruction code or constant data, starting at address 1000'1000_H. This excludes Flash sector 0, which is used to store system information and is always read only.

The Flash memory will insert waitstates during memory read automatically if needed.

For details of Flash memory access, refer to the Flash Architecture chapter.

7.4.2 SRAM Access

The XMC1200 provides 16 Kbytes of SRAM for instruction code or constant data, as well as system variables such as the system stack, starting at address 2000'0000_H.

The SRAM supports 8-bit, 16-bit and 32-bit writes, and generates one parity bit for each 8 bits of written data. A read operation will check for parity errors on the 32-bit read data. Accesses to the SRAM require no wait states.

The 16 Kbytes of SRAM is logically divided into four blocks of 4 Kbytes each. Accesses to blocks 1, 2 and 3 can be disabled and enabled again during run-time with the peripheral privilege access scheme. See PAU chapter for details.

Note: The address range 2000'0000_H to 2000'01FF_H will be overwritten by the start-up software during device start-up. Therefore, these addresses should not be targeted during the download of code/data by the bootstrap loader into the SRAM nor should they store critical data that are still needed by the application after a system reset or SW master reset.

7.4.3 ROM Access

The XMC1200 provides 8 Kbytes of ROM, which contains the startup software, vector table and user routines.

Read accesses to the ROM require no wait states.

7.5 Memory Protection Strategy

Two aspects of memory protection are considered:

1. Intellectual Property (IP) Protection
2. Memory Access Protection during Run-time

The memory protection measures available in XMC1200 are listed in [Table 7-3](#).

Table 7-3 Memory Protection Measures

Protection Aspects	Protection Measures	Protection Target
IP protection	Blocking of unauthorized external access	Flash memory contents
Memory access protection	Bit protection scheme	Specific system-critical registers/bit fields
	Peripheral privilege access control	Specific address ranges; each range can be controlled independently

7.5.1 Intellectual Property (IP) Protection

IP protection refers to the prevention against unauthorized read out of critical data and user IP from Flash memory.

7.5.1.1 Blocking of Unauthorized External Access

In XMC1200, the Boot Mode Index (BMI) is used to control the boot options such that once the BMI is programmed to enter user mode (productive), it is not allowed to enter the other boot modes without an erase of the complete user Flash (including sector 0).

Therefore, boot options that load and execute external code, including unauthorized code that might read out the Flash memory contents, will be blocked and only user code originating from the Flash memory can be executed.

7.5.2 Memory Access Protection during Run-time

Memory access protection refers to the prevention against unintended write access on a memory address space during run-time.

7.5.2.1 Bit Protection Scheme

The bit protection scheme prevents direct software writing of selected register bits (i.e., protected bits) using the PASSWD register in the SCU module. When the bit field MODE is 11_B , writing 10011_B to the bit field PASS opens access to writing of all protected bits, and writing 10101_B to the bit field PASS closes access to writing of all protected bits. In both cases, the value of the bit field MODE is not changed even if PASSWD register is written with 98_H or $A8_H$. It can only be changed when bit field PASS is written with 11000_B , for example, writing $0000'00C0_H$ to PASSWD register disables the bit protection scheme.

Access is opened for maximum 32 MCLKs if the “close access” password is not written. If “open access” password is written again before the end of 32 MCLK cycles, there will be a recount of 32 MCLK cycles.

Table 7-4 shows the list of protected bit in XMC1200.

Table 7-4 List of Protected Register Bit Fields

Register	Bit Field
SCU_CLKCR	FDIV, IDIV, PCLKSEL, RTCLKSEL
SCU_CGATSET0	All bits
SCU_CGATCLR0	All bits
SCU_ANAOFFSET	ADJL_OFFSET
VADC0_ACCPROT0	All bits
VADC0_ACCPROT1	All bits

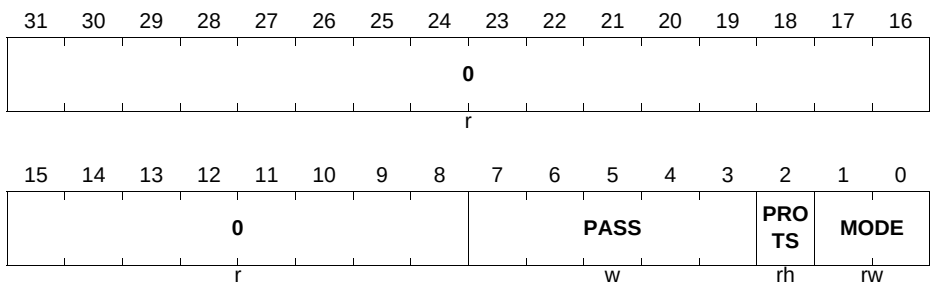
Write to all protected registers except VADC0_ACCPROT[1:0], without opening access through bit field PASS, will be ignored. No bus error will be generated. User should read back the register value to ensure the write has taken place.

Write to VADC0_ACCPROT[1:0], without opening access through bit field PASS, will trigger a hard fault. If an interrupt occurs immediately after the access is opened and the interrupt service routine requires more than 32 MCLK cycles, the write to the register will happen after the access is closed and thereby, triggering a hard fault. To avoid this, interrupts should be disabled before writing to these two registers.

The PASSWD register is also described in the SCU chapter.

SCU_PASSWD

Password Register (4001 0024_H) Reset Value: 0000 0007_H



Field	Bits	Type	Description
MODE	[1:0]	rw	Bit Protection Scheme Control Bits 00 _B Scheme disabled - direct access to the protected bits is allowed. 11 _B Scheme enabled - the bit field PASS has to be written with the passwords to open and close the access to the protected bits. (Default) Others: Scheme enabled, similar to the setting for MODE = 11 _B . These two bits cannot be written directly. To change the value between 11 _B and 00 _B , the bit field PASS must be written with 11000 _B . Only then will the MODE bit field be registered.
PROTS	2	rh	Bit Protection Signal Status Bit This bit shows the status of the protection. 0 _B Software is able to write to all protected bits. 1 _B Software is unable to write to any of the protected bits.
PASS	[7:3]	w	Password Bits This bit protection scheme only recognizes the following three passwords: 11000 _B Enables writing of the bit field MODE. 10011 _B Opens access to writing of all protected bits. 10101 _B Closes access to writing of all protected bits.
0	[31:8]	r	Reserved

7.5.2.2 Peripheral Privilege Access Control

All CPU accesses are privileged accesses. In XMC1200, a separate scheme called Peripheral Privilege Access Control, which allows a peripheral's memory address space to be disabled to block any unintended write or read access, is provided. The address space can be re-enabled when necessary.

Refer to the PAU chapter for details.

7.6 Service Request Generation

Memory modules and other system components are capable of generating error responses indicated to the CPU as bus error exceptions or interrupts.

Types of Error Causes

- Unsupported Access Mode
- Access to Invalid Address
- Data integrity Error (memories only)

Errors that cannot be indicated with bus errors get indicated with service requests that get propagated to the CPU as interrupts.

Unsupported Access Modes

Unsupported access modes can be classified in various ways and are usually specific to the module that access is performed to. Typical examples of unsupported access modes are write access to read-only type of address mapped resources, protected memory regions. For module specific limitations please refer to individual module chapters.

Invalid Address

Accesses to invalid addresses result in error responses. Invalid addresses are defined as those that do not mapped to any valid resources. This applies to single addresses and to wider address ranges. Some invalid addresses within valid module address ranges may not produce error responses and this is specific to individual modules.

Data Integrity Error

Accesses to corrupted data in the memories result in either ECC (Error Correction Code) (ECC) or parity errors. The occurrence of such errors get signaled to the system through an SCU interrupt.

7.7 Debug Behaviour

The bus system in debug mode allows debug probe access to all system resources. No special handling of HALT mode is implemented and all interfaces respond with a valid bus response upon accesses.

7.8 Power, Reset and Clock

The bus system clocking scheme enables stable system operation and accesses to system resources for all valid system clock rates.

7.9 Initialization and System Dependencies

No initialization is required for the memory system from user point of view. All valid memories are available after reset. Some peripherals may need to be initialized (e.g. disable clock gating) before they can be accessed. For details please refer to individual peripheral chapters.

8 Flash Architecture

This chapter describes the non volatile memory (NVM) module.

8.1 Overview

The XMC1200 has an embedded user-programmable NVM for storage of user code and data.

8.1.1 Features

The NVM has the following features:

- Reading by word, writing by block and erasing by page (256 bytes) or sector (4 Kbytes).
- Fast personalization support.
- Automatic verify support.
- Up to 50,000 erase cycles per page.
- Minimum data retention of 10 years in cells that were never previously programmed.
- Flash programming voltage generated on-chip.
- Configurable erase and write protection.
- Power saving sleep mode.
- Incremental write without erase for semaphores.

8.2 Definitions

Throughout the document the terms NVM (Non Volatile Memory) and Flash are used as synonyms, disregarding the fact that NVM describes a broader class of memories, where the described Flash is only a special case.

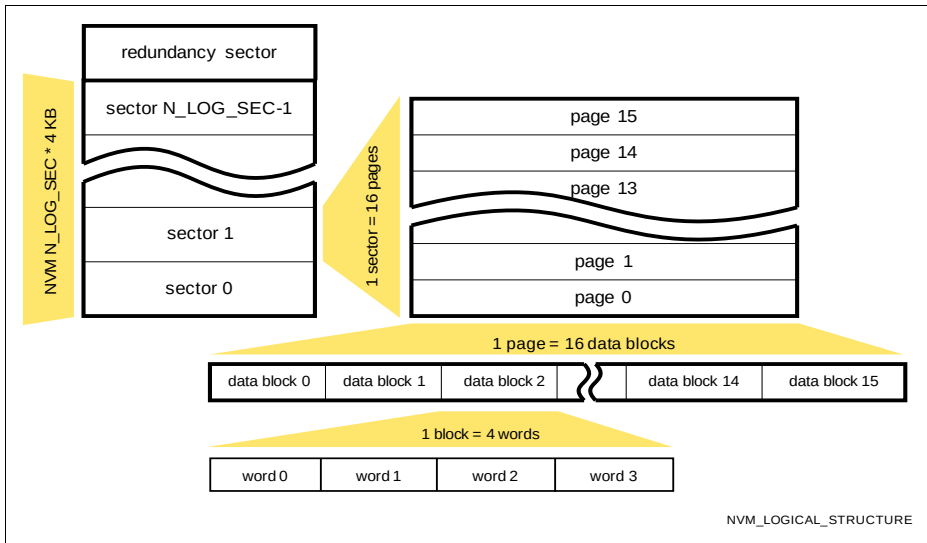


Figure 8-1 Logical structure of the NVM module

8.2.1 Logical and Physical States

Erasing

The erased state of a cell is '1'. Forcing an NVM cell to this state is called erasing. Erasing is possible with a granularity of a page (see below).

Writing

The written state of a cell is '0'. Changing an erased cell to this state is called writing. Writing is possible with a granularity of a block (see below).

Programming

The combination of erasing and writing is called programming. Programming often means also writing a previously erased page.

*Note: The termini **write** and **writing** are also used for accessing special function registers. The meaning depends therefore on the context.*

8.2.2 Data Portions

Word

A word consists of 32 bits. A word represents the data size which is read from or written to the NVM module within one access cycle.

Block

A block consists of 4 words (128 bit data, extended by 4 bit parity, and 6 bit ECC). A block represents the smallest data portion that can be written.

Page

A page consists of 16 blocks.

Sector

A sector consists of 16 pages.

8.2.3 Address Types

Physical Address

Address of the CPU system.

Base Address or Memory Base Address

Physical address of the lower boundary for memory accesses of an NVM module.

Logical Address

Memory address offset inside the NVM module: If the memory is addressed, the logical address is the physical address subtracted by the base address of the module.

Sector Address

Module specific part of the logical address specifying the sector, for calculation see [Section 8.3.1](#).

Page Address

Module specific part of the logical address, for calculation see [Section 8.3.1](#).

8.2.4 Module Specific Definitions

The following table defines NVM specific constants used throughout this chapter.

Table 8-1 Module Specific Definitions

Module size [KB]	204	
Constant name	Value	Comment
N_BLOCKS	16	Number of blocks per page
N_PAGES	16	Number of pages per sector
N_SECTORS	52	Number of sectors including redundancy
N_LOG_SEC	51	Number of sectors excluding redundancy

8.3 Module Components

8.3.1 Memory Cell Array

The non-volatile memory cells are organized in sectors, which consist of pages, which on their part are structured in blocks.

A logical memory address `addr` has the following structure:

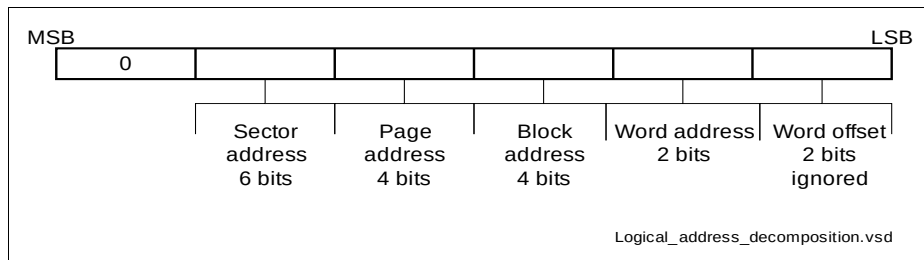


Figure 8-2 Decomposition of Logical Address

- `addr[1:0]` = word offset, for a memory address undefined and ignored
- `addr[3:2]` = word address
- `addr[7:4]` = block address
- `addr[11:8]` = page address
- `addr[17:12]` = sector address.

The memory subsystem always accesses whole words, therefore the word offset is ignored by the NVM module.

8.3.1.1 Page

Each page consists of 16 data blocks of 138 bits each (including parity bits and ECC bits).

A page is the granularity of data that can be erased in the cell array.

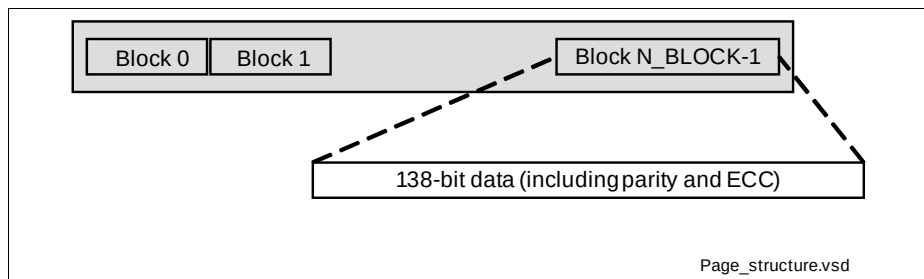


Figure 8-3 Structure of a Page

8.3.1.2 Sector

16 pages form a sector.

The whole cell array is build of 52 sectors.

8.4 Functional Description

The NVM module supports read and write accesses to the memory and to the special function registers (SFRs). No read-modify-write mechanism is supported for SFRs.

The main tasks of the NVM module are reading and writing from/to the memory array.

8.4.1 SFR Accesses

Reading the special function registers is possible in every mode of the NVM module.

Register write is not possible while the state machine is busy. The write is stalled in this case. For other exceptions see [Section 8.8.2.2](#).

8.4.2 Memory Read

The NVM memory can be read with a minimum granularity of a word provided that the word is in the memory address range of the module.

If the word is not within the memory address range of the NVM module, the module does not react at all and a different memory module may handle the access.

Memory read accesses are only possible while no FSM procedure (erase, write, verify, sleep or wake-up) is in progress. A memory read access while the FSM is busy is stalled until the FSM is idle again. Then the access is carried out. Such a stall will also stop the CPU from executing code.

Per default the XMC1200 devices use a configuration with adaptive wait states for read accesses to the flash memory, dynamically adapting to the system frequency and flash access timing without user software interaction.

8.4.2.1 Flash read access with fixed wait states

It is possible to configure the XMC1200 devices to apply fixed wait states to each flash read access, improving determinism of program execution from flash. The required number of wait states depends on the system frequency f_{MCLK} , as defined in the parameter $N_{FWSFLASH}$. The number of wait states can be configured with the bit [NVMCONF.WS](#), the selection of adaptive or fixed wait states is done with the bit [CONFIG1.WS](#).

Attention: Any write operation to the register [CONFIG1](#) to switch between adaptive and fixed wait states configuration must only modify the bit [CONFIG1.FIXWS](#). Changing other bits in [CONFIG1](#) can lead to unpredictable results.

Attention: Before and after the fixed wait states configuration or the system frequency f_{MCLK} is changed, the number of selected wait states must always comply to the parameter $N_{FWSFLASH}$.

Below is a code snippet defining the register addresses, configuring one wait state and then switching to operation with one fixed wait state.

Example

```
// Headers and variables to fix number of wait states to "1"
#define ADDR1 0x40050008 //Address of NVM_NVMCONF
uint32_t * NVM_NVMCONF = (uint32_t *) ADDR1;
#define ADDR2 0x40050048 //Address of NVM_CONFIG1
uint32_t * NVM_CONFIG1 = (uint32_t *) ADDR2;

// init sequence to fix number of wait states to "1"
*NVM_NVMCONF = *NVM_NVMCONF | 0x1000; //Set .WS bit => 1WS
*NVM_CONFIG1 = *NVM_CONFIG1 | 0x0800; //Set .FIXWS bit => fixed
WS scheme
```

8.4.3 Memory Write

From the user's viewpoint data is written directly to the memory array. Module internally one block is buffered and the ECC bits are calculated. Then a finite state machine is started that writes the ECC and data bits to the memory field.

Writing does not support wrap-around, i.e. writing of a block has always to start with word 0 of the selected block and then automatically continues in ascending order up to word 3.

Since a block has to be written in four word writing steps, a special procedure has to be followed to transfer complete block data to the NVM: Writing of a block has always to start with word 0 of the addressed block. The following three writes need to address the other three words of the same block in ascending order. If this rule is not observed, the already provided words are discarded. If in this case the last provided word is addressing a word 0, this word is already accepted as the first word of a new block write procedure. Intermediate read operations do not influence the write data transfer. Intermediate read operations targeting the same address as the interrupted write operation are served from the memory array, i.e. do not read back the already transferred write data.

To write to the memory array, the NVM module has to be set to one-shot or continuous write mode by setting the SFR **NVMPROG** to the corresponding value. Data to be written can now be written to the desired address. It is not checked, if the addressed block was erased before. Writing to a non erased block leads to corrupted data since writing can only clear bits but not set any bits. Reading such a block will lead most probably to an ECC fault.

A write access to the NVM when not in write mode does not trigger an exception or interrupt. The data is lost. Writes to the NVM are also used to trigger other operations which are described in the following subsections. Similarly, a write access to the NVM module has no effect and the data is lost when a protected sector is addressed (see [Section 8.4.7](#)).

Depending on the settings of **NVMPROG**, an automatic verify is performed (see [Section 8.4.6](#)).

In case of a one-shot write, write mode is automatically left. In case of continuous write mode, further write operations to new addresses can follow, until the write mode is explicitly left. Continuous write operations can target blocks within the complete memory without any restriction regarding sector or page borders.

8.4.4 Memory Erase

Only whole pages can be physically erased, i.e. all bits of the addressed page are physically set to '1'.

To erase a page in the memory field, the NVM module has to be set to one-shot or continuous page erase mode by setting the SFR **NVMPROG** to the corresponding value. A write access to a memory location specifies the address of the page to be erased and triggers the erase.

A write access to the NVM when not in page erase mode does not trigger an exception or interrupt because they are also used to trigger other operations; as described in this section. Similarly, no erase is triggered when a protected sector is addressed (see [Section 8.4.7](#)).

In case of a one-shot page erase, page erase mode is automatically left. In case of continuous page erase mode, further page erase operations can follow, until the page erase mode is explicitly left.

8.4.5 Sector Erase

Additionally, whole sectors consisting of 16 pages can be physically erased in parallel, i.e. all bits of the addressed sector are physically set to '1'.

To erase a sector in the memory array, the NVM module has to be set to one-shot or continuous sector erase mode by setting the SFR **NVMPROG** to the corresponding value. Writing arbitrary data to a memory location specifies the address of the sector to be erased.

A write access to the NVM when not in sector erase mode does not trigger an exception or interrupt because it is also used to trigger other operations; as described in this section. Similarly, no erase is triggered when a protected sector is addressed (see [Chapter 8.4.7](#)).

In case of a one-shot sector erase, sector erase mode is automatically left. In case of continuous sector erase mode, further sector erase operations can follow, until the sector erase mode is explicitly left.

8.4.6 Verify

The data written as described in [Section 8.4.3](#) can be verified automatically. The written data in the cell array can be automatically compared to the data still available in the module internal buffer. This is automatically performed two times with hardread written and hardread erased. These hardread levels provide some margin compared to the normal read level to ensure that the data is really programmed with suitably distinct levels for written and erased bits. The verification result can be read at SFR **NVMSTATUS**.

Stand-alone verify operations can also be started by setting the SFR **NVMPROG** to the corresponding value. In this case, data written to a memory location is compared with the content of the memory field at the specified address. The comparison here is performed just once with a read level chosen before from normal read, hardread written and hardread erased.

A write access to the NVM when not in verification mode does not trigger an exception or interrupt because it is also used to trigger other operations; as described in this section. Similarly, a write access to the NVM module has no effect, when a protected sector is addressed (see [Section 8.4.7](#)).

In case of a one-shot verify, verify mode is automatically left. In case of continuous verify mode, further verify operations can follow, until the verify mode is explicitly left.

Note: A continuous write operation without automatic verification, followed by two stand-alone verifications with 'hardread written' and 'hardread erased', is faster than a write operation with continuous automatic verification, since in the second case for every block write the hardread level has to be changed twice, whereas in the first case this change is performed only two times for the complete write data.

On the other hand, for the continuous automatic verification the reference data for the verification is directly available within the NVM module, whereas for the stand-alone verification the reference data needs to be provided again by the CPU.

8.4.7 Erase-Protection and Write-Protection

By setting **NVMCONF.SECPROT**, a configurable number of sectors can be selected to be protected from any modification, i.e. a range of sectors starting with sector 0 can be defined to be erase-protected and write-protected.

8.5 Redundancy

To increase the production yield, the NVM module contains redundancy. Redundancy is transparent to the user.

8.6 Properties and Implementation of Error Correcting Code (ECC)

The error correcting code (ECC) for the data blocks is a one-bit error correction and a (partial) double-bit error detection for every data block of 128 bit, which uses 4 parity bits and 6 ECC bits in addition to the protected 128 data bits. The correct ECC bits for every block are generated automatically when the data is written.

8.7 Service Request Generation

The NVM module supports immediate error and status information to the user by interrupt generation.

A NVM interrupt can be issued because of the following events:

- Completion of:
 - NVM operations started through NVMPROG.ACTION (except for verify-only sequence)
 - NVM wake-up sequence
- NVM ECC double-bit error

The NVM interrupt request is generated to the CPU through the SCU. Therefore, related interrupt control bits are located in the SCU but with the following exceptions:

- There are two sets of NVM ECC double-bit error status flag and clear status bit:
 - NVMSTATUS.ECC2READ and NVMPROG.RSTECC in NVM module
 - SCU_RAWSR.FLECC2I and SCU_SRCLR.FLECC2I in SCU module
- It is sufficient to use just one of the two sets and ignore the other.
- The interrupt enable bit for the NVM operation complete interrupt is located only in the NVMCONF register.

8.8 Power, Reset and Clock

The following sections describe the power, reset and clock sources of the NVM module.

8.8.1 Power Supply

The NVM module sources all voltages required for read, program and erase operations from the on-chip Embedded Voltage Regulator (EVR).

The standard V_{DDC} is used for all digital control functions.

8.8.2 Power Saving Modes

The NVM module supports the following power saving modes. The modes differ in power consumption and in the time to restart the memory.

8.8.2.1 NVM Idle Mode

Idle mode is entered after reset after charging the pumps. In idle mode the power consumption is less than during a memory read access or write access.

Any operation of the NVM module (SFR access or memory access) can be started from idle mode without time delay.

8.8.2.2 NVM Sleep Mode

Entering and leaving NVM sleep mode requires special state machine sequences, which need some time. Therefore, besides SFR accesses, the NVM module cannot be used immediately after wake-up from sleep mode, as indicated by **NVMSTATUS.BUSY**.

NVM sleep mode is entered via WFE/WFI when Flash Power down is activated, see SCU chapter. Alternatively, sleep mode for the NVM module can be triggered by writing the respective bit in SFR **NVMCONF**.

In NVM sleep mode only the SFR **NVMCONF** can be read and written, all other SFRs can only be read. No memory access is possible in sleep mode.

8.8.3 Reset

The NVM module is reset with the system reset.

8.8.4 Clock

The NVM module is operating at the same clock speed as main clock, MCLK.

8.9 Registers

Table 8-3 shows a complete list of the NVM special function registers.

Table 8-2 Registers Address Space

Module	Base Address	End Address	Note
NVM	4005 0000 _H	4005 00FF _H	

Table 8-3 Registers Overview

Register Short Name	Register Long Name	Offset Address	Page Number
NVMSTATUS	NVM Status Register	0000 _H	Page 8-12
NVMPROG	NVM Programming Control Register	0004 _H	Page 8-14
NVMCONF	NVM Configuration Register	0008 _H	Page 8-16

The register is addressed wordwise.

Reading an SFR is not blocked, while the NVM module is busy. If the SFR value depends on the completion of an NVM sequence, **NVMSTATUS**.BUSY must be polled for 0_B, before the SFR is read. Otherwise, reading the SFR might yield a value that is not updated yet.

8.9.1 NVM Registers

NVM Status Register

NVMSTATUS

NVM Status Register

(0000_H)

Reset Value: 0002_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0									WRP ERR	ECC 2RE AD	ECC 1RE AD	VERR		SLE EP	BUS Y
r									r	r	r	r		r	r

Field	Bits	Type	Description
0	15:7	r	Reserved Read as 0.
WRPERR	6	r	Write Protocol Error The flag accumulates write protocol violations during the last 4-word write operations (for write or verify). It is also set when a triggered operation was ignored because of write protection. The correct protocol is defined in Section 8.4.3 . It is reset by hardware when NVMPROG.RSTECC is written. 0 _B WRPROTOK , No write protocol failure occurred. 1 _B WRPROTFAIL , At least one write protocol failure was detected.
ECC2READ	5	r	ECC2 Read¹⁾ The flag accumulates ECC two bit failure during memory read operations. It is reset by hardware when NVMPROG.RSTECC is written. 0 _B ECC2RDOK , No ECC two bit failure during memory read operations. 1 _B ECC2RDFAIL , At least one ECC two bit failure was detected.

Field	Bits	Type	Description
ECC1READ	4	r	ECC1 Read¹⁾ The flag accumulates ECC single bit failure during the last memory read operations. It is reset by hardware when NVMPROG.RSTECC is written. 0 _B ECC1RDOK , No ECC single bit failure occurred. 1 _B ECC1RDFAIL , At least one ECC single bit failure was detected and corrected.
VERR	3:2	r	Verify Error The flag is reset by hardware, when NVMPROG.RSTVERR is written. The flag is also reset, when write mode or verify-only mode are entered, i.e. NVMPROG.ACTION.OPTYPE = 0001 _B or NVMPROG.ACTION.VERIFY = 11 _B . The flag accumulates, i.e. VERR is updated every time a value higher than the current value is required, until write mode or verify-only mode are left (automatically in case of a one-shot write operation). Information on number of fail bits during verify procedure(s): 00 _B NOFAIL , No fail bit. 01 _B ONEFAIL , One fail bit in one data block. 10 _B TWOFAIL , Two fail bits in two different data blocks. 11 _B MOREFAIL , Two or more fail bits in one data block, or three or more fail bits overall.
SLEEP	1	r	Sleep Mode 0 _B READY , NVM not in sleep mode, and no sleep or wake up procedure in progress. 1 _B SLEEP , NVM in sleep mode, or busy due to a sleep or wake up procedure.
BUSY	0	r	Busy 0 _B READY , The NVM is not busy. Memory reads from the cell array and register write accesses are possible. 1 _B BUSY , The NVM is busy. Memory reads and register write accesses are not possible.

1) If a block is read from the field that contains two or more parity errors ECC1 and ECC2 errors may be flagged simultaneously.

NVM Programming Control Register

NVMPROG

NVM Programming Control Register (0004_H)

Reset Value: 0000_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		RST ECC	RST VER R		0										
r		rw	rw		r										

Field	Bits	Type	Description
0	15:14	r	Reserved Read as 0; should be written with 0.
RSTECC	13	rw	Reset ECC Can only be set by software, is reset automatically by hardware. 0 _B NOP , No action. 1 _B RESET , Reset of NVMSTATUS.ECCxREAD and NVMSTATUS.WRPERR .
RSTVERR	12	rw	Reset Verify Error Can only be set by software, is reset automatically by hardware. 0 _B NOP , No action. 1 _B RESET , Reset of NVMSTATUS.VERR .
0	11:8	r	Reserved Read as 0; should be written with 0.

Field	Bits	Type	Description
ACTION	7:0	rw	ACTION: [VERIFY, ONE_SHOT, OPTYPE] This field selects an erase, write, or verify operation. See also More details on ACTION. ACTION is a concatenation of three bit fields: ACTION[7:6] = VERIFY, ACTION[5:4] = ONE_SHOT and ACTION[3:0] = OPTYPE. OPTYPE defines the following operations: 0000_B: idle or verify-only, that depends on the setting of VERIFY; 0001_B: write; 0010_B: page erase. 0100_B: sector erase. ONE_SHOT is a parameter of OPTYPE with the following values: 01_B: once or 10_B: continuously. In case of 01_B, ACTION is automatically reset to idle mode after operation has been performed. VERIFY defines a second parameter of OPTYPE: 01_B: verification of written data with hardread levels after every write operation, 10_B: no verification, 11_B: verification of array content. The following operations are defined, other values are interpreted as 00_H 00_H , Idle state, no action triggered. Writing 00_H exits current mode. 51_H , Start one-shot write operation with automatic verify. 91_H , Start one-shot write operation without verify. 61_H , Start continuous write operation with automatic verify of every write. A1_H , Start continuous write operation without verify. 92_H , Start one-shot page erase operation. 94_H , Start one-shot sector erase operation. A4_H , Start continuous sector erase operation. A2_H , Start continuous page erase operation. D0_H , Start one-shot verify-only: Written data is compared to array content. E0_H , Start continuous verify-only: Written data is compared to array content.

More details on ACTION

The operation selected by ACTION is performed, when a write to the NVM address range is performed, which defines the address (and block data) for the operation. Afterwards, in case of a one-shot operation, ACTION is automatically reset.

Verification results can be read at **NVMSTATUS.VERR**.

ACTION can only be changed when the current value of ACTION is 00_H, otherwise ACTION is set to 00_H. Once ACTION is not idle, ACTION can only be written again with its current value; any other value leads to a reset of ACTION.

Only write operations can be automatically verified. Page erase operations cannot use automatic verify, they must be started with ACTION.VERIFY = 10_B.

If the correct erasing of a page or sector is to be verified, a separate sequence using ACTION.VERIFY = 11_B has to be started.

A verify operation requires the provision of the data for a complete block and always includes the ECC bits. The ECC bits for every block are generated automatically when the data is written.

A verify operation started with ACTION.VERIFY = 01_B is automatically performed with both hardread written and hardread erased levels.

A verify operation started with ACTION.VERIFY = 11_B is performed with the single hardread level defined by **NVMCONF.HRLEV** at this starting time.

A sequence started by setting ACTION will set **NVMSTATUS.BUSY** only after the transfer of the address (and block data) is performed. The end of the sequence can be detected either by polling NVMSTATUS.BUSY or by waiting for an NVM interrupt (not for verify-only sequence).

Entering sleep mode resets ACTION.

NVM Configuration Register

NVMCONF is the only SFR that can be written while the module is in sleep mode. This is necessary to enable the use of NVM_ON = 0_B to go to sleep mode and of NVM_ON = 1_B to wake-up again.

NVMCONF

NVM Configuration Register (0008_H) **Reset Value: 9000_H**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NVM_ON	INT_ON	0	WS	SECPROT								0	HRLEV	0	
RW	RW	RW	RW	RW								r	RW	RW	

Field	Bits	Type	Description
NVM_ON	15	rw	NVM On When cleared, no software code can be executed anymore from the NVM, until it is set again. I.e., already the software code that initiates the change in NVM_ON itself may not reside in the NVM, otherwise the software is stalled forever. 0 _B SLEEP , NVM is switched to or stays in sleep mode. 1 _B NORM , NVM is switched to or stays in normal mode.
INT_ON	14	rw	Interrupt On When enabled the completion of a sequence started by setting NVMPROG.ACTION (write or erase sequence) will be indicated by NVM interrupt. The same is true for the wake-up sequence. 0 _B INTOFF , No NVM ready interrupts are generated. 1 _B INTON , NVM ready interrupts are generated.
0	13	rw	Reserved for Future Use Must be written with 0 to allow correct operation.
WS	12	rw	Number of fixed Wait States Defines the number of fixed wait states when NVM_CONFIG1.FIXWS = 1 _B . 0 _B 0 fixed wait states. 1 _B 1 fixed wait state.
SECPROT	11:4	rw	Sector Protection¹⁾ This field defines the number of write, erase, verify protected sectors, starting with physical sector 0.
0	3	r	Reserved Read as 0; should be written with 0.
HRLEV	2:1	rw	Hardread Level²⁾ Defines single hardread level for verification with NVMPROG.ACTION.VERIFY = 11 _B : 00 _B NR , Normal read 01 _B HRW , Hardread written 10 _B HRE , Hardread erased 11 _B RFU , Reserved for Future Use
0	0	rw	Reserved for Future Use Must be written with 0 to allow correct operation.

- 1) For SECPROT > 0, SECPROT defines the number of protected sectors. The sectors 0 to SECPROT-1 cannot be written, erased, or verified. All writes that target the protected sectors are accepted, but are internally ignored.
- 2) HRLEV defines the hardread level for a stand-alone verification sequence started with NVMPROG.ACTION.VERIFY = 11_B. This hardread level is used until the end of the verification sequence. HRLEV may not be changed in between.

Configuration 1 Register

The bit NVM_CONFIG1.FIXWS allows to switch between adaptive and fixed wait state configuration.

Attention: Any write operation to the register **CONFIG1** to switch between adaptive and fixed wait states configuration must only modify the bit **CONFIG1.FIXWS**. Changing other bits in **CONFIG1** can lead to unpredictable results.

CONFIG1

Configuration 1 Register

(4005 0048_H)

Reset Value: XXXX_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RES				FIX WS	RES										
rw				rw	rw										

Field	Bits	Type	Description
RES	15:12	rw	Reserved Must not be changed when programming the NVM_CONFIG1 register.
FIXWS	11	rw	Wait States Scheme Defines the scheme by which flash wait states are generated. With fixed wait states NVM_NVMCONF.WS defines the number of wait states. 0 _B adaptive wait states. 1 _B fixed wait states.
RES	10:0	rw	Reserved Must not be changed when programming the NVM_CONFIG1 register.

8.10 Example Sequences

This section presents some low-level programming examples.

In all following operations the protection defined by **NVMCONF**.SECPROT needs to be taken into account.

8.10.1 Writing to Memory

8.10.1.1 Writing a Single Block

This sequence requires that the target block is already erased.

Additional assumption: **NVMPROG**.ACTION = 00_H.

1. Start a one-shot write operation:
Write **NVMPROG**.ACTION = 51_H or 91_H, respectively, if an automatic verification of the written data is to be performed or not.
2. Write data for one block to the physical address.
3. Poll flag **NVMSTATUS**.BUSY until write sequence has finished, or wait for NVMready interrupt (if enabled).
4. If an automatic verification of the written data was requested in the first step, read **NVMSTATUS**.VERR for the verification result.

If no verification of the written data was requested in step 1, and thus no read access to the NVM SFR is required in step 4, step 3 may be omitted.

The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.

8.10.1.2 Writing Blocks

This sequence requires the target blocks are already erased.

Additional assumption: **NVMPROG**.ACTION = 00_H.

1. Start a continuous write operation:
Write **NVMPROG**.ACTION = 61_H or A1_H, respectively, if an automatic verification of the written data is to be performed or not.
2. Write data for one block to the physical address.
3. Poll flag **NVMSTATUS**.BUSY until write sequence has finished, or wait for NVMready interrupt (if enabled).
Optionally, step 3 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.
4. Jump to step 2 unless all data is written.

5. Stop continuous write operation:
Write **NVMPROG**.ACTION = 00_H.
6. If an automatic verification of the written data was requested in the first step, read **NVMSTATUS**.VERR for the verification result.

8.10.2 Erasing Memory

8.10.2.1 Erasing a Single Page

Assumption: **NVMPROG**.ACTION = 00_H.

1. Start a one-shot page erase operation:
Write **NVMPROG**.ACTION = 92_H.
2. Write dummy data for one word to one arbitrary word-aligned physical address of the page to be erased.
3. Poll flag **NVMSTATUS**.BUSY until page erase sequence has finished, or wait for NVMready interrupt (if enabled).

Optionally, step 3 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.

8.10.2.2 Erasing Pages

Assumption: **NVMPROG**.ACTION = 00_H.

1. Start a continuous page erase operation:
Write **NVMPROG**.ACTION = A2_H.
2. Write dummy data for one word to one arbitrary word-aligned physical address of the page to be erased.
3. Poll flag **NVMSTATUS**.BUSY until page erase sequence has finished, or wait for NVMready interrupt (if enabled).

Optionally, step 3 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.

4. Jump to step 2 unless all pages are erased.
5. Stop continuous page erase operation:
Write **NVMPROG**.ACTION = 00_H.

8.10.2.3 Erasing a Single Sector

Assumption: **NVMPROG**.ACTION = 00_H.

1. Start a one-shot sector erase operation:
Write **NVMPROG**.ACTION = 94_H.

2. Write dummy data for one word to one arbitrary word-aligned physical address of the sector to be erased.
3. Poll flag **NVMSTATUS.BUSY** until sector erase sequence has finished, or wait for NVMready interrupt (if enabled).
Optionally, step 3 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.

8.10.2.4 Erasing Sectors

Assumption: **NVMPROG.ACTION** = 00_H.

1. Start a continuous sector erase operation:
Write **NVMPROG.ACTION** = A4_H.
2. Write dummy data for one word to one arbitrary word-aligned physical address of the sector to be erased.
3. Poll flag **NVMSTATUS.BUSY** until sector erase sequence has finished, or wait for NVMready interrupt (if enabled).
Optionally, step 3 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 2 is finished.
4. Jump to step 2 unless all sectors are erased.
5. Stop continuous sector erase operation:
Write **NVMPROG.ACTION** = 00_H.

8.10.3 Verifying Memory

8.10.3.1 Verifying a Single Block

Assumption: **NVMPROG.ACTION** = 00_H.

1. Choose desired hardread level by setting NVMCONF.HRLEV.
2. Start a one-shot verify operation:
Write **NVMPROG.ACTION** = D0_H.
3. Write reference data for one block to the physical address.
4. Poll flag **NVMSTATUS.BUSY** until verify sequence has finished.
5. Read **NVMSTATUS.VERR** for the verification result.

8.10.3.2 Verifying Blocks

Assumption: **NVMPROG.ACTION** = 00_H.

1. Choose desired hardread level by setting NVMCONF.HRLEV.

2. Start a continuous verify operation:
Write **NVMPROG**.ACTION = E0_H.
3. Write reference data for one block to the physical address.
4. Poll flag **NVMSTATUS**.BUSY until verify sequence has finished.
Optionally, step 4 may be omitted: The next access to the NVM module or the next write access to an NVM SFR (which ever comes first) will be automatically stalled, until the operation started in step 3 is finished.
5. Jump to step 3 unless all blocks are verified.
6. Stop continuous verify operation:
Write **NVMPROG**.ACTION = 00_H.
7. Read **NVMSTATUS**.VERR for the verification result.

8.10.4 Writing to an Already Written Block

Normally, writing additional bits in an already written block is not feasible, since the already written ECC bits and the parity bits would need an update, too, which in most cases would require to erase some bits, which is not possible. The result would be an ECC-faulty block.

For special purposes a repeated update of specially constructed data is possible, e.g. to store some marker bits for use in a power loss recovery SW implementation.

Starting with an erased block, and making use of the special structure of the ECC, it is possible to repeatedly add two newly written bits in identical bit positions to two arbitrary words of the block. This principle is shown in the exemplary writing scheme of [Table 8-4](#), where a block is updated 32 times without corruption of the ECC, i.e. the data stays ECC protected throughout the procedure.

Table 8-4 Incremental Update of a Block with Specially Constructed Data

Operation	Block Write Data	Resulting Block Content ¹⁾
Erase block		FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
Add 1 st value	FFFFFFFF FFFFFFFFC FFFFFFFF FFFFFFFC	FFFFFFFF FFFFFFFFC FFFFFFFF FFFFFFFC
Add 2 nd value	FFFFFFFF FFFFFFFF3 FFFFFFFF FFFFFFF3	FFFFFFFF FFFFFFFF0 FFFFFFFF FFFFFFF0
Add 3 rd value	FFFFFFFF FFFFFFFCF FFFFFFFF FFFFFFCF	FFFFFFFF FFFFFFFC0 FFFFFFFF FFFFFFC0
Add 4 th value	FFFFFFFF FFFFFFF3F FFFFFFFF FFFFFFF3F	FFFFFFFF FFFFFFF00 FFFFFFFF FFFFFFF00

Table 8-4 Incremental Update of a Block with Specially Constructed Data
(cont'd)

Operation	Block Write Data	Resulting Block Content ¹⁾
Add 5 th value	FFFFFFFF FFFFCFF FFFFFFFF FFFCFF	FFFFFFFF FFFFC00 FFFFFFFF FFFC00
Add 6 th value	FFFFFFFF FFFF3FF FFFFFFFF FFF3FF	FFFFFFFF FFFF000 FFFFFFFF FFF000
...	...	...
15 th value	FFFFFFFF CFFFFFFF FFFFFFFF CFFFFFFF	FFFFFFFF C000000 FFFFFFFF C000000
16 th value	FFFFFFFF 3FFFFFFF FFFFFFFF 3FFFFFFF	FFFFFFFF 0000000 FFFFFFFF 0000000
17 th value	FFFFFFFC FFFFFFFF FFFFFFFC FFFFFFF	FFFFFFFC 0000000 FFFFFFFC 0000000
...	...	...
30 th value	F3FFFFFF FFFFFFFF F3FFFFFF FFFFFFF	F000000 0000000 F000000 0000000
31 st value	CFFFFFFF FFFFFFFF CFFFFFFF FFFFFFF	C000000 0000000 C000000 0000000
32 nd value	3FFFFFFF FFFFFFFF 3FFFFFFF FFFFFFF	0000000 0000000 0000000 0000000
Add to invalidate written values ²⁾	FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFE	Same as before, but ECC2-faulty

1) ECC-clean and parity-clean (ECC bits and parity bits all stay erased), except where indicated otherwise.

2) This write data can be written on any of the states above (except the completely erased state), always resulting in an unchanged data content, but now with an ECC2 error (three ECC bits and one parity bit are written).

Other combinations of write values are possible, too, as long as the basic “add two identical bits in each of two words” is adhered to. In [Table 8-4](#) it is also shown that an invalidation of the data by deliberately creating an ECC2 error is possible.

To minimize the write times and also to minimize the cycle load of the block, it is important to only write the new bits of the block as shown in [Table 8-4](#). In principle it is possible to repeatedly write also the already written bits again, but this would unnecessarily increase the writing times and would also increase the cycle load.

8.10.5 Sleep Mode

Assumption: Active mode (**NVMSTATUS.SLEEP** = 0_B) and **NVMSTATUS.BUSY** = 0_B.

To Enter Sleep Mode

1. Execute WFE/WFI or **NVMCONF.NVM_ON** = 0_B.
2. **NVMSTATUS.BUSY** = 1_B and **NVMSTATUS.SLEEP** = 1_B until sleep mode is reached.
3. **NVMSTATUS.BUSY** = 0_B and **NVMSTATUS.SLEEP** = 1_B while in sleep mode.

To Wake-up from Sleep Mode

1. Any wake-up event and **NVMCONF.NVM_ON** = 1_B.
2. **NVMSTATUS.BUSY** = 1_B and **NVMSTATUS.SLEEP** = 1_B until active mode is reached.
3. Poll flag **NVMSTATUS.BUSY** until wake-up sequence has finished, or wait for NVMready interrupt (if enabled).
4. **NVMSTATUS.BUSY** = 0_B and **NVMSTATUS.SLEEP** = 0_B while in active mode.

A wake-up event while the goto sleep sequence has not finished yet, does not shorten this sequence, but only directly starts the wake-up sequence afterwards.

8.10.6 Timing

This state diagram shows the transitions and timings of all possible sequences.

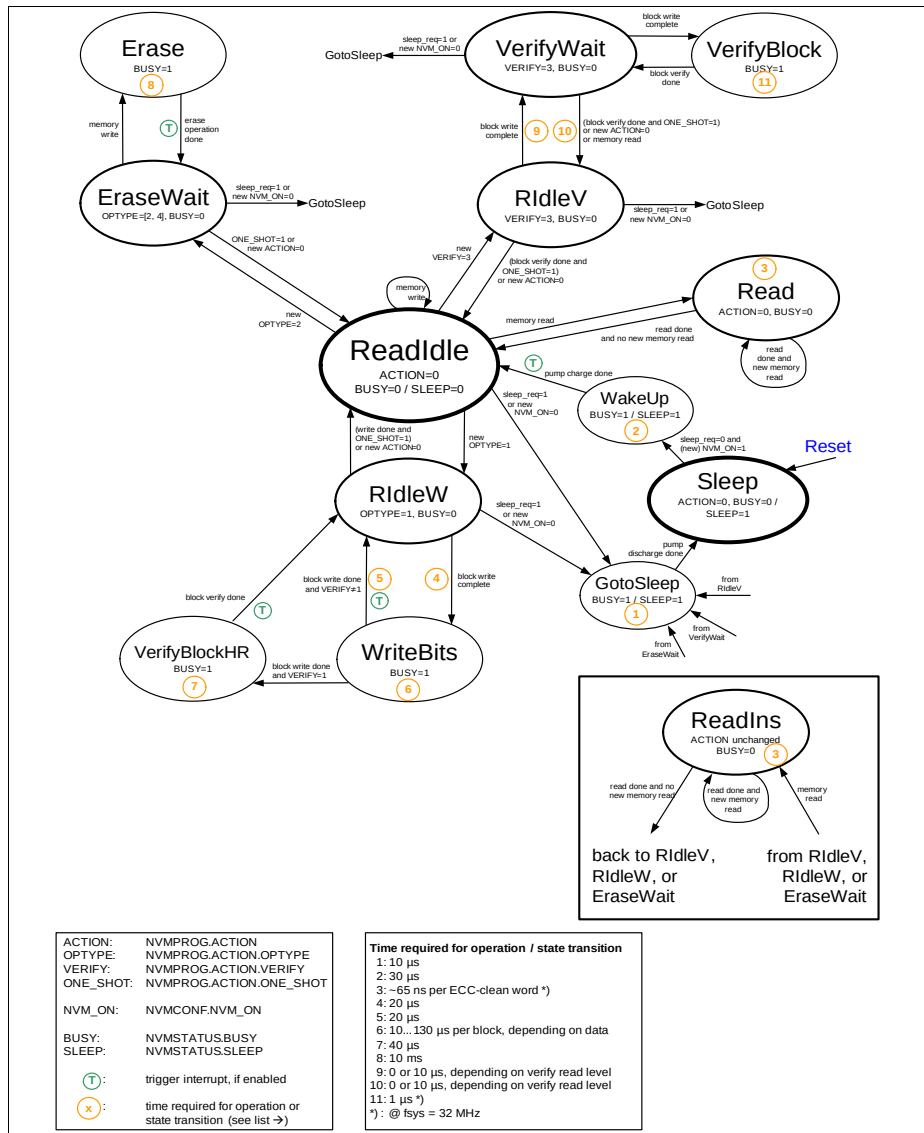


Figure 8-4 State Diagram of the NVM Module Timings are preliminary

9 Peripheral Access Unit (PAU)

This chapter describes Peripheral Access Unit (PAU) in XMC1200.

9.1 Overview

The PAU supports access control of memories and peripherals in a central place.

9.1.1 Features

The PAU provides the following features:

- Allows user application to enable/disable the access to the registers of a peripheral
- Generates a HardFault exception when there is an access to a disabled or unassigned address location
- Provides information on availability of peripherals and size of memories

9.2 Peripheral Privilege Access Control

The user application can use the Peripheral Privilege Access Registers, PRIVDISn, to disable access to a peripheral. When the PDISx bit corresponding to the peripheral is set, the memory address space mapped to the peripheral is rendered invalid. An access to such an invalid address causes a HardFault exception.

The application can clear the same bit to enable accesses to the peripheral again.

Table 9-1 shows the peripherals and their assigned PDISx bits. Peripherals without a PDISx bit are accessible at all times.

Table 9-1 Peripherals Availability and Privilege Access Control

Peripheral	Address Grouping	AVAILn.AVAILx bit	PRIVDIS.PDISx bit
Flash	Flash SFRs	-	PRIVDIS0.2
SRAM	RAM Block 1	AVAIL0.5	PRIVDIS0.5
	RAM Block 2	AVAIL0.6	PRIVDIS0.6
	RAM Block 3	AVAIL0.7	PRIVDIS0.7
WDT	WDT	-	PRIVDIS0.19
Ports	Port 0	AVAIL0.22	PRIVDIS0.22
	Port 1	AVAIL0.23	PRIVDIS0.23
	Port 2	AVAIL0.24	PRIVDIS0.24
USIC0	USIC0_CH0	AVAIL1.0	PRIVDIS1.0
	USIC0_CH1	AVAIL1.1	PRIVDIS1.1
PRNG	PRNG	AVAIL1.4	-

Peripheral Access Unit (PAU)

Table 9-1 Peripherals Availability and Privilege Access Control

Peripheral	Address Grouping	AVAILn.AVAILx bit	PRIVDIS.PDISx bit
VADC0	VADC0 Basic SFRs	AVAIL1.5	PRIVDIS1.5
	VADC0 Group 0 SFRs	AVAIL1.6	PRIVDIS1.6
	VADC0 Group 1 SFRs	AVAIL1.7	PRIVDIS1.7
SHS0	SHS0	AVAIL1.8	PRIVDIS1.8
CCU4	CC40 and CCU40 Kernel SFRs	AVAIL1.9	PRIVDIS1.9
	CC41	AVAIL1.10	PRIVDIS1.10
	CC42	AVAIL1.11	PRIVDIS1.11
	CC43	AVAIL1.12	PRIVDIS1.12
LEDTS0	LEDTS0 Sync Master	AVAIL2.13	PRIVDIS2.13
LEDTS1	LEDTS1 Sync Slave	AVAIL2.14	PRIVDIS2.14
BCCU0	BCCU0	AVAIL2.15	PRIVDIS2.15

9.3 Peripheral Availability and Memory Size

The availability of peripherals and memory sizes varies according to product variants. The user application can read the Peripheral Availability Registers, AVAILn, to check for the availability of peripherals in a product variant. Refer to [Table 9-1](#) for the bit assignment. Similarly, the Memory Size Registers (e.g. FLSIZE for Flash memory) can be used to check for the size of the available memories.

9.4 Service Request Generation

The PAU generates a hard fault exception when there is an access to an invalid address.

9.5 Debug Behaviour

The PAU does not support a suspend mode while the system is halted by the debugger. That means that the PAU continues its operation during debug halt.

9.6 Power, Reset and Clock

The PAU is located in the core power domain. The module can be reset to its default state by a system reset.

The PAU module is clocked by the main clock, MCLK, from SCU

9.7 Initialization and System Dependencies

The PAU is always available after reset.

9.8 PAU Registers

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 9-2 Registers Address Space

Module	Base Address	End Address	Note
PAU	4000 0000 _H	4000 FFFF _H	

Table 9-3 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
Reserved	Reserved	0000 _H - 003C _H	nBE	nBE	
AVAIL0	Peripheral Availability Register 0	0040 _H	U, PV	BE	Page 9-8
AVAIL1	Peripheral Availability Register 1	0044 _H	U, PV	BE	Page 9-9
AVAIL2	Peripheral Availability Register 2	0048 _H	U, PV	BE	Page 9-10
Reserved	Reserved	004C _H - 007C _H	nBE	nBE	
PRIVDIS0	Peripheral Privilege Access Register 0	0080 _H	U, PV	U, PV	Page 9-4
PRIVDIS1	Peripheral Privilege Access Register 1	0084 _H	U, PV	U, PV	Page 9-5
PRIVDIS2	Peripheral Privilege Access Register 2	0088 _H	U, PV	U, PV	Page 9-7
Reserved	Reserved	008C _H - 03FC _H	nBE	nBE	
ROMSIZE	ROM Size Register	0400 _H	U, PV	BE	Page 9-11

Peripheral Access Unit (PAU)

Table 9-3 Register Overview (cont'd)

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
FLSIZE	Flash Size Register	0404 _H	U, PV	BE	Page 9-12
RAM0SIZE	RAM0 Size Register	0410 _H	U, PV	BE	Page 9-12

9.8.1 Peripheral Privilege Access Registers (PRIVDISn)

The PRIVDISn registers provide the bit to enable and disable access to a peripheral during runtime. When disabled, an access to the peripheral throws a BusFault.

PRIVDIS0

Peripheral Privilege Access Register 0 (0080_H)

Reset Value: 0000 0000_H

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

Field	Bits	Type	Description
PDIS2	2	rw	Flash SFRs Privilege Disable Flag 0 _B Flash SFRs are accessible. 1 _B Flash SFRs are not accessible.
PDIS5	5	rw	RAM Block 1 Privilege Disable Flag 0 _B RAM Block 1 is accessible. 1 _B RAM Block 1 is not accessible.
PDIS6	6	rw	RAM Block 2 Privilege Disable Flag 0 _B RAM Block 2 is accessible. 1 _B RAM Block 2 is not accessible.
PDIS7	7	rw	RAM Block 3 Privilege Disable Flag 0 _B RAM Block 3 is accessible. 1 _B RAM Block 3 is not accessible.

Peripheral Access Unit (PAU)

Field	Bits	Type	Description
PDIS19	19	rw	WDT Privilege Disable Flag 0 _B WDT is accessible. 1 _B WDT is not accessible.
PDIS22	22	rw	Port 0 Privilege Disable Flag 0 _B Port 0 is accessible. 1 _B Port 0 is not accessible.
PDIS23	23	rw	Port 1 Privilege Disable Flag 0 _B Port 1 is accessible. 1 _B Port 1 is not accessible.
PDIS24	24	rw	Port 2 Privilege Disable Flag 0 _B Port 2 is accessible. 1 _B Port 2 is not accessible.
0	[31:25], [21:20], [18:8], [4:3], [1:0]	r	Reserved

PRIVDIS1

Peripheral Privilege Access Register 1 (0084_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		PDIS 12	PDIS 11	PDIS 10	PDIS 9	PDIS 8	PDIS 7	PDIS 6	PDIS 5	0			PDIS 1	PDIS 0	
r		rw	rw	rw	rw	rw	rw	rw	rw	rw	r			rw	rw

Field	Bits	Type	Description
PDIS0	0	rw	USIC0 Channel 0 Privilege Disable Flag 0 _B USIC0 Channel 0 is accessible. 1 _B USIC0 Channel 0 is not accessible.

Peripheral Access Unit (PAU)

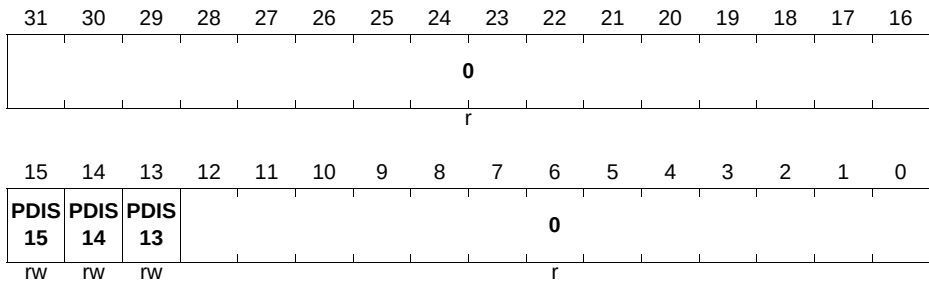
Field	Bits	Type	Description
PDIS1	1	rw	USIC0 Channel 1 Privilege Disable Flag 0_B USIC0 Channel 1 is accessible. 1_B USIC0 Channel 1 is not accessible.
PDIS5	5	rw	VADC0 Basic SFRs Privilege Disable Flag 0_B VADC0 Basic SFRs are accessible. 1_B VADC0 Basic SFRs are not accessible.
PDIS6	6	rw	VADC0 Group 0 SFRs Privilege Disable Flag 0_B VADC0 Group 0 SFRs are accessible. 1_B VADC0 Group 0 SFRs are not accessible.
PDIS7	7	rw	VADC0 Group 1 SFRs Privilege Disable Flag 0_B VADC0 Group 1 SFRs are accessible. 1_B VADC0 Group 1 SFRs are not accessible.
PDIS8	8	rw	SHS0 Privilege Disable Flag 0_B SHS0 is accessible. 1_B SHS0 is not accessible.
PDIS9	9	rw	CC40 and CCU40 Kernel SFRs Privilege Disable Flag 0_B CC40 and CCU40 Kernel SFRs are accessible. 1_B CC40 and CCU40 Kernel SFRs are not accessible.
PDIS10	10	rw	CC41 Privilege Disable Flag 0_B CC41 is accessible. 1_B CC41 is not accessible.
PDIS11	11	rw	CC42 Privilege Disable Flag 0_B CC42 is accessible. 1_B CC42 is not accessible.
PDIS12	12	rw	CC43 Privilege Disable Flag 0_B CC43 is accessible. 1_B CC43 is not accessible.
0	[31:13] , [4:2]	r	Reserved

Peripheral Access Unit (PAU)

PRIVDIS2

Peripheral Privilege Access Register 2 (0088_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
PDIS13	13	rw	LEDTS0 Sync Master Privilege Disable Flag 0 _B LEDTS0 Sync Master is accessible. 1 _B LEDTS0 Sync Master is not accessible.
PDIS14	14	rw	LEDTS1 Sync Slave Privilege Disable Flag 0 _B LEDTS1 Sync Slave is accessible. 1 _B LEDTS1 Sync Slave is not accessible.
PDIS15	15	rw	BCCU0 Privilege Disable Flag 0 _B BCCU0 is accessible. 1 _B BCCU0 is not accessible.
0	[31:16] , [12:0]	r	Reserved

9.8.2 Peripheral Availability Registers (AVAILn)

The AVAILn registers indicate the available peripherals for the particular device variant.

Note: The reset values of AVAILn registers show the configuration with all peripherals available. Actual values might differ depending on the product variant.

Peripheral Access Unit (PAU)

AVAIL0

Peripheral Availability Register 0

(0040_H)

Reset Value: 01CF 00FF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							AVAI L24	AVAI L23	AVAI L22	0		1			
r							r	r	r	r		r			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0							AVAI L7	AVAI L6	AVAI L5	1					
r							r	r	r	r					

Field	Bits	Type	Description
AVAIL5	5	r	RAM Block 1 Availability Flag 0 _B RAM block 1 is not available. 1 _B RAM block 1 is available.
AVAIL6	6	r	RAM Block 2 Availability Flag 0 _B RAM block 2 is not available. 1 _B RAM block 2 is available.
AVAIL7	7	r	RAM Block 3 Availability Flag 0 _B RAM block 3 is not available. 1 _B RAM block 3 is available.
AVAIL22	22	r	Port 0 Availability Flag 0 _B Port 0 is not available. 1 _B Port 0 is available.
AVAIL23	23	r	Port 1 Availability Flag 0 _B Port 1 is not available. 1 _B Port 1 is available.
AVAIL24	24	r	Port 2 Availability Flag 0 _B Port 2 is not available. 1 _B Port 2 is available.
1	[19:16] , [4:0]	r	Reserved
0	[31:25] , [21:20] , [15:8]	r	Reserved

Peripheral Access Unit (PAU)

AVAIL1

Peripheral Availability Register 1

(0044_H)

Reset Value: 0000 1FF7_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			AVAIL12	AVAIL11	AVAIL10	AVAIL9	AVAIL8	AVAIL7	AVAIL6	AVAIL5	AVAIL4	0	1	AVAIL1	AVAIL0
r			r	r	r	r	r	r	r	r	r	r	r	r	r

Field	Bits	Type	Description
AVAIL0	0	r	USIC0 Channel 0 Availability Flag 0 _B USIC0 Channel 0 is not available. 1 _B USIC0 Channel 0 is available.
AVAIL1	1	r	USIC0 Channel 1 Availability Flag 0 _B USIC0 Channel 1 is not available. 1 _B USIC0 Channel 1 is available.
AVAIL4	4	r	PRNG Availability Flag 0 _B PRNG is not available. 1 _B PRNG is available.
AVAIL5	5	r	VADC0 Basic SFRs Availability Flag 0 _B VADC0 Basic SFRs are not available. 1 _B VADC0 Basic SFRs are available.
AVAIL6	6	r	VADC0 Group 0 SFRs Availability Flag 0 _B VADC0 Group 0 SFRs are not available. 1 _B VADC0 Group 0 SFRs are available.
AVAIL7	7	r	VADC0 Group 1 SFRs Availability Flag 0 _B VADC0 Group 1 SFRs are not available. 1 _B VADC0 Group 1 SFRs are available.
AVAIL8	8	r	SHS0 Availability Flag 0 _B SHS0 is not available. 1 _B SHS0 is available.
AVAIL9	9	r	CC40 Availability Flag 0 _B CC40 is not available. 1 _B CC40 is available.

Peripheral Access Unit (PAU)

Field	Bits	Type	Description
AVAIL10	10	r	CC41 Availability Flag 0_B CC41 is not available. 1_B CC41 is available.
AVAIL11	11	r	CC42 Availability Flag 0_B CC42 is not available. 1_B CC42 is available.
AVAIL12	12	r	CC43 Availability Flag 0_B CC43 is not available. 1_B CC43 is available.
1	2	r	Reserved
0	[31:13] , 3	r	Reserved

AVAIL2

Peripheral Availability Register 2 (0048_H) **Reset Value: 0000 E000_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
AVAIL15	AVAIL14	AVAIL13	0												
r	r	r	r												

Field	Bits	Type	Description
AVAIL13	13	r	LEDTS0 Sync Master Availability Flag 0_B LEDTS0 Sync Master is not available. 1_B LEDTS0 Sync Master is available.
AVAIL14	14	r	LEDTS1 Sync Slave Availability Flag 0_B LEDTS0 Sync Slave is not available. 1_B LEDTS0 Sync Slave is available.
AVAIL15	15	r	BCCU0 Availability Flag 0_B BCCU0 is not available. 1_B BCCU0 is available.

Field	Bits	Type	Description
0	[31:16] , [12:0]	r	Reserved

9.8.3 Memory Size Registers

Memory size registers are available for the ROM, SRAM and Flash memories. They are used to indicate the available size of these memories in the device.

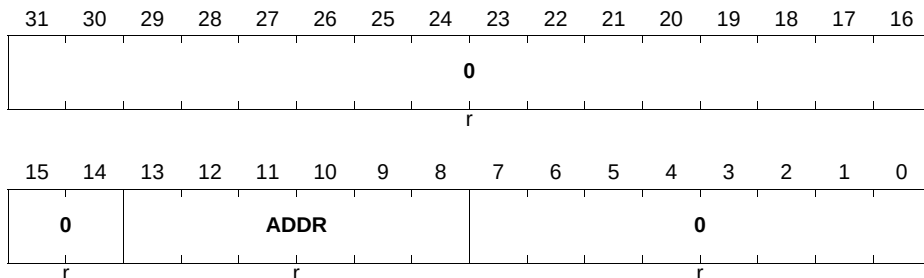
Note: The reset values of the size registers show the configuration of the superset device. Actual values might differ depending on the product variant.

ROMSIZE

ROM Size Register

(0400_H)

Reset Value: 0000 0B00_H



Field	Bits	Type	Description
ADDR	[13:8]	r	ROM Size Size of user-readable ROM in bytes = ADDR * 256
0	[31:14] , [7:0]	r	Reserved

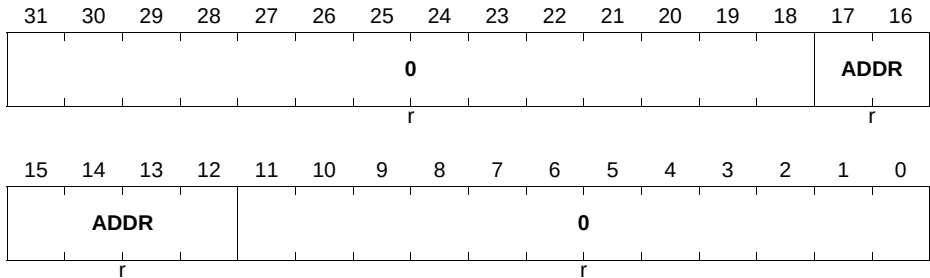
Peripheral Access Unit (PAU)

FLSIZE

Flash Size Register

(0404_H)

Reset Value: 0003 3000_H



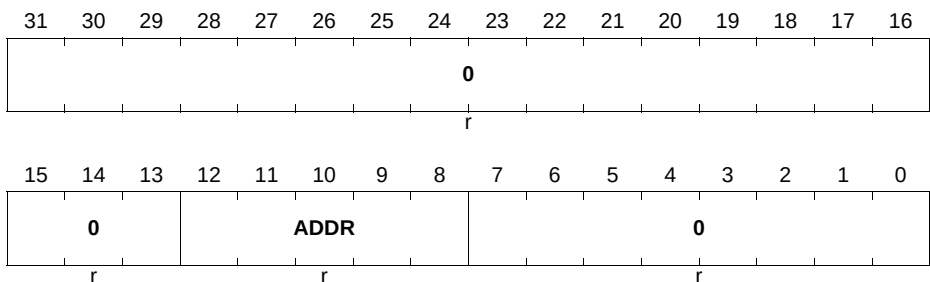
Field	Bits	Type	Description
ADDR	[17:12]	r	Flash Size Size of the Flash (excluding Flash sector 0) in Kbytes = (ADDR - 1) * 4
0	[31:18] , [11:0]	r	Reserved

RAM0SIZE

RAM0 Size Register

(0410_H)

Reset Value: 0000 1000_H



Field	Bits	Type	Description
ADDR	[12:8]	r	RAM0 Size Size of RAM block 0 in bytes = ADDR * 256 For total RAM size, RAM blocks 1 to 3 have to be also taken into consideration.

Peripheral Access Unit (PAU)

Field	Bits	Type	Description
0	[31:13] , [7:0]	r	Reserved

System Control

10 Window Watchdog Timer (WDT)

Purpose of the Window Watchdog Timer module is improvement of system integrity. WDT triggers the system reset or other corrective action like e.g. an interrupt if the main program, due to some fault condition, neglects to regularly service the watchdog (also referred to as “kicking the dog”, “petting the dog”, “feeding the watchdog” or “waking the watchdog”). The intention is to bring the system back from the unresponsive state into normal operation.

References

[6] Cortex-M0 User Guide, ARM DUI 0467B (ID081709)

10.1 Overview

A successful servicing of the WDT results in a pulse on the signal `wdt_service`. The signal is offered also as an alternate function output can be used to show to an external watchdog that the system is alive.

The WDT timer is a 32-bit counter, which counts up from 0_H . It can be serviced while the counter value is within the window boundary, i.e. between the lower and the upper boundary value. Correct servicing results in a reset of the counter to 0_H . A so called “Bad Service” attempt results in the system reset request.

The timer block is running on the f_{WDT} clock which is independent from the bus clock. The timer value is updated in the corresponding AHB register **TIM**. This mechanism enables immediate response on a read access from the bus.

10.1.1 Features

The watchdog timer (WDT) is an independent window watchdog timer.

The features are:

- Triggers system reset when not serviced on time or serviced in a wrong way
- Servicing restricted to be within boundaries of refresh window
- Can run from an independent clock
- Provides service indication to an external pin
- Can be suspended in halting mode
- Provides optional pre-warning alarm before reset

Window Watchdog Timer (WDT)

Table 10-1 Application Features

Feature	Purpose/Application
System reset upon Bad Servicing	Triggered to restore system stable operation and ensure system integrity
Servicing restricted to be within defined boundaries of refresh window	Allows to consider minimum and maximum software timing
Independent clocks	To ensure that WDT counts even in case of the system clock failure
Service indication on external pin	For dual-channel watchdog solution, additional external control of system integrity
Suspending in HALT mode	Enables safe debugging with productive code
Pre-warning alarm	Software recovery to allow corrective action via software recovery routine bringing system back from the unresponsive state into normal operation

10.1.2 Block Diagram

The WDT block diagram is shown in [Figure 10-1](#).

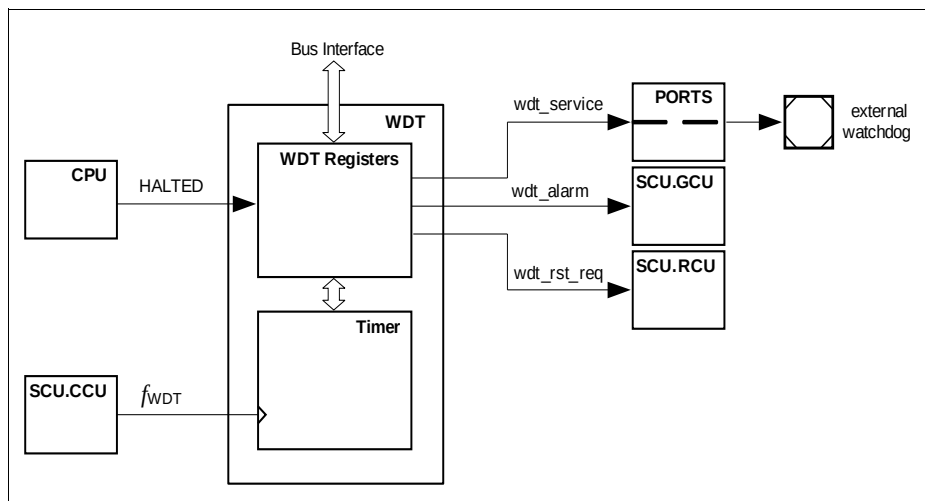


Figure 10-1 Watchdog Timer Block Diagram

10.2 Time-Out Mode

An overflow results in an immediate reset request going to the RCU of the SCU via the signal `wdt_rst_req` whenever the counter crosses the upper boundary it triggers an overflow event pre-warning is not enabled with `CTR` register. A successful servicing performed with writing a unique value, referred to as “Magic Word” to the `SRV` register of the WDT within the valid servicing window, results in a pulse on the signal `wdt_service` and reset of the timer counter.

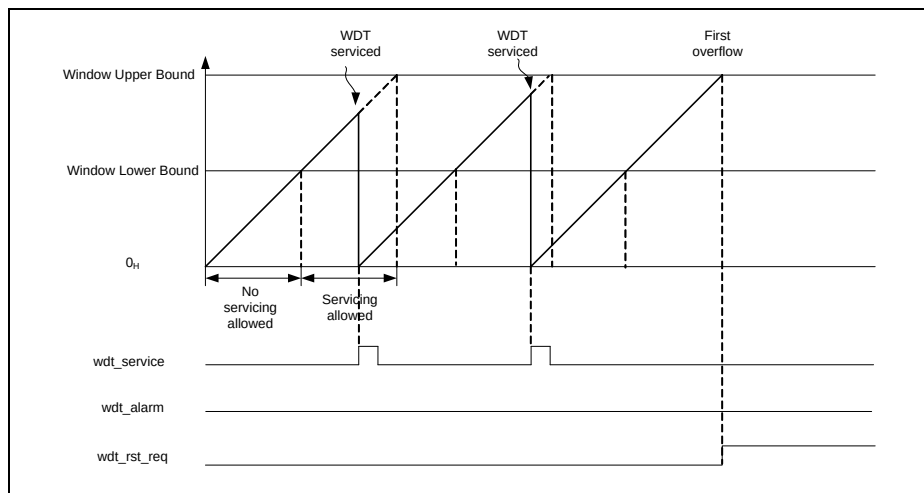


Figure 10-2 Reset without pre-warning

The example scenario depicted in **Figure 10-2** shows two consecutive service pulses generated from WDT module as the result of successful servicing within valid time windows. The situation where no service has been performed immediately triggers generation of reset request on the `wdt_rst_req` output after the counter value has exceeded window upper bound value.

10.3 Pre-warning Mode

While in pre-warning mode the effect of the overflow event is different with and without pre-warning enabled. The first crossing of the upper bound triggers the outgoing alarm signal `wdt_alarm` when pre-warning is enabled. Only the next overflow results a reset request. The alarm status is shown via register `WDTSTS` and can be cleared via register `WDTCLR`. A clear of the alarm status will bring the WDT back to normal state.

Window Watchdog Timer (WDT)

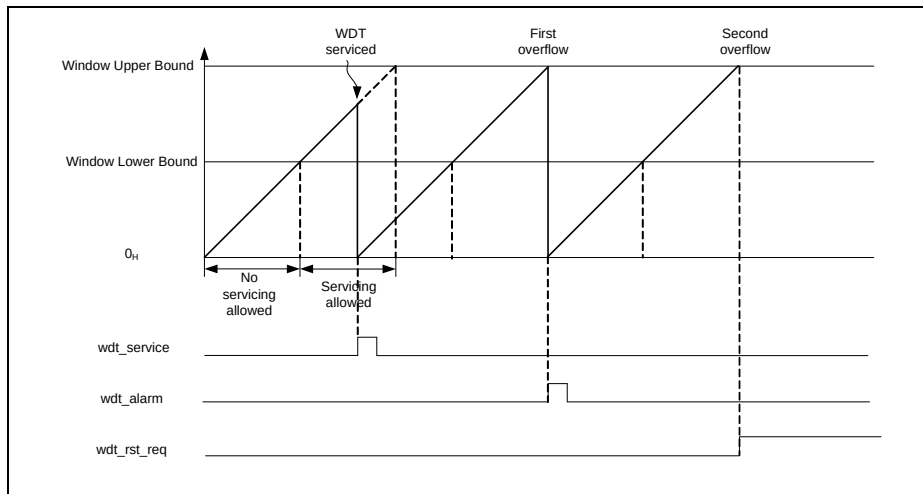


Figure 10-3 Reset after pre-warning

The example scenario depicted in [Figure 10-3](#) shows service pulse generated from WDT module as the result of successful servicing within valid time window. WDT generates alarm pulse on `wdt_alarm` upon first missing servicing. The alarm signal is routed as interrupt request to the SCU. Within this alarm service request the user can clear the WDT status bit and give a proper WDT service before it overflows next time. Otherwise WDT generates reset request on `wdt_rstn` upon the second missing service.

10.4 Bad Service Operation

A bad service attempt results in a reset request. A bad service attempt can be due to servicing outside the window boundaries or servicing with an invalid Magic Word.

Window Watchdog Timer (WDT)

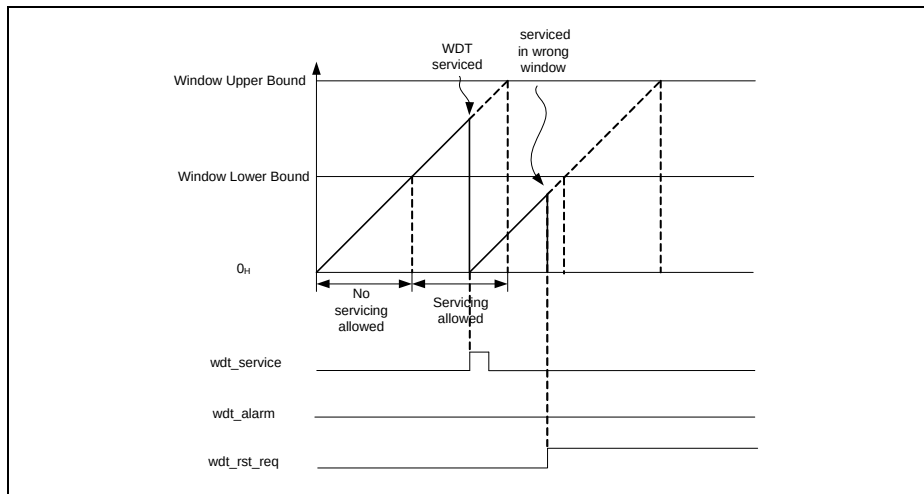


Figure 10-4 Reset upon servicing in a wrong window

The example in [Figure 10-4](#) shows servicing performed outside of valid servicing window. Attempt to service WDT while counter value remains below the window lower bound results in immediate reset request on wdt_rst_req signal.

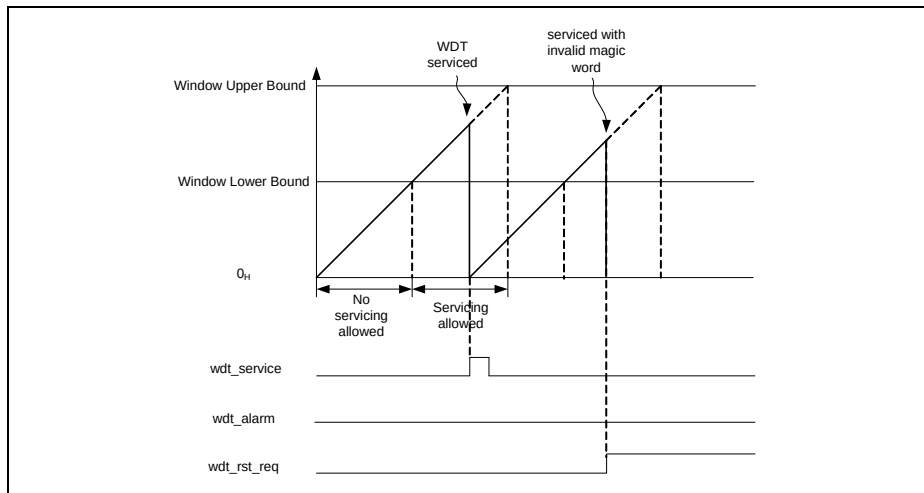


Figure 10-5 Reset upon servicing with a wrong magic word

Window Watchdog Timer (WDT)

The example in [Figure 10-5](#) shows servicing performed within a valid servicing window but with an invalid Magic Word. Attempt to write a wrong word to the [SRV](#) register results in immediate reset request on `wdt_rst_req` signal.

10.5 Service Request Processing

The WDT generates watchdog alarm service requests via `wdt_alarm` output signal upon first counter overflow over watchdog upper bound when pre-warning mode is enabled. The alarm service request is serviced in SCU.

Service requests can be disabled respectively by service request mask register in SCU.

10.6 Debug Behavior

The WDT function can be suspended when the CPU enters HALT mode. WDT debug function is controlled with DSP bit field in [CTR](#) register and it is set to be suspended by default.

10.7 Power, Reset and Clock

The WDT module is a part of the core domain and supplied with V_{DDC} voltage.

All WDT registers get reset with the system reset.

A sticky bit in the Reset Status Register, RSTSTAT, of SCU/RCU module indicates whether the last system reset has been triggered by the WDT module. This bit does not get reset with system reset.

The input clock of the WDT counter is provided by the internal 32kHz standby clock from SCU/CCU module, independently from the AHB interface clock.

The WDT module clock is default disabled and can be enabled via the `SCU_CGATCLR0` register. Enabling and disabling the module clock could cause load change and clock blanking could happen as explained in the CCU (Clock Gating Control) section of the SCU chapter. It is strongly recommended to setup the module clock in the user initialisation code to avoid clock blanking during runtime.

10.8 Initialization and Control Sequence

Programming model of the WDT module assumes several scenarios where different control sequences apply.

Note: Some of the scenarios described in this chapter require operations on system level that are not in the scope of the WDT module description, therefore for detailed information please refer to relevant chapters of this document.

10.8.1 Initialization & Start of Operation

Complete WDT module initialization is required upon system reset.

Window Watchdog Timer (WDT)

- check reason for last system reset in order to determine power state
 - read out SCU_RSTSTAT.RSTSTAT register bit field to determine last system reset cause and clear this bit using bit SCU_RSTCLR.RSCLR
 - perform appropriate operations dependent on the last system reset cause
- WDT software initialization sequence
 - enable WDT clock with SCU_CGATCLR0.WDT register bit field
 - set lower window bound with WDT_WLB register
 - set upper window bound with WDT_WUB register
 - configure external watchdog service indication (optional, please refer to PORT chapter)
 - enable interrupt for pre-warning alarm on system level with SCU_SRMSK register (optional, used in WDT pre-warning mode only)
- software start sequence
 - select mode (Time-Out or Pre-warning) and enable WDT module with WDT_CTR register
- service the watchdog
 - write magic word to WDT_SRV register within valid time window

10.8.2 Software Stop & Resume Operation

The WDT module can be stopped and re-started at any point of time for e.g. debug purpose using software sequence.

- software stop sequence
 - disable WDT module with WDT_CTR register
- perform any user operations
- software start (resume) sequence
 - enable WDT module with WDT_CTR register with WDT_CTR register
- service the watchdog
 - write magic word to WDT_SRV register within valid time window

10.8.3 Enter Sleep/Deep-Sleep & Resume Operation

The WDT counter clock can be configured to stop while in sleep or deep-sleep mode. No direct software interaction with the WDT is required in those modes and no watchdog time-out will fire if the WDT clock is configured to stop while CPU is sleeping.

- software configuration sequence for sleep/deep-sleep mode
 - configure WDT behavior with SCU_CGATx register
- enter sleep/deep-sleep mode software sequence

Window Watchdog Timer (WDT)

- select sleep or deep-sleep mode in CPU (for details please refer to Cortex-M0 documentation [6])
- enter selected mode (for details please refer to Cortex-M0 documentation [6])
- wait for a wake-up event (no software interaction, CPU stopped)
- resume operation (CPU clock restarted automatically on an event)
- service the watchdog
 - write magic word to WDT_SRV register within valid time window

10.8.4 Pre-warning Alarm Handling

The WDT will fire pre-warning alarm before requesting system reset while in pre-warning mode and not serviced within valid time window. The WDT status register indicating alarm must be cleared before the timer counter value crosses the upper bound for the second time after firing the alarm. After clearing of the alarm status regular watchdog servicing must be performed within valid time window.

- alarm event
 - exception routine (service request) clearing WDT_WDTSTAT register with WDT_WDTCLR register
- service the watchdog
 - write magic word to WDT_SRV register within valid time window

Window Watchdog Timer (WDT)

10.9 WDT Registers

Registers Overview

The absolute register address is calculated by adding:
Module Base Address + Offset Address

Table 10-2 Registers Address Space

Module	Base Address	End Address	Note
WDT	4002 0000 _H	4002 FFFF _H	Watchdog Timer Registers

Table 10-3 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
WDT Kernel Registers					
ID	Module ID Register	00 _H	U, PV	PV	Page 10-9
CTR	Control Register	04 _H	U, PV	PV	Page 10-10
SRV	Service Register	08 _H	BE	PV	Page 10-11
TIM	Timer Register	0C _H	U, PV	BE	Page 10-13
WLB	Window Lower Bound	10 _H	U, PV	PV	Page 10-13
WUB	Window Upper Bound	14 _H	U, PV	PV	Page 10-14
WDTSTS	Watchdog Status Register	18 _H	U, PV	PV	Page 10-14
WDTCLR	Watchdog Status Clear Register	1C _H	U, PV	PV	Page 10-15

10.9.1 Registers Description

ID

The module unique ID register.

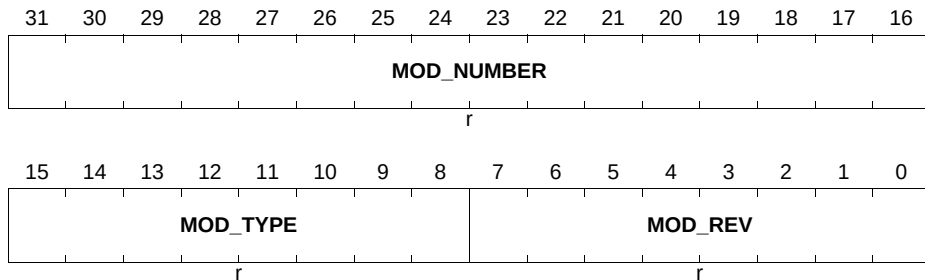
Window Watchdog Timer (WDT)

ID

WDT Module ID Register

(0000_H)

Reset Value: 00AD C0XX_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number Indicates the revision number of the implementation. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type This bit field is fixed to C0 _H .
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines the module identification number.

CTR

The operation mode control register.

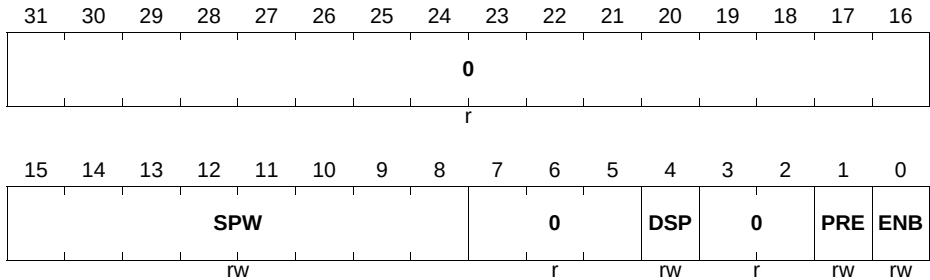
Window Watchdog Timer (WDT)

CTR

WDT Control Register

(04_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
ENB	0	rw	Enable 0 _B disables watchdog timer, 1 _B enables watchdog timer
PRE	1	rw	Pre-warning 0 _B disables pre-warning 1 _B enables pre-warning,
DSP	4	rw	Debug Suspend 0 _B watchdog timer is stopped during debug halting mode 1 _B watchdog timer is not stopped during debug halting mode
SPW	[15:8]	rw	Service Indication Pulse Width Pulse width (SPW+1) of service indication in f _{WDT} cycles
0	[3:2], [7:5], [31:16]	r	reserved

SRV

The WDT service register. Software must write a magic word while the timer value is within the valid window boundary. Writing the magic word while the timer value is within the window boundary will service the watchdog and result a reload of the timer with 0H.

Window Watchdog Timer (WDT)

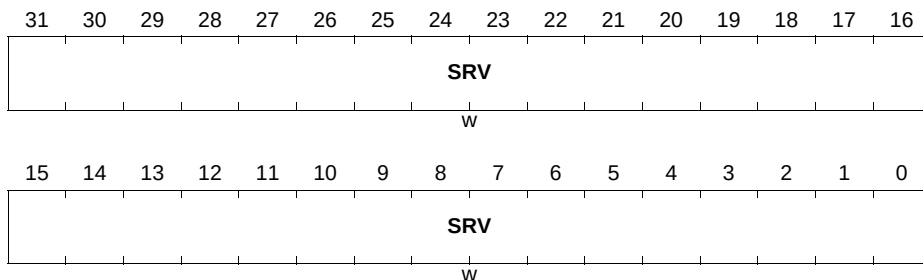
Upon writing data different than the magic word within valid time window or writing even correct Magic Word but outside of the valid time window no servicing will be performed. Instead will request an immediate system reset request.

SRV

WDT Service Register

(08_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
SRV	[31:0]	w	Service Writing the magic word ABADCAFE _H while the timer value is within the window boundary will service the watchdog.

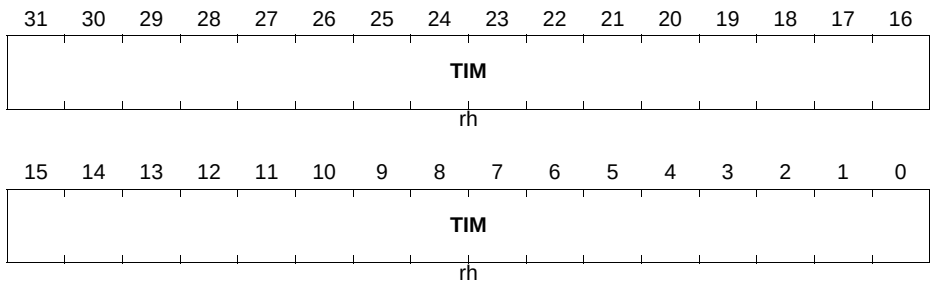
Window Watchdog Timer (WDT)

TIM

The actual watchdog timer register count value. This register can be read by software in order to determine current position in the WDT time window.

TIM

WDT Timer Register (0C_H) **Reset Value: 0000 0000_H**



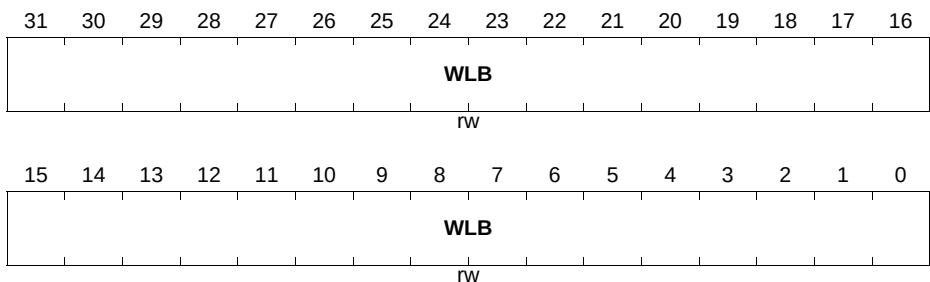
Field	Bits	Type	Description
TIM	[31:0]	rh	Timer Value Actual value of watchdog timer value.

WLB

The Window Lower Bound register defines the lower bound for servicing window. Servicing of the watchdog has only effect within the window boundary

WLB

WDT Window Lower Bound Register (10_H) **Reset Value: 0000 0000_H**



Window Watchdog Timer (WDT)

Field	Bits	Type	Description
WLB	[31:0]	rw	Window Lower Bound Lower bound for servicing window. Setting the lower bound to 0 _H disables the window mechanism.

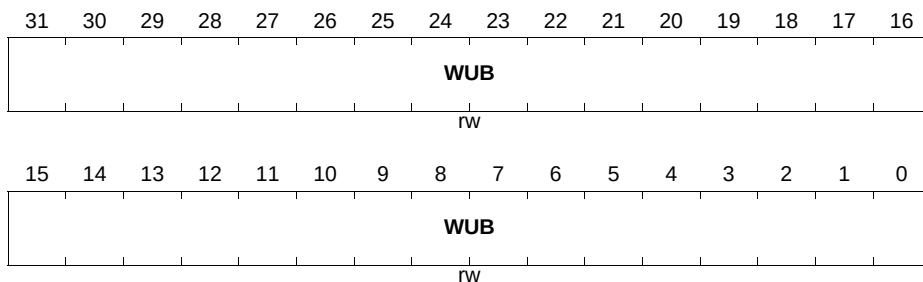
WUB

The Window Upper Bound register defines the upper bound for servicing window. Servicing of the watchdog has only effect within the window boundary.

WUB

WDT Window Upper Bound Register (14_H)

Reset Value: FFFF FFFF_H



Field	Bits	Type	Description
WUB	[31:0]	rw	Window Upper Bound Upper Bound for servicing window. The WDT triggers an reset request when the timer is crossing the upper bound value without pre-warning enabled. With pre-warning enabled the first crossing triggers a watchdog alarm and the second crossing triggers a system reset.

WDTSTS

The status register contains sticky bit indicating occurrence of alarm condition.

Window Watchdog Timer (WDT)

WDTSTS

WDT Status Register

(0018_H)

Reset Value: 00000000_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														ALM S	
r														rh	

Field	Bits	Type	Description
ALMS	0	rh	Pre-warning Alarm 1 _B pre-warning alarm occurred, 0 _B no pre-warning alarm occurred
0	[31:1]	r	reserved

WDTCLR

The status register contains sticky bitfield indicating occurrence of alarm condition.

WDTCLR

WDT Clear Register

(001C_H)

Reset Value: 00000000_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														ALM C	
r														w	

Window Watchdog Timer (WDT)

Field	Bits	Type	Description
ALMC	0	w	Pre-warning Alarm 1 _B clears pre-warning alarm 0 _B no-action
0	[31:1]	r	reserved

10.10 Interconnects

Table 10-4 Pin Table

Input/Output	I/O	Connected To	Description
Clock and Reset Signals			
f_{WDT}	I	SCU.CCU	timer clock
Timer Signals			
wdt_service	O	PORTS	service indication to external watchdog
HALTED	I	CPU	In halting mode debug. HALTED remains asserted while the core is in debug.
Service Request Connectivity			
wdt_alarm	O	SCU.GCU	pre-warning alarm
wdt_rst_req	O	SCU.RCU	reset request

11 Real Time Clock (RTC)

Real-time clock (RTC) is a clock that keeps track of the current time. RTCs are present in almost any electronic device which needs to keep accurate time in a digital format for clock displays and computer systems.

11.1 Overview

The RTC module tracks time with separate registers for hours, minutes, and seconds. The calendar registers track date, day of the week, month and year with automatic leap year correction¹⁾. The clock of RTC is selectable via bit SCU_CLKCR.RTCLKSEL.

The timer may remains operational during sleep or deep sleep mode.

11.1.1 Features

The features of the Real Time Clock (RTC) module are:

- Real time keeping with
 - 32.768 kHz external clock
 - 32.768 kHz internal clock
- Periodic time-based interrupt
- Programmable alarm interrupt on time match
- Supports wake-up mechanism from sleep or deep sleep mode

Table 11-1 Application Features

Feature	Purpose/Application
Precise real time keeping	Reduced need for time adjustments
Periodic time-based interrupt	Scheduling of operations performed on precisely defined intervals
Programmable alarm interrupt on time match	Scheduling of operations performed on precisely defined times
Supports wake-up mechanism from sleep or deep sleep mode	Autonomous wakeups from sleep or deep sleep mode for system state control and maintenance routine operations

11.1.2 Block Diagram

The RTC block diagram is shown in [Figure 11-1](#).

¹⁾ The automatic leap year correction is performed when the year is divisible by 4.

Real Time Clock (RTC)

The main building blocks of the RTC is Time Counter implementing real time counter and RTC Registers containing multi-field registers for the time counter and alarm programming register where dedicated fields represent a separate values for elapsing second, minutes, hours, days, days of week, months and years.

The RTC module is controlled directly from SCU module and shares system bus interface with other sub-modules of SCU.

Access to the RTC registers is performed via Register Mirror updated over serial interface.

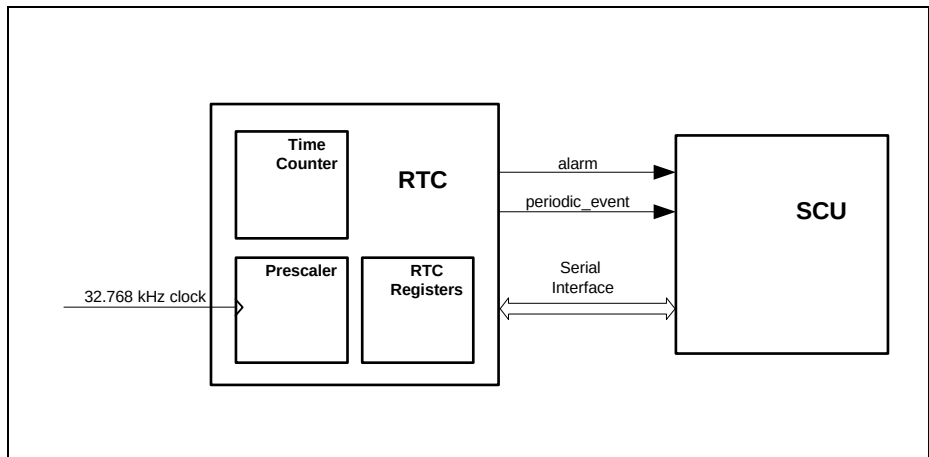


Figure 11-1 Real Time Clock Block Diagram Structure

11.2 RTC Operation

The RTC timer counts seconds, minutes, hours, days, days of week, months and years the time in separate fields (see [Figure 11-2](#)). Individual bit fields of the RTC counter can be programmed and read with software over serial interface via mirror registers in SCU module.

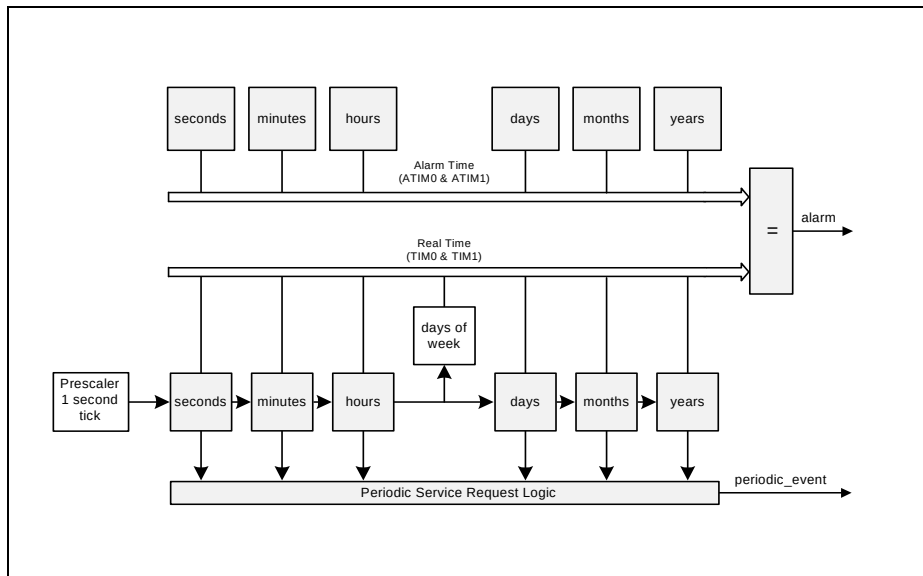


Figure 11-2 Block Diagram of RTC Time Counter

Occurrence of an internal timer event is stored in the service request raw status register **RAWSTAT**. The values of the status register **RAWSTAT** drive the outgoing service request lines alarm and periodic_event.

11.3 Register Access Operations

The RTC module is a part of SCU from programming model perspective and shares register address space for configuration with other sub-modules of SCU. RTC registers are instantiated in the RTC module and mirrored in SCU. The registers get updated in both clock domains over serial interface running at 32kHz clock rate.

Any update of the registers is performed with some delay required for data to propagate to and from the mirror registers over serial interface. Accesses to the RTC registers in core domain must not block the bus interface of SCU module. For details of the register mirror and serial communication handling please refer to SCU chapter.

For consistent write to the timer registers **TIM0** and **TIM1**, the register **TIM0** has to be written before the register **TIM1**. Transfer of the new values from the register mirror starts only after both registers have been written.

For consistent read-out of the timer registers **TIM0** and **TIM1**, the register **TIM0** has to be read before the register **TIM1**. The value of **TIM1** is stored in a shadow register upon each read of **TIM0** before they get copied to the mirror register in core domain.

11.4 Service Request Processing

The RTC generates service requests upon:

- periodic timer events
- configured alarm condition

The service requests can be processed in the core domain as regular service requests or as wake-up triggers from sleep or deep sleep mode.

11.4.1 Periodic Service Request

The periodic timer service request is raised whenever a non-masked field of the timer counter gets updated. Masking of the bits is performed using **MSKSR** register. Periodic Service requests can be disabled with **MSKSR**.

11.4.2 Timer Alarm Service Request

The alarm interrupt is triggered when **TIM0** and **TIM1** bit fields values match all corresponding bit fields values of **ATIM0**, **ATIM1** registers. The Timer Alarm Service requests can be enabled/disabled with the **MSKSR** register .

11.5 Debug Behavior

The RTC function can be suspended when the CPU enters HALT mode. RTC debug function is controlled with SUS bit field in **CTR** register.

Note: In XMC1200, bit CTR.SUS is reset to its default value by any reset. Hence, if suspend function is required during debugging, it is recommended to enable the debug suspend function in the user initialisation code. Before programming the register, the module clock has to be enabled and special care need to be handled while enabling the module clock as described in the CCU (Clock Gating Control) section of the SCU chapter.

11.6 Power, Reset and Clock

RTC can be programmed to remains powered up in sleep and deep sleep mode.

The RTC module remains in reset state after initial power up until reset released.

The RTC timer is running from an internal or external 32.768 kHz clock selectable with CLKCR.RTCCLKSEL control register of SCU/CCU module as shown in **Figure 11-3**. The prescaler setting of 7FFF_H results in an once per second update of the RTC timer.

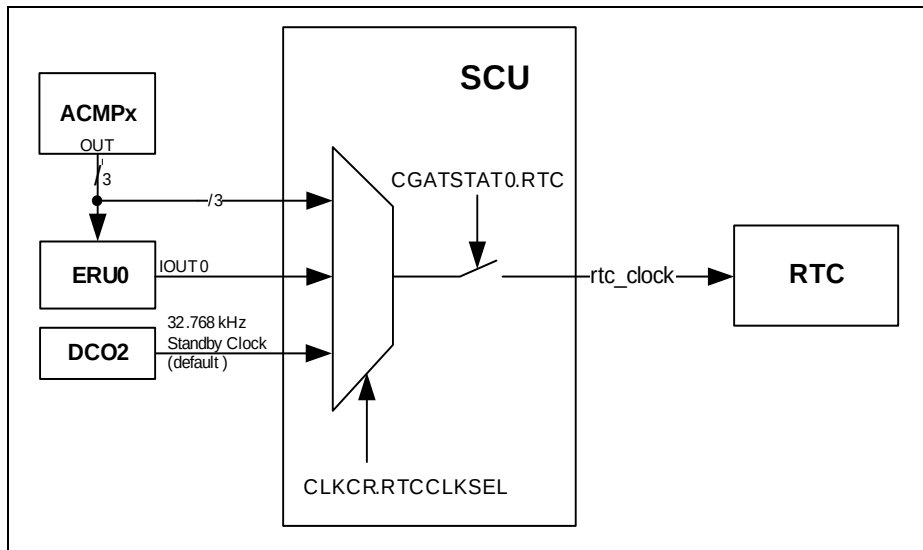


Figure 11-3 RTC Clock selection

The RTC module clock is default disabled and can be enabled via the SCU_CGATCLR0 register.

Note: Before changing RTC clock source via CLKCR.RTCCLKSEL, the RTC clock must be gated using bit CGATSET0.RTC.

11.7 Initialization and Control Sequence

Programming model of the RTC module assumes several scenarios where different control sequences apply.

Note: Some of the scenarios described in this chapter require operations on system level that are not in the scope of the RTC module description, therefore for detailed information please refer to relevant chapters of this document.

11.7.1 Initialization & Start of Operation

Complete RTC module initialization is required upon reset. Accesses to RTC registers are performed via dedicated mirror registers (for more details please refer to SCU chapter)

- enable the clock to RTC module
 - write one to SCU_CGATCLR0.RTC
- program RTC_TIM0 and RTC_TIM1 registers with current time

Real Time Clock (RTC)

- check SCU_MIRRSTS to ensure that no transfer over serial interface is pending to the RTC_TIM0 and RTC_TIM1 registers
- write a new value to the RTC_TIM0 and RTC_TIM1 registers
- enable RTC module to start counting time
 - write one to RTC_CTR.ENB

Note: To ensure a successful transfer over serial interface, RTC_TIM0 and RTC_TIM1 can only be written once for each transfer. In addition, these registers must be written in 32-bit data width. Individual bit access will not start the serial transfer operation.

11.7.2 Configure and Enable Periodic Event

The RTC periodic event configuration require programming in order to enable interrupt request generation out upon a change of value in the corresponding bit fields.

- enable service request for periodic timer events in RTC module
 - set respective bit field (MPSE, MPMI, MPHO, MPDA, MPMO, MPYE) in RTC_MSKSR register to enable the individual periodic timer events

11.7.3 Configure and Enable Timer Event

The RTC alarm event configuration require programming in order to enable interrupt request generation out upon compare match of values in the corresponding bit fields of TIM0 and TIM1 against ATIM0 and ATIM1 respectively.

- program compare values in individual bit fields of ATIM0 and ATIM1 in RTC module
 - check SCU_MIRRSTS to ensure that no transfer over serial interface is pending to the RTC_ATIM0 and RTC_ATIM1 registers
 - write to RTC_ATIM0 and RTC_ATIM1 registers
- enable service request for timer alarm events in RTC module
 - set MAI bit field of RTC_MSKSR register in order enable individual periodic timer events

Note: To ensure a successful transfer over serial interface, RTC_ATIM0 and RTC_ATIM1 can only be written once for each transfer. In addition, these registers must be written in 32-bit data width. Individual bit access will not start the serial transfer operation.

11.8 RTC Registers

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 11-2 Registers Address Space

Module	Base Address	End Address	Note
RTC	4001 0A00 _H	4001 0AFF _H	

Table 11-3 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
RTC Kernel Registers					
ID	ID Register	0000 _H	U, PV	BE	Page 11-7
CTR	Control Register	0004 _H	U, PV	PV	Page 11-8
RAWSTAT	Raw Service Request Register	0008 _H	U, PV	BE	Page 11-9
STSSR	Status Service Request Register	000C _H	U, PV	BE	Page 11-10
MSKSR	Mask Service Request Register	0010 _H	U, PV	PV	Page 11-11
CLRSR	Clear Service Request Register	0014 _H	U, PV	PV	Page 11-13
ATIM0	Alarm Time Register 0	0018 _H	U, PV	PV	Page 11-14
ATIM1	Alarm Time Register 1	001C _H	U, PV	PV	Page 11-15
TIM0	Time Register 0	0020 _H	U, PV	PV	Page 11-16
TIM1	Time Register 1	0024 _H	U, PV	PV	Page 11-17

11.8.1 Registers Description

ID

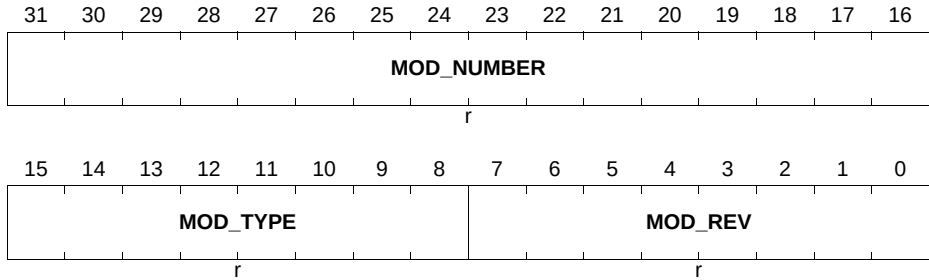
Read-only ID register of the RTC module containing unique identification code of the RTC module.

ID

RTC Module ID Register

(00_H)

Reset Value: 00A3 C0XX_H



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number Indicates the revision number of the implementation. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE	[15:8]	r	Module Type This bit field is fixed to C0 _H .
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines the module identification number.

CTR

RTC Control Register providing control means of the operation mode of the module.

Real Time Clock (RTC)

CTR

RTC Control Register

(04_H)

Reset Value: 7FFF 0000_H

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

Field	Bits	Type	Description
ENB	0	rw	RTC Module Enable 0 _B disables RTC module 1 _B enables RTC module
SUS	1	rw	Debug Suspend Control 0 _B RTC is not stopped during halting mode debug 1 _B RTC is stopped during halting mode debug
DIV	[31:16]	rw	Divider Value reload value of RTC prescaler. Clock is divided by DIV+1. 7FFF _H is default value for RTC mode with 32.768 kHz crystal or external clock
0	[15:2]	r	Reserved Read as 0; should be written with 0

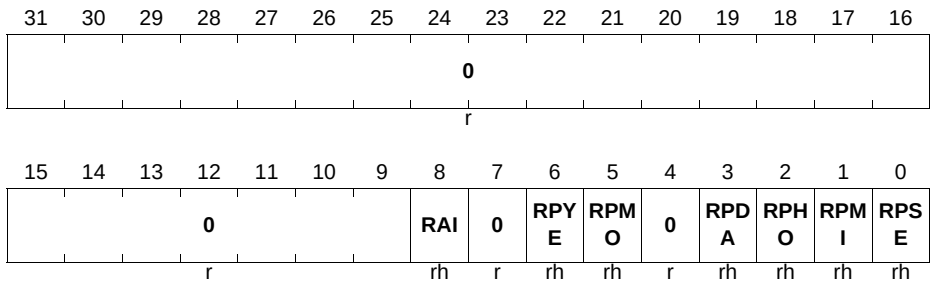
RAWSTAT

RTC Raw Service Request Register contains raw status info i.e. before status mask takes effect on generation of service requests or interrupts. This register serves debug purpose but can be also used for polling of the status without generating service requests.

RAWSTAT

RTC Raw Service Request Register (08_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RPSE	0	rh	Raw Periodic Seconds Service Request Set whenever seconds count increments
RPMI	1	rh	Raw Periodic Minutes Service Request Set whenever minutes count increments
RPHO	2	rh	Raw Periodic Hours Service Request Set whenever hours count increments
RPDA	3	rh	Raw Periodic Days Service Request Set whenever days count increments
RPMO	5	rh	Raw Periodic Months Service Request Set whenever months count increments
RPYE	6	rh	Raw Periodic Years Service Request Set whenever years count increments
RAI	8	rh	Alarm Service Request Set whenever count value matches compare value
0	4, 7, [31:9]	r	Reserved

STSSR

RTC Service Request Status Register contains status info reflecting status mask effect on generation of service requests or interrupts. This register needs to be accessed by software in order to determine the actual cause of an event.

STSSR

RTC Service Request Status Register (0C_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								SAI	0	SPY E	SPM O	0	SPD A	SPH O	SPMI E
r								rh	r	rh	rh	r	rh	rh	rh

Field	Bits	Type	Description
SPSE	0	rh	Periodic Seconds Service Request Status after masking
SPMI	1	rh	Periodic Minutes Service Request Status after masking
SPHO	2	rh	Periodic Hours Service Request Status after masking
SPDA	3	rh	Periodic Days Service Request Status after masking
SPMO	5	rh	Periodic Months Service Request Status after masking
SPYE	6	rh	Periodic Years Service Request Status after masking
SAI	8	rh	Alarm Service Request Status after masking
0	4, 7, [31:9]	r	reserved

MSKSR

RTC Service Request Mask Register contains masking value for generation control of service requests or interrupts.

MSKSR

RTC Service Request Mask 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
0							MAI	0	MPY E	MPM O	0	MPD A	MPH O	MPM I	MPS E
r							rw	r	rw	rw	r	rw	rw	rw	rw

Field	Bits	Type	Description
MPSE	0	rw	Periodic Seconds Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MPMI	1	rw	Periodic Minutes Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MPHO	2	rw	Periodic Hours Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MPDA	3	rw	Periodic Days Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MPMO	5	rw	Periodic Months Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MPYE	6	rw	Periodic Years Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
MAI	8	rw	Alarm Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
0	4, 7, [31:9]	r	Reserved

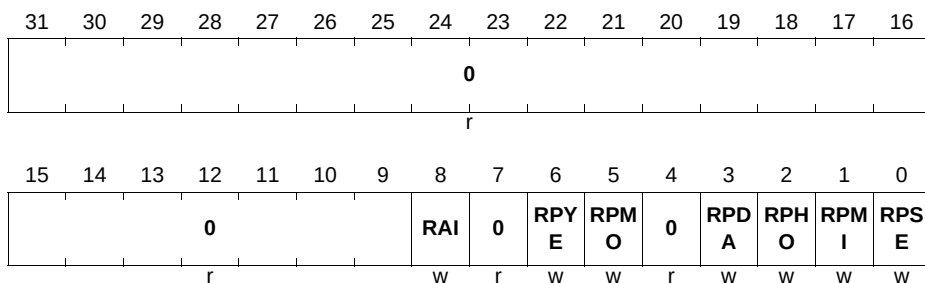
CLRSR

RTC Clear Service Request Register serves purpose of clearing sticky bits of **RAWSTAT** and **STSSR** registers. Write one to a bit in order to clear the status bit. Writing zero has no effect on the set nor reset bits.

CLRSR

RTC Clear Service Request Register (14_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RPSE	0	w	Raw Periodic Seconds Interrupt Clear 0 _B no effect 1 _B clear status bit
RPMI	1	w	Raw Periodic Minutes Interrupt Clear 0 _B no effect 1 _B clear status bit
RPHO	2	w	Raw Periodic Hours Interrupt Clear 0 _B no effect 1 _B clear status bit
RPDA	3	w	Raw Periodic Days Interrupt Clear 0 _B no effect 1 _B clear status bit
RPMO	5	w	Raw Periodic Months Interrupt Clear 0 _B no effect 1 _B clear status bit
RPYE	6	w	Raw Periodic Years Interrupt Clear 0 _B no effect 1 _B clear status bit

Real Time Clock (RTC)

Field	Bits	Type	Description
RAI	8	w	Raw Alarm Interrupt Clear 0 _B no effect 1 _B clear status bit
0	4, 7, [31:9]	r	Reserved

ATIM0

RTC Alarm Time Register 0 serves purpose of programming single alarm time at a desired point of time reflecting comparison against **TIMO** register. The ATIM0 register contains portion of bit fields for seconds, minutes, hours and days. Upon attempts to write an invalid value to a bit field e.g. exceeding maximum value a default value gets programmed as described for each individual bit fields.

ATIM0

RTC Alarm Time Register 0 (18_H) Reset Value: 0000 0000_H

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

Field	Bits	Type	Description
ASE	[5:0]	rw	Alarm Seconds Compare Value Match of seconds timer count to this value triggers alarm seconds interrupt. Setting value equal or above 3C _H results in setting the field value to 0 _H
AMI	[13:8]	rw	Alarm Minutes Compare Value Match of minutes timer count to this value triggers alarm minutes interrupt. Setting value equal or above 3C _H results in setting the field value to 0 _H

Real Time Clock (RTC)

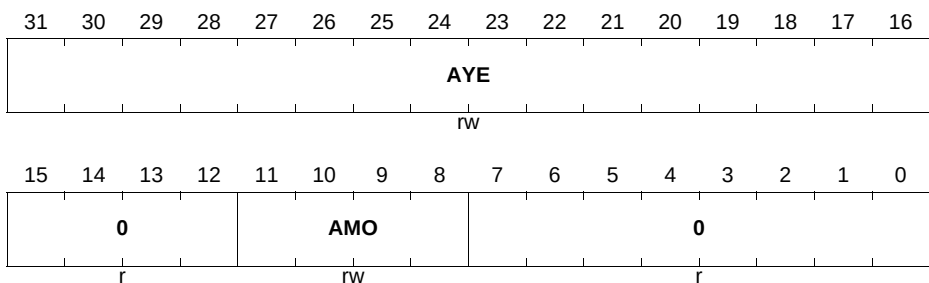
Field	Bits	Type	Description
AHO	[20:16]	rw	Alarm Hours Compare Value Match of hours timer count to this value triggers alarm hours interrupt. Setting value equal or above 18 _H results in setting the field value to 0 _H
ADA	[28:24]	rw	Alarm Days Compare Value Match of days timer count to this value triggers alarm days interrupt. Setting value equal or above 1F _H results in setting the field value to 0 _H
0	[7:6], [15:14], [23:21], [31:29]	r	Reserved

ATIM1

RTC Alarm Time Register 1 serves purpose of programming single alarm time at a desired point of time reflecting comparison against **TIM1** register. The ATIM1 register contains portion of bit fields for months and years. Upon attempts to write an invalid value to a bit field e.g. exceeding maximum value a default value gets programmed as described for each individual bit fields.

ATIM1

RTC Alarm Time Register 1 (1C_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
AMO	[11:8]	rw	Alarm Month Compare Value Match of months timer count to this value triggers alarm month interrupt. Setting value equal or above the number of days of the actual month count results in setting the field value to 0 _H
AYE	[31:16]	rw	Alarm Year Compare Value Match of years timer count to this value triggers alarm years interrupt.
0	[7:0], [15:12]	r	Reserved

TIM0

RTC Time Register 0 contains current time value for seconds, minutes, hours and days. The bit fields get updated in intervals corresponding with their meaning accordingly. The register needs to be programmed to reflect actual time after initial power up and will continue counting time also while in sleep or deep sleep mode if enabled. Upon attempts to write an invalid value to a bit field e.g. exceeding maximum value a default value gets programmed as described for each individual bit fields.

TIM0

RTC Time Register 0 (20_H) **Reset Value: 0000 0000_H**

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

Field	Bits	Type	Description
SE	[5:0]	rwh	Seconds Time Value Setting value equal or above $3C_H$ results in setting the field value to 0_H . Value can only be written, when RTC is disabled via bit CTR.ENB.
MI	[13:8]	rwh	Minutes Time Value Setting value equal or above $3C_H$ results in setting the field value to 0_H . Value can only be written, when RTC is disabled via bit CTR.ENB.
HO	[20:16]	rwh	Hours Time Value Setting value equal or above 18_H results in setting the field value to 0_H . Value can only be written, when RTC is disabled via bit CTR.ENB.
DA	[28:24]	rwh	Days Time Value Setting value equal or above the number of days of the actual month count results in setting the field value to 0_H . Value can only be written, when RTC is disabled via bit CTR.ENB. Days counter starts with value 0 for the first day of month.
0	[7:6], [15:14], [23:21], [31:29]	r	Reserved

TIM1

RTC Time Register 1 contains current time value for days of week, months and years. The bit fields get updated in intervals corresponding with their meaning accordingly. The register needs to be programmed to reflect actual time after initial power up and will continue counting time also while in sleep or deep sleep if enabled. Upon attempts to write an invalid value to a bit field e.g. exceeding maximum value a default value gets programmed as described for each individual bit fields.

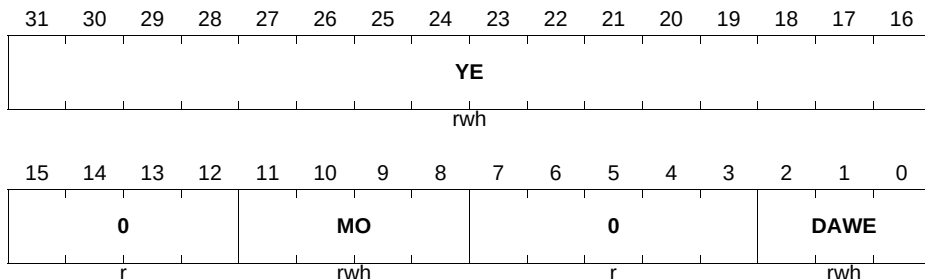
Real Time Clock (RTC)

TIM1

RTC Time Register 1

(24_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DAWE	[2:0]	rwh	Days of Week Time Value Setting value above 6 _H results in setting the field value to 0 _H . Value can only be written, when RTC is disabled via bit CTR.ENB. Days counter starts with value 0 for the first day of week.
MO	[11:8]	rwh	Month Time Value Setting value equal or above C _H results in setting the field value to 0 _H . Value can only be written, when RTC is disabled via bit CTR.ENB. Months counter starts with value 0 for the first month of year.
YE	[31:16]	rwh	Year Time Value Value can only be written, when RTC is disabled.
0	[7:3], [15:12]	r	Reserved

11.9 Interconnects

Table 11-4 Pin Connections

Input/Output	I/O	Connected To	Description
Clock Signals			
f_{RTC}	I	SCU.CCU	32.768 kHz clock selected
Debug Signals			
HALTED	I	CPU	Indicates the processor is in debug state and halted
Service Request Connectivity			
periodic_event	O	SCU.GCU	Timer periodic service request
alarm	O	SCU.GCU	Alarm service request

12 System Control Unit (SCU)

The SCU is the SoC power, reset and a clock manager with additional responsibility of providing system stability protection and other auxiliary functions.

12.1 Overview

The functionality of the SCU described in this chapter is organized in the following sub-chapters, representing different aspects of system control:

- Miscellaneous control functions, GCU [Chapter 12.2](#)
- Power control, PCU [Chapter 12.3](#)
- Reset operation, RCU [Chapter 12.4](#)
- Clock Control, CCU [Chapter 12.5](#)

12.1.1 Features

The following features are provided for monitoring and controlling the system:

- General Control
 - Start-up Software (SSW) and Boot Mode Support
 - Memory Content Protection
 - Interrupt Handling
- Power control
 - On-chip core supply generation via EVR
 - Power Validation
 - Supply Watchdog
 - Voltage Monitoring
 - Load Change Handling
- Reset Control
 - Reset assertion on various reset request sources
 - System Reset Generation
 - Inspection of reset sources after reset
- Clock Control
 - Clock Generation
 - Clock Supervision
 - Individual Peripheral Clock Gating
 - Clock Blanking Support

12.1.2 Block Diagram

Figure 12-1 shows the following sub-units:

- Power Control Unit (PCU)
- Reset Control Unit (RCU)
- Clock Control Unit (CCU)
- General Control Unit (GCU)

All the SFRs in SCU module are accessible via the AHB and the 16-bit APB bus interface as shown in **Figure 12-1**. The APB bus interface is used to access the group of SFR called ANACTRL register. These registers are used to configure the analog modules in the system, namely, the embedded voltage regulator (EVR) and the digitally controlled oscillators (DCO1 and DCO2). The other group of SFR called SCU register are accessible via the AHB bus interface.

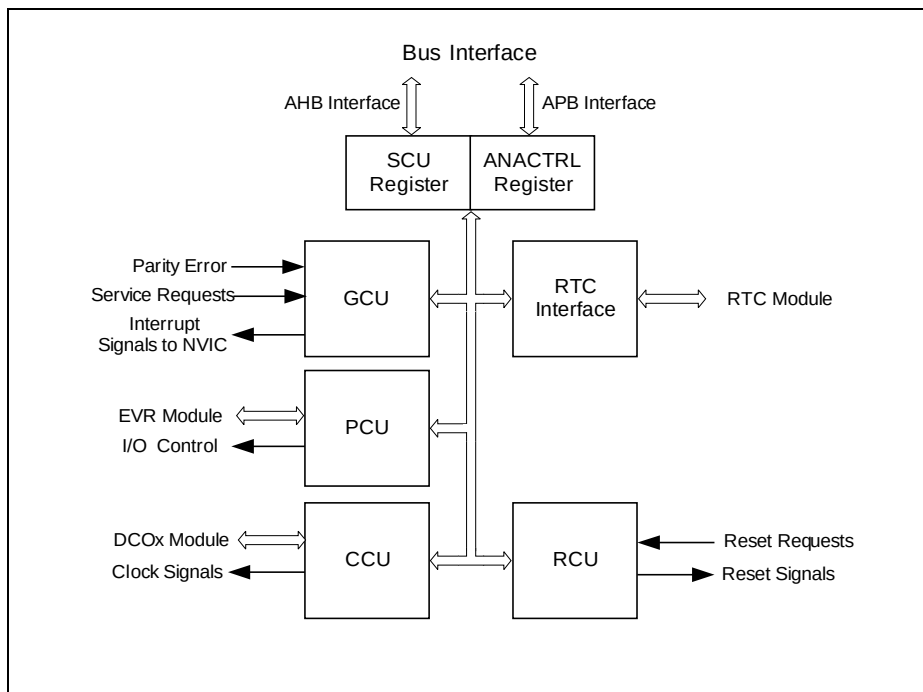


Figure 12-1 SCU Block Diagram

Interface of General Control Unit

The General Control Unit GCU has a memory fault interface to the memory validation logic of each on-chip SRAM and the Flash to receive memory fault events, as parity errors.

Interface of Power Control Unit

The Power Control Unit PCU has an interface to the Embedded Voltage Regulator (EVR) and an interface to the CCU module. The PCU related signals are described in more detail in [Chapter 12.3](#).

Interface of Reset Control Unit

The Reset Control Unit RCU has an interface to the Embedded Voltage Regulator (EVR). The RCU receives the power-on reset and the brownout reset information from the EVR. Reset requests are coming to the unit from the watchdog, the CPU, the GCU and the clock control unit (CCU). The RCU is providing the reset signals to all other units of the chip in the core power domain. The RCU related signals are described in more detail in [Chapter 12.4](#).

Interface of Clock Control Unit

The Clock Control Unit (CCU) receives the clock source from the on-chip Digitally Controlled Oscillator (DCO). The CCU provides the clock signals to all other units of the chip.

Interface of RTC

Access to the RTC module is served over a serial interface. The interface provides mirror registers updated via the serial interface to the RTC module registers. Update of the mirror registers over the serial is controlled using **MIRRSTS** registers. End of update can also trigger service requests via **SRRAW** register. Refresh of the registers in the register mirror are performed continuously, as fast as possible in order to instantly reflect any register state change on both sides.

The RTC module functionality is described in separate RTC chapter.

12.2 Miscellaneous Control Functions (GCU)

System Control implements system management functions accessible via GCU registers. General system control including various auxiliary function is performed in the General Control Unit (GCU).

12.2.1 Service Requests Handling

Service request events listed in [Table 12-1](#) can result in assertion of an interrupt. Please refer to [SRMSK](#) a register description.

The interrupt structure is shown in [Figure 12-2](#). The interrupt request or the corresponding interrupt set bit (in register [SRSET](#)) can trigger the interrupt generation at the selected interrupt node x. The service request pulse is generated independently from the interrupt flag in register [SRRRAW](#). The interrupt flag can be cleared by software by writing to the corresponding bit in register [SRCLR](#).

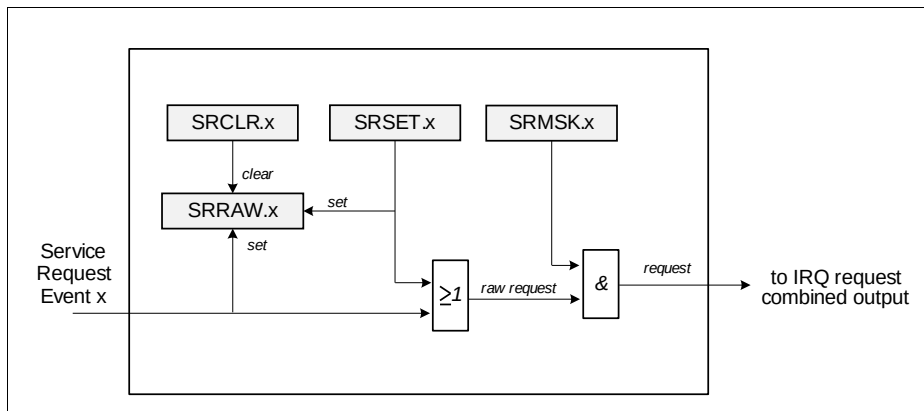


Figure 12-2 Service Request Handling

The flag in register [SRRRAW](#) can be cleared by software by writing to the corresponding bit in register [SRCLR](#). All trap requests are combined to one common line and connected to a regular interrupt node of NVIC.

Note: When servicing an SCU service request, make sure that all related request flags are cleared after the identified request has been handled.

12.2.1.1 Service Request Sources

The SCU supports service request sources listed in [Table 12-1](#) and reflected in the [SRRRAW](#), [SRMSK](#), [SRCLR](#) and [SRSET](#) registers. The events that trigger these service

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requests are described in the respective module chapters or in the various sections within SCU.

Table 12-1 Service Requests

Modules	Service Request Name	Service Request Short Name	SCU.SRx
NVM	Flash Double Bit ECC Event	FLECC2I	SR0
	Flash Operation Complete Event	FLCMPLTI	
	16kbytes SRAM Parity Error Event	PESRAMI	
	USIC0 SRAM Parity Error Event	PEU0I	
SCU:CCU	Loss of Clock Event	LOCI	SR1
	Standby Clock Failure Event	SBYCLKFI	
SCU:PCU	VDDP Pre-warning Event	VDDPI	
	VDROP Event	VDROPI	
	VCLIP Event	VCLIPI	
SCU:GCU	Temperature Sensor Done Event	TSE_DONE	SR2
	Temperature Sensor Compare High Event	TSE_HIGH	
	Temperature Sensor Compare Low Event	TSE_LOW	
WDT	WDT pre-warning	PRWARN	
RTC	RTC Periodic Event	PI	
	RTC Alarm	AI	
	RTC CTR Mirror Register Updated	RTC_CTR	
	RTC ATIM0 Mirror Register Updated	RTC_ATIM0	
	RTC ATIM1 Mirror Register Updated	RTC_ATIM1	
	RTC TIM0 Mirror Register Updated	RTC_TIM0	
	RTC TIM1 Mirror Register Updated	RTC_TIM1	
ORC	Out of Range Comparator Event	ORCxI [x = 0 - 7]	SR2
ACMP	Analog Comparator Event	ACMP0I, ACMP1I, ACMP2I	

12.2.2 SRAM Memory Content Protection

For supervising the content of the on-chip SRAM memories, the following mechanism is provided:

All on-chip SRAMs provide protection of content via parity checking. The parity logic generates additional parity bits which are stored along with each data word at a write operation. A read operation implies checking of the previous stored parity information.

An occurrence of a parity error is observable at the **SRRAW** status register. It is configurable via **SRMSK** whether a memory error should trigger an interrupt. It can also trigger a system reset when **RSTCON.SPERSTEN** or **RSTCON.U0PERSTEN** is set to 1.

A parity control software test, such as to support in-system testing to fulfill Class B requirements, can be enabled with bit **PMTSR.MTENS** for the 16 kbytes SRAM memory individually. Once this bit is set, an inverted parity bit is generated during a write operation. When a read operation is performed on this SRAM address, a parity error shall be detected.

Note: Test software should be located in a different memory space.

12.2.3 Summary of ID

This section describes the various ID in XMC1200.

Module Identification

The module identification register indicates the function and the design step of each peripherals. Register **SCU_ID** is used for SCU module.

System ROM Table ID

The PID values in the system ROM table are defined in the **Table 12-2**. The XMC1200 system ROM table is located at F000 0000_H. Cortex-M0 ROM table is described in the debug chapter.

Table 12-2 PID Values of XMC1200 System ROM Table

Name	Offset	Reference	Values
PID0	FE0 _H	XMC1200 Part Number [7:0]	ED _H
PID1	FE4 _H	bits [7:4] JEP106 ID code [3:0] bits [3:0] XMC1200 Part Number [11:8]	11 _H
PID2	FE8 _H	bits [7:4] XMC1200 Revision bit [3] == 1: JEDEC assigned ID fields bits [2:0] JEP106 ID code [6:4]	1C _H

Table 12-2 PID Values of XMC1200 System ROM Table

Name	Offset	Reference	Values
PID3	FEC _H	bits [7:4] RevAnd, minor revision field bits [3:0] if non-zero indicate a customer-modified block	00 _H
PID4	FD0 _H	bits [7:4] 4KB count bits [3:0] JEP106 continuation code	00 _H

Chip Identification Number

The chip identification number is a 8 word length number. It consists of the values in register DBGROMID, IDCHIP, register PAU_FLSIZE, register PAU_RAM0SIZE and register PAU_AVAILn(n=0-2) respectively. This number is for easy identification of product variants information of the device, example, package type, the temperature profile, flash size, RAM size and the peripheral availability.

12.3 Power Management (PCU)

Power management control is performed in the Power Control Unit (PCU).

12.3.1 Functional Description

The XMC1200 is running from a single external power supply of 1.8 - 5.5V (V_{DDP}). The main supply voltage is supervised by a supply watchdog.

The I/Os is running directly from the external supply voltage. The core voltage (V_{DDC}) is generated by an on-chip Embedded Voltage Regulator (EVR). The safe voltage range of the core voltage is supervised by a power validation circuit, which is part of the EVR.

12.3.2 System States

The system has the following general system states:

- Off
- Active
- Sleep
- Deep-Sleep

Figure 12-3 shows the state diagram and the transitions between the states.

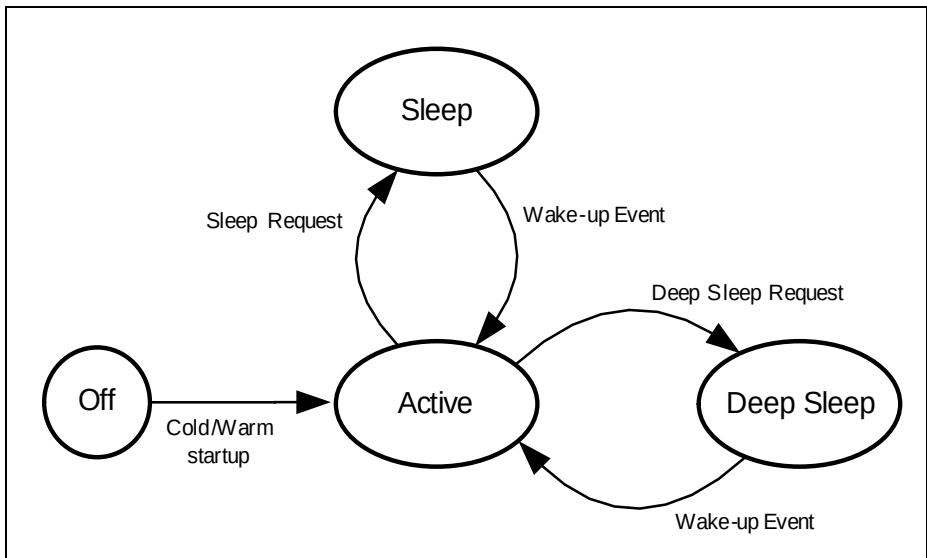


Figure 12-3 System States Diagram

Active State

The active state is the normal operation state. The system is fully powered. The CPU is usually running from a high-speed clock. Depending on the application, the system clock might be slowed down. Unused peripherals might be stopped by gating the clock to these peripherals.

Sleep State

The sleep state of the system corresponds to the sleep state of the CPU. The state is entered via WFI or WFE instruction of the CPU. In this state, the clock to the CPU is stopped. To save power, the clock of the peripherals that are not needed during sleep state can be gated by register **CGATSET0** before entering sleep state.

The Flash can be put into shutdown mode during active state to achieve a further power reduction before entering sleep state via bit NVMCONF.NVM_ON. However, user code would have to be executed in SRAM before entering sleep state and after waking up from sleep state.

To avoid the switching of code execution to SRAM due to the shutdown of flash, register **PWRSVCR** can be used. When FPD bit is set, flash is shutdown only when the device has entered sleep state. The shut down operation is performed after the core has executed WFI/WFE instruction. After a wake-up event is detected, the system will resumed to the previous state i.e. the flash is operable again before the CPU can continue to fetch and execute the code. In this case, user code can be executed in Flash and no switching to SRAM is needed. In this approach, the wake-up time is longer because of the time needed for flash to reach the active state.

Peripherals can continue to operate unaffected and eventually generate an event to wake-up the CPU. In User with Debug mode (UMD) or User with Debug mode and HAR (UMHAR), a Debug HALT request is also able to wake-up the CPU. Any accordingly configured interrupt will bring the CPU back to operation via the NVIC or the M0 debug system.

Deep-Sleep State

The deep-sleep state is entered on the same mechanism as the sleep state with the addition that user code has enabled the deep-sleep state in system control register. This state is similar to sleep state, except that in deep-sleep state, the PCLK and MCLK will be switched to a slow standby clock and DCO1 will be put into power-down mode.

The analog comparator could also be kept active during deep-sleep state. It can be switched to low power mode to save power.

The shutting down of flash via NVMCONF.NVM_ON or PWRSVCR.FPD as explained in above section is applicable for deep-sleep mode.

Peripherals that continue to operate will run using the slow standby clock and can eventually generate an event to wake-up the CPU. In User with Debug mode (UMD) or

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User with Debug mode and HAR (UMHAR), a Debug HALT request is also able to wake-up the CPU. Any accordingly configured interrupt will bring the CPU back to operation via the NVIC or the M0 debug system. The clock system is restored to the previous configuration for active state upon wake-up. Peripherals that are active will run with restored clock configuration.

The SRAM content is preserved in the deep-sleep state.

Note: It is recommended to slow down the PCLK and MCLK before entering deep sleep mode to prevent a sudden load change that could cause a brownout reset.

12.3.3 Embedded Voltage Regulator (EVR)

The EVR generates the core voltage V_{DDC} out of the external supplied voltage V_{DDP} . The EVR provides 2 supply monitoring detectors for the input voltage V_{DDP} . The generated core voltage V_{DDC} is monitored by a power validation circuit (PV).

12.3.4 Power-on Reset

The EVR starts operation as soon as V_{DDP} is above defined minimum level. It releases the reset, when the external voltage V_{DDP} and the generated voltage V_{DDC} are above the reset thresholds and reaching the nominal values.

12.3.5 Power Validation

A power validation circuit monitors the internal core supply voltage, V_{DDC} . It monitors that the core voltage is above the voltage threshold V_{DDCBO} which guarantees safe operation. Whenever the voltage falls below the threshold level, a brownout reset is generated.

12.3.6 Supply Voltage Monitoring

There are 2 detectors, namely, External voltage detector (VDEL) and External brownout detector (BDE) in the EVR that are used to monitor the V_{DDP} .

VDEL detector compares the supply voltage against a pre-warning threshold voltage. The threshold level is programmable via register ANAVDEL.VDEL_SELECT. An interrupt if enabled, will be triggered if a level below this threshold is detected and the flag, VDDPI, in SRRAW register bit is set. An indication bit, VDESR.VDDPPW, shows the output of the detector. During power-up, this indication bit can be polled to ensure that the external supply has reached the pre-warning voltage before starting the application code.

BDE detector is used to trigger a brownout reset when the V_{DDP} supply voltage drops below the defined threshold. Similarly, it is also used to ensure a proper startup during the power-up phase.

The Data Sheet defines the nominal value and applied hysteresis

12.3.7 V_{DDC} Response During Load Change

In XMC1200, the core voltage level, V_{DDC} , drops below the typical threshold when there is an increase in the load and rises when there is a decrease in the load. 2 detectors, VDROP and VCLIP detectors are used to monitor the lower limits and the upper limits of the core voltage level respectively (detectors details are described in the next section). A VDROP event happens when VDDC drops below the VDROP threshold voltage. A VCLIP event happens when VDDC rises above the VCLIP threshold voltage. Each of these events can trigger its dedicated interrupt if enabled via SRMSK register and the event status can be monitored via SRRW register.

In XMC1200, the following scenarios may trigger a VDROP/VCLIP event due to load change:

- Changing the MCLK and PCLK frequency via CLKCR register
- Enabling/Gating the peripheral clock via the CGATSET0/CGATCLR0 registers

When a sudden load change happens ($< 4 \times \text{baseload}$ or $> 0.25 \times \text{baseload}$), regardless of an increase or decrease in load, the EVR needs time (15 μs) to regulate the core voltage back to a stable nominal voltage. During this period of time, the system is expected to maintain in the current load and no load change is allowed. Status bit VDDC2LOW and VDDC2HIGH in CRCLK register are used to indicate whether the voltage is stable.

Note: It is not recommended to increase the load more than 4 times of the baseload or decrease the load to less than 0.25 times of the baseload. If a bigger than the specified load change is required, the recommendation is to change the load in steps that each step is within the limits. For example, a final load of 16mA from the current baseload of 1mA needs at least 2 steps. A step from 1mA to 4mA followed by another step from 4mA to 16mA

The VDDC2LOW and VDDC2HIGH status bit is generated by a 10-bit counter using DCO1, 64MHz clock as the clock input. It is implemented to count the 16 μs (default) that is needed to have a stable V_{DDC} after a VDROP or VCLIP event happens. The length of this counter can be changed depending on the amount of load change via bit CLKCR.CNTADJ. The larger is the load change, the more is the time that user needs to wait for a stable clock. Refer to datasheet for a guideline of the current consumption of each module.

Using the example above, after programming some configuration that causes a change in load from 1mA to 4mA, user can poll for VDDC2LOW (CNTADJ=3FF_H) to ensure the 16 μs (max) needed to regulate EVR. After VDDC2LOW is set to 0, another load change from 4mA to 16mA can be performed and the cycle repeats for each step of load change.

During a VDROP event, clock blanking happens and the detail description is documented in **“Clock Blanking” on Page 12-17**. CPU clock and peripheral clocks continue to run during VCLIP event.

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Note: When overflow event happens while the VDROP=1 (time to overflow based on the CNTADJ value is shorter than the time the device stays in a vdrop event), the 10-bit counter will automatically be restarted with the CNTADJ value.

Note: VDROP and VCLIP detectors are disabled during deep sleep mode.

12.3.8 Flash Power Control

The Flash module can be switched off to reduce static power. In sleep or deep-sleep state, it is dependent on the setting of register **PWRSVCR** whether the Flash module will be put to sleep or not in this state. The user has to evaluate the reduced leakage current against the longer startup time. In addition, the Flash can also be put to sleep using NVMCONF.NVM_ON before entering these power save modes.

12.4 Reset Control (RCU)

Reset Control Unit performs control of all reset related functionality including:

- Reset assertion on various reset request sources
- Inspection of reset sources after reset
- Selective reset of peripheral

12.4.1 Functional Description

The XMC1200 has the following reset types for the system:

- Master Reset, MRESET
- System Reset, SYSRESET

Master Reset, MRESET

Master reset is triggered by:

- Power-on reset (PORST)
- V_{DDP} or V_{DDC} undervoltage reset (also known as brownout reset)
- SW master reset via setting bit RSTCON.MRSTEN to 1

A complete reset to the device is executed by a master reset. Master reset is triggered by a power-on reset upon power-up. Whenever the supply V_{DDP} is ramped-up and crossing the V_{DDP} and V_{DDC} voltage threshold, the power-on reset is released. A power-on reset (also known as brown-out reset) is asserted again whenever the V_{DDP} voltage or the V_{DDC} voltage falls below reset thresholds. In additional, a master reset can be triggered by setting bit RSTCON.MRSTEN.

The sources that trigger a master reset also triggers a system reset SYSRESET.

System Reset, SYSRESET

System reset is triggered by:

- SW reset via Cortex M0 Application Interrupt and Reset Control Register (AIRCR)
- Lockup signal from Cortex M0 when enabled at RCU
- Watchdog reset
- Memory parity error when enabled
- Flash ECC double bit error when enabled
- Loss of clock when enabled
- sources that trigger a master reset

A system reset affects almost all logics. The only exceptions are RCU registers and Debug system when debug probe is present. The reset gets extended to the length defined by implementation requirements.

The debug system is reset by System Reset in normal operation mode when debug probe is not present. When debug probe is present, System Reset must not affect the Debug system.

12.4.2 Reset Status

The EVR provides the cause of a power on reset to the RCU. The reset cause can be inspected after resuming operation by reading register **RSTSTAT**. This register also indicates the source of event that causes the triggering of a system reset.

All registers of the RCU undergo reset only by a master reset except for RSTSTAT and RSTCON register. RSTSTAT register is only reset by a power-on reset and RSTCON is reset by any reset type.

*Note: Clearing of the reset status via register bit **RSTCLR.RSCLR** is strongly recommended to ensure a clear indication of the cause of next reset.*

Table 12-3 shows an overview of the reset signals their source and effects on the various parts of the system.

Table 12-3 Reset Overview

Module/Function	Power-on Reset	Master Reset by SW bit	System Reset
CPU Core	yes	yes	yes
SCU	yes	yes	yes, except reset indication bit
Peripherals	yes	yes	yes
Debug System	yes	yes	see footnote ¹⁾²⁾
Port Control	yes	yes	yes
SRAM	Affected,unreliable	Not affected	Not affected
Flash	yes	yes	yes
EVR	yes	no ³⁾	no
Clock System	yes	yes	yes

1) Debug system will be reset only if debug probe is not present.

2) Access to debug interface is disabled after every reset even when debug probe is present. See Warm Reset section of Debug System chapter for more details.

3) The supply to EVR will not be affected and hence a complete reset to EVR is not possible. However, it will be partially affected by the reset in the ANACTRL module.

12.5 Clock Control (CCU)

12.5.1 Features

The clock control unit CCU has the following functionality:

- Dedicated RTC and standby clock
- Clock Supervisory
 - Oscillator watchdog
- Wide range of frequency scaling of system frequencies
- Individual peripheral clock gating

12.5.2 Clock System and Control

Figure 12-4 shows the block diagram of the clock system in XMC1200. It consists of two oscillator (DCO1¹) and DCO2) and a clock control unit (CCU). DCO1 has a clock output, dco1_dclk running at 64MHz. DCO2 is used to generate the standby clock running at 32.768kHz. The main clock, MCLK, and fast peripheral clock, PCLK, are generated from dco1_dclk. PCLK is running in either the same frequency as MCLK or double the frequency of MCLK. It is selectable via CLKCR.PCLKSEL.

Figure 12-4 shows the list of peripherals that are running in the PCLK domain. The rest of the peripherals except RTC and WDT are clocked by MCLK which is the same as the core and bus system. RTC and WDT is running at a frequency of 32.768kHz from the standby clock which is asynchronous to the MCLK and PCLK clock.

1) The accuracy of the DCO1 clock output can be improved by calibrating it based on the die temperature given by the temperature sensor. Refer to [Section 12.5.4](#) for detailed description.

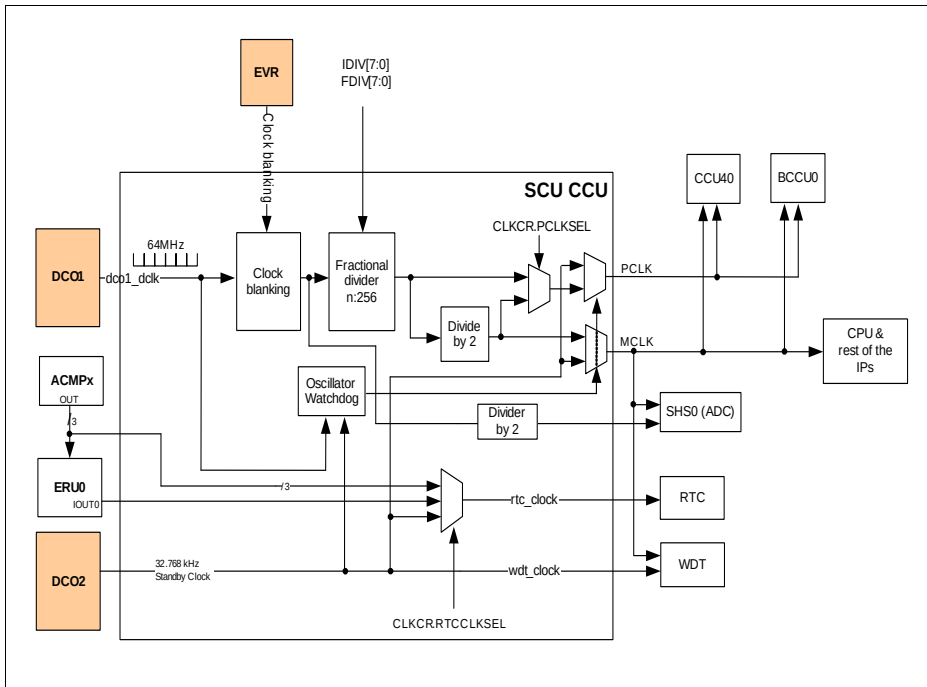


Figure 12-4 Clock System Block Diagram

Note: SHS(ADC) clock will not switched to standby clock source when there is a loss of clock event.

Note: RTC_extclk are further described in RTC chapter .

Fractional Divider

The frequency of MCLK and PCLK are programmable through a fractional divider. PCLK has a range of frequency from 125kHz to 64MHz and MCLK has a range from 125kHz to 32MHz.

The following formula calculate the MCLK clock frequency.

(12.1)

$$\left(\text{MCLK} = \frac{\text{dco\_dclk}}{(2) \times \left(\text{IDIV} + \frac{\text{FDIV}}{256} \right)} \right) \text{ for IDIV} > 0$$

The following formula calculate the PCLK clock frequency when CLKCR.PCLKSEL is set to 1 and it is double the frequency of MCLK.

(12.2)

$$\left(\text{PCLK} = \frac{\text{dco\_dclk}}{\left(\text{IDIV} + \frac{\text{FDIV}}{256} \right)} \right) \text{ for IDIV} > 0$$

IDIV represents an unsigned 8-bit integer from the bit field CLKCR.IDIV and FDIV/256 defines the fractional divider selection in CLKCR.FDIV. Changing of the MCLK and PCLK can be done within 2 clock cycles. While changing the frequency of MCLK clock and PCLK clock, it is recommended to disable all interrupts to prevent any access to flash that may results in an unsuccessful flash operation.

*Note: Changing the MCLK and PCLK frequency may result in a load change that causes clock blanking to happen. Refer to **Clock Blanking** and **VDDC Response During Load Change** for more details.*

Clock Blanking

To prevent a brown-out reset in case of a sudden positive load change, the clock blanking circuitry is used. It freezed the clock input to the fractional divider to regulate the

System Control Unit (SCU)

load change. The clock blanking only causes a small jitter if it is considered over a longer time period.

The clock blanking is activated when V_{DDC} is detected to be below the VDROF threshold. Once the V_{DDC} is above this threshold, the enabled clocking is resume. This voltage drop detector is part of the EVR and it is activated by default upon any reset.

To monitor clock blanking activities, user can enable interrupt but can only enter ISR after the clock resume.

In addition to the use of clock blanking function to prevent a brown-out reset, the system is also expected to maintain in the current load and no further load change is allowed for 16 usec (max). Detail description of the core voltage behaviors during load change are described in **“VDDC Response During Load Change” on Page 12-11**.

As described in **“VDDC Response During Load Change” on Page 12-11**, the status bit CLKCR.VDDC2LOW is used to indicate to user that the core voltage, V_{DDC} , is below the nominal voltage and EVR is in the process of regulating it. During this period, the clock could be also not running in the selected speed and it is recommended to poll this bit before continuing with any large change to the current load.

Note: It is recommended to slow down the PCLK and MCLK before entering deep sleep mode to prevent a sudden load change that could cause a brownout reset when entering .

12.5.2.1 Oscillator Watchdog

The oscillator watchdog (OWD) monitors the DCO1 clock frequency using the standby clock as the reference clock. It can be disabled via OSCCSR.OWDEN. By setting bit OSCCSR.OWDRES¹⁾, the detection for DCO1 clock frequency can be restarted. The detection status output is only valid after some cycles of the standby clock frequency. When the OWD is disabled, the detection status will be reset and no detection is possible.

If the OWD is enabled before entering deep sleep mode, it will be disabled automatically by hardware when it enters deep sleep mode and re-enabled again after exiting deep sleep mode. The detection is reset and restarted after device wake-up from deep sleep mode.

12.5.2.2 Loss of Clock Detection and Recovery

Loss of clock happens when the oscillator watchdog (OWD) detects a DCO1 frequency that is less than 50 MHz or more than 68.5 MHz during normal operation. In this case,

1) It is recommended to clear the status bit SRRAW.LOCI and SRRAW.SBYCLKFI before restarting the detection.

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an interrupt will be generated if it is enabled. Concurrently, the oscillator status flag, `OSCCSR.OSC2L` or `OSCCSR.OSC2H`, is set to 1 and the system clock will be provided by the standby clock of 32.768kHz. Emergency routines can be executed to safely shut down the system. Beside triggering an interrupt when the loss of clock happens, a system reset can also be triggered if it is enabled by `RSTCON.LOCRSTEN`.

Note: Switching to standby clock during loss of clock event happens only if DCO2 is still running (>0MHz). Bit `SRRAW.SBYCLKFI` indicates the fail status of the standby clock.

The XMC1200 remains in this loss of clock state until the next reset or after a successful clock recovery has been performed. A clock recovery could be carried out by restarting the detection by setting bit `OSCCSR.OWDRES`. Upon detecting a stable oscillator frequency of more than 50 MHz and lower than 68.5MHz, `OSC2L` and `OSC2H` will be set to 0 and the MCLK will switched automatically to the DCO1 clock source.

12.5.2.3 Standby Clock Failure

The standby clock failure event happens when the OWD detects a failure in standby clock where the clock stops running (~0kHz). Bit `SRRAW.SBYCLKFI` is set to 1 and trigger an interrupt via `SCU_SR1` service request if the interrupt is enabled in register `SRMSK`.

12.5.2.4 Startup Control for System Clock

When the XMC1200 starts up after reset, system frequency is provided by the DCO1 oscillator. After reset, CPU runs in 8MHz, default frequency. User can change the clock frequency that is used to execute the SSW and the user application code by defining it in the flash memory location 1000 1010_H. This feature allows the flexibility of device performance e.g. speed vs power consumption optimisation during start-up. For details, please refer to the section “Clock system handling by SSW” in the “Boot and Startup” chapter.

12.5.3 Clock Gating Control

The clock to peripherals can be individually gated and parts of the system can be stopped by registers `CGATSET0`. After a master reset, only core, memories, SCU and PORT peripheral are not clock gated. The rest of the peripherals are default clock gated. User can select the clock of individual modules to be enabled by SSW after reset by defining it in the flash memory location 1000 1014_H. Refer to Boot and Startup chapter for more details.

Load change during module clock enabling or gating

Enabling or gating the clock to peripherals could result in a load change that could cause clock blanking to happen. In addition, a load change of more than 4 times the current

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load would required the system to maintain in the current load and no further load change is allowed for 16 usec (max). See **VDDC Response During Load Change** for more details.

Module clock gating in Sleep and Deep-Sleep modes

It is recommended to gate the clock using registers **CGATSET0** for module that is not needed during sleep mode or deep-sleep mode. These modules must be disabled before entering sleep or deep-sleep mode. In addition, the PCLK and MCLK will be switched to a slow standby clock and DCO1 will be put into power-down mode in deep-sleep mode.

12.5.4 Calibrating DCO based on Temperature

In XMC1200, DCO1 clock frequency can be calibrated during runtime to achieve a better accuracy. Based on the measured temperature using the on-chip temperature sensor(TSE), an offset value can be obtained using the formulae as shown below:

(12.3)

$$\text{OFFSET}[\text{steps}] = b + \frac{(a - b)(c - d)}{(e - d)}$$

where :

OFFSET value is range from 0 to 4

c is the measured temperature [°C]

a is constant DCO_ADJLO_T2

b is constant DCO_ADJLO_T1

d is constant ANA_TSE_T1

e is constant ANA_TSE_T2

The 4 constants in the formulae are stored in flash configuration page shown in **Table 12-4**.

Table 12-4 DCO calibration data in Flash sector 0 (CS0)

Address	Length	Function
DCO calibration data:		
1000'0F30 _H	1 B	ANA_TSE_T1
1000'0F31 _H	1 B	ANA_TSE_T2

Table 12-4 DCO calibration data in Flash sector 0 (CS0)

Address	Length	Function
1000'0F32 _H	1 B	DCO_ADJLO_T1
1000'0F33 _H	1 B	DCO_ADJLO_T2

Input the offset value (rounded to the nearest integer) to register bit [ANAOFFSET](#).ADJL_OFFSET to start the DCO1 calibration. The offset value must be within the range of 0 to 8. This bit field is bit protected. DCO1 will take about 5 usec(max) for clock to be adjusted to the new frequency.

An example code is provided in the Oscillator Handling Device Guide.

12.6 Service Request Generation

The SCU module provides 3 service request outputs SR[2:0]. SR0 is for system critical request, such as loss of clock event. SR1 is for the common SCU request such as TSE request. SR2 is for ACMP and ORC requests. The service request outputs SR[2:0] are connected to interrupt nodes in the Nested Vectored Interrupt Controller (NVIC).

Refer to [Section 12.2.1](#) for more details.

12.7 Debug Behavior

The SCU module does not get affected with the HALTED signal from SCU upon debug activities performed using external debug probe.

12.8 Power, Reset and Clock

The SCU module implements functions that involve various types of modules controlled directly or via dedicated interfaces that are instantiated in different power, clock and reset domains. These modules are functionally considered parts of the SCU and therefore SCU is also considered a multi domain circuit in this sense.

Power domains:

Power domains get separated with appropriate power separation cells.

- Core domain supplied with V_{DDC} voltage
- Pad domain supplied with V_{DDP} voltage

Clock domains:

All cross-domain interfaces implement signal synchronization.

- internal SCU clock is MCLK, always identical to the CPU clock
- RTC and register mirror interface clock is 32.786 kHz clock generated from DCO2 oscillator

Reset domains:

All resets get internally synchronized to respective clocks.

- System Reset ($\overline{\text{SYSRESET}}$) resets most of the logics in SCU and can be triggered from various sources (please refer to **Reset Control (RCU)** section for more details)
- Master Reset ($\overline{\text{MRESET}}$) contributes in generation of the System Reset and gets triggered upon power-up sequence of the Core domain

12.9 Registers

This section describes the registers of SCU which some of them resides in the ANACTRL module. Most of the registers are reset by SYSRESET reset signal but some of the registers can be reset only with power-on reset. SCU registers are accessible via the AHB-lite bus. ANACTRL registers are accessible via the APB bus. ANACTRL registers have name starting with “ANA”.

Table 12-5 Base Addresses of sub-sections of SCU registers

Short Name	Description	Offset Addr. ¹⁾
GCU Registers	Offset address of General Control Unit	0000 _H
PCU Registers	Offset address of Power Control Unit	0200 _H
CCU Registers	Offset address of Clock Control Unit	0300 _H
RCU Registers	Offset address of Reset Control Unit	0400 _H
RTC Registers	Offset address of Real Time Clock Module	0A00 _H
ANACTRL Registers	Offset address of ANACTRL registers	1000 _H

1) The absolute register address is calculated as follows:

Module Base Address + Sub-Module Offset Address (shown in this column) + Register Offset Address

Following access to SCU/ANACTRL SFRs result in an AHB/APB error response:

- Read or write access to undefined address
- Write access to read-only registers
- Write access to startup protected registers

Table 12-6 Registers Address Space

Module	Base Address	End Address	Note
SCU	4001 0000 _H	4001 FFFF _H	System Control Unit Registers

Table 12-7 Registers Overview

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
PCU Registers (ANACTRL)					
ANAVDEL	Voltage Detector Control register	1050 _H	U, PV	U, PV	Page 12-25
PCU Registers (SCU)					
VDESR	Voltage Detector Status Register	0000 _H	U, PV	U, PV	Page 12-26
CCU Registers (SCU)					
CLKCR	Clock Control	0000 _H	U, PV	U, PV, BP	Page 12-27
PWRSVCR	Power Save Control Register	0004 _H	U, PV	U, PV	Page 12-29
CGATSTAT0	Clock Gating Status for Peripherals 0	0008 _H	U, PV	U, PV	Page 12-30
CGATSET0	Clock Gating Set for Peripherals 0	000C _H	U, PV	U, PV, BP	Page 12-31
CGATCLR0	Clock Gating Clear for Peripherals 0	0010 _H	U, PV	U, PV, BP	Page 12-33
OSCCSR	Oscillator Control and Status Register	0014 _H	U, PV	U, PV	Page 12-34
CCU Registers (ANACTRL)					
ANAOFFSET	DCO1 Offset Register	106C _H	U, PV	U, PV, BP	Page 12-36
RCU Registers (SCU)					
RSTSTAT	Reset Status	0000 _H	U, PV	BE	Page 12-37
RSTSET	Reset Set Register	0004 _H	U, PV	U, PV	Page 12-38
RSTCLR	Reset Clear Register	0008 _H	U, PV	U, PV	Page 12-38
RSTCON	Reset Control Register	000C _H	U, PV	U, PV	Page 12-39
GCU Registers (SCU)					
ID	Module Identification Register	0008 _H	U, PV	BE	Page 12-41
IDCHIP	Chip ID	0004 _H	U, PV	SP	Page 12-42

System Control Unit (SCU)

Table 12-7 Registers Overview (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
DBGROMID	DBGROMID	0000 _H	U, PV	SP	Page 12-43
SSW0	SSW Support Register	0014 _H	U, PV	U, PV	Page 12-43
CCUCON	CCUx Global Start Control Register	0030 _H	U, PV	U, PV	Page 12-44
SRRAW	RAW Service Request Status	0038 _H	U, PV	BE	Page 12-45
SRMSK	Service Request Mask	003C _H	U, PV	U, PV	Page 12-47
SRCLR	Service Request Clear	0040 _H	U, PV	U, PV	Page 12-50
SRSET	Service Request Set	0044 _H	U, PV	U, PV	Page 12-52
PASSWD	Bit protection Register	0024 _H	U, PV	U, PV	Page 12-55
MIRRSTS	Mirror Update Status Register	0048 _H	U, PV	BE	Page 12-57
PMTSR	Parity Memory Test Select Register	0054 _H	U, PV	U, PV	Page 12-58

1) The absolute register address is calculated as follows:

Module Base Address + Sub-Module Offset Address + Offset Address (shown in this column)

12.9.1 PCU Registers (ANACTRL)

ANAVDEL

Voltage Detector Control register.

ANAVDEL

Voltage Detector Control Register (1050_H)

Reset Value:001C_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0											VDEL_N	VDEL_TIM_ADJ	VDEL_SELECT		
r											rw	rw	rw		

Field	Bits	Type	Description
VDEL_SELECT	1:0	rw	VDEL Range Select With these bits the VDDP range is set. 00 _B 2.25V 01 _B 3.0V 10 _B 4.4V
VDEL_TIM_ADJ	3:2	rw	VDEL Timing Setting These bits control the reaction speed of the VDEL. The value is determined by characterisation. 00 _B typ 1μs - slowest response time 01 _B typ 500n 10 _B typ 250n 11 _B no delay - fastest response time.
VDEL_EN	4	rw	VDEL unit Enable 0 _B VDEL is disabled 1 _B VDEL is active
0	15:5	r	Reserved Read as 0; should be written with 0.

12.9.2 PCU Registers (SCU)

VDESR

Voltage Detector status register.

VDESR

Voltage Detector Status Register (0200_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														VDD	VCLI
r														PPW	P
														rh	rh

System Control Unit (SCU)

Field	Bits	Type	Description
VCLIP	0	rh	VCLIP Indication VCLIP monitoring bit. 0 _B VCLIP is not active 1 _B VCLIP is active
VDDPPW	1	rh	VDDPPW Indication 0 _B VDDP is above pre-warning threshold 1 _B VDDP is below pre-warningthreshold
0	[31:2]	r	Reserved Read as 0; should be written with 0.

12.9.3 CCU Registers (SCU)

CLKCR

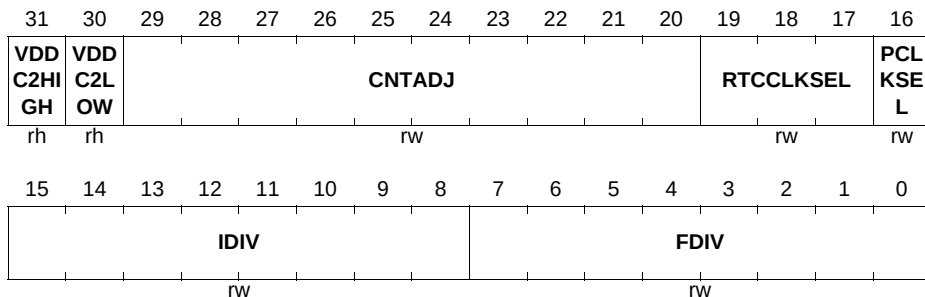
Clock control register.

CLKCR

Clock Control Register

(0300_H)

Reset Value: 3FF0 0400_H



Field	Bits	Type	Function
FDIV	[7:0]	rw	Fractional Divider Selection Selects the fractional divider to be $n/256$, where n is the value of FDIV and is in the range of 0 to 255. For example, writing 0001_B to FDIV selects the fractional divider to be $1/256$. This bit is protected by the bit protection scheme as described in Memory Organization chapter <i>Note: Fractional divider has no effect if IDIV = 00_H.</i>
IDIV	[15:8]	rw	Divider Selection 00_H Divider is bypassed. 01_H 1; MCLK = 32 MHz 02_H 2; MCLK = 16 MHz 03_H 3; MCLK = 10.67 MHz 04_H 4; MCLK = 8 MHz FE_H 254; MCLK = 126 kHz FF_H 255; MCLK = 125.5 kHz This bit is protected by the bit protection scheme as described in Memory Organization chapter
PCLKSEL	16	rw	PCLK Clock Select 0_B PCLK = MCLK 1_B PCLK = 2 x MCLK This bit is protected by the bit protection scheme as described in Memory Organization chapter
RTCCLKSEL	[19:17]	rw	RTC Clock Select 000_B 32.768kHz standby clock 001_B 32.768kHz external clock from ERU0.IOUT0 010_B 32.768kHz external clock from ACMP0.OUT 011_B 32.768kHz external clock from ACMP1.OUT 100_B 32.768kHz external clock from ACMP2.OUT 101_B Reserved 110_B Reserved 111_B Reserved This bit is protected by the bit protection scheme as described in Memory Organization chapter

System Control Unit (SCU)

Field	Bits	Type	Function
CNTADJ	[29:20]	rw	Counter Adjustment 000 _H 1 clock cycles of the DCO1, 64MHz clock 001 _H 2 clock cycles of the DCO1, 64MHz clock 002 _H 3 clock cycles of the DCO1, 64MHz clock 003 _H 4 clock cycles of the DCO1, 64MHz clock 004 _H 5 clock cycles of the DCO1, 64MHz clock 3FE _H 1023 clock cycles of the DCO1, 64MHz clock 3FF _H 1024 clock cycles of the DCO1, 64MHz clock
VDDC2LOW	30	rh	VDDC too low 0 _B VDDC is not too low and the fractional divider input clock is running at the targeted frequency 1 _B VDDC is too low and the fractional divider input clock is not running at the targeted frequency
VDDC2HIGH	31	rh	VDDC too high 0 _B VDDC is not too high 1 _B VDDC is too high

PWRSVCR

Configuration register that defines some system behaviour aspects while in deep-sleep mode or sleep mode. The original system state gets restored upon wakeup from sleep mode or deep-sleep mode.

PWRSVCR

Power Save Control Register (0304_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															FPD
r															rw

Field	Bits	Type	Description
FPD	0	rw	Flash Power Down 0 _B no effect 1 _B Flash power down when entering power save mode. Upon wake-up, CPU is able to fetch code from flash.
0	[31:1]	r	Reserved Read as 0.

CGATSTAT0

Clock gating status for XMC1200 peripherals. After reset, all peripherals as listed in the registers are not running. Their module clock are gated.

Every bit in this register is protected by the bit protection scheme as described in Memory Organization chapter.

CGATSTAT0

Peripheral 0 Clock Gating Status (0308_H) **Reset Value: 0000 07FF_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					RTC	WDT	1	LED TS1	LED TS0	BCC U0	USIC 0	CCU 40	1	VAD C	
r					r	r	r	r	r	r	r	r	r	r	r

Field	Bits	Type	Description
VADC	0	r	VADC and SHS Gating Status 0 _B gating de-asserted 1 _B gating asserted
CCU40	2	r	CCU40 Gating Status 0 _B gating de-asserted 1 _B gating asserted

System Control Unit (SCU)

Field	Bits	Type	Description
USIC0	3	r	USIC0 Gating Status 0 _B gating de-asserted 1 _B gating asserted
BCCU0	4	r	BCCU0 Gating Status 0 _B gating de-asserted 1 _B gating asserted
LEDTS0	5	r	LEDTS0 Gating Status 0 _B gating de-asserted 1 _B gating asserted
LEDTS1	6	r	LEDTS1 Gating Status 0 _B gating de-asserted 1 _B gating asserted
WDT	9	r	WDT Gating Status 0 _B gating de-asserted 1 _B gating asserted
RTC	10	r	RTC Gating Status 0 _B gating de-asserted 1 _B gating asserted
0	[31:11]	r	Reserved
1	1, [8:7]	r	Reserved

CGATSET0

Clock gating enable for XMC1200 peripherals. Write one to selected bit to enable gating of corresponding clock, writing zeros has no effect.

Every bit in this register is protected by the bit protection scheme as described in Memory Organization chapter.

CGATSET0

Peripheral 0 Clock Gating Set

(030C_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					RTC	WDT	0		LED TS1	LED TS0	BCC U0	USIC 0	CCU 40	0	VAD C
r					w	w	r	w	w	w	w	w	w	r	w

Field	Bits	Type	Description
VADC	0	w	VADC and SHS Gating Set 0 _B no effect 1 _B enable gating
CCU40	2	w	CCU40 Gating Set 0 _B no effect 1 _B enable gating
USIC0	3	w	USIC0 Gating Set 0 _B no effect 1 _B enable gating
BCCU0	4	w	BCCU0 Gating Set 0 _B no effect 1 _B enable gating
LEDTS0	5	w	LEDTS0 Gating Set 0 _B no effect 1 _B enable gating
LEDTS1	6	w	LEDTS1 Gating Set 0 _B no effect 1 _B enable gating
WDT	9	w	WDT Gating Set 0 _B no effect 1 _B enable gating

System Control Unit (SCU)

Field	Bits	Type	Description
RTC	10	w	RTC Gating Set 0 _B no effect 1 _B enable gating
0	1, [8:7], [31:11]	r	Reserved

CGATCLR0

Clock gating disable for XMC1200 peripherals. Write one to selected bit to disable gating of corresponding clock, writing zeros has no effect.

CGATCLR0

Peripheral 0 Clock Gating Clear (0310_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					RTC	WDT	0		LED TS1	LED TS0	BCC U0	USIC 0	CCU 40	0	VAD C
r					w	w	r		w	w	w	w	w	r	w

Field	Bits	Type	Description
VADC	0	w	VADC and SHS Gating Clear 0 _B no effect 1 _B disable gating
CCU40	2	w	CCU40 Gating Clear 0 _B no effect 1 _B disable gating
USIC0	3	w	USIC0 Gating Clear 0 _B no effect 1 _B disable gating
BCCU0	4	w	BCCU0 Gating Clear 0 _B no effect 1 _B disable gating

System Control Unit (SCU)

Field	Bits	Type	Description
LEDTS0	5	w	LEDTS0 Gating Clear 0 _B no effect 1 _B disable gating
LEDTS1	6	w	LEDTS1 Gating Clear 0 _B no effect 1 _B disable gating
WDT	9	w	WDT Gating Clear 0 _B no effect 1 _B disable gating
RTC	10	w	RTC Gating Clear 0 _B no effect 1 _B disable gating
0	1, [8:7], [31:11]	r	Reserved

OSCCSR

Oscillator Control and Status Register.

OSCCSR

Oscillator Control and Status Register

(0314_H)

Reset Value: 0000 000X_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0														OWD EN	OWD RES
r														rw	rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0														OSC 2H	OSC 2L
r														rh	rh

Field	Bits	Type	Description
OSC2L	0	rh	Oscillator Valid Low Status Bit This bit indicates if the frequency output of OSC is usable. This is checked by the Oscillator Watchdog. 0_B The OSC frequency is usable 1_B The OSC frequency is not usable. Frequency is too low.
OSC2H	1	rh	Oscillator Valid High Status Bit This bit indicates if the frequency output of OSC is usable. This is checked by the Oscillator Watchdog. 0_B The OSC frequency is usable 1_B The OSC frequency is not usable. Frequency is too high.
OWDRES	16	rwh	Oscillator Watchdog Reset Setting this bit will restart the oscillator detection. This bit will be automatically reset to 0 after OWD is reset which takes 2 standby clock cycles due to synchronisation. 0_B The Oscillator Watchdog is not cleared and remains active 1_B The Oscillator Watchdog is cleared and restarted. The OSC2L and OSC2H flag will be held in the last value until it is updated after 3 standby clock cycles.
OWDEN	17	rw	Oscillator Watchdog Enable 0_B The Oscillator Watchdog is disabled 1_B The Oscillator Watchdog is enabled <i>Note: OSC2H and OSC2L will be cleared to 0 when OWD is disabled.</i>
0	[15:2], [31:18]	r	Reserved Read as 0.

12.9.4 CCU Registers (ANACTRL)

ANAOFFSET

DCO1 Offset register.

ANAOFFSET

DCO1 Offset Register

(106C_H)

Reset Value: 0004_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												ADJL_OFFSET			
r												rw			

Field	Bits	Type	Description
ADJL_OFFSET	3:0	rw	ADJL Offset register The adjusted oscillator frequency can be varied according to the steps programmed. This bit is protected by the bit protection scheme as described in Memory Organization chapter 0 _H - 3.75%, typ. 1 _H - 2.85%, typ. ... 4 _H 0, default 5 _H + 0.95%, typ. ... 8 _H + 3.75%, typ.
0	15:4	r	Reserved Read as 0; should be written with 0.

12.9.5 RCU Registers (SCU)

RSTSTAT

Reset status register. This register needs to be checked after system startup in order to determine last reset reason. User should clear this register after reading it to ensure a clear status when the next reset happen. This register is reset by a power-on reset.

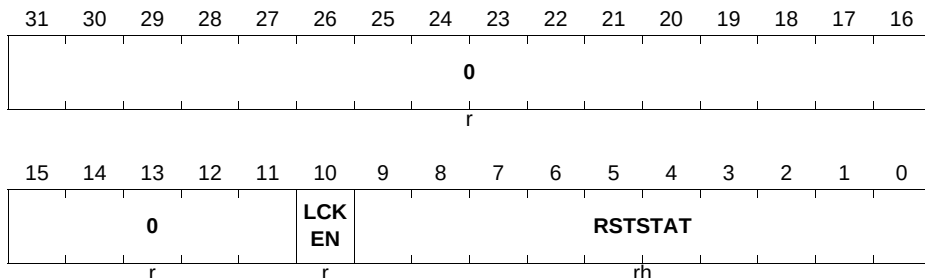
System Control Unit (SCU)

RSTSTAT

RCU Reset Status

(0400_H)

Reset Value: 0000 0XXX_H



Field	Bits	Type	Description
RSTSTAT	[9:0]	rh	Reset Status Information Provides reason of last reset 0000000001 _B Power on reset or Brownout reset XXXXXXXX1X _B Master reset via bit RSTCON.MRSTEN XXXXXXXX1X _B CPU system reset request XXXXXX1XXX _B CPU lockup reset XXXXX1XXXX _B Flash ECC reset XXXX1XXXXX _B WDT reset XXX1XXXXXX _B Loss of clock reset XX1XXXXXXX _B Parity Error reset
LCKEN	10	r	Enable Lockup Status 0 _B Reset by Lockup disabled 1 _B Reset by Lockup enabled
0	[31:11]	r	Reserved

RSTSET

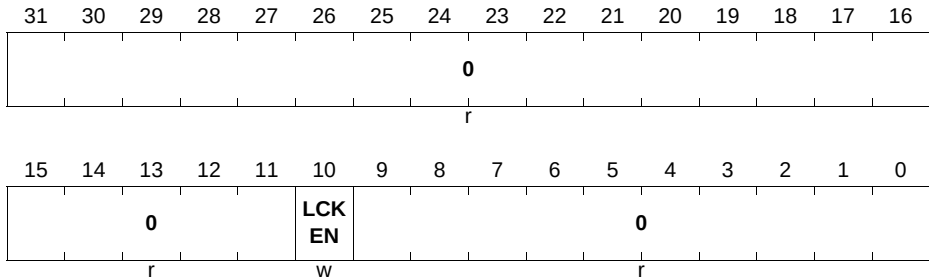
Selective configuration of reset behaviour in the system. Write one to set selected bit, writing zeros has no effect.

RSTSET

RCU Reset Set Register

(0404_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
LCKEN	10	w	Enable Lockup Reset 0 _B no effect 1 _B Enable reset when Lockup gets asserted
0	[9:0], [31:11]	r	Reserved

RSTCLR

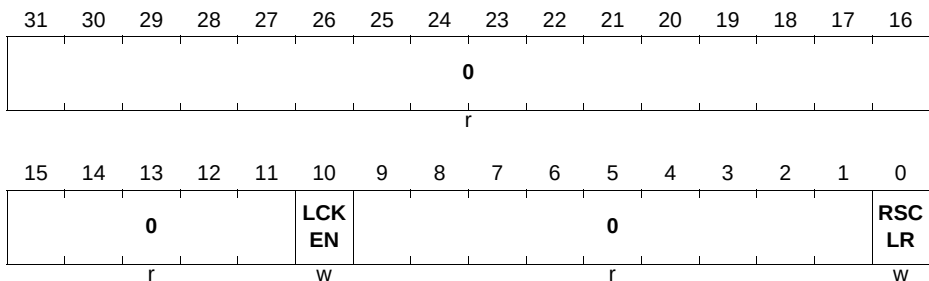
Selective configuration of reset behaviour in the system. Write one to clear selected bit, writing zeros has no effect.

RSTCLR

RCU Reset Clear Register

(0408_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
RSCLR	0	w	Clear Reset Status 0 _B no effect 1 _B Clears field RSTSTAT.RSTSTAT
LCKEN	10	w	Enable Lockup Reset 0 _B no effect 1 _B Disable reset when Lockup gets asserted
0	[9:1], [31:11]	r	Reserved

RSTCON

Enabling of reset triggered by critical events. It is reset by any reset type.

RSTCON

RCU Reset Control Register (040C_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															MRS TEN
r															w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												U0P ERS TEN	SPE RST EN	LOC RST EN	ECC RST EN
r												rw	rw	rw	rw

Field	Bits	Type	Description
ECCRSTEN	0	rw	Enable ECC Error Reset 0 _B No reset when ECC double bit error occur 1 _B Reset when ECC double bit error occur
LOCRSTEN	1	rw	Enable Loss of Clock Reset 0 _B No reset when loss of clock occur 1 _B Reset when loss of clock occur
SPERSTEN	2	rw	Enable 16kbytes SRAM Parity Error Reset 0 _B No reset when SRAM parity error occur 1 _B Reset when SRAM parity error occur

System Control Unit (SCU)

Field	Bits	Type	Description
U0PERSTEN	3	rw	Enable USIC0 SRAM Parity Error Reset 0 _B No reset when USIC0 memory parity error occur 1 _B Reset when USIC0 memory parity error occur
MRSTEN	16	w	Enable Master Reset 0 _B No effect 1 _B Triggered Master reset
0	[15:4], [31:17]	r	Reserved

12.9.6 GCU Registers (SCU)

ID

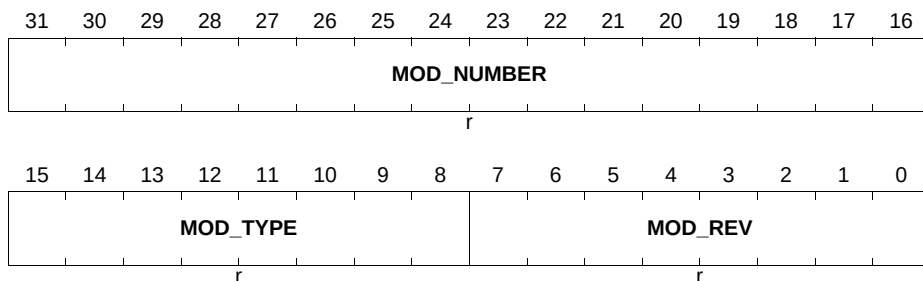
Register containing unique ID of the module.

ID

SCU Module ID Register

(0008_H)

Reset Value: 00F1 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 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.

IDCHIP

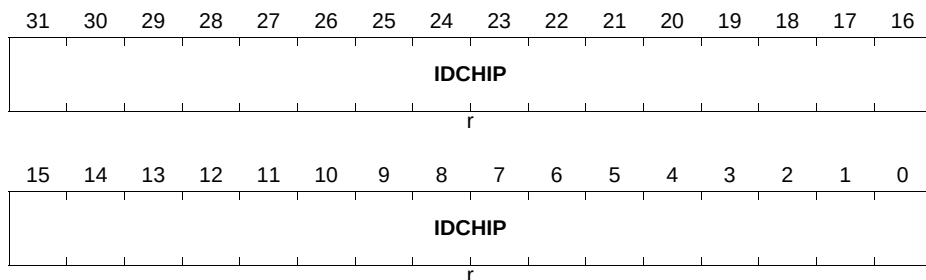
Register containing a unique ID of the chip in the XMC family. The value of this register formed part of the chip identification number as described in [Chip Identification Number](#).

IDCHIP

Chip ID Register

(0004_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
IDCHIP	[31:0]	r	CHIP ID 0001 2XXX _H XMC1200 0001 XXX2 _H temperature : -40 - 85 °C 0001 XXX3 _H temperature : -40 - 105 °C 0001 XX1X _H TSSOP38 pin package 0001 XX2X _H TSSOP28 pin package 0001 XX3X _H TSSOP16 pin package 0001 XX4X _H VQFN40 pin package 0001 XX6X _H VQFN24 pin package Others Reserved

DBGROMID

Register containing unique manufactory ID, part number and the design stepping code of the chip.

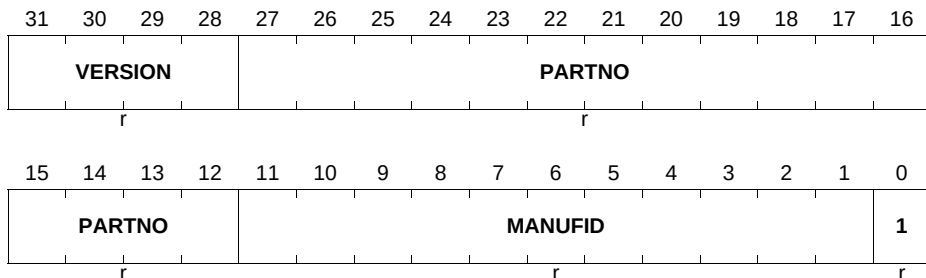
System Control Unit (SCU)

DBGROMID

Debug System ROM ID Register

(0000_H)

Reset Value: 201E D083_H



Field	Bits	Type	Description
MANUFID	[11:1]	r	Manufactory Identity
PARTNO	[27:12]	r	Part Number
VERSION	[31:28]	r	Product version
1	0	r	Reserved Read as 1; should be written with 1.

SSW0

Software support registers.

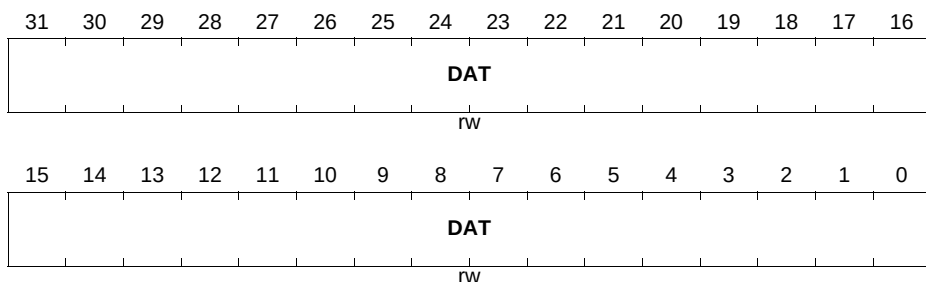
SSW0 is used to change the BMI value.

SSW0

SSW Register 0

(0014_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DAT	[31:0]	rw	SSW Data <i>Note: SSW registers can be reset with master reset only</i>

CCUCON

CAPCOM module control register.

CCUCON

CCU Control Register (0030_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															GSC 40
r															rw

Field	Bits	Type	Description
GSC40	0	rw	Global Start Control CCU40 This register can be used to control a synchronous start of multiple timers of CCU40. It also can be used to control additional functions that are available in the timers, e.g. Count or Capture. For a complete description of the available set of functions, please address the specific section of the CCU4 chapters. Writing 1 or 0 into this field will not by itself trigger a synchronous start of multiple timers and one must before configure the specific peripheral function accordingly.
0	[31:1]	r	Reserved Read as 0; should be written with 0.

System Control Unit (SCU)

SRRAW

Service request status without masking. Write one to a bit in SRCLR register to clear a bit or SRSET to set a bit. Writing zero has no effect.

SRRAW

SCU Raw Service Request Status (0038_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TSE _LO W	TSE _HIG H	TSE _DO NE	RTC _TIM 1	RTC _TIM 0	RTC _ATI M1	RTC _ATI M0	RTC _CT R	0	SBY CLK FI	VCLI PI	FLC MPL TI	FLE CC2I	PEU OI	PES RAM I	LOCI
rh	rh	rh	rh	rh	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
ORC 7I	ORC 6I	ORC 5I	ORC 4I	ORC 3I	ORC 2I	ORC 1I	ORC 0I	VDR OPI	ACM P2I	ACM P1I	ACM P0I	VDD PI	AI	PI	PRW ARN
rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
PRWARN	0	rh	WDT pre-warning Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
PI	1	rh	RTC Raw Periodic Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
AI	2	rh	RTC Raw Alarm Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
VDDPI	3	rh	VDDP pre-warning Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
ACMP0I	4	rh	Analog Comparator 0 Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
ACMP1I	5	rh	Analog Comparator 1 Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred

System Control Unit (SCU)

Field	Bits	Type	Description
ACMP2I	6	rh	Analog Comparator 2 Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
VDROPI	7	rh	VDROP Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
ORCxI (x=0-7)	x+8	rh	Out of Range Comparator X Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
LOCI	16	rh	Loss of Clock Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
PESRAMI	17	rh	16kbytes SRAM Parity Error Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
PEU0I	18	rh	USIC0 SRAM Parity Error Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
FLECC2I	19	rh	Flash Double Bit ECC Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
FLCMPLTI	20	rh	Flash Operation Complete Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
VCLIP I	21	rh	VCLIP Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
SBYCLKFI	22	rh	Standby Clock Failure Event Status Before Masking 0 _B No standby clock failure has occurred 1 _B Standby clock failure has occurred

System Control Unit (SCU)

Field	Bits	Type	Description
RTC_CTR	24	rh	RTC CTR Mirror Register Update Status Before Masking 0 _B not updated 1 _B update completed
RTC_ATIM0	25	rh	RTC ATIM0 Mirror Register Update Status Before Masking 0 _B not updated 1 _B update completed
RTC_ATIM1	26	rh	RTC ATIM1 Mirror Register Update Status Before Masking 0 _B not updated 1 _B update completed
RTC_TIM0	27	rh	RTC TIM0 Mirror Register Update Before Masking 0 _B not updated 1 _B update completed
RTC_TIM1	28	rh	RTC TIM1 Mirror Register Update Status Before Masking 0 _B not updated 1 _B update completed
TSE_DONE	29	rh	TSE Measurement Done Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
TSE_HIGH	30	rh	TSE Compare High Temperature Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
TSE_LOW	31	rh	TSE Compare Low Temperature Event Status Before Masking 0 _B Event has not occurred 1 _B Event has occurred
0	23	r	Reserved

SRMSK

Service request mask used to mask outputs of RAW register. When the bit is set to 1, an interrupt or service request will be triggered when the event happens.

System Control Unit (SCU)

SRMSK

SCU Service Request Mask

(003C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TSE _LO W	TSE _HIG H	TSE _DO NE	RTC _TIM 1	RTC _TIM 0	RTC _ATI M1	RTC _ATI M0	RTC _CT R	0	SBY CLK FI	VCLI PI	0	FLE CC2I	PEU OI	PES RAM I	LOCI
rw	rw	rw	rw	rw	rw	rw	rw	r	rw	rw	r	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ORC 7I	ORC 6I	ORC 5I	ORC 4I	ORC 3I	ORC 2I	ORC 1I	ORC 0I	VDR OPI	ACM P2I	ACM P1I	ACM P0I	VDD PI	0	PRW ARN	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	r		rw

Field	Bits	Type	Description
PRWARN	0	rw	WDT pre-warning Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
VDDPI	3	rw	VDDP pre-warning Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
ACMP0I	4	rw	Analog Comparator 0 Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
ACMP1I	5	rw	Analog Comparator 1 Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
ACMP2I	6	rw	Analog Comparator 2 Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
VDROPI	7	rw	VDROP Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
ORCxI (x=0-7)	x+8	rw	Out of Range Comparator X Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
LOCI	16	rw	Loss of Clock Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt

System Control Unit (SCU)

Field	Bits	Type	Description
PESRAMI	17	rw	16kbytes SRAM Parity Error Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
PEU0I	18	rw	USIC0 SRAM Parity Error Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
FLECC2I	19	rw	Flash Double Bit ECC Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
VCLIPi	21	rw	VCLIP Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
SBYCLKFI	22	rw	Standby Clock Failure Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
RTC_CTR	24	rw	RTC CTR Mirror Register Update Mask 0 _B disable interrupt 1 _B enable interrupt
RTC_ATIM0	25	rw	RTC ATIM0 Mirror Register Update Mask 0 _B disable interrupt 1 _B enable interrupt
RTC_ATIM1	26	rw	RTC ATIM1 Mirror Register Update Mask 0 _B disable interrupt 1 _B enable interrupt
RTC_TIM0	27	rw	RTC TIM0 Mirror Register Update Mask 0 _B disable interrupt 1 _B enable interrupt
RTC_TIM1	28	rw	RTC TIM1 Mirror Register Update Mask 0 _B disable interrupt 1 _B enable interrupt
TSE_DONE	29	rw	TSE Measurement Done Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
TSE_HIGH	30	rw	TSE Compare High Temperature Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt

System Control Unit (SCU)

Field	Bits	Type	Description
TSE_LOW	31	rw	TSE Compare Low Temperature Interrupt Mask 0 _B disable interrupt 1 _B enable interrupt
0	[2:1], 20, 23	r	Reserved

SRCLR

Clear service request bits of register SRRAW. Write one to clear corresponding bits. Writing zeros has no effect.

SRCLR

SCU Service Request Clear (0040_H) Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TSE_LO_W	TSE_HI_H	TSE_DO_NE	RTC_TIM_1	RTC_TIM_0	RTC_ATI_M1	RTC_ATI_M0	RTC_CT_R	0	SBY_CLK_FI	VCLI_PI	FLC_MPL_TI	FLE_CC2I	PEU_OI	PES_RAM_I	LOCI
W	W	W	W	W	W	W	W	r	W	W	W	W	W	W	W
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ORC_7I	ORC_6I	ORC_5I	ORC_4I	ORC_3I	ORC_2I	ORC_1I	ORC_0I	VDR_OPI	ACM_P2I	ACM_P1I	ACM_P0I	VDD_PI	AI	PI	PRW_ARN
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
PRWARN	0	w	WDT pre-warning Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
PI	1	w	RTC Periodic Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
AI	2	w	RTC Alarm Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
VDDPI	3	w	VDDP pre-warning Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register

System Control Unit (SCU)

Field	Bits	Type	Description
ACMP0I	4	w	Analog Comparator 0 Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
ACMP1I	5	w	Analog Comparator 1 Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
ACMP2I	6	w	Analog Comparator 2 Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
VDROPI	7	w	VDROP Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
ORCxI (x=0-7)	x+8	w	Out of Range Comparator X Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
LOCI	16	w	Loss of Clock Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
PESRAMI	17	w	16kbytes SRAM Parity Error Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
PEU0I	18	w	USIC0 SRAM Parity Error Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
FLECC2I	19	w	Flash Double Bit ECC Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
FLCMLPTI	20	w	Flash Operation Complete Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
VCLIP I	21	w	VCLIP Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
SBYCLKFI	22	w	Standby Clock Failure Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register

System Control Unit (SCU)

Field	Bits	Type	Description
RTC_CTR	24	w	RTC CTR Mirror Register Update Clear 0 _B no effect 1 _B clear status bit in the raw status register
RTC_ATIM0	25	w	RTC ATIM0 Mirror Register Update Clear 0 _B no effect 1 _B clear status bit in the raw status register
RTC_ATIM1	26	w	RTC ATIM1 Mirror Register Update Clear 0 _B no effect 1 _B clear status bit in the raw status register
RTC_TIM0	27	w	RTC TIM0 Mirror Register Update Clear 0 _B no effect 1 _B clear status bit in the raw status register
RTC_TIM1	28	w	RTC TIM1 Mirror Register Update Clear 0 _B no effect 1 _B clear status bit in the raw status register
TSE_DONE	29	w	TSE Measurement Done Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
TSE_HIGH	30	w	TSE Compare High Temperature Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
TSE_LOW	31	w	TSE Compare Low Temperature Interrupt Clear 0 _B no effect 1 _B clear status bit in the raw status register
0	23	r	Reserved

SRSET

Set service request fits of register SRRAW. Write one to set corresponding bits. Writing zeros has no effect.

System Control Unit (SCU)

SRSET

SCU Service Request Set

(0044_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TSE _LO W	TSE _HIG H	TSE _DO NE	RTC _TIM 1	RTC _TIM 0	RTC _ATI M1	RTC _ATI M0	RTC _CT R	0	SBY CLK FI	VCLI PI	FLC MPL TI	FLE CC2I	PEU OI	PES RAM I	LOCI
W	W	W	W	W	W	W	W	r	W	W	W	W	W	W	W
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ORC 7I	ORC 6I	ORC 5I	ORC 4I	ORC 3I	ORC 2I	ORC 1I	ORC 0I	VDR OPI	ACM P2I	ACM P1I	ACM P0I	VDD PI	AI	PI	PRW ARN
W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W

Field	Bits	Type	Description
PRWARN	0	w	WDT pre-warning Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
PI	1	w	RTC Periodic Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
AI	2	w	RTC Alarm Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
VDDPI	3	w	VDDP pre-warning Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
ACMP0I	4	w	Analog Comparator 0 Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
ACMP1I	5	w	Analog Comparator 1 Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
ACMP2I	6	w	Analog Comparator 2 Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
VDROPI	7	w	VDROP Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register

System Control Unit (SCU)

Field	Bits	Type	Description
ORCxI (x=0-7)	x+8	w	Out of Range Comparator X Interrupt Set 0_B no effect 1_B set status bit in the raw status register
LOCI	16	w	Loss of Clock Interrupt Set 0_B no effect 1_B set status bit in the raw status register
PESRAMI	17	w	16kbytes SRAM Parity Error Interrupt Set 0_B no effect 1_B set status bit in the raw status register
PEU0I	18	w	USIC0 SRAM Parity Error Interrupt Set 0_B no effect 1_B set status bit in the raw status register
FLECC2I	19	w	Flash Double Bit ECC Interrupt Set 0_B no effect 1_B set status bit in the raw status register
FLCMLPTI	20	w	Flash Operation Complete Interrupt Set 0_B no effect 1_B set status bit in the raw status register
VCLIP I	21	w	VCLIP Interrupt Set 0_B no effect 1_B set status bit in the raw status register
SBYCLKFI	22	w	Standby Clock Failure Interrupt Set 0_B no effect 1_B set status bit in the raw status register
RTC_CTR	24	w	RTC CTR Mirror Register Update Set 0_B no effect 1_B set status bit in the raw status register
RTC_ATIM0	25	w	RTC ATIM0 Mirror Register Update Set 0_B no effect 1_B set status bit in the raw status register
RTC_ATIM1	26	w	RTC ATIM1 Mirror Register Update Set 0_B no effect 1_B set status bit in the raw status register
RTC_TIM0	27	w	RTC TIM0 Mirror Register Update Set 0_B no effect 1_B set status bit in the raw status register

System Control Unit (SCU)

Field	Bits	Type	Description
RTC_TIM1	28	w	RTC TIM1 Mirror Register Update Set 0 _B no effect 1 _B set status bit in the raw status register
TSE_DONE	29	w	TSE Measurement Done Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
TSE_HIGH	30	w	TSE Compare High Temperature Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
TSE_LOW	31	w	TSE Compare Low Temperature Interrupt Set 0 _B no effect 1 _B set status bit in the raw status register
0	23	r	Reserved

PASSWD

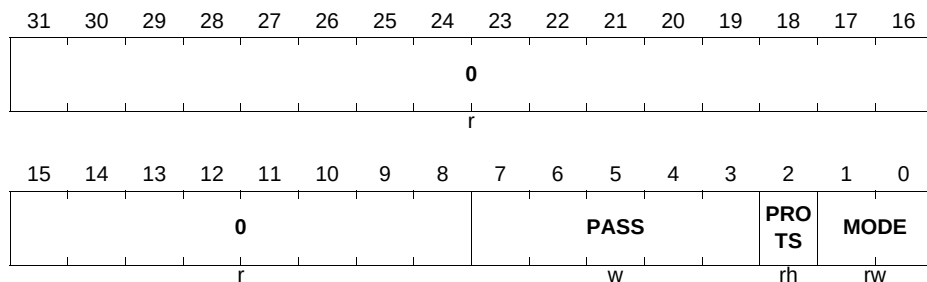
The PASSWD register is used to control the bit protection scheme.

PASSWD

Password Register

(0024_H)

Reset Value: 0000 0007_H



System Control Unit (SCU)

Field	Bits	Type	Description
MODE	[1:0]	rw	Bit Protection Scheme Control Bits 00 _B Scheme disabled - direct access to the protected bits is allowed. 11 _B Scheme enabled - the bit field PASS has to be written with the passwords to open and close the access to the protected bits. (Default) Others: Scheme enabled, similar to the setting for MODE = 11 _B . These two bits cannot be written directly. To change the value between 11 _B and 00 _B , the bit field PASS must be written with 11000 _B . Only then will the MODE bit field be registered.
PROTS	2	rh	Bit Protection Signal Status Bit This bit shows the status of the protection. 0 _B Software is able to write to all protected bits. 1 _B Software is unable to write to any of the protected bits.
PASS	[7:3]	w	Password Bits This bit protection scheme only recognizes the following three passwords: 11000 _B Enables writing of the bit field MODE. 10011 _B Opens access to writing of all protected bits. 10101 _B Closes access to writing of all protected bits.
0	[31:8]	r	Reserved

MIRRSTS

Mirror status register for control of communication between SCU and RTC.

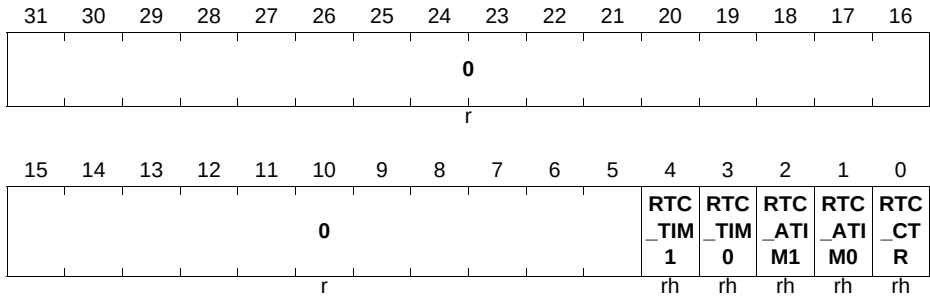
System Control Unit (SCU)

MIRRSTS

Mirror Update Status Register

(0048_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Function
RTC_CTR	0	rh	RTC CTR Mirror Register Update Status 0 _B no update pending 1 _B update pending
RTC_ATIM0	1	rh	RTC ATIM0 Mirror Register Update Status 0 _B no update pending 1 _B update pending
RTC_ATIM1	2	rh	RTC ATIM1 Mirror Register Update Status 0 _B no update pending 1 _B update pending
RTC_TIM0	3	rh	RTC TIM0 Mirror Register Update Status 0 _B no update pending 1 _B update pending
RTC_TIM1	4	rh	RTC TIM1 Mirror Register Update Status 0 _B no update pending 1 _B update pending
0	[31:14]	r	Reserved Read as 0; should be written with 0.

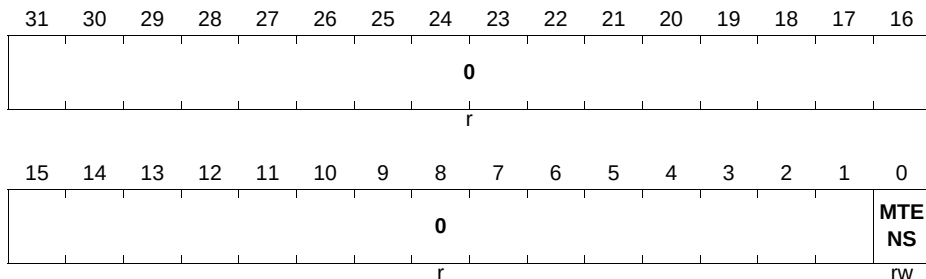
PMTSR

This register selects parity test output from a memory instance.

PMTSR

Parity Memory Test Select Register (0054_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
MTENS	0	rw	Parity Test Enable Control for 16kbytes SRAM Controls the test multiplexer for the 16kbytes SRAM. 0 _B standard operation 1 _B generate an inverted parity bit during a write operation
0	31:1]	r	Reserved Should be written with 0.

13 Pseudo Random Number Generator (PRNG)

13.1 Overview

The pseudo random bit generator (PRNG) provides random data with fast generation times.

13.1.1 Features

The PRNG includes the following features:

- Fast random data generation times:
 - 17 to 18 clock cycles generation time for 16-bit random data
 - 9 to 10 clock cycles generation time for 8-bit random data
- Fulfills statistical tests according to NIST-800

13.2 Description of Operation Modes

13.2.1 Key Loading Mode

Before the PRNG can be used it has to be initialized by the user software.

The key (seed) k of the PRNG is a bit string $k = (k_{n-1}, k_{n-2}, \dots, k_2, k_1, k_0)$ of length n . A key length of 80 bits is recommended, although smaller or larger key lengths are possible. It is recommended to use chip individual seed values.

The initialization of the PRNG consists of two basic phases:

1. Key loading
2. Warm-up

Key loading is initialized by setting the bit **PRNG_CTRL.KLD** to "1". In the key loading mode, **PRNG_WORD** acts always as a 16 bit destination register. The p partial words W_i ($0 \leq i < p$) of the key $k = (W_{p-1}, \dots, W_1, W_0)$, with $W_i = (k_{15i}, \dots, k_1, k_0)$, are sequentially written to **PRNG_WORD** in the order $W_0, W_1, \dots, W_{p-1}$. A useful seed size is 80 bits (i.e., 5 data words, $p=5$). Because the bits of the partial key word are sequentially loaded into the internal state of the PRNG, loading of a key word will take 16 clock cycles. The **PRNG_CHK.RDV** flag is set to "0" while loading is in progress. A flag value of "1" indicates that the next partial key word can be written to **PRNG_WORD**.

After the complete key has been loaded, the **PRNG_CTRL.KLD** flag must be set to "0" to prepare the following warm-up phase. This operation takes one clock cycle.

The warm-up phase provides a thorough diffusion of the key bits. For this purpose the user must read and discard 64 random bits from the register **PRNG_WORD**. The

Pseudo Random Number Generator (PRNG)

random data output block must be set to either $b = 8$ or 16 bits. This is achieved by setting the corresponding value of the **PRNG_CTRL.RDBS** field.

The flag **PRNG_CHK.RDV** set to "1" indicates that the next random data block of width b can be read from **PRNG_WORD**.

If, for any reason, **PRNG_CTRL.RDBS** is reset to the default value of 00_B , the PRNG must be initialized once more – i.e., a key must be loaded and a warm-up phase carried out.

13.2.2 Streaming Mode

The flag **PRNG_CHK.RDV** set to 1_B indicates that the next random data block can be read from **PRNG_WORD**. After a word has been read the flag **PRNG_CHK.RDV** is reset to 0_B by the hardware and generation of new random bits starts. The PRNG requires 17–18 clock cycles to generate a 16 random bits and 9–10 clock cycles to generate eight random bits. From a software point of view it is not necessary to poll the **PRNG_CHK.RDV** flag. Consecutive read accesses to **PRNG_WORD** will be delayed automatically by hardware as long as **PRNG_CHK.RDV** is "0".

The width of the output data block is changed by setting the value of **PRNG_CTRL.RDBS**. This should be done before entering streaming mode, otherwise if the change is made during streaming, the new setting will not come into effect until the next generation cycle is started. The hardware checks that the selected number of bits are available and the flag **PRNG_CHK.RDV** is set when this condition is true.

In order to avoid reading a duplicate random byte when switching from 8-bit to 16-bit operation mode the last byte generated in the 8-bit mode should first be discarded before switching to 16-bit mode.

Note: PRNG_WORD should be accessed as 16 bit register, the upper 16 bits (of a 32 bit access) are ignored on a write and zeroes on a read and therefore contains no random data.

13.2.3 Refreshing and Restarting a Random Bit Stream

The random bit sequence can be refreshed with a new key. In this case the entropy contained in the last internal state is not cleared, but instead the new key is mixed into the current PRNG state. This is referred to as refreshing.

Refreshing is a means of introducing additional entropy into the generation of the random bit sequence. Without refreshing, the entire entropy rests in the initial key (or seed) that was used for initializing the PRNG during first key loading. Thereafter, the generation of the random bit sequence is purely deterministic. The deterministic process is broken whenever refreshing is performed. Refreshing implies that it is not possible to reproduce the same random result using the same key for data generation.

Since the internal state of the PRNG cannot be read and set directly, a sequence cannot be restored from any given state. A random bit sequence based on a certain initial key

Pseudo Random Number Generator (PRNG)

can, however, be continued. To this means, a segment s of the output sequence is stored and this segment is used as a initial key later on. The segment $s = (s_{n-1}, s_{n-2}, \dots, s_2, s_1, s_0)$ of length n should be fresh – i.e., generated after the last bits used in the application. The length of s should be at least $n = 80$ bits. This way a pseudorandom bit sequence can be continued after a system reset without requiring new key material. This process is known as restarting.

Note: Integration in a multi-application/multitasking environment together with the requirement to obtain a reproducible pseudorandom bit sequence would necessitate a state saving and restoring feature. Hence the OS must be able to save the PRNG state before giving control to application 2 and restore the state before returning control to application 1. This is not possible with the PRNG module.

13.3 Service Request Generation

The PRNG does not generate any service request.

13.4 Debug Behavior

The PRNG does not support a suspend mode while the system is halted by the debugger. That means that the PRNG continues its operation during debug halt.

13.5 Power, Reset and Clock

The PRNG module is located in the core power domain. The module can be reset to its default state by a system reset.

The PRNG module is clocked by the main clock, MCLK, from SCU.

13.6 Initialization and System Dependencies

The PRNG is always available after reset.

Refer to [Section 13.2.1](#) for the initialization steps.

13.7 Registers

The interface of the PRNG comprises the registers PRNG_WORD, PRNG_CHK and PRNG_CTRL.

Table 13-1 Registers Address Space

Module	Base Address	End Address	Note
PRNG	4802 0000 _H	4802 000F _H	

Pseudo Random Number Generator (PRNG)

Table 13-2 Registers Overview

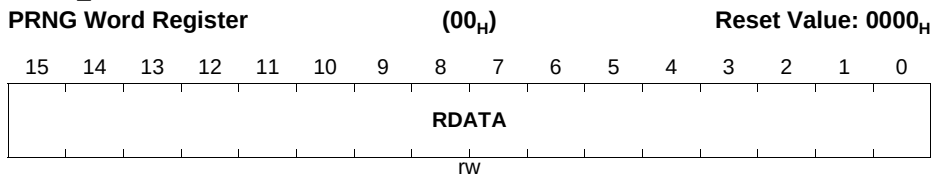
Register Short Name	Register Long Name	Offset Address	Page Number
Data Registers			
PRNG_WORD	PRNG word register	00 _H	Page 13-4
PRNG_CHK	PRNG status check register	04 _H	Page 13-5
Control Registers			
PRNG_CTRL	PRNG control register	0C _H	Page 13-6

The register is addressed wordwise.

13.7.1 Data Registers

Pseudo RNG Word Register

PRNG_WORD



Field	Bits	Type	Description
RDATA	15:0	rw	Random Data Random bit block or key to load. In the streaming mode the range of valid random bits is defined by the settings given by PRNG_CTRL.RDSB and the value of the flag PRNG_CHK.RDV. In the key loading mode the seed value (key) is written via this register. In this case, the key is written in units of 16 bits.

Pseudo Random Number Generator (PRNG)

Additional Information

Notes

1. Reading `PRNG_WORD` while the PRNG is running in key loading mode (configured by setting `PRNG_CTRL.KLD`) will return the last value written to the register, whereas write accesses to the register while the PRNG is running in streaming mode (`PRNG_CTRL.KLD = '0'`) will be ignored.
2. Write access to `SFR PRNG_WORD`:
It is strongly recommended to wait until the SFR bit `PRNG_CHK.RDV` indicates that the register `PRNG_WORD` is ready to receive (new) data (which will be used to seed the PRNG.)
3. Read access to `SFR PRNG_WORD`:
It is strongly recommended to check the SFR bit `PRNG_CHK.RDV` before reading `SFR PRNG_WORD`.

Pseudo RNG Status Check Register

PRNG_CHK

PRNG Status Check Register (04_H) **Reset Value: 0000_H**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
							0								RDV
							r								r

Field	Bits	Type	Description
RDV	0	r	Random Data / Key Valid Flag 0 _B INV , New random data block is not yet ready to be read. In "Key Loading Mode" on Page 13-1) this flag is set to 0 _B while loading is in progress. 1 _B VAL , Random data block is valid. In key loading mode this value indicates that the next partial key word can be written to PRNG_WORD .
0	15:1	r	Reserved

Additional Information

*Note: If a word or byte is read from **PRNG_WORD** although the data is not ready (**PRNG_CHK.RDV = 0_B**), the system stalls until the data becomes ready.*

Pseudo Random Number Generator (PRNG)

13.7.2 Control Registers

Pseudo RNG Control Register

PRNG_CTRL

PRNG Control Register

(0C_H)

Reset Value: 0000_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
												KLD	RDBS		0
												rw	rw		r

Field	Bits	Type	Description
KLD	3	rw	Key Load Operation Mode 0 _B STRM, Streaming mode (default) 1 _B KLD, Key loading mode
RDBS	2:1	rw	Random Data Block Size Set random data block size for read access (16 bits always used for key loading) 00 _B RES, Reset state (no random data block size defined) ¹⁾ , value of PRNG_WORD is undefined. 01 _B BYTE, 8 bits in PRNG_WORD.RDATA[7:0] 10 _B WORD, 16 bits in PRNG_WORD.RDATA[15:0] 11 _B RFU, Reserved for future use, value of PRNG_WORD is undefined.
0	0	r	Reserved
0	15:4	r	Reserved

1) Once the reset value for RDBS (00_B) is set, the PRNG must be fully initialized before the functionality can be used. Initialization requires key loading, followed by a warm-up phase.

Additional Information

Note: It is recommended not to change the PRNG_CTRL.KLD flag during key load. Otherwise the distribution of the bits of the PRNG will not be equal.

Communication Peripherals

14 LED and Touch-Sense (LEDTS)

The LED and Touch-Sense (LEDTS) drives LEDs and controls touch pads used as human-machine interface (HMI) in an application.

Table 14-1 Abbreviations in chapter

Abbreviation	Meaning
LEDTS	LED and Touch-sense
TSD	time slice duration
TFD	time frame duration
TPD	time period duration

14.1 Overview

The LEDTS can measure the capacitance of up to 8 touch pads using the relaxation oscillator (RO) topology. The pad capacitance is measured by generating oscillations on the pad for a fixed time period and counting them. The module can also drive up to 64 LEDs in an LED matrix. Touch pads and LEDs can share pins to minimize the number of pins needed for such applications. This configuration is realized by the module controlling the touch pads and driving the LEDs in a time-division multiplexed manner.

The LEDs in the LED matrix are organized into columns and lines. Every line can be shared between up to 8 LEDs and one touch pad. Certain functions such as column enabling, function selection and control are controlled by hardware. Application software is required to update the LED lines and evaluate the touch pad measurement results.

14.1.1 Features

This device contains 2 LEDTS kernels. Each kernel has an LED driving function and a touch-sensing function.

For the LED driving function, an LEDTS kernel provides these features:

- Selection of up to 8 LED columns; Up to 7 LED columns if touch-sense function is also enabled
- Configurable active time in LED columns to control LED brightness
- Possibility to drive up to 8 LEDs per column, common-anode or common-cathode
- Shadow activation of line pattern for LED column time slice; LED line patterns are updated synchronously to column activation
- Configurable interrupt enable on selected event
- Line and column pins controlled by port SFR setting

For the touch-sensing function, an LEDTS kernel provides these features:

- Up to 8 touch input lines

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- Only one pad can be measured at any time; selection of active pad controllable by software or hardware round-robin
- Flexible measurement time on touch pads
- Pin oscillation control circuit with adjustments for oscillation
- 16-bit counter: For counting oscillations on pin.
- Configurable interrupt enable on selected event
- Pin over-rule control for active touch input line (pin)

Note: This chapter refers to the LED or touch-sense pins, e.g. 'pin COL[x]', 'pin TSIN[x]'. In all instances, it refers to the user-configured pin(s) which selects the LED/touch-sense function. Refer to [Section 14.9.5](#) for more elaboration.

Note: This chapter describes the full capability of the LEDTS. The amount of features available on the device is limited by the device pins assigned. Please refer to the [Section 14.12](#) for the pins assigned to the LEDTS.

Table 14-2 LEDTS Applications

Use Case	Application
Non-mechanical switch	HMI
LED feedback	HMI
Simple PWM	PWM

14.1.2 Block Diagram

The LEDTS block diagram is shown in [Figure 14-1](#).

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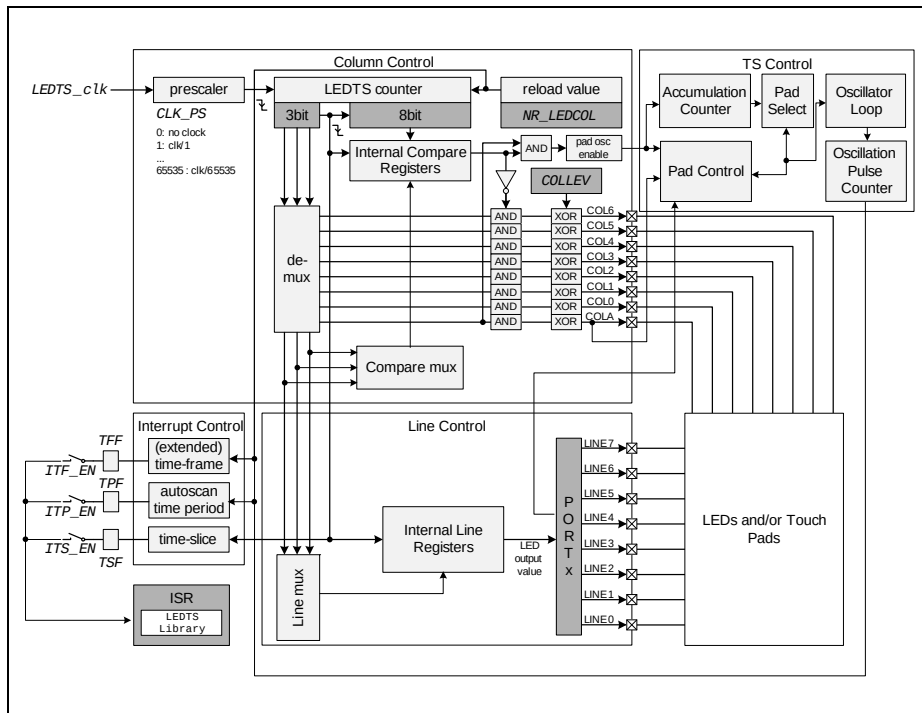


Figure 14-1 LEDTS Block Diagram

14.2 Functional Overview

The same pin can support LED & touch-sense functions in a time-multiplexed manner. LED mode or touch-sense mode can be enabled by hardware for respective function controls.

Time-division multiplexing is done by dividing the time domain into time slots. This basic time slot is called a **time slice**. In one time slice, one LED column is activated or the capacitance of one touch pad is measured.

A **time frame** is composed of 1 or more time slices, up to a maximum of eight. There is one time slice for every LED column enabled. If only LED function is enabled, a time frame can compose up to 8 LED time slices. However, if touch sense function is enabled, the last time slice in every time frame is reserved for touch-sense function. This reduces the maximum number of time slices that can be used for LED function in each time frame to 7. Only one time slice is used for touch sense function in every time frame. This is regardless of the number of touch pads enabled.

In each time slice used for LED function, only one LED column is enabled at a time. In the time slice reserved for touch-sense function, oscillations are enabled and measured on the pin which is activated. No LED column is active during this time slice. A touch pad input line (TSIN[x] pin) is active when its pad turn is enabled. If more than one touch pad input lines are enabled, the enabling and measurement on the touch pads is performed in a round robin manner. Only one touch pad is measured in every time frame.

The resolution of oscillation measurement can be increased by accumulating oscillation counts on each touch input line. When enabled by configuration of "Accumulate Count" (ACCCNT), the pad turn can be extended on consecutive time frames by up to 16 times. This also means that the same touch pad will be measured in consecutive time frames. This control will be handled by hardware. Otherwise it is also possible to enable for software control where the active pad turn is fully under user control.

The number of consecutive time frames, for which a pad turn has been extended, forms an **extended time frame**. When touch-sense function is enabled for automatic hardware pad turn control, several (extended) time frames make up one **autoscan time period** where all pad turns are completed. The time slice duration is configured centrally for the LED and/or touch-sense functions, using the LEDTS-counter. Refer to the description in [Section 14.3](#), [Section 14.9.3](#) and [Figure 14-4](#).

If enabled, a time slice interrupt is triggered on overflow of the 8LSBs of the LEDTS-counter for each new time slice started. The (extended) time frame interrupt may also be enabled. It is triggered on (the configured counts of) overflow of the whole LEDTS-counter. The autoscan time period interrupt may also be enabled. However, this interrupt will require that the hardware pad turn control is enabled. It is triggered when hardware completes the last pad turn on the highest enabled touch input line TSIN[NR_TSIN].

The column activation and pin oscillation duty cycles can be configured for each time slice. This allows the duration of activation of LED columns and/or touch-sense

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oscillation counting to be flexible. This is also how the relative brightness of the LEDs can be controlled. In case of touch pads, the activation time is called the oscillation window.

Figure 14-2 shows an example for a LED matrix configuration with touch pads. The configuration in this example is 8 X 4 LED matrix with 4 touch input lines enabled in sequence by hardware. Here no pad turn is extended by ACCCNT, so four time frames complete an autoscan time period.

In the time slice interrupt, software can:

- set up line pattern for next time slice
- set up compare value for next time slice
- evaluate current function in time slice (especially for analysis/debugging)

Refer to **Section 14.9.1** for **Interpretation of Bit Field FNCOL** to determine the currently active time slice.

The (extended) time frame interrupt indicates one touch input line TSIN[x] has been sensed (once or number of times in consecutive frames), application-level software can, for example:

- start touch-sense processing (e.g. filtering) routines and update status
- update LED display data to SFR

In the autoscan time period interrupt which indicates all touch-sense input TSIN[x] have been scanned one round, application-level software can:

- evaluate touch detection result & action
- update LED display data to SFR

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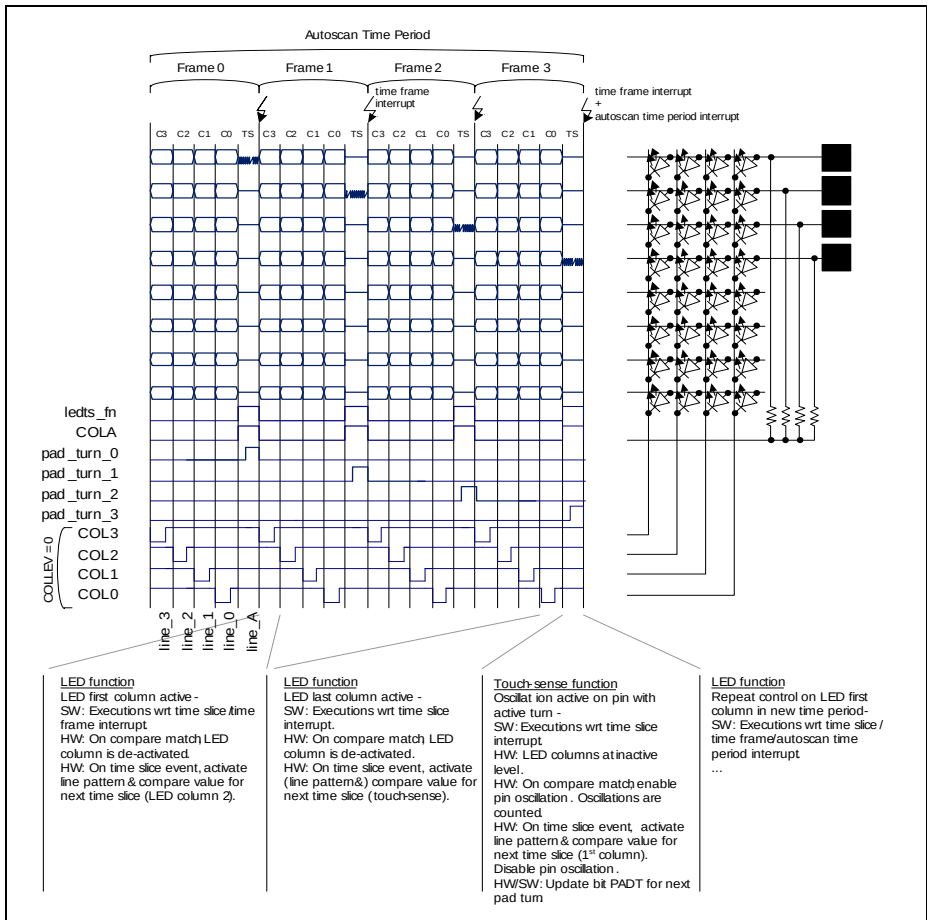


Figure 14-2 Time-Multiplexed LEDTS Functions on Pin (Example)

14.3 LED Drive Mode

LED driving is supported mainly for LED column selection and line control. At one time, only one column is active. The corresponding line level at high or low determines if the associated LED on column is lit or not. Up to eight columns are supported (if only LED function is enabled), and up to eight LEDs can be controlled per column.

With direct LED drive, adjustment of luminence for different types of LEDs with different forward voltages is supported. A compare register for LEDTS-counter is provided so that the duty cycle for column enabling per time slice can be adjusted. The LED column is enabled from the beginning of the time slice until compare match event. For 100% duty cycle for LED column enable in time slice, the compare value should be set to FF_{H_1} . If the compare value is set to 00_{H_1} , the LED column will stay at passive level during the time slice. The internal compare register for each time slice is updated by shadow transfer from their corresponding compare SFR. This takes place automatically at the beginning of each time slice, refer to **Figure 14-3**.

Updating of LED line pattern (LED enabling) per column (time slice) is performed via a similar shadow transfer mechanism, as illustrated in **Figure 14-3**. This shadow transfer of the corresponding line pattern to the internal line SFR takes place automatically at the beginning of each new time slice.

Note: Any write to any compare or line SFR within the time slice does not affect the internal latched configuration of current time slice.

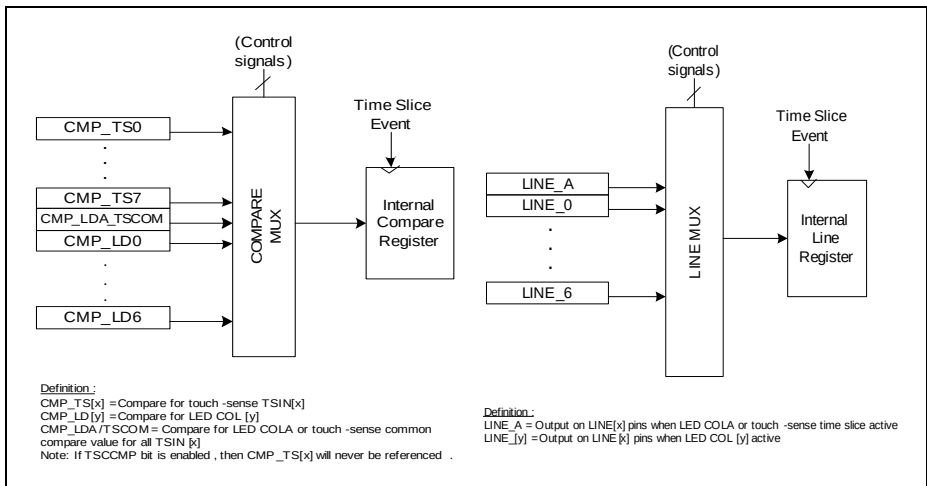


Figure 14-3 Activate Internal Compare/Line Register for New Time Slice

When the LEDTS-counter is first started (enable input clock by CLK_PS), a shadow transfer of line pattern and compare value is activated for the first time slice (column).

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A time slice interrupt can be enabled. A new time slice starts on the overflow of the 8LSBs of the LEDTS-counter.

Figure 14-4 shows the LED function control circuit. This circuit also provides the control for enabling the pad oscillator. A 16-bit divider provides pre-scale possibilities to flexibly configure the internal LEDTS-counter count rate, which overflows in one time frame. During a time frame comprising a configurable number of time slices, the configured number of LED columns are activated in sequence. In the last time slice of the time frame, touch-sense function is activated if enabled.

The LEDTS-counter is started when bit CLK_PS is set to any value other than 0 and either the LED or touch-sense function is enabled. It does not run when both functions are disabled. To avoid over-write of function enable which disturbs the hardware control during LEDTS-counter running, the TS_EN and LD_EN bits can only be modified when bit CLK_PS = 0. It is nonetheless possible to set the bits TS_EN and LD_EN in one single write to SFR **GLOBCTL** when setting CLK_PS from 0 to 1, or from 1 to 0.

When started, the counter starts running from a reset/reload value based on enabled function(s): 1) the number of columns (bit-field NR_LEDCOL) when LED function is enabled, 2) add one time slice at end of time frame when touch-sense function is enabled. The counter always counts up and overflows from 7FFH to the reload value which is the same as the reset value. Within each time frame, the sequence of LED column enabling always starts from the most-significant enabled column (column with highest numbering).

To illustrate this point, in the case of four LED columns and one touch pad input enabled, the column enabling sequence will be in as follows:

- Start with COL3,
- followed by COL2,
- followed by COL1,
- followed by COL0,
- then COLA for touch sense function.

If the touch-sense function is not enabled, COLA will be available for LED function as the last LED column time slice of a time frame. The column enabling sequence will then be as follows:

- Start with COL2,
- followed by COL1,
- followed by COL0,
- then COLA.

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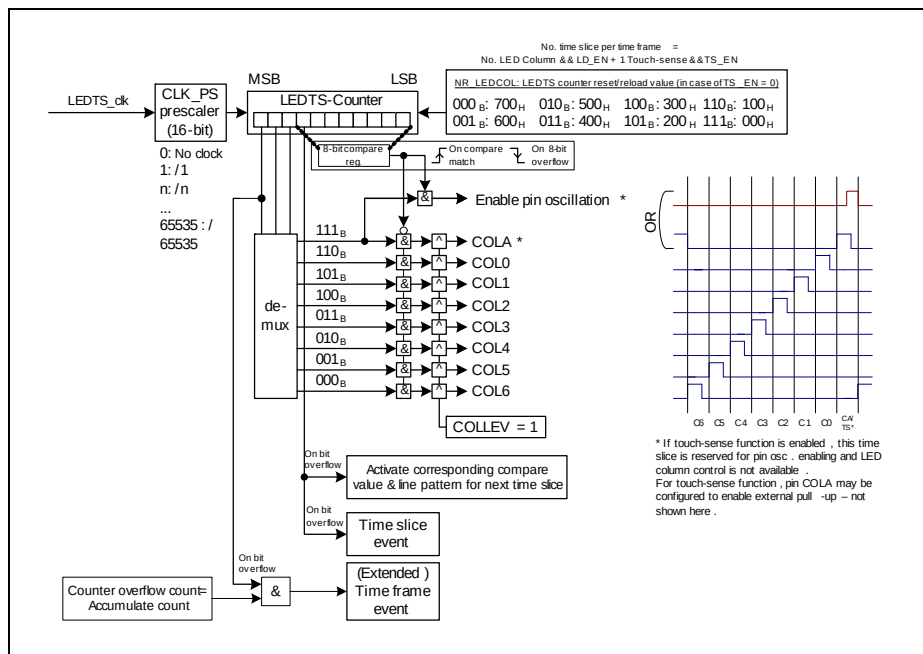


Figure 14-4 LED Function Control Circuit (also provides pad oscillator enable)

In [Section 14.9.3](#), the time slice duration and formulations for LEDTS related timings are provided.

14.3.1 LED Pin Assignment and Current Capability

One LED column pin is enabled within each configured time slice duration to control up to eight LEDs at a time. The assignment of COL[x] to pins is configurable to provide options for application pin usage. The current capability of device pins is also a consideration factor for deciding pin assignment to LED function.

The product data-sheet provides data for all I/O parameters relevant to LED drive.

14.4 Touch-Sense Mode

Figure 14-5 shows the pin oscillation control unit, which is integrated with the standard PORTS pad. The active pad turn (`pad_turn_x`) for a touch input line is defined as the time duration within the touch-sense time slice (COL A) where the TS-counter is counting oscillations on the TSIN[x] pin. In the case of hardware pad turn control (default), the same TS-counter is connected sequentially on enabled touch input lines to execute a round-robin touch-sensing of TSIN[x] pins.

The pad scheme refers to the pad configuration during the charging and discharging phases of the pad oscillators. There are 2 types of pad schemes available for selection, **Scheme A** (default) and **Scheme B**. These 2 schemes offer a variation for pad oscillation behaviour. In addition to this, there are two types of hysteresis configurations available for the touch input pad which are the standard and large hystereses. These selections can be made via PORTS SFR settings, refer to **Section 14.9.5**.

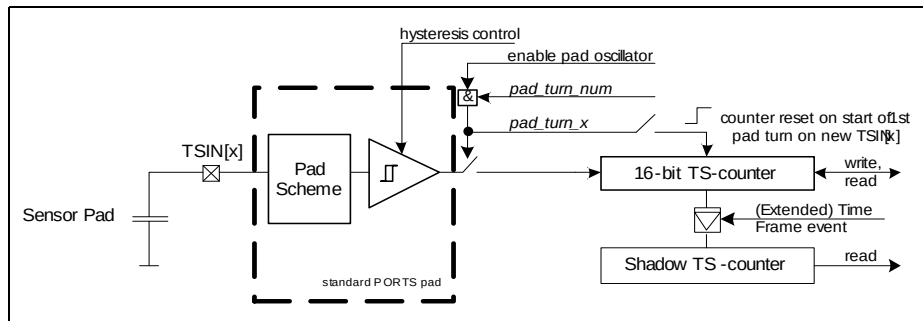


Figure 14-5 Touch-Sense Oscillator Control Circuit

In an example of four touch input lines enabled, the sequence order of touch-sense time slice (COL A) in sequential frames is as follows:

- Always starts with TSIN0,
- followed by TSIN1 in touch-sense time slice of next frame,
- followed by TSIN2 in next touch-sense time slice,
- then TSIN3, and repeat cycle.

It is possible to enable the touch-sense time slice on the same touch input line for consecutive frames (up to 16 times), to accumulate the oscillation count in TS-counter (see **Figure 14-6**). To illustrate this point, in the same case of four touch input lines enabled, and 2 accumulation counts configured, is as follows:

- Always starts with TSIN0,
- followed by TSIN0 again in touch-sense time slice of next frame,
- followed by TSIN1 in touch-sense time slice of next frame,
- followed by TSIN1 again in touch-sense time slice of next frame,
- followed by TSIN2 in touch-sense time slice of next frame,

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- followed by TSIN2 again in touch-sense time slice of next frame,
- followed by TSIN3 in touch-sense time slice of next frame,
- then TSIN3 again, and repeat cycle.

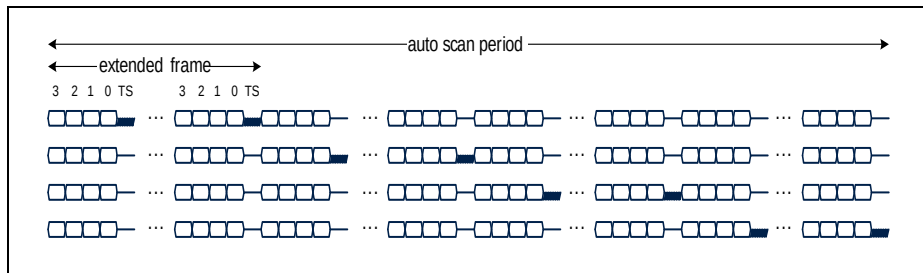


Figure 14-6 Hardware-Controlled Pad Turns for Autoscan of Four TSIN[x] with Extended Frames

There is a 16-bit TS-counter register and there is a 16-bit shadow TS-counter register. The former is both write- and read-accessible, while the latter is only read-accessible. The actual TS-counter counts the latched number of oscillations and can only be written when there is no active pad turn. The content of the TS-counter is latched to the shadow register on every (extended) time frame event. Reading from the shadow register therefore shows the latest valid oscillation count on one TSIN[x] input, ensuring for the application SW there is at least one time slice duration to get the valid oscillation count and meanwhile the actual TS-counter could continually update due to enabled pin oscillations in current time slice.

The TS-counter and shadow TS-counter have another user-enabled function on (extended) time frame event, which is to validate the counter value differences. When this function is enabled by the user and in case the counter values do not differ by 2^n LSB bits ('n' is configurable), the (extended) time frame interrupt request is gated (no interrupt) and the time frame event flag TFF is not set. This gating is on top of the time frame interrupt enable/disable control.

The TS-counter may be enabled for automatic reset (to 00_{H}) on the start of a new pad turn on the next TSIN[x], i.e. resets in the first touch-sense time slice of each (extended) time frame. Bit TSCTROVF indicates that the counter has overflowed. Alternatively, it can be configured such that the TS-counter stops counting in touch-sense time slice(s) of the same extended frame when the count value saturates, i.e. does not overflow & stops at FFFF_{H} . In this case, the TS-counter starts running again only in a new (extended) frame on the start of a new pad turn on the next TSIN[x].

The touch-sense function is time-multiplexed with the LED function on enabled LINE[x]/TSIN[x] pins. During the touch-sense time slice for the other TSIN pins which are not on active pad turn, the corresponding LINE[x] output remains active. It is

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recommended that software takes care to set the line bits to 1 to avoid current sink from pin COLA.

The touch-sense function is active in the last time slice of a time frame. Refer to [Section 14.2](#), and [Section 14.3](#) for more details on time slice allocation and configuration.

The oscillation is enabled on the pin with valid turn for a configurable duration. A compare value provides the means to adjust the duty cycle within the time slice. The pin oscillation is enabled (TS-counter is counting) only on compare match until the end of the time slice. The time interval, in which the TS-counter is counting, is called the oscillation window. For a 100% duty cycle, the compare value has to be set to 00_H . In this case, the oscillation window fills in the entire time slice. Setting the compare value to FF_H results in no pin oscillation in time slice.

The time slice interrupt, (extended) time frame interrupt and/or autoscan time period interrupt may be enabled as required for touch-sense control.

Scheme A

Figure 14-7 provides an illustration of the touch-sense oscillator control circuit in Scheme A. The pad is configured to input mode with weak internal pull-up enabled during the charge phase. The pad is then configured to output mode and the pad is put to output low during the discharge phase. Open drain is always active in this pad scheme. **Figure 14-8** shows the pin oscillation profile for this scheme.

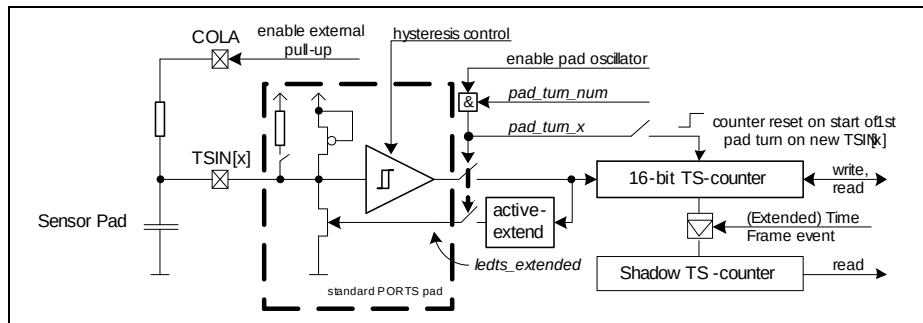


Figure 14-7 Scheme A Touch-Sense Oscillator Control Circuit

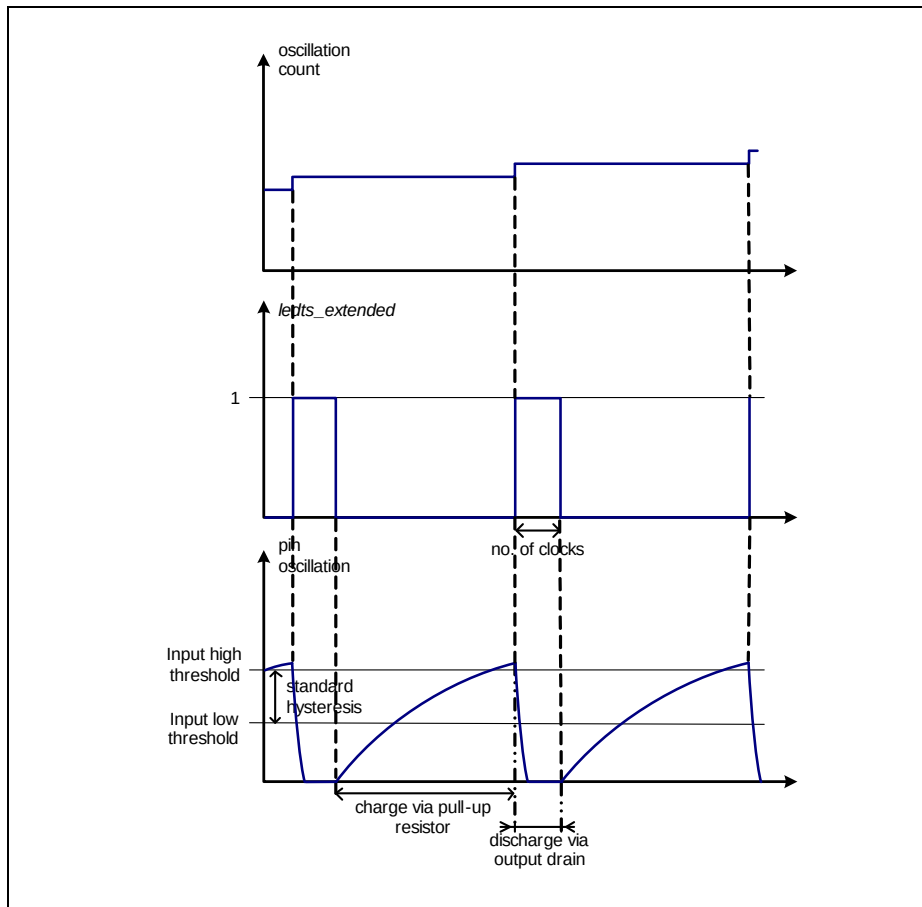


Figure 14-8 Scheme A Pin Oscillation Profile

The configuration of the active touch-sense pin TSIN[x] is over-ruled by hardware in the active duration to enable oscillations, reference [Section 14.9.5](#). In particular, the weak internal pull-up enable over-rule can be optionally de-activated (correspondingly internal pull-down disable over-rule is also de-activated; PORTS pin SFR setting for pull applies instead), such as when the user system utilize external resistor for pull-up instead. In the whole duration of the touch-sense time slice, COLA is activated high. This activates a pull-up via an external resistor connected to pin COLA. This configuration provides some flexibility to adjust the pin oscillation rate for adaptation to user system.

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A configurable pin-low-level active extension is provided for adjustment of oscillation per user system. The extension is active during the discharge phase of oscillation (Figure 14-8), and can be configured to be extended by a number of peripheral clocks. The register bit field **FNCTL.TSOEXT** determines the duration of the extension. This function is very useful if there is a series resistor between the pin and the touch pad which makes the discharge slower.

Scheme B

Figure 14-9 provides an illustration of the touch-sense oscillator control circuit in Scheme B. The pad is configured to input mode (output disabled) during both charge and discharge phases. The weak internal pull-up is activated during the charge phase. During the discharge phase, pull-down is enabled for the pad. Figure 14-10 shows the pin oscillation profile for this scheme.

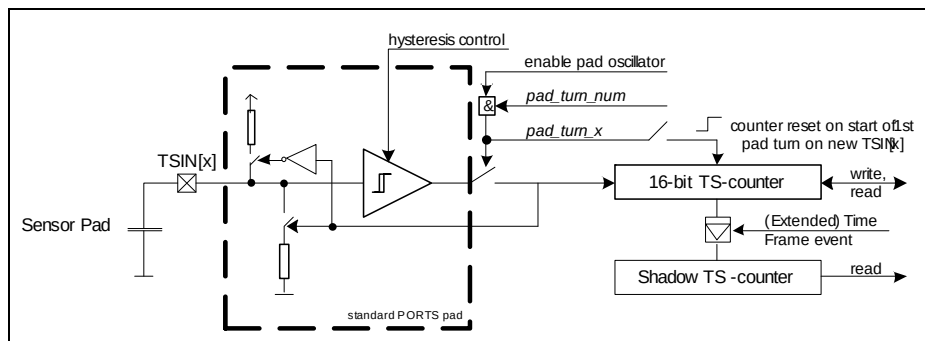


Figure 14-9 Scheme B Touch-Sense Oscillator Control Circuit

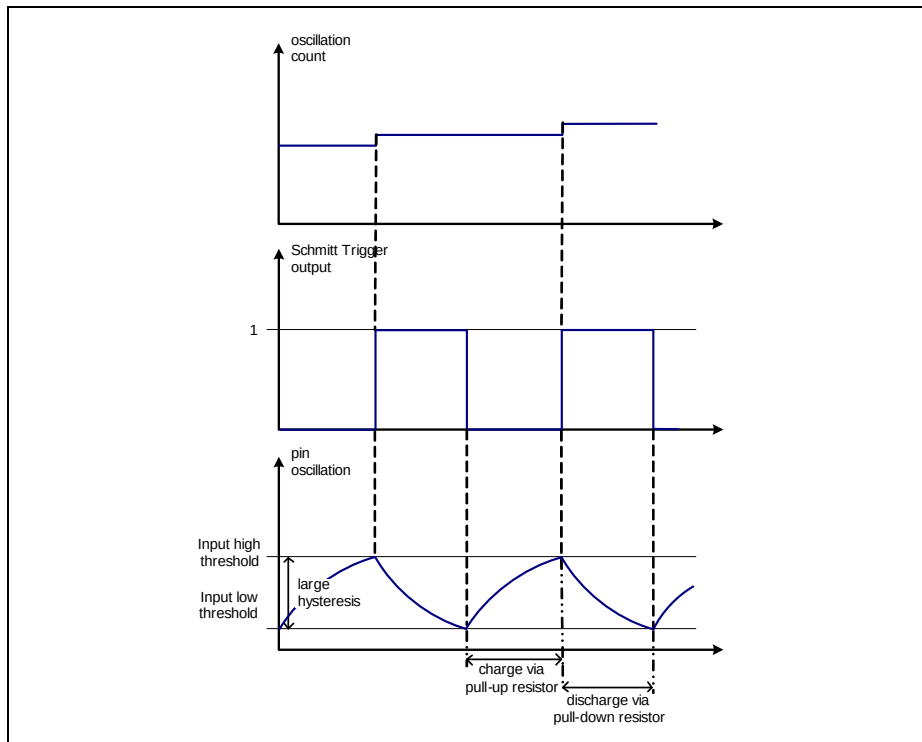


Figure 14-10 Scheme B Pin Oscillation Profile

The configuration of the active touch-sense pin TSIN[x] is over-ruled by hardware in the active duration to enable oscillations, reference [Section 14.9.5](#). However, unlike in [Scheme A](#), the option for an external pull-up over-rule is unavailable. Likewise, the pin-low-level active extension feature is also unavailable.

For this scheme, although 2 types of pad hysteresis configurations are available, it should be noted that only the large hysteresis will be meaningful to use.

14.4.1 Finger Sensing

When a finger is placed on the sensor pad, it increases the pin capacitance and frequency of oscillation on pin is reduced. The pin oscillation frequency without finger touch is typically expected to be in the range of 100 kHz to 5 MHz. Various factors affect the oscillation frequency including the size of touch pad, ground planes around and below the pad, the material and thickness of the overlay cover, the trace length and the individual pin itself (every pin has a different pull-up resistance).

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In a real-world application, the printed circuit board (PCB) will not be touched directly. Instead, there is usually some sort of a transparent cover material, like a piece of plexiglass sheet, glued onto the PCB. In most of these applications, the oscillation frequency will change by about 2-10% when touched. This change in oscillation frequency can be considered to be very small, and therefore, further signal processing is necessary for reliable detection. Typically, this processing takes the form of a moving average calculation. It is never recommended to try to detect touches based on the raw oscillation count value.

As described in above section, some flexibility is provided to adjust the oscillation frequency in the user system: 1) Configurable pin low-level active extension, 2) Alternative enabling of external pull-up with resistance selectable by user. With a configurable time slice duration, the software can configure the duration of the active pad turn (adjustable within time slice using compare function) and set a count threshold for oscillations to detect if there is a finger touch or not.

To increase touch-sensing oscillation count accuracy, the input clock to LEDTS kernel should be set as high as possible.

14.5 Operating both LED Drive and Touch-Sense Modes

It is possible to enable both LED driving and touch-sense functions in a single time frame. If both functions are enabled, up to 7 time slices are configurable for the LED function, and the last time slice is reserved for touch-sensing function.

The touch-sense function is time-multiplexed with the LED function on enabled LINE[x]/TSIN[x] pins. During the touch-sense time slice (COLA), the corresponding LINE[s] output remains active for the other TSIN pins which are not on active pad turn. In a typical application, COLA is not used and the oscillation is generated by the internal pad structure only. The bits in LINE_A will determine whether the pads, that are not being measured in the given COLA time slice, have a floating or 0V value. This setting usually has a serious effect on the sensitivity and noise robustness of the touch pads.

Refer to [Section 14.2](#) and [Section 14.3](#) for more details on time slice allocation and configuration.

14.6 Service Request Processing

There are three interrupts triggered by LEDTS kernel, all assigned on same node: 1) time slice event, 2) (extended) time frame event, 3) autoscan time period event. The flags are set on event or when CLK_PS is set from 0 regardless of whether the corresponding interrupt is enabled or not. When enabled, the event (including setting of CLK_PS from 0) activates the SR0 interrupt request from the kernel.

[Table 14-3](#) lists the interrupt event sources from the LEDTS, and the corresponding event interrupt enable bit and flag bit.

Table 14-3 LEDTS Interrupt Events

Event	Event Interrupt Enable Bit	Event Flag Bit
Start of Time Slice	GLOBCTL.ITS_EN	EVFR.TSF
Start of (Extended) Time Frame ¹⁾	GLOBCTL.ITF_EN	EVFR.TFF
Start of Autoscan Time Period	GLOBCTL.ITP_EN	EVFR.TPF

1) In case of consecutive pad turns enabled on same TSIN[x] pin by ACCCNT bit-field, interrupt is not triggered on a time frame – but on the extended time frame.

[Table 14-4](#) shows the interrupt node assignment for each LEDTS interrupt source.

Table 14-4 LEDTS Events' Interrupt Node Control

Event	Interrupt Node Enable Bit	Interrupt Node Flag Bit	Node ID
Start of Time Slice: Kernel 0	LEDTS0.SR0	LEDTS0.SR0	29
Start of (Extended) Time Frame: Kernel 0			
Start of Autoscan Time Period: Kernel 0			
Start of Time Slice: Kernel 1	LEDTS1.SR0	LEDTS1.SR0	30
Start of (Extended) Time Frame: Kernel 1			
Start of Autoscan Time Period: Kernel 1			

14.7 Debug Behavior

The LEDTS timers/counters LEDTS-counter and TS-counter can be enabled (together) for suspend operation when debug mode becomes active (indicated by HALTED signal from CPU).

In debug suspend mode, write and read access are possible. Writing to bit fields that require **GLOBCTL.CLK_PS = 0** will still be ignored.

At the onset of debug suspend, these counters stop counting (retains the last value) for the duration of the device in debug mode. The function that was active in current time slice on the onset of debug suspend, continues to be active. When debug suspend is revoked, the kernel would resume operation according to latest SFR settings.

*In XMC1200, bit **GLOBCTL.SUSCFG** is reset to its default value by any reset. If suspend function is required during debugging, it is recommended that it is enabled in the user initialization code. Before programming the bit, the module clock has to be enabled and special care needs to be taken while enabling the module clock as described in the CCU (Clock Gating Control) section of the SCU chapter.*

14.8 Power, Reset and Clock

The module clock is disabled by default and can be enabled via the SCU_CGATCLR0 register. Enabling and disabling the module clock could cause a load change and clock blanking could occur as described in the CCU (Clock Gating Control) section of the SCU chapter. It is strongly recommended to setup the module clock in the user initialization code to avoid clock blanking during runtime.

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The LEDTS kernel is clocked and accessible on the peripheral bus frequency. User should set up consistent time-slice durations for correct function by ensuring a constant frequency input clock when the kernel is in operation. It is recommended to set the input clock ledts_clk to highest frequency where possible, for optimal touch-sensing accuracy.

Kernel is in operation in active mode except power-down modes where touch-sensing and LED functions are not available.

14.9 Initialisation and System Dependencies

This section provides hints for enabling the LEDTS functions and using them.

14.9.1 Function Enabling

It is recommended to set up all configuration for the LEDTS in all SFRs before write **GLOBCTL** SFR to enable and start LED and/or touch-sense function(s).

Note: SFR bits especially affecting the LEDTS-counter configuration for LED/touch-sense function can only be written when the counter is not running i.e. CLK_PS = 0. Refer to SFR bit description [Section 14.11](#).

Enable LED Function Only

To enable LED function only: set LD_EN, clear TS_EN.

Initialization after reset:

```
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000XX10;
//set LD_EN and start LEDTS-counter on prescaled clock
//CLK_PS != 0)
```

Re-configuration during run-time:

```
GLOBCTL &= 0x0000X00X; //stop LEDTS-counter by clearing prescaler
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000XX10;
```

Enable Touch-Sense Function Only

To enable touch-sense function only: clear LD_EN, set TS_EN.

Initialization after reset:

```
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000XX01;
//set TS_EN and start LEDTS-counter on prescaled clock
//(CLK_PS != 0)
```

Re-configuration during run-time:

```
GLOBCTL &= 0x0000X00X; //stop LEDTS-counter by clearing prescaler
GLOBCTL = #0bXXXXXXXX XXXXXXXX XXX00000 0000XX01;
```

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Enable Both LED and Touch-Sense Function

To enable both functions: set LD_EN, set TS_EN.

Initialization after reset:

```
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000XX11;  
//set TS_EN and start LEDTS-counter on prescaled clock  
//(CLK_PS != 0)
```

Re-configuration during run-time:

```
GLOBCTL &= 0x0000X00X; //stop LEDTS-counter by clearing prescaler  
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000XX11;
```

Enable Synchronized Kernel Start (Multiple Kernels)

Initialization after reset:

```
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000X1XX;  
//set CMTR and start LEDTS-counter on prescaled clock
```

Note: The slave kernel(s) has to be started first before the master kernel.

Re-configuration during run-time:

```
GLOBCTL &= 0x0000X00X; //stop LEDTS-counter by clearing prescaler  
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 0000X1XX;
```

The slave kernel(s) has to be started first before the master kernel.

Enable Autoscan Time Period Synchronization (Multiple Kernels)

Initialization after reset:

```
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 00001XXX;  
//set ENSYNC and start LEDTS-counter on prescaled clock
```

Note: The slave kernel(s) has to be started first before the master kernel.

Re-configuration during run-time:

```
GLOBCTL &= 0x0000X00X; //stop LEDTS-counter by clearing prescaler  
GLOBCTL = 0bXXXXXXXX XXXXXXXX XXX00000 00001XXX;
```

The slave kernel(s) has to be started first before the master kernel.

14.9.2 Interpretation of Bit Field FNCOL

The interpretation of the FNCOL bit field can be handled by software. The following example where six time slices are enabled (per time frame), with five LED columns and touch-sensing enabled, illustrates this ([Table 14-5](#)).

The FNCOL bit field provides information on the function/column active in the previous time slice. With this information, software can determine the active function/column in

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current time slice and prepare the necessary values (to be shadow-transferred) valid for the next time slice.

Referring to the example below, when the FNCOL bit field is 111_B, it can be derived that the touch-sensing function/column was active in the previous time slice and therefore the current active column is LED COL[4]. Hence, the software can update the shadow line and compare registers for LED COL[3] so that these changes will be reflected when LED COL[3] gets activated in the next time slice.

Table 14-5 Interpretation of FNCOL Bit Field

FNCOL	Active Function / Column in Current Time Slice	SW Prepare via “Shadow” Registers for Function / Column of Next Time Slice
111 _H	LED COL[4]	LED COL[3]
010 _H	LED COL[3]	LED COL[2]
011 _H	LED COL[2]	LED COL[1]
100 _H	LED COL[1]	LED COL[0]
101 _H	LED COL[0]	Touch Input Line TSIN[PADT]
110 _H	Touch Input Line TSIN[PADT]	LED COL[4]

14.9.3 LEDTS Timing Calculations

LEDTS main timing or duration formulation are provided in following.

Count-Rate (CR):

$$CR = (fCLK) \div (PREscaler) \quad (14.1)$$

where fCLK = LEDTS module input clock; PREscaler = **GLOBCTL.CLK_PS**

Time slice duration (TSD):

$$TSD = 2^8 \div (CR) \quad (14.2)$$

Time frame duration (TFD):

$$TFD = (\text{Number of time slices}) \times TSD \quad (14.3)$$

Extended TFD:

$$\text{ExtendedTFD} = \text{ACCCNT} \times TFD \quad (14.4)$$

where ACCCNT = **FNCTL.ACCCNT**

Autoscan time period duration (TPD):

$$TPD = (\text{Number of touch-sense inputs TSIN[x]}) \times TFD \quad (14.5)$$

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LED drive active duration:

$$\text{LED Drive Active Duration} = \text{TSD} \times \text{Compare\_VALUE} \div 2^8 \quad (14.6)$$

Touch-sense drive active duration:

$$\text{Touch-sense Drive Active Duration} = \text{TSD} \times (2^8 - \text{Compare\_VALUE}) \div 2^8 \quad (14.7)$$

14.9.4 Time-Multiplexed LED and Touch-Sense Functions on Pin

Some hints are provided regarding the time-multiplexed usage of a pin for LED and touch-sense function:

- The maximum number of LED columns = 7 when touch-sense function is also enabled.
- If enabled by pin, COLA outputs HIGH to enable external R (resistor) as pull-up for touch-sense function.
- During touch-sense time slice, it is recommended to set LED lines to output LOW.
- During LED time slice, COLA outputs LOW and will sink current if connected lines output HIGH.
- The effective capacitance for each TSIN[x] depends largely on what is connected to the pin and the application board layout. All touch-pads for the application should be calibrated for robust touch-detection.

14.9.5 LEDTS Pin Control

The user may flexibly assign pins as provided by PORTS SFRs, for the LEDTS functions:

- COL[x] (for LED column control)
- LINE[x] (for LED line control)
- TSIN[x] (for touch-sensing)

Refer also to [Section 14.3](#) for more considerations with regards to which COL[x] and/or LINE[x]/TSIN[x] will be active based on user configuration.

User code must configure the assigned LED pin PORTS SFR alternate output selection for the LED function, see [Table 14-7](#) and [Figure 14-11](#) for [Scheme A](#), or [Figure 14-12](#) for [Scheme B](#).

For the touch-sense function, it is also required to configure the PORTS SFRs to enable the hardware function on TSIN[x] pin (similarly alternate output COLA). However, the LEDTS will provide some pin over-rule controls to the assigned touch-sense pin with active pad turn, see [Table 14-7](#) and [Figure 14-11](#) for [Scheme A](#), or [Figure 14-12](#) for [Scheme B](#). The PORTS SFR Pn_HWSEL allows selection between 2 types of configurations:

1. Pn_HWSEL = 01_B

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- This configures the port pin to output low (strong zero) during the discharging of touch pad.
- 2. Pn_HWSEL = 10_B
- This configures the port pin to enable pull-down device during the discharging of touch pad.

The PORTS SFR Pn_PHx allows selection between 2 types of hysteresis configurations:

1. Pn_PHx = 0XX_B
 - This sets the pad to standard hysteresis mode.
2. Pn_PHx = 1XX_B
 - This sets the pad to large hysteresis mode.

From these pad and hysteresis configurations available, a total of 4 different combinations can be derived ([Table 14-6](#)).

Table 14-6 Combinations of pad and hysteresis configurations

	Pad Configuration	Hysteresis Configuration
Combination 1	Output mode (output low)	Standard
Combination 2	Output mode (output low)	Large
Combination 3 ¹⁾	Input mode (pull-down enabled)	Standard
Combination 4	Input mode (pull-down enabled)	Large

1) It can be noted that it is meaningless to use this combination due to the slower charge and discharge speed.

Table 14-7 LEDTS Pin Control Signals

Function	ld/ts_en	ledts_fn	Pin	Control of Assigned Pin
LED column	LD_EN = 1	0 = LED	Enable COL[x]; Passive level on COL[the rest]. If TS_EN = 1, COLA = 0.	PORTS SFR setting

LED and Touch-Sense (LEDTS)

Table 14-7 LEDTS Pin Control Signals

Function	ld/ts_en	ledts_fn	Pin	Control of Assigned Pin
LED line	LD_EN = 1	0 = LED	LINE[x] = internal line register value latched from bit field LINE_[x]	PORTS SFR setting
Touch-sense	TS_EN = 1	1 = Touch-sense	Enable TSIN[x] for oscillation. All other TSIN pins output line value. Passive level on COL[the rest] except COLA = 1.	Hardware over-rule on pad_turn_x¹⁾ for active duration: <u>Scheme A (default)</u> - Enable pull-up, disable pull-down (pull over-rule can be disabled by bit EPULL) - Set to output mode (both input, output stages enabled) - Enable open-drain <u>Scheme B</u> - Pull-up, pull-down controlled by pad input driver signal (EPULL option disabled for this scheme) - Set to input mode (input stage enabled, output stage disabled) - Disable open-drain

1) For the other pad inputs not on turn, there is no HW over-rule which means the PORTS SFR setting is active.

LED and Touch-Sense (LEDTS)

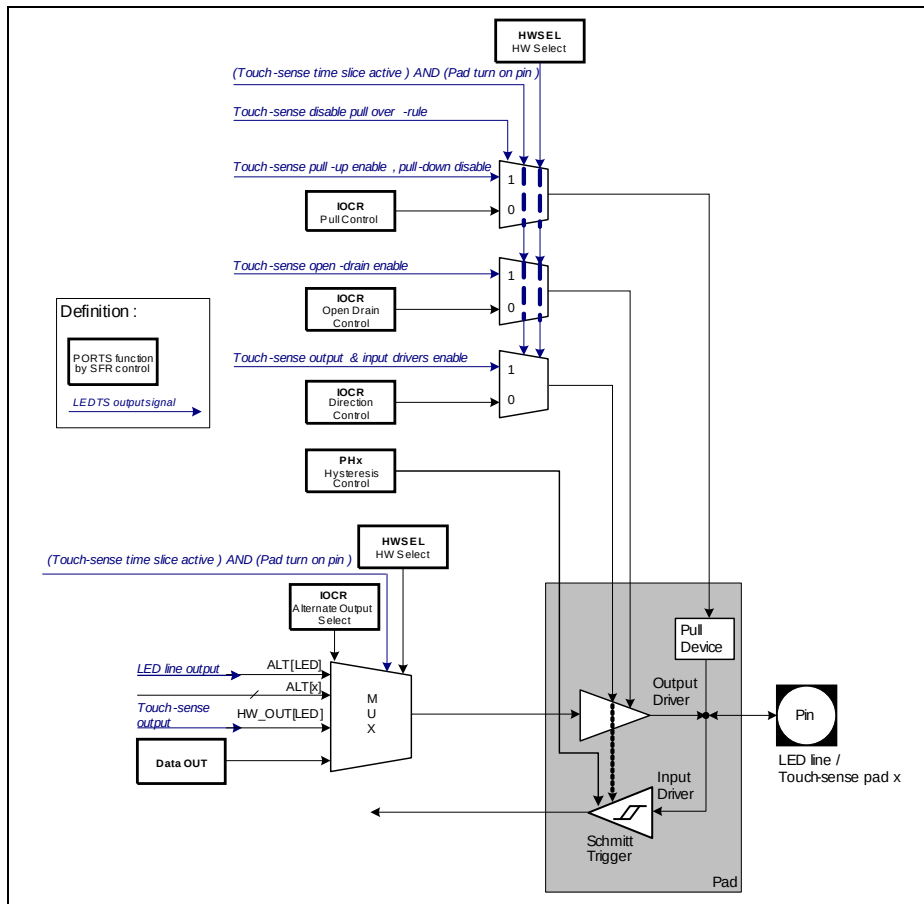


Figure 14-11 Over-rule Control on Pin for Touch-Sense Function (Scheme A)

LED and Touch-Sense (LEDTS)

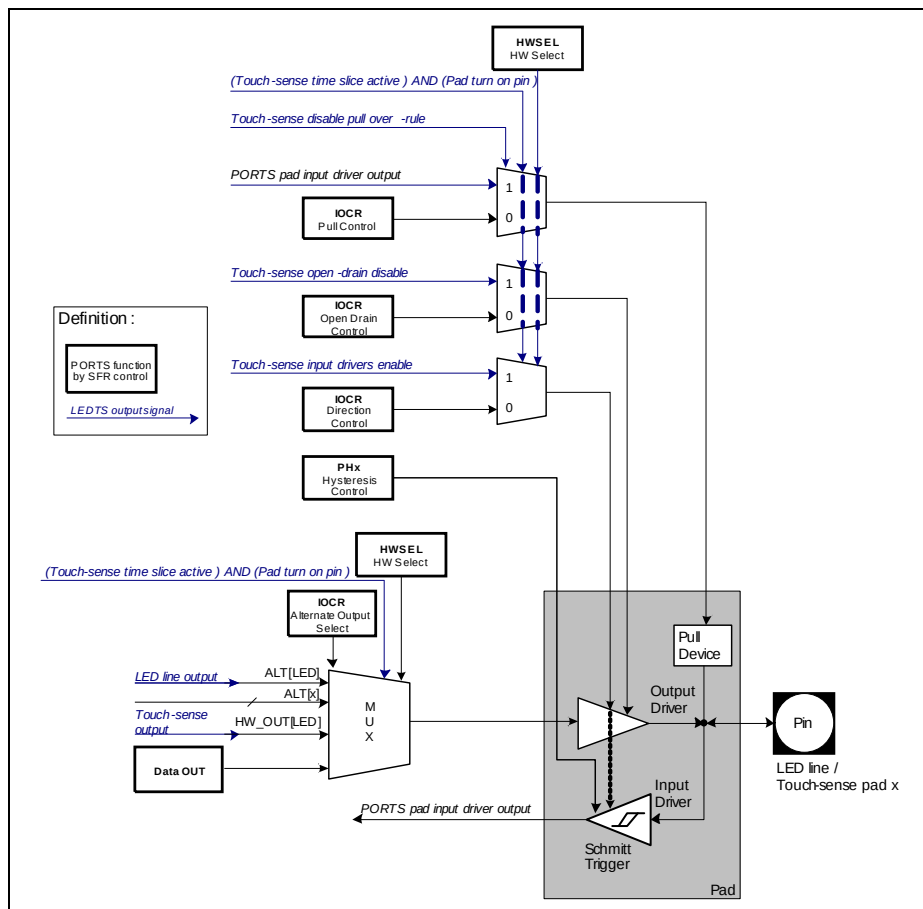


Figure 14-12 Over-rule Control on Pin for Touch-Sense Function (Scheme B)

14.9.6 Software Hints

This section provides some useful software hints:

- Compare value 00_H enables oscillation for the full duration of the time slice, whereas FF_H disables oscillation.
- In order to maximize the resolution of the oscillation window, compare value should be selected to maximize the oscillation count without overflowing the TS-counter.
- Valid pad detection period (the time required to detect a valid touch on a pad) can be extended by:

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- enabling dummy LED columns (without assigning/setting the LED column pins)
- selecting bigger pre-scale factor (**GLOBCTL.CLK_PS**)
- accumulating the number of pad oscillations (**FNCTL.ACCCNT**)
- Valid pad detection period can be reduced by:
 - selecting smaller pre-scale factor (**GLOBCTL.CLK_PS**)
 - reducing the number of accumulations for pad oscillations (**FNCTL.ACCCNT**)
- When using multiple kernels, and slave kernel is taking its clock from the master, it is recommended to start the slave kernel first (by writing to its **GLOBCTL.CLK_PS** bit field to a non-zero value) before the master kernel.

14.9.7 Hardware Design Hints

This section provides some hardware design hints:

- Touch button oscillation frequency changes when the value of the external pull-up resistor (connected to COLA pin) changes. This results in different sensitivity of the touch button as well as the crosstalk between the adjacent touch buttons.
 - A suitable pull-up resistor should be selected to balance the sensitivity of the touch button and the accuracy of the detection.
- The presence of LEDs modifies the equivalent capacitance for a touch pad. A larger number of LEDs connected to a touch pad will increase the self-capacitance of the pad. This makes the pad less sensitive.
- If possible, LEDs should be located near to the touch pads, to reduce the additional parasitic capacitance introduced by the traces.

14.10 Multiple Kernels Usage and Synchronization

A single LEDTS kernel comprises of control and status for:

- Up to 8 time slices per time frame (equivalent to max. 8 LED columns, or 7 if touch-sense is enabled)
- Up to 8 LED lines per column
- Up to 8 touch-sense inputs

A kernel therefore provides on up to 16 pins, to drive maximum 64 LEDs or lesser in combination with touch-sense function on up to 8 touch-sense inputs that can possibly be extended to support more than 8 touchpads such as to implement dual-pad which is effectively a single touchpad connected on two touch-sense inputs (refer to **Figure 14-2**).

Some products implement multiple instances of the LEDTS kernel, and can therefore drive even more LEDs and sense more touchpads. Synchronization amongst the kernels is supported on hardware for synchronized start of LEDTS-counters on same clock setting and in the aspect to simplify touch-sensing analysis handling by software.

In case of LED driving across kernels, it is advised to balance the number of LED time slices amongst the kernels to optimize the display synchronization.

Synchronized Start of Kernels

Every kernel has a control bit CMTR which defines if the kernel is a master or slave with respect to LEDTS-counter clock control. A kernel defined as clock master generates its own LEDTS-counter clock based on input clock and corresponding SFR bit setting CLK_PS in its GLOBCTL register. A kernel defined as clock slave ignores the setting of clock configuration in its own SFR and instead, its counter directly takes the clock provided by Kernel0. Regardless of CMTR setting, Kernel0 always takes its own generated clock based on its own SFR setting. The synchronized start of kernels is illustrated in **Figure 14-13**.

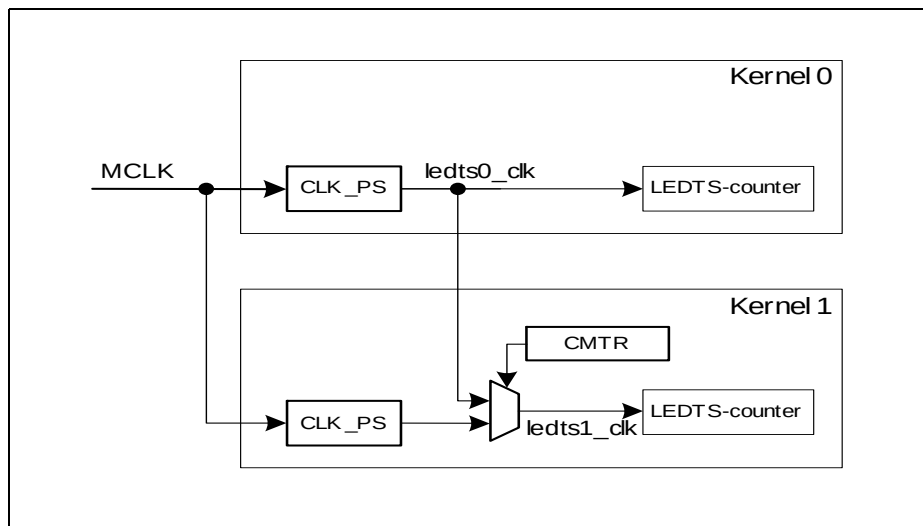


Figure 14-13 Synchronized Kernel Start Options (Example with 2 Kernels)

Synchronization On Enabled Autoscan Time Period

When touch-sensing function is enabled, synchronization among kernels on enabled autoscan time period can be enabled to simplify software handling for touch-sensing analysis for touch detection & action. To “enable autoscan time period”, it is necessary to enable the hardware pad turn control. When software pad turn control is enabled instead, no synchronization is handled by hardware.

The synchronization is achieved on Kernel0’s autoscan time period. This means Kernel0 must be enabled and configured such that it has the longer/longest autoscan time period duration (TPD). All other kernels enabled for the synchronization (bit ENSYNC) will have its respective LEDTS-counter clock gated (no progress to new time slices) upon autoscan time period event of the kernel. Only upon Kernel0 autoscan time period event,

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all the clock gating are removed and all synchronized kernels continue progressing on time slices. This mechanism is illustrated on [Figure 14-14](#).

To summarize, kernels synchronization for touch-sensing on enabled autoscan time period is possible/useful only when the following conditions are met:

- touch-sense function is enabled on all kernels
- hardware pad turn control is enabled on all kernels
- Kernel0 is enabled and has the longer/longest TPD
- all respective kernels have its LEDTS-counter running on clock output from Kernel0

When using this synchronization feature, the **GLOBCTL.CLK_PS** bit field for the slave kernels have to be set to a non-zero value before setting the **GLOBCTL.CLK_PS** bit field for the master kernel (Kernel0).

Synchronization on enabled autoscan time period allows touch-sense software to evaluate only once, after all touchpads have been sensed across all kernels. Based on the result of touch detection across all these respective touchpads, software can then evaluate the actual touch status and react accordingly.

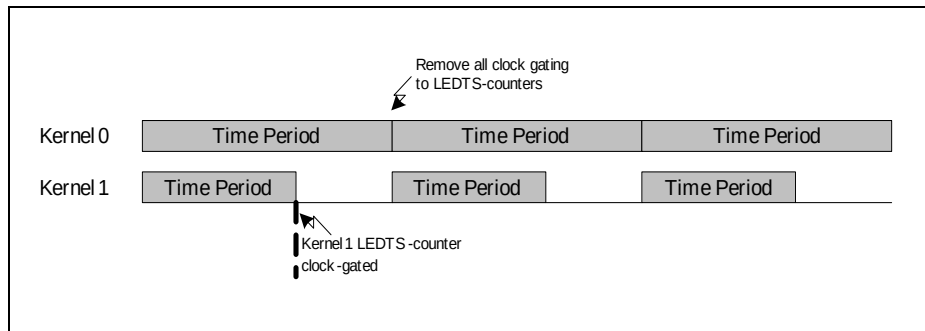


Figure 14-14 Illustration of Synchronization on Enabled Autoscan Time Period (Example with 2 Kernels)

14.11 Registers

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 14-8 Registers Address Space

Module	Base Address	End Address	Note
LEDTS0	5002 0000 _H	5002 002B _H	
LEDTS1	5002 0400 _H	5002 042B _H	

The prefix "**LEDTSx**_" is added to the register names in this table to indicate they belong to the LEDTS kernel. In this naming convention, x indicates the kernel number (e.g. LEDTS0_ for the LEDTS0 kernel and "LEDTS1_" for the LEDTS1 kernel).

Note: Register bits marked "w" always deliver 0 when read.

Access rights within the address range of an LEDTS kernel:

- Read or write access to defined register addresses: U, PV
- Accesses to empty addresses: nBE

Table 14-9 Register Overview of LEDTS

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
ID	Module Identification Register	0000 _H	U, PV	U, PV	Page 14-31
GLOBCTL	Global Control Register	0004 _H	U, PV	U, PV	Page 14-32
FNCTL	Function Control Register	0008 _H	U, PV	U, PV	Page 14-34
EVFR	Event Flag Register	000C _H	U, PV	U, PV	Page 14-38
TSVAL	Touch-Sense TS-Counter Value	0010 _H	U, PV	U, PV	Page 14-39
LINE0	Line Pattern Register 0	0014 _H	U, PV	U, PV	Page 14-40
LINE1	Line Pattern Register 1	0018 _H	U, PV	U, PV	Page 14-41
LDCMP0	LED Compare Register 0	001C _H	U, PV	U, PV	Page 14-41
LDCMP1	LED Compare Register 1	0020 _H	U, PV	U, PV	Page 14-42

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Table 14-9 Register Overview of LEDTS

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
TSCMP0	Touch-Sense Compare Register 0	0024 _H	U, PV	U, PV	Page 14-43
TSCMP1	Touch-Sense Compare Register 1	0028 _H	U, PV	U, PV	Page 14-43
Reserved	Reserved	002C _H - 1FFC _H	nBE	nBE	

14.11.1 Registers Description

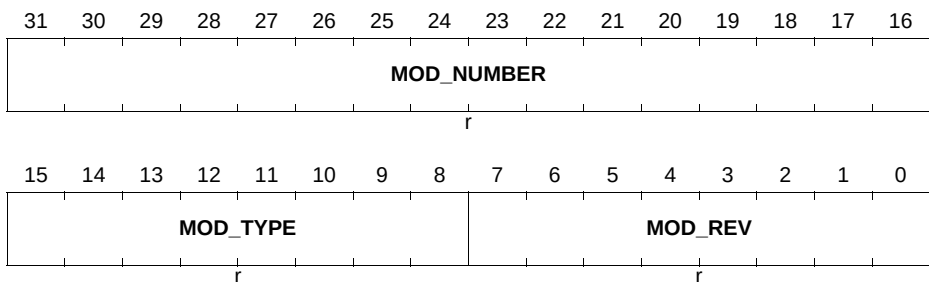
The LEDTS SFRs are organized into registers for global initialization control, functional control comprising TS-counter value, line pattern and compare value registers.

LEDTSx_ID

The module identification register indicate the function and the design step of the peripheral.

ID

Module Identification Register (00_H) **Reset Value:00AB 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 a 00 _H (first revision).

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
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.

GLOBCTL

The GLOBCTL register is used to initialize the LEDTS global controls.

GLOBCTL

Global Control Register (04_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CLK_PS															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ITP_EN	ITF_EN	ITS_EN	FEN_VAL	MASKVAL			SUS_CFG	0				ENS_YNC	CMT_R	LD_EN	TS_EN
rw	rw	rw	rw	rw			rw	r				rw	rw	rw	rw

Field	Bits	Type	Description
TS_EN¹⁾	0	rw	Touch-Sense Function Enable Set to enable the kernel for touch-sense function control when CLK_PS is set from 0.
LD_EN¹⁾	1	rw	LED Function Enable Set to enable the kernel for LED function control when CLK_PS is set from 0.

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
CMTR¹⁾	2	rw	Clock Master Disable 0_B Kernel generates its own clock for LEDTS-counter based on SFR setting 1_B LEDTS-counter takes its clock from another master kernel If this bit is set, the bit field GLOBCTL.CLK_PS needs to be set to a non-zero value to activate the kernel, even though it is taking its clock from the master kernel.
ENSYNC¹⁾	3	rw	Enable Autoscan Time Period Synchronization 0_B No synchronization 1_B Synchronization enabled on Kernel0 autoscan time period
SUSCFG	8	rw	Suspend Request Configuration 0_B Ignore suspend request 1_B Enable suspend according to request
MASKVAL	[11:9]	rw	Mask Number of LSB Bits for Event Validation This defines the number of LSB bits to mask for TS-counter and shadow TS-counter comparison when Time Frame validation is enabled. 0_D Mask LSB bit 1_D Mask 2 LSB bits ... 7_D Mask 8 LSB bits
FENVAL	12	rw	Enable (Extended) Time Frame Validation When enabled, TS-counter and shadow TS-counter values are compared to validate a Time Frame event for set flag and interrupt request. When validation fail, TFF flag does not get set and interrupt is not requested. 0_B Disable 1_B Enable
ITS_EN	13	rw	Enable Time Slice Interrupt 0_B Disable 1_B Enable
ITF_EN	14	rw	Enable (Extended) Time Frame Interrupt 0_B Disable 1_B Enable

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
ITP_EN	15	rw	Enable Autoscan Time Period Interrupt 0 _B Disable 1 _B Enable (valid only for case of hardware-enabled pad turn control)
CLK_PS	[31:16]	rw	LEDTS-Counter Clock Pre-Scale Factor The constant clock input is prescaled according to setting. 0 _D No clock 1 _D Divide by 1 ... 65535 _D Divide by 65535 This bit can only be set to any other value (from 0) provided at least one of touch-sense or LED function is enabled. The LEDTS-counter starts running on the input clock from reset/reload value based on enabled function(s) (and NR_LEDCOL). Refer Section 14.3 for details. When this bit is clear to 0 from other value, the LEDTS-counter stops running and resets.
0	[7:4]	r	Reserved Read as 0; should be written with 0.

1) This bit can only be modified when bit CLK_PS = 0.

FNCTL

The FNCTL control register provides control bits for the LED and Touch Sense functions.

FNCTL

Function Control Register

(08_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
NR_LEDCOL			COL LEV	NR_TSIN			TSC TRS AT	TSC TRR	TSOEXT	TSC CMP	ACCCNT				
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								FNCOL			EPU LL	PAD TSW	PADT		
r								rh			rw	rw	rwh		

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
PADT	[2:0]	rw	Touch-Sense TSIN Pad Turn This is the TSIN[x] pin that is next or currently active in pad turn. When PADTSW = 0, the value is updated by hardware at the end of touch-sense time slice. Software write is always possible. However, PADT must not be written during an active pad turn. 0_D TSIN0 ... 7_D TSIN7
PADTSW¹⁾	3	rw	Software Control for Touch-Sense Pad Turn 0_B The hardware automatically enables the touch-sense inputs in sequence round-robin, starting from TSIN0. 1_B Disable hardware control for software control only. The touch-sense input is configured in bit PADT.
EPULL	4	rw	Enable External Pull-up Configuration on Pin COLA When set, the internal pull-up over-rule on active touch-sense input pin is disabled. 0_B HW over-rule to enable internal pull-up is active on TSIN[x] for set duration in touch-sense time slice. With this setting, it is not specified to assign the COLA to any pin. 1_B Enable external pull-up: Output 1 on pin COLA for whole duration of touch-sense time slice. <i>Note: Independent of this setting, COLA always outputs 1 for whole duration of touch-sense time slice.</i>
FNCOL	[7:5]	rh	Previous Active Function/LED Column Status Shows the active function / LED column in the previous time slice. Updated on start of new time-slice when LEDTS-counter 8LSB over-flows. Controlled by latched value of the internal DE-MUX, see Figure 14-4 .

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
ACCCNT¹⁾	[19:16]	rw	Accumulate Count on Touch-Sense Input Defines the number of times a touch-sense input/pin is enabled in touch-sense time slice of consecutive frames. This provides to accumulate oscillation count on the TSIN[x]. 0 _D 1 time 1 _D 2 times ... 15 _D 16 times
TSCCMP	20	rw	Common Compare Enable for Touch-Sense 0 _B Disable common compare for touch-sense 1 _B Enable common compare for touch-sense
TSOEXT	[22:21]	rw	Extension for Touch-Sense Output for Pin-Low-Level 00 _B Extend by 1 ledts_clk 01 _B Extend by 4 ledts_clk 10 _B Extend by 8 ledts_clk 11 _B Extend by 16 ledts_clk
TSCTRR	23	rw	TS-Counter Auto Reset 0 _B Disable TS-counter automatic reset 1 _B Enable TS-counter automatic reset to 00H on the first pad turn of a new TSIN[x]. Triggered on compare match in time slice.
TSCTRSAT	24	rw	Saturation of TS-Counter 0 _B Disable 1 _B Enable. TS-counter stops counting in the touch-sense time slice(s) of the same (extended) frame when it reaches FFH. Counter starts to count again on the first pad turn of a new TSIN[x], triggered on compare match.
NR_TSIN¹⁾	[27:25]	rw	Number of Touch-Sense Input Defines the number of touch-sense inputs TSIN[x]. Used for the hardware control of pad turn enabling. 0 _D 1 ... 7 _D 8

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
COLLEV	28	rw	Active Level of LED Column 0 _B Active low 1 _B Active high
NR_LEDCOL¹⁾	[31:29]	rw	Number of LED Columns Defines the number of LED columns. 000 _B 1 LED column 001 _B 2 LED columns 010 _B 3 LED columns 011 _B 4 LED columns 100 _B 5 LED columns 101 _B 6 LED columns 110 _B 7 LED columns 111 _B 8 LED columns (if bit TS_EN = 1, a maximum number of 7 LED columns is allowed. Combination of TS_EN = 1 and NR_LEDCOL = 111 _B is disallowed) <i>Note: LED column is enabled in sequence starting from highest column number. If touch-sense function is not enabled, COLA is activated in last time slice.</i>
0	[15:8]	r	Reserved Read as 0; should be written with 0.

1) This bit can only be modified when bit CLK_PS = 0.

EVFR

The EVFR register contains the status flags for events and control bits for requesting clearance of event flags.

LED and Touch-Sense (LEDTS)

EVFR

Event Flag Register

(0C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
0													CTP F	CTF F	CTS F	
r													w	w	w	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0													TSC TRO VF	TPF	TFF	TSF
r													rh	rh	rh	rh

Field	Bits	Type	Description
TSF	0	rh	Time Slice Interrupt Flag Set on activation of each new time slice, including when bit CLK_PS is set from 0. To be cleared by software.
TFF	1	rh	(Extended) Time Frame Interrupt Flag Set on activation of each new (extended) time frame, including when bit CLK_PS is set from 0.
TPF	2	rh	Autoscan Time Period Interrupt Flag Set on activation of each new time period, including when bit CLK_PS is set from 0. This bit will never be set in case of hardware pad turn control is disabled (bit PADTSW = 1).
TSCTROVF	3	rh	TS-Counter Overflow Indication This bit indicates whether a TS-counter overflow has occurred. This bit is cleared on new pad turn, triggered on compare match. 0 _B No overflow has occurred. 1 _B The TS-counter has overflowed at least once.
CTSF	16	w	Clear Time Slice Interrupt Flag 0 _B No action. 1 _B Bit TSF is cleared. Read always as 0.

LED and Touch-Sense (LEDTS)

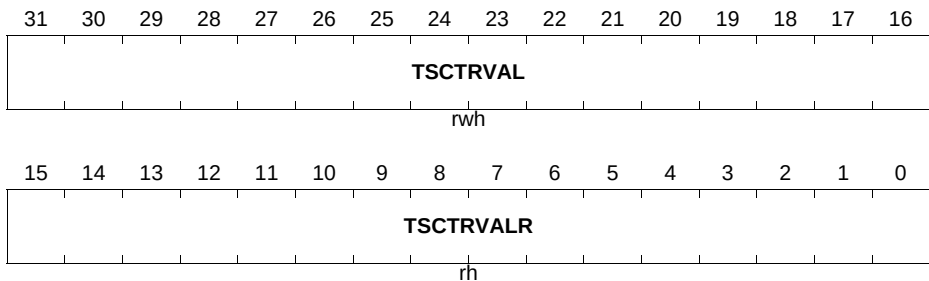
Field	Bits	Type	Description
CTFF	17	w	Clear (Extended) Time Frame Interrupt Flag 0_B No action. 1_B Bit TFF is cleared. Read always as 0.
CTPF	18	w	Clear Autoscan Time Period Interrupt Flag 0_B No action. 1_B Bit TPF is cleared. Read always as 0.
0	[31:19], [15:4]	r	Reserved Read as 0; should be written with 0.

TSVAL

The TSVAL register holds the current and shadow touch sense counter values.

TSVAL

Touch-sense TS-Counter Value (10_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
TSCTRVALR	[15:0]	rh	Shadow TS-Counter Value (Read) This is the latched value of the TS-counter (on every extended time frame event). It shows the latest valid oscillation count from the last completed time slice.

LED and Touch-Sense (LEDTS)

Field	Bits	Type	Description
TSCTRVAL	[31:16]	rwh	TS-Counter Value This is the actual TS-counter value. It can only be written when no pad turn is active. The counter may be enabled for automatic reset once per (extended) frame on the start of a new pad turn on the next TSIN[x] pin.

LINE_x (x = 0-1)

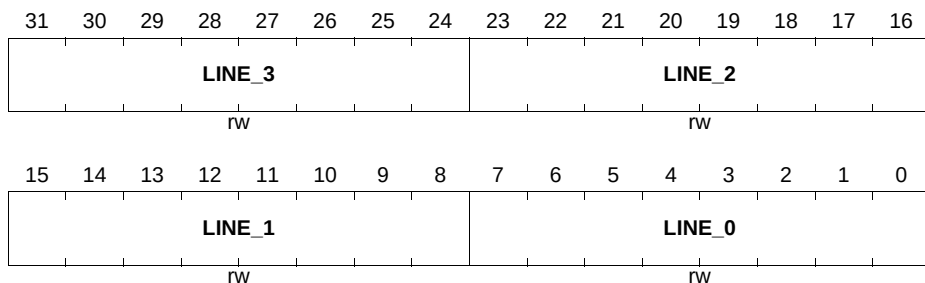
The LINE_x registers hold the values that are output to the respective line pins during their active column period.

LINE0

Line Pattern Register 0

(14_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
LINE_0, LINE_1, LINE_2, LINE_3	[7:0], [15:8], [23:16], [31:24]	rw	Output on LINE[x] This value is output on LINE[x] to pin when LED COL[x] is active.

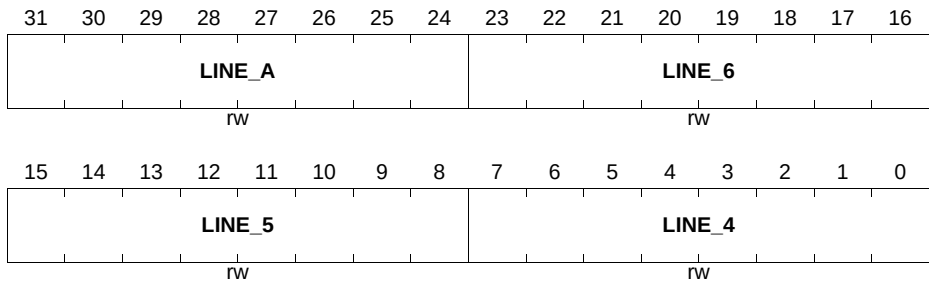
LED and Touch-Sense (LEDTS)

LINE1

Line Pattern Register 1

(18_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
LINE_4, LINE_5, LINE_6	[7:0], [15:8], [23:16]	rw	Output on LINE[x] This value is output on LINE[x] to pin when LED COL[x] is active.
LINE_A	[31:24]	rw	Output on LINE[x] This value is output on LINE[x] to pin when LED COLA or touch-sense time slice is active.

LDCMPx (x = 0-1)

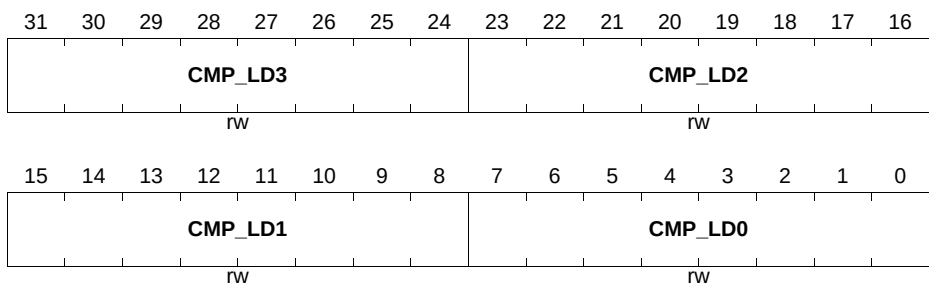
The LDCMPx registers hold the COMPARE values for their respective LED columns. These values are used for LED brightness control.

LDCMP0

LED Compare Register 0

(1C_H)

Reset Value: 0000 0000_H



LED and Touch-Sense (LEDTS)

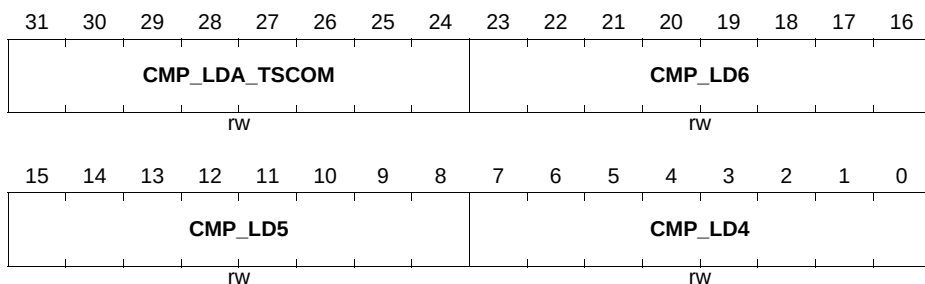
Field	Bits	Type	Description
CMP_LD0, CMP_LD1, CMP_LD2, CMP_LD3	[7:0], [15:8], [23:16], [31:24]	rw	Compare Value for LED COL[x]

LDCMP1

LED Compare Register 1

(20_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CMP_LD4, CMP_LD5, CMP_LD6	[7:0], [15:8], [23:16]	rw	Compare Value for LED COL[x]
CMP_LDA_TS COM	[31:24]	rw	Compare Value for LED COLA / Common Compare Value for Touch-sense Pad Turns LED function The compare value for LED COLA is only valid when touch-sense function is not enabled. Touch-sense function The common compare value for touch-sense pad turns is enabled by set TSCCMP bit. When enabled for common compare, settings in SFRs LEDTS_TSCMP0,1 are not referenced.

TSCMPx (x = 0-1)

The TSCMPx registers hold the COMPARE values for their respective touch pad input lines. These values determine the size of the pad oscillation window for each pad input lines during their pad turn.

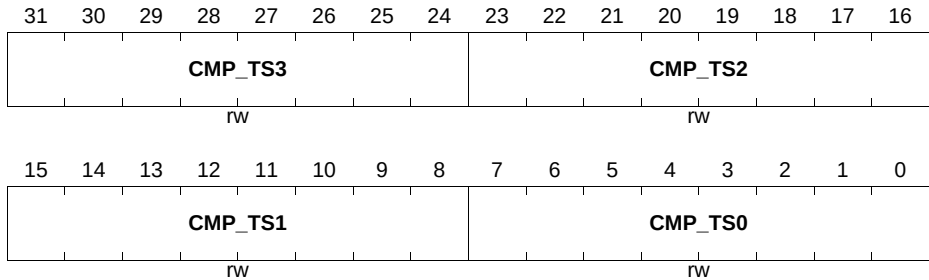
LED and Touch-Sense (LEDTS)

TSCMP0

Touch-sense Compare Register 0

(24_H)

Reset Value: 0000 0000_H



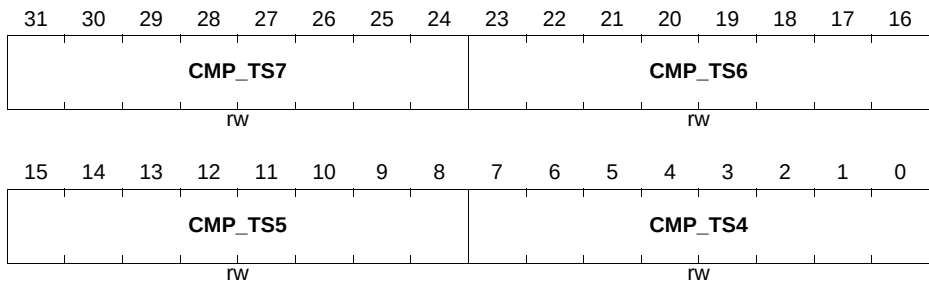
Field	Bits	Type	Description
CMP_TS0, CMP_TS1, CMP_TS2, CMP_TS3	[7:0], [15:8], [23:16], [31:24]	rw	Compare Value for Touch-Sense TSIN[x]

TSCMP1

Touch-sense Compare Register 1

(28_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
CMP_TS4, CMP_TS5, CMP_TS6, CMP_TS7	[7:0], [15:8], [23:16], [31:24]	rw	Compare Value for Touch-Sense TSIN[x]

LED and Touch-Sense (LEDTS)
14.12 Interconnects

The LEDTS has interconnection to other peripherals enabling higher level of automation without requiring software. [Table 14-10](#) provides a list of the pin connections.

LEDTSx.FN is an output signal denoting LEDTS active function. This signal can be used as a source for VADC request gating and background gating. LEDTSx.SR0 is an output signal denoting LEDTS kernel service request. This signal can be used either as an interrupt trigger or for general purpose to CCU4.

Table 14-10 Pin Connections

Input/Output	I/O	Connected To	Description
LEDTS0.TSIN0	I	P0.7	LEDTS Touch-sense 0 input
LEDTS0.TSIN1	I	P0.6	LEDTS Touch-sense 1 input
LEDTS0.TSIN2	I	P0.5	LEDTS Touch-sense 2 input
LEDTS0.TSIN3	I	P0.4	LEDTS Touch-sense 3 input
LEDTS0.TSIN4	I	P0.3	LEDTS Touch-sense 4 input
LEDTS0.TSIN5	I	P0.2	LEDTS Touch-sense 5 input
LEDTS0.TSIN6	I	P0.1	LEDTS Touch-sense 6 input
LEDTS0.TSIN7	I	P0.0	LEDTS Touch-sense 7 input
LEDTS0.LINE0	O	P0.7	LEDTS Line 0 output
LEDTS0.LINE1	O	P0.6	LEDTS Line 1 output
LEDTS0.LINE2	O	P0.5	LEDTS Line 2 output
LEDTS0.LINE3	O	P0.4	LEDTS Line 3 output
LEDTS0.LINE4	O	P0.3	LEDTS Line 4 output
LEDTS0.LINE5	O	P0.2	LEDTS Line 5 output
LEDTS0.LINE6	O	P0.1	LEDTS Line 6 output
LEDTS0.LINE7	O	P0.0	LEDTS Line 7 output
LEDTS0.COLA	O	P0.8 P1.5	LEDTS Column A output
LEDTS0.COL0	O	P0.7 P0.15 P1.0	LEDTS Column 0 output
LEDTS0.COL1	O	P0.6 P0.14 P1.1	LEDTS Column 1 output

LED and Touch-Sense (LEDTS)
Table 14-10 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
LEDTS0.COL2	O	P0.5 P0.13 P1.2	LEDTS Column 2 output
LEDTS0.COL3	O	P0.4 P0.12 P1.3	LEDTS Column 3 output
LEDTS0.COL4	O	P0.11 P1.4	LEDTS Column 4 output
LEDTS0.COL5	O	P0.10 P1.6	LEDTS Column 5 output
LEDTS0.COL6	O	P0.9	LEDTS Column 6 output
LEDTS0.EXTENDED0	O	P0.7.HW0	
LEDTS0.EXTENDED1	O	P0.6.HW0	
LEDTS0.EXTENDED2	O	P0.5.HW0	
LEDTS0.EXTENDED3	O	P0.4.HW0	
LEDTS0.EXTENDED4	O	P0.3.HW0	
LEDTS0.EXTENDED5	O	P0.2.HW0	
LEDTS0.EXTENDED6	O	P0.1.HW0	
LEDTS0.EXTENDED7	O	P0.0.HW0	
LEDTS0.FN	O	VADC0.BGREQGTI	VADC background gating input I
		VADC0.G0REQGTI	VADC request gating input I
		VADC0.G1REQGTI	VADC request gating input I
LEDTS0.SR0	O	NVIC	Interrupt trigger
		CCU40.IN2L	General purpose function
LEDTS1.TSIN0	I	P0.8	LEDTS Touch-sense 0 input
LEDTS1.TSIN1	I	P0.9	LEDTS Touch-sense 1 input
LEDTS1.TSIN2	I	P0.10	LEDTS Touch-sense 2 input
LEDTS1.TSIN3	I	P0.11	LEDTS Touch-sense 3 input
LEDTS1.TSIN4	I	P0.12	LEDTS Touch-sense 4 input
LEDTS1.TSIN5	I	P0.13	LEDTS Touch-sense 5 input
LEDTS1.TSIN6	I	P0.14	LEDTS Touch-sense 6 input
LEDTS1.TSIN7	I	P0.15	LEDTS Touch-sense 7 input

LED and Touch-Sense (LEDTS)
Table 14-10 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
LEDTS1.LINE0	O	P0.8	LEDTS Line 0 output
LEDTS1.LINE1	O	P0.9	LEDTS Line 1 output
LEDTS1.LINE2	O	P0.10	LEDTS Line 2 output
LEDTS1.LINE3	O	P0.11	LEDTS Line 3 output
LEDTS1.LINE4	O	P0.12	LEDTS Line 4 output
LEDTS1.LINE5	O	P0.13	LEDTS Line 5 output
LEDTS1.LINE6	O	P0.14	LEDTS Line 6 output
LEDTS1.LINE7	O	P0.15	LEDTS Line 7 output
LEDTS1.COLA	O	P1.0	LEDTS Column A output
LEDTS1.COL0	O	P0.15 P1.1	LEDTS Column 0 output
LEDTS1.COL1	O	P0.14 P1.2	LEDTS Column 1 output
LEDTS1.COL2	O	P0.13 P1.3	LEDTS Column 2 output
LEDTS1.COL3	O	P0.12 P1.4 P2.11	LEDTS Column 3 output
LEDTS1.COL4	O	P2.10	LEDTS Column 4 output
LEDTS1.COL5	O	P2.0	LEDTS Column 5 output
LEDTS1.COL6	O	P2.1	LEDTS Column 6 output
LEDTS1.EXTENDED0	O	P0.8.HW0	
LEDTS1.EXTENDED1	O	P0.9.HW0	
LEDTS1.EXTENDED2	O	P0.10.HW0	
LEDTS1.EXTENDED3	O	P0.11.HW0	
LEDTS1.EXTENDED4	O	P0.12.HW0	
LEDTS1.EXTENDED5	O	P0.13.HW0	
LEDTS1.EXTENDED6	O	P0.14.HW0	
LEDTS1.EXTENDED7	O	P0.15.HW0	
LEDTS1.FN	O	VADC0.BGREQGTJ	VADC background gating input J
		VADC0.G0REQGTJ	VADC request gating input J
		VADC0.G1REQGTJ	VADC request gating input J

LED and Touch-Sense (LEDTS)**Table 14-10 Pin Connections (cont'd)**

Input/Output	I/O	Connected To	Description
LEDTS1.SR0	O	NVIC	Interrupt trigger
		CCU40.IN3L	General purpose function

15 Universal Serial Interface Channel (USIC)

The **Universal Serial Interface Channel** module (USIC) is a flexible interface module covering several serial communication protocols. A USIC module contains two independent communication channels named USICx_CH0 and USICx_CH1, with x being the number of the USIC module (e.g. channel 0 of USIC module 0 is referenced as USIC0_CH0). The user can program during run-time which protocol will be handled by each communication channel and which pins are used.

References

The following documents are referenced for further information

- [7] IIC Bus Specification (Philips Semiconductors v2.1)
- [8] IIS Bus Specification (Philips Semiconductors June 5 1996 revision)

Table 15-1 Abbreviations

CTQ	Time Quanta Counter
DSU	Data Shift Unit
f_{PERIPH}	USIC module clock frequency
f_{PIN}	Input frequency to baud rate generator
MCLK	Master Clock <i>Note: In the USIC chapter, the module clock is referred to as f_{PERIPH}</i>
PPP	Protocol Pre-Processor
RSR	Receive Shift Register
SCLK	Shift Clock
TSR	Transmit Shift Register

15.1 Overview

This section gives an overview about the feature set of the USIC.

15.1.1 Features

Each USIC channel can be individually configured to match the application needs, e.g. the protocol can be selected or changed during run time without the need for a reset. The following protocols are supported:

- **UART** (ASC, asynchronous serial channel)
 - Module capability: receiver/transmitter with max. baud rate $f_{\text{PERIPH}} / 4$

Universal Serial Interface Channel (USIC)

- Wide baud rate range down to single-digit baud rates
- Number of data bits per data frame: 1 to 63
- MSB or LSB first
- **LIN** Support by hardware (Local Interconnect Network)
 - Data transfers based on ASC protocol
 - Baud rate detection possible by built-in capture event of baud rate generator
 - Checksum generation under software control for higher flexibility
- **SSC/SPI** (synchronous serial channel with or without slave select lines)
 - Standard, Dual and Quad SPI format supported
 - Module capability: maximum baud rate $f_{\text{PERIPH}} / 2$, limited by loop delay
 - Number of data bits per data frame 1 to 63, more with explicit stop condition
 - Parity bit generation supported
 - MSB or LSB first
- **IIC** (Inter-IC Bus)
 - Application baud rate 100 kbit/s to 400 kbit/s
 - 7-bit and 10-bit addressing supported
 - Full master and slave device capability
- **IIS** (infotainment audio bus)
 - Module capability: maximum baud rate $f_{\text{PERIPH}} / 2$

Note: The real baud rates that can be achieved in a real application depend on the operating frequency of the device, timing parameters as described in the Data Sheet, signal delays on the PCB and timings of the peer device.

In addition to the flexible choice of the communication protocol, the USIC structure has been designed to reduce the system load (CPU load) allowing efficient data handling. The following aspects have been considered:

- **Data buffer capability**
The standard buffer capability includes a double word buffer for receive data and a single word buffer for transmit data. This allows longer CPU reaction times (e.g. interrupt latency).
- **Additional FIFO buffer capability**
In addition to the standard buffer capability, the received data and the data to be transmitted can be buffered in a FIFO buffer structure. The size of the receive and the transmit FIFO buffer can be programmed independently. Depending on the application needs, a total buffer capability of 64 data words can be assigned to the receive and transmit FIFO buffers of a USIC module (the two channels of the USIC module share the 64 data word buffer).
In addition to the FIFO buffer, a bypass mechanism allows the introduction of high-priority data without flushing the FIFO buffer.
- **Transmit control information**
For each data word to be transmitted, a 5-bit transmit control information has been added to automatically control some transmission parameters, such as word length, frame length, or the slave select control for the SPI protocol. The transmit control

Universal Serial Interface Channel (USIC)

information is generated automatically by analyzing the address where the user software has written the data word to be transmitted (32 input locations = $2^5 = 5$ bit transmit control information).

This feature allows individual handling of each data word, e.g. the transmit control information associated to the data words stored in a transmit FIFO can automatically modify the slave select outputs to select different communication targets (slave devices) without CPU load. Alternatively, it can be used to control the frame length.

- **Flexible frame length control**

The number of bits to be transferred within a data frame is independent of the data word length and can be handled in two different ways. The first option allows automatic generation of frames up to 63 bits with a known length. The second option supports longer frames (even unlimited length) or frames with a dynamically controlled length.

- **Interrupt capability**

The events of each USIC channel can be individually routed to one of 6 service request outputs SR[5:0] available for each USIC module, depending on the application needs. Furthermore, specific start and end of frame indications are supported in addition to protocol-specific events.

- **Flexible interface routing**

Each USIC channel offers the choice between several possible input and output pins connections for the communications signals. This allows a flexible assignment of USIC signals to pins that can be changed without resetting the device.

- **Input conditioning**

Each input signal is handled by a programmable input conditioning stage with programmable filtering and synchronization capability.

- **Baud rate generation**

Each USIC channel contains its own baud rate generator. The baud rate generation can be based either on the internal module clock or on an external frequency input. This structure allows data transfers with a frequency that can not be generated internally, e.g. to synchronize several communication partners.

- **Transfer trigger capability**

In master mode, data transfers can be triggered by events generated outside the USIC module, e.g. by an input pin or a timer unit (transmit data validation). This feature allows time base related data transmission.

- **Debugger support**

The USIC offers specific addresses to read out received data without interaction with the FIFO buffer mechanism. This feature allows debugger accesses without the risk of a corrupted receive data sequence.

To reach a desired baud rate, two criteria have to be respected, the module capability and the application environment. The module capability is defined with respect to the module's input clock frequency, being the base for the module operation. Although the module's capability being much higher (depending on the module clock and the number

Universal Serial Interface Channel (USIC)

of module clock cycles needed to represent a data bit), the reachable baud rate is generally limited by the application environment. In most cases, the application environment limits the maximum reachable baud rate due to driver delays, signal propagation times, or due to EMI reasons.

Note: Depending on the selected additional functions (such as digital filters, input synchronization stages, sample point adjustment, data structure, etc.), the maximum reachable baud rate can be limited. Please also take care about additional delays, such as (internal or external) propagation delays and driver delays (e.g. for collision detection in ASC mode, for IIC, etc.).

Universal Serial Interface Channel (USIC)

A block diagram of the USIC module/channel structure is shown in **Figure 15-1**.

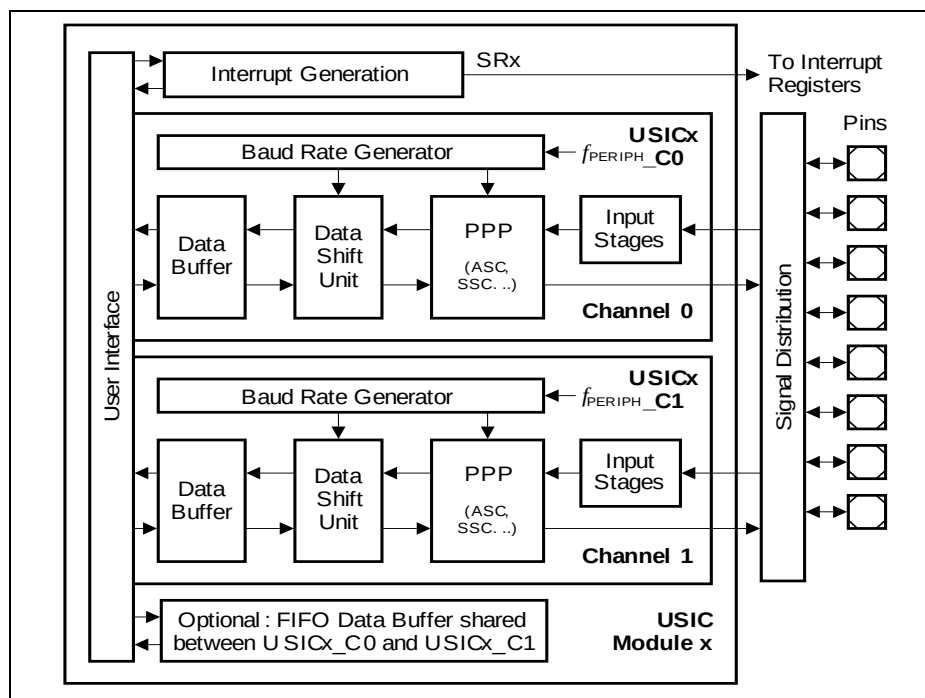


Figure 15-1 USIC Module/Channel Structure

15.2 Operating the USIC

This section describes how to operate the USIC communication channel.

15.2.1 USIC Structure Overview

This section introduces the USIC structure.

15.2.1.1 Channel Structure

The USIC module contains two independent communication channels, with a structure as shown in [Figure 15-1](#).

The data shift unit and the data buffering of each channel support full-duplex data transfers. The protocol-specific actions are handled by the protocol pre-processors (PPP). In order to simplify data handling, an additional FIFO data buffer is optionally available for each USIC module to store transmit and receive data for each channel.

Due to the independent channel control and baud rate generation, the communication protocol, baud rate and the data format can be independently programmed for each communication channel.

15.2.1.2 Input Stages

For each protocol, the number of input signals used depends on the selected protocol. Each input signal is handled by an input stage (called DX_n, where n=0-5) for signal conditioning, such as input selection, polarity control, or a digital input filter. They can be classified according to their meaning for the protocols, see [Table 15-2](#).

The inputs marked as "optional" are not needed for the standard function of a protocol and may be used for enhancements. The descriptions of protocol-specific items are given in the related protocol chapters. For the external frequency input, please refer to the baud rate generator section, and for the transmit data validation, to the data handling section.

Universal Serial Interface Channel (USIC)
Table 15-2 Input Signals for Different Protocols

Selected Protocol	Shift Data Input(s) (handled by DX0, DX3, DX4 and DX5)¹⁾	Shift Clock Input (handled by DX1)	Shift Control Input (handled by DX2)
ASC, LIN	RXD	optional: external frequency input or TXD collision detection	optional: transmit data validation
Standard SSC, SPI (Master)	DIN0 (MRST, MISO)	optional: external frequency input or delay compensation	optional: transmit data validation or delay compensation
Standard SSC, SPI (Slave)	DIN0 (MTSR, MOSI)	SCLKIN	SELIN
Dual- SSC, SPI (Master)	DIN[1:0] (MRST[1:0], MISO[1:0])	optional: external frequency input or delay compensation	optional: transmit data validation or delay compensation
Dual- SSC, SPI (Slave)	DIN[1:0] (MTSR[1:0], MOSI[1:0])	SCLKIN	SELIN
Quad- SSC, SPI (Master)	DIN[3:0] (MRST[3:0], MISO[3:0])	optional: external frequency input or delay compensation	optional: transmit data validation or delay compensation
Quad- SSC, SPI (Slave)	DIN[3:0] (MTSR[3:0], MOSI[3:0])	SCLKIN	SELIN
IIC	SDA	SCL	optional: transmit data validation
IIS (Master)	DIN0	optional: external frequency input or delay compensation	optional: transmit data validation or delay compensation
IIS (Slave)	DIN0	SCLKIN	WAIN

1) ASC, IIC, IIS and standard SSC protocols use only DX0 as the shift data input.

Universal Serial Interface Channel (USIC)

Note: To allow a certain flexibility in assigning required USIC input functions to port pins of the device, each input stage can select the desired input location among several possibilities.

The available USIC signals and their port locations are listed in the interconnects section, see [Page 15-226](#).

15.2.1.3 Output Signals

For each protocol, up to 14 protocol-related output signals are available. The number of actually used outputs depends on the selected protocol. They can be classified according to their meaning for the protocols, see [Table 15-3](#).

The outputs marked as “optional” are not needed for the standard function of a protocol and may be used for enhancements. The descriptions of protocol-specific items are given in the related protocol chapters. The MCLKOUT output signal has a stable frequency relation to the shift clock output (the frequency of MCLKOUT can be higher than for SCLKOUT) for synchronization purposes of a slave device to a master device. If the baud rate generator is not needed for a specific protocol (e.g. in SSC slave mode), the SCLKOUT and MCLKOUT signals can be used as clock outputs with 50% duty cycle with a frequency that can be independent from the communication baud rate.

Table 15-3 Output Signals for Different Protocols

Selected Protocol	Shift Data Output(s) DOUT[3:0] ¹⁾	Shift Clock Output SCLKOUT	Shift Control Outputs SELO[7:0]	Master Clock Output MCLKOUT
ASC, LIN	TXD	not used	not used	optional: master time base
Standard SSC, SPI (Master)	DOUT0 (MTSR, MOSI)	master shift clock	slave select, chip select	optional: master time base
Standard SSC, SPI (Slave)	DOUT0 (MRST, MISO)	optional: independent clock output	not used	optional: independent clock output
Dual-SSC, SPI (Master)	DOUT[1:0] (MTSR[1:0], MOSI[1:0])	master shift clock	slave select, chip select	optional: master time base
Dual-SSC, SPI (Slave)	DOUT[1:0] (MRST[1:0], MISO[1:0])	optional: independent clock output	not used	optional: independent clock output

Universal Serial Interface Channel (USIC)

Table 15-3 Output Signals for Different Protocols (cont'd)

Selected Protocol	Shift Data Output(s) DOUT[3:0] ¹⁾	Shift Clock Output SCLKOUT	Shift Control Outputs SELO[7:0]	Master Clock Output MCLKOUT
Quad-SSC, SPI (Master)	DOUT[3:0] (MSTR[3:0], MOSI[3:0])	master shift clock	slave select, chip select	optional: master time base
Quad-SSC, SPI (Slave)	DOUT[3:0] (MRST[3:0], MISO[3:0])	optional: independent clock output	not used	optional: independent clock output
IIC	SDA	SCL	not used	optional: master time base
IIS (master)	DOUT0	master shift clock	WA	optional: master time base
IIS (slave)	DOUT0	optional: independent clock output	not used	optional: independent clock output

1) ASC, IIC, IIS and standard SSC protocols use only DOUT0 as the shift data output.

Note: To allow a certain flexibility in assigning required USIC output functions to port pins of the device, most output signals are made available on several port pins. The port control itself defines pin-by-pin which signal is used as output signal for a port pin (see port chapter). The available USIC signals and their port locations are listed in the interconnects section, see [Page 15-226](#).

15.2.1.4 Baud Rate Generator

Each USIC Channel contains a baud rate generator structured as shown in [Figure 15-2](#). It is based on coupled divider stages, providing the frequencies needed for the different protocols. It contains:

- A fractional divider to generate the input frequency $f_{PIN} = f_{FD}$ for baud rate generation based on the internal system frequency f_{PERIPH} .
- The DX1 input to generate the input frequency $f_{PIN} = f_{DX1}$ for baud rate generation based on an external signal.
- Two protocol-related counters: the divider mode counter to provide the master clock signal MCLK, the shift clock signal SCLK, and other protocol-related signals; and the capture mode timer for time interval measurement, e.g. baud rate detection.
- A time quanta counter associated to the protocol pre-processor defining protocol-specific timings, such shift control signals or bit timings, based on the input frequency f_{CTQIN} .

Universal Serial Interface Channel (USIC)

- The output signals MCLKOUT and SCLKOUT of the protocol-related divider that can be made available on pins. In order to adapt to different applications, some output characteristics of these signals can be configured.
 For device-specific details about availability of USIC signals on pins please refer to the interconnects section.

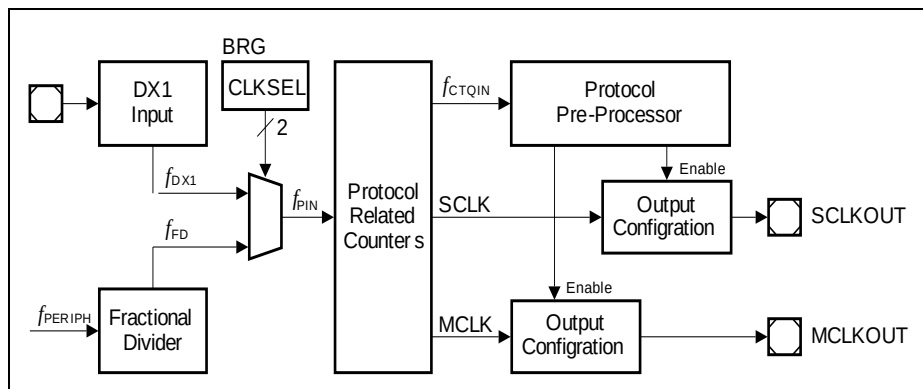


Figure 15-2 Baud Rate Generator

15.2.1.5 Channel Events and Interrupts

The notification of the user about events occurring during data traffic and data handling is based on:

- Data transfer events related to the transmission or reception of a data word, independent of the selected protocol.
- Protocol-specific events depending on the selected protocol.
- Data buffer events related to data handling by the optional FIFO data buffers.

15.2.1.6 Data Shifting and Handling

The data handling of the USIC module is based on an independent data shift unit (DSU) and a buffer structure that is similar for the supported protocols. The data shift and buffer registers are 16-bit wide (maximum data word length), but several data words can be concatenated to achieve longer data frames. The DSU inputs are the shift data (handled by input stage DX0, DX3, DX4 and DX5), the shift clock (handled by the input stage DX1), and the shift control (handled by the input stage DX2). The signal DOUT[3:0] represents the shift data outputs.

Universal Serial Interface Channel (USIC)

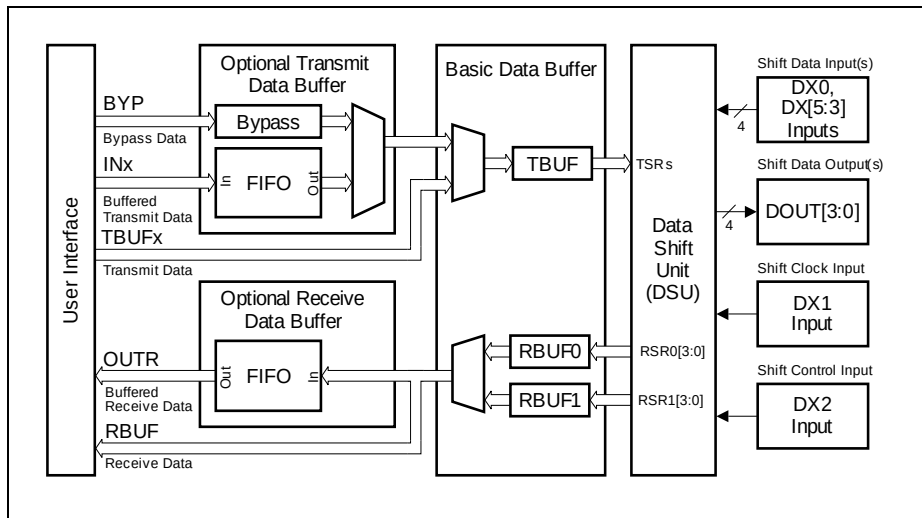


Figure 15-3 Principle of Data Buffering

The principle of data handling comprises:

- A transmitter with transmit shift registers (TSR and TSR[3:0]) in the DSU and a transmit data buffer (TBUF). A data validation scheme allows triggering and gating of data transfers by external events under certain conditions.
- A receiver with two alternating sets of receive shift registers (RSR0[3:0] and RSR1[3:0]) in the DSU and a double receive buffer structure (RBUF0, RBUF1). The alternating receive shift registers support the reception of data streams and data frames longer than one data word.
- A user interface to handle data, interrupts, and status and control information.

Basic Data Buffer Structure

The read access to received data and the write access of data to be transmitted can be handled by a basic data buffer structure.

The received data stored in the receiver buffers RBUF0/RBUF1 can be read directly from these registers. In this case, the user has to take care about the reception sequence to read these registers in the correct order. To simplify the use of the receive buffer structure, register RBUF has been introduced. A read action from this register delivers the data word received first (oldest data) to respect the reception sequence. With a read access from at least the low byte of RBUF, the data is automatically declared to be no longer new and the next received data word becomes visible in RBUF and can be read out next.

Universal Serial Interface Channel (USIC)

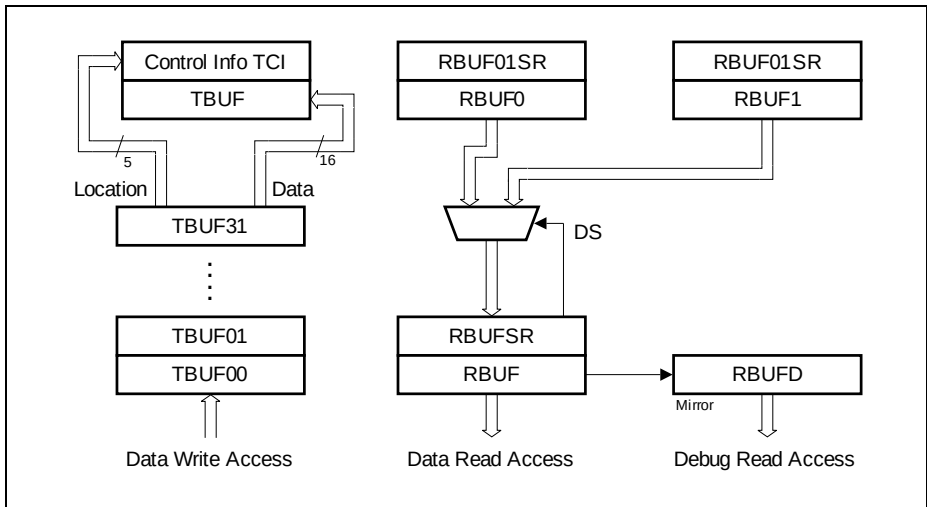


Figure 15-4 Data Access Structure without additional Data Buffer

It is recommended to read the received data words by accesses to RBUF and to avoid handling of RBUF0 and RBUF1. The USIC module also supports the use of debug accesses to receive data words. Debugger read accesses should not disturb the receive data sequence and, as a consequence, should not target RBUF. Therefore, register RBUFD has been introduced. It contains the same value as RBUF, but a read access from RBUFD does not change the status of the data (same data can be read several times). In addition to the received data, some additional status information about each received data word is available in the receiver buffer status register RBUF01SR (related to data in RBUF0 and RBUF1) and RBUFSR (related to data in RBUF).

Transmit data can be loaded to TBUF by software by writing to the transmit buffer input locations TBUF_x ($x = 00-31$), consisting of 32 consecutive addresses. The data written to one of these input locations is stored in the transmit buffer TBUF. Additionally, the address of the written location is evaluated and can be used for additional control purposes. This 5-bit wide information (named **Transmit Control Information TCI**) can be used for different purposes in different protocols.

FIFO Buffer Structure

To allow easier data setup and handling, an additional data buffering mechanism can be optionally supported. The data buffer is based on the first-in-first-out principle (FIFO) that ensures that the sequence of transferred data words is respected.

If a FIFO buffer structure is used, the data handling scheme (data with associated control information) is similar to the one without FIFO. The additional FIFO buffer can be

Universal Serial Interface Channel (USIC)

independently enabled/disabled for transmission and reception (e.g. if data FIFO buffers are available for a specific USIC channel, it is possible to configure the transmit data path without and the receive data path with FIFO buffering).

The transmit FIFO buffer is addressed by using 32 consecutive address locations for INx instead of TBUFx (x=00-31) regardless of the FIFO depth. The 32 addresses are used to store the 5-bit TCI (together with the written data) associated with each FIFO entry.

The receive FIFO can be read out at two independent addresses, OUTR and OUTDR instead of RBUF and RBUFD. A read from the OUTR location triggers the next data packet to be available for the next read (general FIFO mechanism). In order to allow non-intrusive debugging (without risk of data loss), a second address location (OUTDR) has been introduced. A read at this location delivers the same value as OUTR, but without modifying the FIFO contents.

The transmit FIFO also has the capability to bypass the data stream and to load bypass data to TBUF. This can be used to generate high-priority messages or to send an emergency message if the transmit FIFO runs empty. The transmission control of the FIFO buffer can also use the transfer trigger and transfer gating scheme of the transmission logic for data validation (e.g. to trigger data transfers by events).

Note: The available size of a FIFO data buffer for a USIC channel depends on the specific device. Please refer to the implementation chapter for details about available FIFO buffer capability.

Universal Serial Interface Channel (USIC)

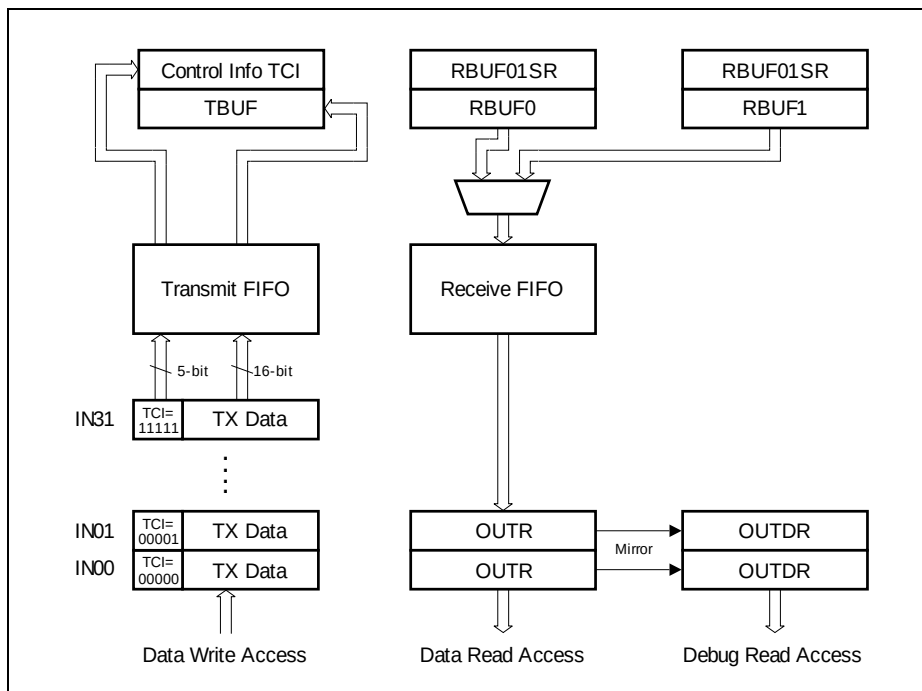


Figure 15-5 Data Access Structure with FIFO

15.2.2 Operating the USIC Communication Channel

This section describes how to operate a USIC communication channel, including protocol control and status, mode control and interrupt handling. The following aspects have to be taken into account:

- Enable the USIC module for operation and configure the behavior for the different device operation modes (see [Page 15-16](#)).
- Configure the pinning (refer to description in the corresponding protocol section).
- Configure the data structure (shift direction, word length, frame length, polarity, etc.).
- Configure the data buffer structure of the optional FIFO buffer area. A FIFO buffer can only be enabled if the related bit in register CCFG is set.
- Select a protocol by CCR.MODE. A protocol can only be selected if the related bit in register CCFG is set.

15.2.2.1 Protocol Control and Status

The protocol-related control and status information are located in the protocol control register PCR and in the protocol status register PSR. These registers are shared between the available protocols. As a consequence, the meaning of the bit positions in these registers is different within the protocols.

Use of PCR Bits

The signification of the bits in register PCR is indicated by the protocol-related alias names for the different protocols.

- PCR for the ASC protocol (see [Page 15-66](#))
- PCR for the SSC protocol (see [Page 15-98](#))
- PCR for the IIC protocol (see [Page 15-129](#))
- PCR for the IIS protocol (see [Page 15-147](#))

Use of PSR Flags

The signification of the flags in register PSR is indicated by the protocol-related alias names for the different protocols.

- PSR flags for the ASC protocol (see [Page 15-69](#))
- PSR flags for the SSC protocol (see [Page 15-102](#))
- PSR flags for the IIC protocol (see [Page 15-132](#))
- PSR flags for the IIS protocol (see [Page 15-150](#))

15.2.2.2 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 a communication channel can be programmed for each of the device operating modes (normal operation, suspend mode). Therefore, each communication channel has an associated kernel state configuration register KSCFG defining its behavior in the following operating modes:

- **Normal operation:**
This operating mode is the default operating mode when no suspend request is pending. The module clock is not switched off and the USIC registers can be read or written. The channel behavior is defined by KSCFG.NOMCFG.
- **Suspend mode:**
This operating mode is requested when a suspend request is pending in the device. The module clock is not switched off and the USIC registers can be read or written. The channel behavior is defined by KSCFG.SUMCFG.

The four kernel modes defined by the register KSCFG are shown in [Table 15-4](#).

Table 15-4 USIC Communication Channel Behavior

Kernel Mode	Channel Behavior	KSCFG. NOMCFG
Run mode 0	Channel operation as specified, no impact on data transfer	00 _B
Run mode 1		01 _B
Stop mode 0	Explicit stop condition as described in the protocol chapters	10 _B
Stop mode 1		11 _B

Generally, bit field KSCFG.NOMCFG should be configured for run mode 0 as default setting for standard operation. If a communication channel should not react to a suspend request (and to continue its operation as in normal mode), bit field KSCFG.SUMCFG has to be configured with the same value as KSCFG.NOMCFG. If the communication channel 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 have to be written to KSCFG.SUMCFG.

The stop conditions are defined for the selected protocol (see mode control description in the protocol section).

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

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from stop mode 0 to stop mode 1 (or vice versa) for the same communication channel.

Note: In XMC1200, bit field KSCFG.SUMCFG is reset to its default value by any reset. If the suspend function is required during debugging, it is recommended that it is enabled in the user initialization code. Before programming the bit field, the module clock has to be enabled and special care needs to be taken while enabling the module clock as described in the CCU (Clock Gating Control) section of the SCU chapter.

15.2.2.3 General Channel Events and Interrupts

The general event and interrupt structure is shown in [Figure 15-6](#). If a defined condition is met, an event is detected and an event indication flag becomes automatically set. The flag stays set until it is cleared by software. If enabled, an interrupt can be generated if an event is detected. The actual status of the event indication flag has no influence on the interrupt generation. As a consequence, the event indication flag does not need to be cleared to generate further interrupts.

Additionally, the service request output SRx of the USIC channel that becomes activated in case of an event condition can be selected by an interrupt node pointer. This structure allows to assign events to interrupts, e.g. depending on the application, several events can share the same interrupt routine (several events activate the same SRx output) or can be handled individually (only one event activates one SRx output).

The SRx outputs are connected to interrupt control registers to handle the CPU reaction to the service requests. This assignment is described in the implementation section on [Page 15-153](#).

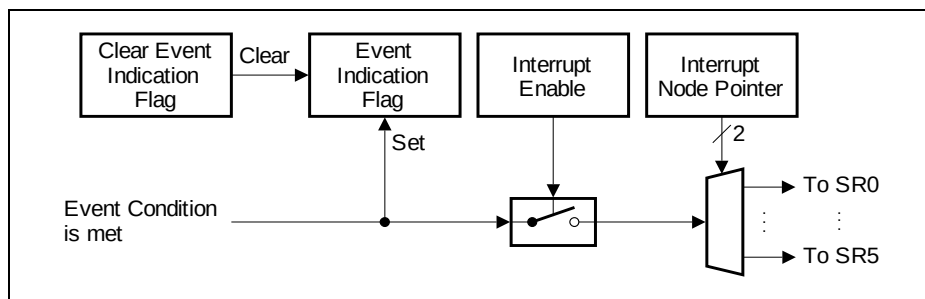


Figure 15-6 General Event and Interrupt Structure

15.2.2.4 Data Transfer Events and Interrupts

The data transfer events are based on the transmission or reception of a data word. The related indication flags are located in register PSR. All events can be individually enabled for interrupt generation.

- **Receive event to indicate that a data word has been received:**
If a new received word becomes available in the receive buffer RBUF0 or RBUF1, either a receive event or an alternative receive event occurs.
The receive event occurs if bit RBUFSR.PERR = 0. It is indicated by flag PSR.RIF and, if enabled, leads to receive interrupt.
- **Receiver start event to indicate that a data word reception has started:**
When the receive clock edge that shifts in the first bit of a new data word is detected and reception is enabled, a receiver start event occurs. It is indicated by flag PSR.RSIF and, if enabled, leads to transmit buffer interrupt.
In full duplex mode, this event follows half a shift clock cycle after the transmit buffer event and indicates when the shift control settings are internally “frozen” for the current data word reception and a new setting can be programmed.
In SSC and IIS mode, the transmit data valid flag TCSR.TDV is cleared in single shot mode with the receiver start event.
- **Alternative receive event to indicate that a specific data word has been received:**
If a new received word becomes available in the receive buffer RBUF0 or RBUF1, either a receive event or an alternative receive event occurs.
The alternative receive event occurs if bit RBUFSR.PERR = 1. It is indicated by flag PSR.AIF and, if enabled, leads to alternative receive interrupt.
Depending on the selected protocol, bit RBUFSR.PERR is set to indicate a parity error in ASC mode, the reception of the first byte of a new frame in IIC mode, and the WA information about right/left channel in IIS mode. In SSC mode, it is used as indication if the received word is the first data word, and is set if first and reset if not.
- **Transmit shift event to indicate that a data word has been transmitted:**
A transmit shift event occurs with the last shift clock edge of a data word. It is indicated by flag PSR.TSIF and, if enabled, leads to transmit shift interrupt.
- **Transmit buffer event to indicate that a data word transmission has been started:**
When a data word from the transmit buffer TBUF has been loaded to the shift register and a new data word can be written to TBUF, a transmit buffer event occurs. This happens with the transmit clock edge that shifts out the first bit of a new data word and transmission is enabled. It is indicated by flag PSR.TBIF and, if enabled, leads to transmit buffer interrupt.
This event also indicates when the shift control settings (word length, shift direction, etc.) are internally “frozen” for the current data word transmission.
In ASC and IIC mode, the transmit data valid flag TCSR.TDV is cleared in single shot mode with the transmit buffer event.
- **Data lost event to indicate a loss of the oldest received data word:**
If the data word available in register RBUF (oldest data word from RBUF0 or RBUF1)

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has not been read out before it becomes overwritten with new incoming data, this event occurs. It is indicated by flag PSR.DLIF and, if enabled, leads to a protocol interrupt.

Table 15-5 shows the registers, bits and bit fields indicating the data transfer events and controlling the interrupts of a USIC channel.

Table 15-5 Data Transfer Events and Interrupt Handling

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Standard receive event	PSR.RIF	PSCR.CRIF	CCR.RIEN	INPR.RINP
Receive start event	PSR.RSIF	PSCR.CRSIF	CCR.RSIEN	INPR.TBINP
Alternative receive event	PSR.AIF	PSCR.CAIF	CCR.AIEN	INPR.AINP
Transmit shift event	PSR.TSIF	PSCR.CTSIF	CCR.TSIEN	INPR.TSINP
Transmit buffer event	PSR.TBIF	PSCR.CTBIF	CCR.TBIEN	INPR.TBINP
Data lost event	PSR.DLIF	PSCR.CDLIF	CCR.DLIEN	INPR.PINP

Figure 15-7 shows the two transmit events and interrupts.

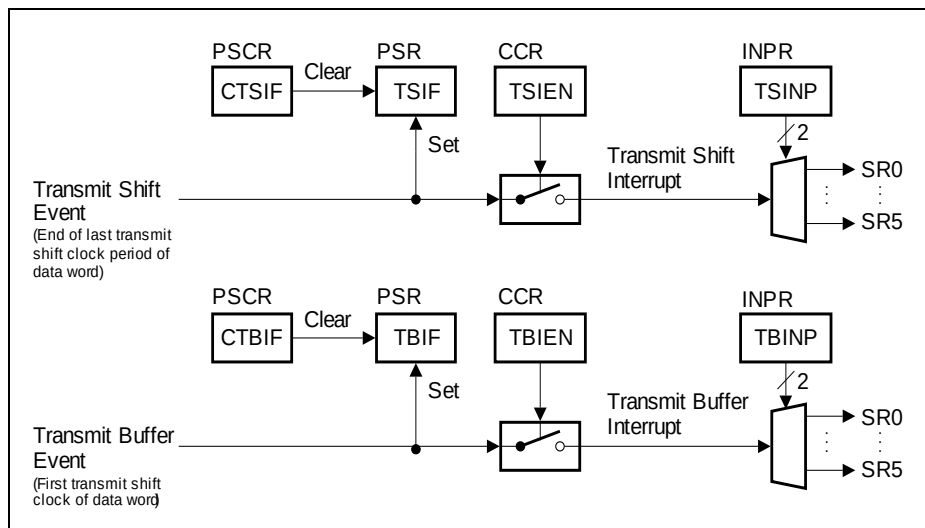


Figure 15-7 Transmit Events and Interrupts

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Figure 15-8 shows the receive events and interrupts.

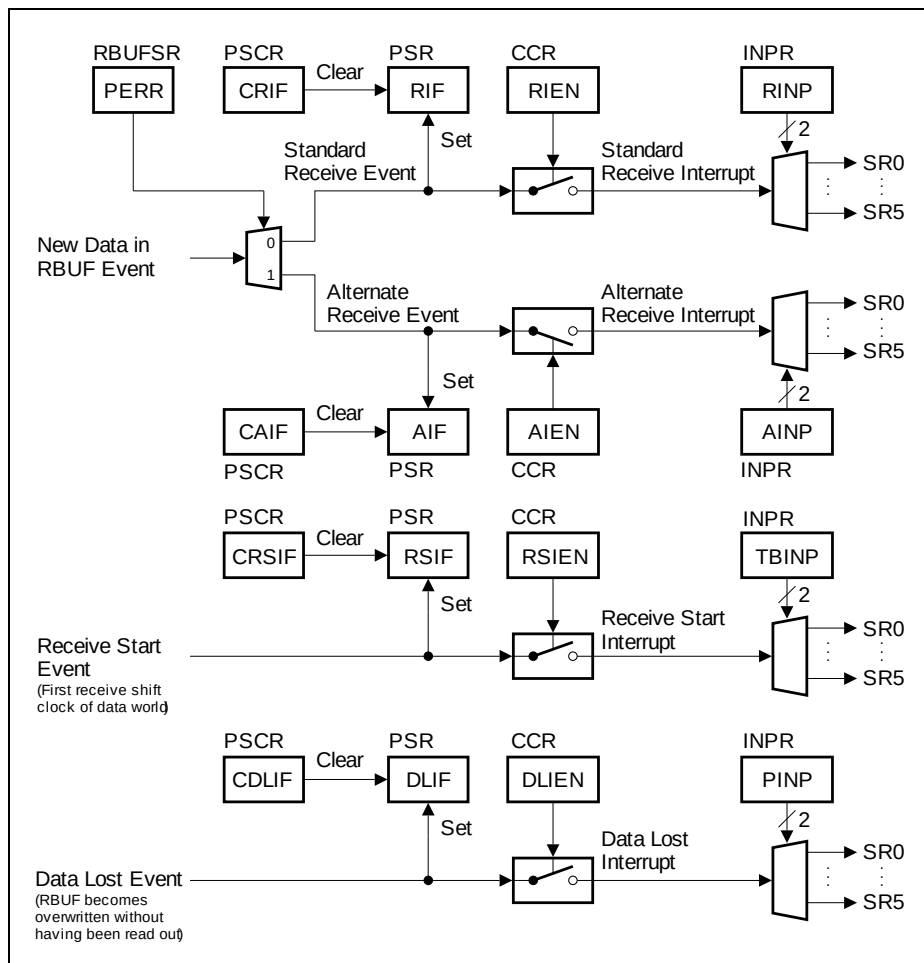


Figure 15-8 Receive Events and Interrupts

15.2.2.5 Baud Rate Generator Event and Interrupt

The baud rate generator event is based on the capture mode timer reaching its maximum value. It is indicated by flag PSR.BRGIF and, if enabled, leads to a protocol interrupt.

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Table 15-6 shows the registers, bits and bit fields indicating the baud rate generator event and controlling the interrupt of a USIC channel.

Table 15-6 Baud Rate Generator Event and Interrupt Handling

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Baud rate generator event	PSR. BRGIF	PSCR. CBRGIF	CCR. BRGIEN	INPR.PINP

Figure 15-9 shows the baud rate generator event and interrupt.

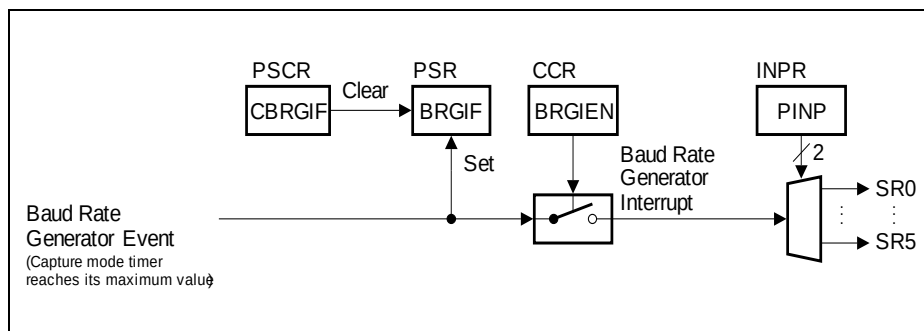


Figure 15-9 Baud Rate Generator Event and Interrupt

15.2.2.6 Protocol-specific Events and Interrupts

These events are related to protocol-specific actions that are described in the corresponding protocol chapters. The related indication flags are located in register PSR. All events can be individually enabled for the generation of the common protocol interrupt.

- Protocol-specific events in ASC mode:
Synchronization break, data collision on the transmit line, receiver noise, format error in stop bits, receiver frame finished, transmitter frame finished
- Protocol-specific events in SSC mode:
MSLS event (start-end of frame in master mode), DX2T event (start/end of frame in slave mode), both based on slave select signals, parity error
- Protocol-specific events in IIC mode:
Wrong transmit code (error in frame sequence), start condition received, repeated start condition received, stop condition received, non-acknowledge received, arbitration lost, slave read request, other general errors
- Protocol-specific events in IIS mode:
DX2T event (change on WA line), WA falling edge or rising edge detected, WA generation finished

Table 15-7 Protocol-specific Events and Interrupt Handling

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Protocol-specific events in ASC mode	PSR.ST[8:2]	PSCR.CST[8:2]	PCR.CTR[7:3]	INPR.PINP
Protocol-specific events in SSC mode	PSR.ST[3:2]	PSCR.CST[3:2]	PCR.CTR[15:14]	INPR.PINP
Protocol-specific events in IIC mode	PSR.ST[8:1]	PSCR.CST[8:1]	PCR.CTR[24:18]	INPR.PINP
Protocol-specific events in IIS mode	PSR.ST[6:3]	PSCR.CST[6:3]	PCR.CTR[6:4], PCR.CTR[15]	INPR.PINP

15.2.3 Operating the Input Stages

All input stages offer the same feature set. They are used for all protocols, because the signal conditioning can be adapted in a very flexible way and the digital filters can be switched on and off separately.

15.2.3.1 General Input Structure

There are generally two types of input stages, one for the data input stages DX0, DX[5:3] and the other for non-data input stages DX[2:1], as shown in [Figure 15-10](#) and [Figure 15-11](#). The difference is that for the data input stages, the input signal can be additionally selected from the port signal HWINn if hardware port control is enabled through CCR.HPCEN bit. All other enable/disable functions and selections are controlled independently for each input stage by bits in the registers DXnCR.

The desired input signal can be selected among the input lines DXnA to DXnG and a permanent 1-level by programming bit field DSEL (for the data input stages, hardware port control must be disabled for DSEL to take effect). Please refer to the interconnects section ([Section 15.12](#)) for the device-specific input signal assignment. Bit DPOL allows a polarity inversion of the selected input signal to adapt the input signal polarity to the internal polarity of the data shift unit and the protocol state machine. For some protocols, the input signals can be directly forwarded to the data shift unit for the data transfers (DSEN = 0, INSW = 1) without any further signal conditioning. In this case, the data path does not contain any delay due to synchronization or filtering.

In the case of noise on the input signals, there is the possibility to synchronize the input signal (signal DXnS is synchronized to f_{PERIPH}) and additionally to enable a digital noise filter in the signal path. The synchronized input signal (and optionally filtered if DFEN = 1) is taken into account by DSEN = 1. Please note that the synchronization leads to a delay in the signal path of 2-3 times the period of f_{PERIPH} .

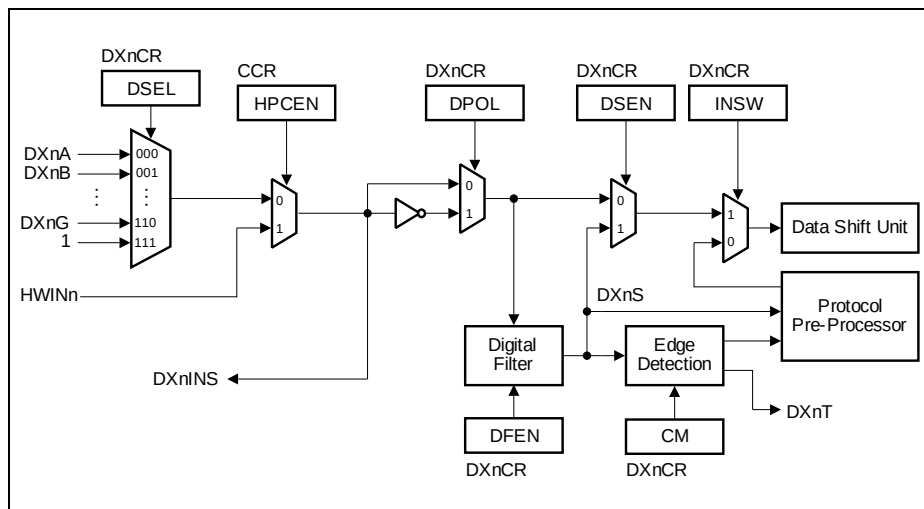


Figure 15-10 Input Conditioning for DX0 and DX[5:3]

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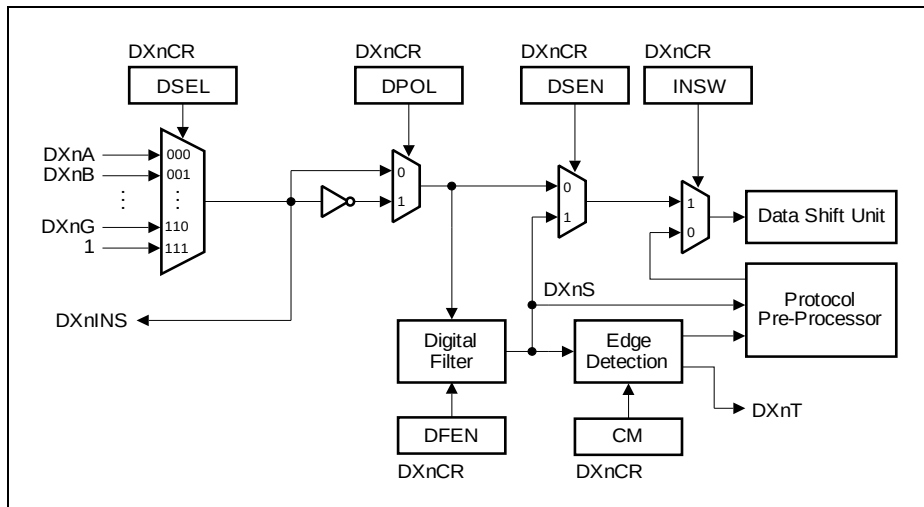


Figure 15-11 Input Conditioning for DX[2:1]

If the input signals are handled by a protocol pre-processor, the data shift unit is directly connected to the protocol pre-processor by $INSW = 0$. The protocol pre-processor is connected to the synchronized input signal $DXnS$ and, depending on the selected protocol, also evaluates the edges.

To support delay compensation in SSC and IIS protocols, the $DX1$ input stage additionally allows the receive shift clock to be controlled independently from the transmit shift clock through the bit $DCEN$. When $DCEN = 0$, the shift clock source is selected by $INSW$ and is the same for both receive and transmit. When $DCEN = 1$, the receive shift clock is derived from the selected input line as shown in [Figure 15-12](#).

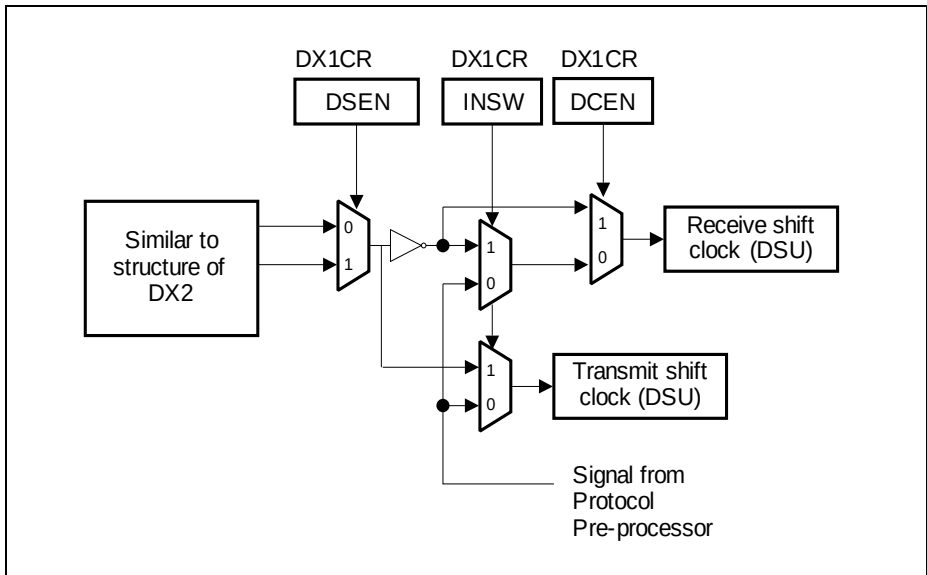


Figure 15-12 Delay Compensation Enable in DX1

15.2.3.2 Digital Filter

The digital filter can be enabled to reduce noise on the input signals. Before being filtered, the input signal becomes synchronized to f_{PERIPH} . If the filter is disabled, signal DXnS corresponds to the synchronized input signal. If the filter is enabled, pulses shorter than one filter sampling period are suppressed in signal DXnS. After an edge of the synchronized input signal, signal DXnS changes to the new value if two consecutive samples of the new value have been detected.

In order to adapt the filter sampling period to different applications, it can be programmed. The first possibility is the system frequency f_{PERIPH} . Longer pulses can be suppressed if the fractional divider output frequency f_{FD} is selected. This frequency is programmable in a wide range and can also be used to determine the baud rate of the data transfers.

In addition to the synchronization delay of 2-3 periods of f_{PERIPH} , an enabled filter adds a delay of up to two filter sampling periods between the selected input and signal DXnS.

15.2.3.3 Edge Detection

The synchronized (and optionally filtered) signal DXnS can be used as input to the data shift unit and is also an input to the selected protocol pre-processor. If the protocol pre-processor does not use the DXnS signal for protocol-specific handling, DXnS can be

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used for other tasks, e.g. to control data transmissions in master mode (a data word can be tagged valid for transmission, see chapter about data buffering).

A programmable edge detection indicates that the desired event has occurred by activating the trigger signal DXnT (introducing a delay of one period of f_{PERIPH} before a reaction to this event can take place).

15.2.3.4 Selected Input Monitoring

The selected input signal of each input stage has been made available with the signals DXnINS. These signals can be used in the system to trigger other actions, e.g. to generate interrupts.

15.2.3.5 Loop Back Mode

The USIC transmitter output signals can be connected to the corresponding receiver inputs of the same communication channel in loop back mode. Therefore, the input "G" of the input stages that are needed for the selected protocol have to be selected. In this case, drivers for ASC, SSC, and IIS can be evaluated on-chip without the connections to port pins. Data transferred by the transmitter can be received by the receiver as if it would have been sent by another communication partner.

15.2.4 Operating the Baud Rate Generator

The following blocks can be configured to operate the baud rate generator, see also [Figure 15-2](#).

15.2.4.1 Fractional Divider

The fractional divider generates its output frequency f_{FD} by either dividing the input frequency f_{PERIPH} by an integer factor n or by multiplication of $n/1024$. It has two operating modes:

- Normal divider mode (FDR.DM = 01_B):
In this mode, the output frequency f_{FD} is derived from the input clock f_{PERIPH} by an integer division by a value between 1 and 1024. The division is based on a counter FDR.RESULT that is incremented by 1 with f_{PERIPH} . After reaching the value 3FF_H, the counter is loaded with FDR.STEP and then continues counting. In order to achieve $f_{\text{FD}} = f_{\text{PERIPH}}$, the value of STEP has to be programmed with 3FF_H. The output frequency in normal divider mode is defined by the equation:

(15.1)

$$f_{\text{FD}} = f_{\text{PERIPH}} \times \frac{1}{n} \quad \text{with } n = 1024 - \text{STEP}$$

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- Fractional divider mode ($FDR.DM = 10_B$):

In this mode, the output frequency f_{FD} is derived from the input clock f_{PERIPH} by a fractional multiplication of $n/1024$ for a value of n between 0 and 1023. In general, the fractional divider mode allows to program the average output clock frequency with a finer granularity than in normal divider mode. Please note that in fractional divider mode f_{FD} can have a maximum period jitter of one f_{PERIPH} period. This jitter is not accumulated over several cycles.

The frequency f_{FD} is generated by an addition of $FDR.STEP$ to $FDR.RESULT$ with f_{PERIPH} . The frequency f_{FD} is based on the overflow of the addition result over $3FF_H$. The output frequency in fractional divider mode is defined by the equation:

(15.2)

$$f_{FD} = f_{PERIPH} \times \frac{n}{1024} \quad \text{with } n = STEP$$

The output frequency f_{FD} of the fractional divider is selected for baud rate generation by $BRG.CLKSEL = 00_B$.

15.2.4.2 External Frequency Input

The baud rate can be generated referring to an external frequency input (instead of to f_{PERIPH}) if in the selected protocol the input stage DX1 is not needed ($DX1CTR.INSW = 0$). In this case, an external frequency input signal at the DX1 input stage can be synchronized and sampled with the system frequency f_{PERIPH} . It can be optionally filtered by the digital filter in the input stage. This feature allows data transfers with frequencies that can not be generated by the device itself, e.g. for specific audio frequencies.

If $BRG.CLKSEL = 10_B$, the trigger signal DX1T determines f_{DX1} . In this mode, either the rising edge, the falling edge, or both edges of the input signal can be used for baud rate generation, depending on the configuration of the DX1T trigger event by bit field $DX1CTR.CM$. The signal MCLK toggles with each trigger event of DX1T.

If $BRG.CLKSEL = 11_B$, the rising edges of the input signal can be used for baud rate generation. The signal MCLK represents the synchronized input signal DX1S.

Both, the high time and the low time of external input signal must each have a length of minimum 2 periods of f_{PERIPH} to be used for baud rate generation.

15.2.4.3 Divider Mode Counter

The divider mode counter is used for an integer division delivering the output frequency f_{PDIV} . Additionally, two divider stages with a fixed division by 2 provide the output signals MCLK and SCLK with 50% duty cycle. If the fractional divider mode is used, the maximum fractional jitter of 1 period of f_{PERIPH} can also appear in these signals. The output frequencies of this divider is controlled by register BRG.

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In order to define a frequency ratio between the master clock MCLK and the shift clock SCLK, the divider stage for MCLK is located in front of the divider by PDIV+1, whereas the divider stage for SCLK is located at the output of this divider.

$$f_{\text{MCLK}} = \frac{f_{\text{PIN}}}{2} \quad (15.3)$$

$$f_{\text{SCLK}} = \frac{f_{\text{PDIV}}}{2} \quad (15.4)$$

In the case that the master clock is used as reference for external devices (e.g. for IIS components) and a fixed phase relation to SCLK and other timing signals is required, it is recommended to use the MCLK signal as input for the PDIV divider. If the MCLK signal is not used or a fixed phase relation is not necessary, the faster frequency f_{PIN} can be selected as input frequency.

$$\begin{aligned} f_{\text{PDIV}} &= f_{\text{PIN}} \times \frac{1}{\text{PDIV} + 1} & \text{if } \text{PPPEN} = 0 \\ f_{\text{PDIV}} &= f_{\text{MCLK}} \times \frac{1}{\text{PDIV} + 1} & \text{if } \text{PPPEN} = 1 \end{aligned} \quad (15.5)$$

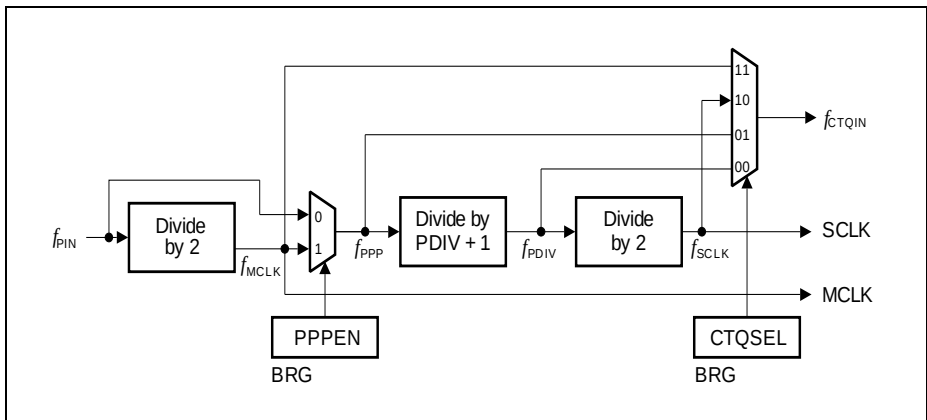


Figure 15-13 Divider Mode Counter

15.2.4.4 Capture Mode Timer

The capture mode timer is used for time interval measurement and is enabled by $\text{BRG.TMEN} = 1$. The timer works independently from the divider mode counter. Therefore, any serial data reception or transmission can continue while the timer is performing timing measurements. The timer counts f_{PPP} periods and stops counting

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when it reaches its maximum value. Additionally, a baud rate generator interrupt event is generated (bit PSR.BRGIF becomes set).

If an event is indicated by DX0T or DX1T, the actual timer value is captured into bit field CMTR.CTV and the timer restarts from 0. Additionally, a transmit shift interrupt event is generated (bit PSR.TSIF becomes set).

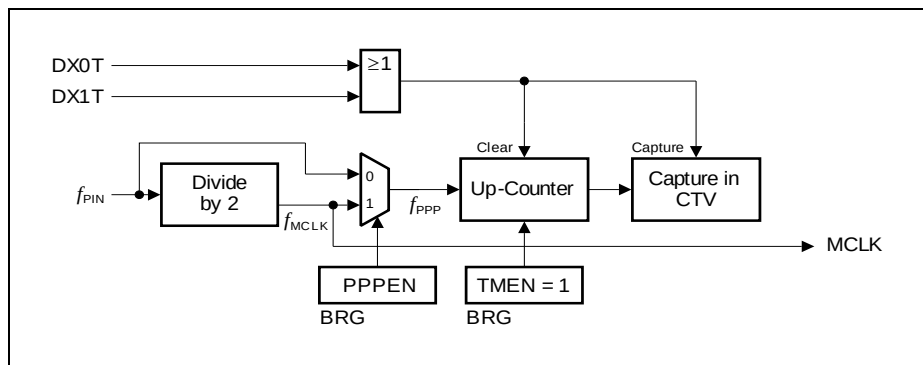


Figure 15-14 Protocol-Related Counter (Capture Mode)

The capture mode timer can be used to measure the baud rate in slave mode before starting or during data transfers, e.g. to measure the time between two edges of a data signal (by DX0T) or of a shift clock signal (by DX1T). The conditions to activate the DXnT trigger signals can be configured in each input stage.

15.2.4.5 Time Quanta Counter

The time quanta counter CTQ associated to the protocol pre-processor allows to generate time intervals for protocol-specific purposes. The length of a time quantum t_q is given by the selected input frequency f_{CTQIN} and the programmed pre-divider value.

The meaning of the time quanta depend on the selected protocol, please refer to the corresponding chapters for more protocol-specific information.

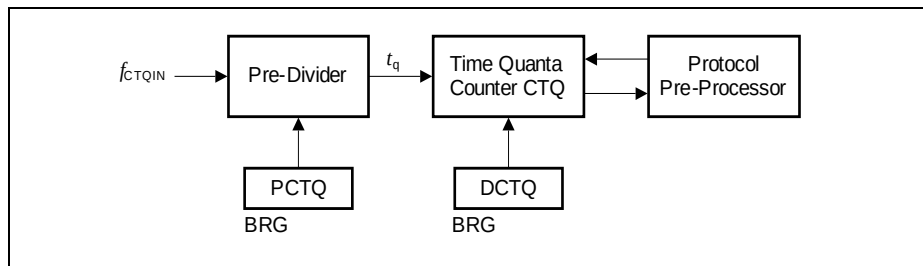


Figure 15-15 Time Quanta Counter

15.2.4.6 Master and Shift Clock Output Configuration

The master clock output signal MCLKOUT available at the corresponding output pin can be configured in polarity. The MCLK signal can be generated for each protocol in order to provide a kind of higher frequency time base compared to the shift clock.

The configuration mechanism of the master clock output signal MCLKOUT ensures that no shortened pulses can occur. Each MCLK period consists of two phases, an active phase, followed by a passive phase. The polarity of the MCLKOUT signal during the active phase is defined by the inverted level of bit BRG.MCLKCFG, evaluated at the start of the active phase. The polarity of the MCLKOUT signal during the passive phase is defined by bit BRG.MCLKCFG, evaluated at the start of the passive phase. If bit BRG.MCLKCFG is programmed with another value, the change is taken into account with the next change between the phases. This mechanism ensures that no shorter pulses than the length of a phase occur at the MCLKOUT output. In the example shown in [Figure 15-16](#), the value of BRG.MCLKCFG is changed from 0 to 1 during the passive phase of MCLK period 2.

The generation of the MCLKOUT signal is enabled/disabled by the protocol pre-processor, based on bit PCR.MCLK. After this bit has become set, signal MCLKOUT is generated with the next active phase of the MCLK period. If PCR.MCLK = 0 (MCLKOUT generation disabled), the level for the passive phase is also applied for active phase.

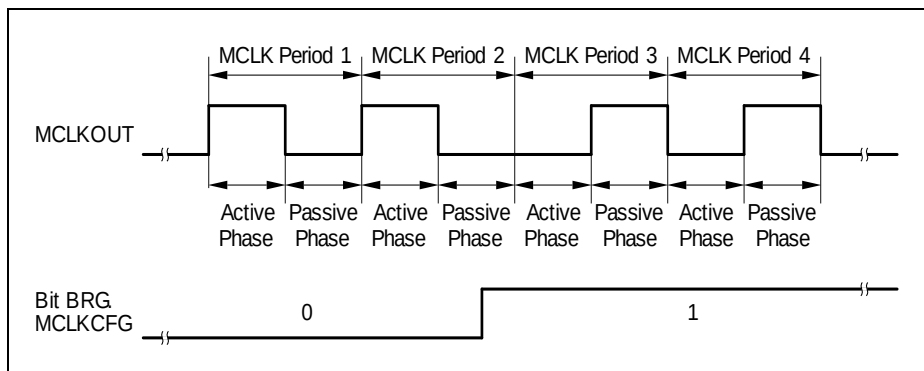


Figure 15-16 Master Clock Output Configuration

The shift clock output signal SCLKOUT available at the corresponding output pin can be configured in polarity and additionally, a delay of one period of f_{PDIV} (= half SCLK period) can be introduced. The delay allows to adapt the order of the shift clock edges to the application requirements. If the delay is used, it has to be taken into account for the calculation of the signal propagation times and loop delays.

The mechanism for the polarity control of the SCLKOUT signal is similar to the one for MCLKOUT, but based on bit field BRG.SCLKCFG. The generation of the SCLKOUT

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signal is enabled/disabled by the protocol pre-processor. Depending on the selected protocol, the protocol pre-processor can control the generation of the SCLKOUT signal independently of the divider chain, e.g. for protocols without the need of a shift clock available at a pin, the SCLKOUT generation is disabled.

15.2.5 Operating the Transmit Data Path

The transmit data path is based on 16-bit wide transmit shift registers (TSR and TSR[3:0]) and a transmit buffer TBUF. The data transfer parameters like data word length, data frame length, or the shift direction are controlled commonly for transmission and reception by the shift control register SCTR. The transmit control and status register TCSR controls the transmit data handling and monitors the transmit status.

A change of the value of the data shift output signal DOUTx only happens at the corresponding edge of the shift clock input signal. The level of the last data bit of a data word/frame is held constant at DOUTx until the next data word begins with the next corresponding edge of the shift clock.

15.2.5.1 Transmit Buffering

The transmit shift registers can not be directly accessed by software, because they are automatically updated with the value stored in the transmit buffer TBUF if a currently transmitted data word is finished and new data is valid for transmission. Data words can be loaded directly into TBUF by writing to one of the transmit buffer input locations TBUFx (see [Page 15-33](#)) or, optionally, by a FIFO buffer stage (see [Page 15-39](#)).

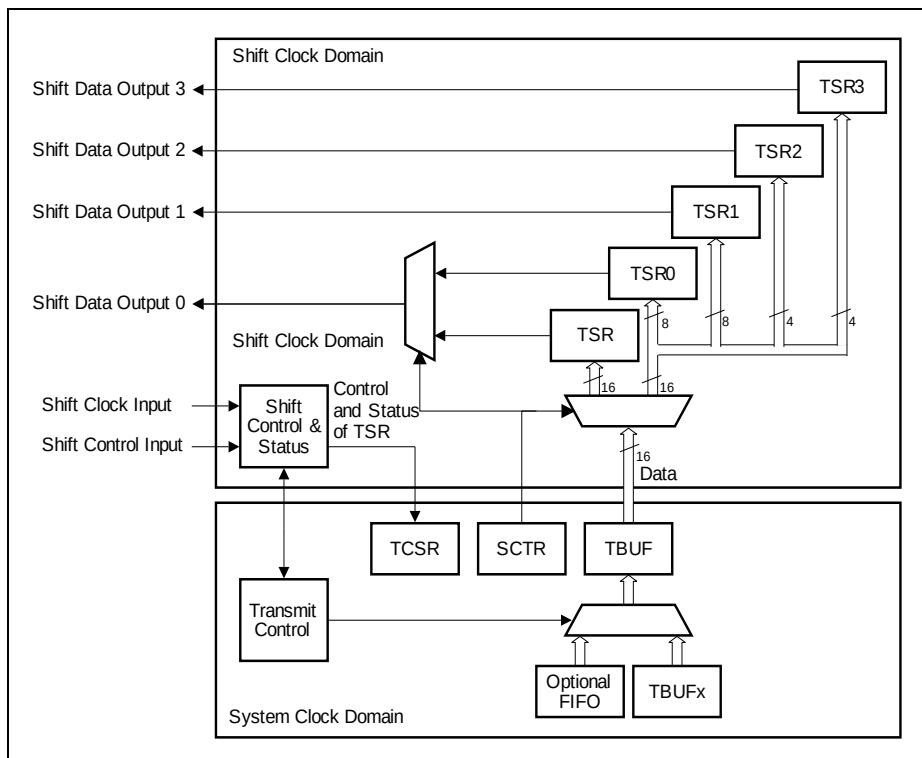


Figure 15-17 Transmit Data Path

15.2.5.2 Transmit Data Shift Mode

The transmit shift data can be selected to be shifted out one, two or four bits at a time through the corresponding number of output lines. This option allows the USIC to support protocols such as the Dual- and Quad-SSC. The selection is done through the bit field DSM in the shift control register SCTR.

Note: The bit field SCTR.DSM controls the data shift mode for both the transmit and receive paths to allow the transmission and reception of data through one to four data lines.

For the shift mode with two or four parallel data outputs, the data word and frame length must be in multiples of two or four respectively. The number of data shifts required to output a specific data word or data frame length is thus reduced by the factor of the number of parallel data output lines. For example, to transmit a 16-bit data word through four output lines, only four shifts are required.

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Depending on the shift mode, different transmit shift registers with different bit composition are used as shown in [Table 15-8](#). Note that the 'n' in the table denotes the shift number less one, i.e. for the first data shift $n = 0$, the second data shift $n = 1$ and continues until the total number of shifts less one is reached.

For all transmit shift registers, whether the first bit shifted out is the MSB or LSB depends on the setting of SCTR.SDIR.

Table 15-8 Transmit Shift Register Composition

Transmit Shift Registers	Single Data Output (SCTR.DSM = 00 _B)	Two Data Outputs (SCTR.DSM = 10 _B)	Four Data Outputs (SCTR.DSM = 11 _B)
TSR	All data bits	Not used	Not used
TSR0	Not used	Bit $n*2$	Bit $n*4$
TSR1	Not used	Bit $n*2 + 1$	Bit $n*4 + 1$
TSR2	Not used	Not used	Bit $n*4 + 2$
TSR3	Not used	Not used	Bit $n*4 + 3$

15.2.5.3 Transmit Control Information

The transmit control information TCI is a 5-bit value derived from the address x of the written TBUF x or IN x input location. For example, writing to TBUF31 generates a TCI of 11111_B.

The TCI can be used as an additional control parameter for data transfers to dynamically change the data word length, the data frame length, or other protocol-specific functions (for more details about this topic, please refer to the corresponding protocol chapters). The way how the TCI is used in different applications can be programmed by the bits WLEMD, FLEMD, SELMD, WAMD and HPCMD in register TCSR. Please note that not all possible settings lead to useful system behavior.

- **Word length control:**
If TCSR.WLEMD = 1, bit field SCTR.WLE is updated with TCI[3:0] if a transmit buffer input location TBUF x is written. This function can be used in all protocols to dynamically change the data word length between 1 and 16 data bits per data word. Additionally, bit TCSR.EOF is updated with TCI[4]. This function can be used in SSC master mode to control the slave select generation to finish data frames. It is recommended to program TCSR.FLEMD = TCSR.SELMD = TCSR.WAMD = TCSR.HPCMD = 0.
- **Frame length control:**
If TCSR.FLEMD = 1, bit field SCTR.FLE[4:0] is updated with TCI[4:0] and SCTR.FLE[5] becomes 0 if a transmit buffer input location TBUF x is written. This function can be used in all protocols to dynamically change the data frame length

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between 1 and 32 data bits per data frame. It is recommended to program $TCSR.SELMD = TCSR.WLEMD = TCSR.WAMD = TCSR.HPCMD = 0$.

- **Select output control:**
If $TCSR.SELMD = 1$, bit field $PCR.CTR[20:16]$ is updated with $TCI[4:0]$ and $PCR.CTR[23:21]$ becomes 0 if a transmit buffer input location $TBUFx$ is written. This function can be used in SSC master mode to define the targeted slave device(s). It is recommended to program $TCSR.WLEMD = TCSR.FLEMD = TCSR.WAMD = TCSR.HPCMD = 0$.
- **Word address control:**
If $TCSR.WAMD = 1$, bit $TCSR.WA$ is updated with $TCI[4]$ if a transmit buffer input location $TBUFx$ is written. This function can be used in IIS mode to define if the data word is transmitted on the right or the left channel. It is recommended to program $TCSR.WLEMD = TCSR.FLEMD = TCSR.SELMD = TCSR.HPCMD = 0$.
- **Hardware Port control:**
If $TCSR.HPCMD = 1$, bit field $SCTR.DSM$ is updated with $TCI[1:0]$ if a transmit buffer input location $TBUFx$ is written. This function can be used in SSC protocols to dynamically change the number of data input and output lines to set up for standard, dual and quad SSC formats.
Additionally, bit $TCSR.HPCDIR$ is updated with $TCI[2]$. This function can be used in SSC protocols to control the pin(s) direction when the hardware port control function is enabled through $CCR.HPCEN = 1$. It is recommended to program $TCSR.FLEMD = TCSR.WLEMD = TCSR.SELMD = TCSR.WAMD = 0$.

15.2.5.4 Transmit Data Validation

The data word in the transmit buffer $TBUF$ can be tagged valid or invalid for transmission by bit $TCSR.TDV$ (transmit data valid). A combination of data flow related and event related criteria define whether the data word is considered valid for transmission. A data validation logic checks the start conditions for each data word. Depending on the result of the check, the transmit shift register is loaded with different values, according to the following rules:

- If a USIC channel is the communication master (it defines the start of each data word transfer), a data word transfer can only be started with valid data in the transmit buffer $TBUF$. In this case, the transmit shift register is loaded with the content of $TBUF$, that is not changed due to this action.
- If a USIC channel is a communication slave (it can not define the start itself, but has to react), a data word transfer requested by the communication master has to be started independently of the status of the data word in $TBUF$. If a data word transfer is requested and started by the master, the transmit shift register is loaded at the first corresponding shift clock edge either with the data word in $TBUF$ (if it is valid for transmission) or with the level defined by bit $SCTR.PDL$ (if the content of $TBUF$ has not been valid at the transmission start). In both cases, the content of $TBUF$ is not changed.

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The control and status bits for the data validation are located in register TCSR. The data validation is based on the logic blocks shown in **Figure 15-18**.

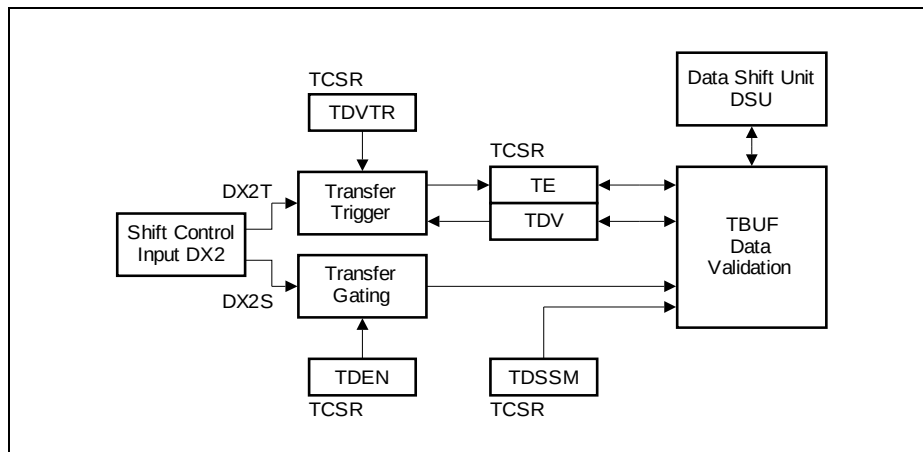


Figure 15-18 Transmit Data Validation

- A transfer gating logic enables or disables the data word transfer from TBUF under software or under hardware control. If the input stage DX2 is not needed for data shifting, signal DX2S can be used for gating purposes. The transfer gating logic is controlled by bit field TCSR.TDEN.
- A transfer trigger logic supports data word transfers related to events, e.g. timer based or related to an input pin. If the input stage DX2 is not needed for data shifting, signal DX2T can be used for trigger purposes. The transfer trigger logic is controlled by bit TCSR.TDVTR and the occurrence of a trigger event is indicated by bit TCSR.TE. For example, this can be used for triggering the data transfer upon receiving the Clear to Send (CTS) signal at DX2 in the RS-232 protocol.
- A data validation logic combining the inputs from the gating logic, the triggering logic and DSU signals. A transmission of the data word located in TBUF can only be started if the gating enables the start, bit TCSR.TDV = 1, and bit TCSR.TE = 1. The content of the transmit buffer TBUF should not be overwritten with new data while it is valid for transmission and a new transmission can start. If the content of TBUF has to be changed, it is recommended to clear bit TCSR.TDV by writing $\text{FMR.MTDV} = 10_{\text{B}}$ before updating the data. Bit TCSR.TDV becomes automatically set when TBUF is updated with new data. Another possibility are the interrupts TBI (for ASC and IIC) or RSI (for SSC and IIS) indicating that a transmission has started. While a transmission is in progress, TBUF can be loaded with new data. In this case the user has to take care that an update of the TBUF content takes place before a new transmission starts.

With this structure, the following data transfer functionality can be achieved:

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- If bit TCSR.TDSSM = 0, the content of the transmit buffer TBUF is always considered as valid for transmission. The transfer trigger mechanism can be used to start the transfer of the same data word based on the selected event (e.g. on a timer base or an edge at a pin) to realize a kind of life-sign mechanism. Furthermore, in slave mode, it is ensured that always a correct data word is transmitted instead of the passive data level.
- Bit TCSR.TDSSM = 1 has to be programmed to allow word-by-word data transmission with a kind of single-shot mechanism. After each transmission start, a new data word has to be loaded into the transmit buffer TBUF, either by software write actions to one of the transmit buffer input locations TBUFx or by an optional data buffer (e.g. FIFO buffer). To avoid that data words are sent out several times or to allow data handling with an additional data buffer (e.g. FIFO), bit TCSR.TDSSM has to be 1.
- Bit TCSR.TDV becoming automatically set when a new data word is loaded into the transmit buffer TBUF, a transmission start can be requested by a write action of the data to be transmitted to at least the low byte of one of the transmit buffer input locations TBUFx. The additional information TCI can be used to control the data word length or other parameters independently for each data word by a single write access.
- Bit field FMR.MTDV allows software driven modification (set or clear) of bit TCSR.TDV. Together with the gating control bit field TCSR.TDEN, the user can set up the transmit data word without starting the transmission. A possible program sequence could be: clear TCSR.TDEN = 00_B, write data to TBUFx, clear TCSR.TDV by writing FMR.MTDV = 10_B, re-enable the gating with TCSR.TDEN = 01_B and then set TCSR.TDV under software control by writing FMR.MTDV = 01_B.

15.2.6 Operating the Receive Data Path

The receive data path is based on two sets of 16-bit wide receive shift registers RSR0[3:0] and RSR1[3:0] and a receive buffer for each of the set (RBUF0 and RBUF1). The data transfer parameters like data word length, data frame length, or the shift direction are controlled commonly for transmission and reception by the shift control registers.

Register RBUF01SR monitors the status of RBUF0 and RBUF1.

15.2.6.1 Receive Buffering

The receive shift registers cannot be directly accessed by software, but their contents are automatically loaded into the receive buffer registers RBUF0 (or RBUF1 respectively) if a complete data word has been received or the frame is finished. The received data words in RBUF0 or RBUF1 can be read out in the correct order directly from register RBUF or, optionally, from a FIFO buffer stage (see [Page 15-39](#)).

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number of parallel data input lines. For example, to receive a 16-bit data word through four input lines, only four shifts are required.

Depending on the shift mode, different receive shift registers with different bit composition are used as shown in [Table 15-8](#). Note that the 'n' in the table denotes the shift number less one, i.e. for the first data shift $n = 0$, the second data shift $n = 1$ and continues until the total number of shifts less one is reached.

For all receive shift registers, whether the first bit shifted in is the MSB or LSB depends on the setting of SCTR.SDIR.

Table 15-9 Receive Shift Register Composition

Receive Shift Registers	Input stage used	Single Data Input (SCTR.DSM = 00 _B)	Two Data Inputs (SCTR.DSM = 10 _B)	Four Data Inputs (SCTR.DSM = 11 _B)
RSR _x 0	DX0	All data bits	Bit $n*2$	Bit $n*4$
RSR _x 1	DX3	Not used	Bit $n*2 + 1$	Bit $n*4 + 1$
RSR _x 2	DX4	Not used	Not used	Bit $n*4 + 2$
RSR _x 3	DX5	Not used	Not used	Bit $n*4 + 3$

15.2.6.3 Baud Rate Constraints

The following baud rate constraints have to be respected to ensure correct data reception and buffering. The user has to take care about these restrictions when selecting the baud rate and the data word length with respect to the module clock frequency f_{PERIPH} .

- A received data word in a receiver shift registers RSR_x[3:0] must be held constant for at least 4 periods of f_{PERIPH} in order to ensure correct loading of the related receiver buffer register RBUF_x.
- The shift control signal has to be constant inactive for at least 5 periods of f_{PERIPH} between two consecutive frames in order to correctly detect the end of a frame.
- The shift control signal has to be constant active for at least 1 period of f_{PERIPH} in order to correctly detect a frame (shortest frame).
- A minimum setup and hold time of the shift control signal with respect to the shift clock signal has to be ensured.

15.2.7 Hardware Port Control

Hardware port control is intended for SSC protocols with half-duplex configurations, where a single port pin is used for both input and output data functions, to control the pin direction through a dedicated hardware interface. All settings in Pn_IOCRy.PCx, except for the input pull device selection and output driver type (open drain or push-pull), are overruled by the hardware port control.

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- FIFO buffer available and selected:
 The transmit FIFO buffer and the bypass structure are only available if CCFG.TB = 1, whereas the receive FIFO buffer is only available if CCFG.RB = 1.
 It is recommended to configure all buffer parameters while there is no data traffic for this USIC channel and the FIFO mechanism is disabled by TBCTR.SIZE = 0 (for transmit buffer) or RBCTR.SIZE = 0 (for receive buffer). The allocation of a buffer area by writing TBCTR or RBCTR has to be done while the corresponding FIFO buffer is disabled. The FIFO buffer interrupt control bits can be modified independently of data traffic.
- FIFO buffer setup:
 The total amount of available FIFO buffer entries limits the length of the transmit and receive buffers for each USIC channel.
- Bypass setup:
 In addition to the transmit FIFO buffer, a bypass can be configured as described on [Page 15-50](#).

15.2.8.1 FIFO Buffer Partitioning

If available, the FIFO buffer area consists of a defined number of FIFO buffer entries, each containing a data part and the associated control information (RCI for receive data, TCI for transmit data). One FIFO buffer entry represents the finest granularity that can be allocated to a receive FIFO buffer or a transmit FIFO buffer. All available FIFO buffer entries of a USIC module are located one after the other in the FIFO buffer area. The overall counting starts with FIFO entry 0, followed by 1, 2, etc.

For each USIC module, a certain number of FIFO entries is available, that can be allocated to the channels of the same USIC module. It is not possible to assign FIFO buffer area to USIC channels that are not located within the same USIC module.

For each USIC channel, the size of the transmit and the receive FIFO buffer can be chosen independently. For example, it is possible to allocate the full amount of available FIFO entries as transmit buffer for one USIC channel. Some possible scenarios of FIFO buffer partitioning are shown in [Figure 15-21](#).

Each FIFO buffer consists of a set of consecutive FIFO entries. The size of a FIFO data buffer can only be programmed as a power of 2, starting with 2 entries, then 4 entries, then 8 entries, etc. A FIFO data buffer can only start at a FIFO entry aligned to its size. For example, a FIFO buffer containing n entries can only start with FIFO entry 0, n , $2*n$, $3*n$, etc. and consists of the FIFO entries $[x*n, (x+1)*n-1]$, with x being an integer number (incl. 0). It is not possible to have “holes” with unused FIFO entries within a FIFO buffer, whereas there can be unused FIFO entries between two FIFO buffers.

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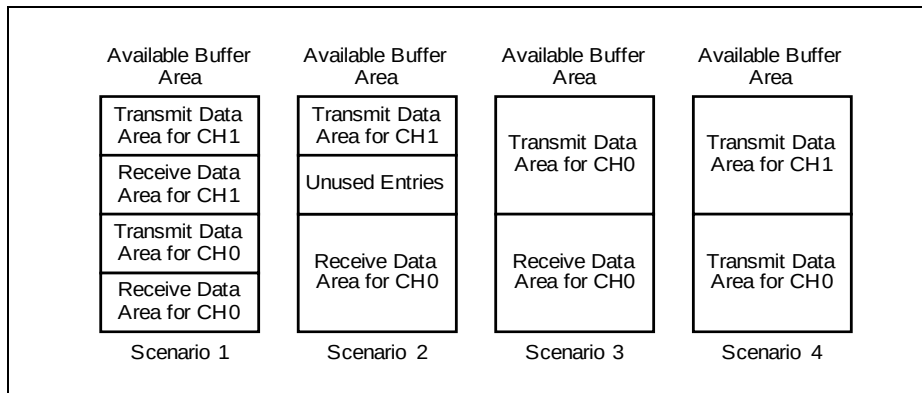


Figure 15-21 FIFO Buffer Partitioning

The data storage inside the FIFO buffers is based on pointers, that are internally updated whenever the data contents of the FIFO buffers have been modified. This happens automatically when new data is put into a FIFO buffer or the oldest data is taken from a FIFO buffer. As a consequence, the user program does not need to modify the pointers for data handling. Only during the initialization phase, the start entry of a FIFO buffer has to be defined by writing the number of the first FIFO buffer entry in the FIFO buffer to the corresponding bit field DPTR in register RBCTR (for a receive FIFO buffer) or TBCTR (for a transmit FIFO buffer) while the related bit field RBCTR.SIZE=0 (or TBCTR.SIZE = 0, respectively). The assignment of buffer entries to a FIFO buffer (regarding to size and pointers) must not be changed by software while the related USIC channel is taking part in data traffic.

15.2.8.2 Transmit Buffer Events and Interrupts

The transmit FIFO buffer mechanism detects the following events, that can lead to interrupts (if enabled):

- Standard transmit buffer event
- Transmit buffer error event

Standard Transmit Buffer Event

The standard transmit buffer event is triggered by the filling level of the transmit buffer (given by TRBSR.TBFLVL) exceeding (TBCTR.LOF = 1) or falling below (TBCTR.LOF = 0)¹⁾ a programmed limit (TBCTR.LIMIT).

¹⁾ If the standard transmit buffer event is used to indicate that new data has to be written to one of the INx locations, TBCTR.LOF = 0 should be programmed.

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If the event trigger with TRBSR.STBT feature is disabled (TBCTR.STBTEN = 0), the trigger of the standard transmit buffer event is based on the transition of the fill level from equal to below or above the limit, not the fact of being below or above.

If TBCTR.STBTEN = 1, the transition of the fill level below or above the programmed limit additionally sets TRBSR.STBT. This bit triggers also the standard transmit buffer event whenever there is a transfer data to TBUF event or write data to INx event, depending on TBCTR.LOF setting.

The way TRBSR.STBT is cleared depends on the trigger mode (selected by TBCTR.STBTM). If TBCTR.STBTM = 0, TRBSR.STBT is cleared by hardware when the buffer fill level equals the programmed limit again (TRBSR.TBFLVL = TBCTR.LIMIT). If TBCTR.STBTM = 1, TRBSR.STBT is cleared by hardware when the buffer fill level equals the buffer size (TRBSR.TBFLVL = TBCTR.SIZE).

Note: The flag TRBSR.STBI is set only when the transmit buffer fill level exceeds or falls below the programmed limit (depending on TBCTR.LOF setting). Standard transmit buffer events triggered by TRBSR.STBT does not set the flag.

Figure 15-22 shows examples of the standard transmit buffer event with the different TBCTR.STBTEN and TBCTR.STBTM settings. These examples are meant to illustrate the hardware behaviour and might not always represent real application use cases.

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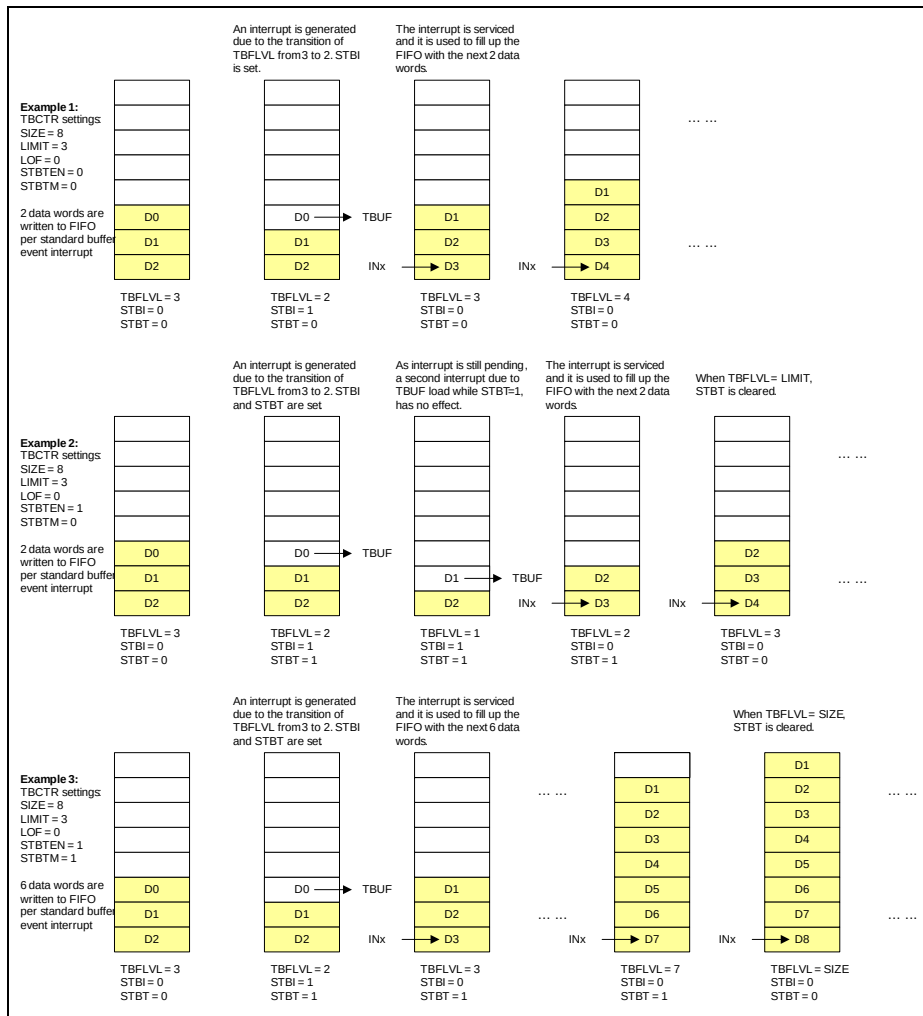


Figure 15-22 Standard Transmit Buffer Event Examples

Transmit Buffer Error Event

The transmit buffer error event is triggered when software has written to a full buffer. The written value is ignored.

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Transmit Buffer Events and Interrupt Handling

Figure 15-23 shows the transmit buffer events and interrupts.

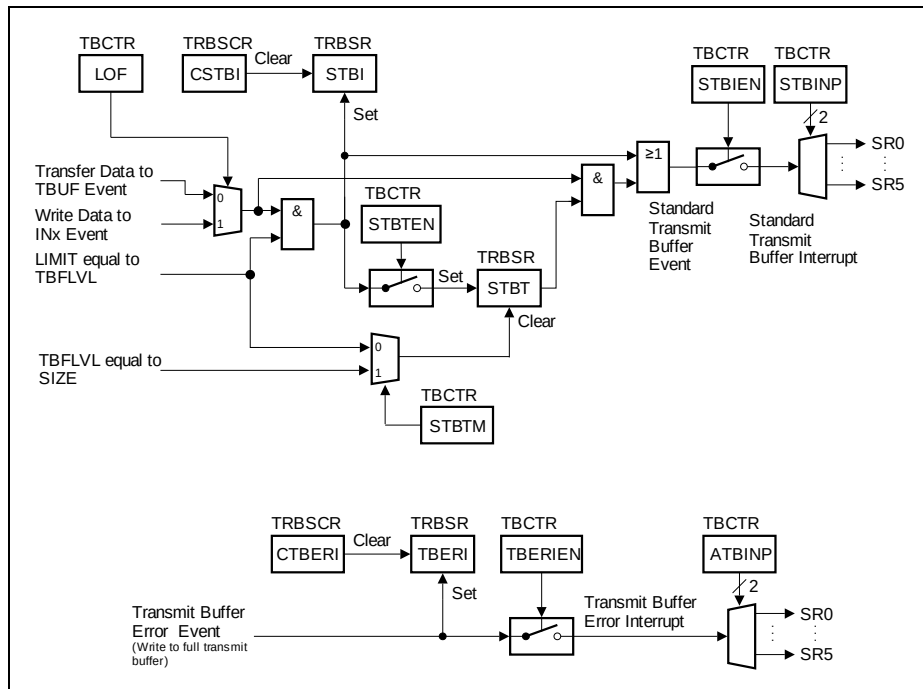


Figure 15-23 Transmit Buffer Events

Table 15-10 shows the registers, bits and bit fields to indicate the transmit buffer events and to control the interrupts related to the transmit FIFO buffers of a USIC channel.

Table 15-10 Transmit Buffer Events and Interrupt Handling

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Standard transmit buffer event	TRBSR. STBI	TRBSR. CSTBI	TBCTR. STBIEN	TBCTR. STBINP
	TRBSR. STBT	Cleared by hardware		
Transmit buffer error event	TRBSR. TBERI	TRBSR. CTBERI	TBCTR. TBERIEN	TBCTR. ATBINP

15.2.8.3 Receive Buffer Events and Interrupts

The receive FIFO buffer mechanism detects the following events, that can lead to an interrupt (if enabled):

- Standard receive buffer event
- Alternative receive buffer event
- Receive buffer error event

The standard receive buffer event and the alternative receive buffer event can be programmed to two different modes, one referring to the filling level of the receive buffer, the other one related to a bit position in the receive control information RCI of the data word that becomes available in OUTR.

If the interrupt generation refers to the filling level of the receive FIFO buffer, only the standard receive buffer event is used, whereas the alternative receive buffer event is not used. This mode can be selected to indicate that a certain amount of data has been received, without regarding the content of the associated RCI.

If the interrupt generation refers to RCI, the filling level is not taken into account. Each time a new data word becomes available in OUTR, an event is detected. If bit RCI[4] = 0, a standard receive buffer event is signaled, otherwise an alternative receive buffer device (RCI[4] = 1). Depending on the selected protocol and the setting of RBCTR.RCIM, the value of RCI[4] can hold different information that can be used for protocol-specific interrupt handling (see protocol sections for more details).

Standard Receive Buffer Event in Filling Level Mode

In filling level mode (RBCTR.RNM = 0), the standard receive buffer event is triggered by the filling level of the receive buffer (given by TRBSR.RBFLVL) exceeding (RBCTR.LOF = 1) or falling below (RBCTR.LOF = 0) a programmed limit (RBCTR.LIMIT).¹⁾

If the event trigger with bit TRBSR.SRBT feature is disabled (RBCTR.SRBTEN = 0), the trigger of the standard receive buffer event is based on the transition of the fill level from equal to below or above the limit, not the fact of being below or above.

If RBCTR.SRBTEN = 1, the transition of the fill level below or above the programmed limit additionally sets the bit TRBSR.SRBT. This bit also triggers the standard receive buffer event each time there is a data read out event or new data received event, depending on RBCTR.LOF setting.

The way TRBSR.SRBT is cleared depends on the trigger mode (selected by RBCTR.SRBTM). If RBCTR.SRBTM = 0, TRBSR.SRBT is cleared by hardware when the buffer fill level equals the programmed limit again (TRBSR.RBFLVL =

¹⁾ If the standard receive buffer event is used to indicate that new data has to be read from OUTR, RBCTR.LOF = 1 should be programmed.

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RBCTR.LIMIT). If RBCTR.SRBTM = 1, TRBSR.SRBT is cleared by hardware when the buffer fill level equals 0 (TRBSR.RBFLVL = 0).

Note: The flag TRBSR.SRBI is set only when the receive buffer fill level exceeds or falls below the programmed limit (depending on RBCTR.LOF setting). Standard receive buffer events triggered by TRBSR.SRBT does not set the flag.

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Figure 15-24 shows examples of the standard receive buffer event with the different RBCTR.SRBTEN and RBCTR.SRBTM settings. These examples are meant to illustrate the hardware behaviour and might not always represent real application use cases.

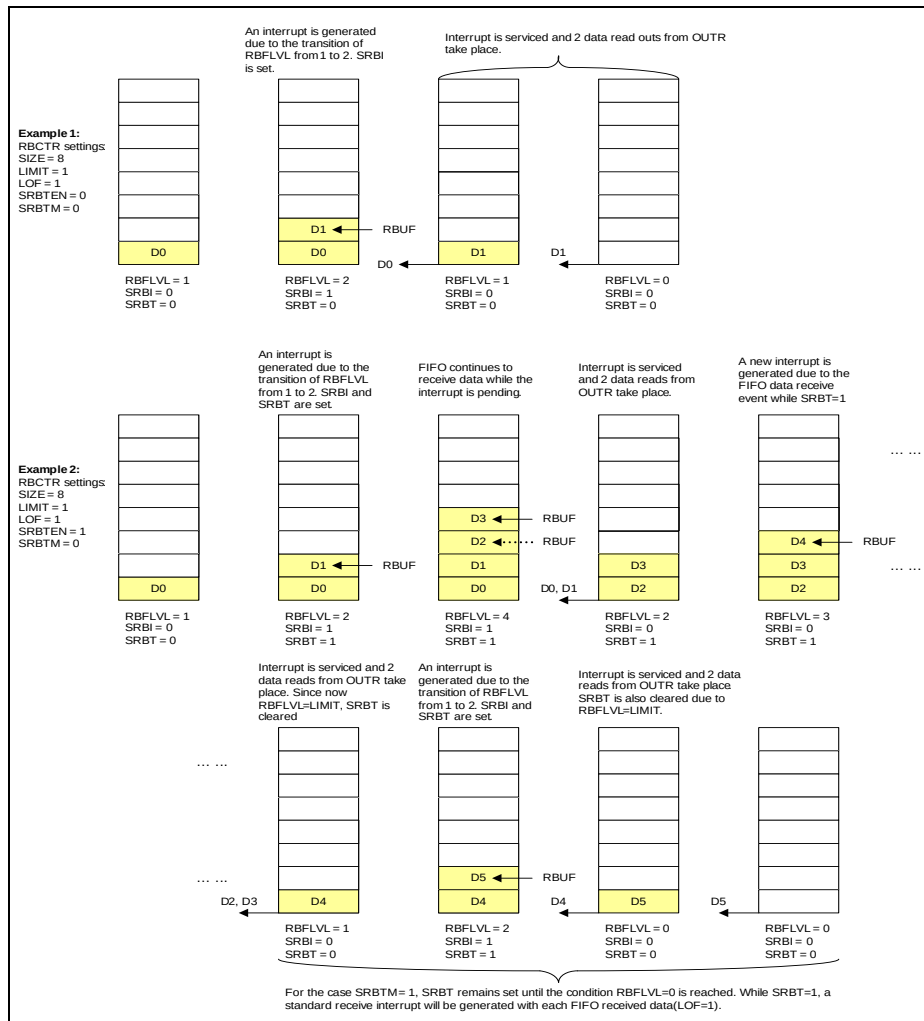


Figure 15-24 Standard Receive Buffer Event Examples

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Standard and Alternate Receive Buffer Events in RCI Mode

In RCI mode ($RBCTR.RNM = 1$), the standard receive buffer event is triggered when the OUTR stage is updated with a new data value with $RCI[4] = 0$.

If the OUTR stage is updated with a new data value with $RCI[4] = 1$, an alternate receive buffer event is triggered instead.

Receive Buffer Error Event

The receive buffer error event is triggered if the software reads from an empty buffer, regardless of $RBCTR.RNM$ value. The read data is invalid.

Receive Buffer Events and Interrupt Handling

Figure 15-25 shows the receiver buffer events and interrupts in filling level mode.

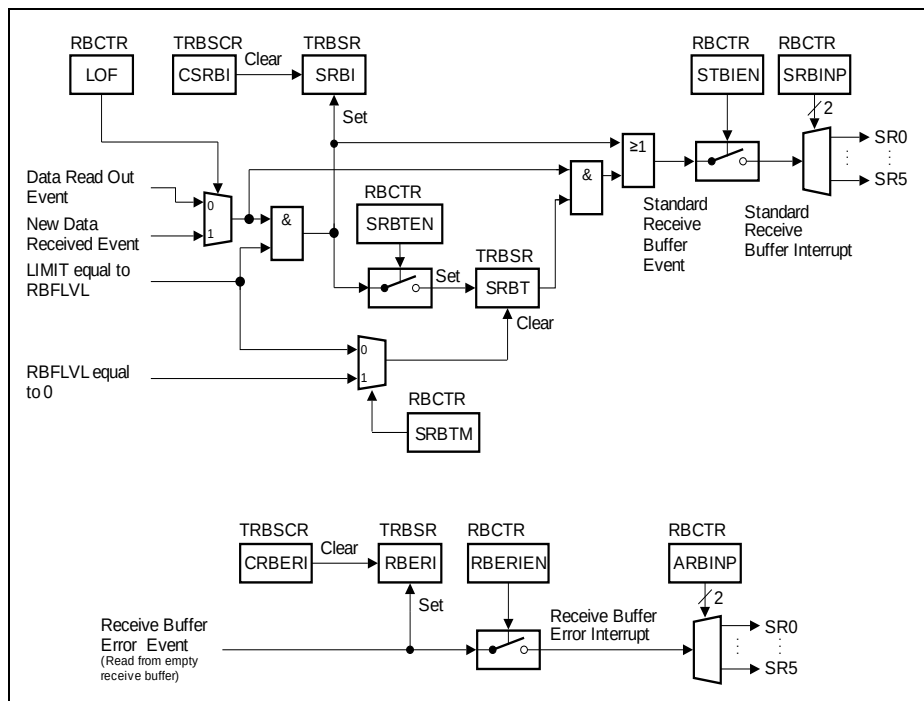


Figure 15-25 Receiver Buffer Events in Filling Level Mode

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Figure 15-26 shows the receiver buffer events and interrupts in RCI mode.

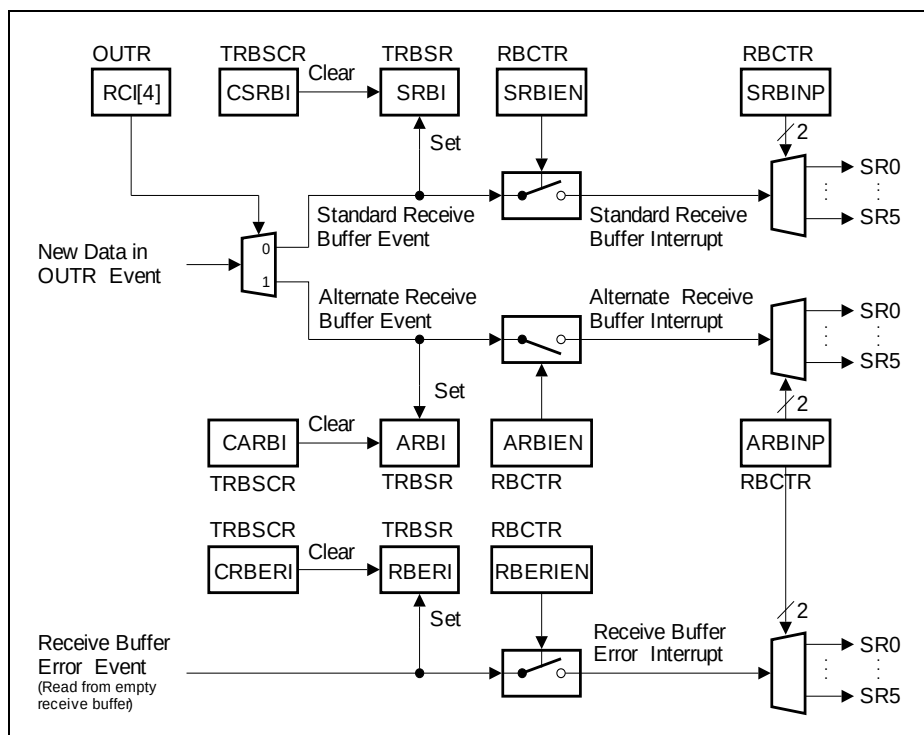


Figure 15-26 Receiver Buffer Events in RCI Mode

Table 15-11 shows the registers, bits and bit fields to indicate the receive buffer events and to control the interrupts related to the receive FIFO buffers of a USIC channel.

Table 15-11 Receive Buffer Events and Interrupt Handling

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Standard receive buffer event	TRBSR. SRBI	TRBSCR. CSRBI	RBCTR. SRBIEN	RBCTR. SRBINP
	TRBSR. SRBT	Cleared by hardware		

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Table 15-11 Receive Buffer Events and Interrupt Handling (cont'd)

Event	Indication Flag	Indication cleared by	Interrupt enabled by	SRx Output selected by
Alternative receive buffer event	TRBSR. ARBI	TRBSCR. CARBI	RBCTR. ARBIEIN	RBCTR. ARBINP
Receive buffer error event	TRBSR. RBERI	TRBSCR. CRBERI	RBCTR. RBERIEN	RBCTR. ARBINTXDP

15.2.8.4 FIFO Buffer Bypass

The data bypass mechanism is part of the transmit FIFO control block. It allows to introduce a data word in the data stream without modifying the transmit FIFO buffer contents, e.g. to send a high-priority message. The bypass structure consists of a bypass data word of maximum 16 bits in register BYP and some associated control information in register BYPCR. For example, these bits define the word length of the bypass data word and configure a transfer trigger and gating mechanism similar to the one for the transmit buffer TBUF.

The bypass data word can be tagged valid or invalid for transmission by bit BYRCR.BDV (bypass data valid). A combination of data flow related and event related criteria define whether the bypass data word is considered valid for transmission. A data validation logic checks the start conditions for this data word. Depending on the result of the check, the transmit buffer register TBUF is loaded with different values, according to the following rules:

- Data from the transmit FIFO buffer or the bypass data can only be transferred to TBUF if TCSR.TDV = 0 (TBUF is empty).
- Bypass data can only be transferred to TBUF if the bypass is enabled by BYPCR.BDEN or the selecting gating condition is met.
- If the bypass data is valid for transmission and has either a higher transmit priority than the FIFO data or if the transmit FIFO is empty, the bypass data is transferred to TBUF.
- If the bypass data is valid for transmission and has a lower transmit priority than the FIFO buffer that contains valid data, the oldest transmit FIFO data is transferred to TBUF.
- If the bypass data is not valid for transmission and the FIFO buffer contains valid data, the oldest FIFO data is transferred to TBUF.
- If neither the bypass data is valid for transmission nor the transmit FIFO buffer contains valid data, TBUF is unchanged.

The bypass data validation is based on the logic blocks shown in [Figure 15-27](#).

- A transfer gating logic enables or disables the bypass data word transfer to TBUF under software or under hardware control. If the input stage DX2 is not needed for

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data shifting, signal DX2S can be used for gating purposes. The transfer gating logic is controlled by bit field BYPCR.BDEN.

- A transfer trigger logic supports data word transfers related to events, e.g. timer based or related to an input pin. If the input stage DX2 is not needed for data shifting, signal DX2T can be used for trigger purposes. The transfer trigger logic is controlled by bit BYPCR.BDVTR.
- A bypass data validation logic combining the inputs from the gating logic, the triggering logic and TCSR.TDV.

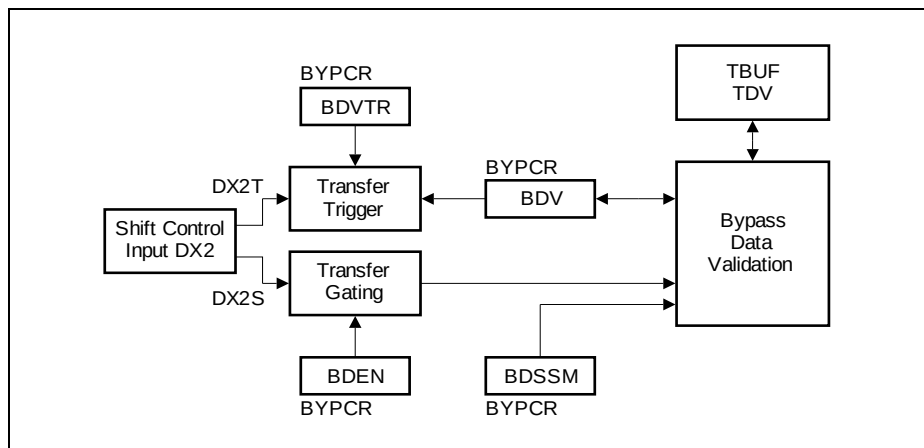


Figure 15-27 Bypass Data Validation

With this structure, the following bypass data transfer functionality can be achieved:

- Bit BYPCR.BDSSM = 1 has to be programmed for a single-shot mechanism. After each transfer of the bypass data word to TBUF, the bypass data word has to be tagged valid again. This can be achieved either by writing a new bypass data word to BYP or by DX2T if BDVTR = 1 (e.g. trigger on a timer base or an edge at a pin).
- Bit BYPCR.BDSSM = 0 has to be programmed if the bypass data is permanently valid for transmission (e.g. as alternative data if the data FIFO runs empty).

15.2.8.5 FIFO Access Constraints

The data in the shared FIFO buffer area is accessed by the hardware mechanisms for data transfer of each communication channel (for transmission and reception) and by software to read out received data or to write data to be transmitted. As a consequence, the data delivery rate can be limited by the FIFO mechanism. Each access by hardware to the FIFO buffer area has priority over a software access, that is delayed in case of an access collision.

In order to avoid data loss and stalling of the CPU due to delayed software accesses, the

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baud rate, the word length and the software access mechanism have to be taken into account. Each access to the FIFO data buffer area by software or by hardware takes one period of f_{PERIPH} . Especially a continuous flow of very short, consecutive data words can lead to an access limitation.

15.2.8.6 Handling of FIFO Transmit Control Information

In addition to the transmit data, the transmit control information TCI can be transferred from the transmit FIFO or bypass structure to the USIC channel. Depending on the selected protocol and the enabled update mechanism, some settings of the USIC channel parameters can be modified. The modifications are based on the TCI of the FIFO data word loaded to TBUF or by the bypass control information if the bypass data is loaded into TBUF.

- TCSR.SELMD = 1: update of PCR.CTR[20:16] by FIFO TCI or BYPCR.BSELO with additional clear of PCR.CTR[23:21]
- TCSR.WLEMD = 1: update of SCTR.WLE and TCSR.EOF by FIFO TCI or BYPCR.BWLE (if the WLE information is overwritten by TCI or BWLE, the user has to take care that FLE is set accordingly)
- TCSR.FLEMD = 1: update of SCTR.FLE[4:0] by FIFO TCI or BYPCR.BWLE with additional clear of SCTR.FLE[5]
- TCSR.HPCMD = 1: update of SCTR.DSM and SCTR.HPCDIR by FIFO TCI or BYPCR.BHPC
- TCSR.WAMD = 1: update of TCSR.WA by FIFO TCI[4]

See [Section 15.2.5.3](#) for more details on TCI.

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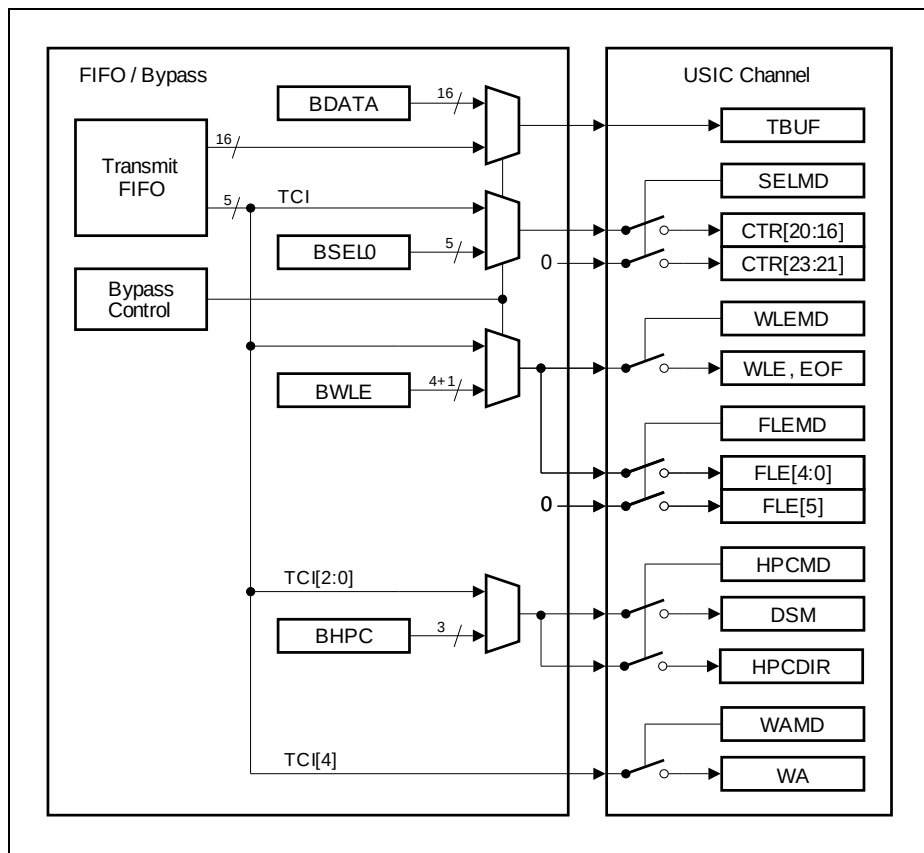


Figure 15-28 TCI Handling with FIFO / Bypass

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15.3 Asynchronous Serial Channel (ASC = UART)

The asynchronous serial channel ASC covers the reception and the transmission of asynchronous data frames and provides a hardware LIN support. The receiver and transmitter being independent, frames can start at different points in time for transmission and reception. The ASC mode is selected by $CCR.MODE = 0010_B$ with $CCFG.ASC = 1$ (ASC mode available).

15.3.1 Signal Description

An ASC connection is characterized by the use of a single connection line between a transmitter and a receiver. The receiver input RXD signal is handled by the input stage DX0.

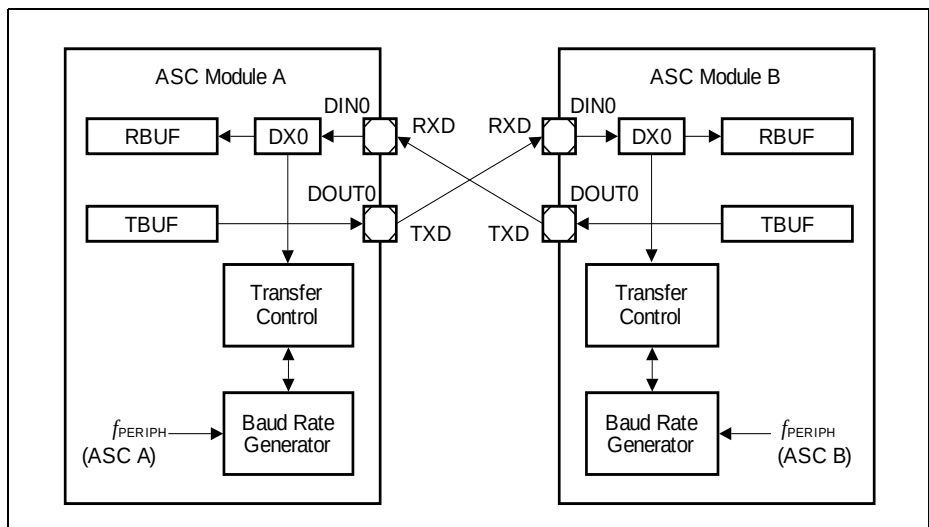


Figure 15-29 ASC Signal Connections for Full-Duplex Communication

For full-duplex communication, an independent communication line is needed for each transfer direction. **Figure 15-29** shows an example with a point-to-point full-duplex connection between two communication partners ASC A and ASC B.

For half-duplex or multi-transmitter communication, a single communication line is shared between the communication partners. **Figure 15-30** shows an example with a point-to-point half-duplex connection between ASC A and ASC B. In this case, the user has to take care that only one transmitter is active at a time. In order to support transmitter collision detection, the input stage DX1 can be used to monitor the level of the transmit line and to check if the line is in the idle state or if a collision occurred. There are two possibilities to connect the receiver input DIN0 to the transmitter output

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DOUT0. Communication partner ASC A uses an internal connection with only the transmit pin TXD, that is delivering its input value as RXD to the DX0 input stage for reception and to DX1 to check for transmitter collisions. Communication partner ASC B uses an external connection between the two pins TXD and RXD.

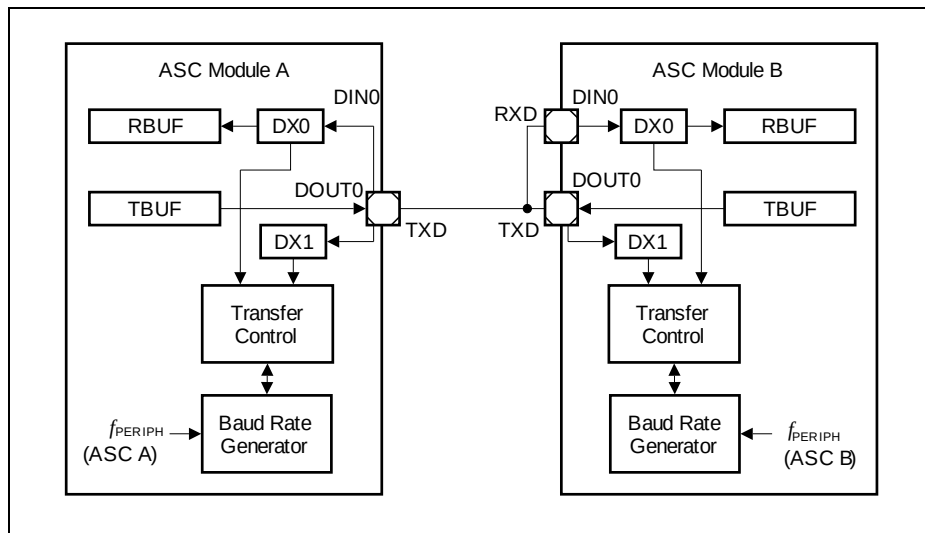


Figure 15-30 ASC Signal Connections for Half-Duplex Communication

15.3.2 Frame Format

A standard ASC frame is shown in [Figure 15-31](#). It consists of:

- An idle time with the signal level 1.
- One start of frame bit (SOF) with the signal level 0.
- A data field containing a programmable number of data bits (1-63).
- A parity bit (P), programmable for either even or odd parity. It is optionally possible to handle frames without parity bit.
- One or two stop bits with the signal level 1.

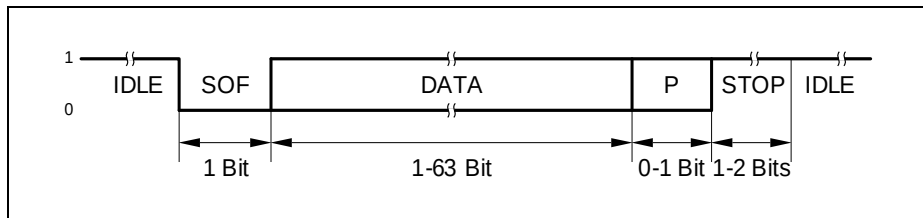


Figure 15-31 Standard ASC Frame Format

The protocol specific bits (SOF, P, STOP) are automatically handled by the ASC protocol state machine and do not appear in the data flow via the receive and transmit buffers.

15.3.2.1 Idle Time

The receiver and the transmitter independently check the respective data input lines (DX0, DX1) for being idle. The idle detection ensures that an SOF bit of a recently enabled ASC module does not collide with an already running frame of another ASC module.

In order to start the idle detection, the user software has to clear bits PSR.RXIDLE and/or PSR.TXIDLE, e.g. before selecting the ASC mode or during operation. If a bit is cleared by software while a data transfer is in progress, the currently running frame transfer is finished normally before starting the idle detection again. Frame reception is only possible if PSR.RXIDLE = 1 and frame transmission is only possible if PSR.TXIDLE = 1. The duration of the idle detection depends on the setting of bit PCR.IDM. In the case that a collision is not possible, the duration can be shortened and the bus can be declared as being idle by setting PCR.IDM = 0.

In the case that the complete idle detection is enabled by PCR.IDM = 1, the data input of DX0 is considered as idle (PSR.RXIDLE becomes set) if a certain number of consecutive passive bit times has been detected. The same scheme applies for the transmitter's data input of DX1. Here, bit PSR.TXIDLE becomes set if the idle condition of this input signal has been detected.

The duration of the complete idle detection is given by the number of programmed data bits per frame plus 2 (in the case without parity) or plus 3 (in the case with parity). The counting of consecutive bit times with 1 level restarts from the beginning each time an edge is found, after leaving a stop mode or if ASC mode becomes enabled.

If the idle detection bits PSR.RXIDLE and/or TXIDLE are cleared by software, the counting scheme is not stopped (no re-start from the beginning). As a result, the cleared bit(s) can become set immediately again if the respective input line still meets the idle criterion.

Please note that the idle time check is based on bit times, so the maximum time can be up to 1 bit time more than programmed value (but not less).

15.3.2.2 Start Bit Detection

The receiver input signal DIN0 (selected signal of input stage DX0) is checked for a falling edge. An SOF bit is detected when a falling edge occurs while the receiver is idle or after the sampling point of the last stop bit. To increase noise immunity, the SOF bit timing starts with the first falling edge that is detected. If the sampled bit value of the SOF is 1, the previous falling edge is considered to be due to noise and the receiver is considered to be idle again.

15.3.2.3 Data Field

The length of the data field (number of data bits) can be programmed by bit field SCTR.FLE. It can vary between 1 and 63 data bits, corresponding to values of SCTR.FLE = 0 to 62 (the value of 63 is reserved and must not be programmed in ASC mode).

The data field can consist of several data words, e.g. a transfer of 12 data bits can be composed of two 8-bit words, with the 12 bits being split into 8-bits of the first word and 4 bits of the second word. The user software has to take care that the transmit data is available in-time, once a frame has been started. If the transmit buffer runs empty during a running data frame, the passive data level (SCTR.PDL) is sent out.

The shift direction can be programmed by SCTR.SDIR. The standard setting for ASC frames with LSB first is achieved with the default setting SDIR = 0.

15.3.2.4 Parity Bit

The ASC allows parity generation for transmission and parity check for reception on frame base. The type of parity can be selected by bit field CCR.PM, common for transmission and reception (no parity, even or odd parity). If the parity handling is disabled, the ASC frame does not contain any parity bit. For consistency reasons, all communication partners have to be programmed to the same parity mode.

After the last data bit of the data field, the transmitter automatically sends out its calculated parity bit if parity generation has been enabled. The receiver interprets this bit as received parity and compares it to its internally calculated one. The received parity bit value and the result of the parity check are monitored in the receiver buffer status registers, RBUFSR and RBUF01SR, as receiver buffer status information. These registers contain bits to monitor a protocol-related argument (PAR) and protocol-related error indication (PERR).

15.3.2.5 Stop Bit(s)

Each ASC frame is completed by 1 or 2 of stop bits with the signal level 1 (same level as the idle level). The number of stop bits is programmable by bit PSR.STPB. A new start bit can be transferred directly after the last stop bit.

15.3.3 Operating the ASC

In order to operate the ASC protocol, the following issues have to be considered:

- **Select ASC mode:**
It is recommended to configure all parameters of the ASC that do not change during run time while $CCR.MODE = 0000_B$. Bit field $SCTR.TRM = 01_B$ has to be programmed. The configuration of the input stages has to be done while $CCR.MODE = 0000_B$ to avoid unintended edges of the input signals and the ASC mode can be enabled by $CCR.MODE = 0010_B$ afterwards.
- **Pin connections:**
Establish a connection of input stage DX0 with the selected receive data input pin (signal DIN0) with $DX0CR.INSW = 0$ and configure a transmit data output pin (signal DOUT0). For collision or idle detection of the transmitter, the input stage DX1 has to be connected to the selected transmit output pin, also with $DX1CR.INSW = 0$. Additionally, program $DX2CR.INSW = 0$.
Due to the handling of the input data stream by the synchronous protocol handler, the propagation delay of the synchronization in the input stage has to be considered.
Note that the step to enable the alternate output port functions should only be done after the ASC mode is enabled, to avoid unintended spikes on the output.
- **Bit timing configuration:**
The desired baud rate setting has to be selected, comprising the fractional divider, the baud rate generator and the bit timing. Please note that not all feature combinations can be supported by the application at the same time, e.g. due to propagation delays. For example, the length of a frame is limited by the frequency difference of the transmitter and the receiver device. Furthermore, in order to use the average of samples ($SMD = 1$), the sampling point has to be chosen to respect the signal settling and data propagation times.
- **Data format configuration:**
The word length, the frame length, and the shift direction have to be set up according to the application requirements by programming the register SCTR. If required by the application, the data input and output signals can be inverted.
Additionally, the parity mode has to be configured ($CCR.PM$).

15.3.3.1 Bit Timing

In ASC mode, each bit (incl. protocol bits) is divided into time quanta in order to provide granularity in the sub-bit range to adjust the sample point to the application requirements. The number of time quanta per bit is defined by bit fields $BRG.DCTQ$ and the length of a time quantum is given by $BRG.PCTQ$.

In the example given in [Figure 15-32](#), one bit time is composed of 16 time quanta ($BRG.DCTQ = 15$). It is not recommended to program less than 4 time quanta per bit time.

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Bit field PCR.SP determines the position of the sampling point for the bit value. The value of PCR.SP must not be set to a value greater than BRG.DCTQ. It is possible to sample the bit value only once per bit time or to take the average of samples. Depending on bit PCR.SMD, either the current input value is directly sampled as bit value, or a majority decision over the input values sampled at the latest three time quanta is taken into account. The standard ASC bit timing consists of 16 time quanta with sampling after 8 or 9 time quanta with majority decision.

The bit timing setup (number of time quanta and the sampling point definition) is common for the transmitter and the receiver. Due to independent bit timing blocks, the receiver and the transmitter can be in different time quanta or bit positions inside their frames. The transmission of a frame is aligned to the time quanta generation.

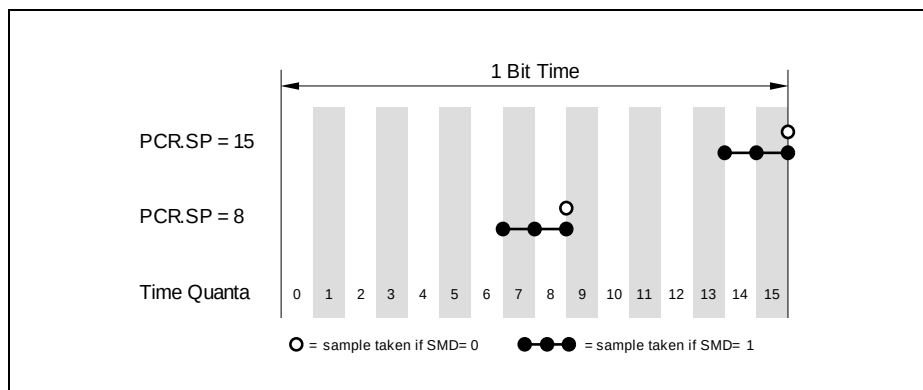


Figure 15-32 ASC Bit Timing

The sample point setting has to be adjusted carefully if collision or idle detection is enabled (via DX1 input signal), because the driver delay and some external delays have to be taken into account. The sample point for the transmit line has to be set to a value where the bit level is stable enough to be evaluated.

If the sample point is located late in the bit time, the signal itself has more time to become stable, but the robustness against differences in the clock frequency of transmitter and receiver decreases.

15.3.3.2 Baud Rate Generation

The baud rate f_{ASC} in ASC mode depends on the number of time quanta per bit time and their timing. The baud rate setting should only be changed while the transmitter and the receiver are idle. The bits in register BRG define the baud rate setting:

- **BRG.CTQSEL**
to define the input frequency f_{CTQIN} for the time quanta generation

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- BRG.PCTQ
to define the length of a time quantum (division of f_{CTQIN} by 1, 2, 3, or 4)
- BRG.DCTQ
to define the number of time quanta per bit time

The standard setting is given by CTQSEL = 00_B ($f_{CTQIN} = f_{PDIV}$) and PPPEN = 0 ($f_{PPP} = f_{PIN}$). Under these conditions, the baud rate is given by:

$$f_{ASC} = f_{PIN} \times \frac{1}{PDIV + 1} \times \frac{1}{PCTQ + 1} \times \frac{1}{DCTQ + 1} \quad (15.6)$$

In order to generate slower frequencies, two additional divide-by-2 stages can be selected by CTQSEL = 10_B ($f_{CTQIN} = f_{SCLK}$) and PPPEN = 1 ($f_{PPP} = f_{MCLK}$), leading to:

$$f_{ASC} = \frac{f_{PIN}}{2 \times 2} \times \frac{1}{PDIV + 1} \times \frac{1}{PCTQ + 1} \times \frac{1}{DCTQ + 1} \quad (15.7)$$

15.3.3.3 Noise Detection

The ASC receiver permanently checks the data input line of the DX0 stage for noise (the check is independent from the setting of bit PCR.SMD). Bit PSR.RNS (receiver noise) becomes set if the three input samples of the majority decision are not identical at the sample point for the bit value. The information about receiver noise gets accumulated over several bits in bit PSR.RNS (it has to be cleared by software) and can trigger a protocol interrupt each time noise is detected if enabled by PCR.RNIEN.

15.3.3.4 Collision Detection

In some applications, such as data transfer over a single data line shared by several sending devices (see [Figure 15-30](#)), several transmitters have the possibility to send on the same data output line TXD. In order to avoid collisions of transmitters being active at the same time or to allow a kind of arbitration, a collision detection has been implemented.

The data value read at the TXD input at the DX1 stage and the transmitted data bit value are compared after the sampling of each bit value. If enabled by PCR.CDEN = 1 and a bit sent is not equal to the bit read back, a collision is detected and bit PSR.COL is set. If enabled, bit PSR.COL = 1 disables the transmitter (the data output lines become 1) and generates a protocol interrupt. The content of the transmit shift register is considered as invalid, so the transmit buffer has to be programmed again.

15.3.3.5 Pulse Shaping

For some applications, the 0 level of transmitted bits with the bit value 0 is not applied at the transmit output during the complete bit time. Instead of driving the original 0 level,

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only a 0 pulse is generated and the remaining time quanta of the bit time are driven with 1 level. The length of a bit time is not changed by the pulse shaping, only the signalling is changed.

In the standard ASC signalling scheme, the 0 level is signalled during the complete bit time with bit value 0 (ensured by programming $\text{PCR.PL} = 000_{\text{B}}$). In the case $\text{PCR.PL} > 000_{\text{B}}$, the transmit output signal becomes 0 for the number of time quanta defined by PCR.PL . In order to support correct reception with pulse shaping by the transmitter, the sample point has to be adjusted in the receiver according to the applied pulse length.

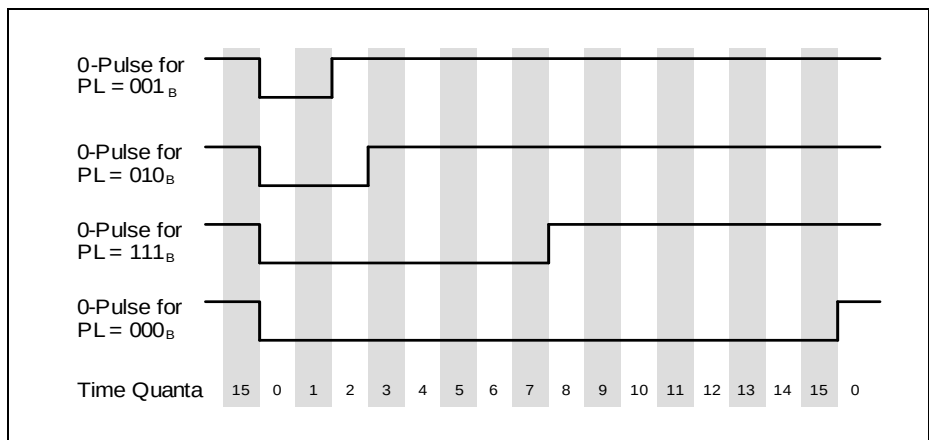


Figure 15-33 Transmitter Pulse Length Control

Figure 15-34 shows an example for the transmission of an 8-bit data word with LSB first and one stop bit (e.g. like for IrDA). The polarity of the transmit output signal has been inverted by $\text{SCTR.DOCFG} = 01_{\text{B}}$.

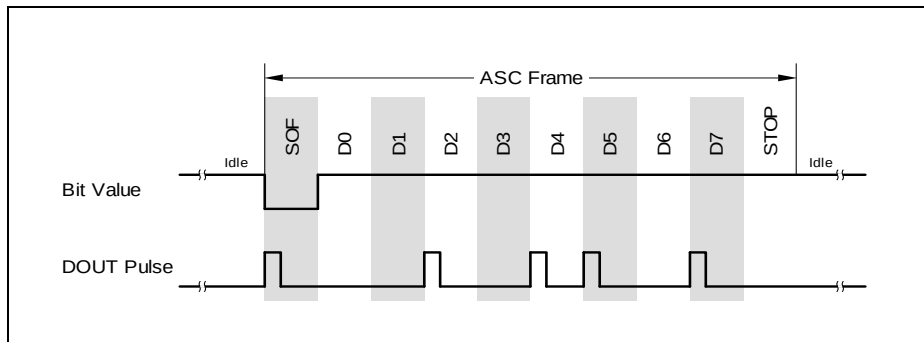


Figure 15-34 Pulse Output Example

15.3.3.6 Automatic Shadow Mechanism

The contents of the protocol control register PCR, as well as bit field SCTR.FLE are internally kept constant while a data frame is transferred by an automatic shadow mechanism (shadowing takes place with each frame start). The registers can be programmed all the time with new settings that are taken into account for the next data frame. During a data frame, the applied (shadowed) setting is not changed, although new values have been written after the start of the data frame.

Bit fields SCTR.WLE and SCTR.SDIR are shadowed automatically with the start of each data word. As a result, a data frame can consist of data words with a different length. It is recommended to change SCTR.SDIR only when no data frame is running to avoid interference between hardware and software.

Please note that the starting point of a data word can be different for a transmitter and a receiver. In order to ensure correct handling, it is recommended to modify SCTR.WLE only while transmitter and receiver are both idle. If the transmitter and the receiver are referring to the same data signal (e.g. in a LIN bus system), SCTR.WLE can be modified while a data transfer is in progress after the RSI event has been detected.

15.3.3.7 End of Frame Control

The number of bits per ASC frame is defined by bit field SCTR.FLE. In order to support different frame length settings for consecutively transmitted frames, this bit field can be modified by hardware. The automatic update mechanism is enabled by TCSR.FLEMD = 1 (in this case, bits TCSR.WLEMD, SELMD, WAMD and HPCMD have to be written with 0).

If enabled, the transmit control information TCI automatically overwrites the bit field TCSR.FLEMD when the ASC frame is started (leading to frames with 1 to 32 data bits). The TCI value represents the written address location of TBUFxx (without additional data

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buffer) or INxx (with additional data buffer). With this mechanism, an ASC with 8 data bits is generated by writing a data word to TBUF07 (IN07, respectively).

15.3.3.8 Mode Control Behavior

In ASC mode, the following kernel modes are supported:

- Run Mode 0/1:
Behavior as programmed, no impact on data transfers.
- Stop Mode 0:
Bit PSR.TXIDLE is cleared. A new transmission is not started. A current transmission is finished normally. Bit PSR.RXIDLE is not modified. Reception is still possible. When leaving stop mode 0, bit TXIDLE is set according to PCR.IDM.
- Stop Mode 1:
Bit PSR.TXIDLE is cleared. A new transmission is not started. A current transmission is finished normally. Bit PSR.RXIDLE is cleared. A new reception is not possible. A current reception is finished normally. When leaving stop mode 1, bits TXIDLE and RXIDLE are set according to PCR.IDM.

15.3.3.9 Disabling ASC Mode

In order to switch off ASC mode without any data corruption, the receiver and the transmitter have to be both idle. This is ensured by requesting Stop Mode 1 in register KSCFG. After waiting for the end of the frame, the ASC mode can be disabled.

15.3.3.10 Protocol Interrupt Events

The following protocol-related events are generated in ASC mode and can lead to a protocol interrupt. The collision detection and the transmitter frame finished events are related to the transmitter, whereas the receiver events are given by the synchronization break detection, the receiver noise detection, the format error checks and the end of the received frame.

Please note that the bits in register PSR are not automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- Collision detection:
This interrupt indicates that the transmitted value (DOUT0) does not match with the input value of the DX1 input stage at the sample point of a bit. For more details refer to [Page 15-60](#).
- Transmitter frame finished:
This interrupt indicates that the transmitter has completely finished a frame. Bit PSR.TFF becomes set at the end of the last stop bit. The DOUT0 signal assignment to port pins can be changed while no transmission is in progress.
- Receiver frame finished:
This interrupt indicates that the receiver has completely finished a frame. Bit

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PSR.RFF becomes set at the end of the last stop bit. The DIN0 signal assignment to port pins can be changed while no reception is in progress.

- Synchronization break detection:
This interrupt can be used in LIN networks to indicate the reception of the synchronization break symbol (at the beginning of a LIN frame).
- Receiver noise detection:
This interrupt indicates that the input value at the sample point of a bit and at the two time quanta before are not identical.
- Format error:
The bit value of the stop bit(s) is defined as 1 level for the ASC protocol. A format error is signalled if the sampled bit value of a stop bit is 0.

15.3.3.11 Data Transfer Interrupt Handling

The data transfer interrupts indicate events related to ASC frame handling.

- Transmit buffer interrupt TBI:
Bit PSR.TBIF is set after the start of first data bit of a data word. This is the earliest point in time when a new data word can be written to TBUF.
With this event, bit TCSR.TDV is cleared and new data can be loaded to the transmit buffer.
- Transmit shift interrupt TSI:
Bit PSR.TSIF is set after the start of the last data bit of a data word.
- Receiver start interrupt RSI:
Bit PSR.RSIF is set after the sample point of the first data bit of a data word.
- Receiver interrupt RI and alternative interrupt AI:
Bit PSR.RIF is set after the sampling point of the last data bit of a data word if this data word is not directly followed by a parity bit (parity generation disabled or not the last word of a data frame).
If the data word is directly followed by a parity bit (last data word of a data frame and parity generation enabled), bit PSR.RIF is set after the sampling point of the parity bit if no parity error has been detected. If a parity error has been detected, bit PSR.AIF is set instead of bit PSR.RIF.
The first data word of a data frame is indicated by RBUFSR.SOF = 1 for the received word.
Bit PSR.RIF is set for a receiver interrupt RI with WA = 0. Bit PSR.AIF is set for a alternative interrupt AI with WA = 1.

15.3.3.12 Baud Rate Generator Interrupt Handling

The baud rate generator interrupt indicate that the capture mode timer has reached its maximum value. With this event, the bit PSR.BRGIF is set.

15.3.3.13 Protocol-Related Argument and Error

The protocol-related argument (RBUFSR.PAR) and the protocol-related error (RBUFSR.PERR) are two flags that are assigned to each received data word in the corresponding receiver buffer status registers.

In ASC mode, the received parity bit is monitored by the protocol-related argument and the result of the parity check by the protocol-related error indication (0 = received parity bit equal to calculated parity value). This information being elaborated only for the last received data word of each data frame, both bit positions are 0 for data words that are not the last data word of a data frame or if the parity generation is disabled.

15.3.3.14 Receive Buffer Handling

If a receive FIFO buffer is available (CCFG.RB = 1) and enabled for data handling (RBCTR.SIZE > 0), it is recommended to set RBCTR.RCIM = 11_b in ASC mode. This leads to an indication that the data word has been the first data word of a new data frame if bit OUTR.RCI[0] = 1, a parity error is indicated by OUTR.RCI[4] = 1, and the received parity bit value is given by OUTR.RCI[3].

The standard receive buffer event and the alternative receive buffer event can be used for the following operations in RCI mode (RBCTR.RNM = 1):

- A standard receive buffer event indicates that a data word can be read from OUTR that has been received without parity error.
- An alternative receive buffer event indicates that a data word can be read from OUTR that has been received with parity error.

15.3.3.15 Sync-Break Detection

The receiver permanently checks the DIN0 signal for a certain number of consecutive bit times with 0 level. The number is given by the number of programmed bits per frame (SCTR.FLE) plus 2 (in the case without parity) or plus 3 (in the case with parity). If a 0 level is detected at a sample point of a bit after this event has been found, bit PSR.SBD is set and additionally, a protocol interrupt can be generated (if enabled by PCR.SBIEN = 1). The counting restarts from 0 each time a falling edge is found at input DIN0. This feature can be used for the detection of a synchronization break for slave devices in a LIN bus system (the master does not check for sync break).

For example, in a configuration for 8 data bits without parity generation, bit PCR.SBD is set after at the next sample point at 0 level after 10 complete bit times have elapsed (representing the sample point of the 11th bit time since the first falling edge).

15.3.3.16 Transfer Status Indication

The receiver status can be monitored by flag PSR[9] = BUSY if bit PCR.CTR[16] (receiver status enable RSTEN) is set. In this case, bit BUSY is set during a complete frame reception from the beginning of the start of frame bit to the end of the last stop bit.

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The transmitter status can be monitored by flag PSR[9] = BUSY if bit PCR.CTR[17] (transmitter status enable TSTEN) is set. In this case, bit BUSY is set during a complete frame reception from the beginning of the start of frame bit to the end of the last stop bit. If both bits RSTEN and TSTEN are set, flag BUSY indicates the logical OR-combination of the receiver and the transmitter status. If both bits are cleared, flag BUSY is not modified depending on the transfer status (status changes are ignored).

15.3.4 ASC Protocol Registers

In ASC mode, the registers PCR and PSR handle ASC related information.

15.3.4.1 ASC Protocol Control Register

In ASC mode, the PCR register bits or bit fields are defined as described in this section.

PCR

Protocol Control Register [ASC Mode]

(3C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MCL K							0							TST EN	RST EN
rw							r							rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	PL				SP			FFIE N	FEIE N	RNIE N	CDE N	SBIE N	IDM	STP B	SMD
	rw				rw			rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
SMD	0	rw	Sample Mode This bit field defines the sample mode of the ASC receiver. The selected data input signal can be sampled only once per bit time or three times (in consecutive time quanta). When sampling three times, the bit value shifted in the receiver shift register is given by a majority decision among the three sampled values. 0 _B Only one sample is taken per bit time. The current input value is sampled. 1 _B Three samples are taken per bit time and a majority decision is made.

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Field	Bits	Type	Description
STPB	1	rw	Stop Bits This bit defines the number of stop bits in an ASC frame. 0 _B The number of stop bits is 1. 1 _B The number of stop bits is 2.
IDM	2	rw	Idle Detection Mode This bit defines if the idle detection is switched off or based on the frame length. 0 _B The bus idle detection is switched off and bits PSR.TXIDLE and PSR.RXIDLE are set automatically to enable data transfers without checking the inputs before. 1 _B The bus is considered as idle after a number of consecutive passive bit times defined by SCTR.FLE plus 2 (in the case without parity bit) or plus 3 (in the case with parity bit).
SBIEN	3	rw	Synchronization Break Interrupt Enable This bit enables the generation of a protocol interrupt if a synchronization break is detected. The automatic detection is always active, so bit SBD can be set independently of SBIEN. 0 _B The interrupt generation is disabled. 1 _B The interrupt generation is enabled.
CDEN	4	rw	Collision Detection Enable This bit enables the reaction of a transmitter to the collision detection. 0 _B The collision detection is disabled. 1 _B If a collision is detected, the transmitter stops its data transmission, outputs a 1, sets bit PSR.COL and generates a protocol interrupt. In order to allow data transmission again, PSR.COL has to be cleared by software.
RNIEN	5	rw	Receiver Noise Detection Interrupt Enable This bit enables the generation of a protocol interrupt if receiver noise is detected. The automatic detection is always active, so bit PSR.RNS can be set independently of PCR.RNIEN. 0 _B The interrupt generation is disabled. 1 _B The interrupt generation is enabled.

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Field	Bits	Type	Description
FEIEN	6	rw	Format Error Interrupt Enable This bit enables the generation of a protocol interrupt if a format error is detected. The automatic detection is always active, so bits PSR.FER0/FER1 can be set independently of PCR.FEIEN. 0 _B The interrupt generation is disabled. 1 _B The interrupt generation is enabled.
FFIEN	7	rw	Frame Finished Interrupt Enable This bit enables the generation of a protocol interrupt if the receiver or the transmitter reach the end of a frame. The automatic detection is always active, so bits PSR.RFF or PSR.TFF can be set independently of PCR.FFIEN. 0 _B The interrupt generation is disabled. 1 _B The interrupt generation is enabled.
SP	[12:8]	rw	Sample Point This bit field defines the sample point of the bit value. The sample point must not be located outside the programmed bit timing ($PCR.SP \leq BRG.DCTQ$).
PL	[15:13]	rw	Pulse Length This bit field defines the length of a 0 data bit, counted in time quanta, starting with the time quantum 0 of each bit time. Each bit value that is a 0 can lead to a 0 pulse that is shorter than a bit time, e.g. for IrDA applications. The length of a bit time is not changed by PL, only the length of the 0 at the output signal. The pulse length must not be longer than the programmed bit timing ($PCR.PL \leq BRG.DCTQ$). This bit field is only taken into account by the transmitter and is ignored by the receiver. 000 _B The pulse length is equal to the bit length (no shortened 0). 001 _B The pulse length of a 0 bit is 2 time quanta. 010 _B The pulse length of a 0 bit is 3 time quanta. ... 111 _B The pulse length of a 0 bit is 8 time quanta.

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Field	Bits	Type	Description
RSTEN	16	rw	Receiver Status Enable This bit enables the modification of flag PSR[9] = BUSY according to the receiver status. 0 _B Flag PSR[9] is not modified depending on the receiver status. 1 _B Flag PSR[9] is set during the complete reception of a frame.
TSTEN	17	rw	Transmitter Status Enable This bit enables the modification of flag PSR[9] = BUSY according to the transmitter status. 0 _B Flag PSR[9] is not modified depending on the transmitter status. 1 _B Flag PSR[9] is set during the complete transmission of a frame.
MCLK	31	rw	Master Clock Enable This bit enables the generation of the master clock MCLK. 0 _B The MCLK generation is disabled and the MCLK signal is 0. 1 _B The MCLK generation is enabled.
0	[30:18]	r	Reserved Returns 0 if read; should be written with 0.

15.3.4.2 ASC Protocol Status Register

In ASC mode, the PSR register bits or bit fields are defined as described in this section. The bits and bit fields in register PSR are not cleared by hardware.

The flags in the PSR register can be cleared by writing a 1 to the corresponding bit position in register PSCR. Writing a 1 to a bit position in PSR sets the corresponding flag, but does not lead to further actions (no interrupt generation). Writing a 0 has no effect. The PSR flags should be cleared by software before enabling a new protocol.

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PSR

Protocol Status Register [ASC Mode] (48_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															BRG IF
r															rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIF	RIF	TBIF	TSIF	DLIF	RSIF	BUS Y	TFF	RFF	FER 1	FER 0	RNS	COL	SBD	RXID LE	TXID LE
rwh	rwh	rwh	rwh	rwh	rwh	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
TXIDLE	0	rwh	Transmission Idle This bit shows if the transmit line (DX1) has been idle. A frame transmission can only be started if TXIDLE is set. 0 _B The transmitter line has not yet been idle. 1 _B The transmitter line has been idle and frame transmission is possible.
RXIDLE	1	rwh	Reception Idle This bit shows if the receive line (DX0) has been idle. A frame reception can only be started if RXIDLE is set. 0 _B The receiver line has not yet been idle. 1 _B The receiver line has been idle and frame reception is possible.
SBD	2	rwh	Synchronization Break Detected¹⁾ This bit is set if a programmed number of consecutive bit values with level 0 has been detected (called synchronization break, e.g. in a LIN bus system). 0 _B A synchronization break has not yet been detected. 1 _B A synchronization break has been detected.
COL	3	rwh	Collision Detected¹⁾ This bit is set if a collision has been detected (with PCR.CDEN = 1). 0 _B A collision has not yet been detected and frame transmission is possible. 1 _B A collision has been detected and frame transmission is not possible.

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Field	Bits	Type	Description
RNS	4	rwh	Receiver Noise Detected¹⁾ This bit is set if receiver noise has been detected. 0 _B Receiver noise has not been detected. 1 _B Receiver noise has been detected.
FER0	5	rwh	Format Error in Stop Bit 0¹⁾ This bit is set if a 0 has been sampled in the stop bit 0 (called format error 0). 0 _B A format error 0 has not been detected. 1 _B A format error 0 has been detected.
FER1	6	rwh	Format Error in Stop Bit 1¹⁾ This bit is set if a 0 has been sampled in the stop bit 1 (called format error 1). 0 _B A format error 1 has not been detected. 1 _B A format error 1 has been detected.
RFF	7	rwh	Receive Frame Finished¹⁾ This bit is set if the receiver has finished the last stop bit. 0 _B The received frame is not yet finished. 1 _B The received frame is finished.
TFF	8	rwh	Transmitter Frame Finished¹⁾ This bit is set if the transmitter has finished the last stop bit. 0 _B The transmitter frame is not yet finished. 1 _B The transmitter frame is finished.
BUSY	9	r	Transfer Status BUSY This bit indicates the receiver status (if PCR.RSTEN = 1) or the transmitter status (if PCR.TSTEN = 1) or the logical OR combination of both (if PCR.RSTEN = PCR.TSTEN = 1). 0 _B A data transfer does not take place. 1 _B A data transfer currently takes place.
RSIF	10	rwh	Receiver Start Indication Flag 0 _B A receiver start event has not occurred. 1 _B A receiver start event has occurred.
DLIF	11	rwh	Data Lost Indication Flag 0 _B A data lost event has not occurred. 1 _B A data lost event has occurred.
TSIF	12	rwh	Transmit Shift Indication Flag 0 _B A transmit shift event has not occurred. 1 _B A transmit shift event has occurred.

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Field	Bits	Type	Description
TBIF	13	rwh	Transmit Buffer Indication Flag 0 _B A transmit buffer event has not occurred. 1 _B A transmit buffer event has occurred.
RIF	14	rwh	Receive Indication Flag 0 _B A receive event has not occurred. 1 _B A receive event has occurred.
AIF	15	rwh	Alternative Receive Indication Flag 0 _B An alternative receive event has not occurred. 1 _B An alternative receive event has occurred.
BRGIF	16	rwh	Baud Rate Generator Indication Flag 0 _B A baud rate generator event has not occurred. 1 _B A baud rate generator event has occurred.
0	[31:17]	r	Reserved Returns 0 if read; should be written with 0.

1) This status bit can generate a protocol interrupt (see [Page 15-22](#)). The general interrupt status flags are described in the general interrupt chapter.

15.3.5 Hardware LIN Support

In order to support the LIN protocol, bit TCSR.FLEMD = 1 should be set for the master. For slave devices, it can be cleared and the fixed number of 8 data bits has to be set (SCTR.FLE = 7_H). For both, master and slave devices, the parity generation has to be switched off (CCR.PM = 00_B) and transfers take place with LSB first (SCTR.SDIR = 0) and 1 stop bit (PCR.STPB = 0).

The Local Interconnect Network (LIN) data exchange protocol contains several symbols that can all be handled in ASC mode. Each single LIN symbol represents a complete ASC frame. The LIN bus is a master-slave bus system with a single master and multiple slaves (for the exact definition please refer to the official LIN specification).

A complete LIN frame contains the following symbols:

- Synchronization break:

The master sends a synchronization break to signal the beginning of a new frame. It contains at least 13 consecutive bit times at 0 level, followed by at least one bit time at 1 level (corresponding to 1 stop bit). Therefore, TBUF11 if the transmit buffer is used, (or IN11 if the FIFO buffer is used) has to be written with 0 (leading to a frame with SOF followed by 12 data bits at 0 level).

A slave device shall detect 11 consecutive bit times at 0 level, which done by the synchronization break detection. Bit PSR.SBD is set if such an event is detected and a protocol interrupt can be generated. Additionally, the received data value of 0 appears in the receive buffer and a format error is signaled.

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If the baud rate of the slave has to be adapted to the master, the baud rate measurement has to be enabled for falling edges by setting $BRG.TMEN = 1$, $DX0CR.CM = 10_H$ and $DX1CR.CM = 00_H$ before the next symbol starts.

- Synchronization byte:
The master sends this symbol after writing the data value 55_H to TBUF07 (or IN07). A slave device can either receive this symbol without any further action (and can discard it) or it can use the falling edges for baud rate measurement. Bit $PSR.TSIF = 1$ (with optionally the corresponding interrupt) indicates the detection of a falling edge and the capturing of the elapsed time since the last falling edge in $CMTR.CTV$. Valid captured values can be read out after the second, third, fourth and fifth activation of $TSIF$. After the fifth activation of $TSIF$ within this symbol, the baud rate detection can be disabled ($BRG.TMEN = 0$) and $BRG.PDIV$ can be programmed with the captured $CMTR.CTV$ value divided by twice the number of time quanta per bit (assuming $BRG.PCTQ = 00_B$).
- Other symbols:
The other symbols of a LIN frame can be handled with ASC data frames without specific actions.

If LIN frames should be sent out on a frame base by the LIN master, the input $DX2$ can be connected to external timers to trigger the transmit actions (e.g. the synchronization break symbol has been prepared but is started if a trigger occurs). Please note that during the baud rate measurement of the ASC receiver, the ASC transmitter of the same USIC channel can still perform a transmission.

15.4 Synchronous Serial Channel (SSC)

The synchronous serial channel SSC covers the data transfer function of an SPI-like module. It can handle reception and transmission of synchronous data frames between a device operating in master mode and at least one device in slave mode. Besides the standard SSC protocol consisting of one input and one output data line, SSC protocols with two (Dual-SSC) or four (Quad-SSC) input/output data lines are also supported. The SSC mode is selected by $CCR.MODE = 0001_B$ with $CCFG.SSC = 1$ (SSC mode is available).

15.4.1 Signal Description

A synchronous SSC data transfer is characterized by a simultaneous transfer of a shift clock signal together with the transmit and/or receive data signal(s) to determine when the data is valid (definition of transmit and sample point).

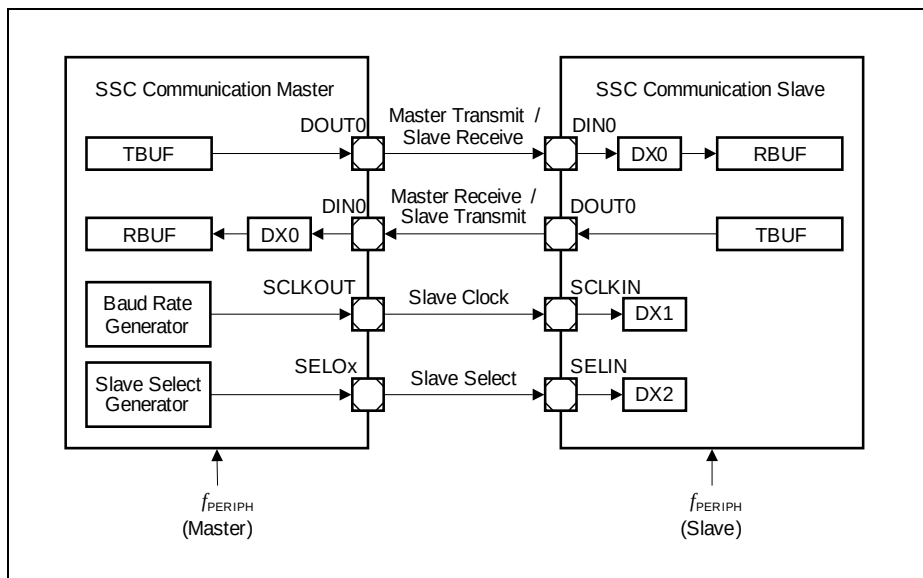


Figure 15-35 SSC Signals for Standard Full-Duplex Communication

In order to explicitly indicate the start and the end of a data transfer and to address more than one slave devices individually, the SSC module supports the handling of slave select signals. They are optional and are not necessarily needed for SSC data transfers. The SSC module supports up to 8 different slave select output signals for master mode operation (named $SELOx$, with $x = 0-7$) and 1 slave select input $SELIN$ for slave mode. In most applications, the slave select signals are active low.

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A device operating in master mode controls the start and end of a data frame, as well as the generation of the shift clock and slave select signals. This comprises the baud rate setting for the shift clock and the delays between the shift clock and the slave select output signals. If several SSC modules are connected together, there can be only one SSC master at a time, but several slaves. Slave devices receive the shift clock and optionally a slave select signal(s). For the programming of the input stages DXn please refer to [Page 15-22](#).

Table 15-12 SSC Communication Signals

SSC Mode	Receive Data	Transmit Data	Shift Clock	Slave Select(s)
Standard SSC Master	MRST ¹⁾ , input DIN0, handled by DX0	MTSR ²⁾ , Output DOUT0	Output SCLKOUT	Output(s) SELOx
Standard SSC Slave	MTSR, input DIN0, handled by DX0	MRST, Output DOUT0	Input SCLKIN, handled by DX1	input SELIN, handled by DX2
Dual-SSC Master	MRST[1:0], input DIN[1:0], handled by DX0 and DX3	MTSR[1:0], Output DOUT[1:0]	Output SCLKOUT	Output(s) SELOx
Dual-SSC Slave	MTSR[1:0], input DIN[1:0], handled by DX0 and DX3	MRST[1:0], Output DOUT[1:0]	Input SCLKIN, handled by DX1	input SELIN, handled by DX2
Quad-SSC Master	MRST[3:0], input DIN[3:0], handled by DX0, DX3, DX4 and DX5	MTSR[3:0], Output DOUT[3:0]	Output SCLKOUT	Output(s) SELOx
Quad-SSC Slave	MTSR[3:0], input DIN[3:0], handled by DX0, DX3, DX4 and DX5	MRST[3:0], Output DOUT[3:0]	Input SCLKIN, handled by DX1	input SELIN, handled by DX2

1) MRST = master receive slave transmit, also known as MISO = master in slave out

2) MTSR = master transmit slave receive, also known as MOSI = master out slave in

Universal Serial Interface Channel (USIC)

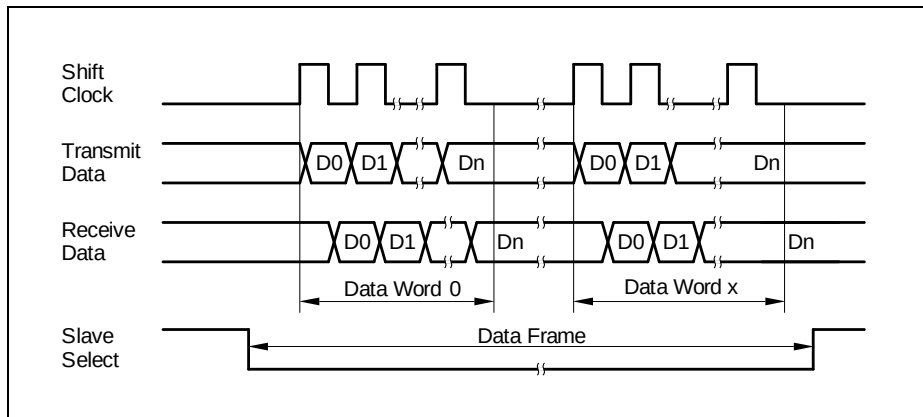


Figure 15-36 4-Wire SSC Standard Communication Signals

15.4.1.1 Transmit and Receive Data Signals

In standard SSC half-duplex mode, a single data line is used, either for data transfer from the master to a slave or from a slave to the master. In this case, MRST and MTSR are connected together, one signal as input, the other one as output, depending on the data direction. The user software has to take care about the data direction to avoid data collision (e.g. by preparing dummy data of all 1s for transmission in case of a wired AND connection with open-drain drivers, by enabling/disabling push/pull output drivers or by switching pin direction with hardware port control enabled). In full-duplex mode, data transfers take place in parallel between the master device and a slave device via two independent data signals MTSR and MRST, as shown in [Figure 15-35](#).

The receive data input signal DIN0 is handled by the input stage DX0. In master mode (referring to MRST) as well as in slave mode (referring to MTSR), the data input signal DIN0 is taken from an input pin. The signal polarity of DOUT0 (data output) with respect to the data bit value can be configured in block DOCFG (data output configuration) by bit field SCTR.DOCFG.

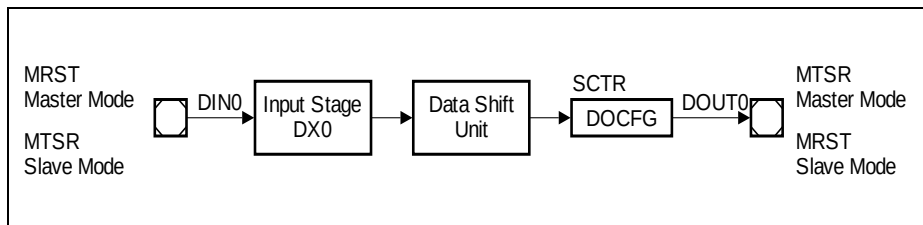


Figure 15-37 SSC Data Signals

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For dual- and quad-SSC modes that require multiple input and output data lines to be used, additional input stages, DINx and DOUTx signals need to be set up.

15.4.1.2 Shift Clock Signals

The shift clock signal is handled by the input stage DX1. In slave mode, the signal SCLKIN is received from an external master, so the DX1 stage has to be connected to an input pin. The input stage can invert the received input signal to adapt to the polarity of SCLKIN to the function of the data shift unit (data transmission on rising edges, data reception on falling edges).

In master mode, the shift clock is generated by the internal baud rate generator. The output signal SCLK of the baud rate generator is taken as shift clock input for the data shift unit. The internal signal SCLK is made available for external slave devices by signal SCLKOUT. For complete closed loop delay compensation in a slave mode, SCLKOUT can also take the transmit shift clock from the input stage DX1. The selection is done through the bit BRG.SCLKOSEL. See [Section 15.4.6.3](#).

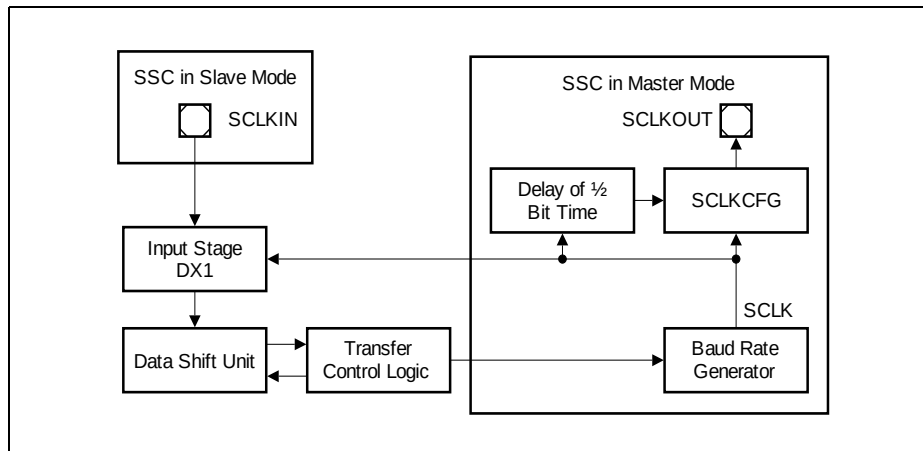


Figure 15-38 SSC Shift Clock Signals

Due to the multitude of different SSC applications, in master mode, there are different ways to configure the shift clock output signal SCLKOUT with respect to SCLK. This is done in the block SCLKCFG (shift clock configuration) by bit field BRG.SCLKCFG, allowing 4 possible settings, as shown in [Figure 15-39](#).

- No delay, no polarity inversion (SCLKCFG = 00_b, SCLKOUT equals SCLK):
The inactive level of SCLKOUT is 0, while no data frame is transferred. The first data bit of a new data frame is transmitted with the first rising edge of SCLKOUT and the first data bit is received in with the first falling edge of SCLKOUT. The last data bit of a data frame is transmitted with the last rising clock edge of SCLKOUT and the last

Universal Serial Interface Channel (USIC)

data bit is received in with the last falling edge of SCLKOUT. This setting can be used in master and in slave mode. It corresponds to the behavior of the internal data shift unit.

- No delay, polarity inversion (SCLKCFG = 01_B):
 The inactive level of SCLKOUT is 1, while no data frame is transferred. The first data bit of a new data frame is transmitted with the first falling clock edge of SCLKOUT and the first data bit is received with the first rising edge of SCLKOUT. The last data bit of a data frame is transmitted with the last falling edge of SCLKOUT and the last data bit is received with the last rising edge of SCLKOUT.
 This setting can be used in master and in slave mode. For slave mode, bit field DX1CR.DPOL = 1_B has to be programmed.
- SCLKOUT is delayed by 1/2 shift clock period, no polarity inversion (SCLKCFG = 10_B):
 The inactive level of SCLKOUT is 0, while no data frame is transferred.
 The first data bit of a new data frame is transmitted 1/2 shift clock period before the first rising clock edge of SCLKOUT. Due to the delay, the next data bits seem to be transmitted with the falling edges of SCLKOUT. The last data bit of a data frame is transmitted 1/2 period of SCLKOUT before the last rising clock edge of SCLKOUT. The first data bit is received 1/2 shift clock period before the first falling edge of SCLKOUT. Due to the delay, the next data bits seem to be received with the rising edges of SCLKOUT. The last data bit is received 1/2 period of SCLKOUT before the last falling clock edge of SCLKOUT.
 This setting can be used only in master mode and not in slave mode (the connected slave has to provide the first data bit before the first SCLKOUT edge, e.g. as soon as it is addressed by its slave select).
- SCLKOUT is delayed by 1/2 shift clock period, polarity inversion (SCLKCFG = 11_B):
 The inactive level of SCLKOUT is 1, while no data frame is transferred.
 The first data bit of a new data frame is transmitted 1/2 shift clock period before the first falling clock edge of SCLKOUT. Due to the delay, the next data bits seem to be transmitted with the rising edges of SCLKOUT. The last data bit of a data frame is transmitted 1/2 period of SCLKOUT before the last falling clock edge of SCLKOUT. The first data bit is received 1/2 shift clock period before the first rising edge of SCLKOUT. Due to the delay, the next data bits seem to be received with the falling edges of SCLKOUT. The last data bit is received 1/2 period of SCLKOUT before the last rising clock edge of SCLKOUT.
 This setting can be used only in master mode and not in slave mode (the connected slave has to provide the first data bit before the first SCLKOUT edge, e.g. as soon as it is addressed by its slave select).

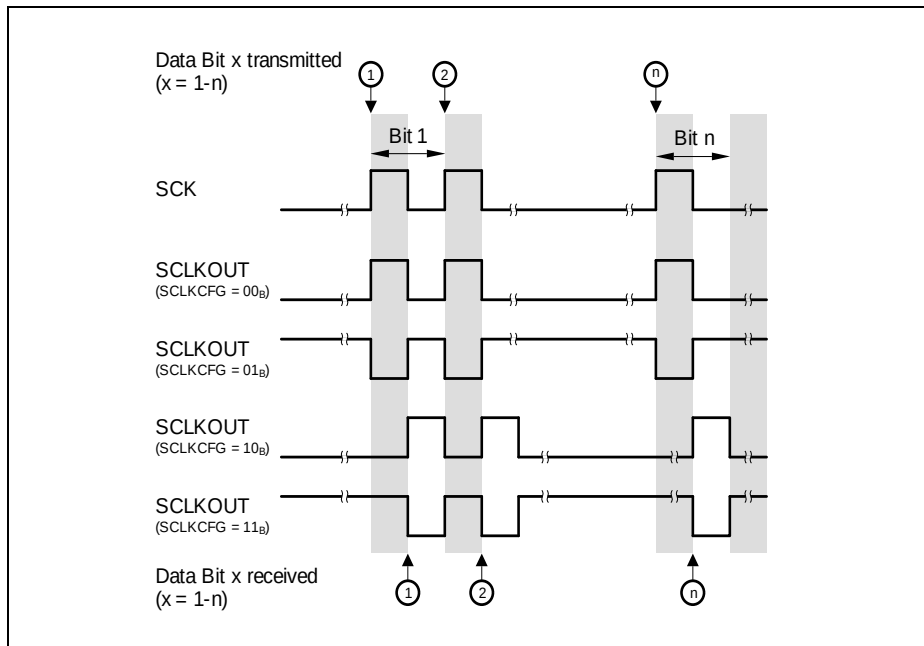


Figure 15-39 SCLKOUT Configuration in SSC Master Mode

Note: If a configuration with delay is selected and a slave select line is used, the slave select delays have to be set up accordingly.

In SSC slave mode, the bit PCR.SLPSEL can be used to configure the clock phase of the data shift.

- When SLPSEL = 0_B, the slave SSC transmits data bits with each leading edge of the selected shift clock input (SCLKIN) and receives data bits with each trailing edge of SCLKIN
- When SLPSEL = 1_B, the slave SSC transmits the first data bit once the selected slave select input (SELIN) becomes active. If SELIN is not used, the DX2 stage has to deliver a 1-level to the data shift unit to shift out the first bit. Subsequent data bits are then transmitted with each trailing edge of SCLKIN. The SSC slave receives all data bits with each leading edge of SCLKIN.

For both settings, the clock polarity is determined by bit 0 of SCLKCFG.

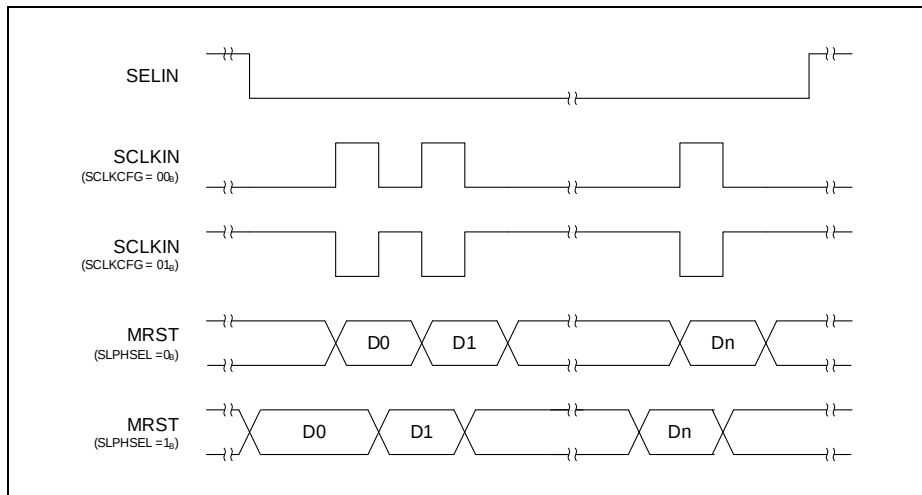


Figure 15-40 SLPHSEL Configuration in SSC Slave Mode

15.4.1.3 Slave Select Signals

The slave select signal is handled by the input stage DX2. In slave mode, the input signal SELIN is received from an external master via an input pin. The input stage can invert the received input signal to adapt the polarity of signal SELIN to the function of the data shift unit (the module internal signals are considered as high active, so a data transfer is only possible while the slave select input of the data shift unit is at 1-level, otherwise, shift clock pulses are ignored and do not lead to data transfers). If an input signal SELIN is low active, it should be inverted in the DX2 input stage.

In master mode, a master slave select signal MSLS is generated by the internal slave select generator. In order to address different external slave devices independently, the internal MSLS signal is made available externally via up to 8 SELO_x output signals that can be configured by the block SELCFG (select configuration).

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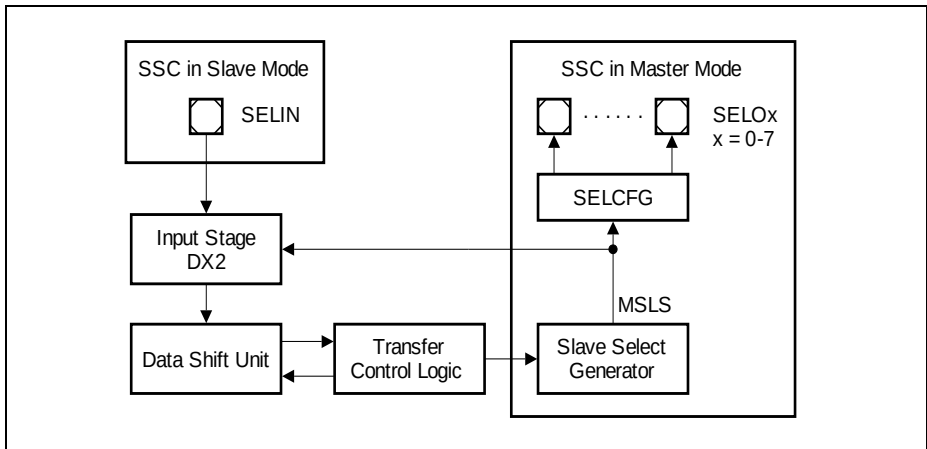


Figure 15-41 SSC Slave Select Signals

The control of the SELCFG block is based on protocol specific bits and bit fields in the protocol control register PCR. For the generation of the MSLS signal please refer to [Section 15.4.3.2](#).

- PCR.SELCTR to chose between direct and coded select mode
- PCR.SELINV to invert the SELOx outputs
- PCR.SELO[7:0] as individual value for each SELOx line

The SELCFG block supports the following configurations of the SELOx output signals:

- **Direct Select Mode (SELCTR = 1):**
 Each SELOx line (with x = 0-7) can be directly connected to an external slave device. If bit x in bit field SELO is 0, the SELOx output is permanently inactive. A SELOx output becomes active while the internal signal MSLS is active (see [Section 15.4.3.2](#)) and bit x in bit field SELO is 1. Several external slave devices can be addressed in parallel if more than one bit in bit field SELO are set during a data frame. The number of external slave devices that can be addressed individually is limited to the number of available SELOx outputs.
- **Coded Select Mode (SELCTR = 0):**
 The SELOx lines (with x = 1-7) can be used as addresses for an external address decoder to increase the number of external slave devices. These lines only change with the start of a new data frame and have no other relation to MSLS. Signal SELO0 can be used as enable signal for the external address decoder. It is active while MSLS is active (during a data frame) and bit 0 in bit field SELO is 1. Furthermore, in coded select mode, this output line is delayed by one cycle of f_{PERIPH} compared to MSLS to allow the other SELOx lines to stabilize before enabling the address decoder.

15.4.2 Operating the SSC

This chapter contains SSC issues, that are of general interest and not directly linked to either master mode or slave mode.

15.4.2.1 Automatic Shadow Mechanism

The contents of the baud rate control register BRG, bit fields SCTR.FLE as well as the protocol control register PCR are internally kept constant while a data frame is transferred (= while MSLS is active) by an automatic shadow mechanism. The registers can be programmed all the time with new settings that are taken into account for the next data frame. During a data frame, the applied (shadowed) setting is not changed, although new values have been written after the start of the data frame.

Bit fields SCTR.WLE, SCTR.DSM, SCTR.HPCDIR and SCTR.SDIR are shadowed automatically with the start of each data word. As a result, a data frame can consist of data words with a different length, or data words that are transmitted or received through different number of data lines. It is recommended to change SCTR.SDIR only when no data frame is running to avoid interference between hardware and software.

Please note that the starting point of a data word are different for a transmitter (first bit transmitted) and a receiver (first bit received). In order to ensure correct handling, it is recommended to refer to the receive start interrupt RSI before modifying SCTR.WLE. If TCSR.WLEMD = 1, it is recommended to update TCSR and TBUFxx after the receiver start interrupt has been generated.

15.4.2.2 Mode Control Behavior

In SSC mode, the following kernel modes are supported:

- Run Mode 0/1:
Behavior as programmed, no impact on data transfers.
- Stop Mode 0/1:
The content of the transmit buffer is considered as not valid for transmission. Although being considered as 0, bit TCSR.TDV it is not modified by the stop mode condition.
In master mode, a currently running word transfer is finished normally, but no new data word is started (the stop condition is not considered as end-of-frame condition). In slave mode, a currently running word transfer is finished normally. Passive data will be sent out instead of a valid data word if a data word transfer is started by the external master while the slave device is in stop mode. In order to avoid passive slave transmit data, it is recommended not to program stop mode for an SSC slave device if the master device does not respect the slave device's stop mode.

15.4.2.3 Disabling SSC Mode

In order to disable SSC mode without any data corruption, the receiver and the transmitter have to be both idle. This is ensured by requesting Stop Mode 1 in register KSCFG. After Stop Mode 1 has been acknowledged by KSCFG.2 = 1, the SSC mode can be disabled.

15.4.2.4 Data Frame Control

An SSC data frame can consist of several consecutive data words that may be separated by an inter-word delay. Without inter-word delay, the data words seem to form a longer data word, being equivalent to a data frame. The length of the data words are most commonly identical within a data frame, but may also differ from one word to another. The data word length information (defined by SCTR.WLE) is evaluated for each new data word, whereas the frame length information (defined by SCTR.FLE) is evaluated at the beginning at each start of a new frame.

The length of an SSC data frame can be defined in two different ways:

- By the number of bits per frame:
If the number of bits per data frame is defined (frame length FLE), a slave select signal is not necessarily required to indicate the start and the end of a data frame.
If the programmed number of bits per frame is reached within a data word, the frame is considered as finished and remaining data bits in the last data word are ignored and are not transferred.
This method can be applied for data frames with up to 63 data bits.
- By the slave select signal:
If the number of bits per data frame is not known, the start/end information of a data frame is given by a slave select signal. If a deactivation of the slave select signal is detected within a data word, the frame is considered as finished and remaining data bits in the last data word are ignored and are not transferred.
This method has to be applied for frames with more than 63 data bits (programming limit of FLE). The advantage of slave select signals is the clearly defined start and end condition of data frames in a data stream. Furthermore, slave select signals allow to address slave devices individually.

15.4.2.5 Parity Mode

The SSC allows parity generation for transmission and parity check for reception on frame base. The type of parity can be selected by bit field CCR.PM, common for transmission and reception (no parity, even or odd parity). If the parity handling is disabled, the SSC frame does not contain any parity bit. For consistency reasons, all communication partners have to be programmed to the same parity mode.

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If parity generation has been enabled, the transmitter automatically extends the clock by one cycle after the last data word of the data frame, and sends out its calculated parity bit in this cycle.

Figure 15-42 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 with parity is always one more than that without parity. The parity bit is transmitted as the last bit of a frame, following the data bits, independent of the shift direction (SCTR.SDIR).

Note: For dual and quad SSC protocols, the parity bit will be transmitted and received only on DOUT0 and DX0 respectively in the extended clock cycle.

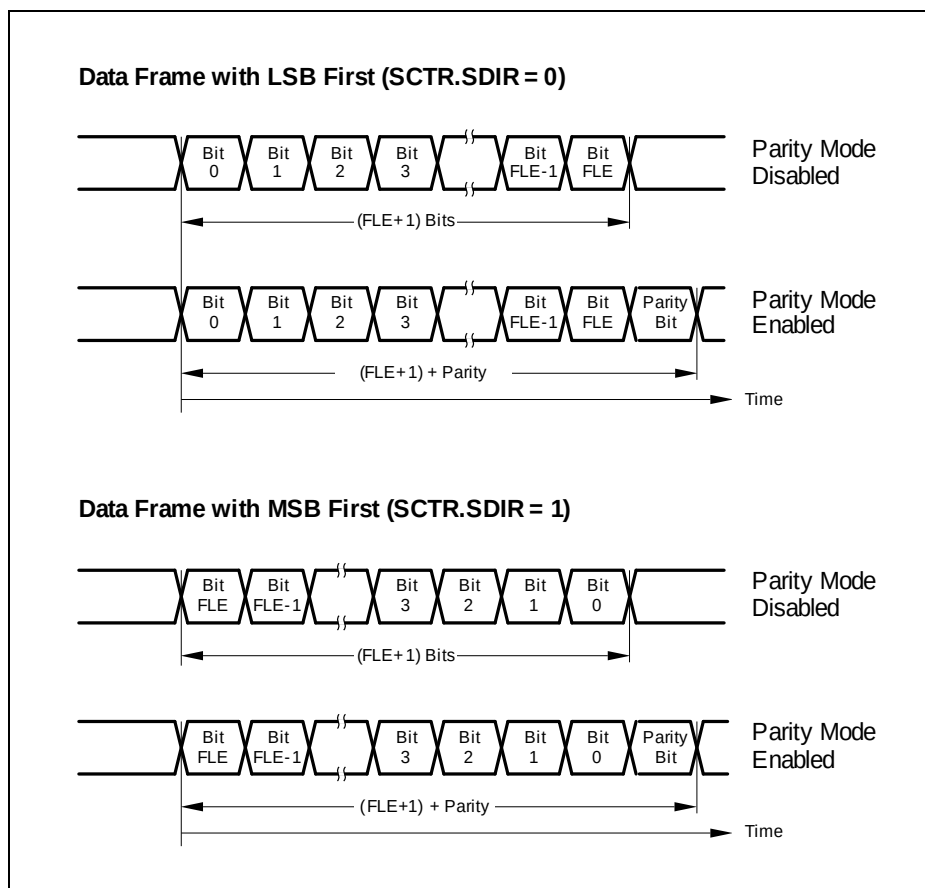


Figure 15-42 Data Frames without/with Parity

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Similarly, after the receiver receives the last word of a data frame as defined by FLE, it expects an additional one clock cycle, which will contain the parity bit. The receiver interprets this bit as received parity and separates it from the received data. The received parity bit value is instead monitored in the protocol-related argument (PAR) of the receiver buffer status registers as receiver buffer status information. The receiver compares the bit to its internally calculated parity and the result of the parity check is indicated by the flag PSR.PARERR. The parity error event generates a protocol interrupt if PCR.PARIEN = 1.

Parity bit generation and detection is not supported for the following cases:

- When frame length is 64 data bits or greater, i.e. $FLE = 63_H$;
- When in slave mode, the end of frame occurs before the number of data bits defined by FLE is reached.

15.4.2.6 Transfer Mode

In SSC mode, bit field SCTR.TRM = 01_B has to be programmed to allow data transfers. Setting SCTR.TRM = 00_B disables and stops the data transfer immediately.

15.4.2.7 Data Transfer Interrupt Handling

The data transfer interrupts indicate events related to SSC frame handling.

- Transmit buffer interrupt TBI:
Bit PSR.TBIF is set after the start of first data bit of a data word.
- Transmit shift interrupt TSI:
Bit PSR.TSIF is set after the start of the last data bit of a data word.
- Receiver start interrupt RSI:
Bit PSR.RSIF is set after the reception of the first data bit of a data word.
With this event, bit TCSR.TDV is cleared and new data can be loaded to the transmit buffer.
- Receiver interrupt RI:
The reception of the second, third, and all subsequent words in a multi-word frame is always indicated by RBUFSR.SOF = 0. Bit PSR.RIF is set after the reception of the last data bit of a data word if RBUFSR.SOF = 0.
Bit RBUFSR.SOF indicates whether the received data word has been the first data word of a multi-word frame or some subsequent word. In SSC mode, it decides if alternative interrupt or receive interrupt is generated.
- Alternative interrupt AI:
The reception of the first word in a frame is always indicated by RBUFSR.SOF = 1. This is true both in case of reception of multi-word frames and single-word frames. In SSC mode, this results in setting PSR.AIF.

15.4.2.8 Baud Rate Generator Interrupt Handling

The baud rate generator interrupt indicate that the capture mode timer has reached its maximum value. With this event, the bit PSR.BRGIF is set.

15.4.2.9 Protocol-Related Argument and Error

The protocol-related argument (RBUFSR.PAR) and the protocol-related error (RBUFSR.PERR) are two flags that are assigned to each received data word in the corresponding receiver buffer status registers.

In SSC mode, the received parity bit is monitored by the protocol-related argument. The received start of frame indication is monitored by the protocol-related error indication (0 = received word is not the first word of a frame, 1 = received word is the first word of a new frame).

Note: For SSC, the parity error event indication bit is located in the PSR register.

15.4.2.10 Receive Buffer Handling

If a receive FIFO buffer is available (CCFG.RB = 1) and enabled for data handling (RBCTR.SIZE > 0), it is recommended to set RBCTR.RCIM = 01_b in SSC mode. This leads to an indication that the data word has been the first data word of a new data frame if bit OUTR.RCI[4] = 1, and the word length of the received data is given by OUTR.RCI[3:0].

The standard receive buffer event and the alternative receive buffer event can be used for the following operation in RCI mode (RBCTR.RNM = 1):

- A standard receive buffer event indicates that a data word can be read from OUTR that has not been the first word of a data frame.
- An alternative receive buffer event indicates that the first data word of a new data frame can be read from OUTR.

15.4.2.11 Multi-IO SSC Protocols

The SSC implements the following three features to support multiple data input/output SSC protocols, such as the dual- and quad-SSC:

1. Data Shift Mode ([Section 15.2.5.2](#))
Configures the data for transmission and reception using one, two or four data lines in parallel, through the bit field SCTR.DSM.
2. Hardware Port Control ([Section 15.2.7](#))
Sets up a dedicated hardware interface to control the direction of the pins overlaid with both DINx and DOUTx functions, through the bit SCTR.HPCDIR.
3. Transmit Control Information ([Section 15.2.5.3](#))
Allows the dynamic control of both the shift mode and pin direction during data transfers by writing to SCTR.DSM and SCTR.HPCDIR with TCI.

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Figure 15-43 shows an example of a Quad-SSC protocol, which requires the master SSC to first transmit a command byte (to request a quad output read from the slave) and a dummy byte through a single data line. At the end of the dummy byte, both master and slave SSC switches to quad data lines, and with the roles of transmitter and receiver reversed. The master SSC then receives the data four bits per shift clock from the slave through the MRST[3:0] lines.

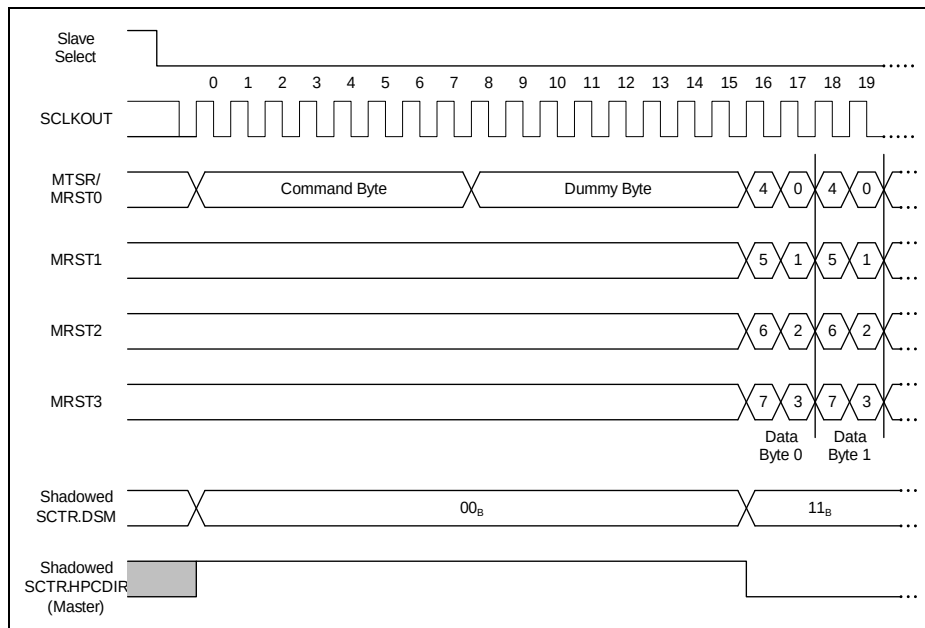


Figure 15-43 Quad-SSC Example

To work with the quad-SSC protocol in the given example, the following issues have to be additionally considered on top of those defined in [Section 15.4.3](#) and [Section 15.4.4](#):

- During the initialization phase:
 - Set CCR.HPCEN to 11_B to enable the dedicated hardware interface to the DX0/DOUT0, DX3/DOUT1, DX4/DOUT2 and DX5/DOUT3 pins.
 - Set TCSR.[4:0] to 10_H to enable hardware port control in TC1
- To start the data transfer:
 - For the master SSC, write the command and dummy bytes into TBUF04 to select a single data line in output mode and initiate the data transfer.
 - For the slave SSC, dummy data can be preloaded into TBUF00 to select a single data line in input mode.
- To switch to quad data lines and pin direction:

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- For the master SSC, write subsequent dummy data to TBUF03 to select quad data lines in input mode to read in valid slave data.
- For the slave SSC, write valid data to TBUF07 for transmission through quad data lines in output mode.

Note: If DOUT[1:0] or DOUT[3:0] pins are already enabled with CCR.HPCEN but SCTR.DSM does not use all pins, the unused DOUTx pins output the passive data level defined by SCTR.PDL.

Figure 15-44 shows the connections for the Quad-SSC example.

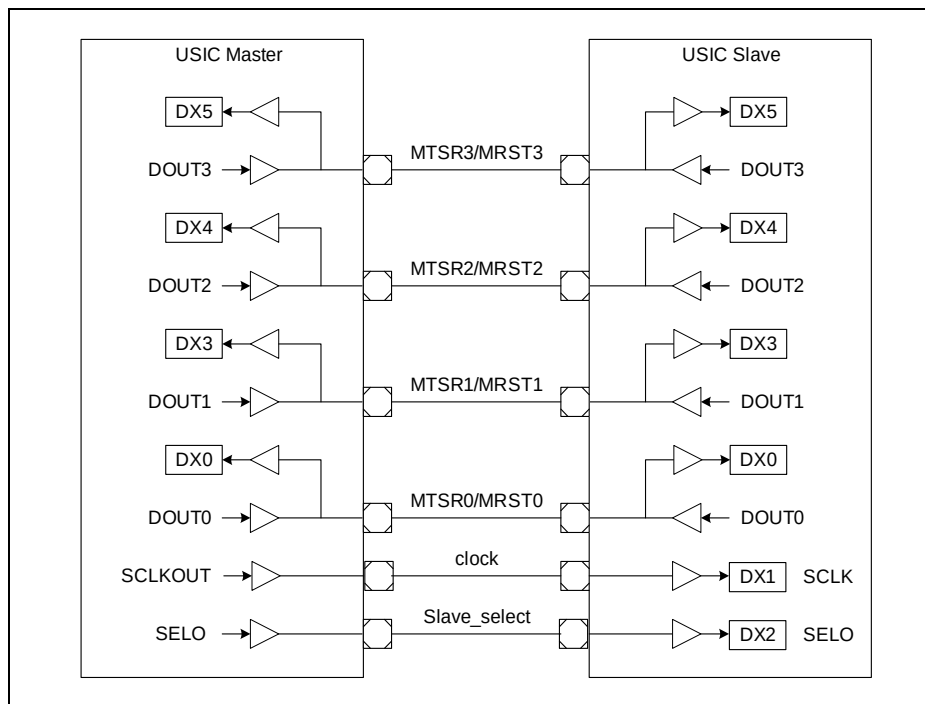


Figure 15-44 Connections for Quad-SSC Example

15.4.3 Operating the SSC in Master Mode

In order to operate the SSC in master mode, the following issues have to be considered:

- **Select SSC mode:**
It is recommended to configure all parameters of the SSC that do not change during run time while CCR.MODE = 0000_B. Bit field SCTR.TRM = 01_B has to be programmed. The configuration of the input stages has to be done while

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CCR.MODE = 0000_B to avoid unintended edges of the input signals and the SSC mode can be enabled by CCR.MODE = 0001_B afterwards.

- Pin connections:
Establish a connection of the input stage (DX0, DX3, DX4, DX5) with the selected receive data input pin (DIN[3:0]) with DXnCR.INSW = 1 and configure the transmit data output pin (DOUT[3:0]). One, two or four such connections may be needed depending on the protocol. For half-duplex configurations, hardware port control can be also used to establish the required connections.
- Baud rate generation:
The desired baud rate setting has to be selected, comprising the fractional divider and the baud rate generator. Bit DX1CR.INSW = 0 has to be programmed to use the baud rate generator output SCLK directly as input for the data shift unit. Configure a shift clock output pin (signal SCLKOUT).
- Slave select generation:
The slave select delay generation has to be enabled by setting PCR.MSLSEN = 1 and the programming of the time quanta counter setting. Bit DX2CR.INSW = 0 has to be programmed to use the slave select generator output MSLS as input for the data shift unit. Configure slave select output pins (signals SELOx) if needed.
- Data format configuration:
The word length, the frame length, the shift direction and shift mode have to be set up according to the application requirements by programming the register SCTR.

Note: The USIC can only receive in master mode if it is transmitting, because the master frame handling refers to bit TDV of the transmitter part.

Note: The step to enable the alternate output port functions should only be done after the SSC mode is enabled, to avoid unintended spikes on the output.

15.4.3.1 Baud Rate Generation

The baud rate (determining the length of one data bit) of the SSC is defined by the frequency of the SCLK signal (one period of f_{SCLK} represents one data bit). The SSC baud rate generation does not imply any time quanta counter.

In a standard SSC application, the phase relation between the optional MCLK output signal and SCLK is not relevant and can be disabled (BRG.PPPEN = 0). In this case, the SCLK signal directly derives from the protocol input frequency f_{PIN} . In the exceptional case that a fixed phase relation between the MCLK signal and SCLK is required (e.g. when using MCLK as clock reference for external devices), the additional divider by 2 stage has to be taken into account (BRG.PPPEN = 1).

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The adjustable divider factor is defined by bit field BRG.PDIV.

$$f_{\text{SCLK}} = \frac{f_{\text{PIN}}}{2} \times \frac{1}{\text{PDIV} + 1} \quad \text{if } \text{PPPEN} = 0$$

$$f_{\text{SCLK}} = \frac{f_{\text{PIN}}}{2 \times 2} \times \frac{1}{\text{PDIV} + 1} \quad \text{if } \text{PPPEN} = 1$$
(15.8)

15.4.3.2 MSLS Generation

The slave select signals indicate the start and the end of a data frame and are also used by the communication master to individually select the desired slave device. A slave select output of the communication master becomes active a programmable time before a data part of the frame is started (leading delay T_{ld}), necessary to prepare the slave device for the following communication. After the transfer of a data part of the frame, it becomes inactive again a programmable time after the end of the last bit (trailing delay T_{td}) to respect the slave hold time requirements. If data frames are transferred back-to-back one after the other, the minimum time between the deactivation of the slave select and the next activation of a slave select is programmable (next-frame delay T_{nf}). If a data frame consists of more than one data word, an optional delay between the data words can also be programmed (inter-word delay T_{iw}).

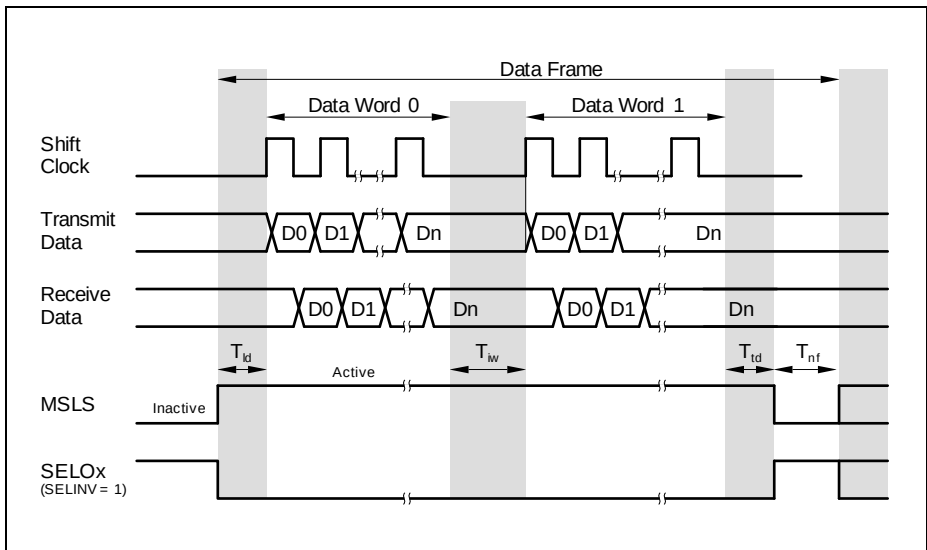


Figure 15-45 MSLS Generation in SSC Master Mode

In SSC master mode, the slave select delays are defined as follows:

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- **Leading delay T_{ld} :**
The leading delay starts if valid data is available for transmission. The internal signal MSLS becomes active with the start of the leading delay. The first shift clock edge (rising edge) of SCLK is generated by the baud rate generator after the leading delay has elapsed.
- **Trailing delay T_{td}**
The trailing delay starts at the end of the last SCLK cycle of a data frame. The internal signal MSLS becomes inactive with the end of the trailing delay.
- **Inter-word delay T_{iw} :**
This delay is optional and can be enabled/disabled by PCR.TIWEN. If the inter-word delay is disabled ($TIWEN = 0$), the last data bit of a data word is directly followed by the first data bit of the next data word of the same data frame. If enabled ($TIWEN = 1$), the inter-word delay starts at the end of the last SCLK cycle of a data word. The first SCLK cycle of the following data word of the same data frame is started when the inter-word delay has elapsed. During this time, no shift clock pulses are generated and signal MSLS stays active. The communication partner has time to “digest” the previous data word or to prepare for the next one.
- **Next-frame delay T_{nf} :**
The next-frame delay starts at the end of the trailing delay. During this time, no shift clock pulses are generated and signal MSLS stays inactive. A frame is considered as finished after the next-frame delay has elapsed.

15.4.3.3 Automatic Slave Select Update

If the number of bits per SSC frame and the word length are defined by bit fields SCTR.FLE and SCTR.WLE, the transmit control information TCI can be used to update the slave select setting PCR.CTR[23:16] to control the SELOx select outputs. The automatic update mechanism is enabled by TCSR.SELMD = 1 (bits TCSR.WLEMD, FLEMD, and WAMD have to be cleared). In this case, the TCI of the first data word of a frame defines the slave select setting of the complete frame due to the automatic shadow mechanism (see [Page 15-62](#)).

15.4.3.4 Slave Select Delay Generation

The slave select delay generation is based on time quanta. The length of a time quantum (defined by the period of the f_{CTQIN}) and the number of time quanta per delay can be programmed.

In standard SSC applications, the leading delay T_{ld} and the trailing delay T_{td} are mainly used to ensure stability on the input and output lines as well as to respect setup and hold times of the input stages. These two delays have the same length (in most cases shorter than a bit time) and can be programmed with the same set of bit fields.

- **BRG.CTQSEL**
to define the input frequency f_{CTQIN} for the time quanta generation for T_{ld} and T_{td}
- **BRG.PCTQ**
to define the length of a time quantum (division of f_{CTQIN} by 1, 2, 3, or 4) for T_{ld} and T_{td}
- **BRG.DCTQ**
to define the number of time quanta for the delay generation for T_{ld} and T_{td}

The inter-word delay T_{iw} and the next-frame delay T_{nf} are used to handle received data or to prepare data for the next word or frame. These two delays have the same length (in most cases in the bit time range) and can be programmed with a second, independent set of bit fields.

- **PCR.CTQSEL1**
to define the input frequency f_{CTQIN} for the time quanta generation for T_{nf} and T_{iw}
- **PCR.PCTQ1**
to define the length of a time quantum (division of f_{CTQIN} by 1, 2, 3, or 4) for T_{nf} and T_{iw}
- **PCR.DCTQ1**
to define the number of time quanta for the delay generation for T_{nf} and T_{iw}
- **PCR.TIWEN**
to enable/disable the inter-word delay T_{iw}

Each delay depends on the length of a time quantum and the programmed number of time quanta given by the bit fields CTQSEL/CTQSEL1, PCTQ/DCTQ and PCTQ1/DCTQ1 (the coding of CTQSEL1 is similar to CTQSEL, etc.). To provide a high flexibility in programming the delay length, the input frequencies can be selected between several possibilities (e.g. based on bit times or on the faster inputs of the protocol-related divider). The delay times are defined as follows:

$$T_{ld} = T_{td} = \frac{(PCTQ + 1) \times (DCTQ + 1)}{f_{CTQIN}} \quad (15.9)$$

$$T_{iw} = T_{nf} = \frac{(PCTQ1 + 1) \times (DCTQ1 + 1)}{f_{CTQIN}}$$

15.4.3.5 Protocol Interrupt Events

The following protocol-related events generated in SSC mode and can lead to a protocol interrupt. They are related to the start and the end of a data frame. After the start of a data frame a new setting could be programmed for the next data frame and after the end of a data frame the SSC connections to pins can be changed.

Please note that the bits in register PSR are not all automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- **MSLS Interrupt:**
This interrupt indicates in master mode (MSLS generation enabled) that a data frame has started (activation of MSLS) and has been finished (deactivation of MSLS). Any change of the internal MSLS signal sets bit PSR.MSLSEV and additionally, a protocol interrupt can be generated if PCR.MSLSIEN = 1. The actual state of the internal MSLS signal can be read out at PSR.MSLS to take appropriate actions when this interrupt has been detected.
- **DX2T Interrupt:**
This interrupt monitors edges of the input signal of the DX2 stage (although this signal is not used as slave select input for data transfers).
A programmable edge detection for the DX2 input signal sets bit PSR.DX2TEV and additionally, a protocol interrupt can be generated if PCR.DX2TIEN = 1. The actual state of the selected input signal can be read out at PSR.DX2S to take appropriate actions when this interrupt has been detected.
- **Parity Error Interrupt:**
This interrupt indicates that there is a mismatch in the received parity bit (in RBUFSR.PAR) with the calculated parity bit of the last received word of a data frame.

15.4.3.6 End-of-Frame Control

The information about the frame length is required for the MSLS generator of the master device. In addition to the mechanism based on the number of bits per frame (selected with $SCTR.FLE < 63$), the following alternative mechanisms for end of frame handling are supported. It is recommended to set $SCTR.FLE = 63$ (if several end of frame mechanisms are activated in parallel, the first end condition being found finishes the frame).

- **Software-based start of frame indication TCSR.SOF:**
 This mechanism can be used if software handles the TBUF data without data FIFO. If bit SOF is set, a valid content of TBUF is considered as first word of a new frame. Bit SOF has to be set before the content of TBUF is transferred to the transmit shift register, so it is recommended to write it before writing data to TBUF. A current data word transfer is finished completely and the slave select delays T_{td} and T_{nf} are applied before starting a new data frame with T_{td} and the content of TBUF. For software-handling of bit SOF, bit $TCSR.WLEMD = 0$ has to be programmed. In this case, all $TBUF[31:0]$ address locations show an identical behavior (TCI not taken into account for data handling).
- **Software-based end of frame indication TCSR.EOF:**
 This mechanism can be used if software handles the TBUF data without data FIFO. If bit EOF is set, a valid content of TBUF is considered as last word of a new frame. Bit EOF has to be set before the content of TBUF is transferred to the transmit shift register, so it is recommended to write it before writing data to TBUF. The data word in TBUF is sent out completely and the slave select delays T_{td} and T_{nf} are applied. A new data frame can start with T_{td} with the next valid TBUF value. For software-handling of bit EOF, bit $TCSR.WLEMD = 0$ has to be programmed. In this case, all $TBUF[31:0]$ address locations show an identical behavior (TCI not taken into account for data handling).
- **Software-based address related end of frame handling:**
 This mechanism can be used if software handles the TBUF data without data FIFO. If bit $TCSR.WLEMD = 1$, the address of the written $TBUF[31:0]$ is used as transmit control information $TCI[4:0]$ to update $SCTR.WLE (= TCI[3:0])$ and $TCSR.EOF (= TCI[4])$ for each data word. The written $TBUF[31:0]$ address location defines the word length and the end of a frame (locations $TBUF[31:16]$ lead to a frame end). For example, writing transmit data to $TBUF[07]$ results in a data word of 8-bit length without finishing the frame, whereas writing transmit data to $TBUF[31]$ leads to a data word length of 16 bits, followed by T_{td} , the deactivation of MSLS and T_{nf} . If $TCSR.WLEMD = 1$, bits $TCSR.EOF$ and SOF , as well as $SCTR.WLE$ must not be written by software after writing data to a TBUF location. Furthermore, it is recommended to clear bits $TCSR.SELMD$, $FLEMD$ and $WAMD$.
- **FIFO-based address related end of frame handling:**
 This mechanism can be used if a data FIFO is used to store the transmit data. The general behavior is similar to the software-based address related end of frame

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handling, except that transmit data is not written to the locations TBUF[31:0], but to the FIFO input locations IN[31:0] instead. In this case, software must not write to any of the TBUF locations.

- TBUF related end of frame handling:
If bit PCR.FEM = 0, an end of frame is assumed if the transmit buffer TBUF does not contain valid transmit data at the end of a data word transmission (TCSR.TDV = 0 or in Stop Mode). In this case, the software has to take care that TBUF does not run empty during a data frame in Run Mode. If bit PCR.FEM = 1, signal MSLS stays active while the transmit buffer is waiting for new data (TCSR.TDV = 1 again) or until Stop Mode is left.
- Explicit end of frame by software:
The software can explicitly stop a frame by clearing bit PSR.MSLS by writing a 1 to the related bit position in register PSCR. This write action immediately clears bit PSR.MSLS, whereas the internal MSLS signal becomes inactive after finishing a currently running word transfer and respecting the slave select delays T_{id} and T_{nf} .

15.4.4 Operating the SSC in Slave Mode

In order to operate the SSC in slave mode, the following issues have to be considered:

- **Select SSC mode:**
It is recommended to configure all parameters of the SSC that do not change during run time while $CCR.MODE = 0000_B$. Bit field $SCTR.TRM = 01_B$ has to be programmed. The configuration of the input stages has to be done while $CCR.MODE = 0000_B$ to avoid unintended edges of the input signals and the SSC mode can be enabled afterwards by $CCR.MODE = 0001_B$.
- **Pin connections:**
Establish the connection of the input stage (DX0, DX3, DX4, DX5) with the selected receive data input pin ($DIN[3:0]$) with $DXnCR.INSW = 1$ and configure the transmit data output pin ($DOUT[3:0]$). One, two or four such connections may be needed depending on the protocol. For half-duplex configurations, hardware port control can be also used to establish the required connections.
Establish a connection of input stage DX1 with the selected shift clock input pin (signal SCLKIN) with $DX1CR.INSW = 1$.
Establish a connection of input stage DX2 with the selected slave select input pin (signal SELIN) with $DX2CR.INSW = 1$. If no slave select input signal is used, the DX2 stage has to deliver a 1-level to the data shift unit to allow data reception and transmission. If a slave device is not selected (DX2 stage delivers a 0 to the data shift unit) and a shift clock pulse are received, the incoming data is not received and the $DOUTx$ signal outputs the passive data level defined by $SCTR.PDL$.
Note that the step to enable the alternate output port functions should only be done after the SSC mode is enabled, to avoid unintended spikes on the output.
- **Baud rate generation:**
The baud rate generator is not needed and can be switched off by the fractional divider.
- **Data format configuration:**
If required, the shift mode can be set up for reception and/or transmission of two or four data bits at one time by programming the register $SCTR$.
- **Slave select generation:**
The slave select delay generation is not needed and can be switched off. The bits and bit fields $MSLSEN$, $SELCTR$, $SELINV$, $CTQSEL1$, $PCTQ1$, $DCTQ1$, $MSLSIEN$, $SELO[7:0]$, and $TIWEN$ in register PCR are not necessary and can be programmed to 0.

15.4.4.1 Protocol Interrupts

The following protocol-related events generated in SSC mode and can lead to a protocol interrupt. They are related to the start and the end of a data frame. After the start of a data frame a new setting could be programmed for the next data frame and after the end of a data frame the SSC connections to pins can be changed.

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Please note that the bits in register PSR are not all automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- **MSLS event:**
The MSLS generation being switched off, this event is not available.
- **DX2T event:**
The slave select input signal SELIN is handled by the DX2 stage and the edges of the selected signal can generate a protocol interrupt. This interrupt allows to indicate that a data frame has started and/or that a data frame has been completely finished. A programmable edge detection for the DX2 input signal activates DX2T, sets bit PSR.DX2TEV and additionally, a protocol interrupt can be generated if PCR.DX2TIEN = 1. The actual state of the selected input signal can be read out at PSR.DX2S to take appropriate actions when this interrupt has been detected.
- **Parity Error Interrupt:**
This interrupt indicates that there is a mismatch in the received parity bit (in RBUFSR.PAR) with the calculated parity bit of the last received word of a data frame.

15.4.4.2 End-of-Frame Control

In slave mode, the following possibilities exist to determine the frame length. The slave device either has to refer to an external slave select signal, or to the number of received data bits.

- **Frame length known in advance by the slave device, no slave select:**
In this case bit field SCTR.FLE can be programmed to the known value (if it does not exceed 63 bits). A currently running data word transfer is considered as finished if the programmed frame length is reached.
- **Frame length not known by the slave, no slave select:**
In this case, the slave device's software has to decide on data word base if a frame is finished. Bit field SCTR.FLE can be either programmed to the word length SCTR.WLE, or to its maximum value to disable the slave internal frame length evaluation by counting received bits.
- **Slave device addressed via slave select signal SELIN:**
If the slave device is addressed by a slave select signal delivered by the communication master, the frame start and end information are given by this signal. In this case, bit field SCTR.FLE should be programmed to its maximum value to disable the slave internal frame length evaluation.

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15.4.5 SSC Protocol Registers

In SSC mode, the registers PCR and PSR handle SSC related information.

15.4.5.1 SSC Protocol Control Registers

In SSC mode, the PCR register bits or bit fields are defined as described in this section.

PCR

Protocol Control Register [SSC Mode]

(3C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MCL K			0			SLP HSE L	TIW EN								
rw			rw			rw	rw					rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DX2 TIEN	MSL SIEN	PARI EN													
rw	rw	rw													

Field	Bits	Type	Description
MSLSEN	0	rw	MSLS Enable This bit enables/disables the generation of the master slave select signal MSLS. If the SSC is a transfer slave, the SLS information is read from a pin and the internal generation is not needed. If the SSC is a transfer master, it has to provide the MSLS signal. 0 _B The MSLS generation is disabled (MSLS = 0). This is the setting for SSC slave mode. 1 _B The MSLS generation is enabled. This is the setting for SSC master mode.
SELCTR	1	rw	Select Control This bit selects the operating mode for the SELO[7:0] outputs. 0 _B The coded select mode is enabled. 1 _B The direct select mode is enabled.

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Field	Bits	Type	Description
SELINV	2	rw	Select Inversion This bit defines if the polarity of the SELO[7:0] outputs in relation to the master slave select signal MSLS. 0_B The SELO outputs have the same polarity as the MSLS signal (active high). 1_B The SELO outputs have the inverted polarity to the MSLS signal (active low).
FEM	3	rw	Frame End Mode This bit defines if a transmit buffer content that is not valid for transmission is considered as an end of frame condition for the slave select generation. 0_B The current data frame is considered as finished when the last bit of a data word has been sent out and the transmit buffer TBUF does not contain new data ($TDV = 0$). 1_B The MSLS signal is kept active also while no new data is available and no other end of frame condition is reached. In this case, the software can accept delays in delivering the data without automatic deactivation of MSLS in multi-word data frames.
CTQSEL1	[5:4]	rw	Input Frequency Selection This bit field defines the input frequency f_{CTQIN} for the generation of the slave select delays T_{iw} and T_{nf} . 00_B $f_{CTQIN} = f_{PDIV}$ 01_B $f_{CTQIN} = f_{PPP}$ 10_B $f_{CTQIN} = f_{SCLK}$ 11_B $f_{CTQIN} = f_{MCLK}$
PCTQ1	[7:6]	rw	Divider Factor PCTQ1 for T_{iw} and T_{nf} This bit field represents the divider factor PCTQ1 (range = 0 - 3) for the generation of the inter-word delay and the next-frame delay. $T_{iw} = T_{nf} = 1/f_{CTQIN} \times (PCTQ1 + 1) \times (DCTQ1 + 1)$
DCTQ1	[12:8]	rw	Divider Factor DCTQ1 for T_{iw} and T_{nf} This bit field represents the divider factor DCTQ1 (range = 0 - 31) for the generation of the inter-word delay and the next-frame delay. $T_{iw} = T_{nf} = 1/f_{CTQIN} \times (PCTQ1 + 1) \times (DCTQ1 + 1)$

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Field	Bits	Type	Description
PARIEN	13	rw	Parity Error Interrupt Enable This bit enables/disables the generation of a protocol interrupt with the detection of a parity error. 0_B A protocol interrupt is not generated with the detection of a parity error. 1_B A protocol interrupt is generated with the detection of a parity error.
MSLSIEN	14	rw	MSLS Interrupt Enable This bit enables/disables the generation of a protocol interrupt if the state of the MSLS signal changes (indicated by PSR.MSLSEV = 1). 0_B A protocol interrupt is not generated if a change of signal MSLS is detected. 1_B A protocol interrupt is generated if a change of signal MSLS is detected.
DX2TIEN	15	rw	DX2T Interrupt Enable This bit enables/disables the generation of a protocol interrupt if the DX2T signal becomes activated (indicated by PSR.DX2TEV = 1). 0_B A protocol interrupt is not generated if DX2T is activated. 1_B A protocol interrupt is generated if DX2T is activated.
SELO	[23:16]	rw	Select Output This bit field defines the setting of the SELO[7:0] output lines. 0_B The corresponding SELOx line cannot be activated. 1_B The corresponding SELOx line can be activated (according to the mode selected by SELCTR).
TIWEN	24	rw	Enable Inter-Word Delay T_{iw} This bit enables/disables the inter-word delay T_{iw} after the transmission of a data word. 0_B No delay between data words of the same frame. 1_B The inter-word delay T_{iw} is enabled and introduced between data words of the same frame.

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Field	Bits	Type	Description
SLPHSEL	25	rw	Slave Mode Clock Phase Select This bit selects the clock phase for the data shifting in slave mode. 0_B Data bits are shifted out with the leading edge of the shift clock signal and latched in with the trailing edge. 1_B The first data bit is shifted out when the data shift unit receives a low to high transition from the DX2 stage. Subsequent bits are shifted out with the trailing edge of the shift clock signal. Data bits are always latched in with the leading edge.
MCLK	31	rw	Master Clock Enable This bit enables/disables the generation of the master clock output signal MCLK, independent from master or slave mode. 0_B The MCLK generation is disabled and output MCLK = 0. 1_B The MCLK generation is enabled.
0	[30:26]	rw	Reserved Returns 0 if read; should be written with 0.

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15.4.5.2 SSC Protocol Status Register

In SSC mode, the PSR register bits or bit fields are defined as described in this section. The bits and bit fields in register PSR are not cleared by hardware.

The flags in the PSR register can be cleared by writing a 1 to the corresponding bit position in register PSR. Writing a 1 to a bit position in PSR sets the corresponding flag, but does not lead to further actions (no interrupt generation). Writing a 0 has no effect. The PSR flags should be cleared by software before enabling a new protocol.

PSR

Protocol Status Register [SSC Mode] (48_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
							0								BRG IF
							r								rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIF	RIF	TBIF	TSIF	DLIF	RSIF			0			PAR ERR	DX2 TEV	MSL SEV	DX2 S	MSL S
rwh	rwh	rwh	rwh	rwh	rwh			r			rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
MSLS	0	rwh	MSLS Status This bit indicates the current status of the MSLS signal. It must be cleared by software to stop a running frame. 0 _B The internal signal MSLS is inactive (0). 1 _B The internal signal MSLS is active (1).
DX2S	1	rwh	DX2S Status This bit indicates the current status of the DX2S signal that can be used as slave select input SELIN. 0 _B DX2S is 0. 1 _B DX2S is 1.
MSLSEV	2	rwh	MSLS Event Detected¹⁾ This bit indicates that the MSLS signal has changed its state since MSLSEV has been cleared. Together with the MSLS status bit, the activation/deactivation of the MSLS signal can be monitored. 0 _B The MSLS signal has not changed its state. 1 _B The MSLS signal has changed its state.

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Field	Bits	Type	Description
DX2TEV	3	rwh	DX2T Event Detected¹⁾ This bit indicates that the DX2T trigger signal has been activated since DX2TEV has been cleared. 0 _B The DX2T signal has not been activated. 1 _B The DX2T signal has been activated.
PARERR	4	rwh	Parity Error Event Detected¹⁾ This bit indicates that there is a mismatch in the received parity bit (in RBUFSR.PAR) with the calculated parity bit of the last received word of the data frame. 0 _B A parity error event has not been activated. 1 _B A parity error event has been activated.
RSIF	10	rwh	Receiver Start Indication Flag 0 _B A receiver start event has not occurred. 1 _B A receiver start event has occurred.
DLIF	11	rwh	Data Lost Indication Flag 0 _B A data lost event has not occurred. 1 _B A data lost event has occurred.
TSIF	12	rwh	Transmit Shift Indication Flag 0 _B A transmit shift event has not occurred. 1 _B A transmit shift event has occurred.
TBIF	13	rwh	Transmit Buffer Indication Flag 0 _B A transmit buffer event has not occurred. 1 _B A transmit buffer event has occurred.
RIF	14	rwh	Receive Indication Flag 0 _B A receive event has not occurred. 1 _B A receive event has occurred.
AIF	15	rwh	Alternative Receive Indication Flag 0 _B An alternative receive event has not occurred. 1 _B An alternative receive event has occurred.
BRGIF	16	rwh	Baud Rate Generator Indication Flag 0 _B A baud rate generator event has not occurred. 1 _B A baud rate generator event has occurred.
0	[9:5], [31:17]	r	Reserved Returns 0 if read; not modified in SSC mode.

1) This status bit can generate a protocol interrupt in SSC mode (see [Page 15-22](#)). The general interrupt status flags are described in the general interrupt chapter.

15.4.6 SSC Timing Considerations

The input and output signals have to respect certain timings in order to ensure correct data reception and transmission. In addition to module internal timings (due to input filters, reaction times on events, etc.), also the timings from the input pin via the input stage (T_{in}) to the module and from the module via the output driver stage to the pin (T_{out}), as well as the signal propagation on the wires (T_{prop}) have to be taken into account.

Please note that there might be additional delays in the DXn input stages, because the digital filter and the synchronization stages lead to systematic delays, that have to be considered if these functions are used.

15.4.6.1 Closed-loop Delay

A system-inherent limiting factor for the baud rate of an SSC connection is the closed-loop delay. In a typical application setup, a communication master device is connected to a slave device in full-duplex mode with independent lines for transmit and receive data. In a general case, all transmitters refer to one shift clock edge for transmission and all receivers refer to the other shift clock edge for reception. The master device's SSC module sends out the transmit data, the shift clock and optionally the slave select signal. Therefore, the baud rate generation (BRG) and slave select generation (SSG) are part of the master device. The frame control is similar for SSC modules in master and slave mode, the main difference is the fact which module generates the shift clock and optionally, the slave select signals.

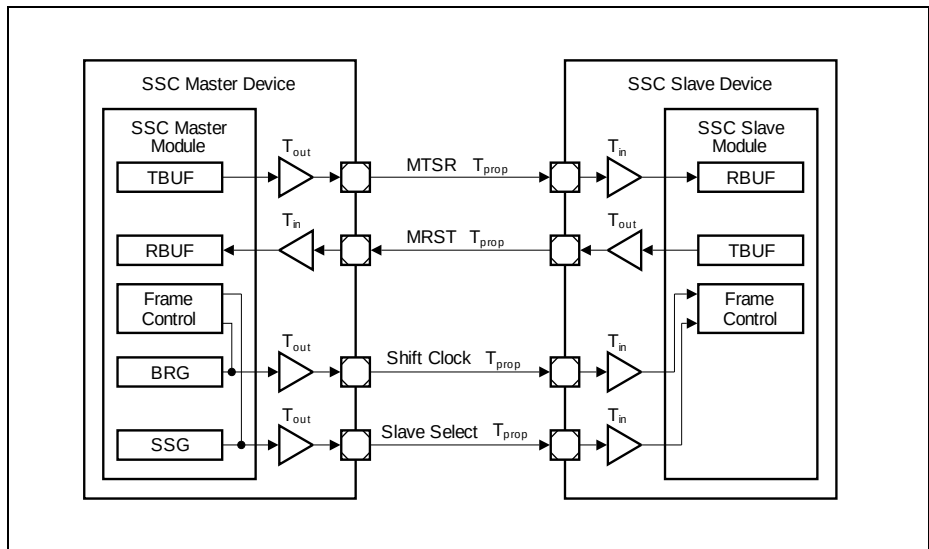


Figure 15-46 SSC Closed-loop Delay

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The signal path between the SSC modules of the master and the slave device includes the master's output driver, the wiring to the slave device and the slave device's input stage. With the received shift clock edges, the slave device receives the master's transmit data and transmits its own data back to the master device, passing by a similar signal path in the other direction. The master module receives the slave's transmit data related to its internal shift clock edges. In order to ensure correct data reception in the master device, the slave's transmit data has to be stable (respecting setup and hold times) as master receive data with the next shift clock edge of the master (generally 1/2 shift clock period). To avoid data corruption, the accumulated delays of the input and output stages, the signal propagation on the wiring and the reaction times of the transmitter/receiver have to be carefully considered, especially at high baud rates.

In the given example, the time between the generation of the shift clock signal and the evaluation of the receive data by the master SSC module is given by the sum of $T_{\text{out\_master}}$ + $2 \times T_{\text{prop}}$ + $T_{\text{in\_slave}}$ + $T_{\text{out\_slave}}$ + $T_{\text{in\_master}}$ + module reaction times + input setup times.

The input path is characterized by an input delay depending mainly on the input stage characteristics of the pads. The output path delay is determined by the output driver delay and its slew rate, the external load and current capability of the driver. The device specific values for the input/output driver are given in the Data Sheet.

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Figure 15-47 describes graphically the closed-loop delay and the effect of two delay compensation options discussed in [Section 15.4.6.2](#) and [Section 15.4.6.3](#).

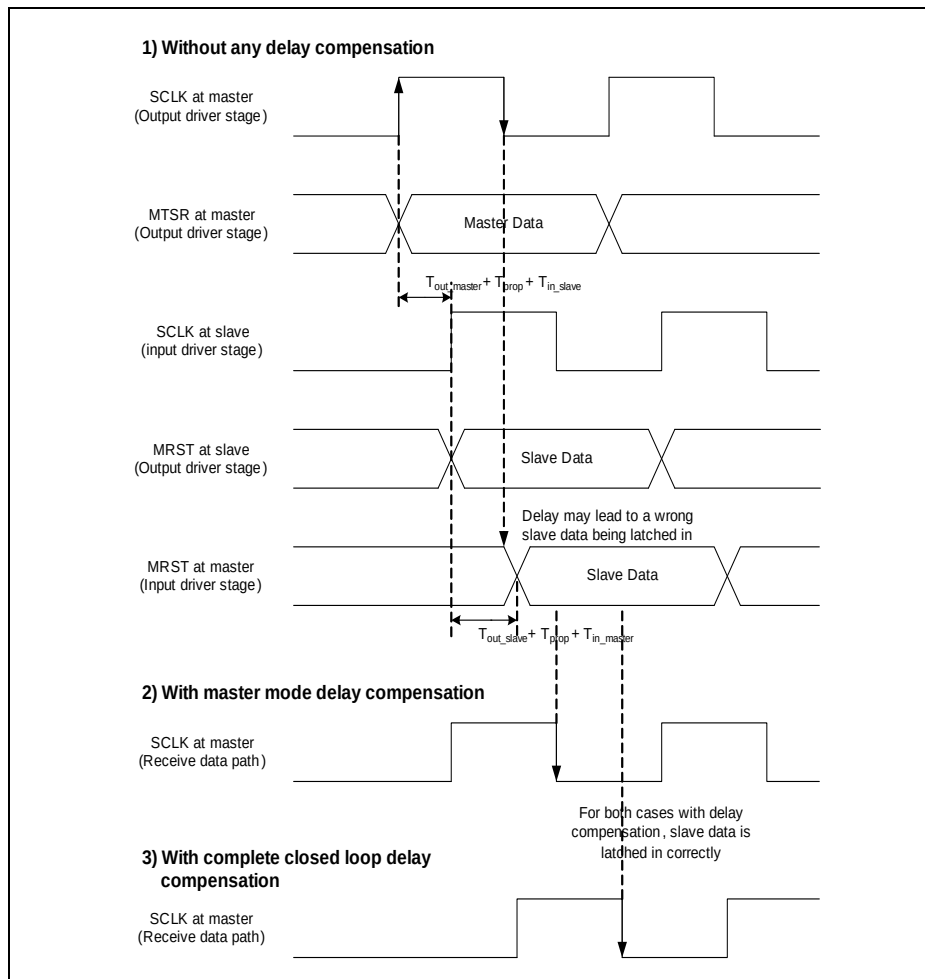


Figure 15-47 SSC Closed-loop Delay Timing Waveform

15.4.6.2 Delay Compensation in Master Mode

A higher baud rate can be reached by delay compensation in master mode. This compensation is possible if (at least) the shift clock pin is bidirectional.

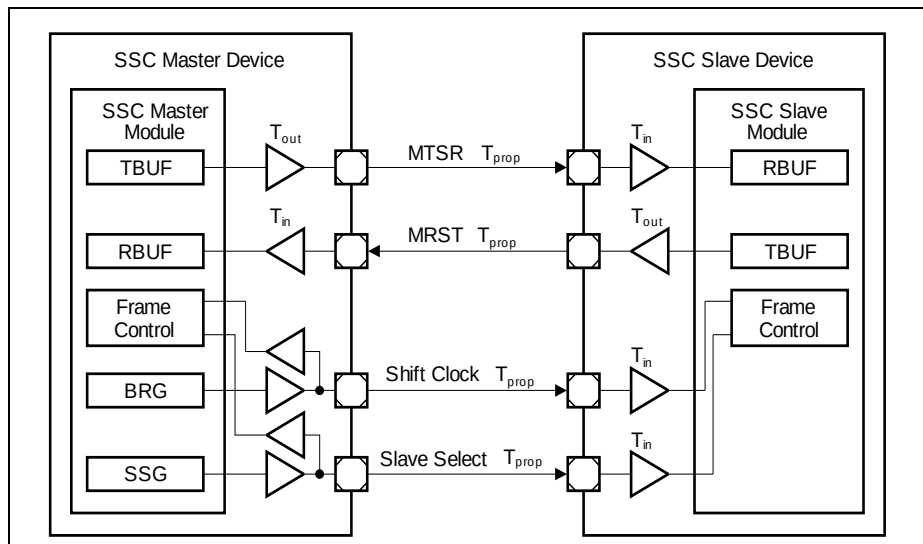


Figure 15-48 SSC Master Mode with Delay Compensation

If the receive shift clock signal in master mode is directly taken from the input function in parallel to the output signal, the output delay of the master device's shift clock output is compensated and only the difference between the input delays of the master and the slave devices have to be taken into account instead of the complete master's output delay and the slave's input delay of the shift clock path. The delay compensation is enabled with $DX1CR.DCEN = 1$ while $DX1CR.INSW = 0$ (transmit shift clock is taken from the baud-rate generator).

In the given example, the time between the evaluation of the shift clock signal and the receive data by the master SSC module is reduced by $T_{in\_master} + T_{out\_master}$.

Although being a master mode, the shift clock input and optionally the slave select signal are not directly connected internally to the data shift unit, but are taken as external signals from input pins. The delay compensation does not lead to additional pins for the SSC communication if the shift clock output pin (slave select output pin, respectively) is/are bidirectional. In this case, the input signal is decoupled from other internal signals, because it is related to the signal level at the pin itself.

15.4.6.3 Complete Closed-loop Delay Compensation

Alternatively, the complete closed-loop delay can be compensated by using one additional pin on both the SSC master and slave devices for the SSC communication.

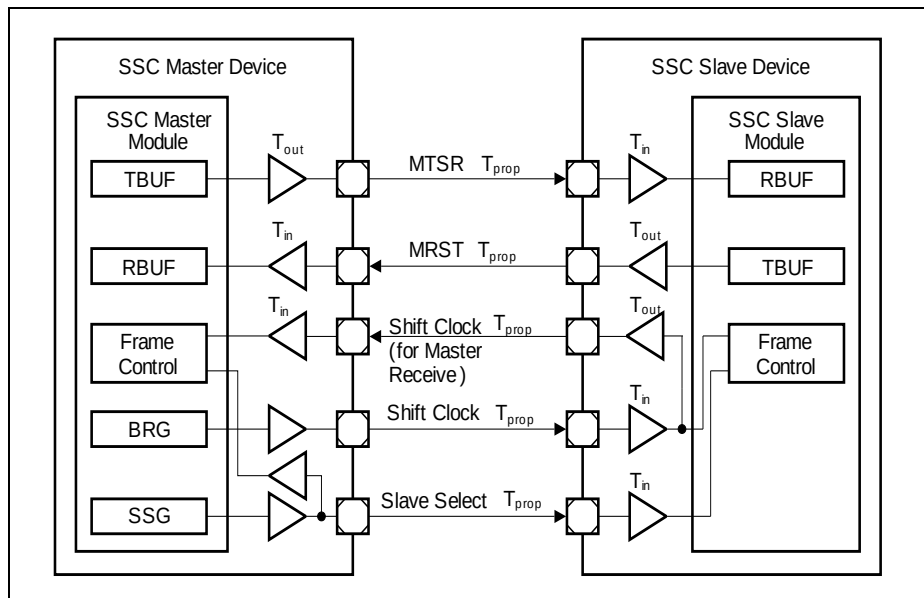


Figure 15-49 SSC Complete Closed-loop Delay Compensation

The principle behind this delay compensation method is to have the slave feedback the shift clock back to the master, which uses it as the receive shift clock. By going through a complete closed-loop signal path, the receive shift clock is thus fully compensated.

The slave has to setup the SCLKOUT pin function to output the shift clock by setting the bit BRG.SCLKOSEL to 1, while the master has to setup the DX1 pin function to receive the shift clock from the slave and enable the delay compensation with DX1CR.DCEN = 1 and DX1CR.INSW = 0.

15.5 Inter-IC Bus Protocol (IIC)

The IIC protocol of the USIC refers to the IIC bus specification [7]. Contrary to that specification, the USIC device assumes rise/fall times of the bus signals of max. 300 ns in all modes. Please refer to the pad characteristics in the AC/DC chapter for the driver capability. CBUS mode and HS mode are not supported.

The IIC mode is selected by $CCR.MODE = 0100_B$ with $CCFG.IIC = 1$ (IIC mode available).

15.5.1 Introduction

USIC IIC Features:

- Two-wire interface, with one line for shift clock transfer and synchronization (shift clock SCL), the other one for the data transfer (shift data SDA)
- Communication in standard mode (100 kBit/s) or in fast mode (up to 400 kBit/s)
- Support of 7-bit addressing, as well as 10-bit addressing
- Master mode operation,
where the IIC controls the bus transactions and provides the clock signal.
- Slave mode operation,
where an external master controls the bus transactions and provides the clock signal.
- Multi-master mode operation,
where several masters can be connected to the bus and bus arbitration can take place, i.e. the IIC module can be master or slave. The master/slave operation of an IIC bus participant can change from frame to frame.
- Efficient frame handling (low software effort)
- Powerful interrupt handling due to multitude of indication flags
- Compensation support for input delays

15.5.1.1 Signal Description

An IIC connection is characterized by two wires (SDA and SCL). The output drivers for these signals must have open-drain characteristics to allow the wired-AND connection of all SDA lines together and all SCL lines together to form the IIC bus system. Due to this structure, a high level driven by an output stage does not necessarily lead immediately to a high level at the corresponding input. Therefore, each SDA or SCL connection has to be input and output at the same time, because the input function always monitors the level of the signal, also while sending.

- Shift data SDA: input handled by DX0 stage, output signal DOUT0
- Shift clock SCL: input handled by DX1 stage, output signal SCLKOUT

Figure 15-29 shows a connection of two IIC bus participants (modules IIC A and IIC B) using the USIC. In this example, the pin assignment of module IIC A shows separate pins for the input and output signals for SDA and SCL. This assignment can be used if the application does not provide pins having DOUT0 and a DX0 stage input for the same pin

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(similar for SCLKOUT and DX1). The pin assignment of module IIC B shows the connection of DOUT0 and a DX0 input at the same pin, also for SCLKOUT and a DX1 input.

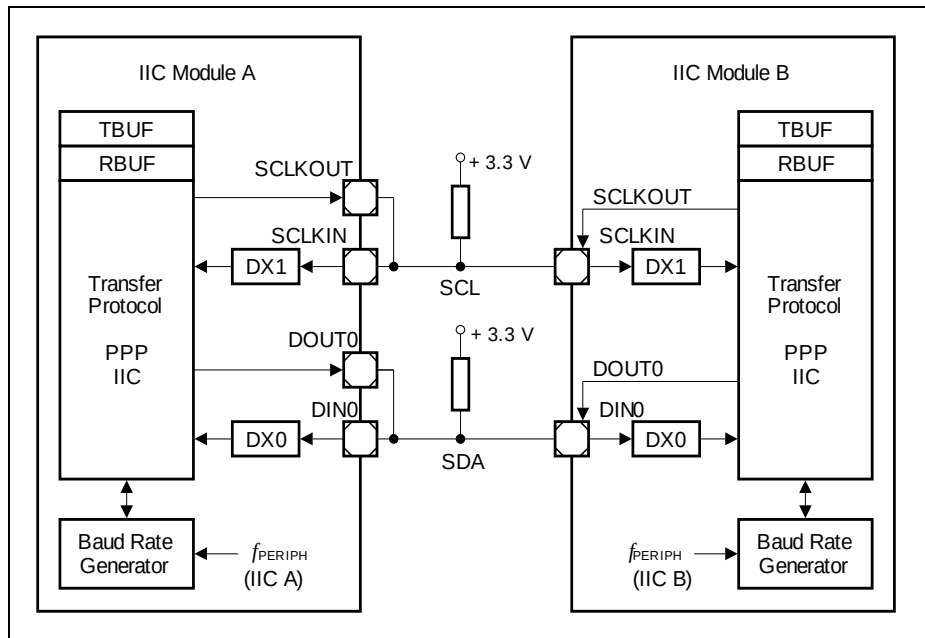


Figure 15-50 IIC Signal Connections

15.5.1.2 Symbols

A symbol is a sequence of edges on the lines SDA and SCL. Symbols contain 10 or 25 time quanta t_q , depending on the selected baud rate. The baud rate generator determines the length of the time quanta t_q , the sequence of edges in a symbol is handled by the IIC protocol pre-processor, and the sequence of symbols can be programmed by the user according to the application needs.

The following symbols are defined:

- **Bus idle:**
SDA and SCL are high. No data transfer takes place currently.
- **Data bit symbol:**
SDA stable during the high phase of SCL. SDA then represents the transferred bit value. There is one clock pulse on SCL for each transferred bit of data. During data transfers SDA may only change while SCL is low.

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- **Start symbol:**
Signal SDA being high followed by a falling edge of SDA while SCL is high indicates a start condition. This start condition initiates a data transfer over the IIC bus after the bus has been idle.
- **Repeated start symbol:**
This start condition initiates a data transfer over the bus after a data symbol when the bus has not been idle. Therefore, SDA is set high and SCL low, followed by a start symbol.
- **Stop symbol:**
A rising edge on SDA while SCL is high indicates a stop condition. This stop condition terminates a data transfer to release the bus to idle state. Between a start condition and a stop condition an arbitrary number of bytes may be transferred.

15.5.1.3 Frame Format

Data is transferred by the 2-line IIC bus (SDA, SCL) using a protocol that ensures reliable and efficient transfers. The sender of a (data) byte receives and checks the value of the following acknowledge field. The IIC being a wired-AND bus system, a 0 of at least one device leads to a 0 on the bus, which is received by all devices.

A data word consists of 8 data bit symbols for the data value, followed by another data bit symbol for the acknowledge bit. The data word can be interpreted as address information (after a start symbol) or as transferred data (after the address).

In order to be able to receive an acknowledge signal, the sender of the data bits has to release the SDA line by sending a 1 as acknowledge value. Depending on the internal state of the receiver, the acknowledge bit is either sent active or passive.

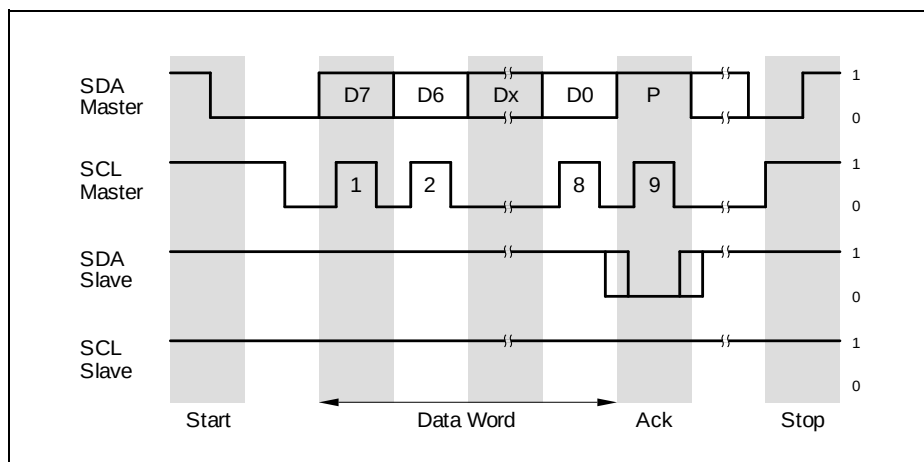


Figure 15-51 IIC Frame Example (simplified)

15.5.2 Operating the IIC

In order to operate the IIC protocol, the following issues have to be considered:

- **Select IIC mode:**
It is recommended to configure all parameters of the IIC that do not change during run time while $CCR.MODE = 0000_B$. Bit field $SCTR.TRM = 11_B$ should be programmed. The configuration of the input stages has to be done while $CCR.MODE = 0000_B$ to avoid unintended edges of the input signals and the IIC mode can be enabled by $CCR.MODE = 0100_B$ afterwards.
- **Pin connections:**
Establish a connection of input stage DX0 (with $DX0CR.DPOL = 0$) to the selected shift data pin SDA (signal DIN0) with $DX0CR.INSW = 0$ and configure the transmit data output signal DOUT0 (with $SCTR.DOCFG = 00_B$) to the same pin. If available, this can be the same pin for input and output, or connect the selected input pin and the output pin to form the SDA line.
The same mechanism applies for the shift clock line SCL. Here, signal SCLKOUT (with $BRG.SCLKCFG = 00_B$) and an input of the DX1 stage have to be connected (with $DX1CR.DPOL = 0$).
The input stage DX2 is not used for the IIC protocol.
If the digital input filters are enabled in the DX0/1 stages, their delays have to be taken into account for correct calculation of the signal timings.
The pins used for SDA and SCL have to be set to open-drain mode to support the wired-AND structure of the IIC bus lines.
Note that the step to enable the alternate output port functions should only be done after the IIC mode is enabled, to avoid unintended spikes on the output.
- **Bit timing configuration:**
In standard mode (100 kBit/s) a minimum module frequency of 2 MHz is necessary, whereas in fast mode (400 kBit/s) a minimum of 10 MHz is required. Additionally, if the digital filter stage should be used to eliminate spikes up to 50 ns, a filter frequency of 20 MHz is necessary.
There could be an uncertainty in the SCL high phase timing of maximum $1/f_{PP}$ if another IIC participant lengthens the SCL low phase on the bus.
More details are given in [Section 15.5.3](#).
- **Data format configuration:**
The data format has to be configured for 8 data bits ($SCTR.WLE = 7$), unlimited data flow ($SCTR.FLE = 3F_H$), and MSB shifted first ($SCTR.SDIR = 1$). The parity generation has to be disabled ($CCR.PM = 00_B$).
- **General hints:**
The IIC slave module becomes active (for reception or transmission) if it is selected by the address sent by the master. In the case that the slave sends data to the master, it uses the transmit path. So a master must not request to read data from the slave address defined for its own channel in order to avoid collisions.
The built-in error detection mechanisms are only activated while the IIC module is

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taking part in IIC bus traffic.

If the slave can not deal with too high frequencies, it can lengthen the low phase of the SCL signal.

For data transfers according to the IIC specification, the shift data line SDA shall only change while SCL = 0 (defined by IIC bus specification).

15.5.2.1 Transmission Chain

The IIC bus protocol requiring a kind of in-bit-response during the arbitration phase and while a slave is transmitting, the resulting loop delay of the transmission chain can limit the reachable maximal baud rate, strongly depending on the bus characteristics (bus load, module frequency, etc.).

Figure 15-50 shows the general signal path and the delays in the case of a slave transmission. The shift clock SCL is generated by the master device, output on the wire, then it passes through the input stage and the input filter. Now, the edges can be detected and the SDA data signal can be generated accordingly. The SDA signal passes through the output stage and the wire to the master receiver part. There, it passes through the input stage and the input filter before it is sampled.

This complete loop has to be finished (including all settling times to obtain stable signal levels) before the SCL signal changes again. The delays in this path have to be taken into account for the calculation of the baud rate as a function of f_{PERIPH} and f_{PPP} .

15.5.2.2 Byte Stretching

If a device is selected as transceiver and should transmit a data byte but the transmit buffer TBUF does not contain valid data to be transmitted, the device ties down SCL = 0 at the end of the previous acknowledge bit. The waiting period is finished if new valid data has been detected in TBUF.

15.5.2.3 Master Arbitration

During the address and data transmission, the master transmitter checks at the rising edge of SCL for each data bit if the value it is sending is equal to the value read on the SDA line. If yes, the next data bit values can be 0. If this is not the case (transmitted value = 1, value read = 0), the master has lost the transmit arbitration. This is indicated by status flag PSR.ARL and can generate a protocol interrupt if enabled by PCR.ARLIEN.

When the transmit arbitration has been lost, the software has to initialize the complete frame again, starting with the first address byte together with the start condition for a new master transmit attempt. Arbitration also takes place for the ACK bit.

15.5.2.4 Non-Acknowledge and Error Conditions

In case of a non-acknowledge or an error, the TCSR.TDV flag remains set, but no further transmission will take place. User software must invalidate the transmit buffer and disable transmissions (by writing FMRL.MTDV = 10_B), before configuring the transmission (by writing TBUF) again with appropriate values to react on the previous event. In the case the FIFO data buffer is used, additionally the FIFO buffer needs to be flushed and filled again.

15.5.2.5 Mode Control Behavior

In multi-master mode, only run mode 0 and stop mode 0 are supported, the other modes must not be programmed.

- **Run Mode 0:**
Behavior as programmed. If TCSR.TDV = 0 (no new valid TBUF entry found) when a new TBUF entry needs to be processed, the IIC module waits for TDV becoming set to continue operation.
- **Run Mode 1:**
Behavior as programmed. If in master mode, TCSR.TDV = 0 (no new valid TBUF entry found) when a new TBUF entry needs to be processed, the IIC module sends a stop condition to finish the frame. In slave mode, no difference to run mode 0.
- **Stop Mode 0:**
Bit TCSR.TDV is internally considered as 0 (the bit itself is not modified by the stop mode). A currently running word is finished normally, but no new word is started in case of master mode (wait for TDV active).
Bit TDV being considered as 0 for master and slave, the slave will force a wait state on the bus if read by an external master, too.
Additionally, it is not possible to force the generation of a STOP condition out of the wait state. The reason is, that a master read transfer must be finished with a not-acknowledged followed by a STOP condition to allow the slave to release his SDA line. Otherwise the slave may force the SDA line to 0 (first data bit of next byte) making it impossible to generate the STOP condition (rising edge on SDA).
To continue operation, the mode must be switched to run mode 0
- **Stop Mode 1:**
Same as stop mode 0, but additionally, a master sends a STOP condition to finish the frame.
If stop mode 1 is requested for a master device after the first byte of a 10 bit address, a stop condition will be sent out. In this case, a slave device will issue an error interrupt.

15.5.2.6 Data Transfer Interrupt Handling

The data transfer interrupts indicate events related to IIC frame handling. As the data input and output pins are the same in IIC protocol, a IIC transmitter also receives the

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output data at its input pin. However, no receive related interrupts will be generated in this case.

- **Transmit buffer event:**
 The transmit buffer event indication flag PSR.TBIF is set when the content of the transmit buffer TBUF has been loaded to the transmit shift register, indicating that the action requested by the TBUF entry has started.
 With this event, bit TCSR.TDV is cleared. This interrupt can be used to write the next TBUF entry while the last one is in progress (handled by the transmitter part).
- **Receive event:**
 This receive event indication flag PSR.RIF indicates that a new data byte has been written to the receive buffer RBUF0/1 (except for the first data byte of a new frame, that is indicated by an alternative receive interrupt). The flag becomes set when the data byte is received (after the falling edge of SCL). This interrupt can be used to read out the received data while a new data byte can be in progress (handled by the receiver part).
- **Alternate receive event:**
 The alternative receive event indication flag AIF is based on bit RBUFSR[9] (same as RBUF[9]), indicating that the received data word has been the first data word of a new data frame.
- **Transmit shift event:**
 The transmit shift event indication flag TSIF is set after the start of the last data bit of a data byte.
- **Receive start event:**
 The receive start event indication flag RSIF is set after the sample point of the first data bit of a data byte.

Note: The transmit shift and receive start events can be ignored if the application does not require them during the IIC data transfer.

15.5.2.7 IIC Protocol Interrupt Events

The following protocol-related events are generated in IIC mode and can lead to a protocol interrupt.

Please note that the bits in register PSR are not all automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- start condition received at a correct position in a frame (PSR.SCR)
- repeated start condition received at a correct position in a frame (PSR.RSCR)
- stop condition transferred at a correct position in a frame (PSR.PCR)
- master arbitration lost (PSR.ARL)
- slave read requested (PSR.SRR)
- acknowledge received (PSR.ACK)
- non-acknowledge received (PSR.NACK)
- start condition not at the expected position in a frame (PSR.ERR)

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- stop condition not at the expected position in a frame (PSR.ERR)
- as slave, 10-bit address interrupted by a stop condition after the first address byte (PSR.ERR)
- TDF slave code in master mode (PSR.WTDF)
- TDF master code in slave mode (PSR.WTDF)
- Reserved TDF code found (PSR.WDTF)
- Start condition code during a running frame in master mode (PSR.WTDF)
- Data byte transmission code after transfer direction has been changed to reception (master read) in master mode (PSR.WTDF)

If a wrong TDF code is found in TBUF, the error event is active until the TDF value is either corrected or invalidated. If the related interrupt is enabled, the interrupt handler should check PSR.WDTF first and correct or invalidate TBUF, before dealing with the other possible interrupt events.

15.5.2.8 Baud Rate Generator Interrupt Handling

The baud rate generator interrupt indicate that the capture mode timer has reached its maximum value. With this event, the bit PSR.BRGIF is set.

15.5.2.9 Receiver Address Acknowledge

After a (repeated) start condition, the master sends a slave address to identify the target device of the communication. The start address can comprise one or two address bytes (for 7 bit or for 10 bit addressing schemes). After an address byte, a slave sensitive to the transmitted address has to acknowledge the reception.

Therefore, the slave's address can be programmed in the device, where it is compared to the received address. In case of a match, the slave answers with an acknowledge (SDA = 0). Slaves that are not targeted answer with a non-acknowledge (SDA = 1).

In addition to the match of the programmed address, another address byte value has to be answered with an acknowledge if the slave is capable to handle the corresponding requests. The address byte 00_H indicates a general call address, that can be acknowledged. The value 01_H stands for a start byte generation, that is not acknowledged

In order to allow selective acknowledges for the different values of the address byte(s), the following control mechanism is implemented:

- The address byte 00_H is acknowledged if bit PCR.ACK00 is set.
- The address byte 01_H is not acknowledged.
- The first 7 bits of a received first address byte are compared to the programmed slave address (PCR.SLAD[15:9]). If these bits match, the slave sends an acknowledge. In addition to this, if the slave address is programmed to 1111 0XX_B, the slave device waits for a second address byte and compares it also to PCR.SLAD[7:0] and sends an acknowledge accordingly to cover the 10 bit addressing mode. The user has to

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take care about reserved addresses (refer to IIC specification for more detailed description). Only the address 1111 0XX₆ is supported.

Under each of these conditions, bit PSR.SLSEL will be set when the addressing delivered a match. This bit is cleared automatically by a (repeated) start condition.

15.5.2.10 Receiver Handling

A selected slave receiver always acknowledges a received data byte. If the receive buffers RBUF0/1 are already full and can not accept more data, the respective register is overwritten (PSR.DLI becomes set in this case and a protocol interrupt can be generated).

An address reception also uses the registers RBUF0/1 to store the address before checking if the device is selected. The received addresses do not set RDV0/1, so the addresses are not handled like received data.

15.5.2.11 Receiver Status Information

In addition to the received data byte, some IIC protocol related information is stored in the 16-bit data word of the receive buffer. The received data byte is available at the bit positions RBUF[7:0], whereas the additional information is monitored at the bit positions RBUF[12:8]. This structure allows to identify the meaning of each received data byte without reading additional registers, also when using a FIFO data buffer.

- RBUF[8]:
Value of the received acknowledge bit. This information is also available in RBUF[8] as protocol argument.
- RBUF[9]:
A 1 at this bit position indicates that after a (repeated) start condition followed by the address reception the first data byte of a new frame has been received. A 0 at this bit position indicates further data bytes. This information is also available in RBUF[9], allowing different interrupt routines for the address and data handling.
- RBUF[10]:
A 0 at this bit position indicates that the data byte has been received when the device has been in slave mode, whereas a 1 indicates a reception in master mode.
- RBUF[11]:
A 1 at this bit position indicates an incomplete/erroneous data byte in the receive buffer caused by a wrong position of a START or STOP condition in the frame. The bit is not identical to the frame error status bit in PSR, because the bit in the PSR has to be cleared by software ("sticky" bit), whereas RBUF[11] is evaluated data byte by data byte. If RBUF[11] = 0, the received data byte has been correct, independent of former errors.
- RBUF[12]:
A 0 at this bit position indicates that the programmed address has been received. A 1 indicates a general call address.

15.5.3 Symbol Timing

The symbol timing of the IIC is determined by the master stimulating the shift clock line SCL. It is different in each of the modes.

- 100 kBaud standard mode (PCR.STIM = 0):
The symbol timing is based on 10 time quanta t_q per symbol. A minimum module clock frequency $f_{\text{PERIPH}} = 2 \text{ MHz}$ is required.
- 400 kBaud fast mode (PCR.STIM = 1):
The symbol timing is based on 25 time quanta t_q per symbol. A minimum module clock frequency $f_{\text{PERIPH}} = 10 \text{ MHz}$ is required.

The baud rate setting should only be changed while the transmitter and the receiver are idle or CCR.MODE = 0. The bits in register BRG define the length of a time quantum t_q that is given by one period of f_{PCTQ} .

- BRG.CTQSEL
to define the input frequency f_{CTQIN} for the time quanta generation
- BRG.PCTQ
to define the length of a time quantum (division of f_{CTQIN} by 1, 2, 3, or 4)
- BRG.DCTQ
to define the number of time quanta per symbol (number of $t_q = \text{DCTQ} + 1$)

The standard setting is given by CTQSEL = 00_B ($f_{\text{CTQIN}} = f_{\text{PDIV}}$) and PPPEN = 0 ($f_{\text{PPP}} = f_{\text{IN}}$). Under these conditions, the frequency f_{PCTQ} is given by:

$$f_{\text{PCTQ}} = f_{\text{PIN}} \times \frac{1}{\text{PDIV} + 1} \times \frac{1}{\text{PCTQ} + 1} \quad (15.10)$$

To respect the specified SDA hold time of 300 ns for standard mode and fast mode after a falling edge of signal SCL, a hold delay t_{HDEL} has been introduced. It also prevents an erroneous detection of a start or a stop condition. The length of this delay can be programmed by bit field PCR.HDEL. Taking into account the input sampling and output update, bit field HDEL can be programmed according to:

(15.11)

$$\begin{aligned} \text{HDEL} &\geq 300 \text{ ns} \times f_{\text{PPP}} - \left(3 \times \frac{f_{\text{PPP}}}{f_{\text{PERIPH}}} \right) + 1 && \text{with digital filter and HDELmin} = 2 \\ \text{HDEL} &\geq 300 \text{ ns} \times f_{\text{PPP}} - \left(3 \times \frac{f_{\text{PPP}}}{f_{\text{PERIPH}}} \right) + 2 && \text{without digital filter and HDELmin} = 1 \end{aligned}$$

If the digital input filter is used, HDEL compensates the filter delay of 2 filter periods (f_{PPP} should be used) in case of a spike on the input signal. This ensures that a data bit on the SDA line changing just before the rising edge or behind the falling edge of SCL will not be treated as a start or stop condition.

Universal Serial Interface Channel (USIC)

15.5.3.1 Start Symbol

Figure 15-52 shows the general start symbol timing.

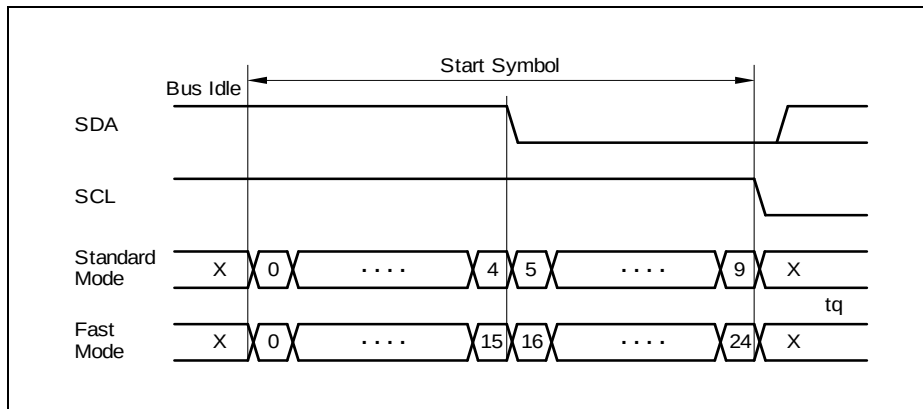


Figure 15-52 Start Symbol Timing

15.5.3.2 Repeated Start Symbol

During the first part of a repeated start symbol, an SCL low value is driven for the specified number of time quanta. Then a high value is output. After the detection of a rising edge at the SCL input, a normal start symbol is generated, as shown in Figure 15-53.

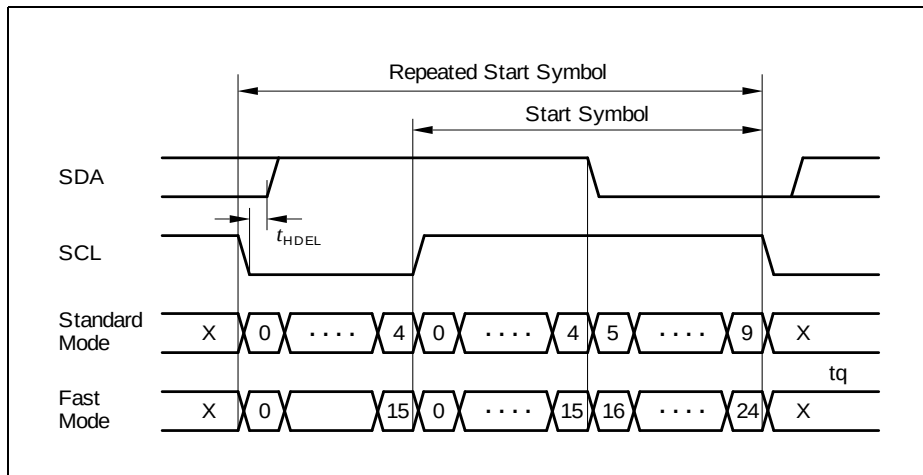


Figure 15-53 Repeated Start Symbol Timing

15.5.3.3 Stop Symbol

Figure 15-54 shows the stop symbol timing.

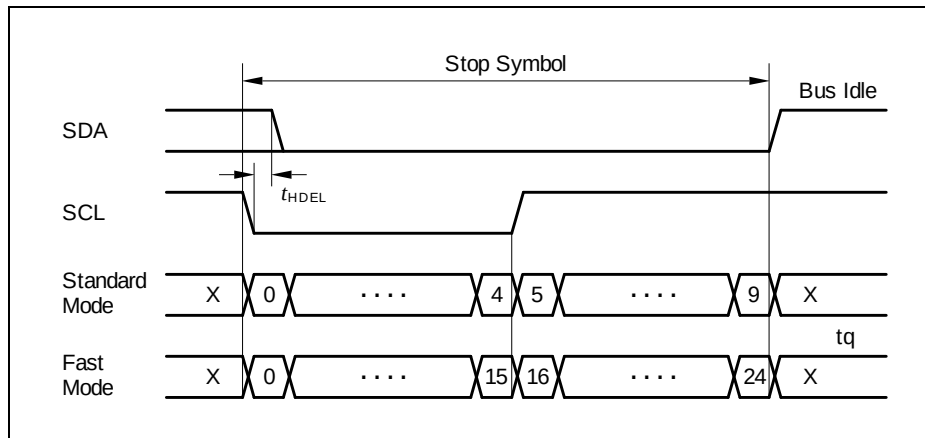


Figure 15-54 Stop Symbol Timing

15.5.3.4 Data Bit Symbol

Figure 15-55 shows the general data bit symbol timing.

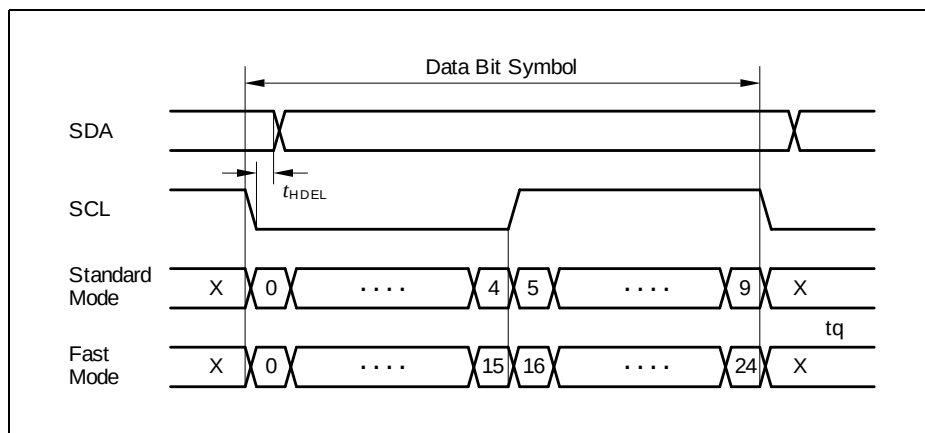


Figure 15-55 Data Bit Symbol

Output SDA changes after the time t_{HDEL} defined by PCR.HDEL has elapsed if a falling edge is detected at the SCL input to respect the SDA hold time. The value of PCR.HDEL allows compensation of the delay of the SCL input path (sampling, filtering).

Universal Serial Interface Channel (USIC)

In the case of an acknowledge transmission, the USIC IIC waits for the receiver indicating that a complete byte has been received. This adds an additional delay of 3 periods of f_{PERIPH} to the path. The minimum module input frequency has to be selected properly to ensure the SDA setup time to SCL rising edge.

15.5.4 Data Flow Handling

The handling of the data flow and the sequence of the symbols in an IIC frame is controlled by the IIC transmitter part of the USIC communication channel. The IIC bus protocol is byte-oriented, whereas a USIC data buffer word can contain up to 16 data bits. In addition to the data byte to be transmitted (located at TBUF[7:0]), bit field TDF (transmit data format) to control the IIC sequence is located at the bit positions TBUF[10:8]. The TDF code defines for each data byte how it should be transmitted (IIC master or IIC slave), and controls the transmission of (repeated) start and stop symbols. This structure allows the definition of a complete IIC frame for an IIC master device only by writing to TBUFx or by using a FIFO data buffer mechanism, because no other control registers have to be accessed. Alternatively, polling of the ACK and NACK bits in PSR register can be performed, and the next data byte is transmitted only after an ACK is received.

If a wrong or unexpected TDF code is encountered (e.g. due to a software error during setup of the transmit buffer), a stop condition will be sent out by the master. This leads to an abort of the currently running frame. A slave module waits for a valid TDF code and sets SCL = 0. The software then has to invalidate the unexpected TDF code and write a valid one.

Please note that during an arbitration phase in multi-master bus systems an unpredictable bus behavior may occur due to an unexpected stop condition.

15.5.4.1 Transmit Data Formats

The following transmit data formats are available in master mode:

Table 15-13 Master Transmit Data Formats

TDF Code	Description
000 _B	Send data byte as master This format is used to transmit a data byte from the master to a slave. The transmitter sends its data byte (TBUF[7:0]), receives and checks the acknowledge bit sent by the slave.
010 _B	Receive data byte and send acknowledge This format is used by the master to read a data byte from a slave. The master acknowledges the transfer with a 0-level to continue the transfer. The content of TBUF[7:0] is ignored.

Universal Serial Interface Channel (USIC)

Table 15-13 Master Transmit Data Formats (cont'd)

TDF Code	Description
011 _B	Receive data byte and send not-acknowledge This format is used by the master to read a data byte from a slave. The master does not acknowledge the transfer with a 1-level to finish the transfer. The content of TBUF[7:0] is ignored.
100 _B	Send start condition If TBUF contains this entry while the bus is idle, a start condition will be generated. The content of TBUF[7:0] is taken as first address byte for the transmission (bits TBUF[7:1] are the address, the LSB is the read/write control).
101 _B	Send repeated start condition If TBUF contains this entry and SCL = 0 and a byte transfer is not in progress, a repeated start condition will be sent out if the device is the current master. The current master is defined as the device that has set the start condition (and also won the master arbitration) for the current message. The content of TBUF[7:0] is taken as first address byte for the transmission (bits TBUF[7:1] are the address, the LSB is the read/write control).
110 _B	Send stop condition If the current master has finished its last byte transfer (including acknowledge), it sends a stop condition if this format is in TBUF. The content of TBUF[7:0] is ignored.
111 _B	Reserved This code must not be programmed. No additional action except releasing the TBUF entry and setting the error bit in PSR (that can lead to a protocol interrupt).

The following transmit data format is available in slave mode (the symbols in a frame are controlled by the master and the slave only has to send data if it has been “asked” by the master):

Table 15-14 Slave Transmit Data Format

TDF Code	Description
001 _B	Send data byte as slave This format is used to transmit a data byte from a slave to the master. The transmitter sends its data byte (TBUF[7:0]) plus the acknowledge bit as a 1.

Universal Serial Interface Channel (USIC)

15.5.4.2 Valid Master Transmit Data Formats

Due to the IIC frame format definitions, only some specific sequences of TDF codes are possible and valid. If the USIC IIC module detects a wrong TDF code in a running frame, the transfer is aborted and flag PCR.WTDF is set. Additionally, an interrupt can be generated if enabled by the user. In case of a wrong TDF code, the frame will be aborted immediately with a STOP condition if the USIC IIC master still owns the SDA line. But if the accessed slave owns the SDA line (read transfer), the master must perform a dummy read with a non-acknowledge so that the slave releases the SDA line before a STOP condition can be sent. The received data byte of the dummy read will be stored in RBUF0/1, but RDV0/1 will not be set. Therefore the dummy read will not generate a receive interrupt and the data byte will not be stored into the receive FIFO.

If the transfer direction has changed in the current frame (master read access), the transmit data request (TDF = 000_B) is not possible and won't be accepted (leading to a wrong TDF Code indication).

Table 15-15 Valid TDF Codes Overview

Frame Position	Valid TDF Codes
First TDF code (master idle)	Start (100 _B)
Read transfer: second TDF code (after start or repeated start)	Receive with acknowledge (010 _B) or receive with not-acknowledge (011 _B)
Write transfer: second TDF code (after start or repeated start)	Transmit (000 _B), repeated start (101 _B), or stop (110 _B)
Read transfer: third and subsequent TDF code after acknowledge	Receive with acknowledge (010 _B) or receive with not-acknowledge (011 _B)
Read transfer: third and subsequent TDF code after not-acknowledge	Repeated start (101 _B) or stop (110 _B)
Write transfer: third and subsequent TDF code	Transmit (000 _B), repeated start (101 _B), or stop (110 _B)

- First TDF code:
A master transfer starts with the TDF start code (100_B). All other codes are ignored, but no WTDF error will be indicated.
- TDF code after a start (100_B) or repeated start code (101_B) in case of a read access:
If a master-read transfer is started (determined by the LSB of the address byte = 1), the transfer direction of SDA changes and the slave will actively drive the data line. In this case, only the codes 010_B and 011_B are valid. To abort the transfer in case of a wrong code, a dummy read must be performed by the master before the STOP condition can be generated.

Universal Serial Interface Channel (USIC)

- TDF code after a start (100_B) or repeated start code (101_B) in case of a write access:
If a master-write transfer is started (determined by the LSB of the address byte = 0), the master still owns the SDA line. In this case, the transmit (000_B), repeated start (101_B) and stop (110_B) codes are valid. The other codes are considered as wrong. To abort the transfer in case of a wrong code, the STOP condition is generated immediately.
- TDF code of the third and subsequent command in case of a read access with acknowledged previous data byte:
If a master-read transfer is started (determined by the LSB of the address byte), the transfer direction of SDA changes and the slave will actively drive the data line. To force the slave to release the SDA line, the master has to not-acknowledge a byte transfer. In this case, only the receive codes 010_B and 011_B are valid. To abort the transfer in case of a wrong code, a dummy read must be performed by the master before the STOP condition can be generated.
- TDF code of the third and subsequent command in case of a read access with a not-acknowledged previous data byte:
If a master-read transfer is started (determined by the LSB of the address byte), the transfer direction of SDA changes and the slave will actively drive the data line. To force the slave to release the SDA line, the master has to not-acknowledge a byte transfer. In this case, only the restart (101_B) and stop code (110_B) are valid. To abort the transfer in case of a wrong code, the STOP condition is generated immediately.
- TDF code of the third and subsequent command in case of a write access:
If a master-write transfer is started (determined by the LSB of the address byte), the master still owns the SDA line. In this case, the transmit (000_B), repeated start (101_B) and stop (110_B) codes are valid. The other codes are considered as wrong. To abort the transfer in case of a wrong code, the STOP condition is generated immediately.
- After a master device has received a non-acknowledge from a slave device, a stop condition will be sent out automatically, except if the following TDF code requests a repeated start condition. In this case, the TDF code is taken into account, whereas all other TDF codes are ignored.

Universal Serial Interface Channel (USIC)

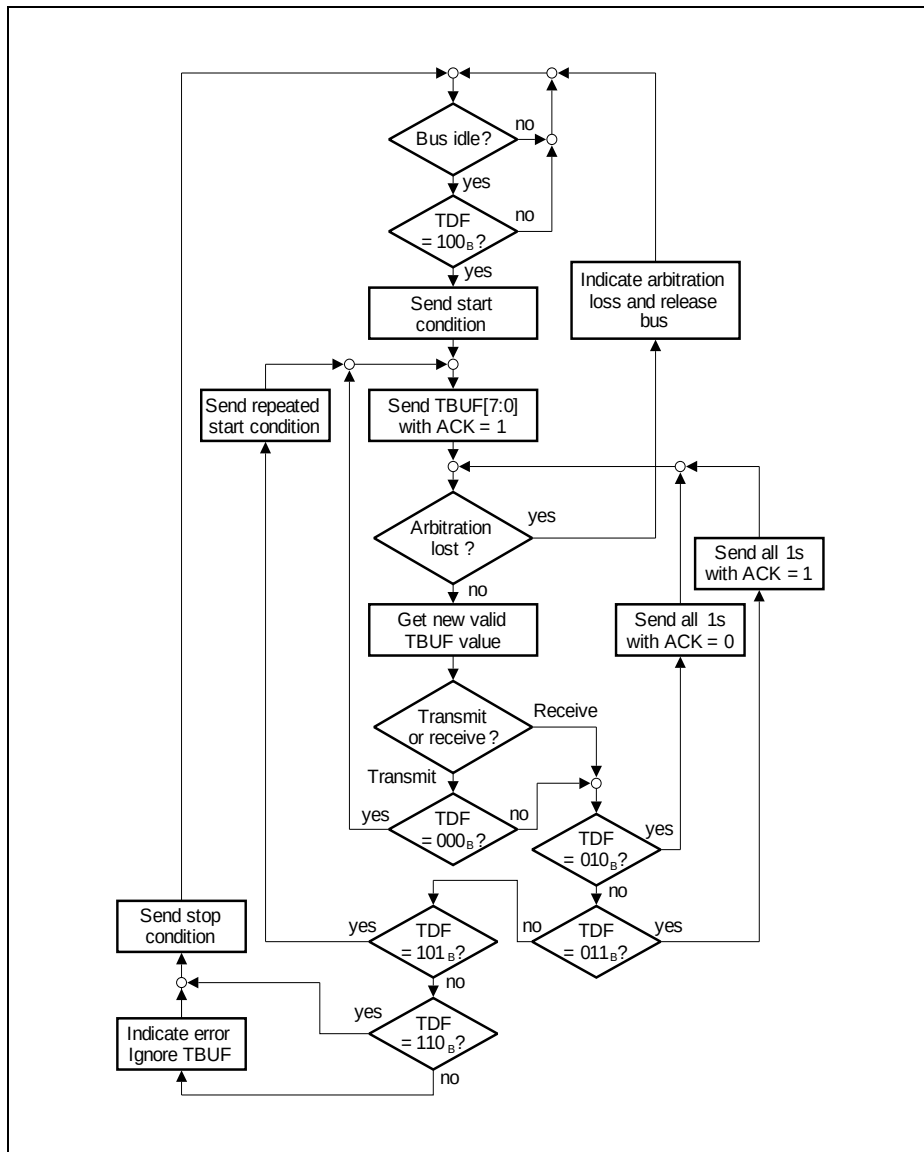


Figure 15-56 IIC Master Transmission

15.5.4.3 Master Transmit/Receive Modes

In master transmit mode, the IIC sends a number of data bytes to a slave receiver. The TDF code sequence for the master transmit mode is shown in [Table 15-16](#).

Table 15-16 TDF Code Sequence for Master Transmit

TDF Code Sequence	TBUF[10:8] (TDF Code)	TBUF[7:0]	IIC Response	Interrupt Events
1st code	100 _B	Slave address + write bit	Send START condition, slave address and write bit	SCR: Indicates a START condition is detected TBIF: Next word can be written to TBUF
2nd code	000 _B	Data or 2nd slave address byte	Send data or 2nd slave address byte	TBIF: Next word can be written to TBUF
Subsequent codes for data transmit	000 _B	Data	Send data	TBIF: Next word can be written to TBUF
Last code	110 _B	Don't care	Send STOP condition	PCR: Indicates a STOP condition is detected

In master receive mode, the IIC receives a number of data bytes from a slave transmitter. The TDF code sequence for the master receive 7-bit and 10-bit addressing modes are shown in [Table 15-17](#) and [Table 15-18](#).

Universal Serial Interface Channel (USIC)
Table 15-17 TDF Code Sequence for Master Receive (7-bit Addressing Mode)

TDF Code Sequence	TBUF[10:8] (TDF Code)	TBUF[7:0]	IIC Response	Interrupt Events
1st code	100 _B	Slave address + read bit	Send START condition, slave address and read bit	SCR: Indicates a START condition is detected TBIF: Next word can be written to TBUF
2nd code	010 _B	Don't care	Receive data and send ACK bit	TBIF: Next word can be written to TBUF AIF: First data received can be read
Subsequent codes for data receive	010 _B	Don't care	Receive data and send ACK bit	TBIF: Next word can be written to TBUF RIF: Subsequent data received can be read
Code for last data to be received	011 _B	Don't care	Receive data and send NACK bit	TBIF: Next word can be written to TBUF RIF: Last data received can be read
Last code	110 _B	Don't care	Send STOP condition	PCR: Indicates a STOP condition is detected

Table 15-18 TDF Code Sequence for Master Receive (10-bit Addressing Mode)

TDF Code Sequence	TBUF[10:8] (TDF Code)	TBUF[7:0]	IIC Response	Interrupt Events
1st code	100 _B	Slave address (1st byte) + write bit	Send START condition, slave address (1st byte) and write bit	SCR: Indicates a START condition is detected TBIF: Next word can be written to TBUF
2nd code	000 _B	Slave address (2nd byte)	Send address (2nd byte)	TBIF: Next word can be written to TBUF

Universal Serial Interface Channel (USIC)

Table 15-18 TDF Code Sequence for Master Receive (10-bit Addressing Mode)
(cont'd)

TDF Code Sequence	TBUF[10:8] (TDF Code)	TBUF[7:0]	IIC Response	Interrupt Events
3rd code	101 _B	1st slave address + read bit	Send repeated START condition, slave address (1st byte) and read bit	RSCR: Indicates a repeated START condition is detected TBIF: Next word can be written to TBUF
4th code	010 _B	Don't care	Receive data and send ACK bit	TBIF: Next word can be written to TBUF AIF: First data received can be read
Subsequent codes for data receive	010 _B	Don't care	Receive data and send ACK bit	TBIF: Next word can be written to TBUF RIF: Subsequent data received can be read
Code for last data to be received	011 _B	Don't care	Receive data and send NACK bit	TBIF: Next word can be written to TBUF RIF: Last data received from slave can be read
Last code	110 _B	Don't care	Send STOP condition	PCR: Indicates a STOP condition is detected

Figure 15-57 shows the interrupt events during the master transmit-slave receive and master receive/slave transmit sequences.

Universal Serial Interface Channel (USIC)

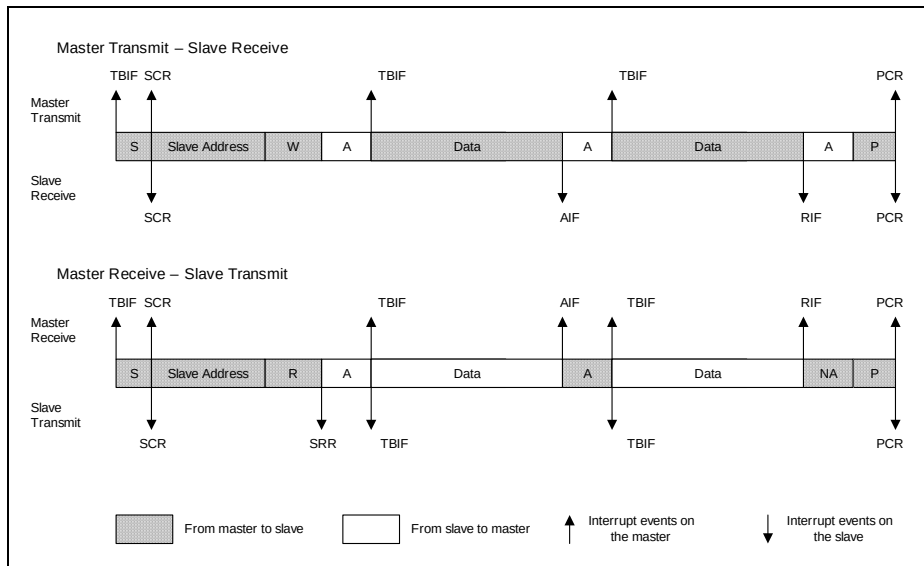


Figure 15-57 Interrupt Events on Data Transfers

15.5.4.4 Slave Transmit/Receive Modes

In slave receive mode, no TDF code needs to be written and data reception is indicated by the alternate receive (AIF) or receive (RIF) events.

In slave transmit mode, upon receiving its own slave address or general call address if this option is enabled, a slave read request event (SRR) will be triggered. The slave IIC then writes the TDF code 001₈ and the requested data to TBUF to transmit the data to the master. The slave does not check if the master reply with an ACK or NACK to the transmitted data.

In both cases, the data transfer is terminated by the master sending a STOP condition, which is indicated by a PCR event. See also [Figure 15-57](#).

15.5.5 IIC Protocol Registers

In IIC mode, the registers PCR and PSR handle IIC related information.

15.5.5.1 IIC Protocol Control Registers

In IIC mode, the PCR register bits or bit fields are defined as described in this section.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
RSCRIEN	19	rw	Repeated Start Condition Received Interrupt Enable This bit enables the generation of a protocol interrupt if a repeated start condition is detected. 0 _B The repeated start condition interrupt is disabled. 1 _B The repeated start condition interrupt is enabled.
PCRIEN	20	rw	Stop Condition Received Interrupt Enable This bit enables the generation of a protocol interrupt if a stop condition is detected. 0 _B The stop condition interrupt is disabled. 1 _B The stop condition interrupt is enabled.
NACKIEN	21	rw	Non-Acknowledge Interrupt Enable This bit enables the generation of a protocol interrupt if a non-acknowledge is detected by a master. 0 _B The non-acknowledge interrupt is disabled. 1 _B The non-acknowledge interrupt is enabled.
ARLIEN	22	rw	Arbitration Lost Interrupt Enable This bit enables the generation of a protocol interrupt if an arbitration lost event is detected. 0 _B The arbitration lost interrupt is disabled. 1 _B The arbitration lost interrupt is enabled.
SRRIEN	23	rw	Slave Read Request Interrupt Enable This bit enables the generation of a protocol interrupt if a slave read request is detected. 0 _B The slave read request interrupt is disabled. 1 _B The slave read request interrupt is enabled.
ERRIEN	24	rw	Error Interrupt Enable This bit enables the generation of a protocol interrupt if an IIC error condition is detected (indicated by PSR.ERR or PSR.WTDF). 0 _B The error interrupt is disabled. 1 _B The error interrupt is enabled.

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Field	Bits	Type	Description
SACKDIS	25	rw	Slave Acknowledge Disable This bit disables the generation of an active acknowledge signal for a slave device (active acknowledge = 0 level). Once set by software, it is automatically cleared with each (repeated) start condition. If this bit is set after a byte has been received (indicated by an interrupt) but before the next acknowledge bit has started, the next acknowledge bit will be sent with passive level. This would indicate that the receiver does not accept more bytes. As a result, a minimum of 2 bytes will be received if the first receive interrupt is used to set this bit. 0_B The generation of an active slave acknowledge is enabled (slave acknowledge with 0 level = more bytes can be received). 1_B The generation of an active slave acknowledge is disabled (slave acknowledge with 1 level = reception stopped).
HDEL	[29:26]	rw	Hardware Delay This bit field defines the delay used to compensate the internal treatment of the SCL signal (see Page 15-118) in order to respect the SDA hold time specified for the IIC protocol.
ACKIEN	30	rw	Acknowledge Interrupt Enable This bit enables the generation of a protocol interrupt if an acknowledge is detected by a master. 0_B The acknowledge interrupt is disabled. 1_B The acknowledge interrupt is enabled.
MCLK	31	rw	Master Clock Enable This bit enables generation of the master clock MCLK (not directly used for IIC protocol, can be used as general frequency output). 0_B The MCLK generation is disabled and MCLK is 0. 1_B The MCLK generation is enabled.

15.5.5.2 IIC Protocol Status Register

The following PSR status bits or bit fields are available in IIC mode. Please note that the bits in register PSR are not cleared by hardware.

The flags in the PSR register can be cleared by writing a 1 to the corresponding bit position in register PSCR. Writing a 1 to a bit position in PSR sets the corresponding flag,

Universal Serial Interface Channel (USIC)

but does not lead to further actions (no interrupt generation). Writing a 0 has no effect. These flags should be cleared by software before enabling a new protocol.

PSR

Protocol Status Register [IIC Mode] (48_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															BRG IF
r															rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIF	RIF	TBIF	TSIF	DLIF	RSIF	ACK	ERR	SRR	ARL	NACK	PCR	RSCR	SCR	WTD F	SLS EL
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
SLSEL	0	rwh	Slave Select This bit indicates that this device has been selected as slave. 0 _B The device is not selected as slave. 1 _B The device is selected as slave.
WTDF	1	rwh	Wrong TDF Code Found¹⁾ This bit indicates that an unexpected/wrong TDF code has been found. A protocol interrupt can be generated if PCR.ERRIEN = 1. 0 _B A wrong TDF code has not been found. 1 _B A wrong TDF code has been found.
SCR	2	rwh	Start Condition Received¹⁾ This bit indicates that a start condition has been detected on the IIC bus lines. A protocol interrupt can be generated if PCR.SCRIEN = 1. 0 _B A start condition has not yet been detected. 1 _B A start condition has been detected.

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Field	Bits	Type	Description
RSCR	3	rwh	Repeated Start Condition Received¹⁾ This bit indicates that a repeated start condition has been detected on the IIC bus lines. A protocol interrupt can be generated if PCR.RSCRIEN = 1. 0 _B A repeated start condition has not yet been detected. 1 _B A repeated start condition has been detected.
PCR	4	rwh	Stop Condition Received¹⁾ This bit indicates that a stop condition has been detected on the IIC bus lines. A protocol interrupt can be generated if PCR.PCRIEN = 1. 0 _B A stop condition has not yet been detected. 1 _B A stop condition has been detected.
NACK	5	rwh	Non-Acknowledge Received¹⁾ This bit indicates that a non-acknowledge has been received in master mode. This bit is not set in slave mode. A protocol interrupt can be generated if PCR.NACKIEN = 1. 0 _B A non-acknowledge has not been received. 1 _B A non-acknowledge has been received.
ARL	6	rwh	Arbitration Lost¹⁾ This bit indicates that an arbitration has been lost. A protocol interrupt can be generated if PCR.ARLIEN = 1. 0 _B An arbitration has not been lost. 1 _B An arbitration has been lost.
SRR	7	rwh	Slave Read Request¹⁾ This bit indicates that a slave read request has been detected. It becomes active to request the first data byte to be made available in the transmit buffer. For further consecutive data bytes, the transmit buffer issues more interrupts. For the end of the transfer, the master transmitter sends a stop condition. A protocol interrupt can be generated if PCR.SRRIEN = 1. 0 _B A slave read request has not been detected. 1 _B A slave read request has been detected.

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Field	Bits	Type	Description
ERR	8	rwh	Error¹⁾ This bit indicates that an IIC error (frame format or TDF code) has been detected. A protocol interrupt can be generated if PCR.ERRIEN = 1. 0 _B An IIC error has not been detected. 1 _B An IIC error has been detected.
ACK	9	rwh	Acknowledge Received¹⁾ This bit indicates that an acknowledge has been received in master mode. This bit is not set in slave mode. A protocol interrupt can be generated if PCR.ACKIEN = 1. 0 _B An acknowledge has not been received. 1 _B An acknowledge has been received.
RSIF	10	rwh	Receiver Start Indication Flag 0 _B A receiver start event has not occurred. 1 _B A receiver start event has occurred.
DLIF	11	rwh	Data Lost Indication Flag 0 _B A data lost event has not occurred. 1 _B A data lost event has occurred.
TSIF	12	rwh	Transmit Shift Indication Flag 0 _B A transmit shift event has not occurred. 1 _B A transmit shift event has occurred.
TBIF	13	rwh	Transmit Buffer Indication Flag 0 _B A transmit buffer event has not occurred. 1 _B A transmit buffer event has occurred.
RIF	14	rwh	Receive Indication Flag 0 _B A receive event has not occurred. 1 _B A receive event has occurred.
AIF	15	rwh	Alternative Receive Indication Flag 0 _B An alternative receive event has not occurred. 1 _B An alternative receive event has occurred.
BRGIF	16	rwh	Baud Rate Generator Indication Flag 0 _B A baud rate generator event has not occurred. 1 _B A baud rate generator event has occurred.
0	[31:17]	r	Reserved Returns 0 if read; not modified in IIC mode.

1) This status bit can generate a protocol interrupt (see [Page 15-22](#)). The general interrupt status flags are described in the general interrupt chapter.

15.6 Inter-IC Sound Bus Protocol (IIS)

This chapter describes how the USIC module handles the IIS protocol. This serial protocol can handle reception and transmission of synchronous data frames between a device operating in master mode and a device in slave mode. An IIS connection based on a USIC communication channel supports half-duplex and full-duplex data transfers. The IIS mode is selected by `CCR.MODE = 0011B` with `CCFG.IIS = 1` (IIS mode is available).

15.6.1 Introduction

The IIS protocol is a synchronous serial communication protocol mainly for audio and infotainment applications [8].

15.6.1.1 Signal Description

A connection between an IIS master and an IIS slave is based on the following signals:

- A shift clock signal SCK, generated by the transfer master. It is permanently generated while an IIS connection is established, also while no valid data bits are transferred.
- A word address signal WA (also named WS), generated by the transfer master. It indicates the beginning of a new data word and the targeted audio channel (e.g. left/right). The word address output signal WA is available on all SELOx outputs if the WA generation is enabled (by `PCR.WAGEN = 1` for the transfer master). The WA signal changes synchronously to the falling edges of the shift clock.
- If the transmitter is the IIS master device, it generates a master transmit slave receive data signal. The data changes synchronously to the falling edges of the shift clock.
- If the transmitter is the IIS slave device, it generates a master receive slave transmit data signal. The data changes synchronously to the falling edges of the shift clock.

The transmitter part and the receiver part of the USIC communication channel can be used together to establish a full-duplex data connection between an IIS master and a slave device.

Table 15-19 IIS IO Signals

IIS Mode	Receive Data	Transmit Data	Shift Clock	Word Address
Master	Input DIN0, handled by DX0	Output DOUT0	Output SCLKOUT	Output(s) SELOx
Slave	Input DIN0, handled by DX0	Output DOUT0	Input SCLKIN, handled by DX1	Input SELIN, handled by DX2

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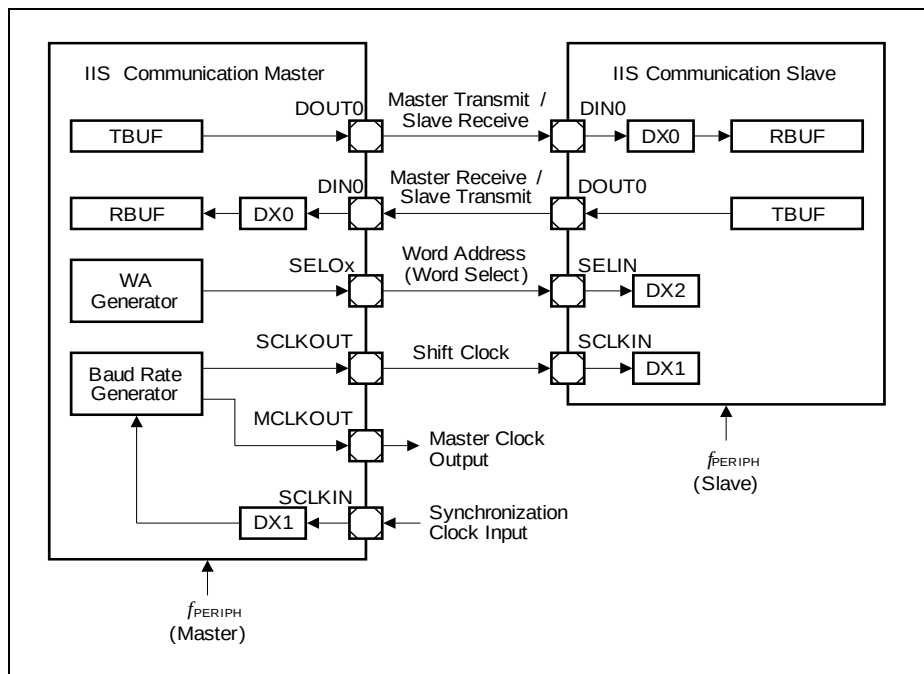


Figure 15-58 IIS Signals

Two additional signals are available for the USIC IIS communication master:

- A master clock output signal MCLKOUT with a fixed phase relation to the shift clock to support oversampling for audio components. It can also be used as master clock output of a communication network with synchronized IIS connections.
- A synchronization clock input SCLKIN for synchronization of the shift clock generation to an external frequency to support audio frequencies that can not be directly derived from the system clock f_{PERIPH} of the communication master. It can be used as master clock input of a communication network with synchronized IIS connections.

15.6.1.2 Protocol Overview

An IIS connection supports transfers for two different data frames via the same data line, e.g. a data frames for the left audio channel and a data frame for the right audio channel. The word address signal WA is used to distinguish between the different data frames. Each data frame can consist of several data words.

Universal Serial Interface Channel (USIC)

In a USIC communication channel, data words are tagged for being transmitted for the left or for the right channel. Also the received data words contain a tag identifying the WA state when the data has been received.

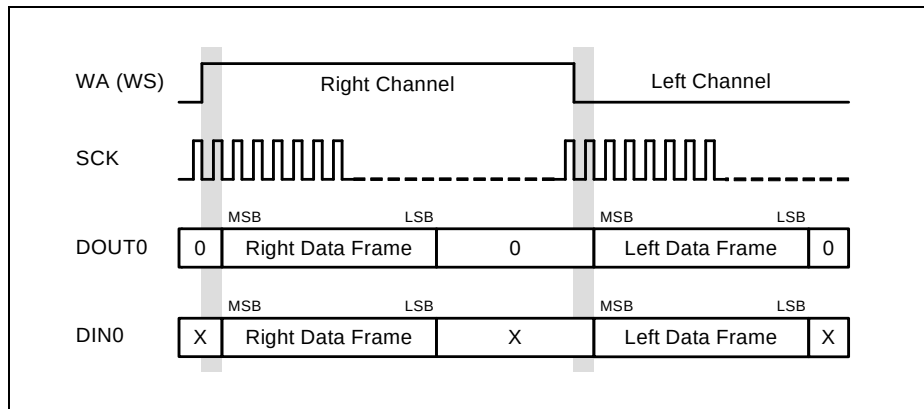


Figure 15-59 Protocol Overview

15.6.1.3 Transfer Delay

The transfer delay feature allows the transfer of data (transmission and reception) with a programmable delay (counted in shift clock periods).

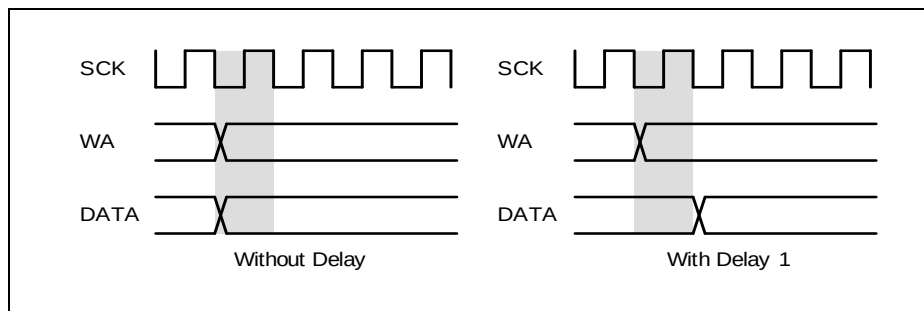


Figure 15-60 Transfer Delay for IIS

15.6.1.4 Connection of External Audio Components

The IIS signals can be used to communicate with external audio devices (such as Codecs) or other audio data sources/destinations.

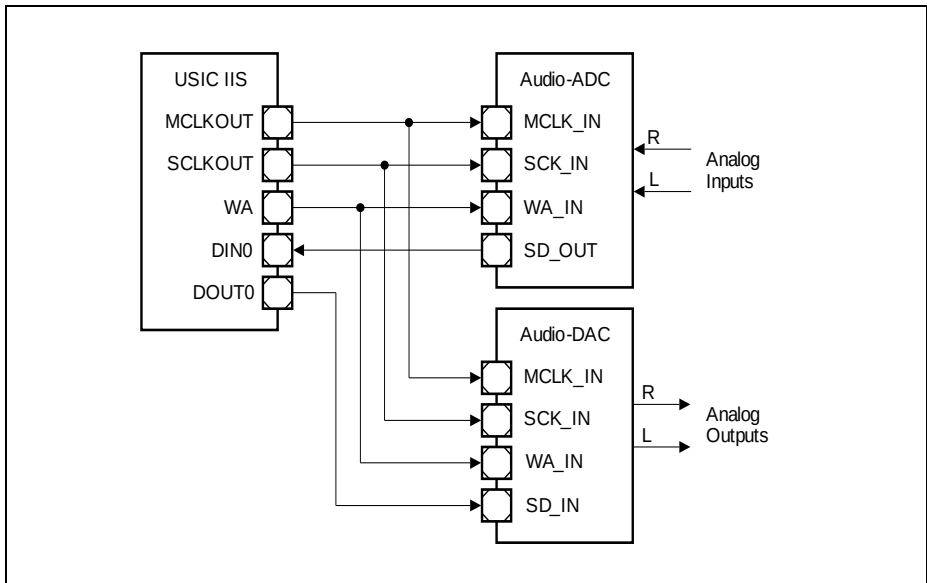


Figure 15-61 Connection of External Audio Devices

In some applications, especially for Audio-ADCs or Audio-DACs, a master clock signal is required with a fixed phase relation to the shift clock signal. The frequency of MCLKOUT is a multiple of the shift frequency SCLKOUT. This factor defines the oversampling factor of the external device (commonly used values: 256 or 384).

15.6.2 Operating the IIS

This chapter contains IIS issues, that are of general interest and not directly linked to master mode or slave mode.

15.6.2.1 Frame Length and Word Length Configuration

After each change of the WA signal, a complete data frame is intended to be transferred (frame length $\leq$ system word length). The number of data bits transferred after a change of signal WA is defined by SCTR.FLE. A data frame can consist of several data words with a data word length defined by SCTR.WLE. The changes of signal WA define the system word length as the number of SCLK cycles between two changes of WA (number of bits available for the right channel and same number available for the left channel).

If the system word length is longer than the frame length defined by SCTR.FLE, the additional bits are transmitted with passive data level (SCTR.PDL). If the system word

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length is smaller than the device frame length, not all LSBs of the transmit data can be transferred.

It is recommended to program bits WLEMD, FLEMD and SELMD in register TCSR to 0.

15.6.2.2 Automatic Shadow Mechanism

The baud rate and shift control setting are internally kept constant while a data frame is transferred by an automatic shadow mechanism. The registers can be programmed all the time with new settings that are taken into account for the next data frame. During a data frame, the applied (shadowed) setting is not changed, although new values have been written after the start of the data frame. The setting is internally “frozen” with the start of each data frame.

Although this shadow mechanism being implemented, it is recommended to change the baud rate and shift control setting only while the IIS protocol is switched off.

15.6.2.3 Mode Control Behavior

In IIS mode, the following kernel modes are supported:

- Run Mode 0/1:
Behavior as programmed, no impact on data transfers.
- Stop Mode 0/1:
Bit PCR.WAGEN is internally considered as 0 (the bit itself is not changed). If WAGEN = 1, the WA generation is stopped, but PSR.END is not set. The complete data frame is finished before entering stop mode, including a possible delay due to PCR.TDEL.
When leaving a stop mode with WAGEN = 1, the WA generation starts from the beginning.

15.6.2.4 Transfer Delay

The transfer delay can be used to synchronize a data transfer to an event (e.g. a change of the WA signal). This event has to be synchronously generated to the falling edge of the shift clock SCK (like the change of the transmit data), because the input signal for the event is directly sampled in the receiver (as a result, the transmitter can use the detection information with its next edge).

Event signals that are asynchronous to the shift clock while the shift clock is running must not be used. In the example in [Figure 15-60](#), the event (change of signal WA) is generated by the transfer master and as a result, is synchronous to the shift clock SCK. With the rising edge of SCK, signal WA is sampled and checked for a change. If a change is detected, a transfer delay counter TDC is automatically loaded with its programmable reload value (PCR.TDEL), otherwise it is decremented with each rising edge of SCK until it reaches 0, where it stops. The transfer itself is started if the value of TDC has become 0. This can happen under two conditions:

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- TDC is reloaded with a PCR.TDEL = 0 when the event is detected
- TDC has reached 0 while counting down

The transfer delay counter is internal to the IIS protocol pre-processor and can not be observed by software. The transfer delay in SCK cycles is given by PCR.TDEL+1.

In the example in [Figure 15-62](#), the reload value PCR.TDEL for TDC is 0. When the samples taken on receiver side show the change of the WA signal, the counter TDC is reloaded. If the reload value is 0, the data transfer starts with 1 shift clock cycle delay compared to the change of WA.

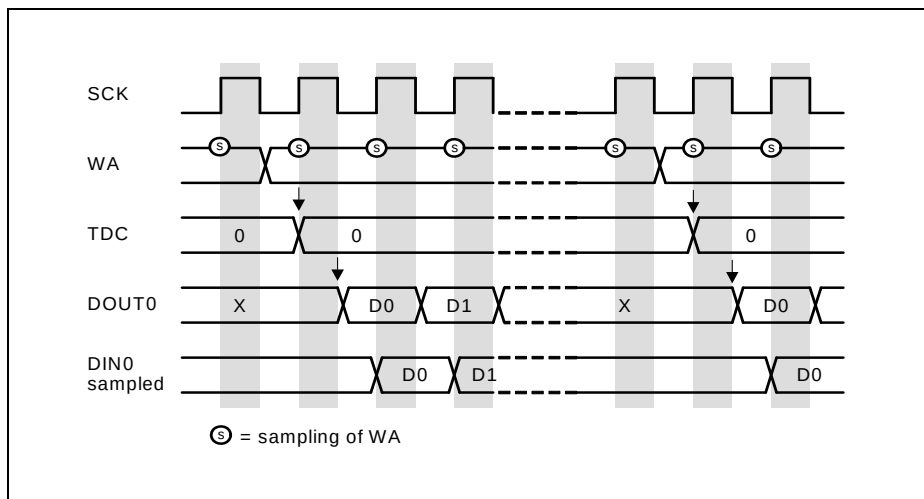


Figure 15-62 Transfer Delay with Delay 1

The ideal case without any transfer delay is shown in [Figure 15-63](#). The WA signal changes and the data output value become valid at the same time. This implies that the transmitter “knows” in advance that the event signal will change with the next rising edge of TCLK. This is achieved by delaying the data transmission after the previously detected WA change the system word length minus 1.

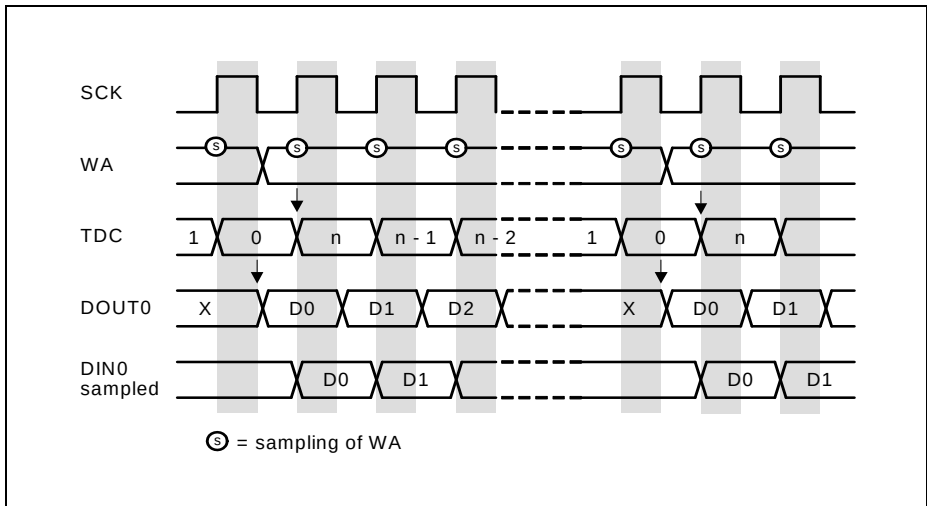


Figure 15-63 No Transfer Delay

If the end of the transfer delay is detected simultaneously to change of WA, the transfer is started and the delay counter is reloaded with PCR.TDEL. This allows to run the USIC as IIS device without any delay. In this case, internally the delay from the previous event elapses just at the moment when a new event occurs. If PCR.TDEL is set to a value bigger than the system word length, no transfer takes place.

15.6.2.5 Parity Mode

Parity generation is not supported in IIS mode and bit field CCR.PM = 00_B has to be programmed.

15.6.2.6 Transfer Mode

In IIS mode, bit field SCTR.TRM = 11_B has to be programmed to allow data transfers. Setting SCTR.TRM = 00_B disables and stops the data transfer immediately.

15.6.2.7 Data Transfer Interrupt Handling

The data transfer interrupts indicate events related to IIS frame handling.

- Transmit buffer interrupt TBI:
Bit PSR.TBIF is set after the start of first data bit of a data word.
- Transmit shift interrupt TSI:
Bit PSR.TSIF is set after the start of the last data bit of a data word.

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- Receiver start interrupt RSI:
Bit PSR.RSIF is set after the reception of the first data bit of a data word.
With this event, bit TCSR.TDV is cleared and new data can be loaded to the transmit buffer.
- Receiver interrupt RI and alternative interrupt AI:
Bit PSR.RIF is set at after the reception of the last data bit of a data word with WA = 0.
Bit RBUFSR.SOF indicates whether the received data word has been the first data word of a new data frame.
Bit PSR.AIF is set at after the reception of the last data bit of a data word with WA = 1.
Bit RBUFSR.SOF indicates whether the received data word has been the first data word of a new data frame.

15.6.2.8 Baud Rate Generator Interrupt Handling

The baud rate generator interrupt indicate that the capture mode timer has reached its maximum value. With this event, the bit PSR.BRGIF is set.

15.6.2.9 Protocol-Related Argument and Error

In order to distinguish between data words received for the left or the right channel, the IIS protocol pre-processor samples the level of the WA input (just after the WA transition) and propagates it as protocol-related error (although it is not an error, but an indication) to the receive buffer status register at the bit position RBUFSR[9]. This bit position defines if either a standard receive interrupt (if RBUFSR[9] = 0) or an alternative receive interrupt (if RBUFSR[9] = 1) becomes activated when a new data word has been received. Incoming data can be handled by different interrupts for the left and the right channel if the corresponding events are directed to different interrupt nodes. Flag PAR is always 0.

15.6.2.10 Transmit Data Handling

The IIS protocol pre-processor allows to distinguish between the left and the right channel for data transmission. Therefore, bit TCSR.WA indicates on which channel the data in the buffer will be transmitted. If TCSR.WA = 0, the data will be transmitted after a falling edge of WA. If TCSR.WA = 1, the data will be transmitted after a rising edge of WA. The WA value sampled after the WA transition is considered to distinguish between both channels (referring to PSR.WA).

Bit TCSR.WA can be automatically updated by the transmit control information TCI[4] for each data word if TCSR.WAMD = 1. In this case, data written to TBUF[15:0] (or IN[15:0] if a FIFO data buffer is used) is considered as left channel data, whereas data written to TBUF[31:16] (or IN[31:16] if a FIFO data buffer is used) is considered as right channel data.

15.6.2.11 Receive Buffer Handling

If a receive FIFO buffer is available (CCFG.RB = 1) and enabled for data handling (RBCTR.SIZE > 0), it is recommended to set RBCTR.RCIM = 11_B in IIS mode. This leads to an indication that the data word has been the first data word of a new data frame if bit OUTR.RCI[0] = 1, and the channel indication by the sampled WA value is given by OUTR.RCI[4].

The standard receive buffer event and the alternative receive buffer event can be used for the following operation in RCI mode (RBCTR.RNM = 1):

- A standard receive buffer event indicates that a data word can be read from OUTR that belongs to a data frame started when WA = 0.
- An alternative receive buffer event indicates that a data word can be read from OUTR that belongs to a data frame started when WA = 1.

15.6.2.12 Loop-Delay Compensation

The synchronous signaling mechanism of the IIS protocol being similar to the one of the SSC protocol, the closed-loop delay has to be taken into account for the application setup. In IIS mode, loop-delay compensation in master mode is also possible to achieve higher baud rates.

Please refer to the more detailed description in the SSC chapter.

15.6.3 Operating the IIS in Master Mode

In order to operate the IIS in master mode, the following issues have to be considered:

- Select IIS mode:
It is recommended to configure all parameters of the IIS that do not change during run time while CCR.MODE = 0000_B. Bit field SCTR.TRM = 11_B has to be programmed. The configuration of the input stages has to be done while CCR.MODE = 0000_B to avoid unintended edges of the input signals and the IIS mode can be enabled by CCR.MODE = 0011_B afterwards.
- Pin connection for data transfer:
Establish a connection of input stage DX0 with the selected receive data input pin (DIN0) with DX0CR.INSW = 1. Configure a transmit data output pin (DOUT0) for a transmitter.
The data shift unit allowing full-duplex data transfers based on the same WA signal, the values delivered by the DX0 stage are considered as data bits (receive function can not be disabled independently from the transmitter). To receive IIS data, the transmitter does not necessarily need to be configured (no assignment of DOUT0 signal to a pin).
- Baud rate generation:
The desired baud rate setting has to be selected, comprising the fractional divider

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and the baud rate generator. Bit DX1CR.INSW = 0 has to be programmed to use the baud rate generator output SCLK directly as input for the data shift unit.

- **Word address WA generation:**
The WA generation has to be enabled by setting PCR.WAGEN = 1 and the programming of the number of shift clock cycles between the changes of WA. Bit DX2CR.INSW = 0 has to be programmed to use the WA generator as input for the data shift unit. Configure WA output pin for signal SELOx if needed.
- **Data format configuration:**
The word length, the frame length, and the shift direction have to be set up according to the application requirements by programming the register SCTR. Generally, the MSB is shifted first (SCTR.SDIR = 1).
Bit TCSR.WAMD can be set to use the transmit control information TCI[4] to distinguish the data words for transmission while WA = 0 or while WA = 1.

Note: The step to enable the alternate output port functions should only be done after the IIS mode is enabled, to avoid unintended spikes on the output.

15.6.3.1 Baud Rate Generation

The baud rate is defined by the frequency of the SCLK signal (one period of f_{SCLK} represents one data bit).

If the fractional divider mode is used to generate f_{PIN} , there can be an uncertainty of one period of f_{PERIPH} for f_{PIN} . This uncertainty does not accumulate over several SCLK cycles. As a consequence, the average frequency is reached, whereas the duty cycle of 50% of the SCLK and MCLK signals can vary by one period of f_{PERIPH} .

In IIS applications, where the phase relation between the optional MCLK output signal and SCLK is not relevant, SCLK can be based on the frequency f_{PIN} (BRG.PPPEN = 0). In the case that a fixed phase relation between the MCLK signal and SCLK is required (e.g. when using MCLK as clock reference for external devices), the additional divider by 2 stage has to be taken into account (BRG.PPPEN = 1). This division is due to the fact that signal MCLK toggles with each cycle of f_{PIN} . Signal SCLK is then based on signal MCLK, see [Figure 15-64](#).

The adjustable integer divider factor is defined by bit field BRG.PDIV.

$$\begin{aligned} f_{SCLK} &= \frac{f_{PIN}}{2} \times \frac{1}{PDIV + 1} & \text{if } PPPEN = 0 \\ f_{SCLK} &= \frac{f_{PIN}}{2 \times 2} \times \frac{1}{PDIV + 1} & \text{if } PPPEN = 1 \end{aligned} \quad (15.12)$$

Note: In the IIS protocol, the master (unit generating the shift clock and the WA signal) changes the status of its data and WA output line with the falling edge of SCK. The slave transmitter also has to transmit on falling edges. The sampling of the received data is done with the rising edges of SCLK. The input stage DX1 and the

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SCLKOUT have to be programmed to invert the shift clock signal to fit to the internal signals.

15.6.3.2 WA Generation

The word address (or word select) line WA regularly toggles after N cycles of signal SCLK. The time between the changes of WA is called system word length and can be programmed by using the following bit fields.

In IIS master mode, the system word length is defined by:

- BRG.CTQSEL = 10_B
to base the WA toggling on SCLK
- BRG.PCTQ
to define the number N of SCLK cycles per system word length
- BRG.DCTQ
to define the number N of SCLK cycles per system word length

$$N = (PCTQ + 1) \times (DCTQ + 1) \quad (15.13)$$

15.6.3.3 Master Clock Output

The master clock signal MCLK can be generated by the master of the IIS transfer (BRG.PPPEN = 1). It is used especially to connect external Codec devices. It can be configured by bit BRG.MCLKCFG in its polarity to become the output signal MCLKOUT.

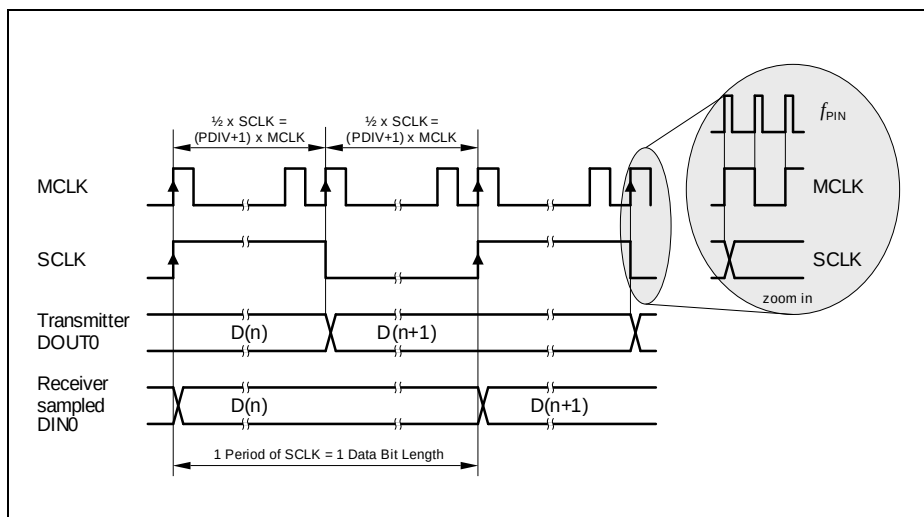


Figure 15-64 MCLK and SCLK for IIS

15.6.3.4 Protocol Interrupt Events

The following protocol-related events are generated in IIS mode and can lead to a protocol interrupt.

Please note that the bits in register PSR are not all automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- **WA rising/falling edge events:**
The WA generation block indicates two events that are monitored in register PSR. Flag PSR.WAFE is set with the falling edge, flag PSR.WARE with the rising edge of the WA signal. A protocol interrupt can be generated if PCR.WAFEIEN = 1 for the falling edge, similar for PCR.WAREIEN = 1 for a rising edge.
- **WA end event:**
The WA generation block also indicates when it has stopped the WA generation after it has been disabled by writing PCR.WAGEN = 0. A protocol interrupt can be generated if PCR.ENDIEN = 1.
- **DX2T event:**
An activation of the trigger signal DX2T is indicated by PSR.DX2TEV = 1 and can generate a protocol interrupt if PCR.DX2TIEN = 1. This event can be evaluated instead of the WA rising/falling events if a delay compensation like in SSC mode (for details, refer to corresponding SSC section) is used.

15.6.4 Operating the IIS in Slave Mode

In order to operate the IIS in slave mode, the following issues have to be considered:

- **Select IIS mode:**
It is recommended to configure all parameters of the IIS that do not change during run time while CCR.MODE = 0000_B. Bit field SCTR.TRM = 11_B has to be programmed. The configuration of the input stages has to be done while CCR.MODE = 0000_B to avoid unintended edges of the input signals and the IIS mode can be enabled by CCR.MODE = 0011_B afterwards.
- **Pin connection for data transfer:**
Establish a connection of input stage DX0 with the selected receive data input pin (DINO) with DX0CR.INSW = 1. Configure a transmit data output pin (DOUT0) for a transmitter.
The data shift unit allowing full-duplex data transfers based on the same WA signal, the values delivered by the DX0 stage are considered as data bits (receive function can not be disabled independently from the transmitter). To receive IIS data, the transmitter does not necessarily need to be configured (no assignment of DOUT0 signal to a pin).
Note that the step to enable the alternate output port functions should only be done after the IIS mode is enabled, to avoid unintended spikes on the output.

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- Pin connection for shift clock:
Establish a connection of input stage DX1 with the selected shift clock input pin (SCLKIN) with DX1CR.INSW = 1 and with inverted polarity (DX1CR.DPOL = 1).
- Pin connection for WA input:
Establish a connection of input stage DX2 with the WA input pin (SELIN) with DX2CR.INSW = 1.
- Baud rate generation:
The baud rate generator is not needed and can be switched off by the fractional divider.
- WA generation:
The WA generation is not needed and can be switched off (PCR.WAGEN = 0).

15.6.4.1 Protocol Events and Interrupts

The following protocol-related event is generated in IIS mode and can lead to a protocol interrupt.

Please note that the bits in register PSR are not all automatically cleared by hardware and have to be cleared by software in order to monitor new incoming events.

- WA rising/falling/end events:
The WA generation being switched off, these events are not available.
- DX2T event:
An activation of the trigger signal DX2T is indicated by PSR.DX2TEV = 1 and can generate a protocol interrupt if PCR.DX2TIEN = 1.

15.6.5 IIS Protocol Registers

In IIS mode, the registers PCR and PSR handle IIS related information.

15.6.5.1 IIS Protocol Control Registers

In IIS mode, the PCR register bits or bit fields are defined as described in this section.

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PCR

Protocol Control Register [IIS Mode]

(3C_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MCLK					0								TDEL		
rw					rw								rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DX2 TIEN					0				ENDI EN	WAR EIEN	WAF EIEN	0	SELI NV	DTE N	WAG EN
rw					rw				rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
WAGEN	0	rw	WA Generation Enable This bit enables/disables the generation of word address control output signal WA. 0_B The IIS can be used as slave. The generation of the word address signal is disabled. The output signal WA is 0. The MCLKO signal generation depends on PCR.MCLK. 1_B The IIS can be used as master. The generation of the word address signal is enabled. The signal starts with a 0 after being enabled. The generation of MCLK is enabled, independent of PCR.MCLK. After clearing WAGEN, the USIC module stops the generation of the WA signal within the next 4 WA periods.
DTEEN	1	rw	Data Transfers Enable This bit enables/disables the transfer of IIS frames as a reaction to changes of the input word address control line WA. 0_B The changes of the WA input signal are ignored and no transfers take place. 1_B Transfers are enabled.

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Field	Bits	Type	Description
SELINV	2	rw	Select Inversion This bit defines if the polarity of the SELOx outputs in relation to the internally generated word address signal WA. 0 _B The SELOx outputs have the same polarity as the WA signal. 1 _B The SELOx outputs have the inverted polarity to the WA signal.
WAFEIEN	4	rw	WA Falling Edge Interrupt Enable This bit enables/disables the activation of a protocol interrupt when a falling edge of WA has been generated. 0 _B A protocol interrupt is not activated if a falling edge of WA is generated. 1 _B A protocol interrupt is activated if a falling edge of WA is generated.
WAREIEN	5	rw	WA Rising Edge Interrupt Enable This bit enables/disables the activation of a protocol interrupt when a rising edge of WA has been generated. 0 _B A protocol interrupt is not activated if a rising edge of WA is generated. 1 _B A protocol interrupt is activated if a rising edge of WA is generated.
ENDIEN	6	rw	END Interrupt Enable This bit enables/disables the activation of a protocol interrupt when the WA generation stops after clearing PCR.WAGEN (complete system word length is processed before stopping). 0 _B A protocol interrupt is not activated. 1 _B A protocol interrupt is activated.
DX2TIEN	15	rw	DX2T Interrupt Enable This bit enables/disables the generation of a protocol interrupt if the DX2T signal becomes activated (indicated by PSR.DX2TEV = 1). 0 _B A protocol interrupt is not generated if DX2T is active. 1 _B A protocol interrupt is generated if DX2T is active.

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Field	Bits	Type	Description
TDEL	[21:16]	rw	Transfer Delay This bit field defines the transfer delay when an event is detected. If bit field TDEL = 0, the additional delay functionality is switched off and a delay of one shift clock cycle is introduced.
MCLK	31	rw	Master Clock Enable This bit enables generation of the master clock MCLK (not directly used for IIC protocol, can be used as general frequency output). 0 _B The MCLK generation is disabled and MCLK is 0. 1 _B The MCLK generation is enabled.
0	3, [14:7], [30:22]	rw	Reserved Returns 0 if read; should be written with 0;

15.6.5.2 IIS Protocol Status Register

The following PSR status bits or bit fields are available in IIS mode. Please note that the bits in register PSR are not cleared by hardware.

The flags in the PSR register can be cleared by writing a 1 to the corresponding bit position in register PSCR. Writing a 1 to a bit position in PSR sets the corresponding flag, but does not lead to further actions (no interrupt generation). Writing a 0 has no effect. These flags should be cleared by software before enabling a new protocol.

PSR

Protocol Status Register [IIS Mode] (48_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0															BRG IF
r															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIF	RIF	TBIF	TSIF	DLIF	RSIF	0		END	WAR E	WAF E	DX2 TEV	0	DX2 S	WA	
rw	rw	rw	rw	rw	rw	r		rw	rw	rw	rw	r	rw	rw	

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Field	Bits	Type	Description
WA	0	rwh	Word Address This bit indicates the status of the WA input signal, sampled after a transition of WA has been detected. This information is forwarded to the corresponding bit position RBUF SR[9] to distinguish between data received for the right and the left channel. 0_B WA has been sampled 0. 1_B WA has been sampled 1.
DX2S	1	rwh	DX2S Status This bit indicates the current status of the DX2S signal, which is used as word address signal WA. 0_B DX2S is 0. 1_B DX2S is 1.
DX2TEV	3	rwh	DX2T Event Detected¹⁾ This bit indicates that the DX2T signal has been activated. In IIS slave mode, an activation of DX2T generates a protocol interrupt if PCR.DX2TIEN = 1. 0_B The DX2T signal has not been activated. 1_B The DX2T signal has been activated.
WAFE	4	rwh	WA Falling Edge Event¹⁾ This bit indicates that a falling edge of the WA output signal has been generated. This event generates a protocol interrupt if PCR.WAFEIEN = 1. 0_B A WA falling edge has not been generated. 1_B A WA falling edge has been generated.
WARE	5	rwh	WA Rising Edge Event¹⁾ This bit indicates that a rising edge of the WA output signal has been generated. This event generates a protocol interrupt if PCR.WAREIEN = 1. 0_B A WA rising edge has not been generated. 1_B A WA rising edge has been generated.

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Field	Bits	Type	Description
END	6	rwh	WA Generation End¹⁾ This bit indicates that the WA generation has ended after clearing PCR.WAGEN. This bit should be cleared by software before clearing WAGEN. 0_B The WA generation has not yet ended (if it is running and WAGEN has been cleared). 1_B The WA generation has ended (if it has been running).
RSIF	10	rwh	Receiver Start Indication Flag 0_B A receiver start event has not occurred. 1_B A receiver start event has occurred.
DLIF	11	rwh	Data Lost Indication Flag 0_B A data lost event has not occurred. 1_B A data lost event has occurred.
TSIF	12	rwh	Transmit Shift Indication Flag 0_B A transmit shift event has not occurred. 1_B A transmit shift event has occurred.
TBIF	13	rwh	Transmit Buffer Indication Flag 0_B A transmit buffer event has not occurred. 1_B A transmit buffer event has occurred.
RIF	14	rwh	Receive Indication Flag 0_B A receive event has not occurred. 1_B A receive event has occurred.
AIF	15	rwh	Alternative Receive Indication Flag 0_B An alternative receive event has not occurred. 1_B An alternative receive event has occurred.
BRGIF	16	rwh	Baud Rate Generator Indication Flag 0_B A baud rate generator event has not occurred. 1_B A baud rate generator event has occurred.
0	2, [9:7], [31:17]	r	Reserved Returns 0 if read; not modified in IIS mode.

1) This status bit can generate a protocol interrupt (see [Page 15-22](#)). The general interrupt status flags are described in the general interrupt chapter.

15.7 Service Request Generation

The USIC module provides 6 service request outputs SR[5:0] to be shared between two channels. The service request outputs SR[5:0] are connected to interrupt nodes in the Nested Vectored Interrupt Controller (NVIC).

Each USIC communication channel can be connected to up to 6 service request handlers (connected to USICx.SR[5:0], though 3 or 4 are normally used, e.g. one for transmission, one for reception, one or two for protocol or error handling, or for the alternative receive events).

15.8 Debug Behaviour

Each USIC communication channel can be pre-configured to enter one of four kernel modes, when the program execution of the CPU is halted by the debugger.

Refer to [Section 15.2.2.2](#) for details.

15.9 Power, Reset and Clock

The USIC module is located in the core power domain. The module can be reset to its default state by a system reset.

The USIC module is clocked by the main clock, MCLK, from SCU. MCLK is disabled by default and can be enabled via the SCU_CGATCLR0 register. Enabling and disabling the module clock could cause a load change and clock blanking could occur as described in the CCU (Clock Gating Control) section of the SCU chapter. It is strongly recommended to set up the module clock in the user initialization code to avoid clock blanking during runtime.

Note: To differentiate from the USIC baud rate generator output, master clock (MCLK), the SCU MCLK is referenced throughout the USIC chapter as f_{PERIPH} .

15.10 Initialization and System Dependencies

The application has to apply the following initialization sequence before operating the USIC module:

- Enable the module by writing 1s to the MODEN and BPMODEN bits in KSCCFG register.

15.11 Registers

[Table 15-20](#) shows all registers which are required for programming a USIC channel, as well as the FIFO buffer. It summarizes the USIC communication channel registers and defines the relative addresses and the reset values.

Please note that all registers can be accessed with any access width (8-bit, 16-bit, 32-bit), independent of the described width.

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All USIC registers (except bit field KSCFG.SUMCFG) are always reset by a system reset. Bit field KSCFG.SUMCFG is reset by a debug reset.

Note: The register bits marked “w” always deliver 0 when read. They are used to modify flip-flops in other registers or to trigger internal actions.

Figure 15-65 shows the register types of the USIC module registers and channel registers. In a specific microcontroller, module registers of USIC module “x” are marked by the module prefix “USICx_”. Channel registers of USIC module “x” are marked by the channel prefix “USICx_CH0_” and “USICx_CH1_”.

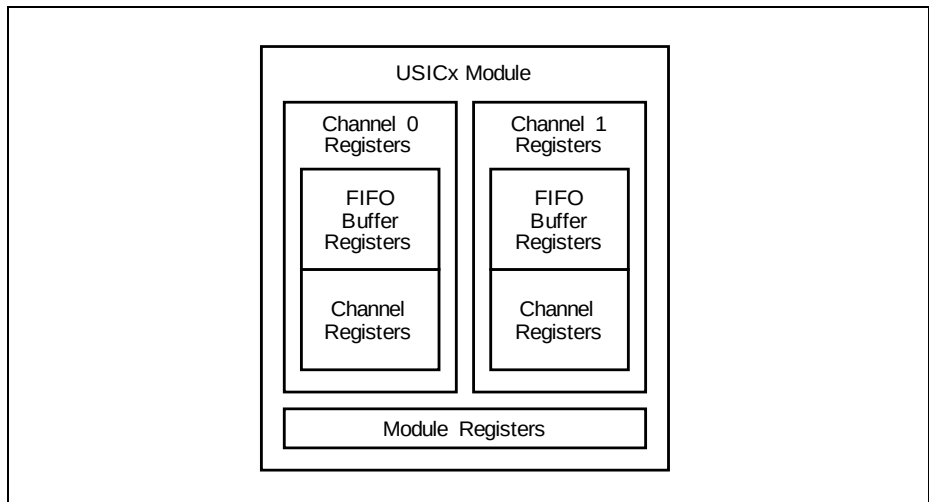


Figure 15-65 USIC Module and Channel Registers

Table 15-20 USIC Kernel-Related and Kernel Registers

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Description see
			Read	Write	
Module Registers ¹⁾					
ID	Module Identification Register	008 _H	U, PV	U, PV	Page 15-158
Channel Registers					
–	reserved	000 _H	BE	BE	–
CCFG	Channel Configuration Register	004 _H	U, PV	U, PV	Page 15-163
KSCFG	Kernel State Configuration Register	00C _H	U, PV	U, PV	Page 15-164
FDR	Fractional Divider Register	010 _H	U, PV	PV	Page 15-177

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Table 15-20 USIC Kernel-Related and Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Description see
			Read	Write	
BRG	Baud Rate Generator Register	014 _H	U, PV	PV	Page 15-178
INPR	Interrupt Node Pointer Register	018 _H	U, PV	U, PV	Page 15-167
DX0CR	Input Control Register 0	01C _H	U, PV	U, PV	Page 15-172
DX1CR	Input Control Register 1	020 _H	U, PV	U, PV	Page 15-174
DX2CR	Input Control Register 2	024 _H	U, PV	U, PV	Page 15-172
DX3CR	Input Control Register 3	028 _H	U, PV	U, PV	
DX4CR	Input Control Register 4	02C _H	U, PV	U, PV	
DX5CR	Input Control Register 5	030 _H	U, PV	U, PV	
SCTR	Shift Control Register	034 _H	U, PV	U, PV	Page 15-182
TCSR	Transmit Control/Status Register	038 _H	U, PV	U, PV	Page 15-185
PCR	Protocol Control Register	03C _H	U, PV	U, PV	Page 15-168 ²⁾
			U, PV	U, PV	Page 15-66 ³⁾
			U, PV	U, PV	Page 15-98 ⁴⁾
			U, PV	U, PV	Page 15-129 ⁵⁾
			U, PV	U, PV	Page 15-148 ⁶⁾
CCR	Channel Control Register	040 _H	U, PV	PV	Page 15-159
CMTR	Capture Mode Timer Register	044 _H	U, PV	U, PV	Page 15-181
PSR	Protocol Status Register	048 _H	U, PV	U, PV	Page 15-169 ²⁾
			U, PV	U, PV	Page 15-70 ³⁾
			U, PV	U, PV	Page 15-102 ⁴⁾
			U, PV	U, PV	Page 15-132 ⁵⁾
			U, PV	U, PV	Page 15-150 ⁶⁾
PSCR	Protocol Status Clear Register	04C _H	U, PV	U, PV	Page 15-170

Universal Serial Interface Channel (USIC)
Table 15-20 USIC Kernel-Related and Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Description see
			Read	Write	
RBUFSR	Receiver Buffer Status Register	050 _H	U, PV	U, PV	Page 15-203
RBUF	Receiver Buffer Register	054 _H	U, PV	U, PV	Page 15-201
RBUFD	Receiver Buffer Register for Debugger	058 _H	U, PV	U, PV	Page 15-202
RBUF0	Receiver Buffer Register 0	05C _H	U, PV	U, PV	Page 15-194
RBUF1	Receiver Buffer Register 1	060 _H	U, PV	U, PV	Page 15-195
RBUF01SR	Receiver Buffer 01 Status Register	064 _H	U, PV	U, PV	Page 15-196
FMR	Flag Modification Register	068 _H	U, PV	U, PV	Page 15-192
–	reserved; do not access this location	06C _H	U, PV	BE	–
–	reserved	070 _H - 07C _H	BE	BE	–
TBUFx	Transmit Buffer Input Location x (x = 00-31)	080 _H + x*4	U, PV	U, PV	Page 15-194

FIFO Buffer Registers

BYP	Bypass Data Register	100 _H	U, PV	U, PV	Page 15-204
BYPCTR	Bypass Control Register	104 _H	U, PV	U, PV	Page 15-205
TBCTR	Transmit Buffer Control Register	108 _H	U, PV	U, PV	Page 15-213
RBCTR	Receive Buffer Control Register	10C _H	U, PV	U, PV	Page 15-217
TRBPTR	Transmit/Receive Buffer Pointer Register	110 _H	U, PV	U, PV	Page 15-225
TRBSR	Transmit/Receive Buffer Status Register	114 _H	U, PV	U, PV	Page 15-208
TRBSCR	Transmit/Receive Buffer Status Clear Register	118 _H	U, PV	U, PV	Page 15-212
OUTR	Receive Buffer Output Register	11C _H	U, PV	U, PV	Page 15-223
OUTDR	Receive Buffer Output Register for Debugger	120 _H	U, PV	U, PV	Page 15-224

Universal Serial Interface Channel (USIC)

Table 15-20 USIC Kernel-Related and Kernel Registers (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Description see
			Read	Write	
–	reserved	124 _H - 17C _H	BE	BE	–
INx	Transmit FIFO Buffer Input Location x (x = 00-31)	180 _H + x*4	U, PV	U, PV	Page 15-222

- 1) Details of the module identification registers are described in the implementation section (see [Page 15-158](#)).
- 2) This page shows the general register layout.
- 3) This page shows the register layout in ASC mode.
- 4) This page shows the register layout in SSC mode.
- 5) This page shows the register layout in IIC mode.
- 6) This page shows the register layout in IIS mode.

15.11.1 Address Map

The registers of the USIC communication channel are available at the following base addresses. The exact register address is given by the relative address of the register (given in [Table 15-20](#)) plus the channel base address (given in [Table 15-21](#)).

Table 15-21 Registers Address Space

Module	Base Address	End Address	Note
USIC0_CH0	48000000 _H	480001FF _H	–
USIC0_CH1	48000200 _H	480003FF _H	–

Table 15-22 FIFO and Reserved Address Space

Module	Base Address	End Address	Access Mode		Note
			Read	Write	
USIC0	48000400 _H	480007FF _H	nBE	nBE if in direct RAM test mode; otherwise BE	USIC0 RAM area, shared between USIC0_CH0 and USIC0_CH1
reserved	48000800 _H	4800FFFF _H	BE	BE	–

15.11.2 Module Identification Registers

The module identification registers indicate the function and the design step of the USIC modules.

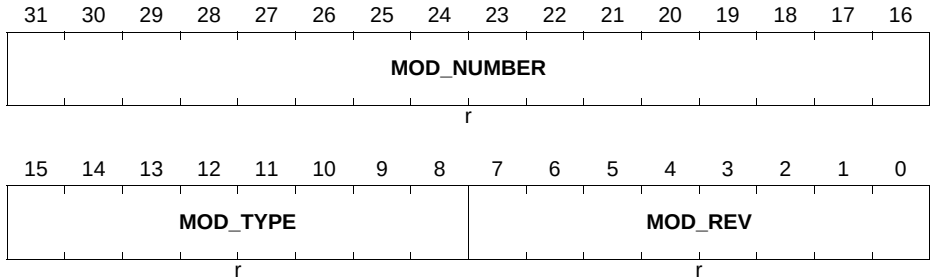
Universal Serial Interface Channel (USIC)

USIC0_ID

Module Identification Register

(4800 0008_H)

Reset Value: 00AA 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 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 USIC module identification number (00AA _H = USIC).

15.11.3 Channel Control and Configuration Registers

15.11.3.1 Channel Control Register

The channel control register contains the enable/disable bits for hardware port control and interrupt generation on channel events, the control of the parity generation and the protocol selection of a USIC channel.

FDR can be written only with a privilege mode access.

Universal Serial Interface Channel (USIC)

CCR

Channel Control 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								BRG IEN
							r								rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIEN	RIEN	TBIE N	TSIE N	DLIE N	RSIE N	PM		HPCEN		0					MODE
rw	rw	rw	rw	rw	rw	rw		rw		r					rw

Field	Bits	Type	Description
MODE	[3:0]	rw	Operating Mode This bit field selects the protocol for this USIC channel. Selecting a protocol that is not available (see register CCFG) or a reserved combination disables the USIC channel. When switching between two protocols, the USIC channel has to be disabled before selecting a new protocol. In this case, registers PCR and PSR have to be cleared or updated by software. 0_H The USIC channel is disabled. All protocol-related state machines are set to an idle state. 1_H The SSC (SPI) protocol is selected. 2_H The ASC (SCI, UART) protocol is selected. 3_H The IIS protocol is selected. 4_H The IIC protocol is selected. Other bit combinations are reserved.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
HPCEN	[7:6]	rw	Hardware Port Control Enable This bit enables the hardware port control for the specified set of DX[3:0] and DOUT[3:0] pins. 00 _B The hardware port control is disabled. 01 _B The hardware port control is enabled for DX0 and DOUT0. 10 _B The hardware port control is enabled for DX3, DX0 and DOUT[1:0]. 11 _B The hardware port control is enabled for DX0, DX[5:3] and DOUT[3:0]. <i>Note: The hardware port control feature is useful only for SSC protocols in half-duplex configurations, such as dual- and quad-SSC. For all other protocols HPCEN must always be written with 00_B.</i>
PM	[9:8]	rw	Parity Mode This bit field defines the parity generation of the sampled input values. 00 _B The parity generation is disabled. 01 _B Reserved 10 _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). 11 _B Odd parity is selected (parity bit = 0 on odd number of 1s in data, parity bit = 1 on even number of 1s in data).
RSIEN	10	rw	Receiver Start Interrupt Enable This bit enables the interrupt generation in case of a receiver start event. 0 _B The receiver start interrupt is disabled. 1 _B The receiver start interrupt is enabled. In case of a receiver start event, the service request output SRx indicated by INPR.TBINP is activated.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DLIEN	11	rw	Data Lost Interrupt Enable This bit enables the interrupt generation in case of a data lost event (data received in RBUFx while RDVx = 1). 0 _B The data lost interrupt is disabled. 1 _B The data lost interrupt is enabled. In case of a data lost event, the service request output SRx indicated by INPR.PINP is activated.
TSIEN	12	rw	Transmit Shift Interrupt Enable This bit enables the interrupt generation in case of a transmit shift event. 0 _B The transmit shift interrupt is disabled. 1 _B The transmit shift interrupt is enabled. In case of a transmit shift interrupt event, the service request output SRx indicated by INPR.TSINP is activated.
TBIEN	13	rw	Transmit Buffer Interrupt Enable This bit enables the interrupt generation in case of a transmit buffer event. 0 _B The transmit buffer interrupt is disabled. 1 _B The transmit buffer interrupt is enabled. In case of a transmit buffer event, the service request output SRx indicated by INPR.TBINP is activated.
RIEN	14	rw	Receive Interrupt Enable This bit enables the interrupt generation in case of a receive event. 0 _B The receive interrupt is disabled. 1 _B The receive interrupt is enabled. In case of a receive event, the service request output SRx indicated by INPR.RINP is activated.
AIEN	15	rw	Alternative Receive Interrupt Enable This bit enables the interrupt generation in case of a alternative receive event. 0 _B The alternative receive interrupt is disabled. 1 _B The alternative receive interrupt is enabled. In case of an alternative receive event, the service request output SRx indicated by INPR.AINP is activated.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
BRGIEN	16	rw	Baud Rate Generator Interrupt Enable This bit enables the interrupt generation in case of a baud rate generator event. 0 _B The baud rate generator interrupt is disabled. 1 _B The baud rate generator interrupt is enabled. In case of a baud rate generator event, the service request output SRx indicated by INPR.PINP is activated.
0	[5:4], [31:17]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.11.3.2 Channel Configuration Register

The channel configuration register contains indicates the functionality that is available in the USIC channel.

CCFG

Channel Configuration Register

(04_H)

Reset Value: 0000 80CF_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
1	0						TB	RB	0		IIS	IIC	ASC	SSC	
r	r						r	r	r		r	r	r	r	

Field	Bits	Type	Description
SSC	0	r	SSC Protocol Available This bit indicates if the SSC protocol is available. 0 _B The SSC protocol is not available. 1 _B The SSC protocol is available.
ASC	1	r	ASC Protocol Available This bit indicates if the ASC protocol is available. 0 _B The ASC protocol is not available. 1 _B The ASC protocol is available.
IIC	2	r	IIC Protocol Available This bit indicates if the IIC functionality is available. 0 _B The IIC protocol is not available. 1 _B The IIC protocol is available.
IIS	3	r	IIS Protocol Available This bit indicates if the IIS protocol is available. 0 _B The IIS protocol is not available. 1 _B The IIS protocol is available.
RB	6	r	Receive FIFO Buffer Available This bit indicates if an additional receive FIFO buffer is available. 0 _B A receive FIFO buffer is not available. 1 _B A receive FIFO buffer is available.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
TB	7	r	Transmit FIFO Buffer Available This bit indicates if an additional transmit FIFO buffer is available. 0 _B A transmit FIFO buffer is not available. 1 _B A transmit FIFO buffer is available.
1	15	r	Reserved Read as 1; should be written with 1.
0	[5:4], [14:8], [31:16]	r	Reserved Read as 0; should be written with 0.

15.11.3.3 Kernel State Configuration Register

The kernel state configuration register KSCFG allows the selection of the desired kernel modes for the different device operating modes.

KSCFG

Kernel State Configuration Register (0C_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				BPS UM	0	SUMCFG		BPN OM	0	NOMCFG		0	BPM ODE N	MOD EN	
r				w	r	rw		w	r	rw		r	w	rw	

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
MODEN	0	rw	Module Enable This bit enables the module kernel clock and the module functionality. 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). 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 USIC registers.
BPMODEN	1	w	Bit Protection for MODEN This bit enables the write access to the bit MODEN. It always reads 0. 0_B MODEN is not changed. 1_B MODEN is updated with the written value.
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 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.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
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.
0	[3:2], 6, 10, [31:12]	r	Reserved Read as 0; should be written with 0. Bit 2 can read as 1 after BootROM exit (but can be ignored).

Universal Serial Interface Channel (USIC)

15.11.3.4 Interrupt Node Pointer Register

The interrupt node pointer register defines the service request output SRx that is activated if the corresponding event occurs and interrupt generation is enabled.

INPR

Interrupt Node Pointer 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													PINP		
r													rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	AINP		0	RINP		0	TBINP		0	TSINP					
r	rw		r	rw		r	rw		r	rw					

Field	Bits	Type	Description
TSINP	[2:0]	rw	Transmit Shift Interrupt Node Pointer This bit field defines which service request output SRx becomes activated in case of a transmit shift interrupt. 000 _B Output SR0 becomes activated. 001 _B Output SR1 becomes activated. 010 _B Output SR2 becomes activated. 011 _B Output SR3 becomes activated. 100 _B Output SR4 becomes activated. 101 _B Output SR5 becomes activated. <i>Note: All other settings of the bit field are reserved.</i>
TBINP	[6:4]	rw	Transmit Buffer Interrupt Node Pointer This bit field defines which service request output SRx will be activated in case of a transmit buffer interrupt or a receive start interrupt. Coding like TSINP.
RINP	[10:8]	rw	Receive Interrupt Node Pointer This bit field defines which service request output SRx will be activated in case of a receive interrupt. Coding like TSINP.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
AINP	[14:12]	rw	Alternative Receive Interrupt Node Pointer This bit field defines which service request output SRx will be activated in case of a alternative receive interrupt. Coding like TSINP.
PINP	[18:16]	rw	Protocol Interrupt Node Pointer This bit field defines which service request output SRx becomes activated in case of a protocol interrupt. Coding like TSINP.
0	3, 7, 11, 15, [31:19]	r	Reserved Read as 0; should be written with 0.

15.11.4 Protocol Related Registers

15.11.4.1 Protocol Control Registers

The bits in the protocol control register define protocol-specific functions. They have to be configured by software before enabling a new protocol. Only the bits used for the selected protocol are taken into account, whereas the other bit positions always read as 0. The protocol-specific meaning is described in the related protocol section.

PCR

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

Field	Bits	Type	Description
CTRx (x = 0-31)	x	rw	Protocol Control Bit x This bit is a protocol control bit.

Universal Serial Interface Channel (USIC)

15.11.4.2 Protocol Status Register

The flags in the protocol status register can be cleared by writing a 1 to the corresponding bit position in register PSCR. Writing a 1 to a bit position in PSR sets the corresponding flag, but does not lead to further actions (no interrupt generation). Writing a 0 has no effect. These flags should be cleared by software before enabling a new protocol. The protocol-specific meaning is described in the related protocol section.

PSR

Protocol Status 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								BRG IF
							r								rwh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AIF	RIF	TBIF	TSIF	DLIF	RSIF	ST9	ST8	ST7	ST6	ST5	ST4	ST3	ST2	ST1	ST0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
STx (x = 0-9)	x	rwh	Protocol Status Flag x See protocol specific description.
RSIF	10	rwh	Receiver Start Indication Flag 0 _B A receiver start event has not occurred. 1 _B A receiver start event has occurred.
DLIF	11	rwh	Data Lost Indication Flag 0 _B A data lost event has not occurred. 1 _B A data lost event has occurred.
TSIF	12	rwh	Transmit Shift Indication Flag 0 _B A transmit shift event has not occurred. 1 _B A transmit shift event has occurred.
TBIF	13	rwh	Transmit Buffer Indication Flag 0 _B A transmit buffer event has not occurred. 1 _B A transmit buffer event has occurred.
RIF	14	rwh	Receive Indication Flag 0 _B A receive event has not occurred. 1 _B A receive event has occurred.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
AIF	15	rwh	Alternative Receive Indication Flag 0 _B An alternative receive event has not occurred. 1 _B An alternative receive event has occurred.
BRGIF	16	rwh	Baud Rate Generator Indication Flag 0 _B A baud rate generator event has not occurred. 1 _B A baud rate generator event has occurred.
0	[31:17]	r	Reserved; read as 0; should be written with 0;

15.11.4.3 Protocol Status Clear Register

Read accesses to this register always deliver 0 at all bit positions.

PSCR

Protocol Status Clear 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															CBR GIF
r															w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CAIF	CRIF	CTBIF	CTSI F	CDLI F	CRSI F	CST 9	CST 8	CST 7	CST 6	CST 5	CST 4	CST 3	CST 2	CST 1	CST 0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
CSTx (x = 0-9)	x	w	Clear Status Flag x in PSR 0 _B No action 1 _B Flag PSR.STx is cleared.
CRSIF	10	w	Clear Receiver Start Indication Flag 0 _B No action 1 _B Flag PSR.RSIF is cleared.
CDLIF	11	w	Clear Data Lost Indication Flag 0 _B No action 1 _B Flag PSR.DLIF is cleared.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
CTSIF	12	w	Clear Transmit Shift Indication Flag 0 _B No action 1 _B Flag PSR.TSIF is cleared.
CTBIF	13	w	Clear Transmit Buffer Indication Flag 0 _B No action 1 _B Flag PSR.TBIF is cleared.
CRIF	14	w	Clear Receive Indication Flag 0 _B No action 1 _B Flag PSR.RIF is cleared.
CAIF	15	w	Clear Alternative Receive Indication Flag 0 _B No action 1 _B Flag PSR.AIF is cleared.
CBRGIF	16	w	Clear Baud Rate Generator Indication Flag 0 _B No action 1 _B Flag PSR.BRGIF is cleared.
0	[31:17]	r	Reserved; read as 0; should be written with 0;

15.11.5 Input Stage Register

15.11.5.1 Input Control Registers

The input control registers contain the bits to define the characteristics of the input stages (input stage DX0 is controlled by register DX0CR, etc.).

Universal Serial Interface Channel (USIC)

DX0CR

Input Control Register 0 (1C_H) **Reset Value:** 0000 0000_H

DX2CR

Input Control Register 2 (24_H) **Reset Value:** 0000 0000_H

DX3CR

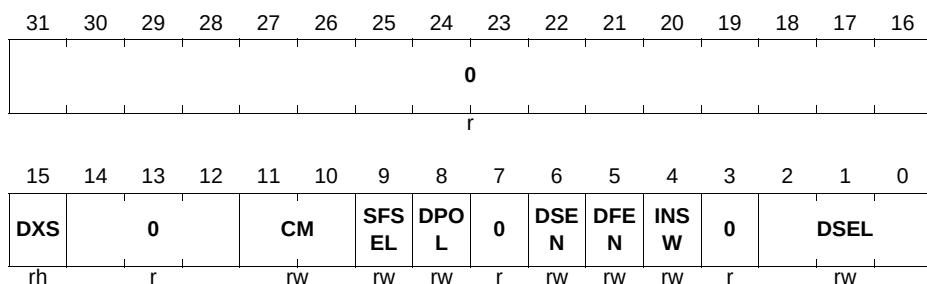
Input Control Register 3 (28_H) **Reset Value:** 0000 0000_H

DX4CR

Input Control Register 4 (2C_H) **Reset Value:** 0000 0000_H

DX5CR

Input Control Register 5 (30_H) **Reset Value:** 0000 0000_H



Field	Bits	Type	Description
DSEL	[2:0]	rw	Data Selection for Input Signal This bit field defines the input data signal for the corresponding input line for protocol pre-processor. The selection can be made from the input vector DXn[G:A]. 000 _B The data input DXnA is selected. 001 _B The data input DXnB is selected. 010 _B The data input DXnC is selected. 011 _B The data input DXnD is selected. 100 _B The data input DXnE is selected. 101 _B The data input DXnF is selected. 110 _B The data input DXnG is selected. 111 _B The data input is always 1.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
INSW	4	rw	Input Switch This bit defines if the data shift unit input is derived from the input data path DXn or from the selected protocol pre-processors. 0_B The input of the data shift unit is controlled by the protocol pre-processor. 1_B The input of the data shift unit is connected to the selected data input line. This setting is used if the signals are directly derived from an input pin without treatment by the protocol pre-processor.
DFEN	5	rw	Digital Filter Enable This bit enables/disables the digital filter for signal DXnS. 0_B The input signal is not digitally filtered. 1_B The input signal is digitally filtered.
DSEN	6	rw	Data Synchronization Enable This bit selects if the asynchronous input signal or the synchronized (and optionally filtered) signal DXnS can be used as input for the data shift unit. 0_B The un-synchronized signal can be taken as input for the data shift unit. 1_B The synchronized signal can be taken as input for the data shift unit.
DPOL	8	rw	Data Polarity for DXn This bit defines the signal polarity of the input signal. 0_B The input signal is not inverted. 1_B The input signal is inverted.
SFSEL	9	rw	Sampling Frequency Selection This bit defines the sampling frequency of the digital filter for the synchronized signal DXnS. 0_B The sampling frequency is f_{PERIPH} . 1_B The sampling frequency is f_{FD} .

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
CM	[11:10]	rw	Combination Mode This bit field selects which edge of the synchronized (and optionally filtered) signal DXnS activates the trigger output DXnT of the input stage. 00 _B The trigger activation is disabled. 01 _B A rising edge activates DXnT. 10 _B A falling edge activates DXnT. 11 _B Both edges activate DXnT.
DXS	15	rh	Synchronized Data Value This bit indicates the value of the synchronized (and optionally filtered) input signal. 0 _B The current value of DXnS is 0. 1 _B The current value of DXnS is 1.
0	3, 7, [14:12], [31:16]	r	Reserved Read as 0; should be written with 0.

DX1CR

Input Control Register 1

(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
DXS	0			CM		SFS EL	DPO L	0	DSE N	DFE N	INS W	DCE N	DSEL		
rh	r			rw		rw	rw	r	rw	rw	rw	rw	rw		

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DSEL	[2:0]	rw	Data Selection for Input Signal This bit field defines the input data signal for the corresponding input line for protocol pre-processor. The selection can be made from the input vector DX1[G:A]. 000 _B The data input DX1A is selected. 001 _B The data input DX1B is selected. 010 _B The data input DX1C is selected. 011 _B The data input DX1D is selected. 100 _B The data input DX1E is selected. 101 _B The data input DX1F is selected. 110 _B The data input DX1G is selected. 111 _B The data input is always 1.
DCEN	3	rw	Delay Compensation Enable This bit selects if the receive shift clock is controlled by INSW or derived from the input data path DX1. 0 _B The receive shift clock is dependent on INSW selection. 1 _B The receive shift clock is connected to the selected data input line. This setting is used if delay compensation is required in SSC and IIS protocols, else DCEN should always be 0.
INSW	4	rw	Input Switch This bit defines if the data shift unit input is derived from the input data path DX1 or from the selected protocol pre-processors. 0 _B The input of the data shift unit is controlled by the protocol pre-processor. 1 _B The input of the data shift unit is connected to the selected data input line. This setting is used if the signals are directly derived from an input pin without treatment by the protocol pre-processor.
DFEN	5	rw	Digital Filter Enable This bit enables/disables the digital filter for signal DX1S. 0 _B The input signal is not digitally filtered. 1 _B The input signal is digitally filtered.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DSEN	6	rw	Data Synchronization Enable This bit selects if the asynchronous input signal or the synchronized (and optionally filtered) signal DX1S can be used as input for the data shift unit. 0_B The un-synchronized signal can be taken as input for the data shift unit. 1_B The synchronized signal can be taken as input for the data shift unit.
DPOL	8	rw	Data Polarity for DXn This bit defines the signal polarity of the input signal. 0_B The input signal is not inverted. 1_B The input signal is inverted.
SFSEL	9	rw	Sampling Frequency Selection This bit defines the sampling frequency of the digital filter for the synchronized signal DX1S. 0_B The sampling frequency is f_{PERIPH} . 1_B The sampling frequency is f_{FD} .
CM	[11:10]	rw	Combination Mode This bit field selects which edge of the synchronized (and optionally filtered) signal DX1S activates the trigger output DX1T of the input stage. 00_B The trigger activation is disabled. 01_B A rising edge activates DX1T. 10_B A falling edge activates DX1T. 11_B Both edges activate DX1T.
DXS	15	rh	Synchronized Data Value This bit indicates the value of the synchronized (and optionally filtered) input signal. 0_B The current value of DX1S is 0. 1_B The current value of DX1S is 1.
0	7, [14:12], [31:16]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.11.6 Baud Rate Generator Registers

15.11.6.1 Fractional Divider Register

The fractional divider register FDR allows the generation of the internal frequency f_{FD} , that is derived from the system clock f_{PERIPH} .

FDR can be written only with a privilege mode access.

FDR

Fractional Divider 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		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 after RESULT has reached 3FF _H . In fractional divider mode STEP defines the value added to RESULT with each input clock cycle.
DM	[15:14]	rw	Divider Mode This bit fields defines the functionality of the fractional divider block. 00 _B The divider is switched off, $f_{FD} = 0$. 01 _B Normal divider mode selected. 10 _B Fractional divider mode selected. 11 _B The divider is switched off, $f_{FD} = 0$.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
RESULT	[25:16]	rh	Result Value In normal divider mode this bit field is updated with f_{PERIPH} according to: $\text{RESULT} = \text{RESULT} + 1$ In fractional divider mode this bit field is updated with f_{PERIPH} according to: $\text{RESULT} = \text{RESULT} + \text{STEP}$ If bit field DM is written with 01_{B} or 10_{B} , RESULT is loaded with a start value of 3FF_{H} .
0	[31:30]	rw	Reserved for Future Use Must be written with 0 to allow correct fractional divider operation.
0	[13:10], [29:26]	r	Reserved Read as 0; should be written with 0.

15.11.6.2 Baud Rate Generator Register

The protocol-related counters for baud rate generation and timing measurement are controlled by the register BRG.

FDR can be written only with a privilege mode access.

BRG

Baud Rate Generator Register (14_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SCLKCFG		MCLKCFG	SCLKSEL	0		PDIV									
rw		rw	rw	r		rw									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0		DCTQ				PCTQ		CTQSEL		0	PPPEN	TMEN	0	CLKSEL	
r		rw				rw		rw		r	rw	rw	r	rw	

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
CLKSEL	[1:0]	rw	Clock Selection This bit field defines the input frequency f_{PIN} 00_B The fractional divider frequency f_{FD} is selected. 01_B Reserved, no action 10_B The trigger signal DX1T defines f_{PIN} . Signal MCLK toggles with f_{PIN} . 11_B Signal MCLK corresponds to the DX1S signal and the frequency f_{PIN} is derived from the rising edges of DX1S.
TMEN	3	rw	Timing Measurement Enable This bit enables the timing measurement of the capture mode timer. 0_B Timing measurement is disabled: The trigger signals DX0T and DX1T are ignored. 1_B Timing measurement is enabled: The 10-bit counter is incremented by 1 with f_{PPP} and stops counting when reaching its maximum value. If one of the trigger signals DX0T or DX1T become active, the counter value is captured into bit field CTV, the counter is cleared and a transmit shift event is generated.
PPPEN	4	rw	Enable 2:1 Divider for f_{PPP} This bit defines the input frequency f_{PPP} . 0_B The 2:1 divider for f_{PPP} is disabled. $f_{PPP} = f_{PIN}$ 1_B The 2:1 divider for f_{PPP} is enabled. $f_{PPP} = f_{MCLK} = f_{PIN} / 2$.
CTQSEL	[7:6]	rw	Input Selection for CTQ This bit defines the length of a time quantum for the protocol pre-processor. 00_B $f_{CTQIN} = f_{PDIV}$ 01_B $f_{CTQIN} = f_{PPP}$ 10_B $f_{CTQIN} = f_{SCLK}$ 11_B $f_{CTQIN} = f_{MCLK}$

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
PCTQ	[9:8]	rw	Pre-Divider for Time Quanta Counter This bit field defines length of a time quantum t_q for the time quanta counter in the protocol pre-processor. $t_q = (PCTQ + 1) / f_{CTQIN}$
DCTQ	[14:10]	rw	Denominator for Time Quanta Counter This bit field defines the number of time quanta t_q taken into account by the time quanta counter in the protocol pre-processor.
PDIV	[25:16]	rw	Divider Mode: Divider Factor to Generate f_{PDIV} This bit field defines the ratio between the input frequency f_{PPP} and the divider frequency f_{PDIV} .
SCLKOSEL	28	rw	Shift Clock Output Select This bit field selects the input source for the SCLKOUT signal. 0_B SCLK from the baud rate generator is selected as the SCLKOUT input source. 1_B The transmit shift clock from DX1 input stage is selected as the SCLKOUT input source. <i>Note: The setting SCLKOSEL = 1 is used only when complete closed loop delay compensation is required for a slave SSC/IIS. The default setting of SCLKOSEL = 0 should be always used for all other cases.</i>
MCLKCFG	29	rw	Master Clock Configuration This bit field defines the level of the passive phase of the MCLKOUT signal. 0_B The passive level is 0. 1_B The passive level is 1.
SCLKCFG	[31:30]	rw	Shift Clock Output Configuration This bit field defines the level of the passive phase of the SCLKOUT signal and enables/disables a delay of half of a SCLK period. 00_B The passive level is 0 and the delay is disabled. 01_B The passive level is 1 and the delay is disabled. 10_B The passive level is 0 and the delay is enabled. 11_B The passive level is 1 and the delay is enabled.
0	2, 5, 15, [27:26]	r	Reserved Read as 0; should be written with 0.

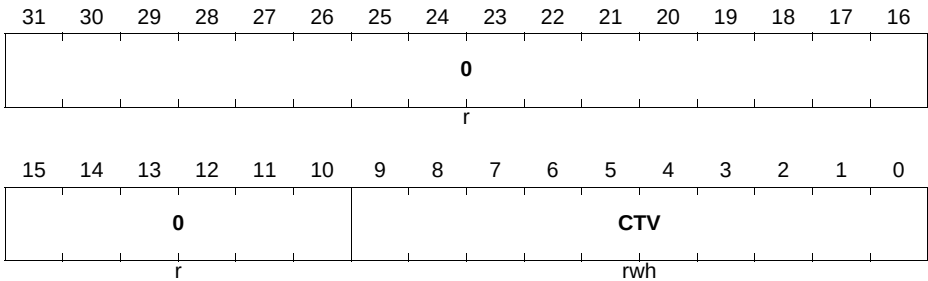
Universal Serial Interface Channel (USIC)

15.11.6.3 Capture Mode Timer Register

The captured timer value is provided by the register CMTR.

CMTR

Capture Mode Timer Register (44_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
CTV	[9:0]	rwh	Captured Timer Value The value of the counter is captured into this bit field if one of the trigger signals DX0T or DX1T are activated by the corresponding input stage.
0	[31:10]	r	Reserved Read as 0; should be written with 0.

15.11.7 Transfer Control and Status Registers

15.11.7.1 Shift Control Register

The data shift unit is controlled by the register SCTR. The values in this register are applied for data transmission and reception.

Please note that the shift control settings SDIR, WLE, FLE, DSM and HPCDIR are shared between transmitter and receiver. They are internally “frozen” for a each data word transfer in the transmitter with the first transmit shift clock edge and with the first receive shift clock edge in the receiver. The software has to take care that updates of these bit fields by software are done coherently (e.g. refer to the receiver start event indication PSR.RSIF).

Universal Serial Interface Channel (USIC)

SCTR

Shift Control Register

(34_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0				WLE				0		FLE					
r				rwh				r		rwh					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						TRM		DOCFG		0	HPC DIR	DSM		PDL	SDIR
r						rw		rw		r	rw	rw		rw	rw

Field	Bits	Type	Description
SDIR	0	rw	Shift Direction This bit defines the shift direction of the data words for transmission and reception. 0 _B Shift LSB first. The first data bit of a data word is located at bit position 0. 1 _B Shift MSB first. The first data bit of a data word is located at the bit position given by bit field SCTR.WLE.
PDL	1	rw	Passive Data Level This bit defines the output level at the shift data output signal when no data is available for transmission. The PDL level is output with the first relevant transmit shift clock edge of a data word. 0 _B The passive data level is 0. 1 _B The passive data level is 1.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DSM	[3:2]	rw	Data Shift Mode This bit field describes how the receive and transmit data is shifted in and out. 00 _B Receive and transmit data is shifted in and out one bit at a time through DX0 and DOUT0. 01 _B Reserved. 10 _B Receive and transmit data is shifted in and out two bits at a time through two input stages (DX0 and DX3) and DOUT[1:0] respectively. 11 _B Receive and transmit data is shifted in and out four bits at a time through four input stages (DX0, DX[5:3]) and DOUT[3:0] respectively. <i>Note: Dual- and Quad-output modes are used only by the SSC protocol. For all other protocols DSM must always be written with 00_B.</i>
HPCDIR	4	rw	Port Control Direction This bit defines the direction of the port pin(s) which allows hardware pin control (CCR.PCEN = 1). 0 _B The pin(s) with hardware pin control enabled are selected to be in input mode. 1 _B The pin(s) with hardware pin control enabled are selected to be in output mode.
DOCFG	[7:6]	rw	Data Output Configuration This bit defines the relation between the internal shift data value and the data output signal DOUTx. X0 _B DOUTx = shift data value X1 _B DOUTx = inverted shift data value

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
TRM	[9:8]	rw	Transmission Mode This bit field describes how the shift control signal is interpreted by the DSU. Data transfers are only possible while the shift control signal is active. 00 _B The shift control signal is considered as inactive and data frame transfers are not possible. 01 _B The shift control signal is considered active if it is at 1-level. This is the setting to be programmed to allow data transfers. 10 _B The shift control signal is considered active if it is at 0-level. It is recommended to avoid this setting and to use the inversion in the DX2 stage in case of a low-active signal. 11 _B The shift control signal is considered active without referring to the actual signal level. Data frame transfer is possible after each edge of the signal.
FLE	[21:16]	rwh	Frame Length This bit field defines how many bits are transferred within a data frame. A data frame can consist of several concatenated data words. If TCSR.FLEMD = 1, the value can be updated automatically by the data handler.
WLE	[27:24]	rwh	Word Length This bit field defines the data word length (amount of bits that are transferred in each data word) for reception and transmission. The data word is always right-aligned in the data buffer at the bit positions [WLE down to 0]. If TCSR.WLEMD = 1, the value can be updated automatically by the data handler. 0 _H The data word contains 1 data bit located at bit position 0. 1 _H The data word contains 2 data bits located at bit positions [1:0]. ... E _H The data word contains 15 data bits located at bit positions [14:0]. F _H The data word contains 16 data bits located at bit positions [15:0].

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
0	5, [15:10], [23:22], [31:28]	r	Reserved Read as 0; should be written with 0.

15.11.7.2 Transmission Control and Status Register

The data transmission is controlled and monitored by register TCSR.

TCSR

Transmit Control/Status 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			TE	TVC	TV	0	TSO F				0				
r			rh	rh	rh	r	rh				r				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	WA	TDV TR		TDEN		0	TDS SM	TDV	EOF	SOF	HPC MD	WA MD	FLE MD	SEL MD	WLE MD
r	rwh	rw		rw		r	rw	rh	rwh	rwh	rw	rw	rw	rw	rw

Field	Bits	Type	Description
WLEMD	0	rw	WLE Mode This bit enables the data handler to automatically update the bit field SCTR.WLE by the transmit control information TCI[3:0] and bit TCSR.EOF by TCI[4] (see Page 15-33). If enabled, an automatic update takes place when new data is loaded to register TBUF, either by writing to one of the transmit buffer input locations TBUFx or by an optional data buffer. 0 _B The automatic update of SCTR.WLE and TCSR.EOF is disabled. 1 _B The automatic update of SCTR.WLE and TCSR.EOF is enabled.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
SELMD	1	rw	Select Mode This bit can be used mainly for the SSC protocol. It enables the data handler to automatically update bit field PCR.CTR[20:16] by the transmit control information TCI[4:0] and clear bit field PCR.CTR[23:21] (see Page 15-33). If enabled, an automatic update takes place when new data is loaded to register TBUF, either by writing to one of the transmit buffer input locations TBUFx or by an optional data buffer. 0_B The automatic update of PCR.CTR[23:16] is disabled. 1_B The automatic update of PCR.CTR[23:16] is disabled.
FLEMD	2	rw	FLE Mode This bit enables the data handler to automatically update bits SCTR.FLE[4:0] by the transmit control information TCI[4:0] and to clear bit SCTR.FLE[5] (see Page 15-33). If enabled, an automatic update takes place when new data is loaded to register TBUF, either by writing to one of the transmit buffer input locations TBUFx or by an optional data buffer. 0_B The automatic update of FLE is disabled. 1_B The automatic update of FLE is enabled.
WAMD	3	rw	WA Mode This bit can be used mainly for the IIS protocol. It enables the data handler to automatically update bit TCSR.WA by the transmit control information TCI[4] (see Page 15-33). If enabled, an automatic update takes place when new data is loaded to register TBUF, either by writing to one of the transmit buffer input locations TBUFx or by an optional data buffer. 0_B The automatic update of bit WA is disabled. 1_B The automatic update of bit WA is enabled.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
HPCMD	4	rw	Hardware Port Control Mode This bit can be used mainly for the dual and quad SSC protocol. It enables the data handler to automatically update bit SCTR.DSM by the transmit control information TCI[1:0] and bit SCTR.HPCDIR by TCI[2] (see Page 15-33). If enabled, an automatic update takes place when new data is loaded to register TBUF, either by writing to one of the transmit buffer input locations TBUFx or by an optional data buffer. 0_B The automatic update of bits SCTR.DSM and SCTR.HPCDIR is disabled. 1_B The automatic update of bits SCTR.DSM and SCTR.HPCDIR is enabled.
SOF	5	rwh	Start Of Frame This bit is only taken into account for the SSC protocol, otherwise it is ignored. It indicates that the data word in TBUF is considered as the first word of a new SSC frame if it is valid for transmission (TCSR.TDV = 1). This bit becomes cleared when the TBUF data word is transferred to the transmit shift register. 0_B The data word in TBUF is not considered as first word of a frame. 1_B The data word in TBUF is considered as first word of a frame. A currently running frame is finished and MSLS becomes deactivated (respecting the programmed delays).

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
EOF	6	rwh	End Of Frame This bit is only taken into account for the SSC protocol, otherwise it is ignored. It can be modified automatically by the data handler if bit WLEMD = 1. It indicates that the data word in TBUF is considered as the last word of an SSC frame. If it is the last word, the MSLS signal becomes inactive after the transfer, respecting the programmed delays. This bit becomes cleared when the TBUF data word is transferred to the transmit shift register. 0_B The data word in TBUF is not considered as last word of an SSC frame. 1_B The data word in TBUF is considered as last word of an SSC frame.
TDV	7	rh	Transmit Data Valid This bit indicates that the data word in the transmit buffer TBUF can be considered as valid for transmission. The TBUF data word can only be sent out if TDV = 1. It is automatically set when data is moved to TBUF (by writing to one of the transmit buffer input locations TBUFx, or optionally, by the bypass or FIFO mechanism). 0_B The data word in TBUF is not valid for transmission. 1_B The data word in TBUF is valid for transmission and a transmission start is possible. New data should not be written to a TBUFx input location while TDV = 1.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
TDSSM	8	rw	TBUF Data Single Shot Mode This bit defines if the data word TBUF data is considered as permanently valid or if the data should only be transferred once. 0_B The data word in TBUF is not considered as invalid after it has been loaded into the transmit shift register. The loading of the TBUF data into the shift register does not clear TDV. 1_B The data word in TBUF is considered as invalid after it has been loaded into the shift register. In ASC and IIC mode, TDV is cleared with the TBI event, whereas in SSC and IIS mode, it is cleared with the RSI event. TDSSM = 1 has to be programmed if an optional data buffer is used.
TDEN	[11:10]	rw	TBUF Data Enable This bit field controls the gating of the transmission start of the data word in the transmit buffer TBUF. 00_B A transmission start of the data word in TBUF is disabled. If a transmission is started, the passive data level is sent out. 01_B A transmission of the data word in TBUF can be started if TDV = 1. 10_B A transmission of the data word in TBUF can be started if TDV = 1 while DX2S = 0. 11_B A transmission of the data word in TBUF can be started if TDV = 1 while DX2S = 1.
TDVTR	12	rw	TBUF Data Valid Trigger This bit enables the transfer trigger unit to set bit TCSR.TE if the trigger signal DX2T becomes active for event driven transfer starts, e.g. timer-based or depending on an event at an input pin. Bit TDVTR has to be 0 for protocols where the input stage DX2 is used for data shifting. 0_B Bit TCSR.TE is permanently set. 1_B Bit TCSR.TE is set if DX2T becomes active while TDV = 1.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
WA	13	rwh	Word Address This bit is only taken into account for the IIS protocol, otherwise it is ignored. It can be modified automatically by the data handler if bit WAMD = 1. Bit WA defines for which channel the data stored in TBUF will be transmitted. 0_B The data word in TBUF will be transmitted after a falling edge of WA has been detected (referring to PSR.WA). 1_B The data word in TBUF will be transmitted after a rising edge of WA has been detected (referring to PSR.WA).
TSOF	24	rh	Transmitted Start Of Frame This bit indicates if the latest start of a data word transmission has taken place for the first data word of a new data frame. This bit is updated with the transmission start of each data word. 0_B The latest data word transmission has not been started for the first word of a data frame. 1_B The latest data word transmission has been started for the first word of a data frame.
TV	26	rh	Transmission Valid This bit represents the transmit buffer underflow and indicates if the latest start of a data word transmission has taken place with a valid data word from the transmit buffer TBUF. This bit is updated with the transmission start of each data word. 0_B The latest start of a data word transmission has taken place while no valid data was available. As a result, the transmission of a data words with passive level (SCTR.PDL) has been started. 1_B The latest start of a data word transmission has taken place with valid data from TBUF.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
TVC	27	rh	Transmission Valid Cumulated This bit cumulates the transmit buffer underflow indication TV. It is cleared automatically together with bit TV and has to be set by writing FMR.ATVC = 1. 0_B Since TVC has been set, at least one data buffer underflow condition has occurred. 1_B Since TVC has been set, no data buffer underflow condition has occurred.
TE	28	rh	Trigger Event If the transfer trigger mechanism is enabled, this bit indicates that a trigger event has been detected (DX2T = 1) while TCSR.TDV = 1. If the event trigger mechanism is disabled, the bit TE is permanently set. It is cleared by writing FMR.MTDV = 10_B or when the data word located in TBUF is loaded into the shift register. 0_B The trigger event has not yet been detected. A transmission of the data word in TBUF can not be started. 1_B The trigger event has been detected (or the trigger mechanism is switched off) and a transmission of the data word in TBUF can be started.
0	9, [23:14], 25, [31:29]	r	Reserved Read as 0; should be written with 0.

15.11.7.3 Flag Modification Registers

The flag modification register FMR allows the modification of control and status flags related to data handling by using only write accesses. Read accesses to FMR always deliver 0 at all bit positions.

Additionally, the service request outputs of this USIC channel can be activated by software (the activation is triggered by the write access and is deactivated automatically).

Universal Serial Interface Channel (USIC)

FMR

Flag Modification 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										SIO5	SIO4	SIO3	SIO2	SIO1	SIO0
r										w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRD V1	CRD V0	0								ATV C	0		MTDV		
w	w	r								w	r		w		

Field	Bits	Type	Description
MTDV	[1:0]	w	Modify Transmit Data Valid Writing to this bit field can modify bits TCSR.TDV and TCSR.TE to control the start of a data word transmission by software. 00 _B No action. 01 _B Bit TDV is set, TE is unchanged. 10 _B Bits TDV and TE are cleared. 11 _B Reserved
ATVC	4	w	Activate Bit TVC Writing to this bit can set bit TCSR.TVC to start a new cumulation of the transmit buffer underflow condition. 0 _B No action. 1 _B Bit TCSR.TVC is set.
CRDV0	14	w	Clear Bits RDV for RBUF0 Writing 1 to this bit clears bits RBUF01SR.RDV00 and RBUF01SR.RDV10 to declare the received data in RBUF0 as no longer valid (to emulate a read action). 0 _B No action. 1 _B Bits RBUF01SR.RDV00 and RBUF01SR.RDV10 are cleared.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
CRDV1	15	w	Clear Bit RDV for RBUF1 Writing 1 to this bit clears bits RBUF01SR.RDV01 and RBUF01SR.RDV11 to declare the received data in RBUF1 as no longer valid (to emulate a read action). 0 _B No action. 1 _B Bits RBUF01SR.RDV01 and RBUF01SR.RDV11 are cleared.
SIO0, SIO1, SIO2, SIO3, SIO4, SIO5	16, 17, 18, 19, 20, 21	w	Set Interrupt Output SRx Writing a 1 to this bit field activates the service request output SRx of this USIC channel. It has no impact on service request outputs of other USIC channels. 0 _B No action. 1 _B The service request output SRx is activated.
0	[3:2], [13:5], [31:22]	r	Reserved Read as 0; should be written with 0.

15.11.8 Data Buffer Registers

15.11.8.1 Transmit Buffer Locations

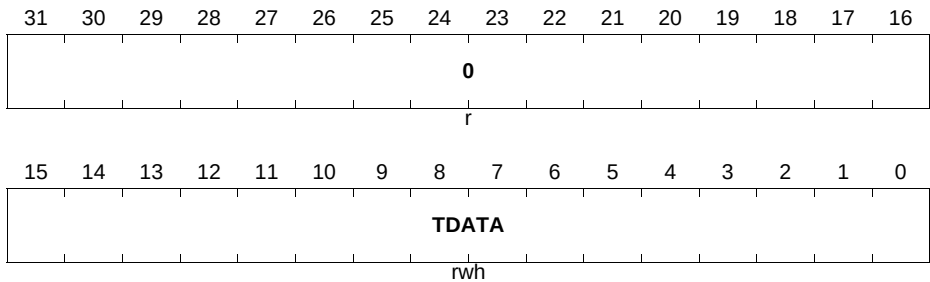
The 32 independent data input locations TBUF00 to TBUF31 are address locations that can be used as data entry locations for the transmit buffer. Data written to one of these locations will appear in a common register TBUF. Additionally, the 5 bit coding of the number [31:0] of the addressed data input location represents the transmit control information TCI (please refer to the protocol sections for more details).

The internal transmit buffer register TBUF contains the data that will be loaded to the transmit shift register for the next transmission of a data word. It can be read out at all TBUF00 to TBUF31 addresses.

Universal Serial Interface Channel (USIC)

TBUF_x (x = 00-31)

Transmit Buffer Input Location x ($80_H + x \cdot 4$) **Reset Value: 0000 0000_H**



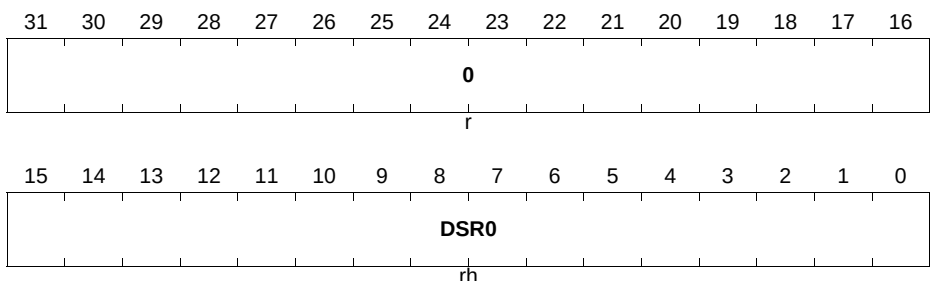
Field	Bits	Type	Description
TDATA	[15:0]	rwh	Transmit Data This bit field contains the data to be transmitted (read view). A data write action to at least the low byte of TDATA sets TCSR.TDV.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

15.11.8.2 Receive Buffer Registers RBUF0, RBUF1

The receive buffer register RBUF0 contains the data received from RSR0[3:0]. A read action does not change the status of the receive data from “not yet read = valid” to “already read = not valid”.

RBUF0

Receiver Buffer Register 0 ($5C_H$) **Reset Value: 0000 0000_H**



Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DSR0	[15:0]	rh	Data of Shift Registers 0[3:0]
0	[31:16]	r	Reserved Read as 0; should be written with 0.

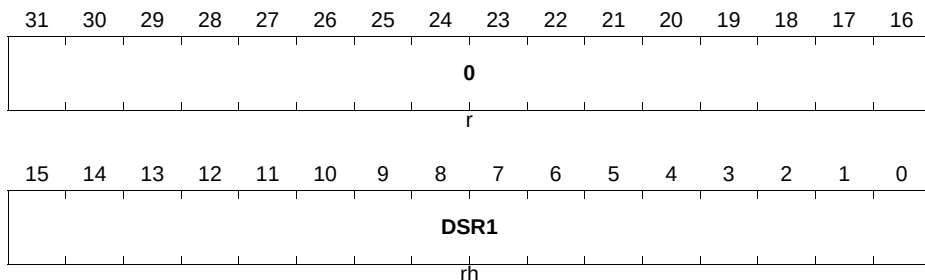
The receive buffer register RBUF1 contains the data received from RSR1[3:0]. A read action does not change the status of the receive data from “not yet read = valid” to “already read = not valid”.

RBUF1

Receiver Buffer Register 1

(60_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DSR1	[15:0]	rh	Data of Shift Registers 1[3:0]
0	[31:16]	r	Reserved Read as 0; should be written with 0.

The receive buffer status register RBUF01SR provides the status of the data in receive buffers RBUF0 and RBUF1.

Universal Serial Interface Channel (USIC)

RBUF01SR

Receiver Buffer 01 Status Register (64_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DS1	RDV 11	RDV 10		0		PER R1	PAR 1	0	SOF 1	0			WLEN1		
rh	rh	rh		r		rh	rh	r	rh	r			rh		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DS0	RDV 01	RDV 00		0		PER R0	PAR 0	0	SOF 0	0			WLEN0		
rh	rh	rh		r		rh	rh	r	rh	r			rh		

Field	Bits	Type	Description
WLEN0	[3:0]	rh	Received Data Word Length in RBUF0 This bit field indicates how many bits have been received within the last data word stored in RBUF0. This number indicates how many data bits have to be considered as receive data, whereas the other bits in RBUF0 have been cleared automatically. The received bits are always right-aligned. For all protocol modes besides dual and quad SSC, Received data word length = WLEN0 + 1 For dual SSC mode, Received data word length = WLEN0 + 2 For quad SSC mode, Received data word length = WLEN0 + 4
SOF0	6	rh	Start of Frame in RBUF0 This bit indicates whether the data word in RBUF0 has been the first data word of a data frame. 0 _B The data in RBUF0 has not been the first data word of a data frame. 1 _B The data in RBUF0 has been the first data word of a data frame.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
PAR0	8	rh	Protocol-Related Argument in RBUF0 This bit indicates the value of the protocol-related argument. This value is elaborated depending on the selected protocol and adds additional information to the data word in RBUF0. The meaning of this bit is described in the corresponding protocol chapter.
PERR0	9	rh	Protocol-related Error in RBUF0 This bit indicates if the value of the protocol-related argument meets an expected value. This value is elaborated depending on the selected protocol and adds additional information to the data word in RBUF0. The meaning of this bit is described in the corresponding protocol chapter. 0_B The received protocol-related argument PAR matches the expected value. The reception of the data word sets bit PSR.RIF and can generate a receive interrupt. 1_B The received protocol-related argument PAR does not match the expected value. The reception of the data word sets bit PSR.AIF and can generate an alternative receive interrupt.
RDV00	13	rh	Receive Data Valid in RBUF0 This bit indicates the status of the data content of register RBUF0. This bit is identical to bit RBUF01SR.RDV10 and allows consisting reading of information for the receive buffer registers. It is set when a new data word is stored in RBUF0 and automatically cleared if it is read out via RBUF. 0_B Register RBUF0 does not contain data that has not yet been read out. 1_B Register RBUF0 contains data that has not yet been read out.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
RDV01	14	rh	Receive Data Valid in RBUF1 This bit indicates the status of the data content of register RBUF1. This bit is identical to bit RBUF01SR.RDV11 and allows consisting reading of information for the receive buffer registers. It is set when a new data word is stored in RBUF1 and automatically cleared if it is read out via RBUF. 0_B Register RBUF1 does not contain data that has not yet been read out. 1_B Register RBUF1 contains data that has not yet been read out.
DS0	15	rh	Data Source This bit indicates which receive buffer register (RBUF0 or RBUF1) is currently visible in registers RBUF(D) and in RBUF0SR for the associated status information. It indicates which buffer contains the oldest data (the data that has been received first). This bit is identical to bit RBUF01SR.DS1 and allows consisting reading of information for the receive buffer registers. 0_B The register RBUF contains the data of RBUF0 (same for associated status information). 1_B The register RBUF contains the data of RBUF1 (same for associated status information).
WLEN1	[19:16]	rh	Received Data Word Length in RBUF1 This bit field indicates how many bits have been received within the last data word stored in RBUF1. This number indicates how many data bits have to be considered as receive data, whereas the other bits in RBUF1 have been cleared automatically. The received bits are always right-aligned. For all protocol modes besides dual and quad SSC, Received data word length = $WLEN1 + 1$ For dual SSC mode, Received data word length = $WLEN1 + 2$ For quad SSC mode, Received data word length = $WLEN1 + 4$

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
SOF1	22	rh	Start of Frame in RBUF1 This bit indicates whether the data word in RBUF1 has been the first data word of a data frame. 0 _B The data in RBUF1 has not been the first data word of a data frame. 1 _B The data in RBUF1 has been the first data word of a data frame.
PAR1	24	rh	Protocol-Related Argument in RBUF1 This bit indicates the value of the protocol-related argument. This value is elaborated depending on the selected protocol and adds additional information to the data word in RBUF1. The meaning of this bit is described in the corresponding protocol chapter.
PERR1	25	rh	Protocol-related Error in RBUF1 This bit indicates if the value of the protocol-related argument meets an expected value. This value is elaborated depending on the selected protocol and adds additional information to the data word in RBUF1. The meaning of this bit is described in the corresponding protocol chapter. 0 _B The received protocol-related argument PAR matches the expected value. The reception of the data word sets bit PSR.RIF and can generate a receive interrupt. 1 _B The received protocol-related argument PAR does not match the expected value. The reception of the data word sets bit PSR.AIF and can generate an alternative receive interrupt.
RDV10	29	rh	Receive Data Valid in RBUF0 This bit indicates the status of the data content of register RBUF0. This bit is identical to bit RBUF01SR.RDV00 and allows consistent reading of information for the receive buffer registers. 0 _B Register RBUF0 does not contain data that has not yet been read out. 1 _B Register RBUF0 contains data that has not yet been read out.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
RDV11	30	rh	Receive Data Valid in RBUF1 This bit indicates the status of the data content of register RBUF1. This bit is identical to bit RBUF01SR.RDV01 and allows consisting reading of information for the receive buffer registers. 0 _B Register RBUF1 does not contain data that has not yet been read out. 1 _B Register RBUF1 contains data that has not yet been read out.
DS1	31	rh	Data Source This bit indicates which receive buffer register (RBUF0 or RBUF1) is currently visible in registers RBUF(D) and in RBUFSR for the associated status information. It indicates which buffer contains the oldest data (the data that has been received first). This bit is identical to bit RBUF01SR.DS0 and allows consisting reading of information for the receive buffer registers. 0 _B The register RBUF contains the data of RBUF0 (same for associated status information). 1 _B The register RBUF contains the data of RBUF1 (same for associated status information).
0	[5:4], 7, [12:10], [21:20], 23, [28:26]	r	Reserved Read as 0; should be written with 0.

15.11.8.3 Receive Buffer Registers RBUF, RBUFD, RBUFSR

The receiver buffer register RBUF shows the content of the either RBUF0 or RBUF1, depending on the order of reception. Always the oldest data (the data word that has been received first) from both receive buffers can be read from RBUF. It is recommended to read out the received data from RBUF instead of RBUF0/1. With a read access of at least the low byte of RBUF, the status of the receive data is automatically changed from “not yet read = valid” to “already read = not valid”, the content of RBUF becomes updated, and the next received data word becomes visible in RBUF.

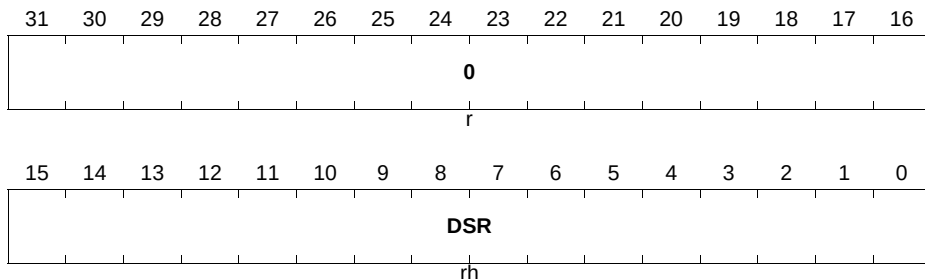
Universal Serial Interface Channel (USIC)

RBUF

Receiver Buffer Register

(54_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DSR	[15:0]	rh	Received Data This bit field monitors the content of either RBUF0 or RBUF1, depending on the reception sequence.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

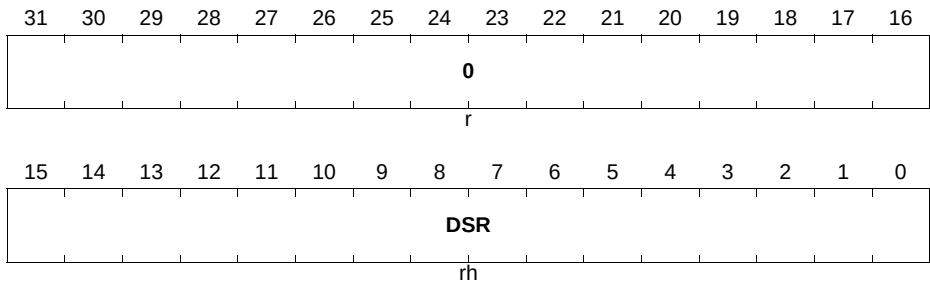
Universal Serial Interface Channel (USIC)

If a debugger should be used to monitor the received data, the automatic update mechanism has to be de-activated to guaranty data consistency. Therefore, the receiver buffer register for debugging RBUFD is available. It is similar to RBUF, but without the automatic update mechanism by a read action. So a debugger (or other monitoring function) can read RBUFD without disturbing the receive sequence.

RBUFD

Receiver Buffer Register for Debugger(58_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DSR	[15:0]	rh	Data from Shift Register Same as RBUF.DSR, but without releasing the buffer after a read action.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

The receive buffer status register RBUF01SR provides the status of the data in receive buffers RBUF and RBUFD. If bits RBUF01SR.DS0 (or RBUF01SR.DS1) are 0, the lower 16-bit content of RBUF01SR is monitored in RBUF01SR, otherwise the upper 16-bit content of RBUF01SR is shown.

RBUF01SR

Receiver Buffer Status 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
DS	RDV1	RDV0	0			PERR	PAR	0	SOF	0	WLEN				
rh	rh	rh	r			rh	rh	r	rh	r	rh				

Field	Bits	Type	Description
WLEN	[3:0]	rh	Received Data Word Length in RBUF or RBUFD Description see RBUF01SR.WLEN0 or RBUF01SR.WLEN1.
SOF	6	rh	Start of Frame in RBUF or RBUFD Description see RBUF01SR.SOF0 or RBUF01SR.SOF1.
PAR	8	rh	Protocol-Related Argument in RBUF or RBUFD Description see RBUF01SR.PAR0 or RBUF01SR.PAR1.
PERR	9	rh	Protocol-related Error in RBUF or RBUFD Description see RBUF01SR.PERR0 or RBUF01SR.PERR1.
RDV0	13	rh	Receive Data Valid in RBUF or RBUFD Description see RBUF01SR.RDV00 or RBUF01SR.RDV10.
RDV1	14	rh	Receive Data Valid in RBUF or RBUFD Description see RBUF01SR.RDV01 or RBUF01SR.RDV11.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DS	15	rh	Data Source of RBUF or RBUFD Description see RBUF01SR.DS0 or RBUF01SR.DS1.
0	[5:4], 7, [12:10], [31:16]	r	Reserved Read as 0; should be written with 0.

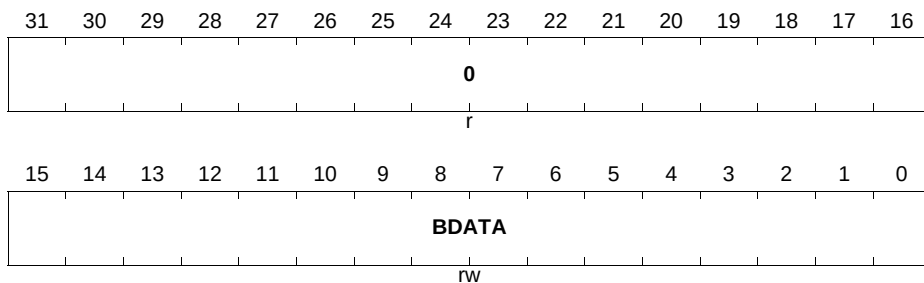
15.11.9 FIFO Buffer and Bypass Registers

15.11.9.1 Bypass Registers

A write action to at least the low byte of the bypass data register sets BYPCR.BDV = 1 (bypass data tagged valid).

BYP

Bypass Data Register (100_H) **Reset Value: 0000 0000_H**



Bit (Field)	Width	Type	Description
BDATA	[15:0]	rw	Bypass Data This bit field contains the bypass data.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

BYPCCR

Bypass Control Register

(104_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								BHPC				BSELO			
r								rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BDV	0	BPRI	BDV	BDEN	0	BDS	SM	0				BWLE			
rh	r	rw	rw	rw	r	rw		r				rw			

Field	Bits	Type	Description
BWLE	[3:0]	rw	Bypass Word Length This bit field defines the word length of the bypass data. The word length is given by BWLE + 1 with the data word being right-aligned in the data buffer at the bit positions [BWLE down to 0]. The bypass data word is always considered as an own frame with the length of BWLE. Same coding as SCTR.WLE.
BDSSM	8	rw	Bypass Data Single Shot Mode This bit defines if the bypass data is considered as permanently valid or if the bypass data is only transferred once (single shot mode). 0 _B The bypass data is still considered as valid after it has been loaded into TBUF. The loading of the data into TBUF does not clear BDV. 1 _B The bypass data is considered as invalid after it has been loaded into TBUF. The loading of the data into TBUF clears BDV.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
BDEN	[11:10]	rw	Bypass Data Enable This bit field defines if and how the transfer of bypass data to TBUF is enabled. 00 _B The transfer of bypass data is disabled. 01 _B The transfer of bypass data to TBUF is possible. Bypass data will be transferred to TBUF according to its priority if BDV = 1. 10 _B Gated bypass data transfer is enabled. Bypass data will be transferred to TBUF according to its priority if BDV = 1 and while DX2S = 0. 11 _B Gated bypass data transfer is enabled. Bypass data will be transferred to TBUF according to its priority if BDV = 1 and while DX2S = 1.
BDVTR	12	rw	Bypass Data Valid Trigger This bit enables the bypass data for being tagged valid when DX2T is active (for time framing or time-out purposes). 0 _B Bit BDV is not influenced by DX2T. 1 _B Bit BDV is set if DX2T is active.
BPRI0	13	rw	Bypass Priority This bit defines the priority between the bypass data and the transmit FIFO data. 0 _B The transmit FIFO data has a higher priority than the bypass data. 1 _B The bypass data has a higher priority than the transmit FIFO data.
BDV	15	rh	Bypass Data Valid This bit defines if the bypass data is valid for a transfer to TBUF. This bit is set automatically by a write access to at least the low-byte of register BYP. It can be cleared by software by writing TRBSCR.CBDV. 0 _B The bypass data is not valid. 1 _B The bypass data is valid.
BSELO	[20:16]	rw	Bypass Select Outputs This bit field contains the value that is written to PCR.CTR[20:16] if bypass data is transferred to TBUF while TCSR.SELMD = 1. In the SSC protocol, this bit field can be used to define which SELOx output line will be activated when bypass data is transmitted.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
BHPC	[23:21]	rw	Bypass Hardware Port Control This bit field contains the value that is written to SCTR[4:2] if bypass data is transferred to TBUF while TCSR.HPCMD = 1. In the SSC protocol, this bit field can be used to define the data shift mode and if hardware port control is enabled through CCR.HPCEN = 1, the pin direction when bypass data is transmitted.
0	[7:4], 9, 14, [31:24]	r	Reserved Read as 0; should be written with 0.

15.11.9.2 General FIFO Buffer Control Registers

The transmit and receive FIFO status information of USICx_CHy is given in registers USICx_CHy.TRBSR.

The bits related to the transmitter buffer in this register can only be written if the transmit buffer functionality is enabled by CCFG.TB = 1, otherwise write accesses are ignored. A similar behavior applies for the bits related to the receive buffer referring to CCFG.RB = 1.

The interrupt flags (event flags) in the transmit and receive FIFO status register TRBSR can be cleared by writing a 1 to the corresponding bit position in register TRBSCR, whereas writing a 0 has no effect on these bits. Writing a 1 by software to SRBI, RBERI, ARBI, STBI, or TBERI sets the corresponding bit to simulate the detection of a transmit/receive buffer event, but without activating any service request output (therefore, see FMR.SIOx).

Bits TBUS and RBUS have been implemented for testing purposes. They can be ignored by data handling software. Please note that a read action can deliver either a 0 or a 1 for these bits. It is recommended to treat them as "don't care".

Universal Serial Interface Channel (USIC)

TRBSR

Transmit/Receive Buffer Status Register

(114_H)

Reset Value: 0000 0808_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	TBFLVL							0	RBFLVL						
r	rh							r	rh						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	STB T	TBU S	TFU LL	TEM PTY	0	TBE RI	STBI	0	SRB T	RBU S	RFU LL	REM PTY	ARBI	RBE RI	SRBI
r	rh	rh	rh	rh	r	rwh	rwh	r	rh	rh	rh	rh	rwh	rwh	rwh

Field	Bits	Type	Description
SRBI	0	rwh	Standard Receive Buffer Event This bit indicates that a standard receive buffer event has been detected. It is cleared by writing TRBSCR.CSRBI = 1. If enabled by RBCTR.SRBIEN, the service request output SRx selected by RBCTR.SRBINP becomes activated if a standard receive buffer event is detected. 0 _B A standard receive buffer event has not been detected. 1 _B A standard receive buffer event has been detected.
RBERI	1	rwh	Receive Buffer Error Event This bit indicates that a receive buffer error event has been detected. It is cleared by writing TRBSCR.CRBERI = 1. If enabled by RBCTR.RBERIEN, the service request output SRx selected by RBCTR.ARBINP becomes activated if a receive buffer error event is detected. 0 _B A receive buffer error event has not been detected. 1 _B A receive buffer error event has been detected.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
ARBI	2	rwh	Alternative Receive Buffer Event This bit indicates that an alternative receive buffer event has been detected. It is cleared by writing <code>TRBSCR.CARBI = 1</code> . If enabled by <code>RBCTR.ARBIE</code> , the service request output <code>SRx</code> selected by <code>RBCTR.ARBINP</code> becomes activated if an alternative receive buffer event is detected. 0_B An alternative receive buffer event has not been detected. 1_B An alternative receive buffer event has been detected.
EMPTY	3	rh	Receive Buffer Empty This bit indicates whether the receive buffer is empty. 0_B The receive buffer is not empty. 1_B The receive buffer is empty.
RFULL	4	rh	Receive Buffer Full This bit indicates whether the receive buffer is full. 0_B The receive buffer is not full. 1_B The receive buffer is full.
RBUS	5	rh	Receive Buffer Busy This bit indicates whether the receive buffer is currently updated by the FIFO handler. 0_B The receive buffer information has been completely updated. 1_B The <code>OUTR</code> update from the FIFO memory is ongoing. A read from <code>OUTR</code> will be delayed. FIFO pointers from the previous read are not yet updated.
SRBT	6	rh	Standard Receive Buffer Event Trigger This bit triggers a standard receive buffer event when set. If enabled by <code>RBCTR.SRBE</code> , the service request output <code>SRx</code> selected by <code>RBCTR.SRBINP</code> becomes activated until the bit is cleared. 0_B A standard receive buffer event is not triggered using this bit. 1_B A standard receive buffer event is triggered using this bit.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
STBI	8	rwh	Standard Transmit Buffer Event This bit indicates that a standard transmit buffer event has been detected. It is cleared by writing <code>TRBSCR.CSTBI = 1</code> . If enabled by <code>TBCTR.STBIEN</code> , the service request output <code>SRx</code> selected by <code>TBCTR.STBINP</code> becomes activated if a standard transmit buffer event is detected. 0_B A standard transmit buffer event has not been detected. 1_B A standard transmit buffer event has been detected.
TBERI	9	rwh	Transmit Buffer Error Event This bit indicates that a transmit buffer error event has been detected. It is cleared by writing <code>TRBSCR.CTBERI = 1</code> . If enabled by <code>TBCTR.TBERIEN</code> , the service request output <code>SRx</code> selected by <code>TBCTR.ATBINP</code> becomes activated if a transmit buffer error event is detected. 0_B A transmit buffer error event has not been detected. 1_B A transmit buffer error event has been detected.
EMPTY	11	rh	Transmit Buffer Empty This bit indicates whether the transmit buffer is empty. 0_B The transmit buffer is not empty. 1_B The transmit buffer is empty.
TFULL	12	rh	Transmit Buffer Full This bit indicates whether the transmit buffer is full. 0_B The transmit buffer is not full. 1_B The transmit buffer is full.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
TBUS	13	rh	Transmit Buffer Busy This bit indicates whether the transmit buffer is currently updated by the FIFO handler. 0_B The transmit buffer information has been completely updated. 1_B The FIFO memory update after write to INx is ongoing. A write to INx will be delayed. FIFO pointers from the previous INx write are not yet updated.
STBT	14	rh	Standard Transmit Buffer Event Trigger This bit triggers a standard transmit buffer event when set. If enabled by TBCTR.STBIEN, the service request output SRx selected by TBCTR.STBINP becomes activated until the bit is cleared. 0_B A standard transmit buffer event is not triggered using this bit. 1_B A standard transmit buffer event is triggered using this bit.
RBFLVL	[22:16]	rh	Receive Buffer Filling Level This bit field indicates the filling level of the receive buffer, starting with 0 for an empty buffer.
TBFLVL	[30:24]	rh	Transmit Buffer Filling Level This bit field indicates the filling level of the transmit buffer, starting with 0 for an empty buffer. <i>Note: The first data word written to Transmit FIFO will be loaded immediately to TBUF and removed from FIFO.</i>
0	7, 10, 15, 23, 31	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

The bits in register TRBSCR are used to clear the notification bits in register TRBSR or to clear the FIFO mechanism for the transmit or receive buffer. A read action always delivers 0.

TRBSCR

Transmit/Receive Buffer Status 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
FLU SHT B	FLU SHR B	0			CBD V	CTB ERI	CST BI	0					CAR BI	CRB ERI	CSR BI
w	w	r			w	w	w	r					w	w	w

Field	Bits	Type	Description
CSRBI	0	w	Clear Standard Receive Buffer Event 0 _B No effect. 1 _B Clear TRBSR.SRBI.
CRBERI	1	w	Clear Receive Buffer Error Event 0 _B No effect. 1 _B Clear TRBSR.RBERI.
CARBI	2	w	Clear Alternative Receive Buffer Event 0 _B No effect. 1 _B Clear TRBSR.ARBI.
CSTBI	8	w	Clear Standard Transmit Buffer Event 0 _B No effect. 1 _B Clear TRBSR.STBI.
CTBERI	9	w	Clear Transmit Buffer Error Event 0 _B No effect. 1 _B Clear TRBSR.TBERI.
CBDV	10	w	Clear Bypass Data Valid 0 _B No effect. 1 _B Clear BYPCR.BDV.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
FLUSHRB	14	w	Flush Receive Buffer 0 _B No effect. 1 _B The receive FIFO buffer is cleared (filling level is cleared and output pointer is set to input pointer value). Should only be used while the FIFO buffer is not taking part in data traffic.
FLUSHTB	15	w	Flush Transmit Buffer 0 _B No effect. 1 _B The transmit FIFO buffer is cleared (filling level is cleared and output pointer is set to input pointer value). Should only be used while the FIFO buffer is not taking part in data traffic.
0	[7:3], [13:11], [31:16]	r	Reserved Read as 0; should be written with 0.

15.11.9.3 Transmit FIFO Buffer Control Registers

The transmit FIFO buffer is controlled by register TBCTR. TBCTR can only be written if the transmit buffer functionality is enabled by CCFG.TB = 1, otherwise write accesses are ignored.

TBCTR

Transmitter Buffer Control Register (108_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TBE	STBI	0	LOF	0	SIZE			0	ATBINP		STBINP				
rw	rw	r	rw	r	rw			r	rw		rw				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STB	STB	LIMIT						0	DPTR						
rw	rw	rw						r	w						

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
DPTR	[5:0]	w	Data Pointer This bit field defines the start value for the transmit buffer pointers when assigning the FIFO entries to the transmit FIFO buffer. A read always delivers 0. When writing DPTR while SIZE = 0, both transmitter pointers TDIPTR and RTDOPTR in register TRBPTR are updated with the written value and the buffer is considered as empty. A write access to DPTR while SIZE > 0 is ignored and does not modify the pointers.
LIMIT	[13:8]	rw	Limit For Interrupt Generation This bit field defines the target filling level of the transmit FIFO buffer that is used for the standard transmit buffer event detection.
STBTM	14	rw	Standard Transmit Buffer Trigger Mode This bit selects the standard transmit buffer event trigger mode. 0_B Trigger mode 0: While TRBSR.STBT=1, a standard buffer event will be generated whenever there is a data transfer to TBUF or data write to INx (depending on TBCTR.LOF setting). STBT is cleared when TRBSR.TBFLVL=TBCTR.LIMIT. 1_B Trigger mode 1: While TRBSR.STBT=1, a standard buffer event will be generated whenever there is a data transfer to TBUF or data write to INx (depending on TBCTR.LOF setting). STBT is cleared when TRBSR.TBFLVL=TBCTR.SIZE.
STBTEN	15	rw	Standard Transmit Buffer Trigger Enable This bit enables/disables triggering of the standard transmit buffer event through bit TRBSR.STBT. 0_B The standard transmit buffer event trigger through bit TRBSR.STBT is disabled. 1_B The standard transmit buffer event trigger through bit TRBSR.STBT is enabled.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
STBINP	[18:16]	rw	Standard Transmit Buffer Interrupt Node Pointer This bit field defines which service request output SRx becomes activated in case of a standard transmit buffer event. 000 _B Output SR0 becomes activated. 001 _B Output SR1 becomes activated. 010 _B Output SR2 becomes activated. 011 _B Output SR3 becomes activated. 100 _B Output SR4 becomes activated. 101 _B Output SR5 becomes activated. <i>Note: All other settings of the bit field are reserved.</i>
ATBINP	[21:19]	rw	Alternative Transmit Buffer Interrupt Node Pointer This bit field define which service request output SRx will be activated in case of a transmit buffer error event. 000 _B Output SR0 becomes activated. 001 _B Output SR1 becomes activated. 010 _B Output SR2 becomes activated. 011 _B Output SR3 becomes activated. 100 _B Output SR4 becomes activated. 101 _B Output SR5 becomes activated. <i>Note: All other settings of the bit field are reserved.</i>
SIZE	[26:24]	rw	Buffer Size This bit field defines the number of FIFO entries assigned to the transmit FIFO buffer. 000 _B The FIFO mechanism is disabled. The buffer does not accept any request for data. 001 _B The FIFO buffer contains 2 entries. 010 _B The FIFO buffer contains 4 entries. 011 _B The FIFO buffer contains 8 entries. 100 _B The FIFO buffer contains 16 entries. 101 _B The FIFO buffer contains 32 entries. 110 _B The FIFO buffer contains 64 entries. 111 _B Reserved

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
LOF	28	rw	Buffer Event on Limit Overflow This bit defines which relation between filling level and programmed limit leads to a standard transmit buffer event. 0_B A standard transmit buffer event occurs when the filling level equals the limit value and gets lower due to transmission of a data word. 1_B A standard transmit buffer interrupt event occurs when the filling level equals the limit value and gets bigger due to a write access to a data input location INx.
STBIEN	30	rw	Standard Transmit Buffer Interrupt Enable This bit enables/disables the generation of a standard transmit buffer interrupt in case of a standard transmit buffer event. 0_B The standard transmit buffer interrupt generation is disabled. 1_B The standard transmit buffer interrupt generation is enabled.
TBERIEN	31	rw	Transmit Buffer Error Interrupt Enable This bit enables/disables the generation of a transmit buffer error interrupt in case of a transmit buffer error event (software writes to a full transmit buffer). 0_B The transmit buffer error interrupt generation is disabled. 1_B The transmit buffer error interrupt generation is enabled.
0	[7:6], [23:22], 27, 29	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.11.9.4 Receive FIFO Buffer Control Registers

The receive FIFO buffer is controlled by register RBCTR. This register can only be written if the receive buffer functionality is enabled by CCFG.RB = 1, otherwise write accesses are ignored.

RBCTR

Receiver Buffer Control Register (10C_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RBE RIEN	SRBI EN	ARBI EN	LOF	RNM	SIZE			RCIM			ARBINP			SRBINP	
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
SRB TEN	SRB TM	LIMIT						0		DPTR					
rw	rw	rw						r		w					

Field	Bits	Type	Description
DPTR	[5:0]	w	Data Pointer This bit field defines the start value for the receive buffer pointers when assigning the FIFO entries to the receive FIFO buffer. A read always delivers 0. When writing DPTR while SIZE = 0, both receiver pointers RDIPTR and RDOPTR in register TRBPTR are updated with the written value and the buffer is considered as empty. A write access to DPTR while SIZE > 0 is ignored and does not modify the pointers.
LIMIT	[13:8]	rw	Limit For Interrupt Generation This bit field defines the target filling level of the receive FIFO buffer that is used for the standard receive buffer event detection.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
SRBTM	14	rw	Standard Receive Buffer Trigger Mode This bit selects the standard receive buffer event trigger mode. 0_B Trigger mode 0: While TRBSR.SRBT=1, a standard receive buffer event will be generated whenever there is a new data received or data read out (depending on RBCTR.LOF setting). SRBT is cleared when TRBSR.RBFLVL=RBCTR.LIMIT. 1_B Trigger mode 1: While TRBSR.SRBT=1, a standard receive buffer event will be generated whenever there is a new data received or data read out (depending on RBCTR.LOF setting). SRBT is cleared when TRBSR.RBFLVL=0.
SRBTEN	15	rw	Standard Receive Buffer Trigger Enable This bit enables/disables triggering of the standard receive buffer event through bit TRBSR.SRBT. 0_B The standard receive buffer event trigger through bit TRBSR.SRBT is disabled. 1_B The standard receive buffer event trigger through bit TRBSR.SRBT is enabled.
SRBINP	[18:16]	rw	Standard Receive Buffer Interrupt Node Pointer This bit field defines which service request output SRx becomes activated in case of a standard receive buffer event. 000_B Output SR0 becomes activated. 001_B Output SR1 becomes activated. 010_B Output SR2 becomes activated. 011_B Output SR3 becomes activated. 100_B Output SR4 becomes activated. 101_B Output SR5 becomes activated. <i>Note: All other settings of the bit field are reserved.</i>

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
ARBINP	[21:19]	rw	Alternative Receive Buffer Interrupt Node Pointer This bit field defines which service request output SRx becomes activated in case of an alternative receive buffer event or a receive buffer error event. 000_B Output SR0 becomes activated. 001_B Output SR1 becomes activated. 010_B Output SR2 becomes activated. 011_B Output SR3 becomes activated. 100_B Output SR4 becomes activated. 101_B Output SR5 becomes activated. <i>Note: All other settings of the bit field are reserved.</i>
RCIM	[23:22]	rw	Receiver Control Information Mode This bit field defines which information from the receiver status register RBUFSR is propagated as 5 bit receiver control information RCI[4:0] to the receive FIFO buffer and can be read out in registers OUT(D)R. 00_B RCI[4] = PERR, RCI[3:0] = WLEN 01_B RCI[4] = SOF, RCI[3:0] = WLEN 10_B RCI[4] = 0, RCI[3:0] = WLEN 11_B RCI[4] = PERR, RCI[3] = PAR, RCI[2:1] = 00_B, RCI[0] = SOF
SIZE	[26:24]	rw	Buffer Size This bit field defines the number of FIFO entries assigned to the receive FIFO buffer. 000_B The FIFO mechanism is disabled. The buffer does not accept any request for data. 001_B The FIFO buffer contains 2 entries. 010_B The FIFO buffer contains 4 entries. 011_B The FIFO buffer contains 8 entries. 100_B The FIFO buffer contains 16 entries. 101_B The FIFO buffer contains 32 entries. 110_B The FIFO buffer contains 64 entries. 111_B Reserved

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
RNM	27	rw	Receiver Notification Mode This bit defines the receive buffer event mode. The receive buffer error event is not affected by RNM. 0_B Filling level mode: A standard receive buffer event occurs when the filling level equals the limit value and changes, either due to a read access from OUTR (LOF = 0) or due to a new received data word (LOF = 1). 1_B RCI mode: A standard receive buffer event occurs when register OUTR is updated with a new value if the corresponding value in OUTR.RCI[4] = 0. If OUTR.RCI[4] = 1, an alternative receive buffer event occurs instead of the standard receive buffer event.
LOF	28	rw	Buffer Event on Limit Overflow This bit defines which relation between filling level and programmed limit leads to a standard receive buffer event in filling level mode (RNM = 0). In RCI mode (RNM = 1), bit fields LIMIT and LOF are ignored. 0_B A standard receive buffer event occurs when the filling level equals the limit value and gets lower due to a read access from OUTR. 1_B A standard receive buffer event occurs when the filling level equals the limit value and gets bigger due to the reception of a new data word.
ARBIEN	29	rw	Alternative Receive Buffer Interrupt Enable This bit enables/disables the generation of an alternative receive buffer interrupt in case of an alternative receive buffer event. 0_B The alternative receive buffer interrupt generation is disabled. 1_B The alternative receive buffer interrupt generation is enabled.

Universal Serial Interface Channel (USIC)

Field	Bits	Type	Description
SRBIEN	30	rw	Standard Receive Buffer Interrupt Enable This bit enables/disables the generation of a standard receive buffer interrupt in case of a standard receive buffer event. 0_B The standard receive buffer interrupt generation is disabled. 1_B The standard receive buffer interrupt generation is enabled.
RBERIEN	31	rw	Receive Buffer Error Interrupt Enable This bit enables/disables the generation of a receive buffer error interrupt in case of a receive buffer error event (the software reads from an empty receive buffer). 0_B The receive buffer error interrupt generation is disabled. 1_B The receive buffer error interrupt generation is enabled.
0	[7:6]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.11.9.5 FIFO Buffer Data Registers

The 32 independent data input locations IN00 to IN31 are addresses that can be used as data entry locations for the transmit FIFO buffer. Data written to one of these locations will be stored in the transmit buffer FIFO. Additionally, the 5-bit coding of the number [31:0] of the addressed data input location represents the transmit control information TCI.

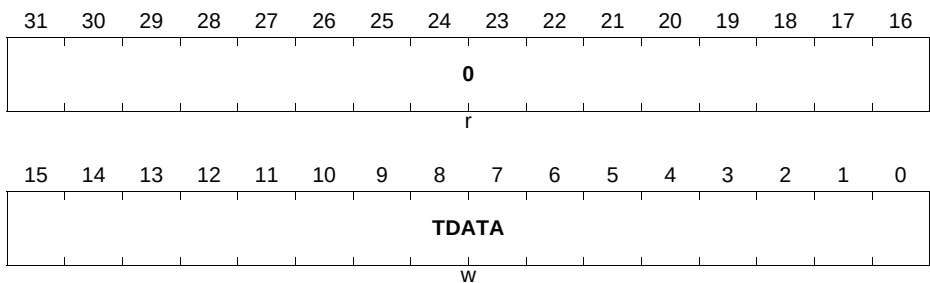
If the FIFO is already full and new data is written to it, the write access is ignored and a transmit buffer error event is signaled.

INx (x = 00-31)

Transmit FIFO Buffer Input Location x

(180_H + x *4)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
TDATA	[15:0]	w	Transmit Data This bit field contains the data to be transmitted (write view), read actions deliver 0. A write action to at least the low byte of TDATA triggers the data storage in the FIFO.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

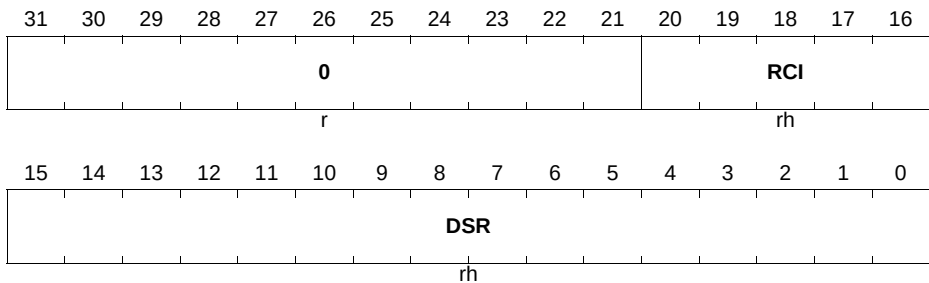
The receiver FIFO buffer output register OUTR shows the oldest received data word in the FIFO buffer and contains the receiver control information RCI containing the information selected by RBCTR.RCIM. A read action from this address location delivers the received data. With a read access of at least the low byte, the data is declared to be read and the next entry becomes visible. Write accesses to OUTR are ignored.

OUTR

Receiver Buffer Output Register

(11C_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DSR	[15:0]	rh	Received Data This bit field monitors the content of the oldest data word in the receive FIFO. Reading at least the low byte releases the buffer entry currently shown in DSR.
RCI	[20:16]	rh	Receiver Control Information This bit field monitors the receiver control information associated to DSR. The bit structure of RCI depends on bit field RBCTR.RCIM.
0	[31:21]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

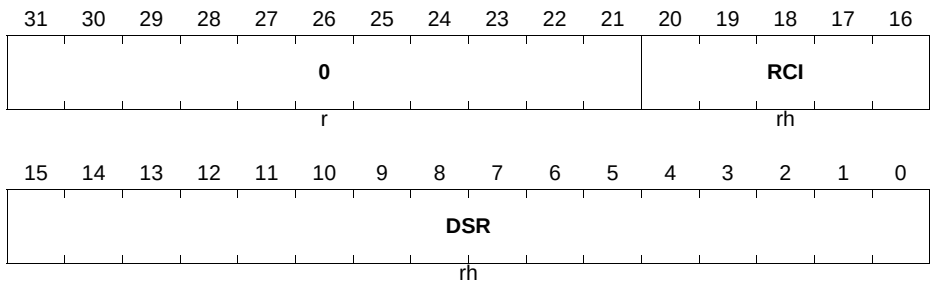
If a debugger should be used to monitor the received data in the FIFO buffer, the FIFO mechanism must not be activated in order to guaranty data consistency. Therefore, a second address set is available, named OUTDR (D like debugger), having the same bit fields like the original buffer output register OUTR, but without the FIFO mechanism. A debugger can read here (in order to monitor the receive data flow) without the risk of data corruption. Write accesses to OUTDR are ignored.

OUTDR

Receiver Buffer Output Register L for Debugger

(120_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
DSR	[15:0]	rh	Data from Shift Register Same as OUTR.DSR, but without releasing the buffer after a read action.
RCI	[20:16]	rh	Receive Control Information from Shift Register Same as OUTR.RCI.
0	[31:21]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.11.9.6 FIFO Buffer Pointer Registers

The pointers for FIFO handling of the transmit and receive FIFO buffers are located in register TRBPTR. The pointers are automatically handled by the FIFO buffer mechanism and do not need to be modified by software. As a consequence, these registers can only be read by software (e.g. for verification purposes), whereas write accesses are ignored.

TRBPTR

Transmit/Receive Buffer Pointer Register

(110_H)

Reset Value: 0000 0000_H

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

Field	Bits	Type	Description
TDIPTR	[5:0]	rh	Transmitter Data Input Pointer This bit field indicates the buffer entry that will be used for the next transmit data coming from the INx addresses.
TDOPTR	[13:8]	rh	Transmitter Data Output Pointer This bit field indicates the buffer entry that will be used for the next transmit data to be output to TBUF.
RDIPTR	[21:16]	rh	Receiver Data Input Pointer This bit field indicates the buffer entry that will be used for the next receive data coming from RBUF.
RDOPTR	[29:24]	rh	Receiver Data Output Pointer This bit field indicates the buffer entry that will be used for the next receive data to be output at the OUT(D)R addresses.
0	[7:6], [15:14], [23:22], [31:30]	r	Reserved Read as 0; should be written with 0.

Universal Serial Interface Channel (USIC)

15.12 Interconnects

The XMC1200 device contains one USIC module (USIC0) with 2 communication channels.

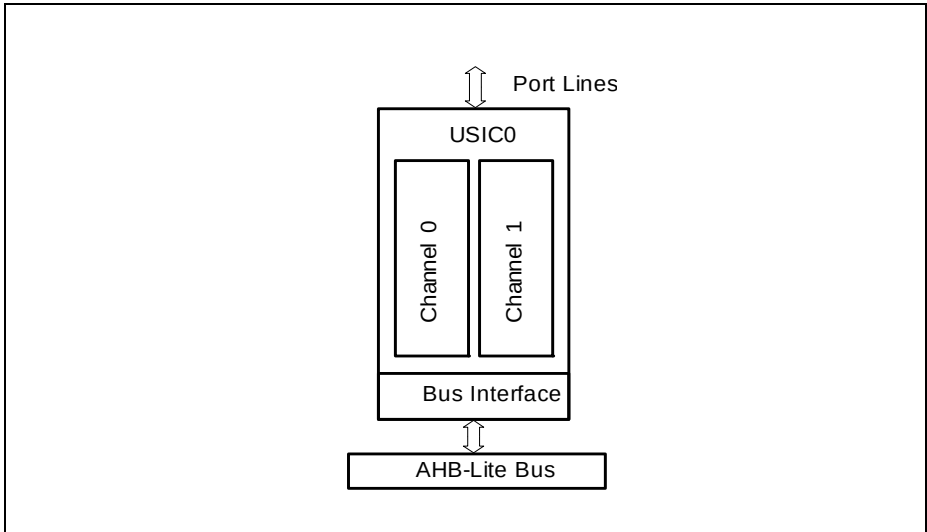


Figure 15-66 USIC Module Structure in XMC1200

Figure 15-67 shows the I/O lines of one USIC channel. The tables in this section define the pin assignments and internal connections of the USIC channels I/O lines in the XMC1200 device. Naming convention: USICx_CHy refers to USIC module x channel y. The meaning of these pins with respect to each protocol is described in the protocols' respective chapters and summarized in [Table 15-2](#) and [Table 15-3](#).

Universal Serial Interface Channel (USIC)

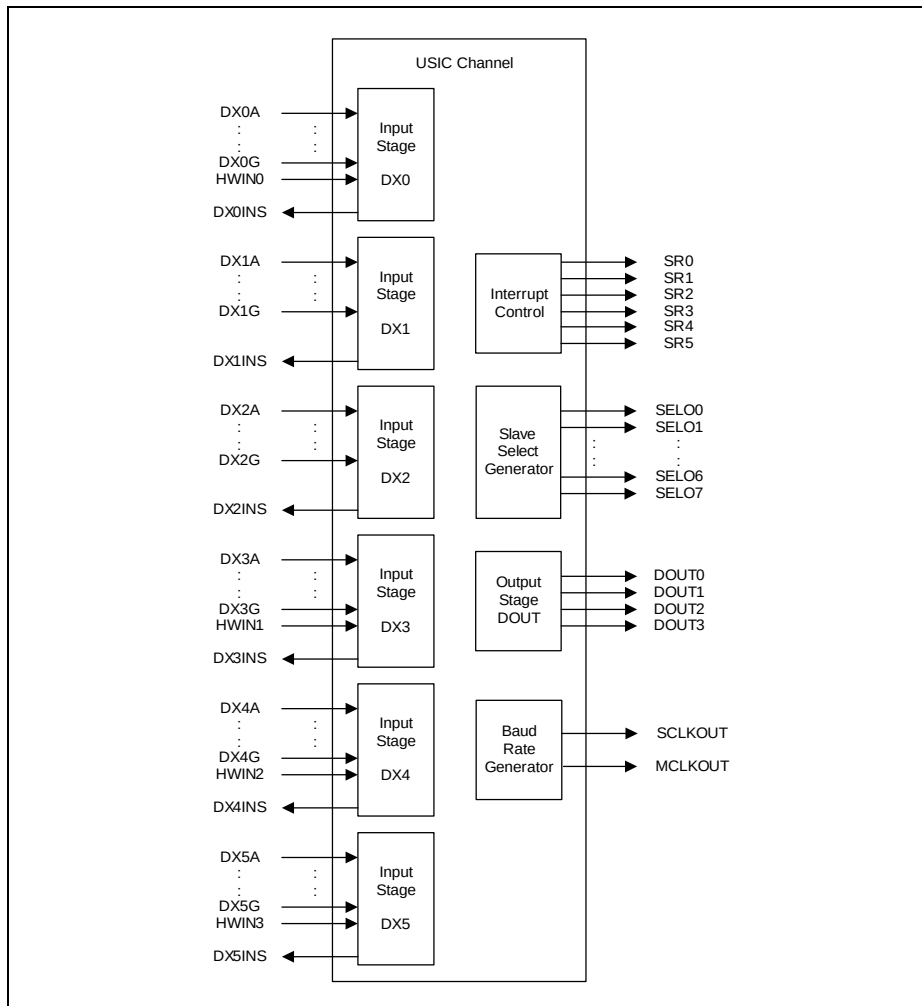


Figure 15-67 USIC Channel I/O Lines

The service request outputs SR[5:0] of one USIC channel is combined with those of the other channel with the module. Therefore, only 6 service request outputs are available per module.

15.12.1 USIC Module 0 Interconnects

The interconnects of USIC module 0 is grouped into the following categories:

Universal Serial Interface Channel (USIC)

- [USIC Module 0 Channel 0 Interconnects \(Table 15-23\)](#)
- [USIC Module 0 Channel 1 Interconnects \(Table 15-24\)](#)
- [USIC Module 0 Module Interconnects \(Table 15-25\)](#)

Table 15-23 USIC Module 0 Channel 0 Interconnects

Input/Output	I/O	Connected To	Description
Data Inputs (DX0)			
USIC0_CH0.DX0A	I	P0.14	Shift data input; used for: • ASC RXD • SSC MTSR/MRST • IIC SDA • IIS DIN
USIC0_CH0.DX0B	I	P0.15	
USIC0_CH0.DX0C	I	P1.0	
USIC0_CH0.DX0D	I	P1.1	
USIC0_CH0.DX0E	I	P2.0	
USIC0_CH0.DX0F	I	P2.1	
USIC0_CH0.DX0G	I	USIC0_CH0.DX3INS	
USIC0_CH0.HWIN0	I	P1.0	HW controlled shift data input
Clock Inputs			
USIC0_CH0.DX1A	I	P0.14	Shift clock input; used for: • SSC Slave SCLKIN • IIC SCL • IIS Slave SCLKIN • Optional for ASC, SSC Master and IIS Master
USIC0_CH0.DX1B	I	P0.8	
USIC0_CH0.DX1C	I	P0.7	
USIC0_CH0.DX1D	I	P1.1	
USIC0_CH0.DX1E	I	P2.0	
USIC0_CH0.DX1F	I	USIC0_CH0.DX0INS	
USIC0_CH0.DX1G	I	USIC0_CH0.DX4INS	
Control Inputs			
USIC0_CH0.DX2A	I	P0.0	Shift control input; used for: • SSC Slave SELIN • IIS Slave WAIN • Optional for ASC, SSC Master, IIC and IIS Master
USIC0_CH0.DX2B	I	P0.9	
USIC0_CH0.DX2C	I	P0.10	
USIC0_CH0.DX2D	I	P0.11	
USIC0_CH0.DX2E	I	P0.12	
USIC0_CH0.DX2F	I	P0.13	
USIC0_CH0.DX2G	I	USIC0_CH0.DX5INS	

Universal Serial Interface Channel (USIC)
Table 15-23 USIC Module 0 Channel 0 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Data Inputs (DX3)			
USIC0_CH0.DX3A	I	P2.2	Shift data input; used for: - Dual and Quad SSC MTSR1/MRST1 - Can be ignored for all other protocols It can also be used as a DX0 function if DX0G input is selected.
USIC0_CH0.DX3B	I	P2.4	
USIC0_CH0.DX3C	I	P2.10	
USIC0_CH0.DX3D	I	P2.8	
USIC0_CH0.DX3E	I	P2.6	
USIC0_CH0.DX3F	I	USIC0_CH0.DX5INS	It can also be used as a DX0 function if DX0G input is selected.
USIC0_CH0.DX3G	I	USIC0_CH0.DOUT0	
USIC0_CH0.HWIN1	I	P1.1	HW controlled shift data input
Data Inputs (DX4)			
USIC0_CH0.DX4A	I	P2.2	Shift data input; used for: - Quad SSC MTSR2/MRST2 - Can be ignored for all other protocols It can also be used as a DX1 function if DX1G input is selected.
USIC0_CH0.DX4B	I	P2.4	
USIC0_CH0.DX4C	I	P2.10	
USIC0_CH0.DX4D	I	P2.8	
USIC0_CH0.DX4E	I	P2.6	
USIC0_CH0.DX4F	I	USIC0_CH0.DX5INS	It can also be used as a DX1 function if DX1G input is selected.
USIC0_CH0.DX4G	I	USIC0_CH0.SCLKOUT	
USIC0_CH0.HWIN2	I	P1.2	HW controlled shift data input
Data Inputs (DX5)			
USIC0_CH0.DX5A	I	P2.9	Shift data input; used for: - Quad SSC MTSR3/MRST3 - Can be ignored for all other protocols It can also be used as a DX2/DX3/DX4 function if DX2G/DX3F/DX4F input is selected.
USIC0_CH0.DX5B	I	P2.3	
USIC0_CH0.DX5C	I	P2.7	
USIC0_CH0.DX5D	I	P2.5	
USIC0_CH0.DX5E	I	P1.4	
USIC0_CH0.DX5F	I	P1.6	It can also be used as a DX2/DX3/DX4 function if DX2G/DX3F/DX4F input is selected.
USIC0_CH0.DX5G	I	USIC0_CH0.SELO0	
USIC0_CH0.HWIN3	I	P1.3	HW controlled shift data input

Universal Serial Interface Channel (USIC)
Table 15-23 USIC Module 0 Channel 0 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Data Outputs			
USIC0_CH0.DOUT0	O	P0.14 P0.15 P1.0 P1.0 (HW1_OUT) P1.1 P1.5 P2.0 P2.1 USIC0_CH0.DX3G	Shift data output; used for: • ASC TXD • SSC MTSR/MRST • IIC SDA • IIS DOUT
USIC0_CH0.DOUT1	O	P1.1 (HW1_OUT)	Shift data output; used for: • Dual and Quad SSC MTSR1/MRST1 • Can be ignored for all other protocols
USIC0_CH0.DOUT2	O	P1.2 (HW1_OUT)	Shift data output; used for: • Quad SSC MTSR2/MRST2 • Can be ignored for all other protocols
USIC0_CH0.DOUT3	O	P1.3 (HW1_OUT)	Shift data output; used for: • Quad SSC MTSR3/MRST3 • Can be ignored for all other protocols
Clock Outputs			
USIC0_CH0.MCLKOUT	O	P0.11	Master clock output (optional for all protocols)
USIC0_CH0.SCLKOUT	O	P0.7 P0.8 P0.14 P1.6 P2.0 USIC0_CH0.DX4G	Shift clock output; used for: • Master SCLKOUT in SSC and IIS • IIC SCL • Can be ignored in ASC

Universal Serial Interface Channel (USIC)

Table 15-23 USIC Module 0 Channel 0 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Control Outputs			
USIC0_CH0.SELO0	O	P0.0 P0.9 P1.4 USIC0_CH0.DX5G	Shift control output; used for: - SSC Master SELO - IIS WA - Can be ignored for all other protocols
USIC0_CH0.SELO1	O	P0.10 P1.5	
USIC0_CH0.SELO2	O	P0.11 P1.6	
USIC0_CH0.SELO3	O	P0.12	
USIC0_CH0.SELO4	O	P0.13	
USIC0_CH0.SELO5	O	not connected	
USIC0_CH0.SELO6	O	not connected	
USIC0_CH0.SELO7	O	not connected	
System Related Outputs			
USIC0_CH0.DX0INS	O	USIC0_CH0.DX1F	Selected DX0 input signal
USIC0_CH0.DX1INS	O	not connected	Selected DX1 input signal
USIC0_CH0.DX2INS	O	CCU40.IN0L	Selected DX2 input signal
USIC0_CH0.DX3INS	O	USIC0_CH0.DX0G	Selected DX3 input signal
USIC0_CH0.DX4INS	O	USIC0_CH0.DX1G	Selected DX4 input signal
USIC0_CH0.DX5INS	O	USIC0_CH0.DX2G USIC0_CH0.DX3F USIC0_CH0.DX4F	Selected DX5 input signal

Universal Serial Interface Channel (USIC)

Table 15-24 USIC Module 0 Channel 1 Interconnects

Input/Output	I/O	Connected To	Description
Data Inputs (DX0)			
USIC0_CH1.DX0A	I	P1.3	Shift data input; used for: • ASC RXD • SSC MTSR/MRST • IIC SDA • IIS DIN
USIC0_CH1.DX0B	I	P1.2	
USIC0_CH1.DX0C	I	P0.6	
USIC0_CH1.DX0D	I	P0.7	
USIC0_CH1.DX0E	I	P2.11	
USIC0_CH1.DX0F	I	P2.10	
USIC0_CH1.DX0G	I	USIC0_CH1.DX3INS	
USIC0_CH1.HWIN0	I	ERU0.PDOUT0	HW controlled shift data input
Clock Inputs			
USIC0_CH1.DX1A	I	P1.3	Shift clock input; used for: • SSC Slave SCLKIN • IIC SCL • IIS Slave SCLKIN • Optional for ASC, SSC Master and IIS Master
USIC0_CH1.DX1B	I	P0.8	
USIC0_CH1.DX1C	I	P0.7	
USIC0_CH1.DX1D	I	0	
USIC0_CH1.DX1E	I	P2.11	
USIC0_CH1.DX1F	I	USIC0_CH1.DX0INS	
USIC0_CH1.DX1G	I	USIC0_CH1.DX4INS	
Control Inputs			
USIC0_CH1.DX2A	I	P0.0	Shift control input; used for: • SSC Slave SELIN • IIS Slave WAIN • Optional for ASC, SSC Master, IIC and IIS Master
USIC0_CH1.DX2B	I	P0.9	
USIC0_CH1.DX2C	I	P0.10	
USIC0_CH1.DX2D	I	P0.11	
USIC0_CH1.DX2E	I	P1.1	
USIC0_CH1.DX2F	I	P2.0	
USIC0_CH1.DX2G	I	USIC0_CH1.DX5INS	

Universal Serial Interface Channel (USIC)
Table 15-24 USIC Module 0 Channel 1 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Data Inputs (DX3)			
USIC0_CH1.DX3A	I	P2.1	Shift data input; used for: - Dual and Quad SSC MTSR1/MRST1 - Can be ignored for all other protocols It can also be used as a DX0 function if DX0G input is selected.
USIC0_CH1.DX3B	I	P2.9	
USIC0_CH1.DX3C	I	P2.3	
USIC0_CH1.DX3D	I	P2.7	
USIC0_CH1.DX3E	I	P2.5	
USIC0_CH1.DX3F	I	USIC0_CH1.DX5INS	It can also be used as a DX0 function if DX0G input is selected.
USIC0_CH1.DX3G	I	USIC0_CH1.DOUT0	
USIC0_CH1.HWIN1	I	0	HW controlled shift data input
Data Inputs (DX4)			
USIC0_CH1.DX4A	I	P2.1	Shift data input; used for: - Quad SSC MTSR2/MRST2 - Can be ignored for all other protocols It can also be used as a DX1 function if DX1G input is selected.
USIC0_CH1.DX4B	I	P2.9	
USIC0_CH1.DX4C	I	P2.3	
USIC0_CH1.DX4D	I	P2.7	
USIC0_CH1.DX4E	I	P2.5	
USIC0_CH1.DX4F	I	USIC0_CH1.DX5INS	It can also be used as a DX1 function if DX1G input is selected.
USIC0_CH1.DX4G	I	USIC0_CH1.SCLKOUT	
USIC0_CH1.HWIN2	I	ERU0.PDOUT1	HW controlled shift data input
Data Inputs (DX5)			
USIC0_CH1.DX5A	I	P2.2	Shift data input; used for: - Quad SSC MTSR3/MRST3 - Can be ignored for all other protocols It can also be used as a DX2/DX3/DX4 function if DX2G/DX3F/DX4F input is selected.
USIC0_CH1.DX5B	I	P2.4	
USIC0_CH1.DX5C	I	P2.8	
USIC0_CH1.DX5D	I	P2.6	
USIC0_CH1.DX5E	I	P1.4	
USIC0_CH1.DX5F	I	P1.5	It can also be used as a DX2/DX3/DX4 function if DX2G/DX3F/DX4F input is selected.
USIC0_CH1.DX5G	I	USIC0.SR0	
USIC0_CH1.HWIN3	I	USIC0_CH1.DOUT0	HW controlled shift data input

Universal Serial Interface Channel (USIC)
Table 15-24 USIC Module 0 Channel 1 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Data Outputs			
USIC0_CH1.DOUT0	O	P0.6 P0.7 P1.2 P1.3 P1.6 P2.10 P2.11 USIC0_CH1.DX3G USIC0_CH1.HWIN3	Shift data output; used for: • ASC TXD • SSC MTSR/MRST • IIC SDA • IIS DOUT
USIC0_CH1.DOUT1	O	not connected	Shift data output; used for: • Dual and Quad SSC MTSR1/MRST1 • Can be ignored for all other protocols
USIC0_CH1.DOUT2	O	not connected	Shift data output; used for: • Quad SSC MTSR2/MRST2 • Can be ignored for all other protocols
USIC0_CH1.DOUT3	O	not connected	Shift data output; used for: • Quad SSC MTSR3/MRST3 • Can be ignored for all other protocols
Clock Outputs			
USIC0_CH1.MCLKOUT	O	P0.6 P0.15	Master clock output (optional for all protocols)
USIC0_CH1.SCLKOUT	O	P0.8 P1.3 P1.4 P2.1 P2.11 USIC0_CH1.DX4G	Shift clock output; used for: • Master SCLKOUT in SSC and IIS • IIC SCL • Can be ignored in ASC

Universal Serial Interface Channel (USIC)

Table 15-24 USIC Module 0 Channel 1 Interconnects (cont'd)

Input/Output	I/O	Connected To	Description
Control Outputs			
USIC0_CH1.SELO0	O	P0.0 P0.9 P1.1	Shift control output; used for: - SSC Master SELO - IIS WA - Can be ignored for all other protocols
USIC0_CH1.SELO1	O	P0.10 P1.4	
USIC0_CH1.SELO2	O	P0.11 P1.5	
USIC0_CH1.SELO3	O	P1.6	
USIC0_CH1.SELO4	O	not connected	
USIC0_CH1.SELO5	O	not connected	
USIC0_CH1.SELO6	O	not connected	
USIC0_CH1.SELO7	O	not connected	
System Related Outputs			
USIC0_CH1.DX0INS	O	USIC0_CH1.DX1F	Selected DX0 input signal
USIC0_CH1.DX1INS	O	not connected	Selected DX1 input signal
USIC0_CH1.DX2INS	O	CCU40.IN1L	Selected DX2 input signal
USIC0_CH1.DX3INS	O	USIC0_CH1.DX0G	Selected DX3 input signal
USIC0_CH1.DX4INS	O	USIC0_CH1.DX1G	Selected DX4 input signal
USIC0_CH1.DX5INS	O	USIC0_CH1.DX2G USIC0_CH1.DX3F USIC0_CH1.DX4F	Selected DX5 input signal

Table 15-25 USIC Module 0 Module Interconnects

Input/Output	I/O	Connected To	Description
USIC0_SR0	O	NVIC USIC0_CH1.DX5G	interrupt output lines (service requests SRx)
USIC0_SR[5:1]	O	NVIC	interrupt output lines (service requests SRx)

Analog Peripherals

16 Versatile Analog-to-Digital Converter (VADC)

The XMC1200 provides a series of analog input channels connected to a cluster of Analog/Digital Converters using the Successive Approximation Register (SAR) principle to convert analog input values (voltages) to discrete digital values.

The XMC1200 is based on Sample&Hold converters, where a cluster contains 2 Sample&Hold units which share a common converter.

The number of analog input channels and ADCs depends on the chosen product type (please refer to **“Product-Specific Configuration” on Page 16-153**).

Table 16-1 Abbreviations used in ADC chapter

Abbreviation	Meaning
ADC	Analog to Digital Converter
ADC Kernel	also known as ADC Group
DNL	Differential Non-Linearity (error)
INL	Integral Non-Linearity (error)
LSB _n	Least Significant Bit: 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)
S&H	Sample and Hold
SCU	System Control Unit of the device
SHS	Sample and Hold Sequencer
TUE	Total Unadjusted Error

16.1 Overview

Each converter of the ADC cluster can operate independent of the others, controlled by a dedicated set of registers and triggered by a dedicated group request source. The results of each channel can be stored in a dedicated channel-specific result register or in a group-specific result register.

A background request source can access all analog input channels that are not assigned to any group request source. These conversions are executed with low priority. The background request source can, therefore, be regarded as an additional background converter.

The Versatile Analog to Digital Converter module (VADC) of the XMC1200 comprises a set of converter blocks that can be operated either independently or via a common

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request source that emulates a background converter. Each converter block is equipped with a dedicated input multiplexer and dedicated request sources, which together build separate groups.

This basic structure supports application-oriented programming and operating while still providing general access to all resources. The almost identical converter groups allow a flexible assignment of functions to channels.

Feature List

The following features describe the functionality of the ADC cluster:

- Input voltage range from 0 V up to analog supply voltage
- Standard (V_{AREF}) reference voltage source and alternate Ground (CH0) selectable for each channel to support ratiometric measurements and different signal scales
- Internal reference voltage source for low voltage range operation
- Two independent sample and hold stages with 8 analog input channels each
- Two active sigma delta hold blocks provided supporting oversampling
- External analog multiplexer control, including adjusted sample time and scan support
- Conversion speed and sample time adjustable to adapt to sensors and reference
- Conversion time below 1 μ s (depending on result width and sample time)
- Flexible source selection and arbitration
 - Programmable arbitrary conversion sequence (single or repeated)
 - Configurable auto scan conversion (single or repeated) in each group
 - Configurable auto scan conversion (single or repeated) in the background (all channels)
 - Conversions triggered by software, timer events, or external events
 - Cancel-inject-restart mode for reduced conversion delay on priority channels
- Powerful result handling
 - Selectable result width of 8/10/12 bits
 - Fast Compare Mode
 - Independent result registers
 - Configurable limit checking against programmable border values
 - Data rate reduction through adding a selectable number of conversion results
 - FIR/IIR filter with selectable coefficients
- Flexible service request generation based on selectable events (2 group-specific, 2 shared interrupts)
- Built-in safety feature: Broken wire detection with programmable default levels
- Support of debug suspend and power saving modes

Note: Additional functions are available from the out of range comparator (see description in the SCU).

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Table 16-2 VADC Applications

Use Case VADC	Application
Automatic scheduling of complex conversion sequences, including prioritization of time-critical conversions	Motor control, Power conversion
Effective result handling for bursts of high-speed conversions	Highly dynamic input signals
Synchronous sampling of 2 input signals	Multi-phase current measurement

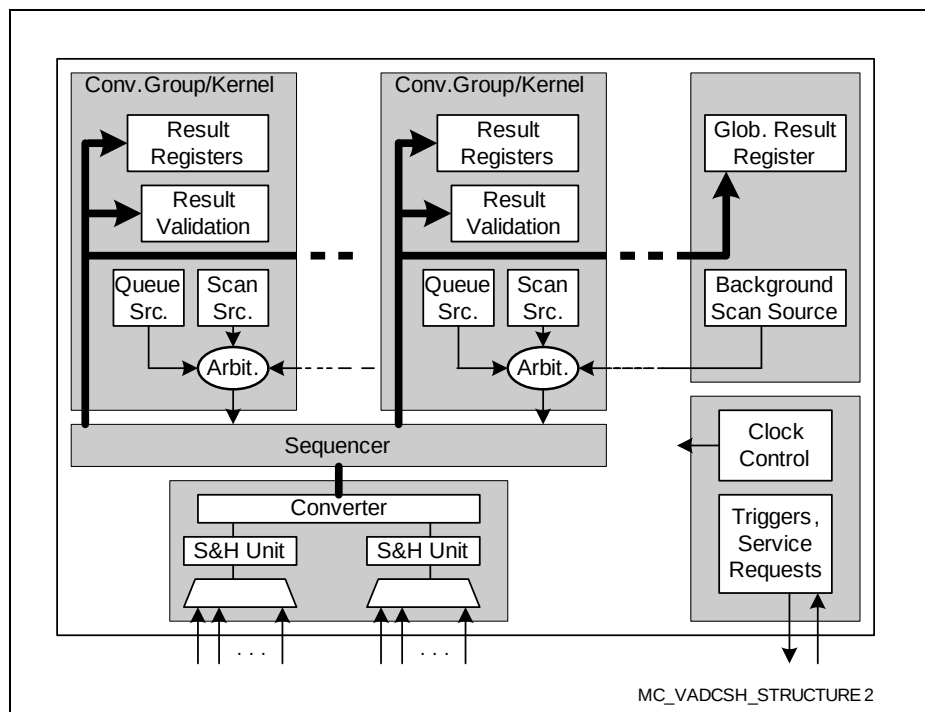


Figure 16-1 ADC Structure Overview

Versatile Analog-to-Digital Converter (VADC)

16.2 Introduction and Basic Structure

The Versatile Analog to Digital Converter module (VADC) of the XMC1200 comprises a set of converter blocks that can be operated either independently or via a common request source that emulates a background converter. Each converter block is equipped with a dedicated input multiplexer and dedicated request sources, which together build separate groups.

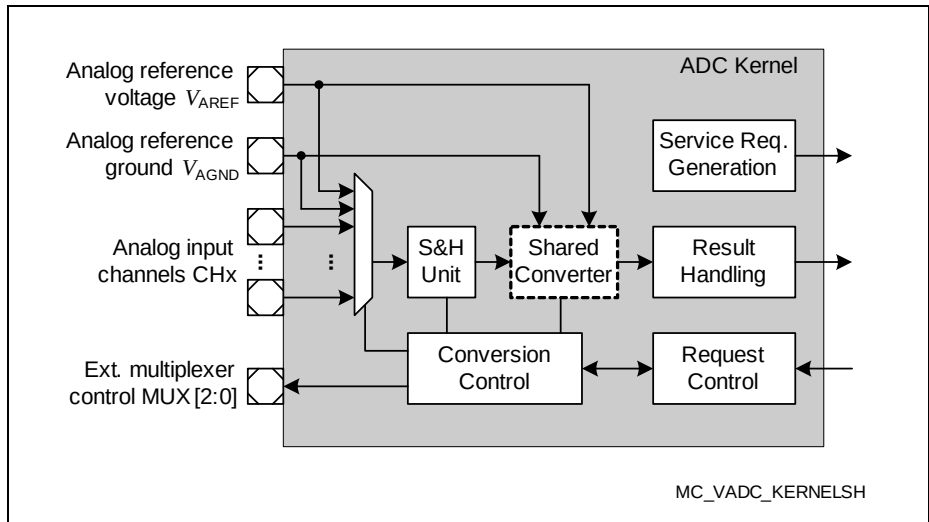


Figure 16-2 ADC Kernel Block Diagram

This basic structure supports application-oriented programming and operating while still providing general access to all resources. The almost identical converter groups allow a flexible assignment of functions to channels.

A set of functional units can be configured according to the requirements of a given application. These units build a path from the input signals to the digital results.

Each kernel provides a dedicated Sample&Hold unit connected to the input multiplexer. Several kernels build a cluster and share a common high-speed converter, whose performance can be assigned to the connected kernels.

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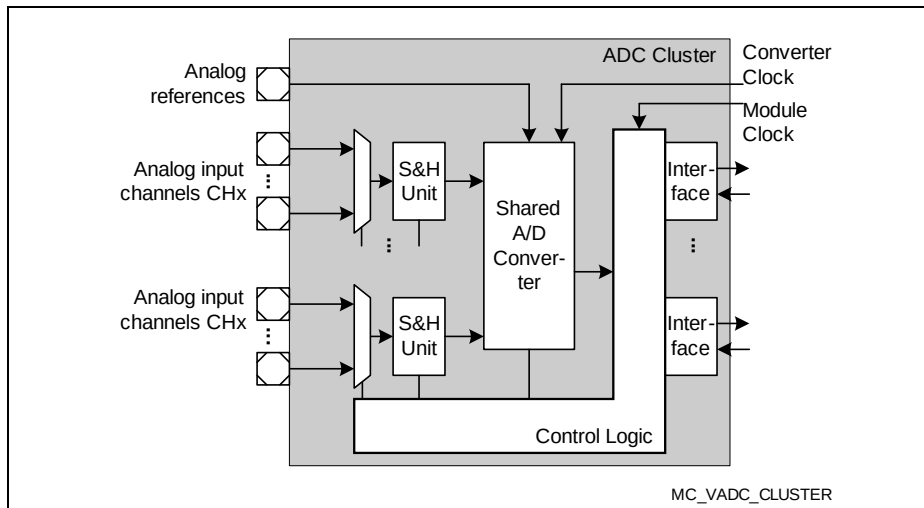


Figure 16-3 ADC Cluster Structure

The basic module clock f_{ADC} is connected to the system clock signal f_{MCLK} .

The converter clock f_{CONV} is connected to a 32-MHz clock signal.

Conversion Modes and Request Sources

Analog/Digital conversions can be requested by several request sources (2 group request sources and the background request source) and can be executed in several conversion modes. The request sources can be enabled concurrently with configurable priorities.

- **Fixed Channel Conversion (single or continuous)**
 A specific channel source requests conversions of one selectable channel (once or repeatedly)
- **Auto Scan Conversion (single or continuous)**
 A channel scan source (request source 1 or 2) requests auto scan conversions of a configurable linear sequence of all available channels (once or repeatedly)
- **Channel Sequence Conversion (single or continuous)**
 A queued source (request source 0) requests a sequence of conversions of up to 8 arbitrarily selectable channels (once or repeatedly)

The conversion modes can be used concurrently by the available request sources, i.e. conversions in different modes can be enabled at the same time. Each source can be enabled separately and can be triggered by external events, such as edges of PWM or timer signals, or pin transitions.

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Request Source Control

Because all request sources can be enabled at the same time, an arbiter resolves concurrent conversion requests from different sources. Each source can be triggered by external signals, by on-chip signals, or by software.

Requests with higher priority can either cancel a running lower-priority conversion (cancel-inject-repeat mode) or be converted immediately after the currently running conversion (wait-for-start mode). If the target result register has not been read, a conversion can be deferred (wait-for-read mode).

Certain channels can also be synchronized with other ADC kernels, so 2 signals can be converted in parallel.

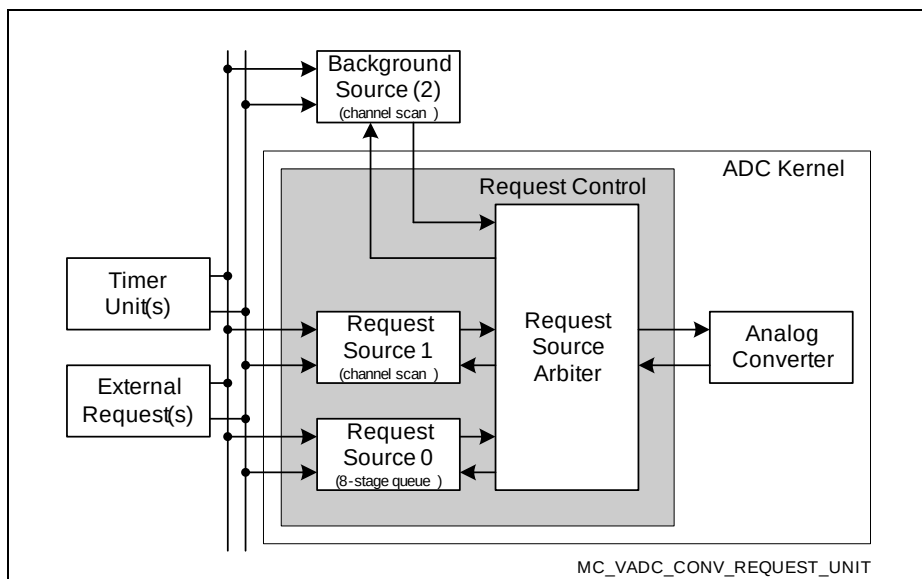


Figure 16-4 Conversion Request Unit

Input Channel Selection

The analog input multiplexer selects one of the available analog inputs (CH0 - CHx¹⁾) to be converted. Three sources can select a linear sequence, an arbitrary sequence, or a specific channel. The priorities of these sources can be configured.

1) The availability of dedicated input channels depends on the package of the used product type. A summary can be found in [Section 16.17.2](#).

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Additional external analog multiplexers can be controlled automatically, if more separate input channels are required than are built in.

Note: Not all analog input channels are necessarily available in all packages, due to pin limitations. Please refer to the implementation description in [Section 16.17](#).

Conversion Control

Conversion parameters, such as sample phase duration, reference voltage, or result resolution can be configured for 4 input classes (2 group-specific classes, 2 global classes). Each channel can be individually assigned to one of these input classes.

The input channels can, thus, be adjusted to the type of sensor (or other analog sources) connected to the ADC.

This unit also controls the built-in multiplexer and external analog multiplexers, if selected.

Analog/Digital Converter

The selected input channel is converted to a digital value by first sampling the voltage on the selected input and then generating the selected number of result bits.

The sample&hold units of a cluster share a common high-speed converter. This converter sequentially generates result values for all sample&hold units. Calibration cycles are executed automatically.

For broken wire detection (see [Section 16.13.1](#)), the converter network can be precharged to a selected voltage before sampling the selected input channel.

Result Handling

The conversion results of each analog input channel can be directed to one of 16 group-specific result registers and one global result register to be stored there. A result register can be used by a group of channels or by a single channel.

The wait-for-read mode avoids data loss due to result overwrite by blocking a conversion until the previous result has been read.

Data reduction (e.g. for digital anti-aliasing filtering) can automatically add up to 4 conversion results before issuing a service request.

Alternatively, an FIR or IIR filter can be enabled that preprocesses the conversion results before sending them to the result register.

Also, result registers can be concatenated to build FIFO structures that store a number of conversion results without overwriting previous data. This increases the allowed CPU latency for retrieving conversion data from the ADC.

Interrupt Service Request Generation

Several ADC events can issue service requests to the CPU:

- **Source events** indicate the completion of a conversion sequence in the corresponding request source. This event can be used to trigger the setup of a new sequence.
- **Channel events** indicate the completion of a conversion for a certain channel. This can be combined with limit checking, as a result the interrupts are generated only if the result is within a defined range of values.
- **Result events** indicate the availability of new result data in the corresponding result register. If data reduction mode is active, events are generated only after a complete accumulation sequence.

Each event can be assigned to one of eight service request nodes. This allows grouping the requests according to the requirements of the application.

Safety Features

Safety-aware applications are supported with mechanisms that help to ensure the integrity of a signal path.

Broken-wire-detection (BWD) preloads the converter network with a selectable level before sampling the input channel. The result will then reflect the preload value if the input signal is no more connected. If buffer capacitors are used, a certain number of conversions may be required to reach the failure indication level.

Multiplexer Diagnostics (MD) connects a weak pull-up or pull-down device to an input channel. A subsequent conversion can then confirm the expected modified signal level. This allows to check the proper operation of the multiplexer.

The pull devices are controlled via the standard port control registers.

16.3 Electrical Models

Each conversion of an analog input voltage to a digital value consists of two consecutive phases:

- During the sample phase, the input voltage is sampled and stored.
The input signal path is a simplified model for this.
- During the conversion phase the stored voltage is converted to a digital result.

Input Signal Path

The ADC of the XMC1200 uses a switched capacitor field represented by C_{AINSW} (small parasitic capacitances are present at each input pin). During the sample phase, the capacitor field C_{AINSW} is connected to the selected analog input CHx via the input multiplexer (modeled by ideal switches and series resistors R_{AIN}).

The switch to CHx is closed during the sample phase and connects the capacitor field to the input voltage V_{AINx} .

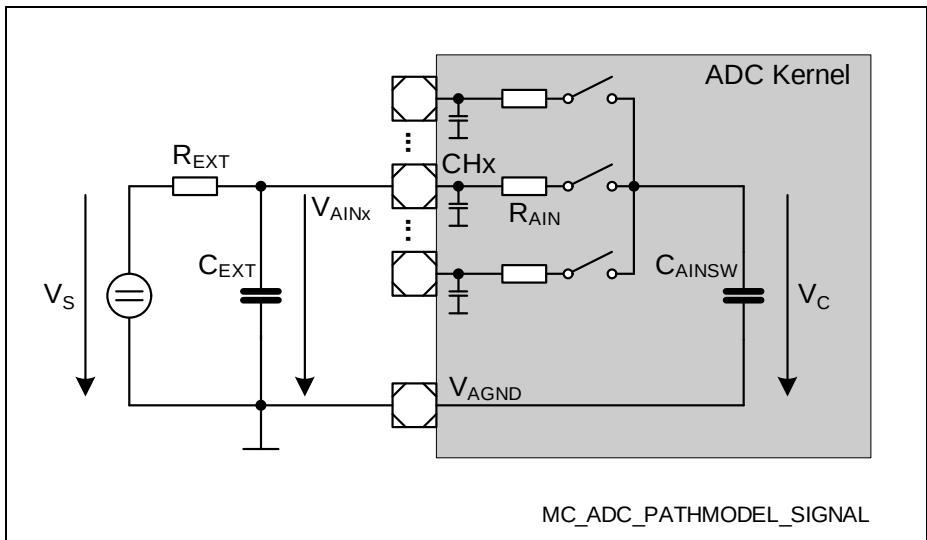


Figure 16-5 Signal Path Model

A simplified model for the analog input signal path is given in **Figure 16-5**. 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_{AINSW} 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

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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 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_{AINSW} .

The resulting low-pass filter of R_{EXT} (usually a parameter of the signal source) and C_{EXT} should be dimensioned according to the application's requirements:

- For quickly changing dynamic signals, a smaller capacitor allows V_{AINx} to follow V_S between two sample phases of the same analog input channel.
- For high-precision conversions, an external blocking capacitor C_{EXT} in the range of at least $2^n \times C_{AINSW}$ keeps the voltage change of V_{AINx} during the sample phase below 1 LSB_n . This voltage change is due to the charge redistribution between C_{EXT} and C_{AINSW} .

Leakage current through the analog input structure of the ADC can generate a voltage drop over R_{EXT} , introducing an error. The ADC input leakage current increases at high temperature and if the input voltage level is close to the analog supply ground V_{SS} or to the analog power supply V_{DDPA} . The input leakage current of an ADC channel can be reduced by avoiding input voltages close to the supplies.

An overload condition (input voltage exceeds the supply range) at adjacent analog inputs injects an additional leakage current (defined by a coupling factor) .

The capacitor C_{AINSW} is automatically discharged at the beginning of a sample phase.

Transfer Characteristics and Error Definitions

The transfer characteristic of the ADC describes the association of analog input voltages to the 2^n discrete digital result values (n bits resolution). Each digital result value (in the range of 0 to 2^n-1) represents an input voltage range defined by the reference voltage range divided by 2^n . This range (called quantization step or code width) represents the granularity (called LSB_n) of the ADC. The discrete character of the digital result generates a system-inherent quantization uncertainty of $\pm 0.5 \text{ LSB}_n$ for each conversion result.

The ideal transfer curve has the first digital transition (between 0 and 1) when the analog input reaches 0.5 LSB_n . The quantization steps are equally distributed over the input voltage range.

Analog input voltages below or above the reference voltage limits lead to a saturation of the digital result at 0 or 2^n-1 .

The real transfer curve can exhibit certain deviations from the ideal transfer curve:

- The **offset error** is the deviation of the real transfer line from the ideal transfer line at the lowest code. This refers to best-fit lines through all possible codes, for both cases.
- The **gain error** is the deviation of the slope of the real transfer line from the slope of the ideal transfer line. This refers to best-fit lines through all possible codes, for both cases.
- The **differential non-linearity error** (DNL) is the deviation of the real code width (variation of the analog input voltage between two adjacent digital conversion results) from the ideal code width.
- The **integral non-linearity error** (INL) is the deviation of the real transfer curve from an adjusted ideal transfer curve (same offset and gain error as the real curve, but equal code widths).
- 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).

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16.4 Configuration of General Functions

While many parameters can be selected individually for each channel, source, or group, some adjustments are valid for the whole ADC cluster:

- Clock control
- Kernel synchronization
- External multiplexer control

16.4.1 General Clocking Scheme and Control

The A/D Converters of the XMC1200 are supplied with a global clock signal from the system f_{ADC} . This clock signal controls all functions of all logic blocks and determines the overall timing. The global configuration register defines common clock bases for all converters of the cluster. This ensures deterministic behavior of converters that shall operate in parallel.

The converter clock f_{CONV} determines the performance of the converters themselves.

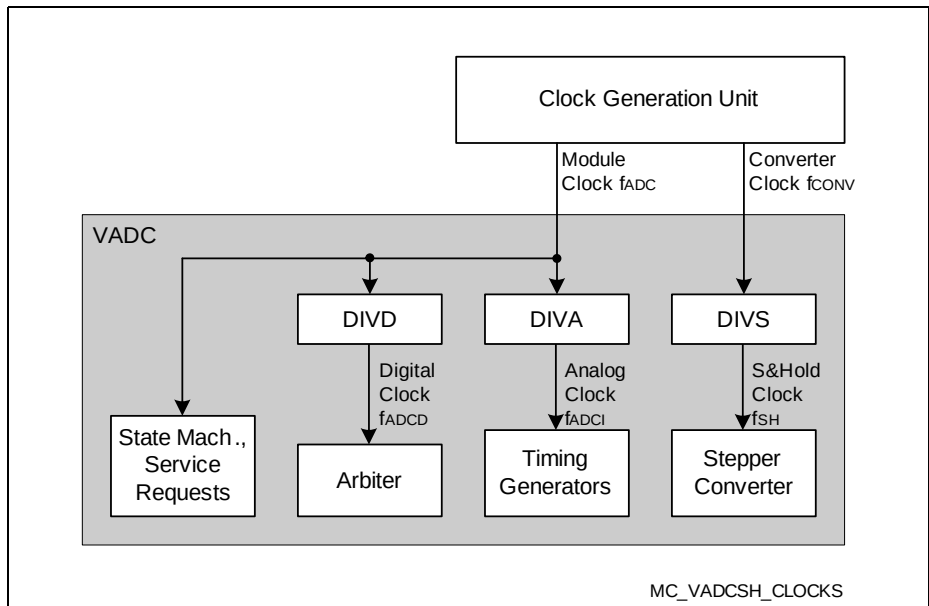


Figure 16-6 Clock Signal Summary

16.4.2 Register Access Control

Several protection schemes are provided to prevent unintended write access to control bitfields of the VADC.

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- A specific register access control scheme provides a versatile protection scheme against unintended corruption of register contents. Registers **ACCPROTO** and **ACCPROT1** allow the restriction of write accesses for several groups of registers. The registers to be protected can be selected by the user. **Table 16-10** lists the registers that belong to each register group. Registers ACCPROTO/1 themselves are protected by the bit protection scheme described SCU chapter.
- Groups of bitfields within a register may also be protected by an associated write control bit. This write control bit (xxWC) must be written with 1 along with the write access to the intended bitfield(s).

16.4.3 Priority Channel and Result Register Assignment

Each channel and result register of a group can be assigned to this group's request sources and is then regarded as a priority channel or result register.

Priority Channel Assignment

An assigned priority channel can only be converted by its own group's request sources. An unassigned channel can also be converted by the background request source.

Priority Result Register Assignment

An assigned result register can only be written by its own group's request sources. A not assigned result register can also be written by the background request source.

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16.5 Analog Module Activation and Control

The analog converter of the ADC is the functional block that generates the digital result values from the selected input voltage. It draws a permanent current during its operation and can be deactivated between conversions to reduce the consumed overall energy.

Note: After reset the analog converters are off. They must be enabled before triggering any action involving a converter.

The accuracy of the conversions is improved by calibrating the analog converter to compensate process, temperature, and voltage variations.

16.5.1 Analog Converter Control

The operating mode is determined by bitfield **GxARBCFG (x = 0 - 1).ANONS**:

- **ANONS = 11_B: Normal Operation**
The converter is active, conversions are started immediately.
Requires no wakeup time.
- **ANONS = 10_B: Reserved**
- **ANONS = 01_B: Slow Standby mode**
The converter enters a power save mode while no activity is required. It automatically returns to normal operation if a conversion is requested. Slow standby mode enables the lowest overall power consumption for the ADC supply.
Requires the wakeup time (see below).
- **ANONS = 00_B: Converter switched Off** (default after reset)
The converter is switched off if all groups of the corresponding cluster are off. Furthermore, digital logic blocks are set to their initial state. If the arbiter is currently running, it completes the actual arbitration round and then stops.
Before starting a conversion, select the active mode for ANONS.
Requires the extended wakeup time (see below).

Bit ANOFF in register SHSCFG forces the analog part into power-down mode, without changing the configuration of the associated groups. While ANOFF = 0, the analog part is controlled automatically as selected by bitfields ANONS in the digital part. Since several groups (with separate ANONS bitfields) are serviced by the same cluster, the analog part is controlled by the following scheme:

Table 16-3 Analog Part Power-Down Control Options

ANON Settings¹⁾	Power-Down Mode
All ANON signals are 00 _B	Analog part off

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Table 16-3 Analog Part Power-Down Control Options (cont'd)

ANON Settings¹⁾	Power-Down Mode
ANON signals are 00 _B or 01 _B	Analog part automatically switched off while no sample-phase and no conversion is active
One or more ANON signals are 11 _B	Analog part always active

1) Taken into account while bit ANOFF = 0.

Note: Since switching off the analog part requires a wake-up phase, the optimum configuration depends on the actual application.

Wakeup Time from Analog Powerdown

When the converter is activated, it needs a certain wakeup time to settle before a conversion can be properly executed. This wakeup time can be established by waiting the required period before starting a conversion, or by adding it to the intended sample time.

The wakeup time is approximately 15 μ s.

Exact numbers can be found in the respective Data Sheets.

Note: The wakeup time is also required after initially enabling the converter.

16.5.2 Converter Handling in Deep Sleep Mode

During deep sleep mode the converter clocks are reduced or switched off. This also influences the converter's state machines.

To ensure proper operation after a deep sleep phase, the following sequence must be respected:

- Complete running conversions or sequences
- Disable the converters by clearing ANONC = 00_B
- Enter deep sleep mode
- - - - deep sleep phase¹⁾ - - -
- Exit deep sleep mode
- Enable converters by setting ANONC = 01_B or 11_B
- Start new conversions or sequences

1) To reduce power consumption, the VADC module clock can be disabled during the deep sleep phase.

16.5.3 Calibration

Calibration automatically compensates deviations caused by process, temperature, and voltage variations. This ensures precise results throughout the operation time.

Several different calibration cycles are executed for offset and gain calibration. To minimize the extra time consumed by calibration, offset and gain calibration cycles are executed alternating.

An initial start-up calibration is required once after a reset for all converters. All converters must be enabled ($ANONS = 11_B$). The start-up calibration is initiated globally by setting bit SUCAL in register GLOBCFG. By setting bit SUCAL in register CALCTR the start-up calibration can be initiated for the corresponding cluster converter. Conversions may be started after the initial calibration sequence. This is indicated by bit $CALS = 1_B$ AND bit $CAL = 0_B$.

The start-up calibration phase takes 1 920 cycles ($1\,920 \times 31.25\text{ ns} = 60\text{ }\mu\text{s}$).

After that, calibration cycles will compensate the effects of drifting parameters. The calibration cycles can be executed before or after (user configuration) a conversion sequence or can be disabled.

Note: Before initiating the start-up calibration without preceding reset, the converters must be disabled ($ANONS = 00_B$) and then enabled ($ANONS = 11_B$).

After a start-up calibration in the lower supply range a settling time of 20 μs is required to ensure proper conversion results.

A calibration timer automatically triggers calibration cycles during idle phases of the ADC. This ensures the specified performance even after an idle phase.

Note: The ADC error depends on the temperature. Therefore, the calibration must be repeated periodically.

Maximum Calibration Interval

While no conversions are requested, the stepper remains in its idle state. In order not to lose accuracy, a counter counts the time since the last executed calibration. This timer is loaded after each calibration with the start value from bitfield CALCTR.CALMAX and counts $128 \times (\text{CALMAX} + 1)$ clocks. If it expires it generates a calibration request which starts the stepper to execute a calibration cycle.

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The nominal internal reference voltage $V_{AREFint}$ is 5 V. The analog input voltage, however, is limited by the actual supply voltage V_{DD} . The full result range can be utilized by selecting higher gain factors according to the levels of the input signals.

Note: Operation in the lower supply voltage range requires longer sampling times for conversions and calibration.

16.5.5 Sigma-Delta-Loop Function

Each standard analog-digital conversion incurs a quantization error due to the limited number of steps i.e. discrete result values. By activating the sigma-delta-loop function this residual quantization error can be forwarded to the next conversion. The residual charge is stored and added to the next sampled charge. Averaging a series of conversion results (with the loop enabled) can, therefore, reduce the induced quantization error.

Note: The data accumulation function of the VADC_{DIG} already supports this averaging.

The loop control bitfields are available in pairs in register **SHS0_LOOP**.

16.6 Conversion Request Generation

The conversion request unit of a group autonomously handles the generation of conversion requests. Three request sources (2 group-specific sources and the background source) can generate requests for the conversion of an analog channel. The arbiter resolves concurrent requests and selects the channel to be converted next.

Upon a trigger event, the request source requests the conversion of a certain analog input channel or a sequence of channels.

- **Software triggers**
directly activate the respective request source.
- **External triggers**
synchronize the request source activation with external events, such as a trigger pulse from a timer generating a PWM signal or from a port pin.

Application software selects the trigger type and source, the channel(s) to be converted, and the request source priority. A request source can also be activated directly by software without requiring an external trigger.

The arbiter regularly scans the request sources for pending conversion requests and selects the conversion request with the highest priority. This conversion request is then forwarded to the converter to start the sampling and conversion of the requested channel.

Each request source can operate in single-shot or in continuous mode:

- **In single-shot mode,**
the programmed conversion (sequence) is requested once after being triggered. A subsequent conversion (sequence) must be triggered again.
- **In continuous mode,**
the programmed conversion (sequence) is automatically requested repeatedly after being triggered once.

For each request source, external triggers are generated from one of 16 selectable trigger inputs (REQTRx[P:A]) and from one of 16 selectable gating inputs (REQGTx[P:A]). The available trigger signals for the XMC1200 are listed in [Section 16.17.3](#).

Note: [Figure 16-4 “Conversion Request Unit” on Page 16-6](#) summarizes the request sources.

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Two types of request sources are available:

- **A queued source** can issue conversion requests for an arbitrary sequence of input channels. The channel numbers for this sequence can be freely programmed¹⁾. This supports application-specific conversion sequences that cannot be covered by a channel scan source. Also, multiple conversions of the same channel within a sequence are supported.

A queued source converts a series of input channels continuously or on a regular time base. For example, if programmed with medium priority, some input channels can be converted upon a specified event (e.g. synchronized to a PWM). Conversions of lower priority sources are suspended in the meantime.

Request source 0 is a group-specific 8-stage queued source.

- **A channel scan source** can issue conversion requests for a coherent sequence of input channels. This sequence begins with the highest enabled channel number and continues towards lower channel numbers. All available channels¹⁾ can be enabled for the scan sequence. Each channel is converted once per sequence.

A scan source converts a series of input channels continuously or on a regular time base. For example, if programmed with low priority, some input channels can be scanned in a background task to update information that is not time-critical.

- Request source 1 is a group-specific channel scan source.
- Request source 2 is a global channel scan source (background source).

The background source can request conversions of all channels of all groups.

1) The availability of dedicated input channels depends on the package of the used product type. A summary can be found in [Section 16.17.2](#).

The background source can only request non-priority channels, i.e. channels that are not selected in registers GxCHASS. Priority channels are reserved for the group-specific request sources 0 and 1.

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16.6.1 Queued Request Source Handling

A queued request source supports short conversion sequences (up to 8) of arbitrary channels of the same group (contrary to a scan request source with a fixed conversion order for the enabled channels). The programmed sequence is stored in a queue buffer (based on a FIFO mechanism). The requested channel numbers are entered via the queue input register **GxQINR0 (x = 0 - 1)**, while queue stage 0 defines the channel to be converted next.

A conversion request is only issued to the request source arbiter if a valid entry is stored in queue stage 0.

If the arbiter aborts a conversion triggered by a queued request source due to higher priority requests, the corresponding conversion parameters are automatically saved in the backup stage. This ensures that an aborted conversion is not lost but takes part in the next arbitration round (before stage 0).

The trigger and gating unit generates trigger events from the selected external (outside the ADC) trigger and gating signals. For example, a timer unit can issue a request signal to synchronize conversions to PWM events.

Trigger events start a queued sequence and can be generated either via software or via the selected hardware triggers. The occurrence of a trigger event is indicated by bit QSRx.EV. This flag is cleared when the corresponding conversion is started or by writing to bit QMRx.CEV.

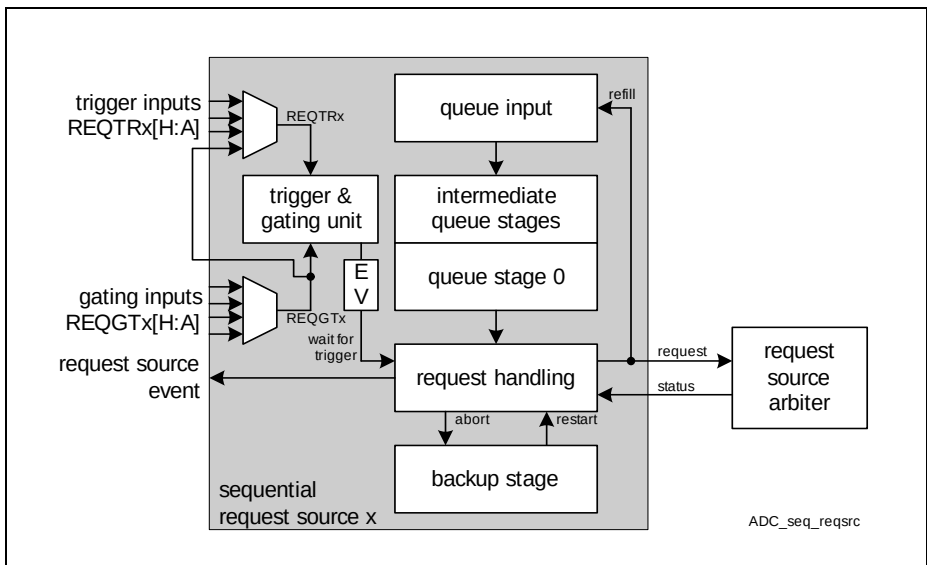


Figure 16-9 Queued Request Source

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A sequence is defined by entering conversion requests into the queue input register (**GxQINR0 (x = 0 - 1)**). Each entry selects the channel to be converted and can enable an external trigger, generation of an interrupt, and an automatic refill (i.e. copy this entry to the top of the queue after conversion). The entries are stored in the queue buffer stages.

The content of stage 0 (**GxQ0R0 (x = 0 - 1)**) selects the channel to be converted next. When the requested conversion is started, the contents of this queue stage is invalidated and copied to the backup stage. Then the next queue entry can be handled (if available).

Note: The contents of the queue stages cannot be modified directly, but only by writing to the queue input or by flushing the queue.

*The current status of the queue is shown in register **GxQSR0 (x = 0 - 1)**.*

If all queue entries have automatic refill selected, the defined conversion sequence can be repeated without re-programming.

Properties of the Queued Request Source

Queued request source 0 provides 8 buffer stages and can handle sequences of up to 8 input channel entries. It supports short application-specific conversion sequences, especially for timing-critical sequences containing also multiple conversions of the same channel.

Queued Source Operation

Configure the queued request source by executing the following actions:

- Define the sequence by writing the entries to the queue input **GxQINR0 (x = 0 - 1)**. Initialize the complete sequence before enabling the request source, because with enabled refill feature, software writes to QINRx are not allowed.
- If hardware trigger or gating is desired, select the appropriate trigger and gating inputs and the proper transitions by programming **GxQCTRL0 (x = 0 - 1)**. Enable the trigger and select the gating mode by programming bitfield ENGTT in register **GxQMR0 (x = 0 - 1)**.¹⁾
- Enable the corresponding arbitration slot (0) to accept conversion requests from the queued source (see register **GxARBPR (x = 0 - 1)**).

Start a queued sequence by generating a trigger event:

- If a hardware trigger is selected and enabled, generate the configured transition at the selected input signal, e.g. from a timer or an input pin.
- Generate a software trigger event by setting **GxQMR0.TREV = 1**.

1) If PDOUT signals from the ERU are used, initialize the ERU accordingly before enabling the gate inputs to avoid an unexpected signal transitions.

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- Write a new entry to the queue input of an empty queue. This leads to a (new) valid queue entry that is forwarded to queue stage 0 and starts a conversion request (if enabled by GxQMR0.ENGST and without waiting for an external trigger).

Note: If the refill mechanism is activated, a processed entry is automatically reloaded into the queue. This permanently repeats the respective sequence (autoscan).

In this case, do not write to the queue input while the queued source is running.

Write operations to a completely filled queue are ignored.

Stop or abort an ongoing queued sequence by executing one of the following actions:

- If external gating is enabled, switch the gating signal to the defined inactive level. This does not modify the queue entries, but only prevents issuing conversion requests to the arbiter.
- Disable the corresponding arbitration slot (0) in the arbiter. This does not modify the queue entries, but only prevents the arbiter from accepting requests from the request handling block.
- Disable the queued source by clearing bitfield ENGST = 00_B.
 - Invalidate the next pending queue entry by setting bit GxQMR0.CLRV = 1.
If the backup stage contains a valid entry, this one is invalidated, otherwise stage 0 is invalidated.
 - Remove all entries from the queue by setting bit GxQMR0.FLUSH = 1.

Queue Request Source Events and Service Requests

A request source event of a queued source occurs when a conversion is finished. A source event service request can be generated based on a request source event according to the structure shown in [Figure 16-10](#). If a request source event is detected, it sets the corresponding indication flag in register **GxSEFLAG (x = 0 - 1)**. 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 **GxSEFCLR (x = 0 - 1)**.

The interrupt enable bit is taken from stage 0 for a normal sequential conversion, or from the backup stage for a repeated conversion after an abort.

The service request output line SR_x that is selected by the request source event interrupt node pointer bitfields in register **GxSEVNP (x = 0 - 1)** becomes activated each time the related request source event is detected (and enabled by GxQ0R0.ENSEI, or GxQBUR0.ENSEI respectively) or the related bit position in register **GxSEFLAG (x = 0 - 1)** is written with a 1 (this write action simulates a request source event).

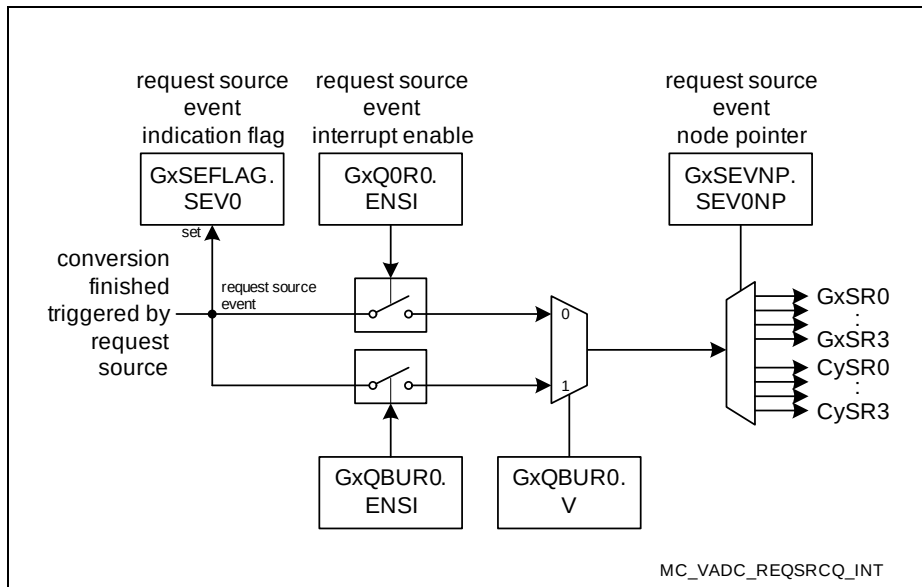


Figure 16-10 Interrupt Generation of a Queued Request Source

16.6.2 Channel Scan Request Source Handling

The VADC provides two types of channel scan sources:

- **Source 1: Group scan source**
This scan source can request all channels of the corresponding group.
- **Source 2: Background scan source**
This scan source can request all channels of all groups.
Priority channels selected in registers **GxCHASS** ($x = 0 - 1$) cannot take part in background conversion sequences.

Both sources operate in the same way and provide the same register interface. The background source provides more request/pending bits because it can request all channels of all groups.

Each analog input channel can be included in or excluded from the scan sequence by setting or clearing the corresponding channel select bit in register **GxASSEL** ($x = 0 - 1$) or **BRSELx** ($x = 0 - 1$). The programmed register value remains unchanged by an ongoing scan sequence. The scan sequence starts with the highest enabled channel number and continues towards lower channel numbers.

Upon a load event, the request pattern is transferred to the pending bits in register **GxASPND** ($x = 0 - 1$) or **BRSPNDx** ($x = 0 - 1$). The pending conversion requests indicate

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which input channels are to be converted in an ongoing scan sequence. Each conversion start that was triggered by the scan request source, automatically clears the corresponding pending bit. If the last conversion triggered by the scan source is finished and all pending bits are cleared, the current scan sequence is considered finished and a request source event is generated.

A conversion request is only issued to the request source arbiter if at least one pending bit is set.

If the arbiter aborts a conversion triggered by the scan request source due to higher priority requests, the corresponding pending bit is automatically set. This ensures that an aborted conversion is not lost but takes part in the next arbitration round.

The trigger and gating unit generates load events from the selected external (outside the ADC) trigger and gating signals. For example, a timer unit can issue a request signal to synchronize conversions to PWM events.

Load events start a scan sequence and can be generated either via software or via the selected hardware triggers. The request source event can also generate an automatic load event, so the programmed sequence is automatically repeated.

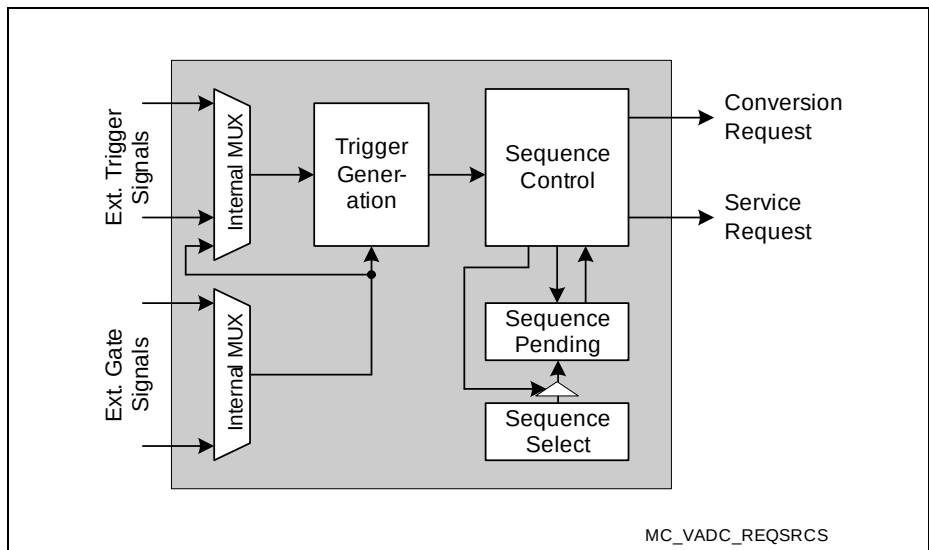


Figure 16-11 Scan Request Source

Scan Source Operation

Configure the scan request source by executing the following actions:

- Select the input channels for the sequence by programming **GxASSEL (x = 0 - 1)** or **BRSELx (x = 0 - 1)**
- If hardware trigger or gating is desired, select the appropriate trigger and gating inputs and the proper signal transitions by programming **GxASCTRL (x = 0 - 1)** or **BRCTRL**. Enable the trigger and select the gating mode by programming **GxASMR (x = 0 - 1)** or **BRSMR**.¹⁾
- Define the load event operation (handling of pending bits, autoscan mode) by programming **GxASMR (x = 0 - 1)** or **BRSMR**.
A load event with bit LDM = 0 copies the content of **GxASSEL (x = 0 - 1)** or **BRSELx (x = 0 - 1)** to **GxASPND (x = 0 - 1)** or **BRSPNDx (x = 0 - 1)** (overwrite mode). This starts a new scan sequence and aborts any pending conversions from a previous scan sequence.
A load event with bit LDM = 1 OR-combines the content of **GxASSEL (x = 0 - 1)** or **BRSELx (x = 0 - 1)** to **GxASPND (x = 0 - 1)** or **BRSPNDx (x = 0 - 1)** (combine mode). This starts a scan sequence that includes pending conversions from a previous scan sequence.
- Enable the corresponding arbitration slot (1) to accept conversion requests from the channel scan source (see register **GxARBPR (x = 0 - 1)**).

Start a channel scan sequence by generating a load event:

- If a hardware trigger is selected and enabled, generate the configured transition at the selected input signal, e.g. from a timer or an input pin.
- Generate a software load event by setting LDEV = 1 (**GxASMR (x = 0 - 1)** or **BRSMR**).
- Generate a load event by writing the scan pattern directly to the pending bits in **GxASPND (x = 0 - 1)** or **BRSPNDx (x = 0 - 1)**. The pattern is copied to **GxASSEL (x = 0 - 1)** or **BRSELx (x = 0 - 1)** and a load event is generated automatically.
In this case, a scan sequence can be defined and started with a single data write action, e.g. under PEC control (provided that the pattern fits into one register).

Note: If autoscan is enabled, a load event is generated automatically each time a request source event occurs when the scan sequence has finished. This permanently repeats the defined scan sequence (autoscan).

Stop or abort an ongoing scan sequence by executing one of the following actions:

- If external gating is enabled, switch the gating signal to the defined inactive level. This does not modify the conversion pending bits, but only prevents issuing conversion requests to the arbiter.

¹⁾ If PDOUT signals from the ERU are used, initialize the ERU accordingly before enabling the gate inputs to avoid an unexpected signal transitions.

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- Disable the corresponding arbitration slot (1 or 2) in the arbiter. This does not modify the contents of the conversion pending bits, but only prevents the arbiter from accepting requests from the request handling block.
- Disable the channel scan source by clearing bitfield ENGT = 00_B. Clear the pending request bits by setting bit CLRPND = 1 (**GxASMR (x = 0 - 1)** or **BRSMR**).

Scan Request Source Events and Interrupt Service Requests

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. If a request source event is detected, it sets the corresponding indication flag in register **GxSEFLAG (x = 0 - 1)**. These flags can also be set by writing a 1 to the corresponding bit position, whereas writing 0 has no effect.

The service request output SR_x that is selected by the request source event interrupt node pointer bitfields in register **GxSEVNP (x = 0 - 1)** becomes activated each time the related request source event is detected (and enabled by ENSI) or the related bit position in register **GxSEFLAG (x = 0 - 1)** is written with a 1 (this write action simulates a request source event).

The indication flags can be cleared by SW by writing a 1 to the corresponding bit position in register **GxSEFCLR (x = 0 - 1)**.¹⁾

1) Please refer to “**Service Request Generation**” on Page 16-64.

16.7 Request Source Arbitration

The request source arbiter regularly polls the request sources of the respective group, one after the other, for pending conversion requests. Each request source is assigned to a certain time slot within an arbitration round, called arbitration slot. The duration of an arbitration slot is user-configurable via register **GLOBCFG**.

The priority of each request source is user-configurable via register **GxARBPR (x = 0 - 1)**, so the arbiter can select the next channel to be converted, in the case of concurrent requests from multiple sources, according to the application requirements.

An unused arbitration slot is considered empty and does not take part in the arbitration. After reset, all slots are disabled and must be enabled (register **GxARBPR (x = 0 - 1)**) to take part in the arbitration process.

Figure 16-12 summarizes the arbitration sequence. An arbitration round consists of one arbitration slot for each available request source. The synchronization source is always evaluated in the last slot and has a higher priority than all other sources. At the end of each arbitration round, the arbiter has determined the highest priority conversion request.

If a conversion is started in an arbitration round, this arbitration round does not deliver an arbitration winner. In the XMC1200, the following request sources are available:

- Arbitration slot 0: **Group Queued source**, 8-stage sequences in arbitrary order
- Arbitration slot 1: **Group Scan source**, sequences in defined order within group
- Arbitration slot 2: **Background Scan source**, sequences in defined order, all groups
- Last arbitration slot: **Synchronization source**, synchronized conversion requests from another group (always handled with the highest priority in a synchronization slave group).

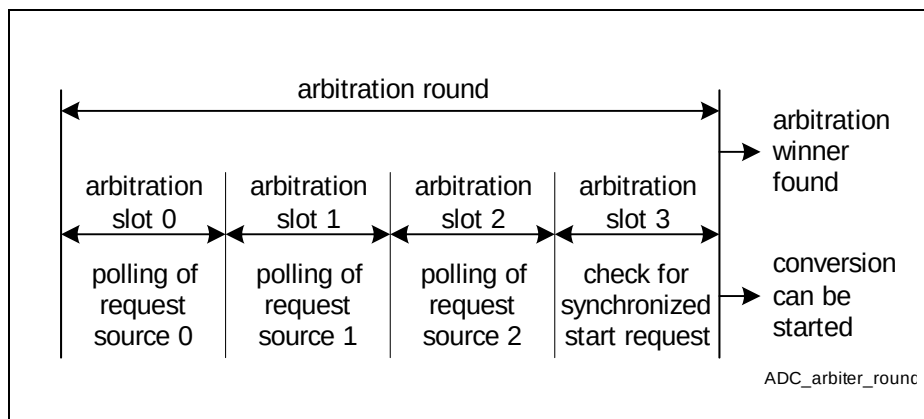


Figure 16-12 Arbitration Round with 4 Arbitration Slots

16.7.1 Arbiter Operation and Configuration

The timing of the arbiter (i.e. of an arbitration round) is determined by the number of arbitration slots within an arbitration round and by the duration of an arbitration slot.

An arbitration round consist of 4...20 arbitration slots (defined by bitfield **GxARBCFG (x = 0 - 1).ARBRND**). 4 slots are sufficient for the XMC1200, more can be programmed to obtain the same arbiter timing for different products.

The duration of an arbitration slot is configurable $t_{\text{Slot}} = (\text{DIVD}+1) / f_{\text{ADC}}$.

The duration of an arbitration round, therefore, is $t_{\text{ARB}} = 4 \times t_{\text{Slot}}$.

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.

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 **GxARBCFG (x = 0 - 1).ARBM = 0**, the **arbiter runs permanently**. In this mode, synchronized conversions of more than one ADC kernel are possible.¹⁾

The trigger for a conversion request 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 **GxARBCFG (x = 0 - 1).ARBM = 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 for a conversion request does not need to be synchronous to the arbiter timing.

In this mode, parallel conversions are not possible for synchronization slave groups.

Each request source has a configurable priority, so the arbiter can resolve concurrent conversion requests from different sources. The request with the highest priority is selected for conversion. These priorities can be adapted to the requirements of a given application (see register **GxARBPR (x = 0 - 1)**).

The **Conversion Start Mode** determines the handling of the conversion request that has won the arbitration.

1) For more information, please refer to **"Synchronization of Conversions" on Page 16-56**.

16.7.2 Conversion Start Mode

When the arbiter has selected the request to be converted next, the handling of this channel depends on the current activity of the converter:

- Converter is currently idle: the conversion of the arbitration winner is started immediately.
- Current conversion has same or higher priority: the current conversion is completed, the conversion of the arbitration winner is started after that.
- Current conversion has lower priority: the action is user-configurable:
 - **Wait-for-start mode:** the current conversion is completed, the conversion of the arbitration winner is started after that. This mode provides maximum throughput, but can produce a jitter for the higher priority conversion.

Example in [Figure 16-13](#):

Conversion A is requested (t1) and started (t2). Conversion B is then requested (t3), but started only after completion of conversion A (t4).

- **Cancel-inject-repeat mode:** the current conversion is aborted, the conversion of the arbitration winner is started after the abortion ($3 f_{ADC}$ cycles).

The aborted conversion request is restored in the corresponding request source and takes part again in the next arbitration round. This mode provides minimum jitter for the higher priority conversions, but reduces the overall throughput.

Example in [Figure 16-13](#):

Conversion A is requested (t6) and started (t7). Conversion B is then requested (t8) and started (t9), while conversion A is aborted but requested again. When conversion B is complete (t10), conversion A is restarted.

Exception: If both requests target the same result register with wait-for-read mode active (see [Section 16.11.3](#)), the current conversion cannot be aborted.

Note: A cancelled conversion can be repeated automatically in each case, or it can be discarded if it was cancelled. This is selected for each source by bit RPTDIS in the corresponding source's mode register.

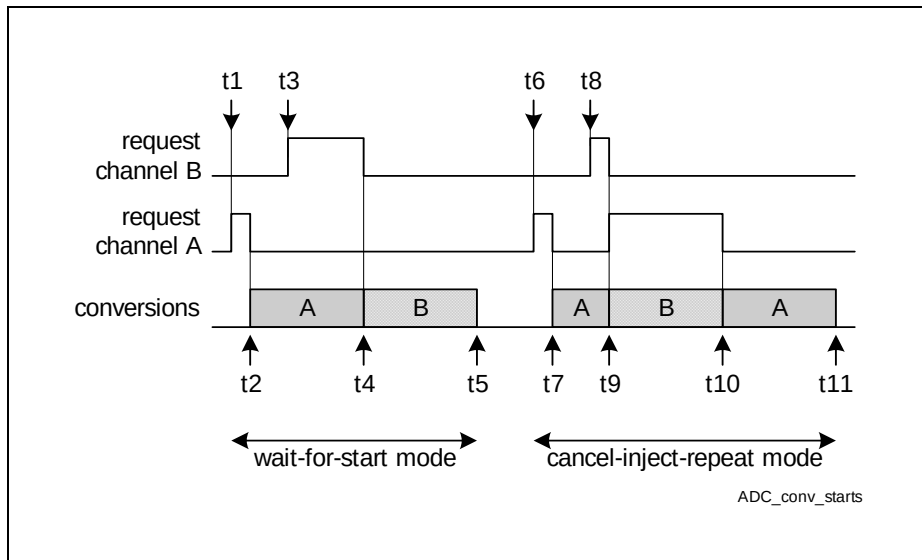


Figure 16-13 Conversion Start Modes

The conversion start mode can be individually programmed for each request source by bits in register **GxARBPR (x = 0 - 1)** and is applied to all channels requested by the source. 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.

16.8 Analog Input Channel Configuration

For each analog input channel a number of parameters can be configured that control the conversion of this channel. The channel control registers define the following parameters:

- **Channel Parameters:** The sample time for this channel and the data width of the result are defined via input classes. Each channel can select one of two classes of its own group or one of two global classes.
- **Reference selection:** an alternate reference ground can be selected
- **Result target:** The conversion result values are stored either in a group-specific result register or in the global result register. The group-specific result registers are selected channel-specific, selected by bitfield RESREG in register **G0CHCTry (y = 0 - 7)** etc.
- **Result position:** The result values can be stored left-aligned or right-aligned. The exact position depends also on the configured result width and on the data accumulation mode.

See also **Figure 16-20 “Result Storage Options” on Page 16-46**.

- **Compare with Standard Conversions (Limit Checking):** Channel events can be generated whenever a new result value becomes available. Channel event generation can be restricted to values that lie inside or outside a user-configurable band.

In Fast Compare Mode, channel events can be generated depending on the transitions of the (1-bit) result.

- **Broken Wire Detection:** This safety feature can detect a missing connection to an analog signal source (sensor).
- **Synchronization of Conversions:** Synchronized conversions are executed at the same time on several converters.

The **Alias Feature** redirects conversion requests defined at channels CH0 and/or CH1 to other analog input channels.

16.8.1 Channel Parameters

Each analog input channel is configured by its associated channel control register.

*Note: For the safety feature “Broken Wire Detection”, refer to **Section 16.13.1**.*

The following features can be defined for each channel:

- The conversion class defines the result width and the sample time
- Generation of channel events and the result value band, if used
- Target of the result defining the target register and the position within the register

The group-specific input class registers define the sample time and data conversion mode for each channel of the respective group that selects them via bitfield ICLSEL in its channel control register GxCHCTry.

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The global input class registers define the sample time and data conversion mode for each channel of any group that selects them via bitfield ICLSEL in its channel control register GxCHCTRY.

16.8.2 Alias Feature

The Alias Feature redirects conversion requests defined at channels CH0 and/or CH1 to other analog input channels (pins). This feature can be used to trigger conversions of the same input pin by independent events and to store the conversion results in 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 service request latency.
- The sensor signal is connected to only one analog input (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 16-14](#)), the internal trigger and data handling features for channel CH0 can be used.
- The channel settings for both conversions can be different (boundary values, service requests, etc.).

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 16-14](#) 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 results can be stored and read out from the result registers RESx (conversion triggered for CHx) and RESy (conversion triggered for CH0). Additionally, different interrupts or limit boundaries can be selected, enabled or disabled.

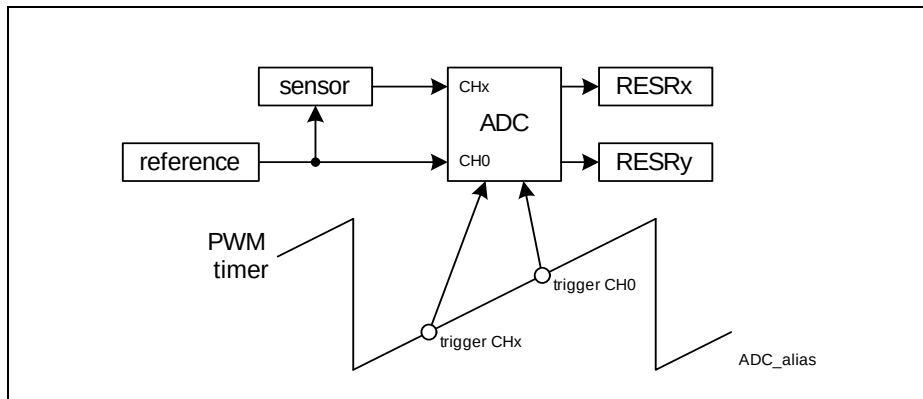


Figure 16-14 Alias Feature

16.8.3 Conversion Modes

A conversion can be executed in several ways. The conversion mode is selected according to the requested resolution of the digital result and according to the acceptable conversion time ([Section 16.10](#)).

Use bitfield CMS/CME in register **GxICLASS0 (x = 0 - 1)** etc. to select a mode.

Standard Conversions

A standard conversion returns a result value with a predefined resolution. 8-bit, 10-bit, and 12-bit resolution can be selected.

These result values can be accumulated, filtered, or used for digital limit checking and determination of extrema.

Note: The converters can operate with and without calibration steps.

Fast Compare Mode

In Fast Compare Mode, the selected input voltage is directly compared with a digital value that is stored in the corresponding result register. This compare operation returns a binary result indicating if the compared input voltage is above or below the given reference value. This result is generated quickly and thus supports monitoring of boundary values.

Fast Compare Mode uses a 10-bit compare value stored left-aligned at bit position 11. Separate positive and negative delta values define an arbitrary hysteresis band.

Selecting Compare Values

Values for digital or analog compare operations can be selected from several sources. The separate GxBOUND registers provide software-defined compare values.

In Fast Compare Mode, the result registers provide the compare value while the bitfields of local GxBOUND registers define positive and negative delta values.

16.8.4 Compare with Standard Conversions (Limit Checking)

The limit checking mechanism can automatically compare each digital conversion result to an upper and a lower boundary value. A channel event can then be generated when the result of a conversion/comparison is inside or outside a user-defined band (see bitfield CHEVMODE and [Figure 16-15](#)).

This feature supports automatic range monitoring and minimizes the CPU load by issuing service requests only under certain predefined conditions.

Note: Channel events can also be generated for each result value (ignoring the band) or they can be suppressed completely.

The boundary values to which results are compared can be selected from several sources (see register GxCHCTRY).

Bitfields BNDSELU and BNDSELL select the valid upper/lower boundary value either from the group-specific boundary register **GxBOUND (x = 0 - 1)** or from the global boundary register **GLOBBOUND**. The group boundary register can be selected for each channel of the respective group, the global boundary register can be selected by each available channel.

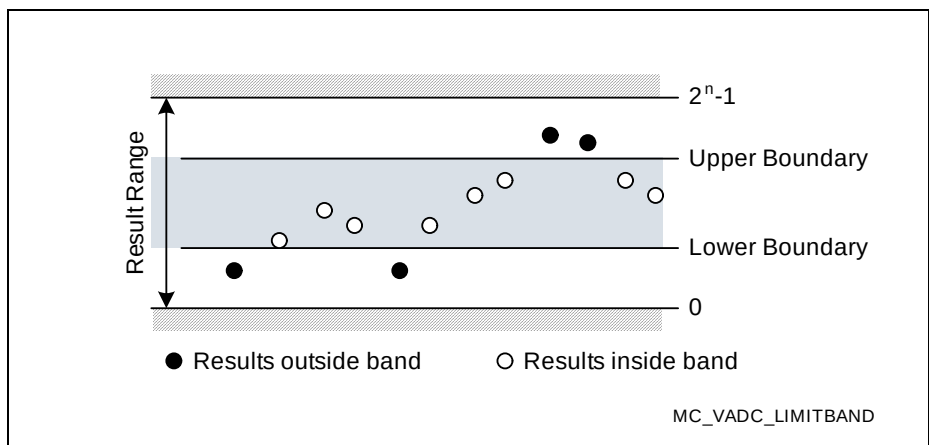


Figure 16-15 Result Monitoring through Limit Checking

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A result value is considered inside the defined band when both of the following conditions are true:

- the value is less than or equal to the selected upper boundary
- the value is greater than or equal to the selected lower boundary

The result range can also be divided into two areas:

To select the lower part as valid band, set the lower boundary to the minimum value (000_H) and set the upper boundary to the highest intended value.

To select the upper part as valid band, set the upper boundary to the maximum value (FFF_H) and set the lower boundary to the lowest intended value.

Finding Extrema (Peak Detection)

The limit checking mechanism uses standard conversions and, therefore, always can provide the actual conversion result that was used for comparison. Combining this with a special FIFO mode, that only updates the corresponding FIFO stage if the result was above (or below) the current value of the stage, provides the usual conversion results and at the same time stores the highest (or lowest) result of a conversion sequence. For this operation the FIFO stage below the standard result must be selected as the compare value. Mode selection is done via bitfield FEN in register $GxRCRy$.

Before starting a peak detection sequence, write a reasonable start value to the result bitfield in the peak result register (e.g. 0000_H to find the maximum and $FFFF_H$ to find the minimum).

16.8.5 Utilizing Fast Compare Mode

In Fast Compare Mode, the input signal is directly compared to a value in the associated result register. This comparison just provides a binary result (above/below). If the exact result value is not required, this saves conversion time. A channel event can then be generated when the input signal becomes higher (or lower) than the compare value (see bitfield CHEVMODE and [Figure 16-16](#)).

The compare value in Fast Compare Mode is taken from the result register. Bitfields BOUNDARY1 and BOUNDARY0 in register $GxBOUND(x = 0 - 1)$ define delta limits in this case. These deltas are added to (or subtracted from) the original compare value and allow defining an arbitrary hysteresis band.

The actual used compare value depends on the Fast Compare Result FCR (see registers $GORESy(y = 0 - 15)$, etc.):

$GxRESy.FCR = 0$: reference value + upper delta

$(GxRESy.RESULT + GxBOUND.BOUNDARY0)$

$GxRESy.FCR = 1$: reference value - lower delta

$(GxRESy.RESULT - GxBOUND.BOUNDARY1)$

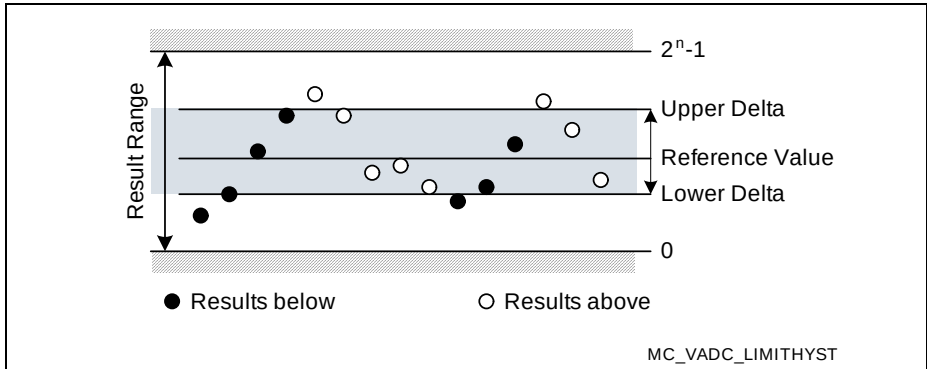


Figure 16-16 Result Monitoring through Compare with Hysteresis

16.8.6 Boundary Flag Control

Both limit checking mechanisms can be configured to automatically control the boundary flags. These boundary flags are also available as control signals for other modules. The flags can be set or cleared when the defined level is exceeded and the polarity of the output signal can be selected. A gate signal can be selected to enable the boundary flag operation while the gate is active.

Each boundary flag is available at group-specific output lines. Node pointers additionally route them to one of four boundary signals or one of the associated common service request lines, see register **GxBFLNP** ($x = 0 - 1$).

For standard conversions, a boundary flag will be set when the conversion result is above the defined band, and will be cleared when the conversion result is below the defined band.

The band between the two boundary values defines a hysteresis for setting/clearing the boundary flags.

Using this feature on three channels that monitor linear hall elements can produce signals to feed the three hall inputs of a position interface.

In Fast Compare Mode, a boundary flag reflects the result of the comparisons, i.e. it will be set/cleared when the compared signal level is above the compare value, and will be cleared/set when the signal level is below the compare value. The delta values define a hysteresis band around the compare value.

Note: Clear register GxBOUND (i.e. the deltas) if a hysteresis is not wanted.

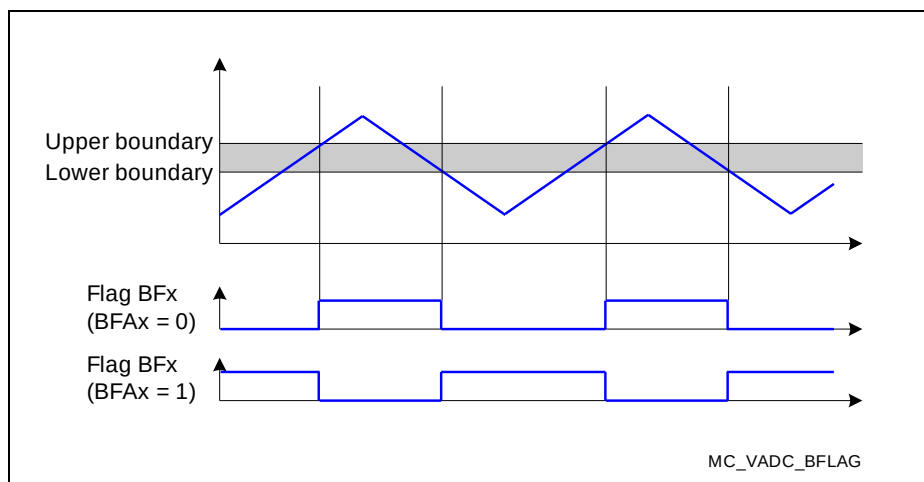


Figure 16-17 Boundary Flag Switching

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Boundary flags can be switched by each compare operation, or the influence of compare operations can be restricted to the active phases of the corresponding request source gate signal (see **GxBFLC (x = 0 - 1)**).

Note: If a boundary flag is used together with Fast Compare Mode, it is recommended not to direct results from other channels to the corresponding result register.

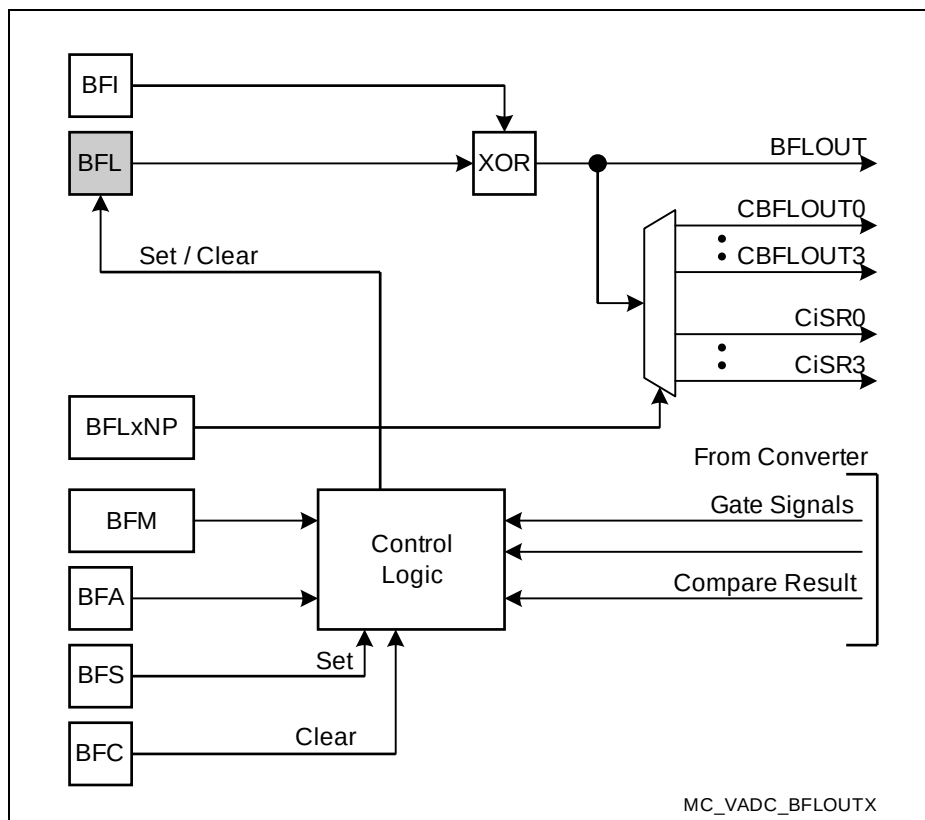


Figure 16-18 Boundary Flag Control

A boundary flag **BFLy** is assigned to result register **GxRESy** and thus to an arbitrary channel.

16.9 Conversion Scheduling

The converter clusters of the VADC combine one high-speed converter with several sample&hold units which can operate in parallel.

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The XMC1200 comprises 1 cluster with 2 S&H units each.

Since all S&H units use one converter, the actual conversion must be associated with certain S&H units. An 8-stage stepper continuously scans the conversion requests of the S&H units of a cluster and starts a conversion if one of them is found active.

Each of the 8 steps can be assigned to one of the available groups (via bitfield KSELx in register **SHS0_STEPCFG**) and can be enabled to take part in the round-robin scheme. The default programming after reset establishes a linear round-robin scheme that enables and scans all interfaces one after the other. In this case, all interfaces are handled in the same way. The other steps are disabled.

By selecting certain groups multiple times within the stepper sequence the associated S&H units can be scanned more often. In particular in accelerated timing mode this leads to a higher conversion rate on these kernels. This additional functionality makes the enhanced performance of the SHADC available to the application.

Example:

Default: 0 - 1 (2) (3) (4) (5) (6) (7) [2 S&H units: steps 2-7 disabled]

Boost1: 0 - 1 - 1 (3) (4) (5) (6) (7) [steps 3-7 disabled]

Note: The default configuration of the stepper provides an upward-compatible operation.

Empty steps, i.e. steps where the associated S&H unit has no conversion request, are disregarded and the stepper proceeds with the next enabled step.

If all steps are empty the stepper enters its idle state until a conversion request or a calibration request (see **Section**) is activated.

General Timing Behavior

Conversion results are returned to the digital logic after the time interval defined by the parameters f_{ADC} , sample time, conversion width, etc. This compatible timing mode provides the same behavior as predecessor modules. This supports existing applications that are ported to the XMC1200.

To exploit the performance of the high-speed converter, an accelerated timing mode is enabled by setting bit AT in register TIMCFG. In this case, each result value is returned as soon as it is converted. Combined with boosting certain groups (see above) this can deliver a high conversion rate.

Also the sample time can be reduced (bitfield SST) to achieve higher conversion rates.

16.10 Conversion Timing

The total time required for a conversion comprises the time from the start of the sample phase¹⁾ until the availability of the result.

The frequency at which conversions are triggered also depends on several configurable factors:

- The selected conversion time, according to the input class definitions. For conversions using an external multiplexer, also the extended sample times count.
- Delays induced by cancelled conversions that must be repeated.
- Delays due to equidistant sampling of other channels.
- The configured arbitration cycle time.
- The frequency of external trigger signals, if enabled.

Note: In compatible timing mode, conversion timing is defined in the same way as known from predecessor modules. Existing applications find a smooth upgrade path.

16.10.1 Timing Definition

The actual response time of a conversion depends on the position of the conversion within the cluster's conversion round

The conversion timing depends on the following factors (partly user-definable):

- The converter clock frequency, where $f_{SH} = f_{CONV} / (DIVS+1)$
- The selected sample time, where $t_S = SST \times t_{ADC}$ (short sample time)
- The result width N (8/10/12 bits)
- The post-calibration time, if selected (after a conversion round)
- The position of the conversion within the stepper sequence
- Synchronization steps done at module clock speed

The conversion time is the sum of sample time, conversion steps, and synchronization. It can be computed with the following formula:

$$t_{CN} = SST \times t_{ADC} + (4 \times t_{SH})^2 + (N + 8) \times t_{SH} + (5 \times t_{ADC})^3$$

A conversion round comprises 2 conversions (for 2 sample&hold units) and a calibration step. Calibration steps are executed after each conversion round (up to $12 \times t_{SH}$)⁴⁾, so the maximum complete conversion round including all 2 S&H units will take:

$$t_{CR} = SST \times t_{ADC} + 4 \times t_{SH} + (N+8) \times t_{SH} + (N+8) \times t_{SH} + 5 \times t_{ADC} + 12 \times t_{SH}^4$$

- 1) The time from the trigger event that requests the corresponding conversion until the start of the sample phase depends on the arbitration and can, therefore, only be determined when the system setup is known.
- 2) These clock cycles are required between the end of the sample phase and the beginning of the conversion. They can be excluded if this phase occurs during another conversion.
- 3) These clock cycles are required to transport the converted result value to the digital result register. They only need to be counted when computing the total conversion performance of a cluster.
- 4) Offset and gain calibration steps are executed alternating, where gain calibration takes more time than offset calibration (9 cycles).

Timing Examples

System assumptions:

$f_{\text{CONV}} = 32 \text{ MHz}$, $\text{DIVS} = 0$, i.e. $t_{\text{SH}} = t_{\text{CONV}} = 31.25 \text{ ns}$,

$f_{\text{ADC}} = 32 \text{ MHz}$, i.e. $t_{\text{ADC}} = 31.25 \text{ ns}$,

$\text{SST} = 3$, i.e. $t_{\text{S}} = 94 \text{ ns}$

According to the given formula the following minimum conversion times can be achieved:
(The numbers in parentheses apply for the 2nd conversion of a round)

12-bit conversion:

$$t_{\text{CN12}} = 3 \times t_{\text{ADC}} + 4 \times t_{\text{SH}} + 20 \times t_{\text{SH}} + 5 \times t_{\text{ADC}} = 32 \times 31.25 \text{ ns} = 1\,000 \text{ ns} \text{ (1\,625 ns)}$$

10-bit conversion:

$$t_{\text{CN10}} = 3 \times t_{\text{ADC}} + 4 \times t_{\text{SH}} + 18 \times t_{\text{SH}} + 5 \times t_{\text{ADC}} = 30 \times 31.25 \text{ ns} = 937.5 \text{ ns} \text{ (1\,500 ns)}$$

An average conversion round including all 2 S&H units and calibration will take up to:

$$t_{\text{CR}} = 1\,625 \text{ ns} + 10.5 \times 31.25 \text{ ns} = 1\,954 \text{ ns} \text{ (12-bit conversion)}^{1)}$$

The maximum time for an isolated conversion will take up to:

$$t_{\text{C1}} = 1\,000 \text{ ns} + 12 \times 31.25 \text{ ns} = 1\,375 \text{ ns} \text{ (12-bit conversion)}^{2)}$$

1) 10.5 calibration clock cycles are the average resulting from alternating offset and gain calibration steps.

2) 12 calibration clock cycles are the maximum resulting from a gain calibration step.

16.10.2 Compatible Timing Mode

The conversion timing depends on the following factors (partly user-definable):

- The ADC conversion clock frequency, where $f_{\text{ADCI}} = f_{\text{ADC}} / (\text{DIVA} + 1)^{1)}$
- The selected sample time, where $t_{\text{S}} = (2 + \text{STC}) \times t_{\text{ADCI}}$
(STC = additional sample time, see also [Table 16-11](#))
- The result width N (8/10/12 bits)
- The post-calibration time PC, if selected (PC = 2, otherwise 0)
- Synchronization steps done at module clock speed

The conversion time is the sum of sample time, conversion steps, and synchronization. It can be computed with the following formula:

$$t_{\text{CN}} = (2 + \text{STC} + \text{N} + \text{PC}) \times t_{\text{ADCI}} + 2 \times t_{\text{ADC}}$$

Timing Examples Compatible Mode

According to the given formula the following minimum conversion times can be achieved:

System assumptions for 12-bit calibrated conversions:

$$f_{\text{ADC}} = 32 \text{ MHz i.e. } t_{\text{ADC}} = 31.25 \text{ ns, DIVA} = 3^{1)}, f_{\text{ADCI}} = 8 \text{ MHz i.e. } t_{\text{ADCI}} = 125 \text{ ns}$$

$$t_{\text{CN12C}} = (2 + 12 + 2) \times t_{\text{ADCI}} + 2 \times t_{\text{ADC}} = 16 \times 125 \text{ ns} + 2 \times 31.25 \text{ ns} = 2\,063 \text{ ns}$$

System assumptions for 12-bit uncalibrated conversions:

$$f_{\text{ADC}} = 32 \text{ MHz i.e. } t_{\text{ADC}} = 31.25 \text{ ns, DIVA} = 3^{1)}, f_{\text{ADCI}} = 8 \text{ MHz i.e. } t_{\text{ADCI}} = 125 \text{ ns}$$

$$t_{\text{CN12U}} = (2 + 12) \times t_{\text{ADCI}} + 2 \times t_{\text{ADC}} = 14 \times 125 \text{ ns} + 2 \times 31.25 \text{ ns} = 1\,813 \text{ ns}$$

System assumptions for 10-bit conversions:

$$f_{\text{ADC}} = 32 \text{ MHz i.e. } t_{\text{ADC}} = 31.25 \text{ ns, DIVA} = 3^{1)}, f_{\text{ADCI}} = 8 \text{ MHz i.e. } t_{\text{ADCI}} = 125 \text{ ns}$$

$$t_{\text{CN10}} = (2 + 10) \times t_{\text{ADCI}} + 2 \times t_{\text{ADC}} = 12 \times 125 \text{ ns} + 2 \times 31.25 \text{ ns} = 1\,563 \text{ ns}$$

1) f_{ADCI} is a virtual frequency which is used to control the conversion timing in compatible timing mode.
DIVA must be 3 or higher for conversions in compatible mode.

16.11 Conversion Result Handling

The A/D converters can preprocess the conversions result data to a certain extent before storing them for retrieval by the CPU. This supports the subsequent handling of result data by the application software.

Conversion result handling comprises the following functions:

- **Storage of Conversion Results** to user-configurable registers
- **Data Alignment** according to result width and endianness
- **Wait-for-Read Mode** to avoid loss of data
- **Result Event Generation**
- Data reduction or anti-aliasing filtering (see [Section 16.11.6](#))

16.11.1 Storage of Conversion Results

The conversion result values of a certain group can be stored in one of the 16 associated group result registers or in the common global result register (can be used, for example, for the channels of the background source (see [Selecting a Result Register](#)).

This structure provides different locations for the conversion results of different sets of channels. Depending on the application needs (data reduction, auto-scan, alias feature, etc.), the user can distribute the conversion results to minimize CPU load.

Each result register has an individual data valid flag (VF) associated with it. This flag indicates when “new” valid data has been stored in the corresponding result register and can be read out.

For standard conversions, result values are available in bitfield RESULT. Conversions in Fast Compare Mode use bitfield RESULT for the reference value, so the result of the operation is stored in bit FCR.

Result registers can be read via two different views. These views use different addresses but access the same register data:

- When a result register is read via the **application view**, the corresponding valid flag is automatically cleared when the result is read. This provides an easy handshake between result generation and retrieval. This also supports wait-for-read mode.
- When a result register is read via the **debug view**, the corresponding valid flag remains unchanged when the result is read. This supports debugging by delivering the result value without disturbing the handshake with the application.

The application can retrieve conversion results through several result registers:

- Group result register:
Returns the result value and the channel number
- Global result register:
Returns the result value and the channel number and the group number

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16.11.2 Data Alignment

The position of a conversion result value within the selected result register depends on 3 configurations (summary in **Figure 16-20**):

- The selected result width (12/10/8 bits, selected by the conversion mode)
- The selected result position (Left/Right-aligned)
- The selected data accumulation mode (data reduction)

These options provide the conversion results in a way that minimizes data handling for the application software.

Bit in Result Register		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Standard Conversions	12-Bit	0	0	0	0	11	10	9	8	7	6	5	4	3	2	1	0
	10-Bit Left-Aligned	0	0	0	0	9	8	7	6	5	4	3	2	1	0	0	0
	10-Bit Right-Aligned	0	0	0	0	0	0	9	8	7	6	5	4	3	2	1	0
	8-Bit Left-Aligned	0	0	0	0	7	6	5	4	3	2	1	0	0	0	0	0
	8-Bit Right-Aligned	0	0	0	0	0	0	0	0	7	6	5	4	3	2	1	0
Accumulated Conversions	12-Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	10-Bit Left-Aligned	13	12	11	10	9	8	7	6	5	4	3	2	1	0	0	0
	10-Bit Right-Aligned	0	0	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	8-Bit Left-Aligned	11	10	9	8	7	6	5	4	3	2	1	0	0	0	0	0
	8-Bit Right-Aligned	0	0	0	0	11	10	9	8	7	6	5	4	3	2	1	0

MC_VADC_RESPOS

Figure 16-20 Result Storage Options

Bitfield RESULT can be written by software to provide the reference value for Fast Compare Mode. In this mode, bits 11-2 are evaluated, the other bits are ignored.

16.11.3 Wait-for-Read Mode

The wait-for-read mode prevents data loss due to overwriting a result register with a new conversion result before the CPU has read the previous data. For example, auto-scan conversion sequences or other sequences with “relaxed” timing requirements may use a common result register. However, the results come from different input channels, so an overwrite would destroy the result from the previous conversion¹⁾.

Wait-for-read mode automatically suspends the start of a conversion for this channel from this source until the current result has been read. So a conversion or a conversion sequence can be requested by a hardware or software trigger, while each conversion is only started after the result of the previous one has been read. This automatically aligns the conversion sequence with the CPU capability to read the formerly converted result (latency).

If wait-for-read mode is enabled for a result register (bit GxRCRy.WFR = 1), a request source does not generate a conversion request while the targeted result register contains valid data (indicated by the valid flag VF = 1) or if a currently running conversion targets the same result register.

If two request sources target the same result register with wait-for-read mode selected, a higher priority source cannot interrupt a lower priority conversion request started before the higher priority source has requested its conversion. Cancel-inject-repeat mode does not work in this case. In particular, this must be regarded if one of the involved sources is the background source (which usually has lowest priority). If the higher priority request targets a different result register, the lower priority conversion can be cancelled and repeated afterwards.

Note: Wait-for-read mode is ignored for synchronized conversions of synchronization slaves (see [Section 16.12](#)).

1) Repeated conversions of a single channel that use a separate result register will not destroy other results, but rather update their own previous result value. This way, always the actual signal data is available in the result register.

16.11.4 Result FIFO Buffer

Result registers can either be used as direct target for conversion results or they can be concatenated with other result registers of the same ADC group to form a result FIFO buffer (first-in-first-out buffer mechanism). A result FIFO stores several measurement results that can be read out later with a “relaxed” CPU response timing. It is possible to set up more than one FIFO buffer structure with the available result registers.

Result FIFO structures of two or more registers are built by concatenating result registers to their following “neighbor” result register (with next higher index, see [Figure 16-21](#)). This is enabled by setting bitfield GxRCRy.FEN = 01_b.

Conversion results are stored to the register with the highest index of a FIFO structure. Software reads the values from the FIFO register with the lowest index.

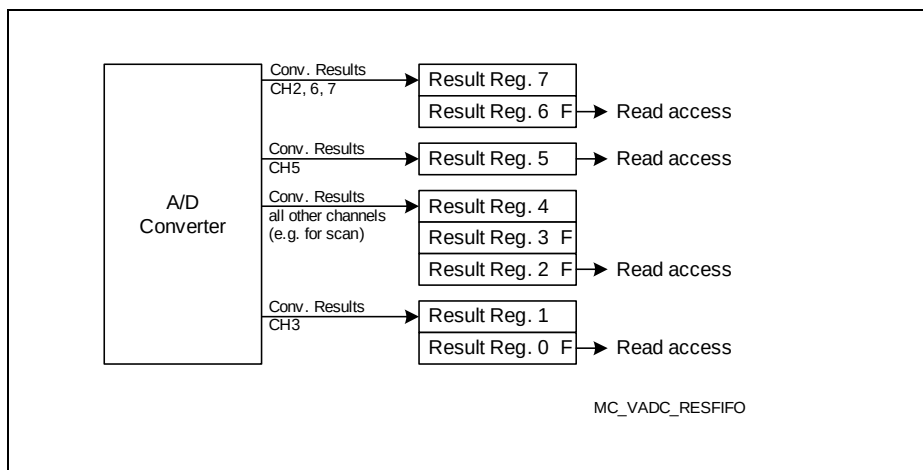


Figure 16-21 Result FIFO Buffers

In the example shown the result registers have been configured in the following way:

- 2-stage buffer consisting of result registers 7-6
- dedicated result register 5
- 3-stage buffer consisting of result registers 4-3-2
- 2-stage buffer consisting of result registers 1-0

[Table 16-4](#) summarizes the required configuration of result registers if they are combined to build result FIFO buffers.

Table 16-4 Properties of Result FIFO Registers

Function	Input Stage	Intermed. Stage	Output Stage
Result target	YES	no	no
Application read	no	no	YES
Data reduction mode	YES	no	no
Wait-for-read mode	YES	no	no
Result event interrupt	no	no	YES
FIFO enable (FEN)	00 _B	01 _B	01 _B
Registers in example	7, 4, 1	3	6, 2, 0

Note: If enabled, a result interrupt is generated for each data word in the FIFO.

16.11.5 Result Event Generation

A result event can be generated when a new value is stored to a result register. Result events can be restricted due to data accumulation and be generated only if the accumulation is complete.

Result events can also be suppressed completely.

16.11.6 Data Modification

The data resulting from conversions can be automatically modified before being used by an application. Several options can be selected (bitfield DMM in register **G0RCRy (y = 0 - 15)** etc.) which reduce the CPU load required to unload and/or process the conversion data.

- **Standard Data Reduction Mode (for GxRES0 ... GxRES15):**
Accumulates 2, 3, or 4 result values within each result register before generating a result interrupt. This can remove some noise from the input signal.
- **Result Filtering Mode (FIR, for GxRES7, GxRES15):**
Applies a 3rd order Finite Impulse Response Filter (FIR) with selectable coefficients to the conversion results for the selected result register.
- **Result Filtering Mode (IIR, for GxRES7, GxRES15):**
Applies a 1st order Infinite Impulse Response Filter (IIR) with selectable coefficients to the conversion results for the selected result register.
- **Difference Mode (for GxRES1 ... GxRES15):**
Subtracts the contents of result register GxRES0 from the conversion results for the selected result register. Bitfield DRCTR is not used in this mode.

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Table 16-5 Function of Bitfield DRCTR

DRCTR	Standard Data Reduction Mode (DMM = 00_B)	DRCTR	Result Filtering Mode (DMM = 01_B)¹⁾
0000 _B	Data Reduction disabled	0000 _B	FIR filter: a=2, b=1, c=0
0001 _B	Accumulate 2 result values	0001 _B	FIR filter: a=1, b=2, c=0
0010 _B	Accumulate 3 result values	0010 _B	FIR filter: a=2, b=0, c=1
0011 _B	Accumulate 4 result values	0011 _B	FIR filter: a=1, b=1, c=1
0100 _B	Reserved	0100 _B	FIR filter: a=1, b=0, c=2
0101 _B	Reserved	0101 _B	FIR filter: a=3, b=1, c=0
0110 _B	Reserved	0110 _B	FIR filter: a=2, b=2, c=0
0111 _B	Reserved	0111 _B	FIR filter: a=1, b=3, c=0
1000 _B	Reserved	1000 _B	FIR filter: a=3, b=0, c=1
1001 _B	Reserved	1001 _B	FIR filter: a=2, b=1, c=1
1010 _B	Reserved	1010 _B	FIR filter: a=1, b=2, c=1
1011 _B	Reserved	1011 _B	FIR filter: a=2, b=0, c=2
1100 _B	Reserved	1100 _B	FIR filter: a=1, b=1, c=2
1101 _B	Reserved	1101 _B	FIR filter: a=1, b=0, c=3
1110 _B	Reserved	1110 _B	IIR filter: a=2, b=2
1111 _B	Reserved	1111 _B	IIR filter: a=3, b=4

1) The filter registers are cleared while bitfield DMM ≠ 01_B.

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Standard Data Reduction Mode

The data reduction mode can be used as digital filter for anti-aliasing or decimation purposes. It accumulates a maximum of 4 conversion values to generate a final result.

Each result register can be individually enabled for data reduction, controlled by bitfield DRCTR in registers **G0CHCTry (y = 0 - 7)**. The data reduction counter DRC indicates the actual status of the accumulation.

Note: Conversions for other result registers can be inserted between conversions to be accumulated.

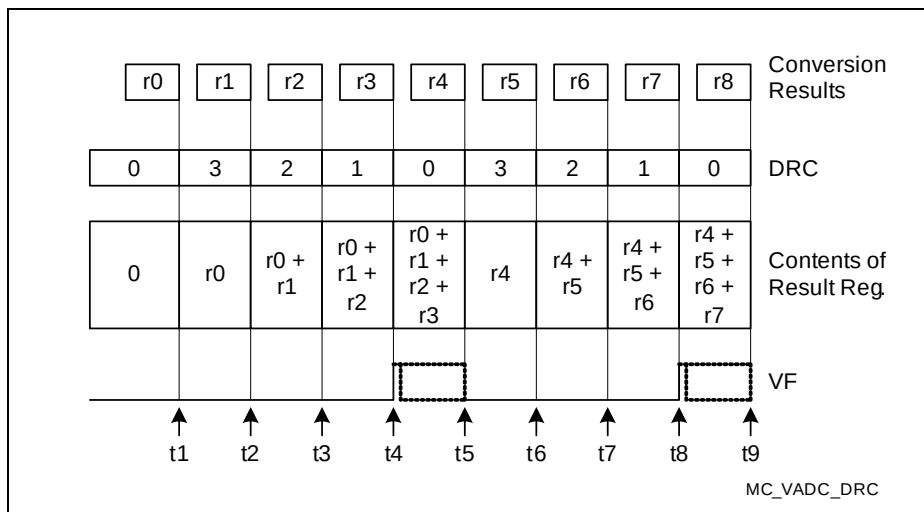


Figure 16-22 Standard Data Reduction Filter

This example shows a data reduction sequence of 4 accumulated conversion results. Eight conversion results (r0 ... r7) are accumulated and produce 2 final results.

When a conversion is complete and stores data to a result register that has data reduction mode enabled, the data handling is controlled by the data reduction counter DRC:

- If DRC = 0 (t1, t5, t9 in the example), the conversion result is stored to the register. DRC is loaded with the contents of bitfield DRCTR (i.e. the accumulation begins).
- If DRC > 0 (t2, t3, t4 and t6, t7, t8 in the example), the conversion result is added to the value in the result register. DRC is decremented by 1.
- If DRC becomes 0, either decremented from 1 (t4 and t8 in the example) or loaded from DRCTR, the valid bit for the respective result register is set and a result register event occurs.

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The final result must be read before the next data reduction sequence starts (before t5 or t9 in the example). This automatically clears the valid flag.

*Note: Software can clear the data reduction counter DRC by clearing the corresponding valid Flag (via **GxVFR** ($x = 0 - 1$)).*

The response time to read the final data reduction results can be increased by associating the adjacent result register to build a result FIFO (see [Figure 16-23](#)). In this case, the final result of a data reduction sequence is loaded to the adjacent register. The value can be read from this register until the next data reduction sequence is finished (t8 in the 2nd example).

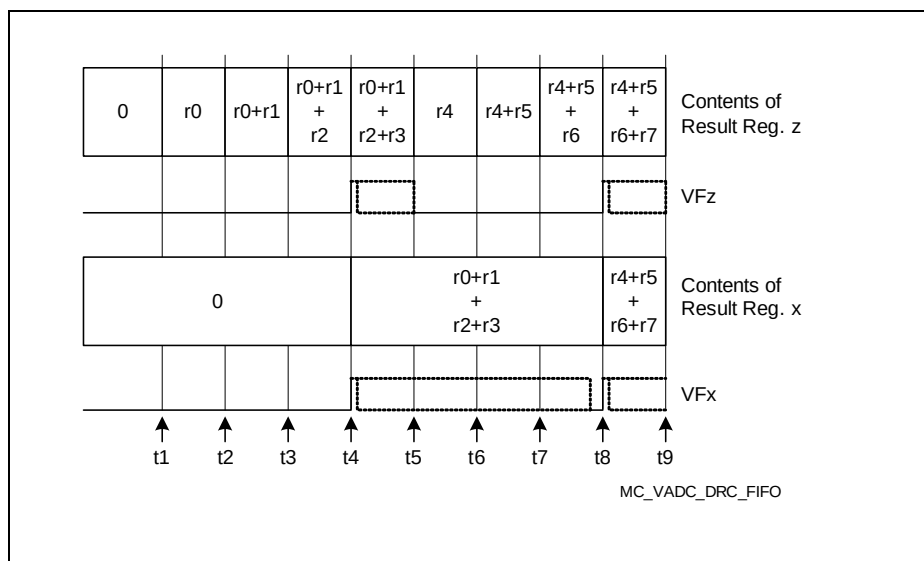


Figure 16-23 Standard Data Reduction Filter with FIFO Enabled

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Finite Impulse Response Filter Mode (FIR)

The FIR filter (see [Figure 16-24](#)) provides 2 result buffers for intermediate results (RB1, RB2) and 3 configurable tap coefficients (a, b, c).

The conversion result and the intermediate result buffer values are added weighted with their respective coefficients to form the final value for the result register. Several predefined sets of coefficients can be selected via bitfield DRCTR (coding listed in [Table 16-5](#)) in registers **G0RESy (y = 0 - 15)** and **GLOBRES**. These coefficients lead to a gain of 3 or 4 to the ADC result producing a 14-bit value. The valid flag (VF) is activated for each sample after activation, i.e. for each sample it generates a valid result.

Note: Conversions for other result registers can be inserted between conversions to be filtered.

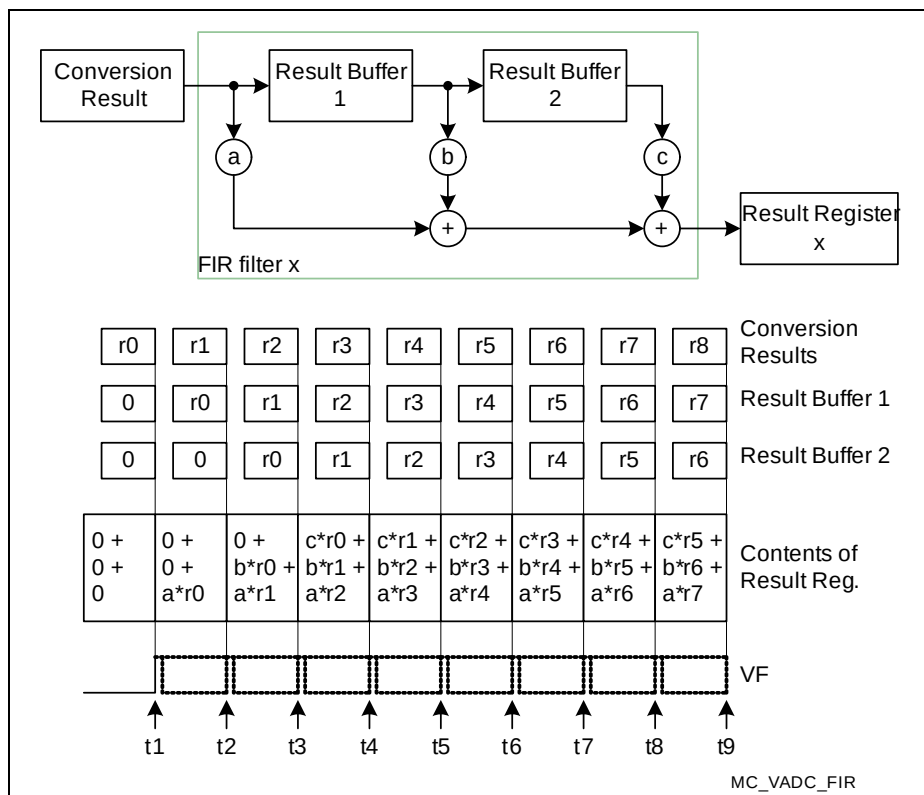


Figure 16-24 FIR Filter Structure

Note: The filter registers are cleared while bitfield DMM $\neq$ 01_B.

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Infinite Impulse Response Filter Mode (IIR)

The IIR filter (see [Figure 16-25](#)) provides a result buffer (RB) and 2 configurable coefficients (a, b). It represents a first order low-pass filter.

The conversion result, weighted with the respective coefficient, and a fraction of the previous result are added to form the final value for the result register. Several predefined sets of coefficients can be selected via bitfield DRCTR (coding listed in [Table 16-5](#)) in registers **G0RESy (y = 0 - 15)** and **GLOBRES**. These coefficients lead to a gain of 4 to the ADC result producing a 14-bit value. The valid flag (VF) is activated for each sample after activation, i.e. for each sample generates a valid result.

Note: Conversions for other result registers can be inserted between conversions to be filtered.

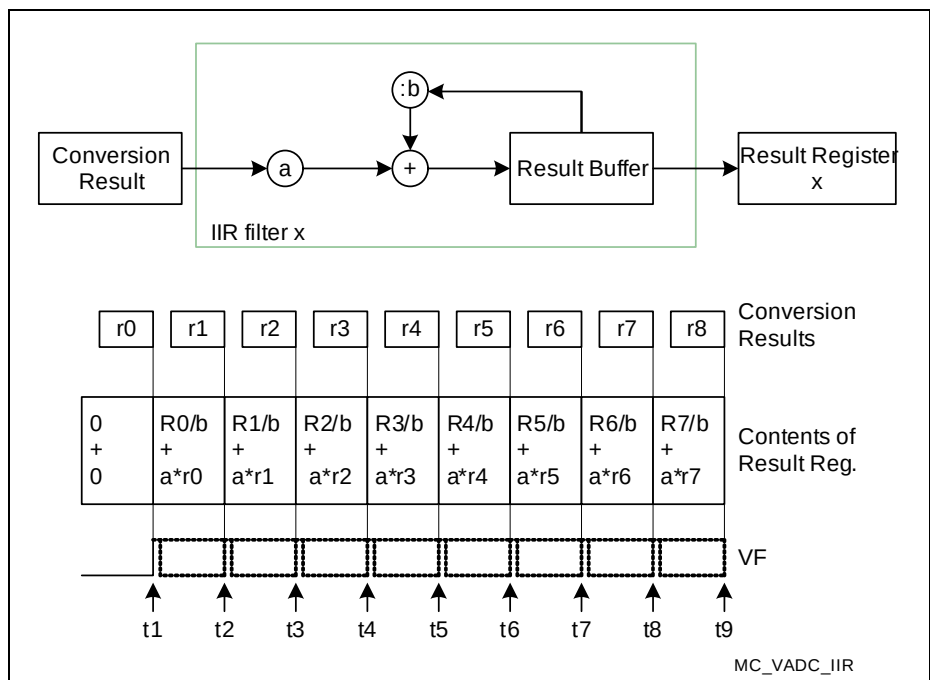


Figure 16-25 IIR Filter Structure

Note: The filter registers are cleared while bitfield DMM $\neq$ 01_B.

Difference Mode

Subtracting the contents of result register 0 from the actual result puts the results of the respective channel in relation to another signal. No software action is required.

The reference channel must store its result(s) into result register 0. The reference value can be determined once and then be used for a series of conversions, or it can be converted before each related conversion.

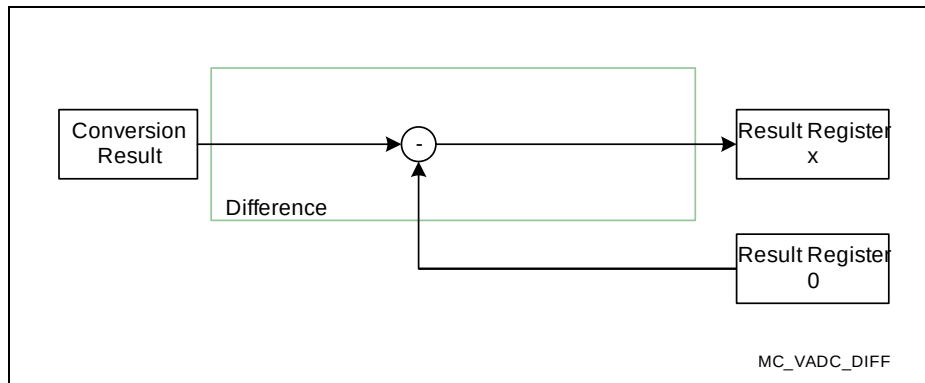


Figure 16-26 Result Difference

16.12 Synchronization of Conversions

The conversions of an ADC kernel can be scheduled either self-timed according to the kernel's configuration or triggered by external (outside the ADC) signals:

Synchronized conversions support parallel conversion of channels within a synchronization group¹⁾. This optimizes e.g. the control of electrical drives.

Equidistant sampling supports conversions in a fixed raster with minimum jitter. This optimizes e.g. filter algorithms or audio applications.

16.12.1 Synchronized Conversions for Parallel Sampling

Several independent ADC kernels¹⁾ implemented in the XMC1200 can be synchronized for simultaneous 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 channels start simultaneously. Synchronized kernels convert the same channel that is requested by the master. 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 (one or more). In the example shown in [Figure 16-27](#), input channels CH3 of the ADC kernels 0 and 1 are converted synchronously, whereas other input channels do not lead to parallel conversions.

One kernel operates as synchronization master, the other kernel(s) operate(s) as synchronization slave. Each kernel can play either role. Master and slave kernels form a "conversion group" to control parallel sampling:

- **The synchronization master** ADC kernel can request a synchronized conversion of a certain channel (SYNC = 1 in the corresponding channel control register **G0CHCTRY** (y = 0 - 7) etc.), which is also requested in the connected slave ADC kernel.
Wait-for-read mode is supported for the master.
- **The synchronization slave** ADC kernel reacts to incoming synchronized conversion requests from the master. While no synchronized conversions are requested, the slave kernel can execute "local" conversions.
 - The slave timing must be configured according to the master timing (ARBRND in register **GxARBPR** (x = 0 - 1)) to enable parallel conversions.
 - A parallel conversion request is always handled with highest priority and cancel-inject-repeat mode.
 - Wait-for-read mode is ignored in the slave. Previous results may be overwritten, in particular, if the same result register is used by other conversions.

1) For a summary, please refer to ["Synchronization Groups in the XMC1200" on Page 16-154](#).

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- The arbiter must run permanently (bit **GxARBPR (x = 0 - 1).ARBM = 0**) for the synchronization slave.
Initialize the slave before the master to have the arbiters run synchronously.
- Once started, a parallel conversion cannot be aborted.

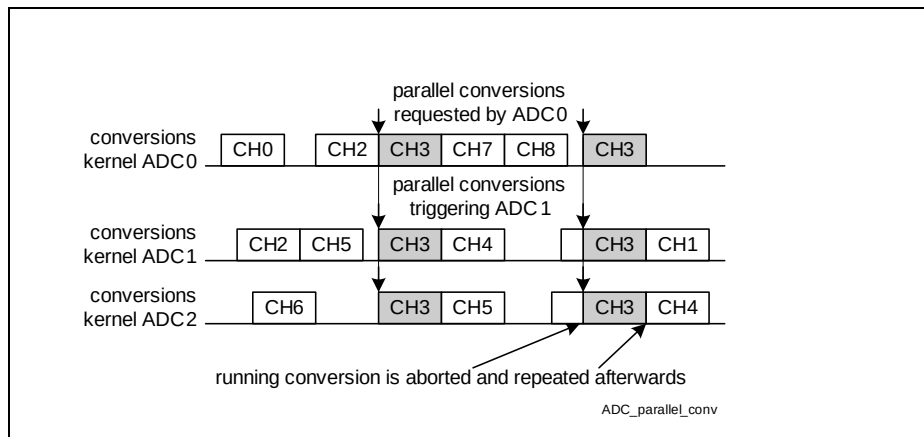


Figure 16-27 Parallel Conversions

The shown example uses synchronized conversions for channel CH3. The other channel conversions are controlled by their own kernels. ADC0 is the master, ADC1 is the slave.

The synchronization master controls the slave by providing the control information **GxARBCFG (x = 0 - 1).ANONS** (see [Figure 16-28](#)) and the requested channel number. Bitfields **GxSYNCTR (x = 0 - 1).STSEL** select the source of the ANON information for the master (00_B) and the slave(s) (01_B/10_B/11_B).

STSEL = 00_B always selects the own ANON information, and is, therefore, meant for the synchronization master or for stand-alone operation. The other control inputs (STSEL = 01_B/10_B/11_B) are connected to the other kernels of a synchronization group in ascending order (see also [Table 16-13 "Synchronization Groups in the XMC1200" on Page 16-154](#)).

The ready signals indicate when a slave kernel is ready to start the sample phase of a parallel conversion. Bit **GxSYNCTR (x = 0 - 1).EVALR1 = 1** enables the control by the ready signal.

Note: Synchronized conversions request the same channel number, defined by the master. Using the alias feature (see [Section 16.8.2](#)), analog signals from different input channels can be converted. This is advantageous if e.g. CH0 is used as alternate reference.

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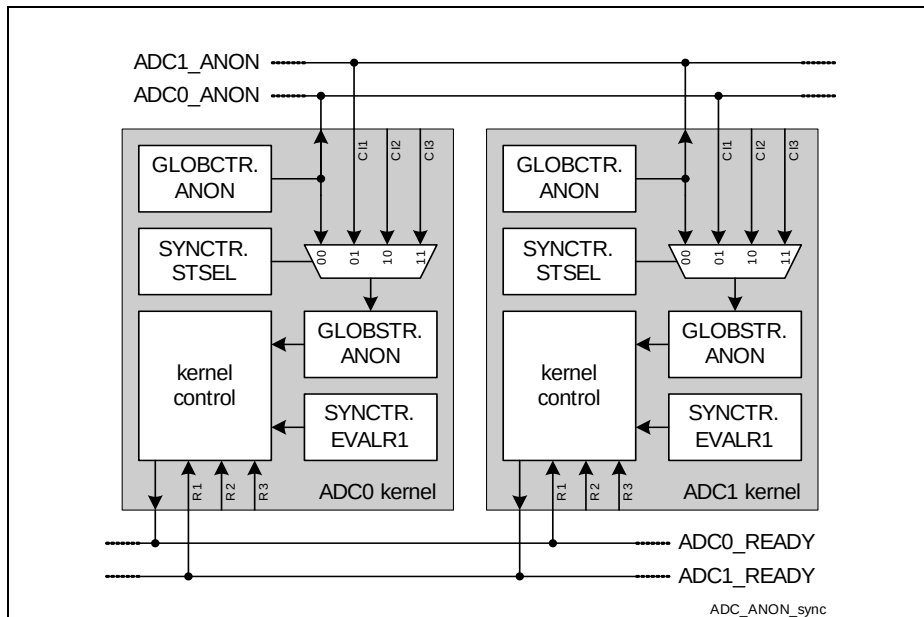


Figure 16-28 Synchronization via ANON and Ready Signals

16.12.2 Equidistant Sampling

To optimize the input data e.g. for filter or audio applications, conversions can be executed in a fixed timing raster. Conversions for equidistant sampling are triggered by an external signal (e.g. a timer). To generate the trigger signal synchronous to the arbiter, the ADC provides an output signal (ARBCNT) that is activated once per arbitration round and serves as timing base for the trigger timer. In this case, the arbiter must run permanently (**GxARBPR (x = 0 - 1).ARBM = 0**). If the timer has an independent time base, the arbiter can be stopped while no requests are pending. The preface time (see [Figure 16-29](#)) must be longer than one arbitration round and the highest possible conversion time.

Select timer mode (TMEN = 1 in register **GxQCTRL0 (x = 0 - 1)** or **GxASCTRL (x = 0 - 1)**) for the intended source of equidistant conversions. In timer mode, a request of this source is triggered and arbitrated, but only started when the trigger signal is removed (see [Figure 16-29](#)) and the converter is idle.

To ensure that the converter is idle and the start of conversion can be controlled by the trigger signal, the equidistant conversion requests must receive highest priority. The preface time between request trigger and conversion start must be long enough for a currently active conversion to finish.

The frequency of signal REQTRx defines the sampling rate and its high time defines the preface time interval where the corresponding request source takes part in the arbitration.

Depending on the used request source, equidistant sampling is also supported for a sequence of 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.

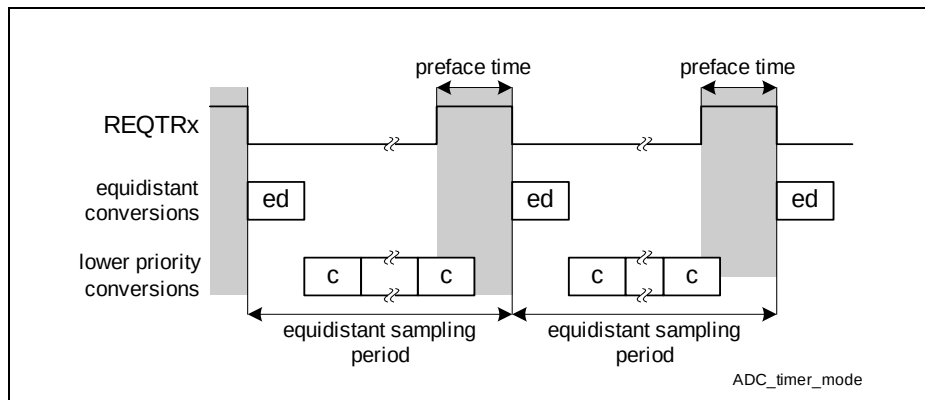


Figure 16-29 Timer Mode for Equidistant Sampling

16.13 Safety Features

Several test features can be enabled to verify the validity of the analog input signals of an application.

- **Broken Wire Detection** validates the connection from the sensor to the input pin,
- **Multiplexer Diagnostics** validates the operation of the internal analog input multiplexer,

16.13.1 Broken Wire Detection

To test the proper connection of an external analog sensor to its input pin, the converter's capacitor can be precharged to a selectable value before the regular sample phase. If the connection to the sensor is interrupted the subsequent conversion value will rather represent the precharged value than the expected sensor result. By using a precharge voltage outside the expected result range (broken wire detection preferably uses V_{AGND} and/or V_{AREF}) a valid measurement (sensor connected) can be distinguished from a failure (sensor detached).

While broken wire detection is disabled, the converter's capacitor is discharged.

Note: The duration of the complete conversion is increased by the preparation phase (same as the sample phase) if the broken wire detection is enabled. This influences the timing of conversion sequences.

Broken wire detection can be enabled for each channel separately by bitfield BWDEN in the corresponding channel control register (**G0CHCTry (y = 0 - 7)**). This bitfield also selects the level for the preparation phase.

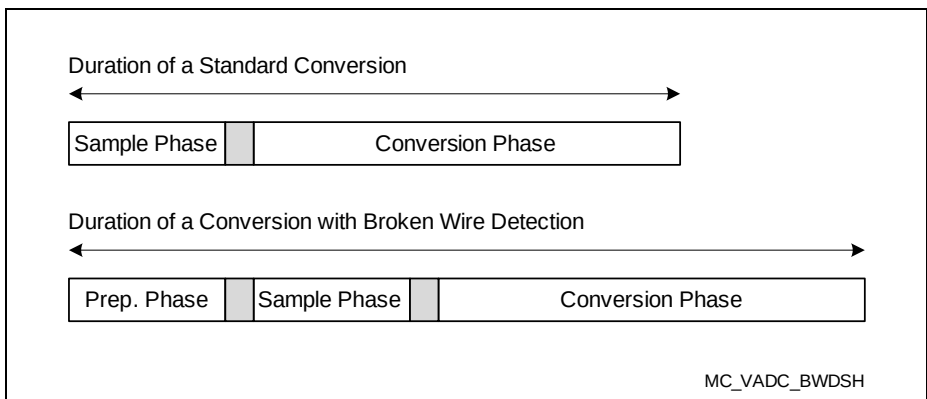


Figure 16-30 Broken Wire Detection

16.13.2 Multiplexer Diagnostics

Additional test structures (pull-ups, pull-downs) can be activated to test the signal path from the sensor to the input pin and the internal signal path from the input pin through the multiplexer to the converter. These pull devices apply additional loads to the signal path.

In combination with a known external input signal this test function shows if the multiplexer connects any pin to the converter input and if this is the correct pin.

The pull devices are activated via the standard port control registers.

16.14 External Multiplexer Control

The number of analog input channels can be increased by connecting external analog multiplexers to an input channel. The ADC can be configured to control these external multiplexers automatically.

For each available EMUX interface (see register [EMUXSEL](#)) one channel can be selected for this operating mode. The ADC supports 1-out-of-8 multiplexers with several control options:

- **Sequence mode** automatically converts all configured external channels when the selected channel is encountered. In the example in [Figure 16-31](#) the following conversions are done: --4-32-31-30-2-1-0--4-32-31-30-2-1-0--...
- **Single-step mode** converts one external channel of the configured sequence when the selected channel is encountered. In the example in [Figure 16-31](#) the following conversions are done: --4-32-2-1-0--4-31-2-1-0--4-30-2-1-0--4-32-... (Single-step mode works best with one channel)
- **Steady mode** converts the configured external channel when the selected channel is encountered. In the example in [Figure 16-31](#) the following conversions are done: --4-32-2-1-0--4-32-2-1-0--4-32-2-1-0--...

Note: The example in [Figure 16-31](#) has an external multiplexer connected to channel CH3. The start selection value EMUXSET is assumed as 2.

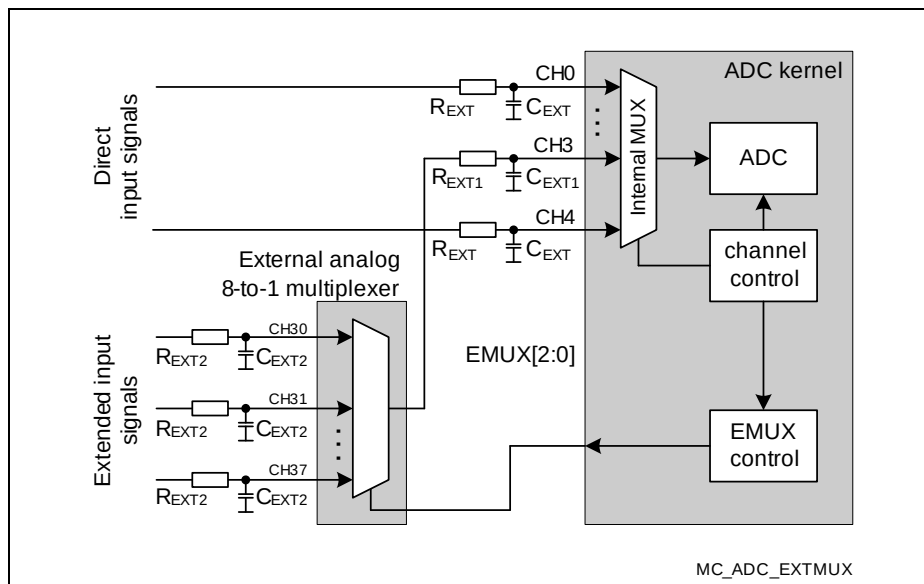


Figure 16-31 External Analog Multiplexer Example

Versatile Analog-to-Digital Converter (VADC)

Bitfield EMUXACT determines the control information sent to the external multiplexer. In single-step mode, EMUXACT is updated after each conversion of an enabled channel. If $EMUXACT = 000_B$ it is reloaded from bitfield EMUXSET, otherwise it is decremented by 1.

Additional external channels may have different properties due to the modified signal path. Local filters may be used at the additional inputs (R_{EXT2} - C_{EXT2} on CH3x in [Figure 16-31](#)). For applications where the external multiplexer is located far from the ADC analog input, it is recommended to add an RC filter directly at the analog input of the ADC (R_{EXT1} - C_{EXT1} on CH3 in [Figure 16-31](#)).

Note: Each RC filter limits the bandwidth of the analog input signal.

Conversions for external channels, therefore, use the alternate conversion mode setting CME. This automatically selects a different conversion mode if required.

Switching the external multiplexer usually requires an additional settling time for the input signal. Therefore, the alternate sample time setting STCE is applied each time the external channel is changed. This automatically fulfills the different sampling time requirements in this case.

In each group an arbitrary channel can be assigned to external multiplexer control (register **GxEMUXCTR** ($x = 0 - 1$)). Each available port interface selects the group whose control lines are output (register **EMUXSEL**).

Control Signals

The external channel number that controls the external multiplexer can be output in standard binary format or Gray-coded. Gray code avoids intermediate multiplexer switching when selecting a sequence of channels, because only one bit changes at a time. [Table 16-6](#) indicates the resulting codes.

Table 16-6 EMUX Control Signal Coding

Channel	0	1	2	3	4	5	6	7
Binary	000_B	001_B	010_B	011_B	100_B	101_B	110_B	111_B
Gray	000	001	011	010	110	111	101	100

Operation Without External Multiplexer

If no external multiplexers are used in an application, the reset values of the control registers provide the appropriate setup.

$EMUXMODE = 00_B$ disables the automatic EMUX control.

Since the control output signals are alternate port output signals, they are only visible at the respective pins if explicitly selected.

16.15 Service Request Generation

Each A/D Converter group can activate up to 4 group-specific service request output signals and up to 4 shared service request output signals. 2 group-specific and 2 shared request signals can issue an interrupt (see [Table 16-15 “Digital Connections in the XMC1200” on Page 16-156](#)).

Several events can be assigned to each service request output. Service requests can be generated by three types of events:

- **Request source events:** indicate that a request source completed the requested conversion sequence and the application software can initiate further actions.
For a scan source (group or background), the event is generated when the complete defined set of channels (pending bits) has been converted.
For a group queue source, the event is generated according to the programming, i.e. when a channel with enabled source interrupt has been converted or when an invalid entry is encountered.
- **Channel events:** indicate that a conversion is finished. Optionally, channel events can be restricted to result values within a programmable value range. This offloads the CPU from background tasks, i.e. a service request is only activated if the specified conversion result range is met or exceeded.
- **Result events:** indicate a new valid result in a result register. Usually, this triggers a read action by the CPU. Optionally, result events can be generated only at a reduced rate if data reduction is active.

Each ADC event is indicated by a dedicated flag that can be cleared by software. If a service request is enabled for a certain event, the service request is generated for each event, independent of the status of the corresponding event indication flag. This ensures that the ADC event can generate a service request without the need to clear the indication flag.

Event flag registers indicate all types of events that occur during the ADC's operation. Software can set each flag by writing a 1 to the respective position in register GxCEFLAG/GxRFLAG to trigger an event. Software can clear each flag by writing a 1 to the respective position in register GxCEFCLR/GxREFCLR. If enabled, service requests are generated for each occurrence of an event, even if the associated flag remains set.

Node Pointer Registers

Requests from each event source can be directed to a set of service request nodes via associated node pointers. Requests from several sources can be directed to the same node; in this case, they are ORed to the service request output signal.

Software Service Request Activation

Each service request can be activated via software by setting the corresponding bit in register **GxSRCT** (**x = 0 - 1**). This can be used for evaluation and testing purposes.

Note: For shared service request lines see common groups in [Table 16-12](#).

Versatile Analog-to-Digital Converter (VADC)

16.16 Registers

The Versatile ADC is built from a series of converter blocks that are controlled in an identical way. This makes programming versatile and scalable. The corresponding registers, therefore, have an individual offset assigned (see [Table 16-8](#)). The exact register location is obtained by adding the respective register offset to the base address (see [Table 16-7](#)) of the corresponding group.

Due to the regular group structure, several registers appear within each group. Other registers are provided for each channel. This is indicated in the register overview table by placeholders:

- $X###_H$ means: $x \times 0400_H + 0###_H$, for $x = 0 - 1$
- $###Y_H$ means: $###0_H + y \times 0004_H$, for $y = 0 - N$ (depends on register type)
- $Z###_H$ means: $4803\ 4000_H + 0###_H$, (SHS0)

Table 16-7 Registers Address Space

Module	Base Address	End Address	Note
VADC0	4803 0000 _H	4803 0BFF _H	

Table 16-8 Registers Overview

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Page Num.
			Read	Write	
ID	Module Identification Register	0008 _H	U, PV	BE	16-71
CLC	Clock Control Register	0000 _H	U, PV	PV	16-72
OCS	OCDS Control and Status Register	0028 _H	U, PV	PV	16-73
GLOBCFG	Global Configuration Register	0080 _H	U, PV	U, PV	16-75
ACCPROT0	Access Protection Register 0	0088 _H	U, PV	U, PV ₁₎	16-78
ACCPROT1	Access Protection Register 1	008C _H	U, PV	U, PV ₁₎	16-79
GxARBCFG	Arbitration Configuration Register	X480 _H	U, PV	U, PV	16-85
GxARBPR	Arbitration Priority Register	X484 _H	U, PV	U, PV	16-88
GxCHASS	Channel Assignment Register, Group x	X488 _H	U, PV	U, PV	16-81
GxRRASS	Result Assignment Register, Group x	X48C _H	U, SV	U, PV	16-82
GxQCTRL0	Queue 0 Source Control Register, Group x	X500 _H	U, PV	U, PV	16-89

Versatile Analog-to-Digital Converter (VADC)
Table 16-8 Registers Overview (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Page Num.
			Read	Write	
GxQMR0	Queue 0 Mode Register, Group x	X504 _H	U, PV	U, PV	16-91
GxQSR0	Queue 0 Status Register, Group x	X508 _H	U, PV	U, PV	16-93
GxQINR0	Queue 0 Input Register, Group x	X510 _H	U, PV	U, PV	16-95
GxQ0R0	Queue 0 Register 0, Group x	X50C _H	U, PV	U, PV	16-97
GxQBUR0	Queue 0 Backup Register, Group x	X510 _H	U, PV	U, PV	16-99
GxASCTRL	Autoscan Source Control Register, Group x	X520 _H	U, PV	U, PV	16-101
GxASMR	Autoscan Source Mode Register, Group x	X524 _H	U, PV	U, PV	16-103
GxASSEL	Autoscan Source Channel Select Register, Group x	X528 _H	U, PV	U, PV	16-105
GxASPND	Autoscan Source Pending Register, Group x	X52C _H	U, PV	U, PV	16-106
BRCTRL	Background Request Source Control Register	0200 _H	U, PV	U, PV	16-107
BRSMR	Background Request Source Mode Register	0204 _H	U, PV	U, PV	16-109
BRSELx	Background Request Source Channel Select Register, Group x	018Y _H	U, PV	U, PV	16-111
BRSPNDx	Background Request Source Channel Pending Register, Group x	01CY _H	U, PV	U, PV	16-112
GxCHCTry	Channel x Control Register	X60Y _H	U, PV	U, PV	16-113
GxICLASS0	Input Class Register 0, Group x	X4A0 _H	U, PV	U, PV	16-115
GxICLASS1	Input Class Register 1, Group x	X4A4 _H	U, PV	U, PV	16-115
GLOBICLASS0	Input Class Register 0, Global	00A0 _H	U, PV	U, PV	16-115
GLOBICLASS1	Input Class Register 1, Global	00A4 _H	U, PV	U, PV	16-115
GxALIAS	Alias Register	X4B0 _H	U, PV	U, PV	16-130

Versatile Analog-to-Digital Converter (VADC)
Table 16-8 Registers Overview (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Page Num.
			Read	Write	
GxBOUND	Boundary Select Register, Group x	X4B8 _H	U, PV	U, PV	16-132
GLOBBOUND	Global Boundary Select Register	00B8 _H	U, PV	U, PV	16-132
GxBFL	Boundary Flag Register, Group x	X4C8 _H	U, PV	U, PV	16-133
GxBFLS	Boundary Flag Software Register, Group x	X4CC _H	U, PV	U, PV	16-134
GxBFLC	Boundary Flag Control Register, Group x	X4D0 _H	U, PV	U, PV	16-135
GxBFLNP	Boundary Flag Node Pointer Register, Group x	X4D4 _H	U, PV	U, PV	16-136
GxRCRy	Group x Result Control Register y	X68Y _H	U, PV	U, PV	16-118
GxRESy	Group x Result Register y	X70Y _H	U, PV	U, PV	16-120
GxRESyDy	Group x Result Register y (debug view)	X78Y _H	U, PV	U, PV	16-121
GLOBRCR	Global Result Control Register	0280 _H	U, PV	U, PV	16-123
GLOBRES	Global Result Register	0300 _H	U, PV	U, PV	16-124
GLOBRESyD	Global Result Register (debug view)	0380 _H	U, PV	U, PV	16-124
GxVFR	Valid Flag Register, Group x	X5F8 _H	U, PV	U, PV	16-125
GxSYNCTR	Synchronization Control Register	X4C0 _H	U, PV	U, PV	16-137
GxEMUXCTR	External Multiplexer Control Register, Group x	X5F0 _H	U, PV	U, PV	16-138
EMUXSEL	External Multiplexer Select Register	03F0 _H	U, PV	U, PV	16-140

Versatile Analog-to-Digital Converter (VADC)
Table 16-8 Registers Overview (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Page Num.
			Read	Write	
GxSEFLAG	Source Event Flag Register, Group x	X588 _H	U, PV	U, PV	16-142
GxCEFLAG	Channel Event Flag Register, Group x	X580 _H	U, PV	U, PV	16-142
GxREFLAG	Result Event Flag Register, Group x	X584 _H	U, PV	U, PV	16-143
GxSEFCLR	Source Event Flag Clear Register, Group x	X598 _H	U, PV	U, PV	16-144
GxCEFCLR	Channel Event Flag Clear Register, Group x	X590 _H	U, PV	U, PV	16-144
GxREFCLR	Result Event Flag Clear Register, Group x	X594 _H	U, PV	U, PV	16-145
GLOBEFLAG	Global Event Flag Register	00E0 _H	U, PV	U, PV	16-145
GxSEVNP	Source Event Node Pointer Register, Group x	X5C0 _H	U, PV	U, PV	16-146
GxCEVNP0	Channel Event Node Pointer Register 0, Group x	X5A0 _H	U, PV	U, PV	16-147
GxREVNP0	Result Event Node Pointer Register 0, Group x	X5B0 _H	U, PV	U, PV	16-148
GxREVNP1	Result Event Node Pointer Register 1, Group x	X5B4 _H	U, PV	U, PV	16-149
GLOBEVNP	Global Event Node Pointer Register	0140 _H	U, PV	U, PV	16-150
GxSRACT	Service Request Software Activation Trigger, Group x	X5C8 _H	U, PV	U, PV	16-152
ID	SHS Module Identification Register	Z008 _H	U, SV	U, SV	16-71
SHSCFG	SHS Configuration Register	Z040 _H	U, SV	U, SV	16-76
CALCTR	SHS Calibration Control Register	Z0BC _H	U, SV	U, SV	16-126
CALGC0	SHS Gain Calibration Control Reg.	Z0C0 _H	U, SV	U, SV	16-128

Versatile Analog-to-Digital Converter (VADC)
Table 16-8 Registers Overview (cont'd)

Register Short Name	Register Long Name	Offset Addr.	Access Mode		Page Num.
			Read	Write	
CALGC1	SHS Gain Calibration Control Reg.	Z0C4 _H	U, SV	U, SV	16-128
GNCTR00	Gain Control Register 0, S&H unit 0	Z180 _H	U, SV	U, SV	16-130
GNCTR10	Gain Control Register 0, S&H unit 1	Z190 _H	U, SV	U, SV	16-130
STEPCFG	SHS Stepper Configuration Register	Z044 _H	U, SV	U, SV	16-83
TIMCFG0	SHS Timing Configuration Register	Z080 _H	U, SV	U, SV	16-84
TIMCFG1	SHS Timing Configuration Register	Z084 _H	U, SV	U, SV	16-84
LOOP	SHS SD Loop Control Register	Z050 _H	U, SV	U, SV	16-141

1) Access to these registers is protected by bit protection scheme described in SCU chapter.

Versatile Analog-to-Digital Converter (VADC)

16.16.1 Module Identification

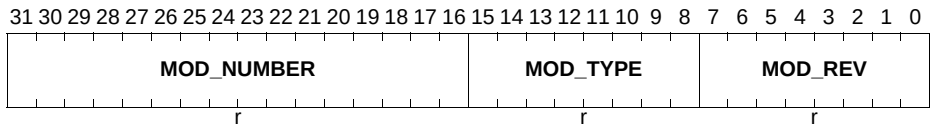
The module identification register indicates the version of the ADC module that is used in the XMC1200.

ID

Module Identification Register (0008_H) **Reset Value: 00C5 C0XX_H**

SHS0_ID

Module Identification Register (4803 4008_H) **Reset Value: 0099 C0XX_H**



Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Indicates the revision number of the implementation. This information depends on the design step.
MOD_TYPE	[15:8]	r	Module Type This internal marker is fixed to C0 _H .
MOD_NUMBER	[31:16]	r	Module Number Indicates the module identification number (00C5 _H = SARADC, 0099 _H = SHS).

Versatile Analog-to-Digital Converter (VADC)

16.16.2 System Registers

A set of standardized registers provides general access to the module and controls basic system functions.

The Clock Control Register **CLC** allows the programmer to adapt the functionality and power consumption of the module to the requirements of the application. Register **CLC** controls the module clock signal and the reactivity to the sleep mode signal.

CLC

Clock Control Register

(0000_H)

Reset Value: 0000 0003_H

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

Field	Bits	Type	Description
DISR	0	rw	Module Disable Request Bit Used for enable/disable control of the module. Also the analog section is disabled by clearing ANONS. 0 _B On request: enable the module clock 1 _B Off request: stop the module clock
DISS	1	r	Module Disable Status Bit 0 _B Module clock is enabled 1 _B Off: module is not clocked
0	2	r	Reserved, write 0, read as 0
EDIS	3	rw	Sleep Mode Enable Control Used to control module's reaction to sleep mode. 0 _B Sleep mode request is enabled and functional 1 _B Module disregards the sleep mode control signal
0	[31:4]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The OCDS control and status register OCS controls the module's behavior in suspend mode (used for debugging) and includes the module-related control bits for the OCDS Trigger Bus (OTGB).

The OCDS Control and Status (OCS) register is cleared by Debug Reset.

The OCS register can only be written when the OCDS is enabled.

If OCDS is being disabled, the OCS register value will not change.

When OCDS is disabled the OCS suspend control is ineffective.

Write access is 32 bit wide only and requires Supervisor Mode.

OCS

OCDS Control and Status Register (0028_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	0	SUS STA	SUS _P	SUS				0	0	0	0	0	0	0	0
r	r	rh	w	rw				r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	TG _P	TGB	TGS	
r	r	r	r	r	r	r	r	r	r	r	r	w	rw	rw	

Field	Bits	Type	Description
TGS	[1:0]	rw	Trigger Set for OTGB0/1 00 _B No Trigger Set output 01 _B Trigger Set 1: TS16_SSIG, input sample signals 10 _B Reserved 11 _B Reserved
TGB	2	rw	OTGB0/1 Bus Select 0 _B Trigger Set is output on OTGB0 1 _B Trigger Set is output on OTGB1
TG_P	3	w	TGS, TGB Write Protection TGS and TGB are only written when TG_P is 1, otherwise unchanged. Read as 0.
0	[23:4]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SUS	[27:24]	rw	OCDS Suspend Control Controls the sensitivity to the suspend signal coming from the OCDS Trigger Switch (OTGS) 0000 _B Will not suspend 0001 _B Hard suspend: Clock is switched off immediately. 0010 _B Soft suspend mode 0: Stop conversions after the currently running one is completed and its result has been stored. No change for the arbiter. 0011 _B Soft suspend mode 1: Stop conversions after the currently running one is completed and its result has been stored. Stop arbiter after the current arbitration round. others: Reserved
SUS_P	28	w	SUS Write Protection SUS is only written when SUS_P is 1, otherwise unchanged. Read as 0.
SUSSTA	29	rh	Suspend State 0 _B Module is not (yet) suspended 1 _B Module is suspended
0	[31:30]	r	Reserved, write 0, read as 0

Table 16-9 TS16_SSIG Trigger Set VADC

Bits	Name	Description
[1:0]	GxSAMPLE	Input signal sample phase of converter group x (x = 1-0)
[15:2]	0	Reserved

Versatile Analog-to-Digital Converter (VADC)

16.16.3 General Registers

The global configuration register provides global control and configuration options that are valid for all converters of the cluster.

GLOBCFG

Global Configuration Register

(0080_H)

Reset Value: 0000 000F_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SU CAL	0	0	0	0	0	0	0	0	0	0	0	0	0	DP CAL 1	DP CAL 0
w	r	r	r	r	r	r	r	r	r	r	r	r	r	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DIV WC	0	0	0	0	0	DIVD		DC MSB	0	0	DIVA				
w	r	r	r	r	r	rw		rw	r	r	rw				

Field	Bits	Type	Description
DIVA	[4:0]	rw	Divider Factor for the Analog Internal Clock Defines the frequency of the basic converter clock f_{ADCI} (base clock for conversion and sample phase). $00_H \quad f_{ADCI} = f_{ADC} / 2^1$ $01_H \quad f_{ADCI} = f_{ADC} / 2$ $02_H \quad f_{ADCI} = f_{ADC} / 3$... $1F_H \quad f_{ADCI} = f_{ADC} / 32$
0	[6:5]	r	Reserved, write 0, read as 0
DCMSB	7	rw	Double Clock for the MSB Conversion Selects an additional clock cycle for the conversion step of the MSB. $0_B \quad 1 \text{ clock cycle for the MSB (standard)}$ $1_B \quad \text{Reserved}$
DIVD	[9:8]	rw	Divider Factor for the Arbiter Clock Defines the frequency of the arbiter clock f_{ADCD} . $00_B \quad f_{ADCD} = f_{ADC}$ $01_B \quad f_{ADCD} = f_{ADC} / 2$ $10_B \quad f_{ADCD} = f_{ADC} / 3$ $11_B \quad f_{ADCD} = f_{ADC} / 4$
0	[14:10]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
DIVWC	15	w	Write Control for Divider Parameters 0_B No write access to divider parameters 1_B Bitfields DIVA, DCMSB, DIVD can be written
DPCALx (x = 0 - 1)	x+16	rw	Disable Post-Calibration 0_B Automatic post-calibration after each conversion of group x 1_B No post-calibration
0	[30:18]	r	Reserved, write 0, read as 0
SUCAL	31	w	Start-Up Calibration The 0-1 transition of bit SUCAL initiates the start-up calibration phase of all calibrated analog converters. 0_B No action 1_B Initiate the start-up calibration phase (indication in bit GxARBCFG.CAL)

1) For valid settings of DIVA, please see [“Conversion Timing” on Page 16-41](#).

SHS0_SHSCFG
SHS Configuration Register
(4803 4040_H)
Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
STATE				TC				0	0	0	0	0	0	SP1	SP0
rh				rw				r	r	r	r	r	r	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SC WC	AN RDY	0	AN OFF	AREF	0	0	0	0	0	0	DIVS				
w	rh	r	rw	rw	r	r	r	r	r	r	rw				

Field	Bits	Type	Description
DIVS	[3:0]	rw	Divider Factor for the SHS Clock Defines the frequency of the clock for the SHS logic and the SAR converter. $0000_B f_{SH} = f_{CONV} / 1$ $0001_B f_{SH} = f_{CONV} / 2$... $1111_B f_{SH} = f_{CONV} / 16$

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
0	[9:4]	r	Reserved, write 0, read as 0
AREF	[11:10]	rw	Analog Reference Voltage Selection 00 _B External reference, upper supply range 01 _B Reserved 10 _B Internal reference, upper supply range 11 _B Internal reference, lower supply range
ANOFF	12	rw	Analog Converter Power Down Force¹⁾ 0 _B Converter controlled by bitfields ANONS (digital control block) 1 _B Converter is permanently off
0	13	r	Reserved, write 0, read as 0
ANRDY	14	rh	Analog Converter Ready 0 _B Converter is in power-down mode 1 _B Converter is operable
SCWC	15	w	Write Control for SHS Configuration 0 _B No write access to SHS configuration 1 _B Bitfields ANOFF, AREF, DIVS can be written
SP0, SP1	16, 17	rh	Sample Pending on S&H Unit x 0 _B No sample pending 1 _B S&H unit x has finished the sample phase
0	[23:18]	r	Reserved, write 0, read as 0
TC	[27:24]	rw	Test Control 1011 _B Internal test functions enabled Others: Normal operation <i>Note: Make sure to write 0000_B to this bitfield for normal operation.</i>
STATE	[31:28]	rh	Current State of Sequencer 0000 _B Idle 0001 _B Offset calibration active 0010 _B Gain calibration active 0011 _B Startup calibration active 1000 _B Stepper process active for S&H unit 0 1001 _B Stepper process active for S&H unit 1 Others: Normal operation

1) See also "Analog Converter Control" on Page 16-14.

Versatile Analog-to-Digital Converter (VADC)

Register Access Control

Several protection schemes are provided to prevent unintended write access to control bitfields of the VADC.

ACCPROT0

Access Protection Register

(0088_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AP GC	0	0	0	0	0	0	0	0	0	0	0	0	0	AP I1	AP I0
rw	r	r	r	r	r	r	r	r	r	r	r	r	r	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AP EM	0	0	0	0	0	0	0	0	0	0	0	0	0	AP C1	AP C0
rw	r	r	r	r	r	r	r	r	r	r	r	r	r	rw	rw

Field	Bits	Type	Description
APC0, APC1	0, 1	rw	Access Protection Channel Control, Group 0 - 1 0 _B Full access to registers 1 _B Write access to channel control registers is blocked
0	[14:2]	r	Reserved, write 0, read as 0
APEM	15	rw	Access Protection External Multiplexer 0 _B Full access to registers 1 _B Write access to external multiplexer registers is blocked
API0, API1	16, 17	rw	Access Protection Initialization, Group 0 - 1 0 _B Full access to registers 1 _B Write access to initialization registers is blocked
0	[30:18]	r	Reserved, write 0, read as 0
APGC	31	rw	Access Protection Global Configuration 0 _B Full access to register 1 _B Write access to global configuration register is blocked

Versatile Analog-to-Digital Converter (VADC)

ACCPROT1

Access Protection Register

(008C_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	0	0	0	0	0	0	0	0	AP R1	AP R0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AP TF	0	0	0	0	0	0	0	0	0	0	0	0	0	AP S1	AP S0
rw	r	r	r	r	r	r	r	r	r	r	r	r	r	rw	rw

Field	Bits	Type	Description
APS0, APS1	0, 1	rw	Access Protection Service Request, Group 0 - 1 0 _B Full access to registers 1 _B Write access to service request registers is blocked
0	[14:2]	r	Reserved, write 0, read as 0
APTF	15	rw	Access Protection Test Function 0 _B Full access to register 1 _B Write access to test function register is blocked
APR0, APR1	16, 17	rw	Access Protection Result Registers, Group 0 - 1 0 _B Full access to registers 1 _B Write access to result registers is blocked
0	[31:18]	r	Reserved, write 0, read as 0

Table 16-10 Register Protection Groups

Control Bits	Registers	Notes
APCx	GxCHCTR0 ... GxCHCTRy	Channel control
APEM	EMUXSEL, GxEMUXCTR	External multiplexer control
APIx	GxARBCFG, GxARBPR, GxCHASS, GxRRASS, GxICLASS0/1, GxSYNCTR	Initialization
APGC	GLOBCFG	Gobal configuration

Versatile Analog-to-Digital Converter (VADC)

Table 16-10 Register Protection Groups (cont'd)

Control Bits	Registers	Notes
APStx	GxSEFLAG, GxSEVNP, GxCEFLAG, GxCEVNP0/1, GxREFLAG, GxREVNP0/1, GxSRACT	Service request control
APTF	-	Test functions
APRx	GxRCR0 ... GxRCR15, GxBOUND, GxRES0 ... GxRES15	Result control

Versatile Analog-to-Digital Converter (VADC)

Priority Channel Assignment

Each channel of a group can be assigned to this group's request sources and is then regarded as a priority channel. An assigned priority channel can only be converted by its own group's request sources. A not assigned channel can also be converted by the background request source.

GxCHASS (x = 0 - 1)

Channel Assignment Register, Group x

$$(x * 0400_H + 0488_H)$$

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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	ASS CH 7	ASS CH 6	ASS CH 5	ASS CH 4	ASS CH 3	ASS CH 2	ASS CH 1	ASS CH 0
r	r	r	r	r	r	r	r	rW	rW	rW	rW	rW	rW	rW	rW

Field	Bits	Type	Description
ASSCH_y (y = 0 - 7)	y	rW	Assignment for Channel y 0 _B Channel y can be a background channel converted with lowest priority 1 _B Channel y is a priority channel within group x
0	[31:8]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Priority Result Register Assignment

Each result register of a group can be assigned to this group's request sources and is then regarded as a reserved resource. An assigned result register can only be written by its own group's request sources. A not assigned result register can also be written by the background request source.

GxRRASS (x = 0 - 1)

Result Assignment Register, Group x

(x * 0400_H + 048C_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ASS RR 15	ASS RR 14	ASS RR 13	ASS RR 12	ASS RR 11	ASS RR 10	ASS RR 9	ASS RR 8	ASS RR 7	ASS RR 6	ASS RR 5	ASS RR 4	ASS RR 3	ASS RR 2	ASS RR 1	ASS RR 0
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Field	Bits	Type	Description
ASSRRy (y = 0 - 15)	y	rW	Assignment for Result Register y 0 _B Result register y can also be written by the background source 1 _B Result register y can only be written by sources within group x
0	[31:16]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The stepper configuration register selects the S&H unit that is serviced during each step of the stepper state machine.

SHS0_STEPCFG

Stepper Configuration Register (4803 4044_H)

Reset Value: 0000 0098_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SEN 7	KSEL7			SEN 6	KSEL6			SEN 5	KSEL5			SEN 4	KSEL4		
rw	rw			rw	rw			rw	rw			rw	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SEN 3	KSEL3			SEN 2	KSEL2			SEN 1	KSEL1			SEN 0	KSEL0		
rw	rw			rw	rw			rw	rw			rw	rw		

Field	Bits	Type	Description
KSEL0, KSEL1, KSEL2, KSEL3, KSEL4, KSEL5, KSEL6, KSEL7	[2:0], [6:4], [10:8], [14:12], [18:16], [22:20], [26:24], [30:28]	rw	Kernel Select Defines the group (i.e. the S&H unit) that is served during this step. The valid values depend on the number of supported kernels/interfaces: 0 ... 1
SEN0, SEN1, SEN2, SEN3, SEN4, SEN5, SEN6, SEN7	3, 7, 11, 15, 19, 23, 27, 31	rw	Step x Enable Defines if or not this step is executed. 0_B Off: This step is not part of the stepper sequence 1_B Active: This step is executed during the sequence

Versatile Analog-to-Digital Converter (VADC)

The timing configuration register TIMCFGx configures the interface timing of the SHS.

SHS0_TIMCFGx (x = 0 - 1)

Timing Configuration Register x

(4803 4080_H + x * 4_H)

Reset Value: 0000 0001_H

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

Field	Bits	Type	Description
AT	0	rw	Accelerated Timing Enables the enhanced conversion timing scheme. 0 _B Compatible timing: Result available after standard conversion time 1 _B Accelerated timing: Result available as soon as converted
0	[3:1]	r	Reserved, write 0, read as 0
FCRT	[7:4]	rw	Fast Compare Mode Response Time Defines the duration of a fast compare operation. A result is generated after (FCRT+1) × 2 × t _{ADCI} . 0 _H Result after t _{ADCI} × 2 ... F _H Result after t _{ADCI} × 32
SST	[13:8]	rw	Short Sample Time Defines the duration of the sample phase. 00 _H Compatible timing: Sample time is defined by DIVA and STC. 01 _H Sample time is t _{ADC} × 1 3F _H Sample time is t _{ADC} × 63
0	[15:14]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
TGEN	[29:16]	rh	Timing Generator Counts the duration of the sample phase, and the conversion in compatible timing mode.
0	[31:30]	r	Reserved, write 0, read as 0

16.16.4 Arbitration and Source Registers

The Arbitration Configuration Register selects the timing and the behavior of the arbiter.

GxARBCFG (x = 0 - 1)

Arbitration Configuration Register, Group x

(x * 0400_H + 0480_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SAMPLE	BUSY	CALS	CAL	0	0	SYNRUN	CHNR				CSRC			ANONS	
rh	rh	rh	rh	r	r	rh	rh				rh			rh	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	ARB M	0	ARBRND		0	0	ANONC	
r	r	r	r	r	r	r	r	rw	r	rw		r	r	rw	

Field	Bits	Type	Description
ANONC	[1:0]	rw	Analog Converter Control Defines the value of bitfield ANONS in a stand-alone converter or a converter in master mode. Coding see ANONS or Section 16.5 .
0	[3:2]	r	Reserved, write 0, read as 0
ARBRND	[5:4]	rw	Arbitration Round Length Defines the number of arbitration slots per arb. round (arbitration round length = t_{ARB}). ¹⁾ 00 _B 4 arbitration slots per round ($t_{ARB} = 4 / f_{ADCD}$) 01 _B 8 arbitration slots per round ($t_{ARB} = 8 / f_{ADCD}$) 10 _B 16 arbitration slots per round ($t_{ARB} = 16 / f_{ADCD}$) 11 _B 20 arbitration slots per round ($t_{ARB} = 20 / f_{ADCD}$)
0	6	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
ARBM	7	rw	Arbitration Mode 0_B The arbiter runs permanently. This setting is required for a synchronization slave (see Section 16.12.1) and for equidistant sampling using the signal ARBCNT (see Section 16.12.2). 1_B The arbiter only runs if at least one conversion request of an enabled request source is pending. This setting ensures a reproducible latency from an incoming request to the conversion start, if the converter is idle. Synchronized conversions are not supported.
0	[15:8]	r	Reserved, write 0, read as 0
ANONS	[17:16]	rh	Analog Converter Control Status Defined by bitfield ANONC in a stand-alone kernel or a kernel in master mode. In slave mode, this bitfield is defined by bitfield ANONC of the respective master kernel. See also Section 16.5 . 00_B Analog converter off 01_B Reserved 10_B Slow standby mode 11_B Normal operation (permanently on)
CSRC	[19:18]	rh	Currently Converted Request Source Indicates the arbitration slot number of the current (BUSY = 1) or of the last (BUSY = 0) conversion. This bitfield is updated when a conversion is started. 00_B Current/last conversion for request source 0 01_B Current/last conversion for request source 1 10_B Current/last conversion for background source 11_B Current/last conversion for synchronization request (slave converter) Other combinations are reserved.
CHNR	[24:20]	rh	Channel Number Indicates the current or last converted analog input channel. This bitfield is updated when a conversion is started.

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SYNRUN	25	rh	Synchronous Conversion Running Indicates that a synchronized (= parallel) conversion is currently running. 0_B Normal conversion or no conversion running 1_B A synchronized conversion is running (cannot be cancelled by higher priority requests!)
0	[27:26]	r	Reserved, write 0, read as 0
CAL	28	rh	Start-Up Calibration Active Indication Indicates the start-up calibration phase of the corresponding analog converter. 0_B Completed or not yet started 1_B Start-up calibration phase is active (set one clock cycle after setting bit SUCAL) <i>Note: Start conversions only after the start-up calibration phase is complete.²⁾</i>
CALS	29	rh	Start-Up Calibration Started Indicates that the start-up calibration has begun. 0_B Requested but not yet started 1_B Start-up calibration has begun <i>Note: Bit CALS is cleared when setting bit SUCAL and is set together with bit CAL.</i>
BUSY	30	rh	Converter Busy Flag 0_B Not busy 1_B Converter is busy with a conversion
SAMPLE	31	rh	Sample Phase Flag 0_B Converting or idle 1_B Input signal is currently sampled

1) The default setting of 4 arbitration slots is sufficient for correct arbitration. The duration of an arbitration round can be increased if required to synchronize requests.

2) The completion of the start-up calibration is indicated by $CAL = 0$ AND $CALS = 1$.
 $CAL = CALS = 0$ indicates that the start-up calibration was requested but has not yet begun.
 $CAL = CALS = 1$ indicates an ongoing calibration phase.

The Arbitration Priority Register defines the request source priority and the conversion start mode for each request source.

Note: Only change priority and conversion start mode settings of a request source while this request source is disabled, and a currently running conversion requested by this source is finished.

Versatile Analog-to-Digital Converter (VADC)

GxARBPR (x = 0 - 1)

Arbitration Priority Register, Group x

(x * 0400_H + 0484_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	AS EN2	AS EN1	AS EN0	0	0	0	0	0	0	0	0
r	r	r	r	r	rw	rw	rw	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	CSM 2	0	PRIO 2	CSM 1	0	PRIO 1	CSM 0	0	PRIO 0	0	PRIO 0	0
r	r	r	r	rw	r	rw	rw	r	rw	rw	r	rw	r	rw	r

Field	Bits	Type	Description
PRIO0, PRIO1, PRIO2	[1:0], [5:4], [9:8]	rw	Priority of Request Source x Arbitration priority of request source x (in slot x) 00 _B Lowest priority is selected. ... 11 _B Highest priority is selected.
CSM0, CSM1, CSM2	3, 7, 11	rw	Conversion Start Mode of Request Source x 0 _B Wait-for-start mode 1 _B Cancel-inject-repeat mode, i.e. this source can cancel conversion of other sources.
0	2, 6, 10, [23:12]	r	Reserved, write 0, read as 0
ASENy (y = 0 - 2)	24 + y	rw	Arbitration Slot y Enable Enables the associated arbitration slot of an arbiter round. The request source bits are not modified by write actions to ASENr. 0 _B The corresponding arbitration slot is disabled and considered as empty. Pending conversion requests from the associated request source are disregarded. 1 _B The corresponding arbitration slot is enabled. Pending conversion requests from the associated request source are arbitrated.
0	[31:27]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The control register of the queue source selects the external gate and/or trigger signals. Write control bits allow separate control of each function with a simple write access.

GxQCTRL0 (x = 0 - 1)

Queue 0 Source Control Register, Group x

(x * 0400_H + 0500_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TM WC	0	0	TM EN	0	0	0	0	GT WC	0	0	GT LVL			GT SEL	
w	r	r	rw	r	r	r	r	w	r	r	rh			rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
XT WC		XT MODE	XT LVL				XT SEL		0	0	0	0			SRCRESREG
w		rw	rh				rw		r	r	r	r			rw

Field	Bits	Type	Description
SRCRESREG	[3:0]	rw	Source-specific Result Register 0000 _B Use GxCHCTry.RESREG to select a group result register 0001 _B Store result in group result register GxRES1 ... 1111 _B Store result in group result register GxRES15
0	[7:4]	r	Reserved, write 0, read as 0
XTSEL	[11:8]	rw	External Trigger Input Selection The connected trigger input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156 <i>Note: XTSEL = 1111_B uses the selected gate input as trigger source (ENGTL must be 0x_B).</i>
XTLVL	12	rh	External Trigger Level Current level of the selected trigger input
XTMODE	[14:13]	rw	Trigger Operating Mode 00 _B No external trigger 01 _B Trigger event upon a falling edge 10 _B Trigger event upon a rising edge 11 _B Trigger event upon any edge

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
XTWC	15	w	Write Control for Trigger Configuration 0_B No write access to trigger configuration 1_B Bitfields XTMODE and XTSEL can be written
GTSEL	[19:16]	rw	Gate Input Selection The connected gate input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156
GTLVL	20	rh	Gate Input Level Current level of the selected gate input
0	[22:21]	r	Reserved, write 0, read as 0
GTWC	23	w	Write Control for Gate Configuration 0_B No write access to gate configuration 1_B Bitfield GTSEL can be written
0	[27:24]	r	Reserved, write 0, read as 0
TMEN	28	rw	Timer Mode Enable 0_B No timer mode: standard gating mechanism can be used 1_B Timer mode for equidistant sampling enabled: standard gating mechanism must be disabled
0	[30:29]	r	Reserved, write 0, read as 0
TMWC	31	w	Write Control for Timer Mode 0_B No write access to timer mode 1_B Bitfield TMEN can be written

Versatile Analog-to-Digital Converter (VADC)

The Queue Mode Register configures the operating mode of a queued request source.

GxQMR0 (x = 0 - 1)

Queue 0 Mode Register, Group x

(x * 0400_H + 0504_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	0	0	0	0	0	0	0	0	0	RPT DIS
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	CEV	FLU SH	TR EV	CLR V	0	0	0	0	0	EN TR	ENGT	
r	r	r	r	w	w	w	w	r	r	r	r	r	rw	rw	

Field	Bits	Type	Description
ENGT	[1:0]	rw	Enable Gate Selects the gating functionality for source 0/2. 00 _B No conversion requests are issued 01 _B Conversion requests are issued if a valid conversion request is pending in the queue 0 register or in the backup register 10 _B Conversion requests are issued if a valid conversion request is pending in the queue 0 register or in the backup register and REQGTx = 1 11 _B Conversion requests are issued if a valid conversion request is pending in the queue 0 register or in the backup register and REQGTx = 0 <i>Note: REQGTx is the selected gating signal.</i>
ENTR	2	rw	Enable External Trigger 0 _B External trigger disabled 1 _B The selected edge at the selected trigger input signal REQTR generates the trigger event
0	[7:3]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CLRV	8	w	Clear Valid 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 (QBUR.V = 1), this entry is cleared, otherwise the entry in queue register 0 is cleared.
TREV	9	w	Trigger Event 0_B No action 1_B Generate a trigger event by software
FLUSH	10	w	Flush Queue 0_B No action 1_B Clear all queue entries (including backup stage) and the event flag EV. The queue contains no more valid entry.
CEV	11	w	Clear Event Flag 0_B No action 1_B Clear bit EV
0	[15:12]	r	Reserved, write 0, read as 0
RPTDIS	16	rw	Repeat Disable 0_B A cancelled conversion is repeated 1_B A cancelled conversion is discarded
0	[31:17]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Queue Status Register indicates the current status of the queued 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).

GxQSR0 (x = 0 - 1)

Queue 0 Status Register, Group x

(x * 0400_H + 0508_H)

Reset Value: 0000 0020_H

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

Field	Bits	Type	Description
FILL	[3:0]	rh	Filling Level for Queue 2 Indicates the number of valid queue entries. 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. 0000 _B There is 1 (if EMPTY = 0) or no (if EMPTY = 1) valid entry in the queue 0001 _B There are 2 valid entries in the queue 0010 _B There are 3 valid entries in the queue ... 0111 _B There are 8 valid entries in the queue others: Reserved
0	4	r	Reserved, write 0, read as 0
EMPTY	5	rh	Queue Empty 0 _B There are valid entries in the queue (see FILL) 1 _B No valid entries (queue is empty)
0	6	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
REQGT	7	rh	Request Gate Level Monitors the level at the selected REQGT input. 0 _B The gate input is low 1 _B The gate input is high
EV	8	rh	Event Detected 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 No trigger event 1 _B A trigger event has been detected
0	[31:9]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Queue Input Register is the entry point for conversion requests of a queued request source.

GxQINR0 (x = 0 - 1)

Queue 0 Input Register, Group x

(x * 0400_H + 0510_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	EX TR	EN SI	RF	REQCHNR				
r	r	r	r	r	r	r	r	w	w	w	w				

Field	Bits	Type	Description
REQCHNR	[4:0]	w	Request Channel Number Defines the channel number to be converted
RF	5	w	Refill 0 _B No refill: this queue entry is converted once and then invalidated 1 _B Automatic refill: this queue entry is automatically reloaded into QINRx when the related conversion is started
ENSI	6	w	Enable Source Interrupt 0 _B No request source interrupt 1 _B A request source event interrupt is generated upon a request source event (related conversion is finished)
EXTR	7	w	External Trigger Enables 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, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

*Note: Registers QINRx share addresses with registers QBURx.
Write operations target the control bits in register QINRx. Read operations return
the status bits from register QBURx.*

Versatile Analog-to-Digital Converter (VADC)

The queue registers 0 monitor the status of the pending request (queue stage 0).

GxQ0R0 (x = 0 - 1)

Queue 0 Register 0, Group x ($x * 0400_H + 050C_H$) **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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	V	EX TR	EN SI	RF	REQCHNR				
r	r	r	r	r	r	r	rh	rh	rh	rh	rh				

Field	Bits	Type	Description
REQCHNR	[4:0]	rh	Request Channel Number Stores the channel number to be converted.
RF	5	rh	Refill Selects the handling of handled requests. 0 _B The request is discarded after the conversion start. 1 _B The request is automatically refilled into the queue after the conversion start.
ENSI	6	rh	Enable Source Interrupt 0 _B No request source interrupt 1 _B A request source event interrupt is generated upon a request source event (related conversion is finished)
EXTR	7	rh	External Trigger Enables external trigger events. 0 _B A valid queue entry immediately leads to a conversion request 1 _B The request handler waits for a trigger event
V	8	rh	Request Channel Number Valid Indicates a valid queue entry in queue register 0. 0 _B No valid queue entry 1 _B The queue entry is valid and leads to a conversion request

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
0	[31:9]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Queue Backup Registers monitor the status of an aborted queued request.

GxQBUR0 (x = 0 - 1)

Queue 0 Backup Register, Group x

(x * 0400_H + 0510_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	V	EXT R	EN SI	RF	REQCHNR				
r	r	r	r	r	r	r	rh	rh	rh	rh	rh				

Field	Bits	Type	Description
REQCHNR	[4:0]	rh	Request Channel Number The channel number of the aborted conversion that has been requested by this request source
RF	5	rh	Refill The refill control bit of the aborted conversion
ENSI	6	rh	Enable Source Interrupt The enable source interrupt control bit of the aborted conversion
EXTR	7	rh	External Trigger The external trigger control bit of the aborted conversion
V	8	rh	Request Channel Number Valid Indicates if the entry (REQCHNR, RF, TR, ENSI) in the queue backup register is valid. Bit V is set when a running conversion (that has been requested by this request source) is aborted, it is cleared when the aborted conversion is restarted. 0 _B Backup register not valid 1 _B Backup register contains a valid entry. This will be requested before a valid entry in queue register 0 (stage 0) will be requested.
0	[31:9]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

*Note: Registers QBURx share addresses with registers QINRx.
Read operations return the status bits from register QBURx. Write operations target the control bits in register QINRx.*

Versatile Analog-to-Digital Converter (VADC)

Registers of Group Scan Source

There is a separate register set for each group scan source. These sources can be operated independently.

The control register of the autoscan source selects the external gate and/or trigger signals.

Write control bits allow separate control of each function with a simple write access.

GxASCTRL (x = 0 - 1)

Autoscan Source Control Register, Group x

(x * 0400_H + 0520_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TM WC	0	0	TM EN	0	0	0	0	GT WC	0	0	GT LVL			GT SEL	
w	r	r	rw	r	r	r	r	w	r	r	rh			rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
XT WC		XT MODE	XT LVL					XT SEL	0	0	0	0			SRCRESREG
w		rw	rh					rw	r	r	r	r			rw

Field	Bits	Type	Description
SRCRESREG	[3:0]	rw	Source-specific Result Register 0000 _B Use GxCHCTry.RESREG to select a group result register 0001 _B Store result in group result register GxRES1 ... 1111 _B Store result in group result register GxRES15
0	[7:4]	r	Reserved, write 0, read as 0
XTSEL	[11:8]	rw	External Trigger Input Selection The connected trigger input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156 <i>Note: XTSEL = 1111_B uses the selected gate input as trigger source (ENGt must be 0x_B).</i>
XTLVL	12	rh	External Trigger Level Current level of the selected trigger input

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
XTMODE	[14:13]	rw	Trigger Operating Mode 00 _B No external trigger 01 _B Trigger event upon a falling edge 10 _B Trigger event upon a rising edge 11 _B Trigger event upon any edge
XTWC	15	w	Write Control for Trigger Configuration 0 _B No write access to trigger configuration 1 _B Bitfields XTMODE and XTSEL can be written
GTSEL	[19:16]	rw	Gate Input Selection The connected gate input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156
GTLVL	20	rh	Gate Input Level Current level of the selected gate input
0	[22:21]	r	Reserved, write 0, read as 0
GTWC	23	w	Write Control for Gate Configuration 0 _B No write access to gate configuration 1 _B Bitfield GTSEL can be written
0	[27:24]	r	Reserved, write 0, read as 0
TMEN	28	rw	Timer Mode Enable 0 _B No timer mode: standard gating mechanism can be used 1 _B Timer mode for equidistant sampling enabled: standard gating mechanism must be disabled
0	[30:29]	r	Reserved, write 0, read as 0
TMWC	31	w	Write Control for Timer Mode 0 _B No write access to timer mode 1 _B Bitfield TMEN can be written

Versatile Analog-to-Digital Converter (VADC)

The Conversion Request Mode Register configures the operating mode of the channel scan request source.

GxASMR (x = 0 - 1)

Autoscan Source Mode Register, Group x

(x * 0400_H + 0524_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	0	0	0	0	0	0	0	0	0	RPT DIS
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	LD EV	CLR PND	REQ GT	0	LDM	SCAN	EN SI	EN TR		
r	r	r	r	r	r	w	w	rh	r	rw	rw	rw	rw		rw

Field	Bits	Type	Description
ENG T	[1:0]	rw	Enable Gate Selects the gating functionality for source 1. 00 _B No conversion requests are issued 01 _B Conversion requests are issued if at least one pending bit is set 10 _B Conversion requests are issued if at least one pending bit is set and REQGTx = 1. 11 _B Conversion requests are issued if at least one pending bit is set and REQGTx = 0. <i>Note: REQGTx is the selected gating signal.</i>
EN TR	2	rw	Enable External Trigger 0 _B External trigger disabled 1 _B The selected edge at the selected trigger input signal REQTR generates the load event
EN SI	3	rw	Enable Source Interrupt 0 _B No request source interrupt 1 _B A request source interrupt is generated upon a request source event (last pending conversion is finished)

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SCAN	4	rw	Autoscan Enable 0_B No autoscan 1_B Autoscan functionality enabled: a request source event automatically generates a load event
LDM	5	rw	Autoscan Source Load Event Mode 0_B Overwrite mode: Copy all bits from the select registers to the pending registers upon a load event 1_B Combine mode: Set all pending bits that are set in the select registers upon a load event (logic OR)
0	6	r	Reserved, write 0, read as 0
REQGT	7	rh	Request Gate Level Monitors the level at the selected REQGT input. 0_B The gate input is low 1_B The gate input is high
CLRPND	8	w	Clear Pending Bits 0_B No action 1_B The bits in register GxASPNDx are cleared
LDEV	9	w	Generate Load Event 0_B No action 1_B A load event is generated
0	[15:10]	r	Reserved, write 0, read as 0
RPTDIS	16	rw	Repeat Disable 0_B A cancelled conversion is repeated 1_B A cancelled conversion is discarded
0	[31:17]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Channel Select Register selects the channels to be converted by the group scan request source. Its bits are used to update the pending register, when a load event occurs.

The number of valid channel bits depends on the channels available in the respective product type (please refer to **“Product-Specific Configuration” on Page 16-153**).

GxASSEL (x = 0 - 1)

Autoscan Source Channel Select Register, Group x

(x * 0400_H + 0528_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CH SEL	CH SEL	CH SEL	CH SEL	CH SEL	CH SEL	CH SEL	CH SEL
r	r	r	r	r	r	r	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh
								7	6	5	4	3	2	1	0

Field	Bits	Type	Description
CHSELy (y = 0 - 7)	y	rwh	Channel Selection Each bit (when set) enables the corresponding input channel of the respective group to take part in the scan sequence. 0 _B Ignore this channel 1 _B This channel is part of the scan sequence
0	[31:8]	r	Reserved, write 0, read as 0

Note: Register GxASSEL is also updated when writing a pattern to register GxASPND.

The Channel Pending Register indicates the channels to be converted in the current conversion sequence. They are updated from the select register, when a load event occurs.

Versatile Analog-to-Digital Converter (VADC)

GxASPND (x = 0 - 1)

Autoscan Source Pending Register, Group x

(x * 0400_H + 052C_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CH PND 7	CH PND 6	CH PND 5	CH PND 4	CH PND 3	CH PND 2	CH PND 1	CH PND 0
r	r	r	r	r	r	r	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
CHPNDy (y = 0 - 7)	y	rwh	Channels Pending Each bit (when set) request the conversion of the corresponding input channel of the respective group. 0 _B Ignore this channel 1 _B Request conversion of this channel
0	[31:8]	r	Reserved, write 0, read as 0

Note: Writing to register GxASPND automatically updates register GxASSEL.

Versatile Analog-to-Digital Converter (VADC)

Registers of Background Scan Source

There is a single register set for the background scan source. This source is common for the complete VADC.

The control register of the background request source selects the external gate and/or trigger signals.

Write control bits allow separate control of each function with a simple write access.

BRCTRL

Background Request Source Control Register

(0200_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	0	0	GT WC	0	0	GT LVL			GT SEL	
r	r	r	r	r	r	r	r	w	r	r	rh			rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
XT WC	XT MODE	XT LVL			XT SEL			0	0	0	0				SRCRESREG
w	rw	rh			rw			r	r	r	r				rw

Field	Bits	Type	Description
SRCRESREG	[3:0]	rw	Source-specific Result Register 0000 _B Use GxCHCTRY.RESREG to select a group result register 0001 _B Store result in group result register GxRES1 ... 1111 _B Store result in group result register GxRES15
0	[7:4]	r	Reserved, write 0, read as 0
XTSEL	[11:8]	rw	External Trigger Input Selection The connected trigger input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156 <i>Note: XTSEL = 1111_B uses the selected gate input as trigger source (ENGTL must be 0X_B).</i>
XTLVL	12	rh	External Trigger Level Current level of the selected trigger input

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
XTMODE	[14:13]	rw	Trigger Operating Mode 00 _B No external trigger 01 _B Trigger event upon a falling edge 10 _B Trigger event upon a rising edge 11 _B Trigger event upon any edge
XTWC	15	w	Write Control for Trigger Configuration 0 _B No write access to trigger configuration 1 _B Bitfields XTMODE and XTSEL can be written
GTSEL	[19:16]	rw	Gate Input Selection The connected gate input signals are listed in Table 16-15 “Digital Connections in the XMC1200” on Page 16-156
GTLVL	20	rh	Gate Input Level Current level of the selected gate input
0	[22:21]	r	Reserved, write 0, read as 0
GTWC	23	w	Write Control for Gate Configuration 0 _B No write access to gate configuration 1 _B Bitfield GTSEL can be written
0	[31:24]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Conversion Request Mode Register configures the operating mode of the background request source.

BRSMR

Background Request Source Mode Register

(0204_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	0	0	0	0	0	0	0	0	0	RPT DIS
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	LD EV	CLR PND	REQ GT	0	LDM	SCAN	EN SI	EN TR	ENGT	
r	r	r	r	r	r	w	w	rh	r	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ENGT	[1:0]	rw	Enable Gate Selects the gating functionality for source 1. 00 _B No conversion requests are issued 01 _B Conversion requests are issued if at least one pending bit is set 10 _B Conversion requests are issued if at least one pending bit is set and REQGTx = 1. 11 _B Conversion requests are issued if at least one pending bit is set and REQGTx = 0. <i>Note: REQGTx is the selected gating signal.</i>
ENTR	2	rw	Enable External Trigger 0 _B External trigger disabled 1 _B The selected edge at the selected trigger input signal REQTR generates the load event
ENSI	3	rw	Enable Source Interrupt 0 _B No request source interrupt 1 _B A request source interrupt is generated upon a request source event (last pending conversion is finished)

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SCAN	4	rw	Autoscan Enable 0_B No autoscan 1_B Autoscan functionality enabled: a request source event automatically generates a load event
LDM	5	rw	Autoscan Source Load Event Mode 0_B Overwrite mode: Copy all bits from the select registers to the pending registers upon a load event 1_B Combine mode: Set all pending bits that are set in the select registers upon a load event (logic OR)
0	6	r	Reserved, write 0, read as 0
REQGT	7	rh	Request Gate Level Monitors the level at the selected REQGT input. 0_B The gate input is low 1_B The gate input is high
CLRPND	8	w	Clear Pending Bits 0_B No action 1_B The bits in registers BRSPNDx are cleared
LDEV	9	w	Generate Load Event 0_B No action 1_B A load event is generated
0	[15:10]	r	Reserved, write 0, read as 0
RPTDIS	16	rw	Repeat Disable 0_B A cancelled conversion is repeated 1_B A cancelled conversion is discarded
0	[31:17]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Channel Select Registers select the channels to be converted by the background request source (channel scan source). Its bits are used to update the pending registers, when a load event occurs.

The number of valid channel bits depends on the channels available in the respective product type (please refer to **“Product-Specific Configuration” on Page 16-153**).

*Note: Priority channels selected in registers **GxCHASS (x = 0 - 1)** will not be converted.*

BRSELx (x = 0 - 1)

Background Request Source Channel Select Register, Group x
(0180_H + x * 0004_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CH SEL G7	CH SEL G6	CH SEL G5	CH SEL G4	CH SEL G3	CH SEL G2	CH SEL G1	CH SEL G0
r	r	r	r	r	r	r	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
CHSELGy (y = 0 - 7)	y	rwh	Channel Selection Group x Each bit (when set) enables the corresponding input channel of the respective group to take part in the background scan sequence. 0 _B Ignore this channel 1 _B This channel is part of the scan sequence
0	[31:8]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Channel Pending Registers indicate the channels to be converted in the current conversion sequence. They are updated from the select registers, when a load event occurs.

BRSPNDx (x = 0 - 1)

Background Request Source Pending Register, Group x

(01C0_H + x * 0004_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CH PND G7	CH PND G6	CH PND G5	CH PND G4	CH PND G3	CH PND G2	CH PND G1	CH PND G0
r	r	r	r	r	r	r	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
CHPNDGy (y = 0 - 7)	y	rwh	Channels Pending Group x Each bit (when set) request the conversion of the corresponding input channel of the respective group. 0 _B Ignore this channel 1 _B Request conversion of this channel
0	[31:8]	r	Reserved, write 0, read as 0

Note: Writing to any of registers BRSPNDx automatically updates the corresponding register BRSELx and generates a load event that copies all bits from all registers BRSELx to BRSPNDx.

Use this shortcut only when writing the last word of the request pattern.

16.16.5 Channel Control Registers

G0CHCTry (y = 0 - 7)

Group 0, Channel y Ctrl. Reg. (0600_H + y * 0004_H) **Reset Value: 0000 0000_H**

G1CHCTry (y = 0 - 7)

Group 1, Channel y Ctrl. Reg. (0A00_H + y * 0004_H) **Reset Value: 0000 0000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	BWD EN	BWD CH	0	0	0	0	0	0	0	RES POS	RES TBS	RESREG			
r	rw	rw	r	r	r	r	r	r	r	rw	rw	rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BNDSELX				REF SEL	SY NC	CHEV MODE		BNDSELU		BNDSELL		0	0	ICLSEL	
rw				rw	rw	rw		rw		rw		r	r	rw	

Field	Bits	Type	Description
ICLSEL	[1:0]	rw	Input Class Select 00 _B Use group-specific class 0 01 _B Use group-specific class 1 10 _B Use global class 0 11 _B Use global class 1
0	[3:2]	r	Reserved, write 0, read as 0
BNDSELL	[5:4]	rw	Lower Boundary Select¹⁾ 00 _B Use group-specific boundary 0 01 _B Use group-specific boundary 1 10 _B Use global boundary 0 11 _B Use global boundary 1
BNDSELU	[7:6]	rw	Upper Boundary Select¹⁾ 00 _B Use group-specific boundary 0 01 _B Use group-specific boundary 1 10 _B Use global boundary 0 11 _B Use global boundary 1

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CHEVMODE	[9:8]	rw	Channel Event Mode Generate a channel event either in normal compare mode (NCM) with limit checking ²⁾ or in Fast Compare Mode (FCM) ³⁾ 00 _B Never 01 _B NCM: If result is inside the boundary band FCM: If result becomes high (above cmp. val.) 10 _B NCM: If result is outside the boundary band FCM: If result becomes low (below cmp. val.) 11 _B NCM: Always (ignore band) FCM: If result switches to either level
SYNC	10	rw	Synchronization Request 0 _B No synchroniz. request, standalone operation 1 _B Request a synchronized conversion of this channel (only taken into account for a master)
REFSEL	11	rw	Reference Input Selection Defines the reference voltage input to be used for conversions on this channel. 0 _B Standard reference Ground V _{SS} 1 _B Alternate reference Ground from CH0 ⁴⁾
BNDSELX	[15:12]	rw	Boundary Extension¹⁾ 0000 _B Standard mode: select boundaries via BNDSELU/BNDSSELL 0001 _B Use result reg. GxRES1 as upper boundary ... 1111 _B Use result reg. GxRES15 as upper boundary
RESREG	[19:16]	rw	Result Register 0000 _B Store result in group result register GxRES0 ... 1111 _B Store result in group result register GxRES15
RESTBS	20	rw	Result Target for Background Source 0 _B Store results in the selected group result register 1 _B Store results in the global result register
RESPOS	21	rw	Result Position 0 _B Store results left-aligned 1 _B Store results right-aligned
0	[27:22]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
BWDCH	[29:28]	rw	Broken Wire Detection Channel 00 _B Select V_{AREF} 01 _B Select V_{AGND} 10 _B Reserved 11 _B Reserved
BWDEN	30	rw	Broken Wire Detection Enable 0 _B Normal operation 1 _B Additional preparation phase is enabled
0	31	r	Reserved, write 0, read as 0

- 1) While BNDSELX $\neq$ 0000_B, bitfields BNDSELU and BNDSELL are concatenated and select the corresponding result register as lower boundary.
- 2) The boundary band is defined as the area where the result is less than or equal to the selected upper boundary and greater than or equal to the selected lower boundary, see [Section 16.8.4](#).
- 3) The result is bit FCR in the selected result register.
- 4) Some channels cannot select an alternate reference.

GxICLASS0 (x = 0 - 1)

Input Class Register 0, Group x

$$(x * 0400_H + 04A0_H)$$

Reset Value: 0000 0000_H

GxICLASS1 (x = 0 - 1)

Input Class Register 1, Group x

$$(x * 0400_H + 04A4_H)$$

Reset Value: 0000 0000_H

GLOBICLASSy (y = 0 - 1)

Input Class Register y, Global

$$(00A0_H + y * 0004_H)$$

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	CME		0	0	0	STCE					
r	r	r	r	r	rw		r	r	r	rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	CMS		0	0	0	STCS					
r	r	r	r	r	rw		r	r	r	rw					

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
STCS	[4:0]	rw	Sample Time Control for Standard Conversions Number of additional clock cycles to be added to the minimum sample phase of 2 analog clock cycles: Coding and resulting sample time see Table 16-11 . For conversions of external channels, the value from bitfield STCE can be used.
0	[7:5]	r	Reserved, write 0, read as 0
CMS	[10:8]	rw	Conversion Mode for Standard Conversions 000 _B 12-bit conversion 001 _B 10-bit conversion 010 _B 8-bit conversion 011 _B Reserved 100 _B Reserved 101 _B 10-bit fast compare mode 110 _B Reserved 111 _B Reserved
0	[15:11]	r	Reserved, write 0, read as 0
STCE	[20:16]	rw	Sample Time Control for EMUX Conversions Number of additional clock cycles to be added to the minimum sample phase of 2 analog clock cycles: Coding and resulting sample time see Table 16-11 . For conversions of standard channels, the value from bitfield STCS is used.
0	[23:21]	r	Reserved, write 0, read as 0
CME	[26:24]	rw	Conversion Mode for EMUX Conversions 000 _B 12-bit conversion 001 _B 10-bit conversion 010 _B 8-bit conversion 011 _B Reserved 100 _B Reserved 101 _B 10-bit fast compare mode 110 _B Reserved 111 _B Reserved
0	[31:27]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Table 16-11 Sample Time Coding

STCS / STCE	Additional Clock Cycles	Sample Time
0 0000 _B	0	$2 / f_{\text{ADCI}}$
0 0001 _B	1	$3 / f_{\text{ADCI}}$
...	...	...
0 1111 _B	15	$17 / f_{\text{ADCI}}$
1 0000 _B	16	$18 / f_{\text{ADCI}}$
1 0001 _B	32	$34 / f_{\text{ADCI}}$
...	...	...
1 1110 _B	240	$242 / f_{\text{ADCI}}$
1 1111 _B	256	$258 / f_{\text{ADCI}}$

Versatile Analog-to-Digital Converter (VADC)

16.16.6 Result Registers

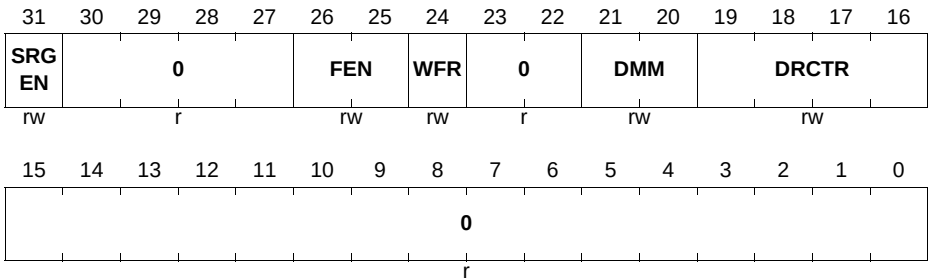
The group result control registers select the behavior of the result registers of a given group.

G0RCRy (y = 0 - 15)

Group 0 Result Control Reg. y (0680_H + y * 0004_H) **Reset Value: 0000 0000_H**

G1RCRy (y = 0 - 15)

Group 1 Result Control Reg. y (0A80_H + y * 0004_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
0	[15:0]	r	Reserved, write 0, read as 0
DRCTR	[19:16]	rw	Data Reduction Control Defines how result values are stored/accumulated in this register for the final result. The data reduction counter DRC can be loaded from this bitfield. The function of bitfield DRCTR is determined by bitfield DMM.
DMM	[21:20]	rw	Data Modification Mode 00 _B Standard data reduction (accumulation) 01 _B Result filtering mode ¹⁾ 10 _B Difference mode 11 _B Reserved See “Data Modification” on Page 16-49
0	[23:22]	r	Reserved, write 0, read as 0
WFR	24	rw	Wait-for-Read Mode Enable 0 _B Overwrite mode 1 _B Wait-for-read mode enabled for this register

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Field	Bits	Type	Description
FEN	[26:25]	rw	FIFO Mode Enable 00 _B Separate result register 01 _B Part of a FIFO structure: copy each new valid result 10 _B Maximum mode: copy new result if bigger 11 _B Minimum mode: copy new result if smaller
0	[30:27]	r	Reserved, write 0, read as 0
SRGEN	31	rw	Service Request Generation Enable 0 _B No service request 1 _B Service request after a result event

1) The filter registers are cleared while bitfield DMM ≠ 01_B.

Versatile Analog-to-Digital Converter (VADC)

The group result registers provide a selectable storage location for all channels of a given group.

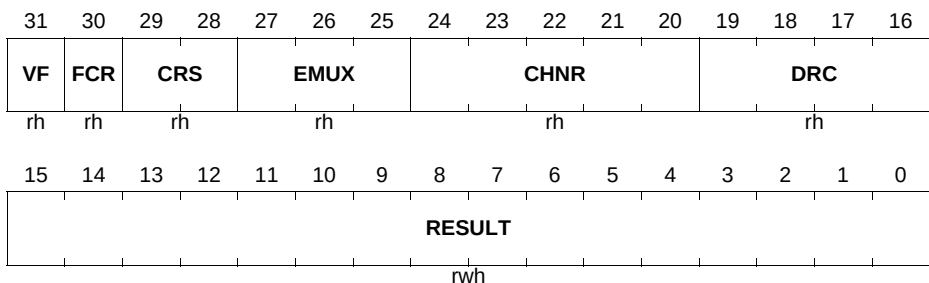
Note: The preset value used in fast compare mode is written to the respective result register. The debug result registers are not writable.

G0RESy (y = 0 - 15)

Group 0 Result Register y $(0700_H + y * 0004_H)$ **Reset Value: 0000 0000_H**

G1RESy (y = 0 - 15)

Group 1 Result Register y $(0B00_H + y * 0004_H)$ **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
RESULT	[15:0]	rwh	Result of Most Recent Conversion The position of the result bits within this bitfield depends on the configured operating mode. Please, refer to Section 16.11.2 .
DRC	[19:16]	rh	Data Reduction Counter Indicates the number of values still to be accumulated for the final result. The final result is available and valid flag VF is set when bitfield DRC becomes zero (by decrementing or by reload). See “Data Modification” on Page 16-49
CHNR	[24:20]	rh	Channel Number Indicates the channel number corresponding to the value in bitfield RESULT.
EMUX	[27:25]	rh	External Multiplexer Setting Indicates the setting of the external multiplexer, corresponding to the value in bitfield RESULT. <i>Note: Available in GxRES0 only. Use GxRES0 if EMUX information is required.</i>

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CRS	[29:28]	rh	Converted Request Source Indicates the request source that as requested the conversion to which the result value in bitfield RESULT belongs. 00 _B Request source 0 01 _B Request source 1 10 _B Request source 2 11 _B Reserved
FCR	30	rh	Fast Compare Result Indicates the result of an operation in Fast Compare Mode. 0 _B Signal level was below compare value 1 _B Signal level was above compare value
VF	31	rh	Valid Flag Indicates a new result in bitfield RESULT or bit FCR. 0 _B No new result available 1 _B Bitfield RESULT has been updated with new result value and has not yet been read, or bit FCR has been updated

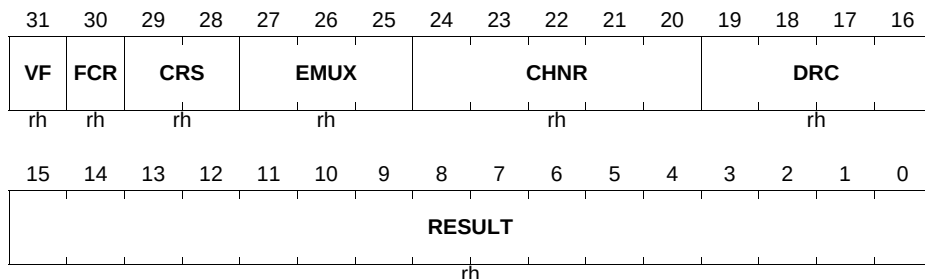
The debug view of the group result registers provides access to all result registers of a given group, however, without clearing the valid flag.

G0RESyDy (y = 0 - 15)

Group 0 Result Reg. y, Debug (0780_H + y * 0004_H) **Reset Value:** 0000 0000_H

G1RESyDy (y = 0 - 15)

Group 1 Result Reg. y, Debug (0B80_H + y * 0004_H) **Reset Value:** 0000 0000_H



Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
RESULT	[15:0]	rh	Result of Most Recent Conversion The position of the result bits within this bitfield depends on the configured operating mode. Please, refer to Section 16.11.2 .
DRC	[19:16]	rh	Data Reduction Counter Indicates the number of values still to be accumulated for the final result. The final result is available and valid flag VF is set when bitfield DRC becomes zero (by decrementing or by reload). See “Data Modification” on Page 16-49
CHNR	[24:20]	rh	Channel Number Indicates the channel number corresponding to the value in bitfield RESULT.
EMUX	[27:25]	rh	External Multiplexer Setting Indicates the setting of the external multiplexer, corresponding to the value in bitfield RESULT. <i>Note: Available in GxRES0 only. Use GxRES0 if EMUX information is required.</i>
CRS	[29:28]	rh	Converted Request Source Indicates the request source that as requested the conversion to which the result value in bitfield RESULT belongs. 00 _B Request source 0 01 _B Request source 1 10 _B Request source 2 11 _B Reserved
FCR	30	rh	Fast Compare Result Indicates the result of an operation in Fast Compare Mode. 0 _B Signal level was below compare value 1 _B Signal level was above compare value

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
VF	31	rh	Valid Flag Indicates a new result in bitfield RESULT or bit FCR. 0 _B No new result available 1 _B Bitfield RESULT has been updated with new result value and has not yet been read, or bit FCR has been updated

The global result control register selects the behavior of the global result register.

GLOBRCR

Global Result Control Register (0280_H) **Reset Value: 0000 0000_H**

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

Field	Bits	Type	Description
0	[15:0]	r	Reserved, write 0, read as 0
DRCTR	[19:16]	rw	Data Reduction Control Defines how result values are stored/accumulated in this register for the final result. The data reduction counter DRC can be loaded from this bitfield. 0000 _B Data reduction disabled others: see “Function of Bitfield DRCTR” on Page 16-50¹⁾
0	[23:20]	r	Reserved, write 0, read as 0
WFR	24	rw	Wait-for-Read Mode Enable 0 _B Overwrite mode 1 _B Wait-for-read mode enabled for this register
0	[30:25]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SRGEN	31	rw	Service Request Generation Enable 0 _B No service request 1 _B Service request after a result event

1) Only standard data reduction is available for the global result register, i.e. DMM is assumed as 00_B.

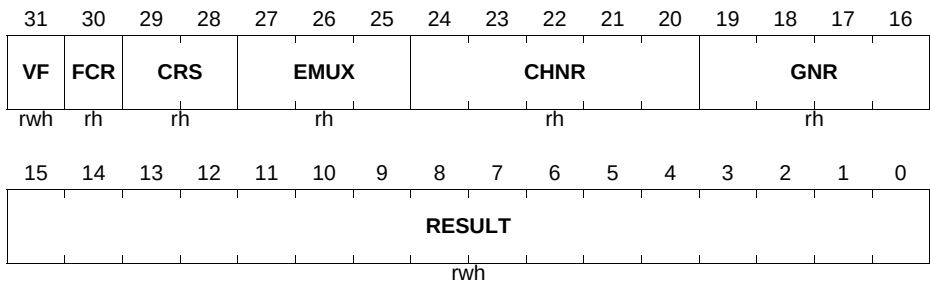
The global result register provides a common storage location for all channels of all groups.

GLOBRES

Global Result Register (0300_H) **Reset Value: 0000 0000_H**

GLOBRESD

Global Result Register, Debug (0380_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
RESULT	[15:0]	rwh	Result of most recent conversion The position of the result bits within this bitfield depends on the configured operating mode. ¹⁾ Please, refer to Section 16.11.2 .
GNR	[19:16]	rh	Group Number Indicates the group to which the channel number in bitfield CHNR refers.
CHNR	[24:20]	rh	Channel Number Indicates the channel number corresponding to the value in bitfield RESULT.
EMUX	[27:25]	rh	External Multiplexer Setting Indicates the setting of the external multiplexer, corresponding to the value in bitfield RESULT.

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CRS	[29:28]	rh	Converted Request Source Indicates the request source that as requested the conversion to which the result value in bitfield RESULT belongs.
FCR	30	rh	Fast Compare Result Indicates the result of an operation in Fast Compare Mode. 0 _B Signal level was below compare value 1 _B Signal level was above compare value
VF	31	rwh	Valid Flag Indicates a new result in bitfield RESULT or bit FCR. 0 _B Read access: No new valid data available Write access: No effect 1 _B Read access: Bitfield RESULT contains valid data and has not yet been read, or bit FCR has been updated Write access: Clear this valid flag and the data reduction counter (overrides a hardware set action) ¹⁾

1) Only writable in register GLOBRES, not in register GLOBRESD.

The valid flag register summarizes the valid flags of all result registers.

GxVFR (x = 0 - 1)

Valid Flag Register, Group x (x * 0400_H + 05F8_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VF15	VF14	VF13	VF12	VF11	VF10	VF9	VF8	VF7	VF6	VF5	VF4	VF3	VF2	VF1	VF0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
VFy (y = 0 - 15)	y	rwh	Valid Flag of Result Register x Indicates a new result in bitfield RESULT or in bit FCR. 0 _B Read access: No new valid data available Write access: No effect 1 _B Read access: Result register x contains valid data and has not yet been read, or bit FCR has been updated Write access: Clear this valid flag and bitfield DRC in register GxRESy (overrides a hardware set action)
0	[31:16]	r	Reserved, write 0, read as 0

16.16.7 Calibration Registers

The calibration control register CALCTR selects basic calibration features.

SHS0_CALCTR

Calibration Control Register (4803 40BC_H) Reset Value: 0310 0400_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SU CAL	0				CALMAX			0					SUCALVAL		
w	r				rw			r					rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GC DIS	OC DIS				CALGNSTC			0	0	0	0	0	0	RAN CAL	CAL ORD
rw	rw				rw			r	r	r	r	r	r	rw	rw

Field	Bits	Type	Description
CALORD	0	rw	Calibration Order 0 _B Do conversions then calibration 1 _B Do calibration then conversions

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
RANCAL	1	rw	Random Calibration 0_B Calibrate after each conversion round 1_B Randomly shift calibration after a conversion round <i>Note: Random calibration is only supported for postcalibration, i.e. CALORD = 0.</i>
0	[7:2]	r	Reserved, write 0, read as 0
CALGNSTC	[13:8]	rw	Gain Calibration Sample Time Control Defines the duration of the sample phase for gain calibration cycles. 00_H Reserved Others: $t_{SGN} = \text{CALGNSTC} / f_{SH}$ <i>Note: To be adjusted for internal reference operation in low voltage range (see Data Sheet).</i>
OCDIS	14	rw	Offset Calibration Disable 0_B Standard calibration 1_B Exclude offset calibration steps from the sequence
GCDIS	15	rw	Gain Calibration Disable 0_B Standard calibration 1_B Exclude gain calibration steps from the sequence
SUCALVAL	[22:16]	rw	Startup Calibration Cycles Defines the number of calibration sequences for the startup calibration. <i>Note: No user control required.</i>
CALMAX	[29:24]	rw	Calibration Maximum Timing Defines the maximum time until the next calibration: $t_{MAX} = 128 / f_{SH} \times (\text{CALMAX} + 1)$
0	30	r	Reserved, write 0, read as 0
SUCAL	31	w	Start-Up Calibration The 0-1 transition of bit SUCAL triggers the start-up calibration phase of the converter. ¹⁾ SUCAL is cleared automatically when the calibration phase begins. 0_B No action 1_B Initiate the start-up calibration phase (indication in bitfield SHSCFG.STATE)

Versatile Analog-to-Digital Converter (VADC)

1) Startup calibration can also be triggered by the known bit SUCAL in register GLOB_CFG in module VADC_DIG.

The gain calibration control register CALGC_x configures the gain calibration features of the associated S&H unit. The calibration values are determined automatically by the calibration mechanism. They can be read to compensate the error introduced by using the alternate reference of another group.

SHS0_CALGC_x (x = 0 - 1)

Gain Calibration Control Register x

$$(4803\ 40C0_H + x * 4_H)$$

Reset Value: 2000 2000_H

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

Field	Bits	Type	Description
CALGNVALS	[13:0]	rwh	Gain Calibration Value, Standard Reference Modified by the calibration steps, controls the gain DAC.
0	14	r	Reserved, write 0, read as 0
GNSWC	15	w	Gain Calibration Write Control, Standard 0 _B No write access to gain calibration parameter 1 _B CALGNVALS can be written
CALGNVALA	[29:16]	rwh	Gain Calibration Value, Alternate Reference Modified by the calibration steps, controls the gain DAC.
0	30	r	Reserved, write 0, read as 0
GNAWC	31	w	Gain Calibration Write Control, Alternate 0 _B No write access to gain calibration parameter 1 _B CALGNVALA can be written

Note: After writing to bitfield CALGNVALS or CALGNVALA a settling time of 10 μs must be respected before starting subsequent conversions.

Versatile Analog-to-Digital Converter (VADC)

The offset calibration control register CALOCx configures the offset calibration features of the associated S&H unit. The calibration values can be written for testing purposes.

There is a separate calibration value for each gain level.

Note: If more than 4 gain levels are used, registers CALOCx can be added at locations $(x * 4_H + 0100_H)$.

SHS0_CALOCx (x = 0 - 1)

Offset Calibration Control Register x

(4803 40E0_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
DIS CAL	CALOFFVAL3							0	CALOFFVAL2						
rw	rwh							r	rwh						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OFF WC	CALOFFVAL1							0	CALOFFVAL0						
w	rwh							r	rwh						

Field	Bits	Type	Description
CALOFFVAL0, CALOFFVAL1, CALOFFVAL2, CALOFFVAL3	[6:0], [14:8], [22:16], [30:24]	rwh	Offset Calibration Value for Gain Level z Modified by the calibration steps, controls the offset DAC and the shift DAC CALOFFVALz corresponds to the settings in register GNCTR.
0	7	r	Reserved, write 0, read as 0
OFFWC	15	w	Offset Calibration Write Control 0 _B No write access to offset cal. parameters 1 _B CALOFFVALz can be written
0	23	r	Reserved, write 0, read as 0
DISCAL	31	rw	Disable Calibration 0 _B Calibration enabled (offset and gain) 1 _B No calibration

Versatile Analog-to-Digital Converter (VADC)

The gain control registers GNCTR_{x0} selects the gain level for each input.

SHS0_GNCTR00

Gain Control Register 00

(4803 4180_H)

Reset Value: 0000 0000_H

SHS0_GNCTR10

Gain Control Register 10

(4803 4190_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GAIN7				GAIN6				GAIN5				GAIN4			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GAIN3				GAIN2				GAIN1				GAIN0			
rw				rw				rw				rw			

Field	Bits	Type	Description
GAIN_z (z = 0 - 7)	[z*4+3: z*4]	rw	Gain Control z 0000 _B Gain factor = 1 0001 _B Gain factor = 3 0010 _B Gain factor = 6 0011 _B Gain factor = 12 Others: Reserved

*Note: The first index (x0) indicates the associated S&H unit.
The channel number is z.*

16.16.8 Miscellaneous Registers

The alias register can replace the channel numbers of channels CH0 and CH1 with another channel number. The reset value disables this redirection.

GxALIAS (x = 0 - 1)

Alias Register, Group x

(x * 0400_H + 04B0_H)

Reset Value: 0000 0100_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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ALIAS1			0			0	0	ALIAS0				
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	rw			r			r	r	rw				

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
ALIAS0	[4:0]	rw	Alias Value for CH0 Conversion Requests Indicates the channel that is converted instead of channel CH0. The conversion is done with the settings defined for channel CH0.
0	[7:5]	r	Reserved, write 0, read as 0
ALIAS1	[12:8]	rw	Alias Value for CH1 Conversion Requests Indicates the channel that is converted instead of channel CH1. The conversion is done with the settings defined for channel CH1.
0	[31:13]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The local boundary register GxBOUND defines group-specific boundary values or delta limits for Fast Compare Mode.

The global boundary register GLOBBOUND defines general compare values for all channels.

Depending on the conversion width, the respective left 12/10/8 bits of a bitfield are used. For 10/8-bit results, the lower 2/4 bits must be zero!

GxBOUND (x = 0 - 1)

Boundary Select Register, Group x

$$(x * 0400_H + 04B8_H)$$

Reset Value: 0000 0000_H

GLOBBOUND

Global Boundary Select Register (00B8_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	0	0	0													0	0	0	0												
r	r	r	r													r	r	r	r												

Field	Bits	Type	Description
BOUNDARY0	[11:0]	rw	Boundary Value 0 for Limit Checking Standard Mode: This value is compared against the left-aligned conversion result. Fast Compare Mode: This value is added to the reference value (upper delta).
0	[15:12]	r	Reserved, write 0, read as 0
BOUNDARY1	[27:16]	rw	Boundary Value 1 for Limit Checking Standard Mode: This value is compared against the left-aligned conversion result. Fast Compare Mode: This value is subtracted from the reference value (lower delta).
0	[31:28]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Boundary Flag Register holds the boundary flags themselves together with bits to select the activation condition and the output signal polarity for each flag.

GxBFL ($x = 0 - 1$)

Boundary Flag Register, Group x

($x * 0400_H + 04C8_H$)

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	0	0	0	0	0	0	BFI 3	BFI 2	BFI 1	BFI 0
r	r	r	r	r	r	r	r	r	r	r	r	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	BFA 3	BFA 2	BFA 1	BFA 0	0	0	0	0	BFL 3	BFL 2	BFL 1	BFL 0
r	r	r	r	rw	rw	rw	rw	r	r	r	r	rh	rh	rh	rh

Field	Bits	Type	Description
BFLy ($y = 0 - 3$)	y	rh	Boundary Flag y 0_B Passive state: result has not yet crossed the activation boundary (see bitfield BFAy), or selected gate signal is inactive, or this boundary flag is disabled 1_B Active state: result has crossed the activation boundary
0	[7:4]	r	Reserved, write 0, read as 0
BFAy ($y = 0 - 3$)	8 + y	rw	Boundary Flag y Activation Select 0_B Set boundary flag BFLy if result is above the defined band or compare value, clear if below 1_B Set boundary flag BFLy if result is below the defined band or compare value, clear if above
0	[15:12]	r	Reserved, write 0, read as 0
BFLy ($y = 0 - 3$)	16 + y	rw	Boundary Flag y Inversion Control 0_B Use BFLy directly 1_B Invert value and use BFLy
0	[31:20]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Boundary Flag Software Register provides means to set or clear each flag by software.

GxBFLS (x = 0 - 1)

Boundary Flag Software Register, Group x

(x * 0400_H + 04CC_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	0	0	0	0	0	0	BFS 3	BFS 2	BFS 1	BFS 0
r	r	r	r	r	r	r	r	r	r	r	r	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	BFC 3	BFC 2	BFC 1	BFC 0
r	r	r	r	r	r	r	r	r	r	r	r	w	w	w	w

Field	Bits	Type	Description
BFCy (y = 0 - 3)	y	w	Boundary Flag y Clear 0 _B No action 1 _B Clear bit BFLy
0	[15:4]	r	Reserved, write 0, read as 0
BFSy (y = 0 - 3)	16 + y	w	Boundary Flag y Set 0 _B No action 1 _B Set bit BFLy
0	[31:20]	r	Reserved, write 0, read as 0

Note: If a boundary flag is used together with Fast Compare Mode, it is recommended not to direct results from other channels to the corresponding result register.

Versatile Analog-to-Digital Converter (VADC)

The Boundary Flag Control Register selects the basic operation of the boundary flags.

GxBFLC (x = 0 - 1)

Boundary Flag Control Register, Group x

(x * 0400_H + 04D0_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BFM 3				BFM 2				BFM 1				BFM 0			
rw				rw				rw				rw			

Field	Bits	Type	Description
BFM0, BFM1, BFM2, BFM3	[3:0], [7:4], [11:8], [15:12]	rw	Boundary Flag y Mode Control 0000 _B Disable boundary flag, BFLy is not changed 0001 _B Always enable boundary flag (follow compare results) 0010 _B Enable boundary flag while gate of source 0 is active, clear BFLy while gate is inactive 0011 _B Enable boundary flag while gate of source 1 is active, clear BFLy while gate is inactive others: Reserved
0	[31:16]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Boundary Flag Node Pointer Register directs signal GxBFLOUT_y to alternate on-chip connections with other modules (in addition to the group-specific outputs). Possible targets are the corresponding common service request lines or the common boundary flag outputs (CBFL0 ... CBFL3).

GxBFLNP (x = 0 - 1)

Boundary Flag Node Pointer Register, Group x

(x * 0400_H + 04D4_H)

Reset Value: 0000 FFFF_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BFL3NP				BFL2NP				BFL1NP				BFL0NP			
rw				rw				rw				rw			

Field	Bits	Type	Description
BFL0NP, BFL1NP, BFL2NP, BFL3NP	[3:0], [7:4], [11:8], [15:12]	rw	Boundary Flag y Node Pointer 0000 _B Select common bondary flag output 0 ... 0011 _B Select common bondary flag output 3 0100 _B Select common service request line C0SR0 ... 0111 _B Select common service request line C0SR3 1111 _B Disabled, no common output signal others: Reserved
0	[31:16]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

The Synchronization Control Register controls the synchronization of kernels for parallel conversions.

Note: Program register GxSYNCTR only while bitfield GxARBCFG.ANONS = 00_B in all ADC kernels of the conversion group. Set the master's bitfield ANONC to 11_B afterwards.

GxSYNCTR (x = 0 - 1)

Synchronization Control Register, Group x

(x * 0400_H + 04C0_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	EVALR1	0	0	STSEL	
r	r	r	r	r	r	r	r	r	r	r	rw	r	r	rw	

Field	Bits	Type	Description
STSEL	[1:0]	rw	Start Selection Controls the synchronization mechanism of the ADC kernel. 00 _B Kernel is synchronization master: Use own bitfield GxARBCFG.ANONC 01 _B Kernel is synchronization slave: Control information from input Cl1 10 _B Reserved 11 _B Reserved <i>Note: Control inputs Clx see Figure 16-28, connected kernels see Table 16-13.</i>
0	[3:2]	r	Reserved, write 0, read as 0
EVALR1	4	rw	Evaluate Ready Input R1 Enables the ready input signal for a kernel of a conversion group. 0 _B No ready input control 1 _B Ready input R1 is considered for the start of a parallel conversion of this conversion group

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
0	[31:5]	r	Reserved, write 0, read as 0

GxEMUXCTR (x = 0 - 1)

External Multiplexer Control Register, Group x

$$(x * 0400_H + 05F0_H)$$

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EMX WC	EMX CSS	EMX ST	EMX COD	EMUX MODE						EMUX CH					
w	rw	rw	rw	rw						rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0		EMUX ACT		0	0	0	0	0		EMUX SET	
r	r	r	r	r		rh		r	r	r	r	r		rw	

Field	Bits	Type	Description
EMUXSET	[2:0]	rw	External Multiplexer Start Selection¹⁾ Defines the initial setting for the external multiplexer.
0	[7:3]	r	Reserved, write 0, read as 0
EMUXACT	[10:8]	rh	External Multiplexer Actual Selection Defines the current value for the external multiplexer selection. This bitfield is loaded from bitfield EMUXSET and modified according to the operating mode selected by bitfield EMUXMODE.
0	[15:11]	r	Reserved, write 0, read as 0
EMUXCH	[25:16]	rw	External Multiplexer Channel Select Defines the channel(s) to which the external multiplexer control is applied. EMXCSS = 0: Channel number , the lower 5 bits select an arbitrary channel (valid numbers are limited by the number of available channels, unused bits shall be 0) EMXCSS = 1: Channel enable , each bit enables the associated channel (multiple channels can be selected/enabled)
0	[25:21]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
EMUXMODE	[27:26]	rw	External Multiplexer Mode 00 _B Software control (no hardware action) 01 _B Steady mode (use EMUXSET value) 10 _B Single-step mode ¹⁾²⁾ 11 _B Sequence mode ¹⁾
EMXCOD	28	rw	External Multiplexer Coding Scheme 0 _B Output the channel number in binary code 1 _B Output the channel number in Gray code
EMXST	29	rw	External Multiplexer Sample Time Control 0 _B Use STCE whenever the setting changes 1 _B Use STCE for each conversion of an external channel
EMXCSS	30	rw	External Multiplexer Channel Selection Style 0 _B Channel number: Bitfield EMUXCH selects an arbitrary channel 1 _B Channel enable: Each bit of bitfield EMUXCH selects the associated channel for EMUX control
EMXWC	31	w	Write Control for EMUX Configuration 0 _B No write access to EMUX cfg. 1 _B Bitfields EMXMODE, EMXCOD, EMXST, EMXCSS can be written

1) For single-step mode and sequence mode: Select the start value before selecting the respective mode.

2) Single-step mode modifies the EMUX channel number each time an EMUX-enabled channel is converted. Therefore, single-step mode works best with a single channel, because otherwise some external channels may be skipped.

Versatile Analog-to-Digital Converter (VADC)

Register EMUXSEL is a global register which assigns an arbitrary group to each of the EMUX interfaces.

EMUXSEL

External Multiplexer Select Register

(03F0_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	EMUX GRP1			EMUX GRP0				
r	r	r	r	r	r	r	r	rw			rw				

Field	Bits	Type	Description
EMUXGRP0, EMUXGRP1	[3:0], [7:4]	rw	External Multiplexer Group for Interface x Defines the group whose external multiplexer control signals are routed to EMUX interface x. ¹⁾
0	[31:8]	r	Reserved, write 0, read as 0

1) The pins that are associated with each EMUX interface are listed in [Table 16-15 "Digital Connections in the XMC1200" on Page 16-156](#).

Versatile Analog-to-Digital Converter (VADC)

The sigma-delta-loop control register LOOP configures the functionality of the sigma-delta-loop(s).

SHS0_LOOP

Loop Control Register

(4803 4050_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LP EN1	0	0	0	0	0	0	LP SH1	0	0	0	LPCH1				
rw	r	r	r	r	r	r	rw	r	r	r	rw				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LP EN0	0	0	0	0	0	0	LP SH0	0	0	0	LPCH0				
rw	r	r	r	r	r	r	rw	r	r	r	rw				

Field	Bits	Type	Description
LPCH0, LPCH1	[4:0], [20:16]	rw	Loop y Channel Selects the input channel, for which the sigma-delta-loop function shall be enabled.
0	[7:5]	r	Reserved, write 0, read as 0
LPSH0, LPSH1	8, 24	rw	Loop y Sample&Hold Unit Selects the S&H unit, to which the indicated channel is assigned.
0	[14:9]	r	Reserved, write 0, read as 0
LPEN0, LPEN1	15, 31	rw	Loop y Enable 0 _H Off: standard operation 1 _H ON: sigma-delta-loop is active
0	[23:21]	r	Reserved, write 0, read as 0
0	[30:25]	r	Reserved, write 0, read as 0

Note: Bitfields LPSHy and LPCHy together select one individual input channel that is associated with the corresponding sigma-delta loop.

Versatile Analog-to-Digital Converter (VADC)

16.16.9 Service Request Registers

GxSEFLAG (x = 0 - 1)

Source Event Flag Register, Group x

(x * 0400_H + 0588_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	SEV 1	SEV 0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	rwh	rwh

Field	Bits	Type	Description
SEV0, SEV1	0, 1	rwh	Source Event 0/1 0 _B No source event 1 _B A source event has occurred
0	[31:2]	r	Reserved, write 0, read as 0

*Note: Software can set all flags in register GxSEFLAG and trigger the corresponding event by writing 1 to the respective bit. Writing 0 has no effect.
Software can clear all flags in register GxSEFLAG by writing 1 to the respective bit in register GxSEFCLR.*

GxCEFLAG (x = 0 - 1)

Channel Event Flag Register, Group x

(x * 0400_H + 0580_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CEV 7	CEV 6	CEV 5	CEV 4	CEV 3	CEV 2	CEV 1	CEV 0
r	r	r	r	r	r	r	r	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CEV_y (y = 0 - 7)	y	rwh	Channel Event for Channel y 0 _B No channel event 1 _B A channel event has occurred
0	[31:8]	r	Reserved, write 0, read as 0

*Note: Software can set all flags in register GxCEFLAG and trigger the corresponding event by writing 1 to the respective bit. Writing 0 has no effect.
Software can clear all flags in register GxCEFLAG by writing 1 to the respective bit in register GxCEFCLR.*

GxREFLAG (x = 0 - 1)
Result Event Flag Register, Group x

$$(x * 0400_H + 0584_H)$$

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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REV 15	REV 14	REV 13	REV 12	REV 11	REV 10	REV 9	REV 8	REV 7	REV 6	REV 5	REV 4	REV 3	REV 2	REV 1	REV 0
rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

Field	Bits	Type	Description
REV_y (y = 0 - 15)	y	rwh	Result Event for Result Register y 0 _B No result event 1 _B New result was stored in register GxRES _y
0	[31:16]	r	Reserved, write 0, read as 0

*Note: Software can set all flags in register GxREFLAG and trigger the corresponding event by writing 1 to the respective bit. Writing 0 has no effect.
Software can clear all flags in register GxREFLAG by writing 1 to the respective bit in register GxREFCLR.*

Versatile Analog-to-Digital Converter (VADC)

GxSEFCLR (x = 0 - 1)

Source Event Flag Clear Register, Group x

(x * 0400_H + 0598_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	0	0	0	0	0	0	0	0	0	0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	SEV 1	SEV 0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	w	w

Field	Bits	Type	Description
SEV0, SEV1	0, 1	w	Clear Source Event 0/1 0 _B No action 1 _B Clear the source event flag in GxSEFLAG
0	[31:2]	r	Reserved, write 0, read as 0

GxCEFCLR (x = 0 - 1)

Channel Event Flag Clear Register, Group x

(x * 0400_H + 0590_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	0	0	0	0	0	0	0	0	0	0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	CEV 7	CEV 6	CEV 5	CEV 4	CEV 3	CEV 2	CEV 1	CEV 0
r	r	r	r	r	r	r	r	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
CEVy (y = 0 - 7)	y	w	Clear Channel Event for Channel y 0 _B No action 1 _B Clear the channel event flag in GxCEFLAG

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
0	[31:8]	r	Reserved, write 0, read as 0

GxREFCLR (x = 0 - 1)

Result Event Flag Clear Register, Group x

(x * 0400_H + 0594_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REV 15	REV 14	REV 13	REV 12	REV 11	REV 10	REV 9	REV 8	REV 7	REV 6	REV 5	REV 4	REV 3	REV 2	REV 1	REV 0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Field	Bits	Type	Description
REyV (y = 0 - 15)	y	w	Clear Result Event for Result Register y 0 _B No action 1 _B Clear the result event flag in GxREFLAG
0	[31:16]	r	Reserved, write 0, read as 0

GLOBEFLAG

Global Event Flag 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	0	REV GLB CLR	0	0	0	0	0	0	0	SEV GLB CLR
r	r	r	r	r	r	r	w	r	r	r	r	r	r	r	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	REV GLB	0	0	0	0	0	0	0	SEV GLB
r	r	r	r	r	r	r	rwh	r	r	r	r	r	r	r	rwh

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SEVGLB	0	rwh	Source Event (Background) 0 _B No source event 1 _B A source event has occurred
0	[7:1]	r	Reserved, write 0, read as 0
REVGLB	8	rwh	Global Result Event 0 _B No result event 1 _B New result was stored in register GLOBRES
0	[15:9]	r	Reserved, write 0, read as 0
SEVGLBCLR	16	w	Clear Source Event (Background) 0 _B No action 1 _B Clear the source event flag SEVGLB
0	[23:17]	r	Reserved, write 0, read as 0
REVGLBCLR	24	w	Clear Global Result Event 0 _B No action 1 _B Clear the result event flag REVGLB
0	[31:25]	r	Reserved, write 0, read as 0

Note: Software can set flags REVGLB and SEVGLB and trigger the corresponding event by writing 1 to the respective bit. Writing 0 has no effect.

Software can clear these flags by writing 1 to bit REVGLBCLR and SEVGLBCLR, respectively.

Setting both bits (e.g. SEVGLB and SEVGLBCLR) simultaneously clears the corresponding flag (e.g. SEVGLB).

GxSEVNP (x = 0 - 1)

Source Event Node Pointer Register, Group x

$$(x * 0400_H + 05C0_H)$$

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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	SEV1NP				SEV0NP			
r	r	r	r	r	r	r	r	rw				rw			

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SEV0NP, SEV1NP	[3:0], [7:4]	rw	Service Request Node Pointer Source Event ⁱ¹⁾ Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select service request line 0 of group x ... 0011 _B Select service request line 3 of group x 0100 _B Select shared service request line 0 ... 0111 _B Select shared service request line 3 1xxx _B Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>
0	[31:8]	r	Reserved, write 0, read as 0

1) Source 0 is an 8-stage queued source, source 1 is a channel scan source.

GxCEVNP0 (x = 0 - 1)

Channel Event Node Pointer Register 0, Group x

(x * 0400_H + 05A0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CEV7NP				CEV6NP				CEV5NP				CEV4NP			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CEV3NP				CEV2NP				CEV1NP				CEV0NP			
rw				rw				rw				rw			

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
CEV0NP, CEV1NP, CEV2NP, CEV3NP, CEV4NP, CEV5NP, CEV6NP, CEV7NP	[3:0], [7:4], [11:8], [15:12], [19:16], [23:20], [27:24], [31:28]	rw	Service Request Node Pointer Channel Event i Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select service request line 0 of group x ... 0011 _B Select service request line 3 of group x 0100 _B Select shared service request line 0 ... 0111 _B Select shared service request line 3 1xxx _B Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>

GxREVNP0 (x = 0 - 1)

Result Event Node Pointer Register 0, Group x

(x * 0400_H + 05B0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
REV7NP				REV6NP				REV5NP				REV4NP			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REV3NP				REV2NP				REV1NP				REV0NP			
rw				rw				rw				rw			

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
REV0NP, REV1NP, REV2NP, REV3NP, REV4NP, REV5NP, REV6NP, REV7NP	[3:0], [7:4], [11:8], [15:12], [19:16], [23:20], [27:24], [31:28]	rw	Service Request Node Pointer Result Event i Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select service request line 0 of group x ... 0011 _B Select service request line 3 of group x 0100 _B Select shared service request line 0 ... 0111 _B Select shared service request line 3 1xxx _B Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>

GxREVNP1 (x = 0 - 1)

Result Event Node Pointer Register 1, Group x

(x * 0400_H + 05B4_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
REV15NP				REV14NP				REV13NP				REV12NP			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REV11NP				REV10NP				REV9NP				REV8NP			
rw				rw				rw				rw			

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
REV8NP, REV9NP, REV10NP, REV11NP, REV12NP, REV13NP, REV14NP, REV15NP	[3:0], [7:4], [11:8], [15:12], [19:16], [23:20], [27:24], [31:28]	rw	Service Request Node Pointer Result Event i Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select service request line 0 of group x ... 0011 _B Select service request line 3 of group x 0100 _B Select shared service request line 0 ... 0111 _B Select shared service request line 3 1xxx _B Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>

GLOBEVNP

Global Event Node Pointer Register

(0140_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	0	0	0	0	0	0	REV0NP			
r	r	r	r	r	r	r	r	r	r	r	r	rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	SEV0NP			
r	r	r	r	r	r	r	r	r	r	r	r	rw			

Versatile Analog-to-Digital Converter (VADC)

Field	Bits	Type	Description
SEV0NP	[3:0]	rw	Service Request Node Pointer Backgr. Source Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select shared service request line 0 of common service request group 0 ... 0011 _B Select shared service request line 3 of common service request group 0 others: Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>
0	[15:4]	r	Reserved, write 0, read as 0
REV0NP	[19:16]	rw	Service Request Node Pointer Global Result Routes the corresponding event trigger to one of the service request lines (nodes). 0000 _B Select shared service request line 0 of common service request group 0 ... 0011 _B Select shared service request line 3 of common service request group 0 others: Reserved <i>Note: For shared service request lines see common groups in Table 16-12.</i>
0	[31:20]	r	Reserved, write 0, read as 0

Versatile Analog-to-Digital Converter (VADC)

GxSRCT (x = 0 - 1)

Service Request Software Activation Trigger, Group x

(x * 0400_H + 05C8_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	0	0	0	0	0	0	0	0	0	0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	AS SR3	AS SR2	AS SR1	AS SR0	0	0	0	0	0	0	AG SR1	AG SR0
r	r	r	r	w	w	w	w	r	r	r	r	r	r	w	w

Field	Bits	Type	Description
AGSRy (y = 0 - 1)	y	w	Activate Group Service Request Node y 0 _B No action 1 _B Activate the associated service request line
0	[7:2]	r	Reserved, write 0, read as 0
ASSRy (y = 0 - 3)	8 + y	w	Activate Shared Service Request Node y 0 _B No action 1 _B Activate the associated service request line
0	[31:12]	r	Reserved, write 0, read as 0

16.17 Interconnects

This section describes the actual implementation of the VADC module into the XMC1200, i.e. the incorporation into the microcontroller system.

16.17.1 Product-Specific Configuration

The functional description describes the features and operating modes of the A/D Converters in a general way. This section summarizes the configuration that is available in this product (XMC1200).

Each converter group is equipped with a separate sample and hold stage and a dedicated analog input multiplexer.

Table 16-12 General Converter Configuration in the XMC1200

Converter Group	Input Channels	Channels with Alternate GND	12-bit Performance	Common Service Request Group
G0	0 ... 7	8	Calibrated S&H-ADC	C0
G1	0 ... 7	8		C0

Synchronization Groups in the XMC1200

The converter kernels in the XMC1200 can be connected to synchronization groups to achieve parallel conversion of several input channels.

Table 16-13 summarizes which kernels can be synchronized for parallel conversions.

Table 16-13 Synchronization Groups in the XMC1200

ADC Kernel	Synchr. Group	Master selected by control input C1x ¹⁾	
		C10 ²⁾	C11
ADC00	A	ADC00	ADC01
ADC01	A	ADC01	ADC00

1) The control input is selected by bitfield STSEL in register **GxSYNCTR (x = 0 - 1)**.

Select the corresponding ready inputs accordingly by bits EVALRx.

2) Control input C10 always selects the own control signals of the corresponding ADC kernel. This selection is meant for the synchronization master or for stand-alone operation.

Versatile Analog-to-Digital Converter (VADC)

16.17.2 Analog Module Connections in the XMC1200

The VADC module accepts a number of analog input signals. The analog input multiplexers select the input channels to be converted from the signals available in this product.

The exact number of analog input channels and the available connection to port pins depend on the employed product type (see also [Table 16-12](#)). A summary of channels enclosing all versions of the XMC1200 can be found in [Table 16-14](#).

Table 16-14 Analog Connections in the XMC1200

Signal	Dir.	Source/Destin.	Description
Supply Voltage and Reference Voltage			
V_{DDM}	I	VDD	positive supply voltage
V_{SSM}	I	VSS	negative supply voltage
V_{AREF}	I	VDD	positive analog reference
V_{AGND}	I	VSS	negative analog reference
Group 0 Analog Inputs			
G0CH0	I	P2.6	analog input channel 0 of group 0
G0CH1	I	P2.8	analog input channel 1 of group 0
G0CH2	I	P2.9	analog input channel 2 of group 0
G0CH3	I	P2.10	analog input channel 3 of group 0
G0CH4	I	P2.11	analog input channel 4 of group 0
G0CH5	I	P2.0	analog input channel 5 of group 0
G0CH6	I	P2.1	analog input channel 6 of group 0
G0CH7	I	P2.2	analog input channel 7 of group 0
Group 1 Analog Inputs			
G1CH0	I	P2.8	analog input channel 0 of group 1
G1CH1	I	P2.7	analog input channel 1 of group 1
G1CH2	I	P2.10	analog input channel 2 of group 1
G1CH3	I	P2.11	analog input channel 3 of group 1
G1CH4	I	P2.9	analog input channel 4 of group 1
G1CH5	I	P2.3	analog input channel 5 of group 1
G1CH6	I	P2.4	analog input channel 6 of group 1
G1CH7	I	P2.5	analog input channel 7 of group 1

Versatile Analog-to-Digital Converter (VADC)
16.17.3 Digital Module Connections in the XMC1200

The VADC module accepts a number of digital input signals and generates a number of output signals. This section summarizes the connection of these signals to other on-chip modules or to external resources via port pins.

Note: The control bitfields for triggers and gates select the corresponding multiplexer input. Values 0000_B ... 1111_B select inputs with suffix -A ... -P.

Table 16-15 Digital Connections in the XMC1200

Signal	Dir.	Source/Destin.	Description
Gate Inputs for Each Group			
GxREQGTA	I	CCU40.ST3	Gating input A (GTSEL = 0000 _B)
GxREQGTB	I	CCU40.ST2	Gating input B (GTSEL = 0001 _B)
GxREQGTC	I	CCU40.ST1	Gating input C (GTSEL = 0010 _B)
GxREQGTD	I	CCU40.ST0	Gating input D (GTSEL = 0011 _B)
GxREQGTE	I	Reserved	Gating input E (GTSEL = 0100 _B)
GxREQGTF	I	Reserved	Gating input F (GTSEL = 0101 _B)
GxREQGTG	I	0	Gating input G (GTSEL = 0110 _B)
GxREQGTH	I	0	Gating input H (GTSEL = 0111 _B)
GxREQGTI	I (s)	LEDTS0.FN	Gating input I (GTSEL = 1000 _B)
GxREQGTJ	I (s)	LEDTS1.FN	Gating input J (GTSEL = 1001 _B)
GxREQGTK	I (s)	ERU0.PDOUT2	Gating input K (GTSEL = 1010 _B)
GxREQGTL	I (s)	ERU0.PDOUT3	Gating input L (GTSEL = 1011 _B)
GxREQGTM	I	Reserved	Gating input M (GTSEL = 1100 _B)
GxREQGTN	I	Reserved	Gating input N (GTSEL = 1101 _B)
GxREQGTO	I	ERU0.PDOUT0	Gating input O (GTSEL = 1110 _B)
GxREQGTP	I	ERU0.PDOUT1	Gating input P (GTSEL = 1111 _B)
GxREQGTSEL	O	GxREQTRP ¹⁾	Selected gating signal of the respective source

Gate Inputs for Global Background Source

BGREQGTA	I	CCU40.ST3	Gating input A (GTSEL = 0000 _B)
BGREQGTB	I	CCU40.ST2	Gating input B (GTSEL = 0001 _B)
BGREQGTC	I	CCU40.ST1	Gating input C (GTSEL = 0010 _B)
BGREQGTD	I	CCU40.ST0	Gating input D (GTSEL = 0011 _B)
BGREQGTE	I	Reserved	Gating input E (GTSEL = 0100 _B)

Versatile Analog-to-Digital Converter (VADC)
Table 16-15 Digital Connections in the XMC1200 (cont'd)

Signal	Dir.	Source/Destin.	Description
BGREQGTf	I	Reserved	Gating input F (GTSEL = 0101 _B)
BGREQGTg	I	0	Gating input G (GTSEL = 0110 _B)
BGREQGT <h></h>	I	0	Gating input H (GTSEL = 0111 _B)
BGREQGTi	I (s)	LEDTS0.FN	Gating input I (GTSEL = 1000 _B)
BGREQGTj	I (s)	LEDTS1.FN	Gating input J (GTSEL = 1001 _B)
BGREQGTk	I (s)	ERU0.PDOUT2	Gating input K (GTSEL = 1010 _B)
BGREQGTl	I (s)	ERU0.PDOUT3	Gating input L (GTSEL = 1011 _B)
BGREQGTm	I	Reserved	Gating input M (GTSEL = 1100 _B)
BGREQGTn	I	Reserved	Gating input N (GTSEL = 1101 _B)
BGREQGT <u>o</u>	I	ERU0.PDOUT0	Gating input O (GTSEL = 1110 _B)
BGREQGTp	I	ERU0.PDOUT1	Gating input P (GTSEL = 1111 _B)
BGREQGTSEL	O	BGREQTRP ¹⁾	Selected gating signal

Trigger Inputs for Each Group

GxREQTRA	I	CCU40.SR2	Trigger input A (XTSEL = 0000 _B)
GxREQTRB	I	CCU40.SR3	Trigger input B (XTSEL = 0001 _B)
GxREQTRC	I	0	Trigger input C (XTSEL = 0010 _B)
GxREQTRD	I	0	Trigger input D (XTSEL = 0011 _B)
GxREQTRE	I	0	Trigger input E (XTSEL = 0100 _B)
G0REQTRF	I	BCCU0.TRIGOUT0	Trigger input F (XTSEL = 0101 _B)
G1REQTRF	I	BCCU0.TRIGOUT1	Trigger input F (XTSEL = 0101 _B)
GxREQTRG	I	ERU0.IOUT2	Trigger input G (XTSEL = 0110 _B)
GxREQTRH	I	ERU0.IOUT3	Trigger input H (XTSEL = 0111 _B)
GxREQTRI	I (s)	Reserved	Trigger input I (XTSEL = 1000 _B)
GxREQTRJ	I (s)	Reserved	Trigger input J (XTSEL = 1001 _B)
GxREQTRK	I (s)	0	Trigger input K (XTSEL = 1010 _B)
GxREQTRL	I (s)	0	Trigger input L (XTSEL = 1011 _B)
GxREQTRM	I	ERU0.IOUT0	Trigger input M (XTSEL = 1100 _B)
GxREQTRN	I	ERU0.IOUT1	Trigger input N (XTSEL = 1101 _B)
GxREQTRO	I	Reserved	Trigger input O (XTSEL = 1110 _B)

Versatile Analog-to-Digital Converter (VADC)
Table 16-15 Digital Connections in the XMC1200 (cont'd)

Signal	Dir.	Source/Destin.	Description
GxREQTRP	I	GxREQGTSEL ¹⁾	Extend triggers to selected gating input of the respective source (XTSEL = 1111 _B)
GxREQTRSEL	O	-	Selected trigger signal of the respective source

Trigger Inputs for Global Background Source

BGREQTRA	I	CCU40.SR2	Trigger input A (XTSEL = 0000 _B)
BGREQTRB	I	CCU40.SR3	Trigger input B (XTSEL = 0001 _B)
BGREQTRC	I	0	Trigger input C (XTSEL = 0010 _B)
BGREQTRD	I	0	Trigger input D (XTSEL = 0011 _B)
BGREQTRE	I	0	Trigger input E (XTSEL = 0100 _B)
BGREQTRF	I	BCCU0.TRIGOUT0	Trigger input F (XTSEL = 0101 _B)
BGREQTRG	I	ERU0.IOUT2	Trigger input G (XTSEL = 0110 _B)
BGREQTRH	I	ERU0.IOUT3	Trigger input H (XTSEL = 0111 _B)
BGREQTRI	I (s)	Reserved	Trigger input I (XTSEL = 1000 _B)
BGREQTRJ	I (s)	Reserved	Trigger input J (XTSEL = 1001 _B)
BGREQTRK	I (s)	0	Trigger input K (XTSEL = 1010 _B)
BGREQTRL	I (s)	0	Trigger input L (XTSEL = 1011 _B)
BGREQTRM	I	ERU0.IOUT0	Trigger input M (XTSEL = 1100 _B)
BGREQTRN	I	ERU0.IOUT1	Trigger input N (XTSEL = 1101 _B)
BGREQTRO	I	Reserved	Trigger input O (XTSEL = 1110 _B)
BGREQTRP	I	BGREQGTSEL ¹⁾	Extend triggers to selected gating input of the background source (XTSEL = 1111 _B)
BGREQTRSEL	O	-	Selected trigger signal of the background source

System-Internal Connections

G0SAMPLE	O	-	Indicates the input signal sample phase
G1SAMPLE	O	-	Indicates the input signal sample phase
G0ARBCNT	O	CCU40.IN3G	Outputs a (count) pulse for each arbiter round
G1ARBCNT	O	-	Outputs a (count) pulse for each arbiter round

Versatile Analog-to-Digital Converter (VADC)
Table 16-15 Digital Connections in the XMC1200 (cont'd)

Signal	Dir.	Source/Destin.	Description
G0SR0	O	NVIC (17)	Service request 0 of group 0
G0SR1	O	NVIC (18)	Service request 1 of group 0
G0SR2	O	-	Service request 2 of group 0
G0SR3	O	-	Service request 3 of group 0
G1SR0	O	NVIC (19)	Service request 0 of group 1
G1SR1	O	NVIC (20)	Service request 1 of group 1
G1SR2	O	-	Service request 2 of group 1
G1SR3	O	-	Service request 3 of group 1
C0SR0	O	NVIC (15)	Service request 0 of common block 0
C0SR1	O	NVIC (16)	Service request 1 of common block 0
C0SR2	O	ERU0.0GU02 ERU0.0GU12	Service request 2 of common block 0
C0SR3	O	ERU0.0GU22 ERU0.0GU32	Service request 3 of common block 0
EMUX00	O	P0.4 P1.1	Control of external analog multiplexer interface 0
EMUX01	O	P0.3 P1.2	
EMUX02	O	P0.2 P1.3	
EMUX10	O	P1.4	Control of external analog multiplexer interface 1
EMUX11	O	P1.5	
EMUX12	O	P1.6	
CBFLOUT0	O	Reserved	Common boundary flag output 0
CBFLOUT1	O	Reserved	Common boundary flag output 1
CBFLOUT2	O	Reserved	Common boundary flag output 2
CBFLOUT3	O	Reserved	Common boundary flag output 3
G0BFLOUT0	O	ERU0.0A3	Boundary flag 0 output of group 0
G1BFLOUT0	O	ERU0.0B3	Boundary flag 0 output of group 1
G0BFLOUT1	O	ERU0.1A3	Boundary flag 1 output of group 0
G1BFLOUT1	O	ERU0.1B3	Boundary flag 1 output of group 1
G0BFLOUT2	O	ERU0.2A3	Boundary flag 2 output of group 0

Versatile Analog-to-Digital Converter (VADC)

Table 16-15 Digital Connections in the XMC1200 (cont'd)

Signal	Dir.	Source/Destin.	Description
G1BFLOUT2	O	ERU0.2B3	Boundary flag 2 output of group 1
G0BFLOUT3	O	ERU0.3A3	Boundary flag 3 output of group 0
G1BFLOUT3	O	ERU0.3B3	Boundary flag 3 output of group 1

1) Internal signal connection.

17 Analog Comparator (ACMP) and Out of Range Comparator (ORC)

This chapter describes the controls for analog comparator (ACMP) and out of range comparator (ORC).

17.1 Overview

This section gives an overview about the feature set of the Analog comparator and the Out of Range Comparator. In XMC1200, there are up to 3 Analog Comparators (ACMPx [x=0-2]) and 8 Out of Range Comparator (ORCx [x=0-7]).

17.1.1 Features

The following features are provided:

- Out of Range Comparator (ORC)
 - Over-voltage monitoring for the analog inputs pins of the ADC module
- Analog Comparator (ACMP)
 - Monitor external voltage level
 - Selectable low power mode
 - Inverted output option

17.2 Analog Comparator (ACMP)

Figure 17-2 shows the block diagram of a Analog Comparator unit.

Analog Comparator (ACMP) and Out of Range Comparator

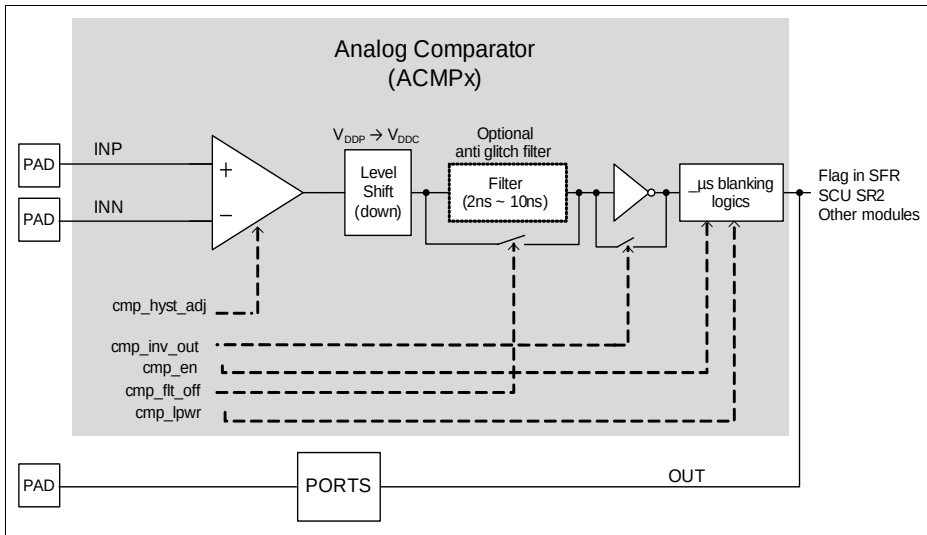


Figure 17-1 Block diagram of Analog Comparator

Input INP is compared with input INN in the pad voltage domain. The digital comparator output signal is shifted down from V_{DDP} power supply voltage level to V_{DDC} core voltage level. A filter (if enabled) absorbs generated spikes and can be controlled via bit ANACMPx.CMP_FLT_OFF. To prevent undefined states immediately after comparator enabling, a blanking module is added to ensure a stable output during transition state. The blanking time is in a range of few usec. With the help of bit ANACMPx.CMP_INV_OUT, the comparator output is inverted. The output of the comparator could be used to wake-up the system from power save mode. It can also be observed from a pin.

The analog comparator can be switched off via bit CMP_EN bit in the ANACMPx register to save power.

Divided Reference Voltage

A resistor chain (in the order of 500kOhm) divides the reference voltage value from ACMP.REF input if bit ANACMP1.REF_DIV_EN is set. According to [Figure 17-2](#), the divided voltage is delivered to pin ACMP1.INP. With bit ANACMP0.ACMP0_SEL and ANACMP2.ACMP2_SEL, all other comparators can be supplied by this divided reference voltage.

Analog Comparator (ACMP) and Out of Range Comparator

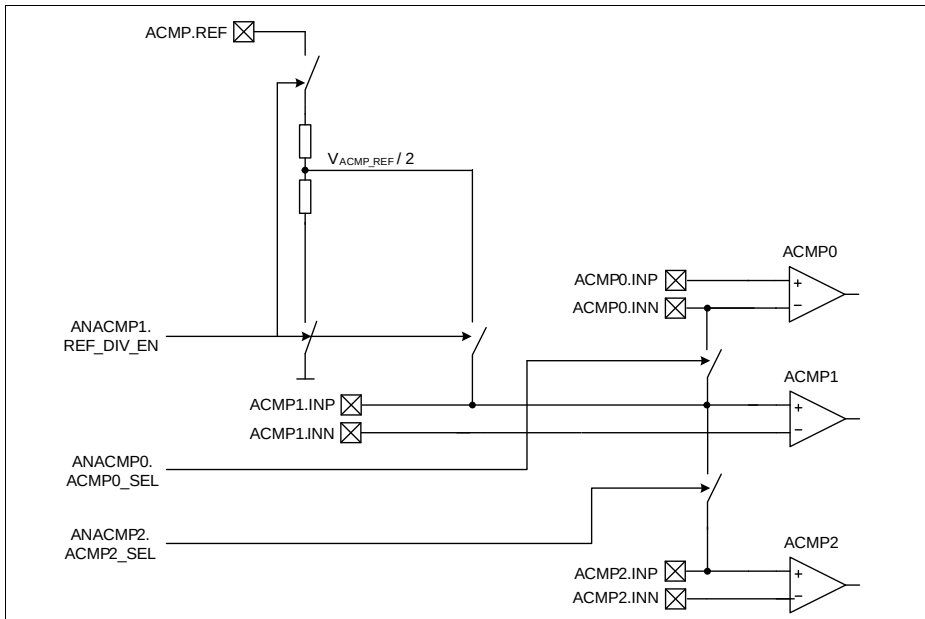


Figure 17-2 Analog Comparator Reference Divider Function

Low Power Mode

A low power state helps to reduce the total power consumption e.g. during sleep mode. It can be enabled by setting ANACMPx.LPWR to HIGH. In this mode, the analog comparators may show a reduced performance. When switching back to normal mode, the blanking time applies to ensure a stable output.

17.3 Out of Range Comparator (ORC)

Out of range comparator (ORC) is built into every ADC channel which will trigger other modules or an interrupt when voltage out of range condition occurs. This happens when voltage at the input channel rises to above V_{DDP} level or when the input channel falls to a voltage below V_{DDP} level.

The out of range comparator is connected to ERU0 modules. All out of range comparator events are assigned to one interrupt node.

Before using the out of range comparator, it has to be enabled by setting the bits at **ORCTRL.ENORCx** and configuring it to detect voltage higher or lower than V_{DDP} by setting bits **ORCTRL.CNFx** (See [Figure 17-3](#)).

Analog Comparator (ACMP) and Out of Range Comparator

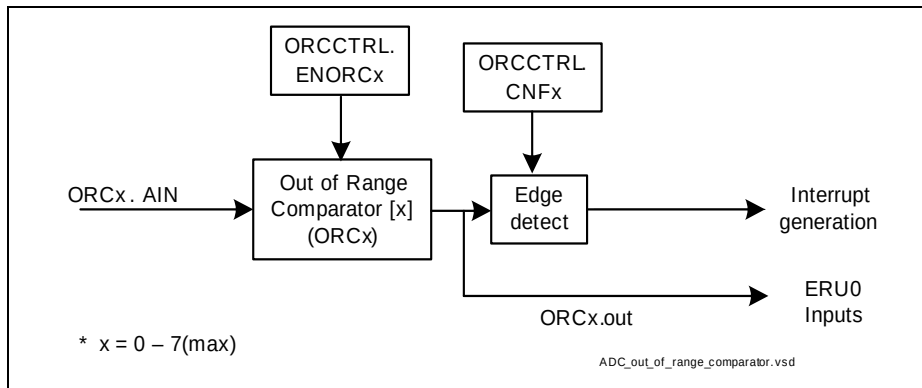


Figure 17-3 Out of range comparator

When a voltage out of range event occurs, the event sets an interrupt request through SCU.SR2 and triggers ERU0 through output of ORC (ORCx.out).

In XMC1200, ORCx.AIN[x=0-7] are connected to P2.2 - P2.9 respectively.

17.4 Service Request Generation

Both the ACMP and ORC has a service request output each. They are combined into a single output and connected to one of the interrupt node in the Nested Vectored Interrupt Controller (NVIC) via SCU.SR2.

The service request handling is part of the GCU block in SCU module. Refer to the “Service Request” description in the GCU section which is part of the SCU chapter for more details.

17.5 Debug Behavior

ACMPx and ORCx are not affected by the debug activities performed using external debug probe.

17.6 Registers

ACMP registers are accessible via the APB bus. ORC registers are accessible via the AHB bus. The absolute register address is calculated by adding:

Module Base Address + Offset Address

Following access to ACMP/ORC SFRs result in an AHB/APB error response:

- Read or write access to undefined address
- Write access to read-only registers

Analog Comparator (ACMP) and Out of Range Comparator

Table 17-1 Registers Address Space

Module	Base Address	End Address	Note
COMPARATOR	4001 0000 _H	4001 FFFF _H	System Control Unit Registers

Table 17-2 Registers Overview

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
ORCx Registers					
ORCCTRL	Out of Range Comparator Control Register	0500 _H	U, PV 32	U, PV 32	Page 17-6
ACMPx Registers					
ANACMP0	Analog Comparator 0 Control Register	105C _H	U, PV	U, PV	Page 17-7
ANACMP1	Analog Comparator 1 Control Register	1060 _H	U, PV	U, PV	Page 17-7
ANACMP2	Analog Comparator 2 Control Register	1064 _H	U, PV	U, PV	Page 17-7

1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

17.6.1 ORC Register

ORCCTRL

Out of Range Comparator Control Register

This register enables the out of range comparator and selects the rising edge trigger or falling edge trigger for the flag register.

Analog Comparator (ACMP) and Out of Range Comparator

ORCCTRL

Out Of Range Comparator Control Register

(0500_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								CNF 7	CNF 6	CNF 5	CNF 4	CNF 3	CNF 2	CNF 1	CNF 0
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
0								ENO RC7	ENO RC6	ENO RC5	ENO RC4	ENO RC3	ENO RC2	ENO RC1	ENO RC0
r								rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ENORCx (x = 0 - 7)	x	rw	Enable Out of Range Comparator x This bit defines if the out of range comparator is enabled in the corresponding analog input channel. 0 _B Out of range comparator disabled. 1 _B Out of range comparator enabled.
CNFx (x = 0 - 7)	x+16	rw	Out of Range Comparator Flag x This bit selects CHx rising edge trigger or falling edge trigger for out of range comparator flag register. 0 _B Falling edge trigger out of range event register. 1 _B Rising edge trigger out of range event register.
0	[15:8], [31:24]	r	Reserved Read as 0; should be written with 0.

17.6.2 ACMP Registers

ANACMP0

Analog Comparator 0 Control Register

Analog Comparator (ACMP) and Out of Range Comparator

ANACMP0

Analog Comparator 0 Control Register(105C_H)

Reset Value: 0020_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CMP_OUT							CMP_LPWR	0	ACMP0_SEL	CMP_HYST_ADJ	CMP_INV_OUT	0	CMP_FLT_OFF	CMP_EN	
rh					r		rw	r	rw	rw	rw	r	rw	rw	

Field	Bits	Type	Description
CMP_EN	0	rw	Comparator enable 0B CMP_DIS , Comparator is disabled 1B CMP_EN , Comparator is enabled
CMP_FLT_OFF	1	rw	Disables comparator filter If set, the comparator glitch-filter is switched off 0B FIL_ON , filter is active 1B FIL_OFF , filter is switched off (to prevent a filter delay)
CMP_INV_OUT	3	rw	Inverted Comparator output The comparator output is simply inverted 0B INV_OFF , no inversion of comparator signal 1B INV_ON , comparator signal is inverted
CMP_HYST_ADJ	5:4	rw	Comparator hysteresis adjust To reduce noise sensitivity a hysteresis voltage can be chosen. It can be switched off with writing 00B HYS_OFF , Comparator hysteresis is switched off 01B HYS1 , Hysteresis _{typ} = 10mV 10B HYS2 , Hysteresis _{typ} = 15mV 11B HYS3 , Hysteresis _{typ} = 20mV

Analog Comparator (ACMP) and Out of Range Comparator

Field	Bits	Type	Description
ACMP0_SEL	6	rw	Connect ACMP0.INN to ACMP1.INP An internal switch connects comparator pad ACMP0.INN with pad ACMP1.INP together. Only one of both input pad shall be driven by a voltage source. The time delay between both pads is caused by the impedance of the switch. When bit ANACMP1.REF_DIV_EN is set, the divided reference voltage is applied not only to ACMP1.INP, but also to ACMP0.INN 0B OFF , ACMP0.INN is not connected 1B ON , ACMP0.INN is connected to ACMP1.INP
CMP_LPWR	8	rw	Low Power Mode If enabled, all three analog comparator units are set into low power mode. If the logic level of this bit is changed, the core has to blank the comparator output information a certain time. 0B HPM , High Power Mode 1B LPM , Low Power Mode
CMP_OUT	15	rh	Comparator output monitor bit This bit corresponds to the comparator output status 0B OUT0 , state "Vminus > Vplus" 1B OUT1 , state "Vminus < Vplus"
0	2, 7, 14:9	r	Reserved Read as 0; should be written with 0.

ANACMP1

Analog Comparator 1 Control Register

ANACMP1

Analog Comparator 1 Control Register(1060_H)

Reset Value: 0020_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CMP_OUT					0				REF_DIV_EN	CMP_HYST_ADJ	CMP_INV_OUT	0	CMP_FLT_OF	CMP_EN	
rh					r				rw	rw	rw	r	rw	rw	

Analog Comparator (ACMP) and Out of Range Comparator

Field	Bits	Type	Description
CMP_EN	0	rw	Comparator enable 0B CMP_DIS , Comparator is disabled 1B CMP_EN , Comparator is enabled
CMP_FLT_OFF	1	rw	Disables comparator filter If set, the comparator glitch-filter is switched off 0B FIL_ON , filter is active 1B FIL_OFF , filter is switched off (to prevent a filter delay)
CMP_INV_OUT	3	rw	Inverted Comparator output The comparator output is simply inverted 0B INV_OFF , no inversion of comparator signal 1B INV_ON , comparator signal is inverted
CMP_HYST_ADJ	5:4	rw	Comparator hysteresis adjust To reduce noise sensitivity a hysteresis voltage can be chosen. It can be switched off with writing 00B HYS_OFF , Comparator hysteresis is switched off 01B HYS1 , Hysteresis_typ = 10mV 10B HYS2 , Hysteresis_typ = 15mV 11B HYS3 , Hysteresis_typ = 20mV
REF_DIV_EN	6	rw	Resistor Divider is enabled and Reference Voltage is applied to ACMP1 The divider reference voltage is applied to the positive ACMP1 input 0B OFF , no resistor is connected 1B ON , the divider resistor is enabled and the voltage is applied to ACMP1.INP
CMP_OUT	15	rh	Comparator output monitor bit This bit corresponds to the comparator output status 0B OUT0 , state "Vminus > Vplus" 1B OUT1 , state "Vminus < Vplus"
0	2, 14:7	r	Reserved Read as 0; should be written with 0.

Analog Comparator (ACMP) and Out of Range Comparator

ANACMP2

Analog Comparator 2 Control Register

ANACMP2

Analog Comparator 2 Control Register(1064_H)

Reset Value: 0020_H

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CMP_OUT					0				ACMP2_SEL	CMP_HYST_ADJ		CMP_INV_OUT	0	CMP_FLT_OFF	CMP_EN
rh					r				rw	rw		rw	r	rw	rw

Field	Bits	Type	Description
CMP_EN	0	rw	Comparator enable 0B CMP_DIS , Comparator is disabled 1B CMP_EN , Comparator is enabled
CMP_FLT_OFF	1	rw	Disables comparator filter If set, the comparator glitch-filter is switched off 0B FIL_ON , filter is active 1B FIL_OFF , filter is switched off (to prevent a filter delay)
CMP_INV_OUT	3	rw	Inverted Comparator output The comparator output is simply inverted 0B INV_OFF , no inversion of comparator signal 1B INV_ON , comparator signal is inverted
CMP_HYST_ADJ	5:4	rw	Comparator hysteresis adjust To reduce noise sensitivity a hysteresis voltage can be chosen. It can be switched off with writing 00B HYS_OFF , Comparator hysteresis is switched off 01B HYS1 , Hysteresis_typ = 10mV 10B HYS2 , Hysteresis_typ = 15mV 11B HYS3 , Hysteresis_typ = 20mV

Analog Comparator (ACMP) and Out of Range Comparator

Field	Bits	Type	Description
ACMP2_SEL	6	rw	Connect ACMP2.INP to ACMP1.INP An internal switch connects comparator pad ACMP2.INP with pad ACMP1.INP together. Only one of both input pad shall be driven by a voltage source. The time delay between both pads is caused by the impedance of the switch. When bit ANACMP1.REF_DIV_EN is set, the divided reference voltage is applied not only to ACMP1.INP, but also to ACMP2.INP 0B OFF , ACMP2.INP is not connected 1B ON , ACMP2.INP is connected to ACMP1.INP
CMP_OUT	15	rh	Comparator output monitor bit This bit corresponds to the comparator output status 0B OUT0 , state "Vminus > Vplus" 1B OUT1 , state "Vminus < Vplus"
0	2, 14:7	r	Reserved Read as 0; should be written with 0.

Analog Comparator (ACMP) and Out of Range Comparator

17.7 Interconnects

ACMP and ORC are connected to the ports, the ERU0 and BCCU0.

Table 17-3 Analog Comparator Pin Connections

Input/Output	I/O	Connected To	Description
ACMP0.INN	I	P2.8	"-" input of ACMP0
ACMP0.INP	I	P2.9	"+" input of ACMP0
ACMP1.INN	I	P2.6	"-" input of ACMP1
ACMP1.INP	I	P2.7	"+" input of ACMP1
ACMP2.INN	I	P2.2	"-" input of ACMP2
ACMP2.INP	I	P2.1	"+" input of ACMP2
ACMP.REF	I	P2.11	Reference input of ACMP
ACMP0.OUT	O	P0.10 P2.10 ERU0.0A0 BCCU0.IN5	output of ACMP0
ACMP1.OUT	O	P1.0 ERU0.1A0 BCCU0.IN0 P2.5.HW0 pull control	output of ACMP1
ACMP2.OUT	O	P0.5 P1.2 ERU0.2A0 BCCU0.IN3 P2.3.HW0 pull control	output of ACMP2

Table 17-4 Out of Range Comparator Pin Connections

Input/Output	I/O	Connected To	Description
ORC0.AIN	I	P2.2	analog input of ORC0
ORC1.AIN	I	P2.3	analog input of ORC1
ORC2.AIN	I	P2.4	analog input of ORC2
ORC3.AIN	I	P2.5	analog input of ORC3
ORC4.AIN	I	P2.6	analog input of ORC4
ORC5.AIN	I	P2.7	analog input of ORC5
ORC6.AIN	I	P2.8	analog input of ORC6

Analog Comparator (ACMP) and Out of Range Comparator

Table 17-4 Out of Range Comparator Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
ORC7.AIN	I	P2.9	analog input of ORC7
ORC0.OUT	O	ERU0.0B2	output of ORC0
ORC1.OUT	O	ERU0.1B2	output of ORC1
ORC2.OUT	O	ERU0.0A2 ERU0.2B2	output of ORC2
ORC3.OUT	O	ERU0.1A2	output of ORC3
ORC4.OUT	O	ERU0.2A2	output of ORC4
ORC5.OUT	O	ERU0.3A2	output of ORC5
ORC6.OUT	O	ERU0.3B2	output of ORC6
ORC7.OUT	O	ERU0.3A0	output of ORC7

18 Temperature Sensor (TSE)

This chapter describes the controls for Temperature Sensor (TSE).

18.1 General Description

The Temperature Sensor (TSE) generates a measurement result that indicates directly the current temperature. The result of the measurement is displayed via bit field ANATSEMON.TSE_MON. The user routines (`_CalcTemperature`) inside ROM takes this value and calculate the actual silicon temperature. This routine can be called by the application software and more details are described in Chapter “Bootstrap Loaders and User Routines”. Library functions are also available and described in the Temperature Sensor device guide. The TSE has to be enabled before it can be used via bit ANATSECTRL.TSE_EN.

The measurement result is ready when the SRRAW.TSE_DONE flag is set. An interrupt can be triggered when it is enabled via SRMSK.TSE_DONE bit. After the measurement is completed and result is stored in TSE_MON, TSE continue with next measurement. Measurement are disabled when TSE_EN is cleared to 0. Hence, reading the TSE_MON value will provide you the latest temperature.

The TSE is capable of generating interrupt requests when TSE temperature measurement in result crosses upper and/or lower threshold value configured in bit ANATSEIH.TSE_IH and ANATSEIL.TSE_IL respectively. Digital comparators are implemented to compare the actual measurement result against configured limits and triggers interrupt if the value fall outside of valid range. Result of comparison is shown as the SRRAW.TSE_HIGH and TSE_LOW flag. The user routines (`_CalcTSEVAR`) can be used to obtain the upper and lower temperature limits needed to program the bit TSE_IH and TSE_IL and more details are described in Chapter “Bootstrap Loaders and User Routines”. Library functions are also available and described in the Temperature Sensor device guide.

18.2 Service Request Generation

The TSE has a service request output for TSE Done, TSE HIGH and TSE Low event. They are combined with events from other modules into a single output and connected to one of the interrupt node in the Nested Vectored Interrupt Controller (NVIC) via SCU.SR1.

The service request handling is part of the GCU block in SCU module. Refer to the “Service Request” description in the GCU section which is part of the SCU chapter for more details.

18.3 Registers

TSE registers are accessible via the APB bus. The absolute register address is calculated by adding:

Module Base Address + Offset Address

Following access to TSE SFRs result in an AHB/APB error response:

- Read or write access to undefined address
- Write access to read-only registers

Table 18-1 Registers Address Space

Module	Base Address	End Address	Note
TSE	4001 0000 _H	4001 FFFF _H	System Control Unit Registers

Table 18-2 Registers Overview

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
ANATSECTRL	Temperature Sensor Control Register	0024 _H	U, PV	U, PV	Page 18-3
ANATSEIH	Temperature Sensor High Interrupt Register	0030 _H	U, PV	U, PV	Page 18-3
ANATSEIL	Temperature Sensor Low Interrupt Register	0034 _H	U, PV	U, PV	Page 18-4
ANATSEMON	Temperature Sensor Counter2 Monitor Register	0040 _H	U, PV	U, PV	Page 18-4

1) The absolute register address is calculated as follows:
Module Base Address + Offset Address (shown in this column)

18.3.1 Registers

ANATSECTRL

Temperature Sensor Control Register

Temperature Sensor (TSE)

ANATSEIL

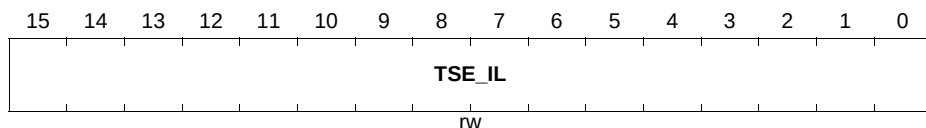
Temperature Sensor Low Temperature Interrupt Register

ANATSEIL

Temperature Sensor Low Temperature Interrupt Register

(1034_H)

Reset Value: FFFF_H



Field	Bits	Type	Description
TSE_IL	15:0	rw	Counter value for low temperature interrupt ANATSEIL value is compared with ANATSEMON An low interrupt is triggered if: ANATSEMON > ANATSEIL The comparison result can be observed from SCU_SRRW.TSE_LOW

ANATSEMON

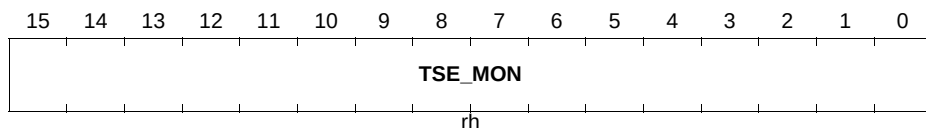
Temperature Sensor Counter2 Monitor Register

ANATSEMON

Temperature Sensor Counter2 Monitor Register

(1040_H)

Reset Value: 0000_H



Temperature Sensor (TSE)

Field	Bits	Type	Description
TSE_MON	15:0	rh	Monitor Counter2 value; loaded by TSE_DONE After each measurement done event (indicated by a set in SCU_SRRAW.TSE_DONE bit), the result is stored in this register.

Industrial Control Peripherals

19 Capture/Compare Unit 4 (CCU4)

The CCU4 peripheral is a major component for systems that need general purpose timers for signal monitoring/conditioning and Pulse Width Modulation (PWM) signal generation. Power electronic control systems like switched mode power supplies or uninterruptible power supplies, can easily be implemented with the functions inside the CCU4 peripheral.

The internal modularity of CCU4, translates into a software friendly system for fast code development and portability between applications.

Table 19-1 Abbreviations table

PWM	Pulse Width Modulation
CCU4x	Capture/Compare Unit 4 module instance x
CC4y	Capture/Compare Unit 4 Timer Slice instance y
ADC	Analog to Digital Converter
POSIF	Position Interface peripheral
SCU	System Control Unit
f_{ccu4}	CCU4 module clock frequency
f_{tclk}	CC4y timer clock frequency

Note: A small “y” or “x” letter in a register indicates an index

19.1 Overview

Each CCU4 module is comprised of four identical 16 bit Capture/Compare Timer slices, CC4y. Each timer slice can work in compare mode or in capture mode. In compare mode one compare channel is available while in capture mode, up to four capture registers can be used in parallel.

Each CCU4 module has four service request lines and each timer slice contains a dedicated output signal, enabling the generation of up to four independent PWM signals. Straightforward timer slice concatenation is also possible, enabling up to 64 bit timing operations. This offers a flexible frequency measurement, frequency multiplication and pulse width modulation scheme.

A programmable function input selector for each timer slice, that offers up to nine functions, discards the need of complete resource mapping due to input ports availability.

A built-in link between the CCU4 and several other modules enable flexible digital motor control loops implementation, e.g. with Hall Sensor monitoring or direct coupling with Encoders.

19.1.1 Features

CCU4 module features

Each CCU4 represents a combination of four timer slices, that can work independently in compare or capture mode. Each timer slice has a dedicated output for PWM signal generation.

All four CCU4 timer slices, CC4y, are identical in terms of available functions and operating modes. Avoiding this way the need of implementing different software routines, depending on which resource of CCU4 is used.

A built-in link between the four timer slices is also available, enabling this way a simplified timer concatenation and sequential operations.

General Features

- 16 bit timer cells
- capture and compare mode for each timer slice
 - four capture registers in capture mode
 - one compare channel in compare mode
- programmable low pass filter for the inputs
- built-in timer concatenation
 - 32, 48 or 64 bit width
- shadow transfer for the period and compare values
- programmable clock prescaler
- normal timer mode
- gated timer mode
- three counting schemes
 - center aligned
 - edge aligned
 - single shot
- PWM generation
- TRAP function
- start/stop can be controlled by external events
- counting external events
- four dedicated service request lines per CCU4

Additional features

- external modulation function
- load controlled by external events
- dithering PWM
- floating point pre scaler
- output state override by an external event
- suitable and flexible connectivity to several modules:
 - motor and power conversion applications
 - high number of signal conditioning possibilities

CCU4 features vs. applications

On [Table 19-2](#) a summary of the major features of the CCU4 unit mapped with the most common applications.

Table 19-2 Applications summary

Feature	Applications
Four independent timer cells	Independent PWM generation: • Multiple buck/boost converter control (with independent frequencies) • Different modes of operation for each timer, increasing the resource optimization • Up to 2 Half-Bridges control • multiple Zero Voltage Switch (ZVS) converter control with easy link to the ADC channels.
Concatenated timer cells	Easy to configure timer extension up to 64 bit: • High dynamic trigger capturing • High dynamic signal measurement
Dithering PWM	Generating a fractional PWM frequency or duty cycle: • To avoid big steps on frequency or duty cycle adjustment in slow control loop applications • Increase the PWM signal resolution over time
Floating prescaler	Automated control signal measurement: • decrease SW activity for monitoring signals with high or unknown dynamics • emulating more than a 16 bit timer for system control
Up to 9 functions via external signals for each timer	Flexible resource optimization: • The complete set of external functions is always available • Several arrangements can be done inside a CCU4, e.g., one timer working in capture mode and one working in compare

Table 19-2 Applications summary (cont'd)

Feature	Applications
4 dedicated service request lines	Specially developed for: • generating interrupts for the microprocessor • flexible connectivity between peripherals, e.g. ADC triggering.
Linking with other modules	Flexible profiles for: • Hall Sensor feedback/monitoring • Motor Encoders feedback/monitoring • PWM parallel modulation • Flexible signal conditioning

19.1.2 Block Diagram

Each CCU4 timer slice can operate independently from the other slices for all the available modes. Each timer slice contains a dedicated input selector for functions linked with external events and has a dedicated compare output signal, for PWM signal generation.

The built-in timer concatenation is only possible with adjacent slices, e.g. CC40/CC41. Combinations for slice concatenations like, CC40/CC42 or CC40/CC43 are not possible.

The individual service requests for each timer slice (four per slice) are multiplexed into four module service requests lines, [Figure 19-1](#).

Capture/Compare Unit 4 (CCU4)

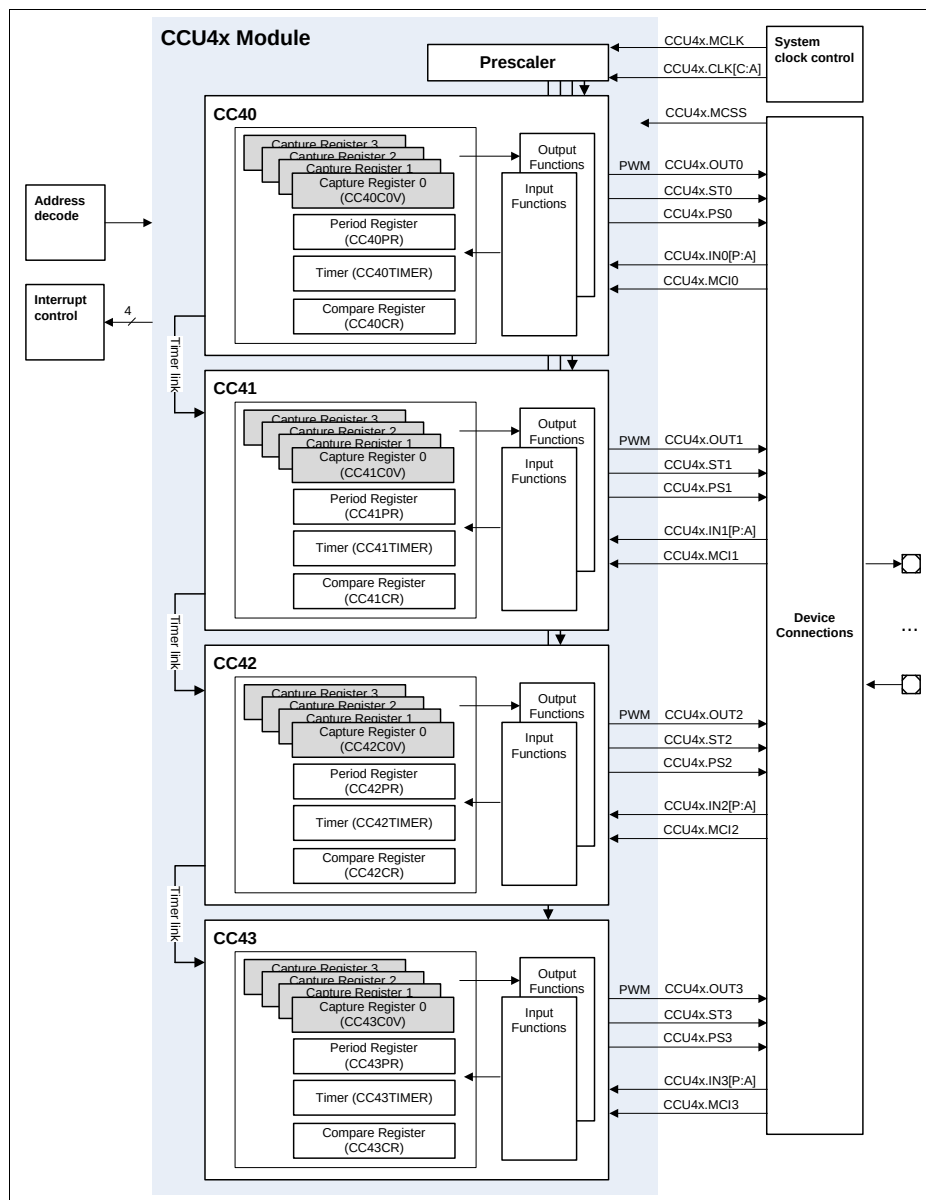


Figure 19-1 CCU4 block diagram

19.2 Functional Description

19.2.1 CC4y Overview

The input path of a CCU4 slice is comprised of a selector ([Section 19.2.2](#)) and a connection matrix unit ([Section 19.2.3](#)). The output path contains a service request control unit, a timer concatenation unit and two units that control directly the state of the output signal for each specific slice (for TRAP and modulation handling), see [Figure 19-2](#).

The timer core is built of a 16 bit counter one period and one compare register in capture mode, or up to four capture registers in capture mode.

In compare mode the period register sets the maximum counting value while the compare channel is controlling the ACTIVE/PASSIVE state of the dedicated comparison slice output.

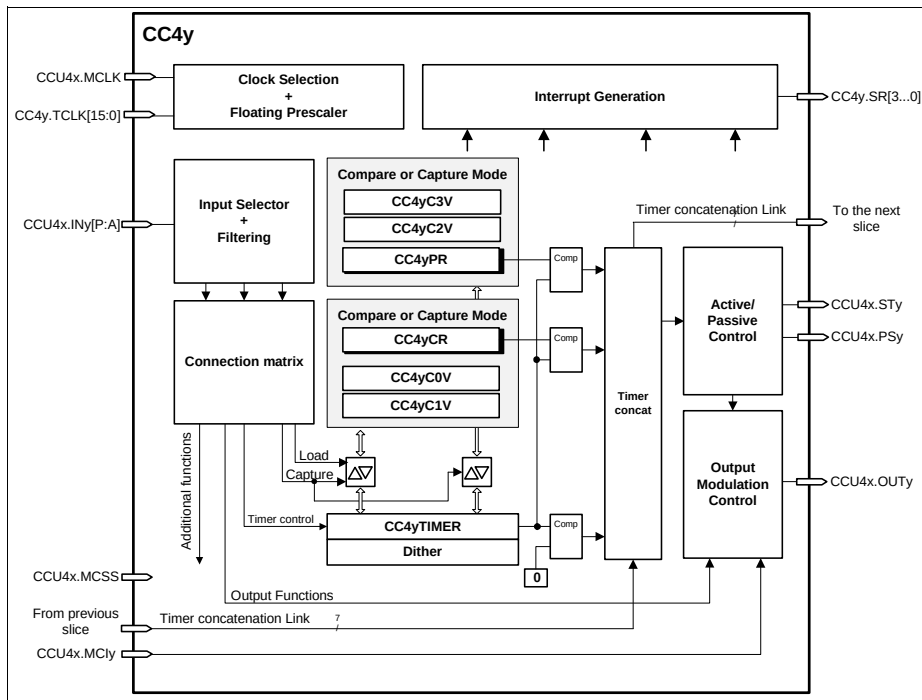


Figure 19-2 CCU4 slice block diagram

Capture/Compare Unit 4 (CCU4)

Each CCU4 slice, with the exception of the first, contains six dedicated inputs outputs that are used for the built-in timer concatenation functionality.

Inputs and outputs that are not seen at the CCU4 boundaries have a nomenclature of CC4y.<name>, whilst CCU4 module inputs and outputs are described as CCU4x.<signal_name>y (indicating the variable y the object slice).

Table 19-3 CCU4 slice pin description

Pin	I/O	Description
CCU4x.MCLK	I	Module clock
CC4y.TCLK[15:0]	I	Clocks from the pre scaler
CCU4x.INy[P:A]	I	Slice functional inputs (used to control the functionality throughout slice external events)
CCU4x.MCIy	I	Multi Channel mode input
CCU4x.MCSS	I	Multi Channel shadow transfer trigger
CC4y.SR[3...0]	O	Slice service request lines
CC4x.STy	O	Slice comparison status value
CCU4x.PSy	O	Multi channel pattern update trigger
CCU4x.OUTy	O	Slice dedicated output pin

Note:

- The status bit outputs of the Kernel, CCU4x.STy, are extended for one more kernel clock cycle.*
- The Service Request signals at the output of the kernel are extended for one more kernel clock cycle.*
- The maximum output signal frequency of the CCU4x.STy outputs is module clock divided by 4.*

The slice timer, can count up or down depending on the selected operating mode. A direction flag holds the actual counting direction.

The timer is connected to two stand alone comparators, one for the period match and one for a compare match. The registers used for period match and comparison match can be programmed to serve as capture registers enabling sequential capture capabilities on external events.

In normal edge aligned counting scheme, the counter is cleared to 0000_H each time that matches the period value defined in the period register. In center aligned mode, the counter direction changes from 'up counting' to 'down counting' after reaching the period

Capture/Compare Unit 4 (CCU4)

value. Both period and compare registers have an aggregated shadow register, which enables the update of the PWM period and duty cycle on the fly.

A single shot mode is also available, where the counter stops after it reaches the value set in the period register.

The start and stop of the counter can be controlled via software access or by a programmable input pin.

Functions like, load, counting direction (up/down), TRAP and output modulation can also be controlled with external events, see [Section 19.2.3](#).

19.2.2 Input Selector

The first unit of the slice input path, is used to select which inputs are used to control the available external functions.

Inside this block the user also has the possibility to perform a low pass filtering of the signals and selecting the active edge(s) or level of the external event, see [Figure 19-3](#).

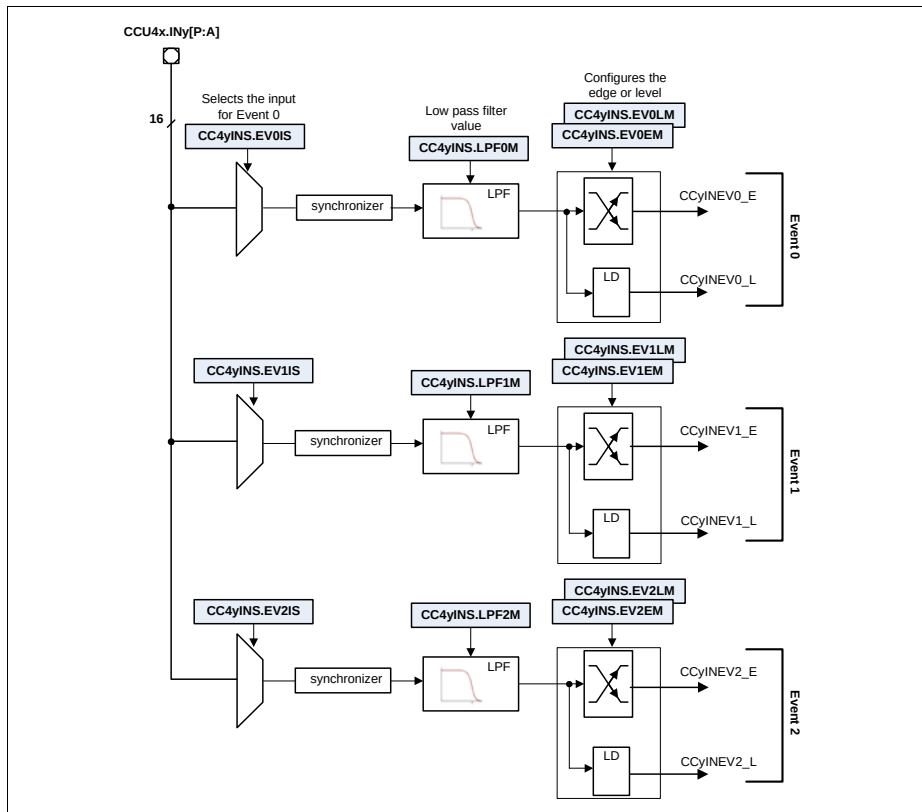


Figure 19-3 Slice input selector diagram

The user has the possibility of selecting any of the CCU4x.INy[P:A] inputs as the source of an event.

At the output of this unit we have a user selection of three events, that were configured to be active at rising, falling or both edges, or level active. These selected events can then be mapped to several functions.

Notice that each decoded event contains two outputs, one edge active and one level active, due to the fact that some functions like counting, capture or load are edge sensitive events while, timer gating or up down counting selection are level active.

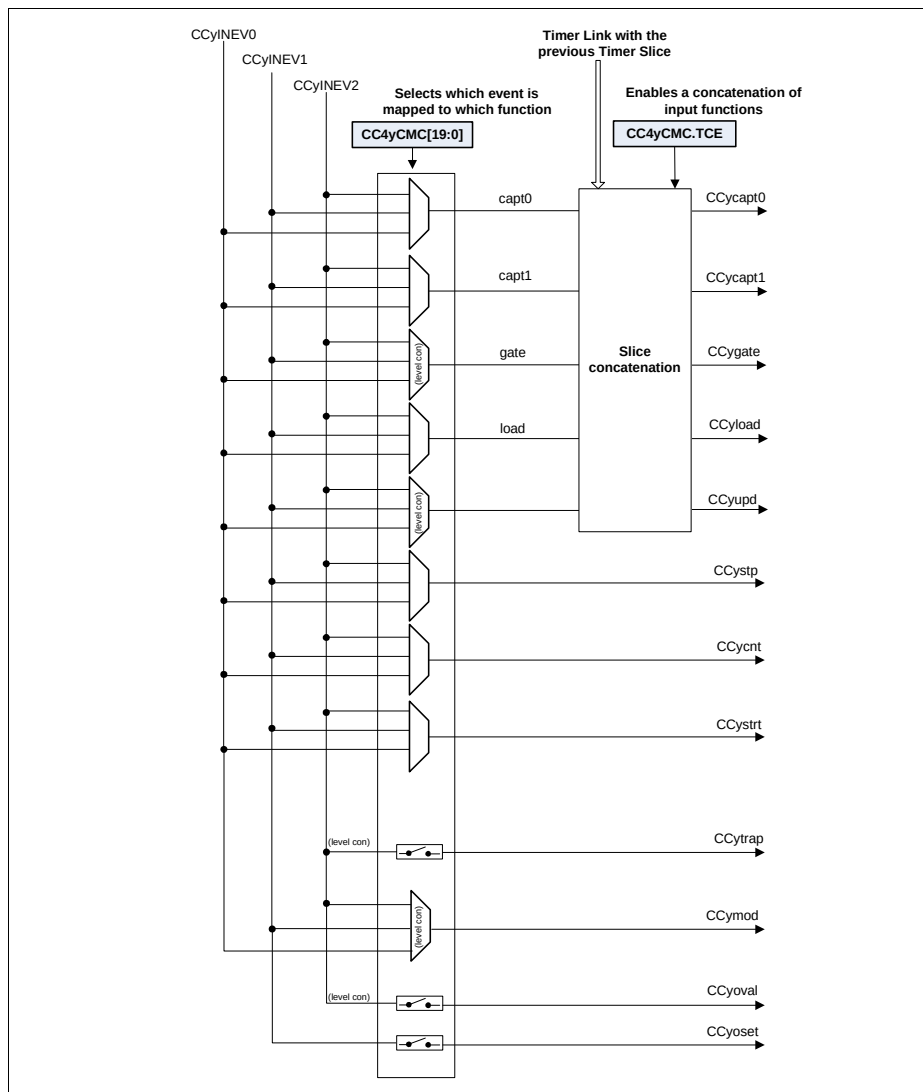
19.2.3 Connection Matrix

The connection matrix maps the events coming from the input selector to several user configured functions, [Figure 19-4](#). The following functions can be enabled on the connection matrix:

Table 19-4 Connection matrix available functions

Function	Brief description	Map to figure Figure 19-4
Start	Edge signal to start the timer	CCystrt
Stop	Edge signal to stop the timer	CCystp
Count	Edge signal used for counting events	CCycnt
Up/down	Level signal used to select up or down counting direction	CCyupd
Capture 0	Edge signal that triggers a capture into the capture registers 0 and 1	CCycapt0
Capture 1	Edge signal that triggers a capture into the capture register 2 and 3	CCycapt1
Gate	Level signal used to gate the timer clock	CCygate
Load	Edge signal that loads the timer with the value present at the compare register	CCyload
TRAP	Level signal used for fail-safe operation	CCytrap
Modulation	Level signal used to modulate/clear the output	CCymod
Status bit override	Status bit is going to be overridden with an input value	CCyoval for the value CCyoset for the trigger

Inside the connection matrix we also have a unit that performs the built-in timer concatenation. This concatenation enables a completely synchronized operation between the concatenated slices for timing operations and also for capture and load actions. The timer slice concatenation is done via the [CC4yCMC.TCE](#) bitfield. For a complete description of the concatenation function, please address [Section 19.2.9](#).



19.2.4 Starting/Stopping the Timer

Each timer slice contains a run bit register that indicates the actual status of the timer, **CC4yTCST.TRB**. The start and stop of the timer can be done via software access or can be controlled directly by external events, see **Figure 19-5**.

Selecting an external signal that acts as a start trigger does not force the user to use an external stop trigger and vice versa.

Selecting the single shot mode, imposes that after the counter reaches the period value the run bit, **CC4yTCST.TRB**, is going to be cleared and therefore the timer is stopped.

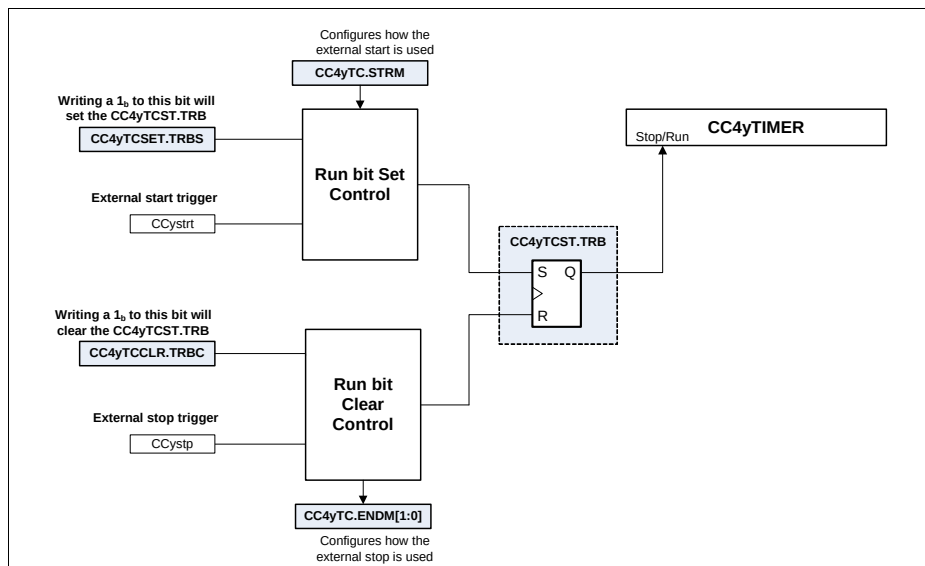


Figure 19-5 Timer start/stop control diagram

One can use the external stop signal to perform the following functions (configuration via **CC4yTC.ENDM**):

- Clear the run bit (stops the timer) - default
- Clear the timer (to 0000_H) but it does not clear the run bit (timer still running)
- Clear the timer and the run bit

One can use the external start to perform the following functions (configuration via **CC4yTC.STRM**):

- Start the timer (resume operation)
- Clear and start the timer

The set (start the timer) of the timer run bit, always has priority over a clear (stop the timer).

Capture/Compare Unit 4 (CCU4)

To start multiple CCU4 timers at the same time/synchronously one should use a dedicated input as external start (see [Section 19.2.7.1](#) for a description how to configure an input as start function). This input should be connected to all the Timers that need to be started synchronously (see [Section 19.8](#) for a complete list of module connections), [Figure 19-6](#).

For starting the timers synchronously via software there is a dedicated input signal, controlled by the SCU (System Control Unit), that is connected to all the CCU4 timers. This signal should then be configured as an external start signal (see [Section 19.2.7.1](#)) and then the software must write a $1_B/0_B$ (depending on the external start signal configuration) to the specific bitfield of the CCUCON register (this register is described on the SCU chapter).

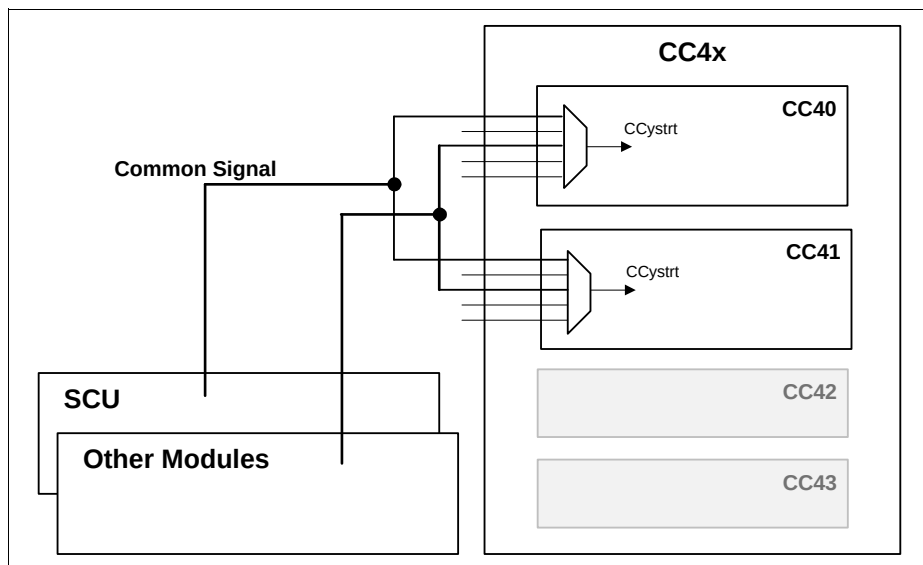


Figure 19-6 Starting multiple timers synchronously

19.2.5 Counting Modes

Each CC4y timer slice can be programmed into three different counting schemes:

- Edge aligned (default)
- Center aligned
- Single shot (can be edge or center aligned)

These three counting schemes can be used as stand alone without the need of selecting any inputs as external event sources. Nevertheless it is also possible to control the

Capture/Compare Unit 4 (CCU4)

counting operation via external events like, timer gating, counting trigger, external stop, external start, etc.

For all the counting modes, it is possible to update on the fly the values for the timer period and compare channel. This enables a cycle by cycle update of the PWM frequency and duty cycle.

The compare channel of each CC4y Timer Slice, has an associated Status Bit (**GCST.CC4yST**), that indicates the active or passive state of the channel, **Figure 19-7**. The set and clear of the status bit and the respective PWM signal generation is dictated by the timer period, compare value and the current counting mode. See the different counting mode descriptions, **Section 19.2.5.3** to **Section 19.2.5.5** to understand how this bit is set and cleared.

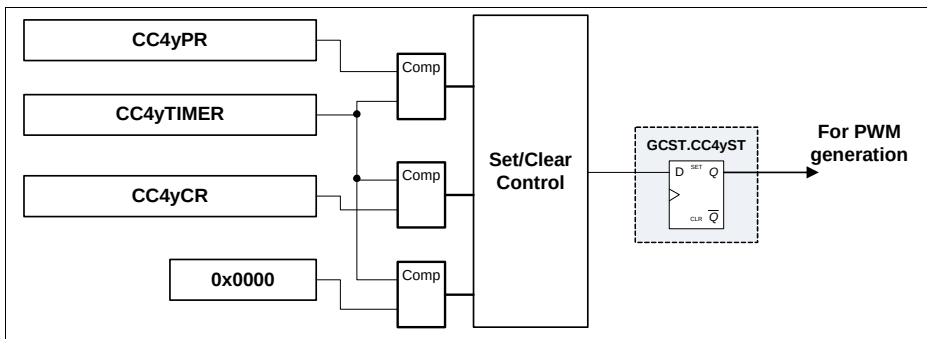


Figure 19-7 CC4y Status Bit

19.2.5.1 Calculating the PWM Period and Duty Cycle

The period of the timer is determined by the value in the period register, **CC4yPR** and by the timer mode.

The base for the PWM signal frequency and duty cycle, is always related to the clock frequency of the timer itself and not to the frequency of the module clock (due to the fact that the timer clock can be a scaled version of the module clock).

In Edge Aligned Mode, the timer period is:

$$T_{\text{per}} = \text{<Period-Value>} + 1; \text{ in } f_{\text{tclk}} \quad (19.1)$$

In Center Aligned Mode, the timer period is:

$$T_{\text{per}} = (\text{<Period-Value>} + 1) \times 2; \text{ in } f_{\text{tclk}} \quad (19.2)$$

For each of these counting schemes, the duty cycle of generated PWM signal is dictated by the value programmed into the **CC4yCR** register.

In Edge Aligned and Center Aligned Mode, the PWM duty cycle is:

$$DC = 1 - \frac{\text{Compare-Value}}{(\text{Period-Value} + 1)} \quad (19.3)$$

Both **CC4yPR** and **CC4yCR** can be updated on the fly via software, enabling a glitch free transition between different period and duty cycle values for the generated PWM signal, [Section 19.2.5.2](#)

19.2.5.2 Updating the Period and Duty Cycle

Each CCU4 timer slice provides an associated shadow register for the period and compare values. This facilitates a concurrent update by software for these two parameters, with the objective of modifying during run time the PWM signal period and duty cycle.

In addition to the shadow registers for the period and compare values, one also has available shadow registers for the floating prescaler and dither functions, **CC4yFPCS** and **CC4yDITS** respectively (please address [Section 19.2.11](#) and [Section 19.2.10](#) for a complete description of these functions).

The structure of the shadow registers can be seen in [Figure 19-8](#).

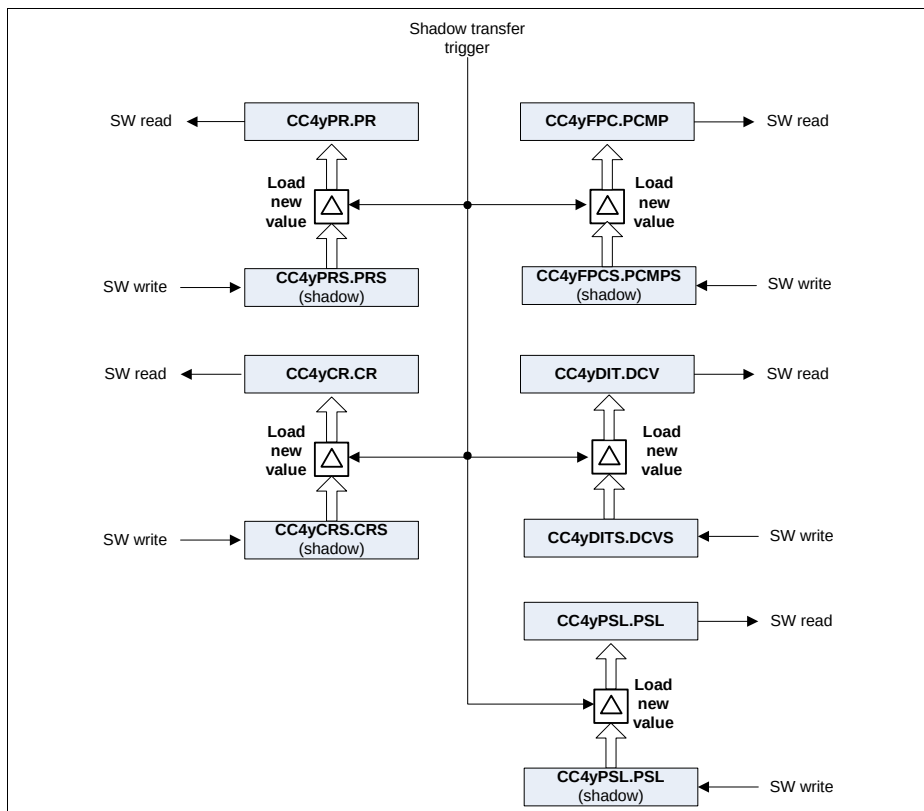


Figure 19-8 Shadow registers overview

The update of these registers can only be done by writing a new value into the associated shadow register and wait for a shadow transfer to occur.

Each group of shadow registers have an individual shadow transfer enable bit, [Figure 19-9](#). The software must set this enable bit to 1_B, whenever an update of the values is needed. These bits are automatically cleared by the hardware, whenever an update of the values is finished. Therefore every time that an update of the registers is needed the software must set again the specific bit(s).

Nevertheless it is also possible to clear the enable bit via software. This can be used in the case that an update of the values needs to be cancelled (after the enable bit has already been set).

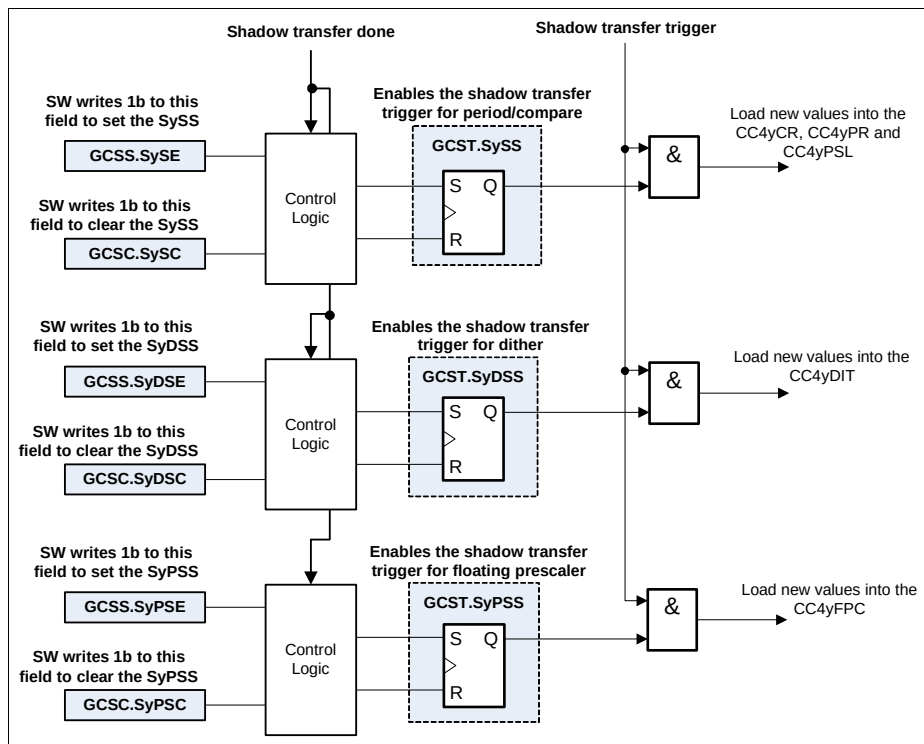


Figure 19-9 Shadow transfer enable logic

The shadow transfer operation is going to be done in the immediately next occurrence of a shadow transfer trigger, after the shadow transfer enable is set (**GCST.SySS**, **GCST.SyDSS**, **GCST.SyPSS** set to 1_B).

The occurrence of the shadow transfer trigger is imposed by the timer counting scheme (edge aligned or center aligned). Therefore the slots when the values are updated can be:

- in the next clock cycle after a Period Match while counting up
- in the next clock cycle after an One Match while counting down
- immediately, if the timer is stopped and the shadow transfer enable bit(s) is set

Figure 19-10 shows an example of the shadow transfer control when the timer slice has been configured into center aligned mode. For a complete description of all the timer slice counting modes, please address [Section 19.2.5.3](#), [Section 19.2.5.4](#) and [Section 19.2.5.5](#).

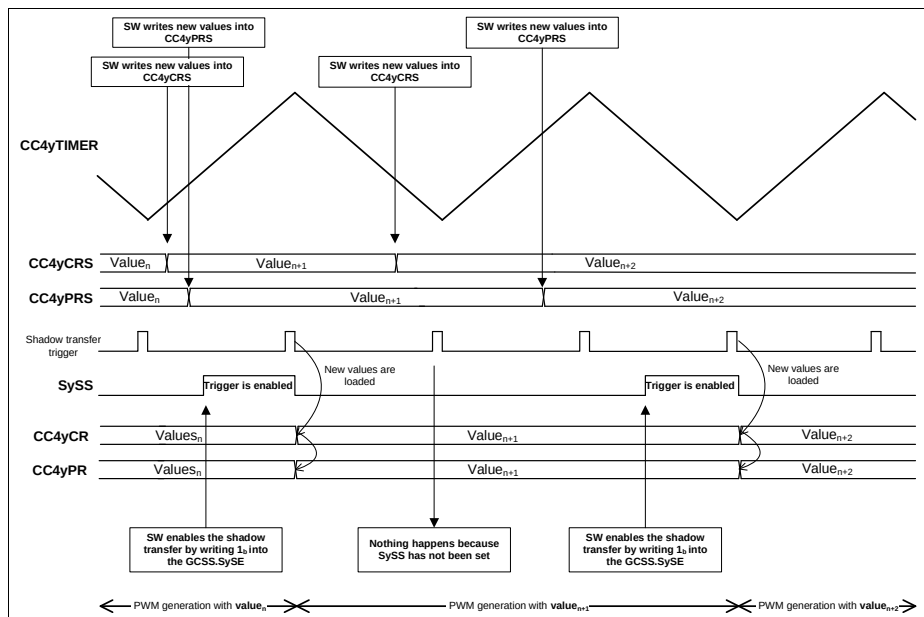


Figure 19-10 Shadow transfer timing example - center aligned mode

In some application cases it may be necessary to request shadow transfers not by software but by hardware. To perform this action each CCU4 contains a dedicated input that can be used to request a shadow transfer by hardware, the CCU4x.MCSS.

This input, when enabled, is used to set the shadow transfer enable bitfields (**GCST.SySS**, **GCST.SyDSS** and **GCST.SyPSS**) of the specific slice. It is possible to select which slice is using this input to perform the synchronization via the **GCTRL.MSEy** bit field. It is also possible to enable the usage of this signal for the three different shadow transfer signals: compare and period values, dither compare value and prescaler compare value. This can be configured on the **GCTRL.MSDE** field.

The structure for using the CCU4x.MCSS input signal can be seen in [Figure 19-9](#). The usage of this signal is just an add on to the shadow transfer control and therefore all the previous described functions are still available.

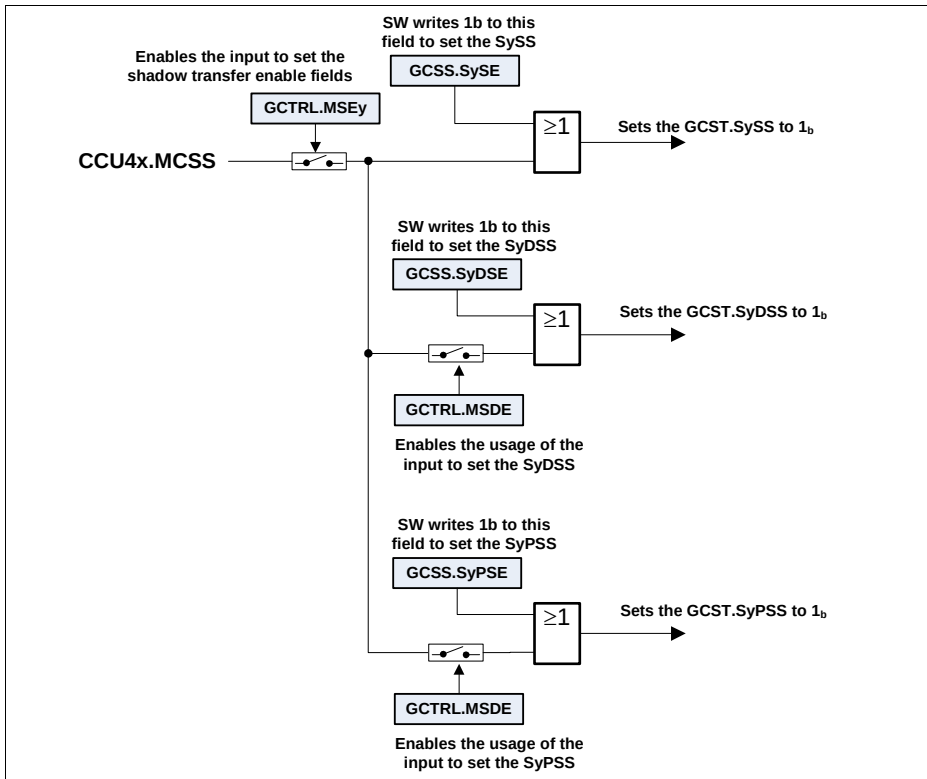


Figure 19-11 Usage of the CCU4x.MCSS input

19.2.5.3 Edge Aligned Mode

Edge aligned mode is the default counting scheme. In this mode, the timer is incremented until it matches the value programmed in the period register, **CC4yPR**. When period match is detected the timer is cleared to 0000_H and continues to be incremented.

In this mode, the value of the period register and compare register are updated with the value written by software into the correspondent shadow register, every time that an overflow occurs (period match), see **Figure 19-12**.

In edge aligned mode, the status bit of the comparison (CC4yST) is set one clock cycle after the timer hits the value programmed into the compare register. The clear of the status bit is done one clock cycle after the timer reaches 0000_H.

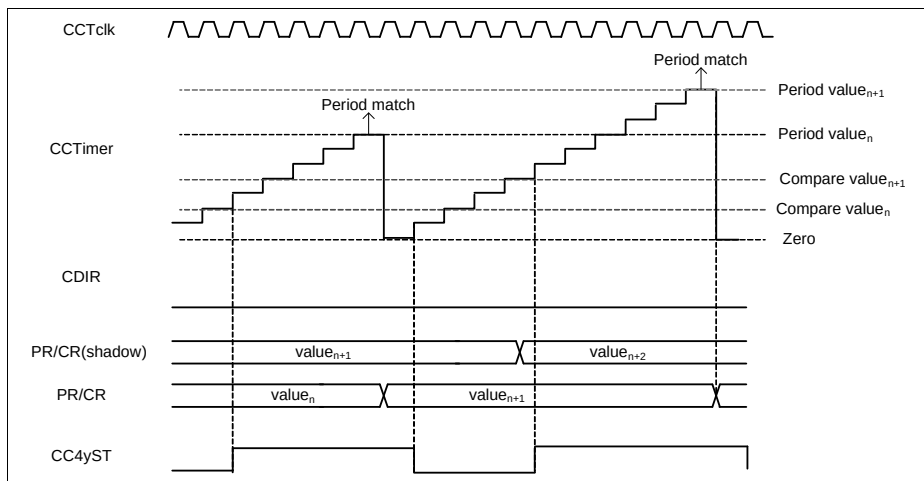


Figure 19-12 Edge aligned mode, **CC4yTCM** = 0_B

19.2.5.4 Center Aligned Mode

In center aligned mode, the timer is counting up or down with respect to the following rules:

- The counter counts up while **CC4yTCST.CDIR** = 0_B and it counts down while **CC4yTCST.CDIR** = 1_B.
- Within the next clock cycle, the count direction is set to counting up (**CC4yTCST.CDIR** = 0_B) when the counter reaches 0001_H while counting down.
- Within the next clock cycle, the count direction is set to counting down (**CC4yTCST.CDIR** = 1_B), when the period match is detected while counting up.

The status bit (CC4yST) is always 1_B when the counter value is equal or greater than the compare value and 0_B otherwise.

While in edge aligned mode, the shadow transfer for compare and period registers is executed once per period. It is executed twice in center aligned mode as follows

- Within the next clock cycle after the counter reaches the period value, while counting up (**CC4yTCST.CDIR** = 0_B).
- Within the next clock cycle after the counter reaches 0001_H, while counting down (**CC4yTCST.CDIR** = 1_B).

*Note: Bit **CC4yTCST.CDIR** changes within the next timer clock after the one-match or the period-match, which means that the timer continues counting in the previous direction for one more cycle before changing the direction.*

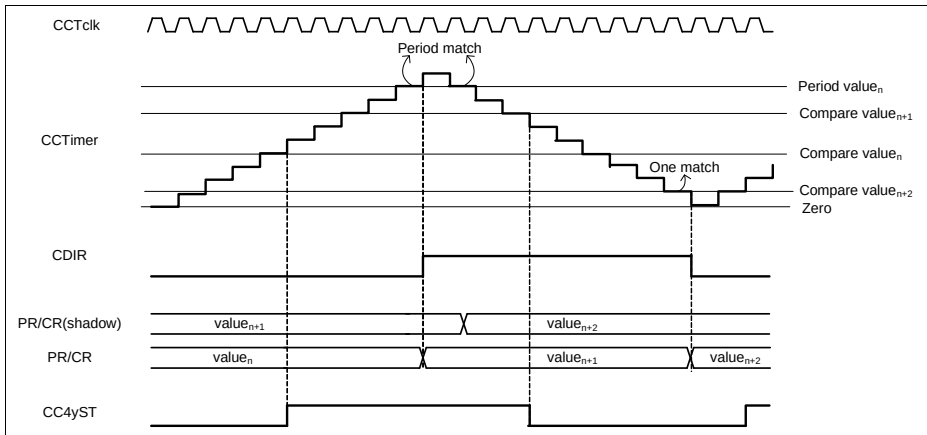


Figure 19-13 Center aligned mode, $CC4yTC.TCM = 1_B$

19.2.5.5 Single Shot Mode

In single shot mode, the timer is stopped after the current timer period is finished. This mode can be used with center or edge aligned scheme.

In edge aligned mode, **Figure 19-14**, the timer is stopped when it is cleared to 0000_H after having reached the period value. In center aligned mode, **Figure 19-15**, the period is finished when the timer has counted down to 0000_H.

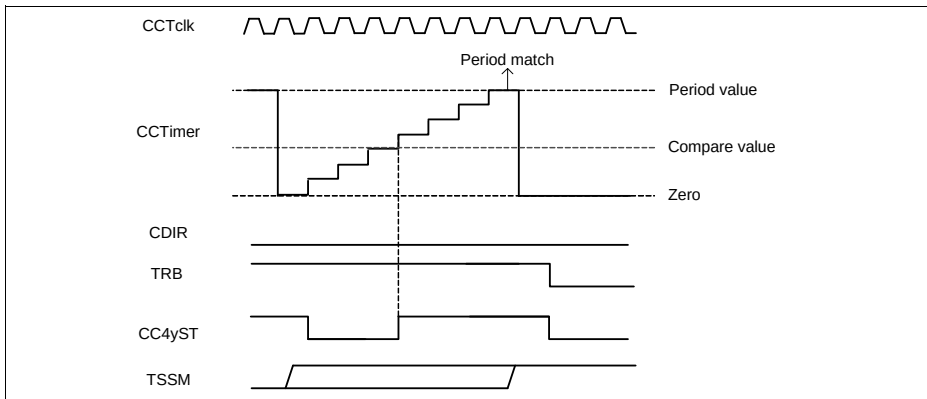


Figure 19-14 Single shot edge aligned - $CC4yTC.TSSM = 1_B$, $CC4yTC.TCM = 0_B$

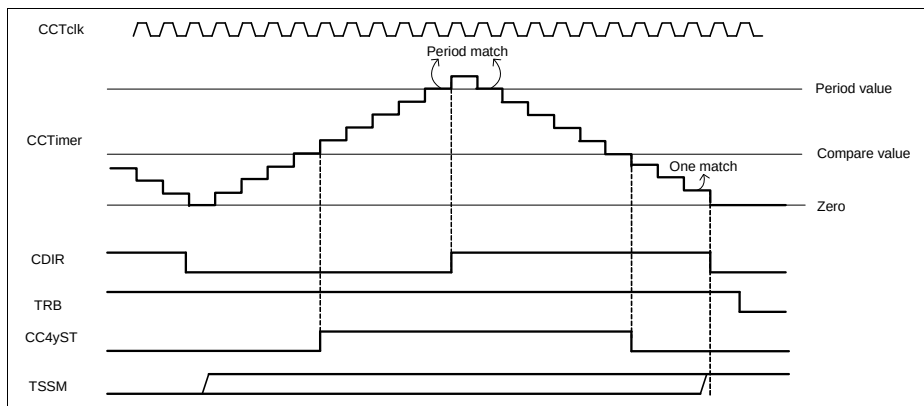


Figure 19-15 Single shot center aligned - $CC4yTC.TSSM = 1_B$, $CC4yTC.TCM = 1_B$

19.2.6 Active/Passive Rules

The general rules that set or clear the associated timer slice status bit (CC4yST), can be generalized independently of the timer counting mode.

The following events set the Status bit (CC4yST) to Active:

- in the next f_{tclk} cycle after a compare match while counting up
- in the next f_{tclk} cycle after a zero match while counting down

The following events set the Status bit (CC4yST) to Inactive:

- in the next f_{tclk} cycle after a zero match (and not compare match) while counting up
- in the next f_{tclk} cycle after a compare match while counting down

If external events are being used to control the timer operation, these rules are still applicable.

The status bit state can only be 'override' via software or by the external status bit override function, [Section 19.2.7.10](#).

The software can at any time write a 1_B into the [GCSS.SySTS](#) bitfield, which will set the status bit [GCST.CC4yST](#) of the specific timer slice. Writing a 1_B into the [GCSC.SySTC](#) bitfield will clear the specific status bit.

19.2.7 External Events Control

Each CCU4 timer slice has the possibility of using up to three different input events, see [Section 19.2.2](#). These three events can then be mapped to Timer Slice functions (the full set of available functions is described at [Section 19.2.3](#))

These events can be mapped to any of the CCU4x.INy[P...A] inputs and there isn't any imposition that an event cannot be used to perform several functions, or that an input

cannot be mapped to several events (e.g. input X triggers event 0 with rising edge and triggers event 1 with the falling edge).

19.2.7.1 External Start/Stop

To select an external start function, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** field and indicating the active edge of the signal on the **CC4yINS.EVxEM** field.

This event should be then mapped to the start or stop functionality by setting the **CC4yCMC.STRTS** (for the start) or the **CC4yTC.ENDM** (for the stop) with the proper value.

Notice that both start and stop functions are edge and not level active and therefore the active/passive configuration is set only by the **CC4yINS.EVxEM**.

The external stop by default just clears the run bit (**CC4yTCST.TRB**), while the start functions does the opposite. Nevertheless one can select an extended subset of functions for the external start and stop. This subset is controlled by the registers **CC4yTC.ENDM** (for the stop) and **CC4yTC.STRM** (for the start).

For the start subset (**CC4yTC.STRM**):

- sets the run bit/starts the timer (resume operation)
- clears the timer, sets the run bit/starts the timer (flush and start)

For the stop subset (**CC4yTC.ENDM**):

- clears the run/stops the timer (stop)
- clears the timer (flush)
- clears the timer, clears the run bit/stops the timer (flush and stop)

If in conjunction with an external start/stop (configured also/only as flush) and external up/down signal is used, during the flush operation the timer is going to be set to 0000_H if the actual counting direction is up or set with the value of the period register if the counting direction is down.

Figure 19-16 to **Figure 19-19** shows the usage of two signals to perform the start/stop functions in all the previously mentioned subsets. External Signal(1) acts as an active HIGH start signal, while External Signal(2) is used as an active HIGH stop function.

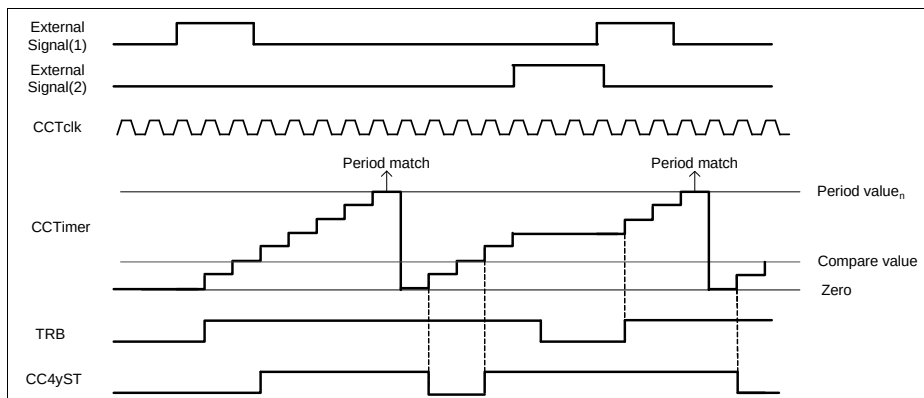


Figure 19-16 Start (as start)/ stop (as stop) - $CC4yTC.STRM = 0_B$, $CC4yTC.ENDM = 00_B$

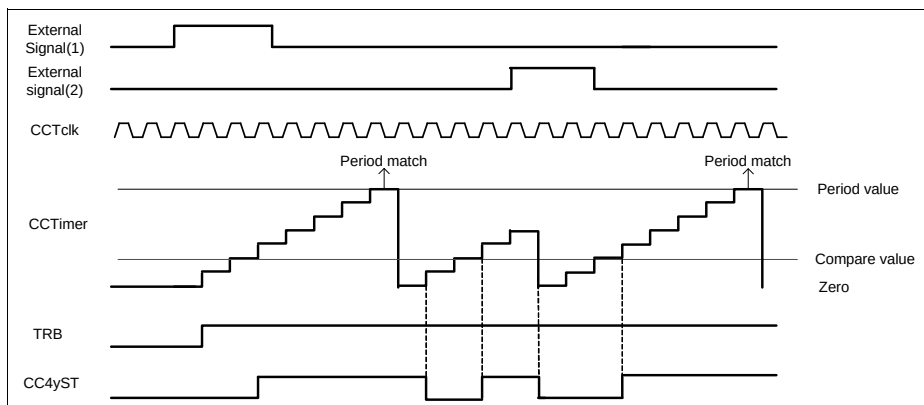


Figure 19-17 Start (as start)/ stop (as flush) - $CC4yTC.STRM = 0_B$, $CC4yTC.ENDM = 01_B$

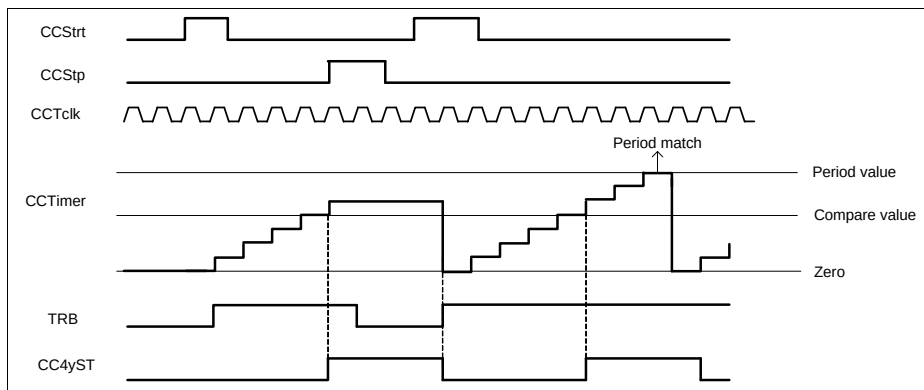


Figure 19-18 Start (as flush and start)/ stop (as stop) - **CC4yTC.STRM = 1_B**,
CC4yTC.ENDM = 00_B

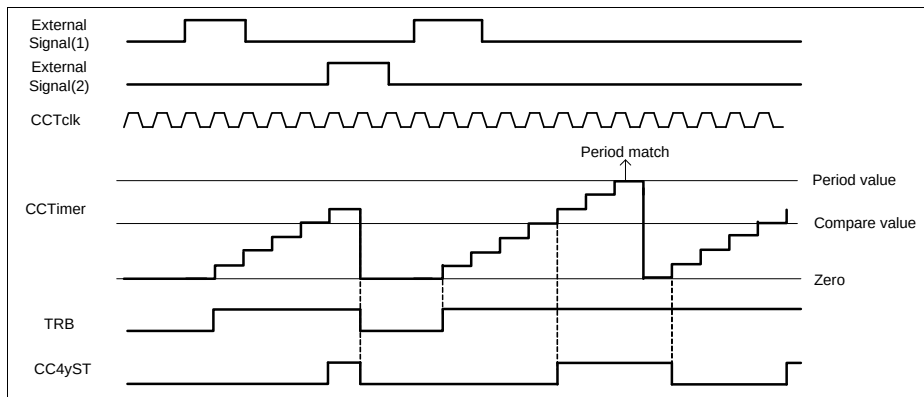


Figure 19-19 Start (as start)/ stop (as flush and stop) - **CC4yTC.STRM = 0_B**,
CC4yTC.ENDM = 10_B

19.2.7.2 External Counting Direction

There is the possibility of selecting an input signal to act as increment/decrement control. To select an external up/down control, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** field and indicating the active level of the signal on the **CC4yINS.EVxLM**. This event should be then mapped to the up/down functionality by setting **CC4yCMC.UDS** with the proper value.

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Notice that the up/down function is level active and therefore the active/passive configuration is set only by the **CC4yINS.EVxLM**.

The status bit of the slice (**CC4yST**) is always set when the timer value is equal or greater than the value stored in the compare register, see [Section 19.2.6](#).

The update of the period and compare register values is done when:

- with the next clock after a period match, while counting up (**CC4yTCST.CDIR** = 0_B)
- with the next clock after a one match, while counting down (**CC4yTCST.CDIR** = 1_B)

The value of the **CC4yTCST.CDIR** register is updated accordingly with the changes on the decoded event. The Up/Down direction is always understood as **CC4yTCST.CDIR** = 1_B when counting down and **CC4yTCST.CDIR** = 0_B when counting up. Using an external signal to perform the up/down counting function and configuring the event as active HIGH means that the timer is counting up when the signal is HIGH and counting down when LOW.

Figure 19-20 shows an external signal being used to control the counting direction of the time. This signal was selected as active HIGH, which means that the timer is counting down while the signal is HIGH and counting up when the signal is LOW.

*Note: For a signal that should impose an increment when LOW and a decrement when HIGH, the user needs to set the **CC4yINS.EVxLM** = 0_B. When the operation is switched, then the user should set **CC4yINS.EVxLM** = 1_B.*

Note: Using an external counting direction control, sets the slice in edge aligned mode.

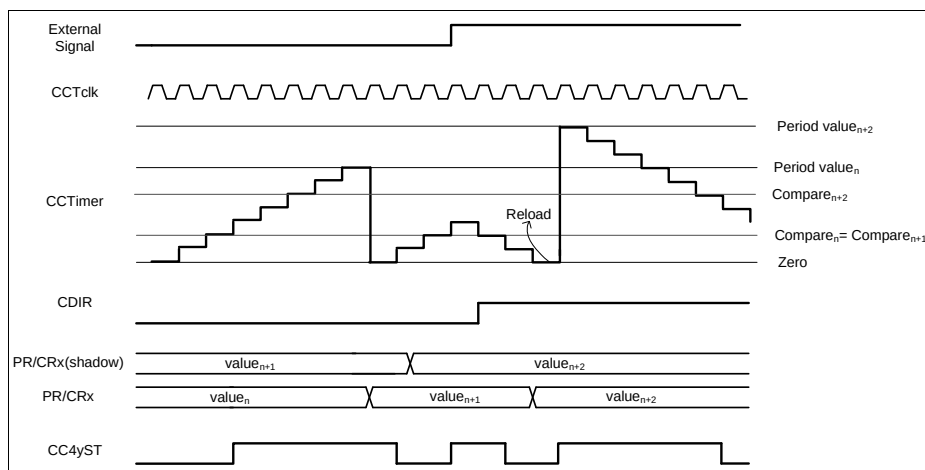


Figure 19-20 External counting direction

19.2.7.3 External Gating Signal

For pulse measurement, the user has the possibility of selecting an input signal that operates as counting gating.

To select an external gating control, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** register and indicating the active level of the signal on the **CC4yINS.EVxLM** register. This event should be then mapped to the gating functionality by setting the **CC4yCMC.GATES** with the proper value.

Notice that the gating function is level active and therefore the active/passive configuration is set only by the **CC4yINS.EVxLM**.

The status bit during an external gating signal continues to be asserted when the compare value is reached and deasserted when the counter reaches 0000_H. One should note that the counter continues to use the period register to identify the wrap around condition. **Figure 19-21** shows the usage of an external signal for gating the slice counter. The signal was set as active LOW, which means the counter gating functionality is active when the external value is zero.

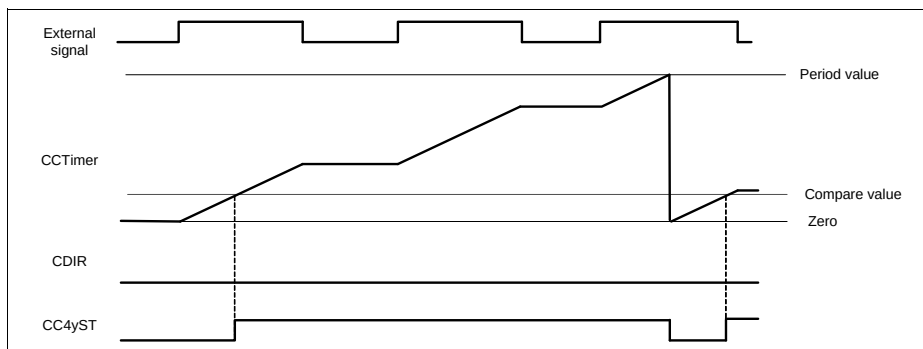


Figure 19-21 External gating

For any type of usage of the external gating function, the specific run bit of the Timer Slice, **CC4yTCST.TRB**, needs to be set. This can be done via an additional external signal or directly via software.

19.2.7.4 External Count Signal

There is also the possibility of selecting an external signal to act as the counting event.

To select an external counting, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** register and indicating the active edge of the signal on the **CC4yINS.EVxEM** register.

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This event should be then mapped to the counting functionality by setting the **CC4yCMC.CNTS** with the proper value.

Notice that the counting function is edge active and therefore the active/passive configuration is set only by the **CC4yINS.EVxEM**.

One can select just a the rising, falling or both edges to perform a count. On **Figure 19-22**, the external signal was selected as a counter event for both falling and rising edges. Wrap around condition is still applied with a comparison with the period register.

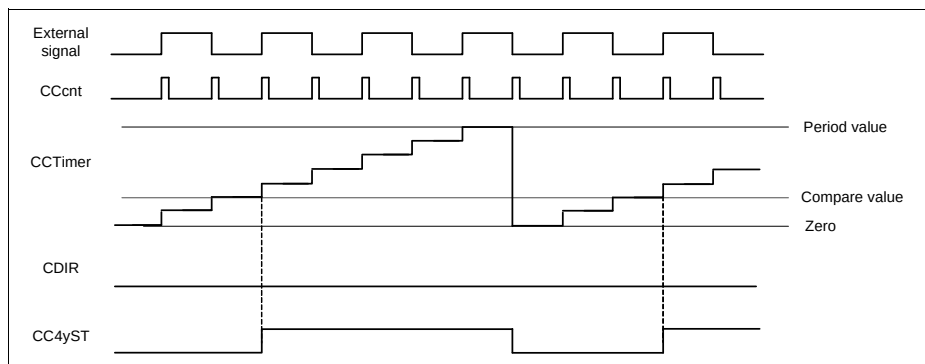


Figure 19-22 External count

For any type of usage of the external gating function, the specific run bit of the Timer Slice, **CC4yTCST.TRB**, needs to be set. This can be done via an additional external signal or directly via software.

19.2.7.5 External Load

Each slice of the CCU4 also has a functionality that enables the user to select an external signal as trigger for reloading the value of the timer with the current value of the compare register (if **CC4yTCST.CDIR** = 0_B) or with the value of the period register (if **CC4yTCST.CDIR** = 1_B).

To select an external load signal, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** register and indicating the active edge of the signal on the **CC4yINS.EVxEM** register. This event should be then mapped to the load functionality by setting the **CC4yCMC.LDS** with the proper value.

Notice that the load function is edge active and therefore the active/passive configuration is set only by the **CC4yINS.EVxEM**.

On figure **Figure 19-23**, the external signal (1) was used to act as a load trigger, active on the rising edge. Every time that a rising edge on external signal (1) is detected, the

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timer value is loaded with the value present on the compare register. If an external signal is being used to control the counting direction, up or down, the timer value can be loaded also with the value set in the period register. The External signal (2) represents the counting direction control (active HIGH). If at the moment that a load trigger is detected, the signal controlling the counting direction is imposing a decrement, then the value set in the timer is the period value.

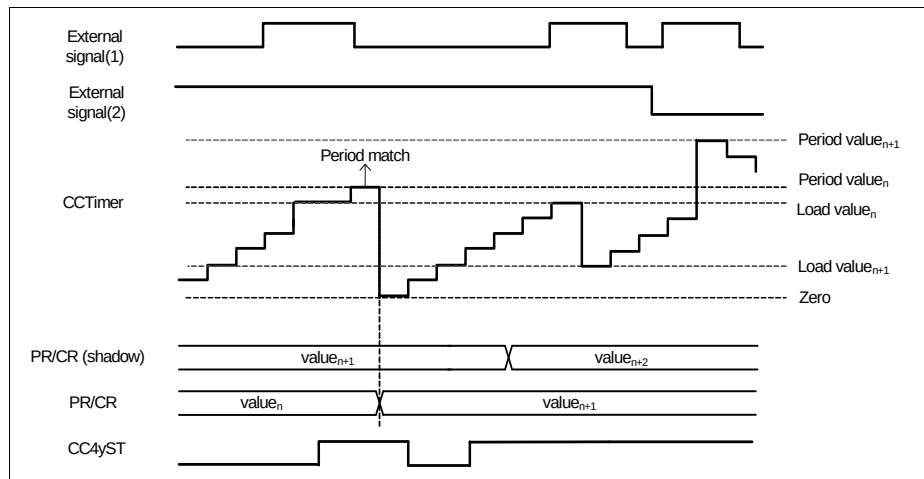


Figure 19-23 External load

19.2.7.6 External Capture

When selecting an external signal to be used as a capture trigger (if **CC4yCMC.CAP0S** or **CC4yCMC.CAP1S** are different from 0_H), the user is automatically setting the specific slice into capture mode.

In capture mode the user can have up to four capture registers, see **Figure 19-26**: capture register 0 (**CC4yC0V**), capture register 1 (**CC4yC1V**), capture register 2 (**CC4yC2V**) and capture register 3 (**CC4yC3V**).

These registers are shared between compare and capture modes which imposes:

- if **CC4yC0V** and **CC4yC1V** are used for capturing, the compare registers **CC4yCR** and **CC4yCRS** are not available (no compare channel)
- if **CC4yC2V** and **CC4yC3V** are used for capturing, the period registers **CC4yPR** and **CC4yPRS** are not available (no period control)

To select an external capture signal, one should map one of the events (output of the input selector) to a specific input signal, by setting the required value in the **CC4yINS.EVxIS** register and indicating the active edge of the signal on the

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CC4yINS.EVxEM register. This event should be then mapped to the capture functionality by setting the **CC4yCMC.CAP0S/CC4yCMC.CAP1S** with the proper value. Notice that the capture function is edge active and therefore the active/passive configuration is set only by the **CC4yINS.EVxEM**.

The user has the possibility of selecting the following capture schemes:

- Different capture events for **CC4yC0V/CC4yC1V** and **CC4yC2V/CC4yC3V**
- The same capture event for **CC4yC0V/CC4yC1V** and **CC4yC2V/CC4yC3V** with the same capture edge. For this capture scheme, only the CCcap1 functionality needs to be programmed. To enable this scheme, the field **CC4yTC.SCE** needs to be set to 1.

Different Capture Events (SCE = 0_B)

Every time that a capture trigger 1 occurs, CCcap1, the actual value of the timer is captured into the capture register 3 and the previous value stored in this register is transferred into capture register 2.

Every time that a capture trigger 0 occurs, CCcap0, the actual value of the timer is captured into the capture register 1 and the previous value stored in this register is transferred into capture register 0.

Every time that a capture procedure into one of the registers occurs, the respective full flag is set. This flag is cleared automatically by HW when the SW reads back the value of the capture register (by reading the specific capture register or by reading the extended capture read value, see [Section 19.2.7.7](#)).

The capture of a new value into a specific capture registers is dictated by the status of the full flag as follows:

$$CC4yC1V_{\text{capt}} = \text{NOT}(CC4yC1V_{\text{full\_flag}} \text{ AND } CC4yC0V_{\text{full\_flag}}) \quad (19.4)$$

$$CC4yC0V_{\text{capt}} = CC4yC1V_{\text{full\_flag}} \text{ AND NOT}(CC4yC0V_{\text{full\_flag}}) \quad (19.5)$$

It is also possible to disable the effect of the full flags reset by setting the **CC4yTC.CCS** = 1_B. This enables a continuous capturing independent if the values captured have been read or not.

*Note: When using the period registers for capturing, **CC4yCMC.CAP1S** different from 00_B, the counter always uses its full 16 bit width as period value.*

On [Figure 19-24](#), an external signal was selected as an event for capturing the timer value into the **CC4yC0V/CC4yC1V** registers. The status bit, CC4yST, during capture mode is asserted whenever a capture trigger is detected and deasserted when the counter matches 0000_H.

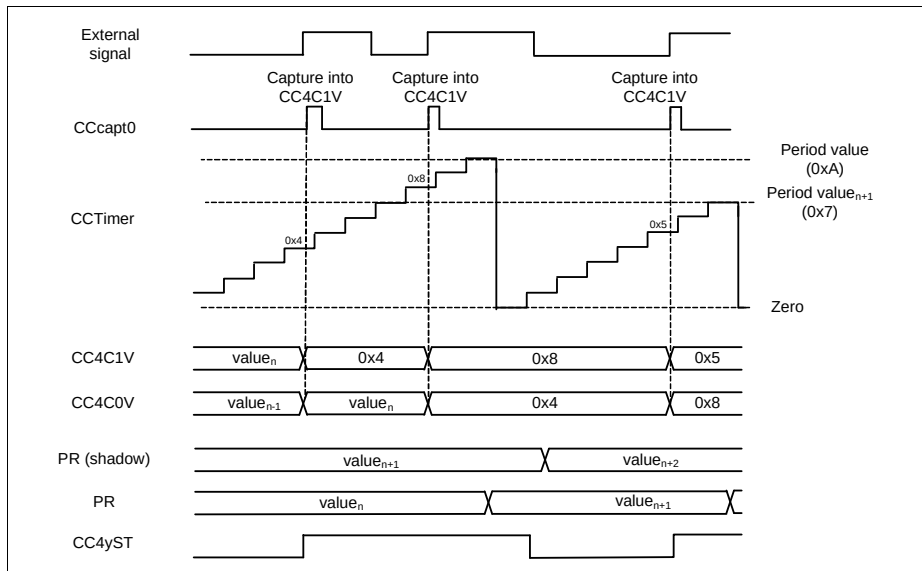


Figure 19-24 External capture - $\text{CC4yCMC.CAP0S} \neq 00_B$, $\text{CC4yCMC.CAP1S} = 00_B$

On [Figure 19-25](#), two different signals were used as source for capturing the timer value into the [CC4yC0V/CC4yC1V](#) and [CC4yC2V/CC4yC3V](#) registers.

External signal(1) was selected as rising edge active capture source for [CC4yC0V/CC4yC1V](#). External signal(2) was selected as the capture source for [CC4yC2V/CC4yC3V](#), but as opposite to the external signal(1), the active edge was selected as falling.

See [Section 19.2.12.4](#), for the complete capture mode usage description.

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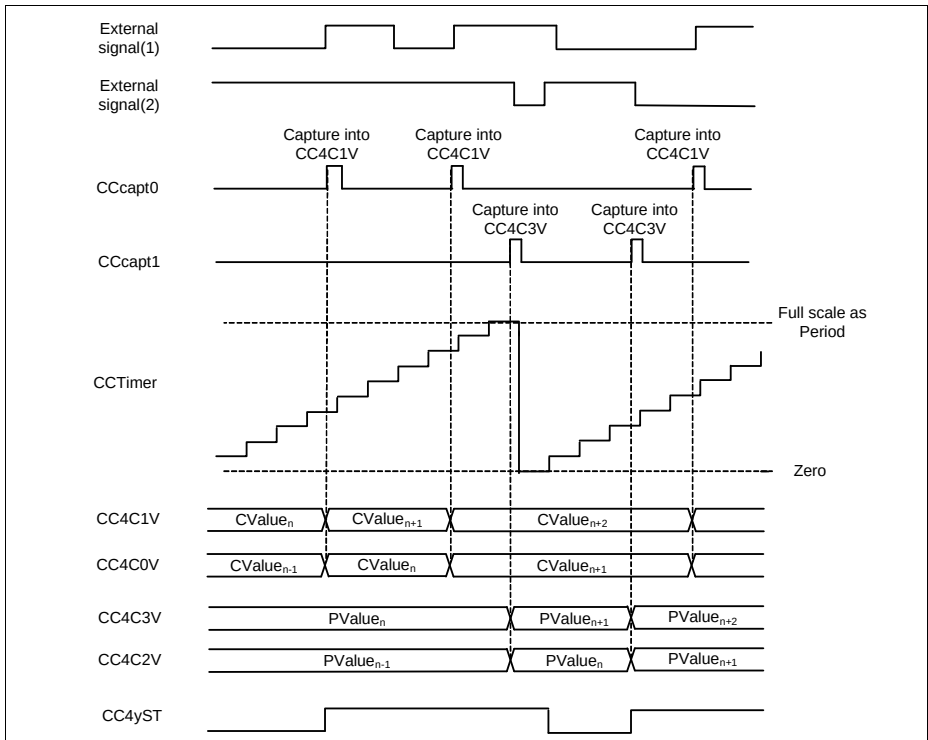


Figure 19-25 External capture - $CC4yCMC.CAP0S \neq 00_B$, $CC4yCMC.CAP1S \neq 00_B$

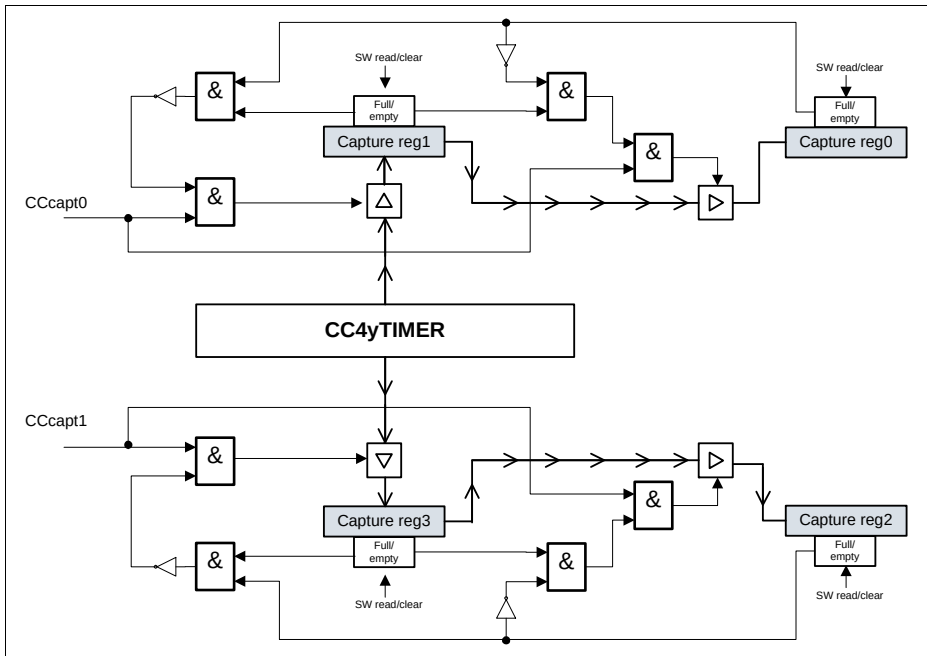


Figure 19-26 Slice capture logic

Same Capture Event (SCE = 1_B)

Setting the field **CC4yTC.SCE** = 1_B, enables the possibility of having 4 capture registers linked with the same capture event, **Figure 19-28**. The function that controls the capture is the **CCCapt1**.

The capture logic follows the same structure shown in **Figure 19-26** but extended to a four register chain, see **Figure 19-27**. The same full flag lock rules are applied to the four register chain (it also can be disabled by setting the **CC4yTC.CCS** = 1_B):

$$CC4yC3V_{capt} = \text{NOT}(CC4yC3V_{full\_flag} \text{ AND } CC4yC2V_{full\_flag} \text{ AND } CC4yC2V_{full\_flag} \text{ AND } CC4yC1V_{full\_flag}) \quad (19.6)$$

$$CC4yC2V_{capt} = CC4yC3V_{full\_flag} \text{ AND NOT}(CC4yC2V_{full\_flag} \text{ AND } CC4yC1V_{full\_flag} \text{ AND } CC4yC0V_{full\_flag}) \quad (19.7)$$

$$CC4yC1V_{capt} = CC4yC2V_{full\_flag} \text{ AND NOT}(CC4yC1V_{full\_flag} \text{ AND } CC4yC0V_{full\_flag}) \quad (19.8)$$

$$CC4yC0V_{capt} = CC4yC1V_{full\_flag} \text{ AND NOT}(CC4yC0V_{full\_flag}) \quad (19.9)$$

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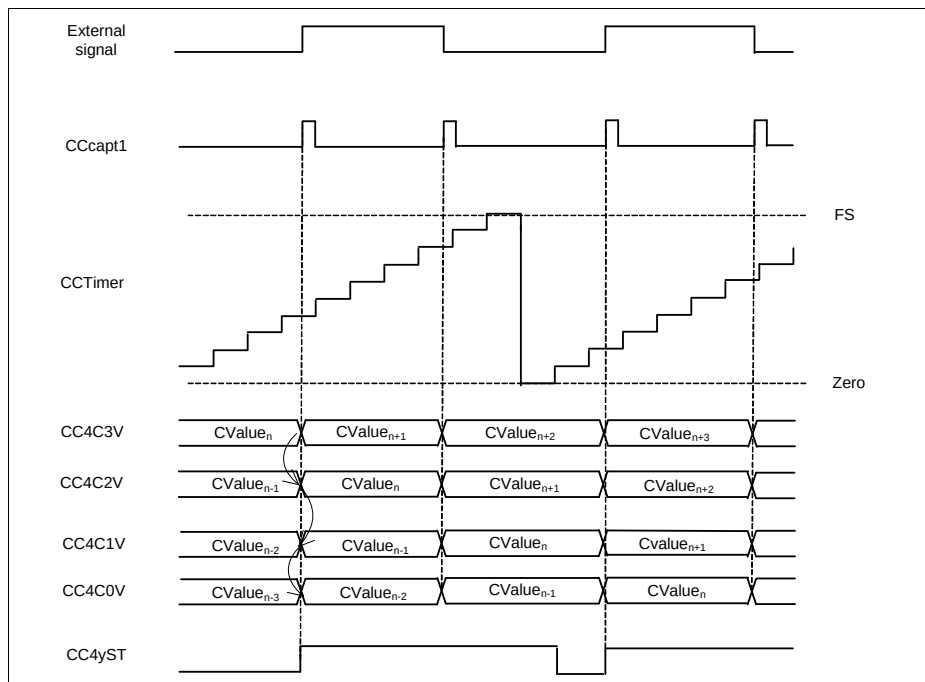


Figure 19-27 External Capture - **CC4yTC.SCE = 1_B**

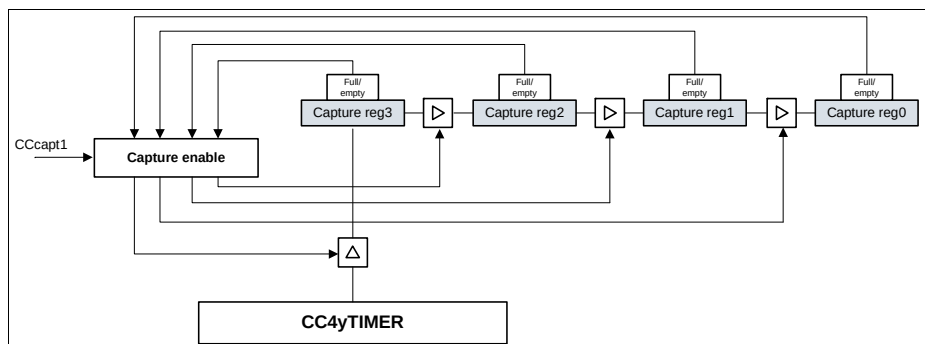


Figure 19-28 Slice Capture Logic - **CC4yTC.SCE = 1_B**

19.2.7.7 Capture Extended Read Back Mode

Each Timer Slice capture logic can operate in a FIFO read back mode. This mode can be enabled by setting the **CC4yTC.ECM** = 1_B. This Extended Read back mode allows the software to read back the capture data always from the same address (**CC4yECRD0** for the structure linked with the capture trigger 0 or **CC4yECRD1** for the one linked with capture trigger 1). This read back will always return the oldest captured value, enabling an easy software routine implementation for reconstructing the capture data.

This function allows the usage of a FIFO structure for each capturing trigger. This relaxes the software read back routine when multiple capture triggers are present, and the software is not fast enough to perform a read operation in each capture event.

This FIFO read back function is present for a depth-4 and depth-2 FIFO structure.

The read back data contains also a lost value bitfield, that indicates if a capture trigger was lost due to the fact that the FIFO structure was full. This bitfield is set whenever a capture event was sensed and the FIFO was full (regardless if the continuous capture mode was enabled or not). This bitfield is cleared automatically by HW whenever the next read of the **CC4yECRD0/CC4yECRD1** register occurs. This bitfield does not indicate how many capture events were lost, it just indicates that between two ECRD reads at least a capture event was lost (this can help the SW evaluate which part of the data read, can be used for calculation).

*Note: When the ECM bitfield is set, reading the individual capture registers is still possible. Nevertheless the full flags can only be cleared by the HW when a read back is done via the **CC4yECRD0/CC4yECRD1** address.*

Depth 4 Structure

The FIFO depth-4 structure is present in the hardware when the capture trigger 1 is enabled and the **CC4yTC.SCE** = 1_B (same capture event), **Figure 19-29**.

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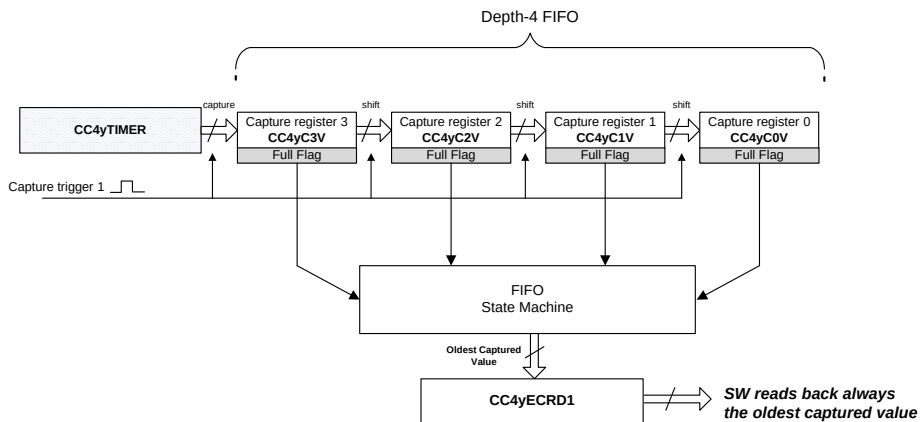


Figure 19-29 Capture Extended Read Back - Depth 4

Capture/Compare Unit 4 (CCU4)

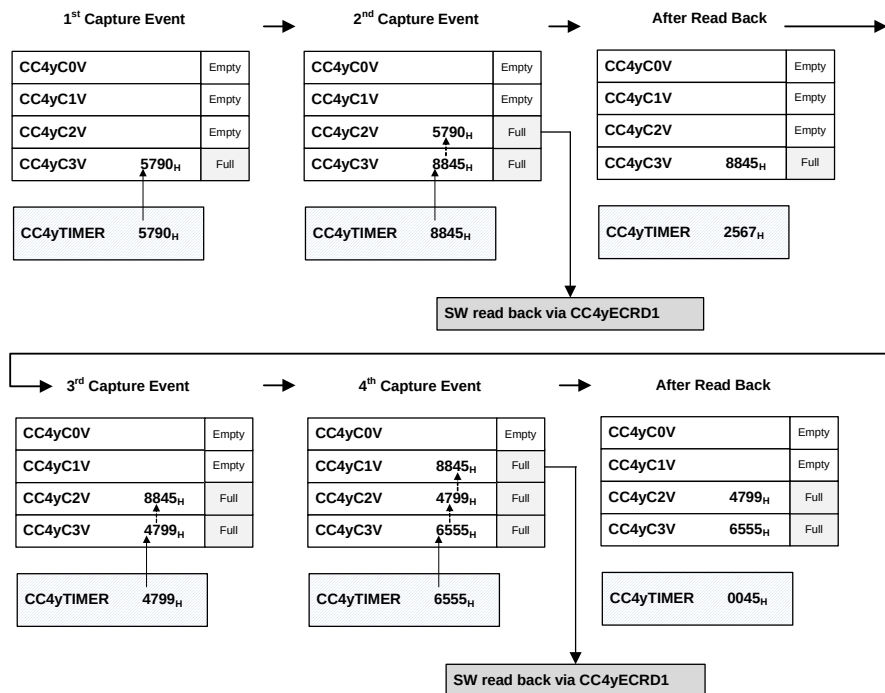


Figure 19-30 Depth 4 software access example

Depth 2 Structure

Each Timer Slice can have two capture structures of depth-2: one used with capture trigger 0 and another with capture trigger 1.

The one linked with capture trigger 0, is accessed via the [CC4yECRD0](#) while the one linked with the capture trigger 1 is accessed via the [CC4yECRD1](#), [Figure 19-31](#).

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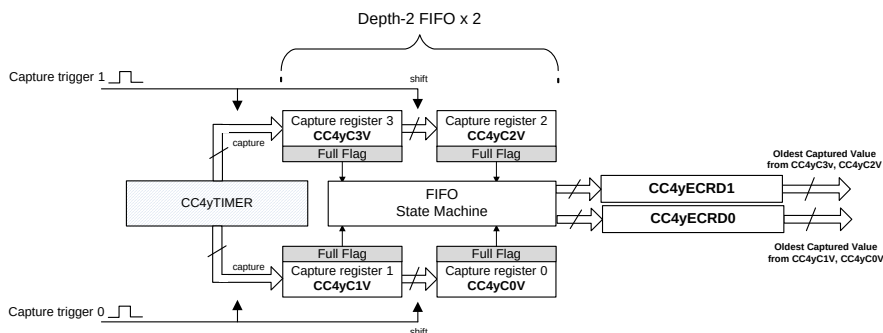


Figure 19-31 Capture Extended Read Back - Depth 2

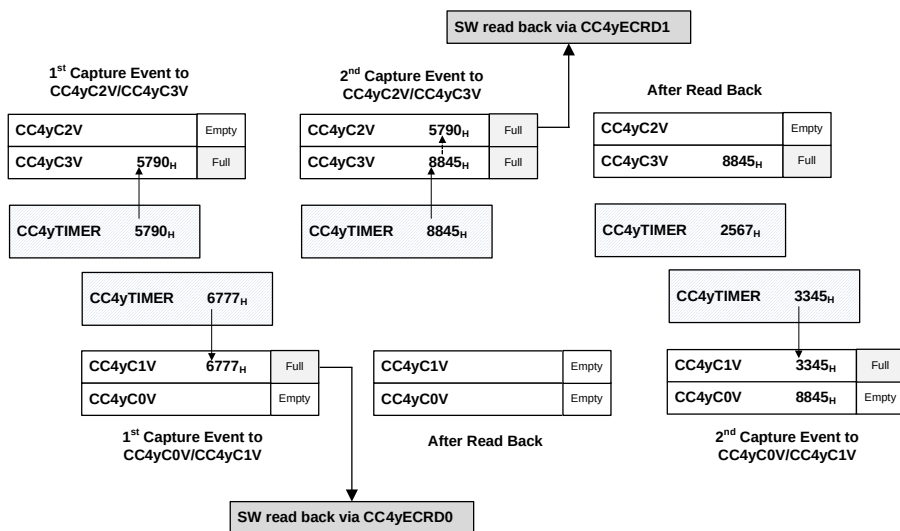


Figure 19-32 Depth 2 software access example

19.2.7.8 External Modulation

An external signal can be used to perform a modulation at the output of each timer slice. To select an external modulation signal, one should map one of the input signals to one of the events, by setting the required value in the **CC4yINS.EVxIS** register and indicating the active level of the signal on the **CC4yINS.EVxLM** register. This event should be then

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mapped to the modulation functionality by setting the **CC4yCMC.MOS** = 01_B if event 0 is being used, **CC4yCMC.MOS** = 10_B if event 1 or **CC4yCMC.MOS** = 11_B if event 2.

Notice that the modulation function is level active and therefore the active/passive configuration is set only by the **CC4yINS.EVxLM**.

The modulation has two modes of operation:

- modulation event is used to clear the CC4yST bit - **CC4yTC.EMT** = 0_B
- modulation event is used to gate the outputs - **CC4yTC.EMT** = 1_B

On **Figure 19-33**, we have an external signal configured to act as modulation source that clears the CC4yST bit, **CC4yTC.EMT** = 0_B. It was programmed to be an active LOW event and therefore, when this signal is LOW the output value follows the normal ACTIVE/PASSIVE rules.

When the signal is HIGH (inactive state), then the CC4yST bit is cleared and the output is forced into the PASSIVE state. Notice that the values of the status bit, CC4yST and the specific output CCU4x.OUTy are not linked together. One can choose for the output to be active LOW or HIGH through the PSL bit.

The exit of the external modulation inactive state is synchronized with the PWM signal due to the fact that the CC4yST bit is cleared and cannot be set while the modulation signal is inactive.

The entering into inactive state also can be synchronized with the PWM signal, by setting **CC4yTC.EMS** = 1_B. With this all possible glitches at the output are avoided, see **Figure 19-34**.

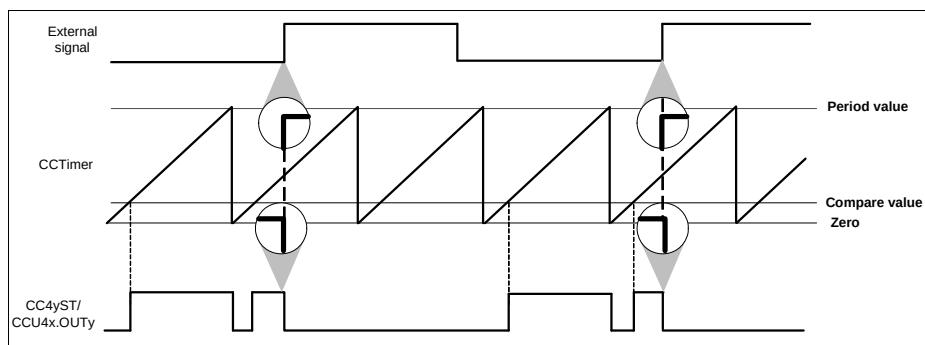


Figure 19-33 External modulation clearing the ST bit - **CC4yTC.EMT = 0_B**

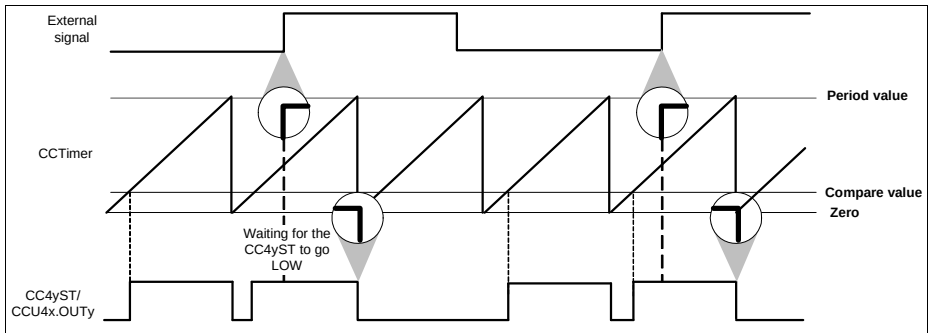


Figure 19-34 External modulation clearing the ST bit - $\text{CC4yTC.EMT} = 0_B$,
 $\text{CC4yTC.EMS} = 1_B$

On Figure 19-35, the external modulation event was used as gating signal of the outputs, $\text{CC4yTC.EMT} = 1_B$. The external signal was configured to be active HIGH, $\text{CC4yINS.EVxLM} = 0_B$, which means that when the external signal is HIGH the outputs are set to the PASSIVE state. In this mode, the gating event can also be synchronized with the PWM signal by setting the $\text{CC4yTC.EMS} = 1_B$.

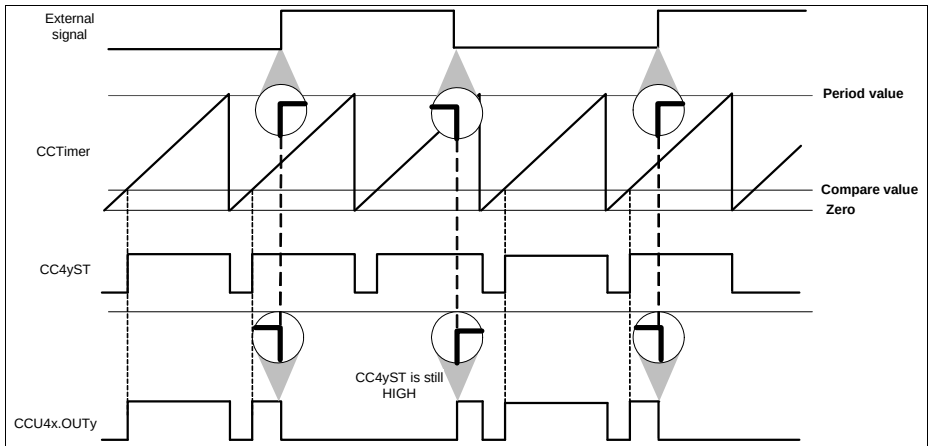


Figure 19-35 External modulation gating the output - $\text{CC4yTC.EMT} = 1_B$

19.2.7.9 TRAP Function

The TRAP functionality allows the PWM outputs to react on the state of an input pin. This functionality can be used to switch off the power devices if the TRAP input becomes active.

To select the TRAP functionality, one should map one of the input signals to event number 2, by setting the required value in the **CC4yINS.EV2IS** register and indicating the active level of the signal on the **CC4yINS.EV2LM** register. This event should be then mapped to the trap functionality by setting the **CC4yCMC.TS = 1_B**.

Notice that the trap function is level active and therefore the active/passive configuration is set only by the **CC4yINTS.EV2LM**.

There are two bitfields that can be monitored via software to crosscheck the TRAP function, **Figure 19-36**:

- The TRAP state bit, **CC4yINTS.E2AS**. This bitfield if the TRAP is currently active or not. This bitfield is therefore setting the specific Timer Slice output, into ACTIVE or PASSIVE state.
- The TRAP Flag, **CC4yINTS.TRPF**. This bitfield is used as a remainder in the case that the TRAP condition is cleared automatically via hardware. This field needs to be cleared by the software.

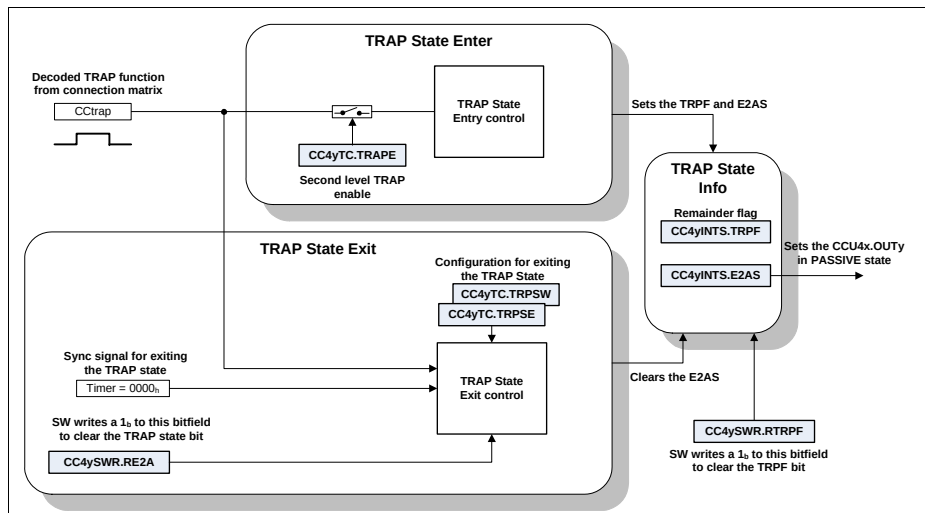


Figure 19-36 Trap control diagram

When a TRAP condition is detected at the selected input pin, both the Trap Flag and the Trap State bit are set to 1_B. The Trap State is entered immediately, by setting the CCU4xOUTY into the programmed PASSIVE state, **Figure 19-37**.

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Exiting the Trap State can be done in two ways (**CC4yTC**.TRPSW register):

- automatically via HW, when the TRAP signal becomes inactive - **CC4yTC**.TRPSW = 0_B
- by SW only, by clearing the **CC4yINTS**.E2AS. The clearing is only possible if the input TRAP signal is in inactive state - **CC4yTC**.TRPSW = 1_B

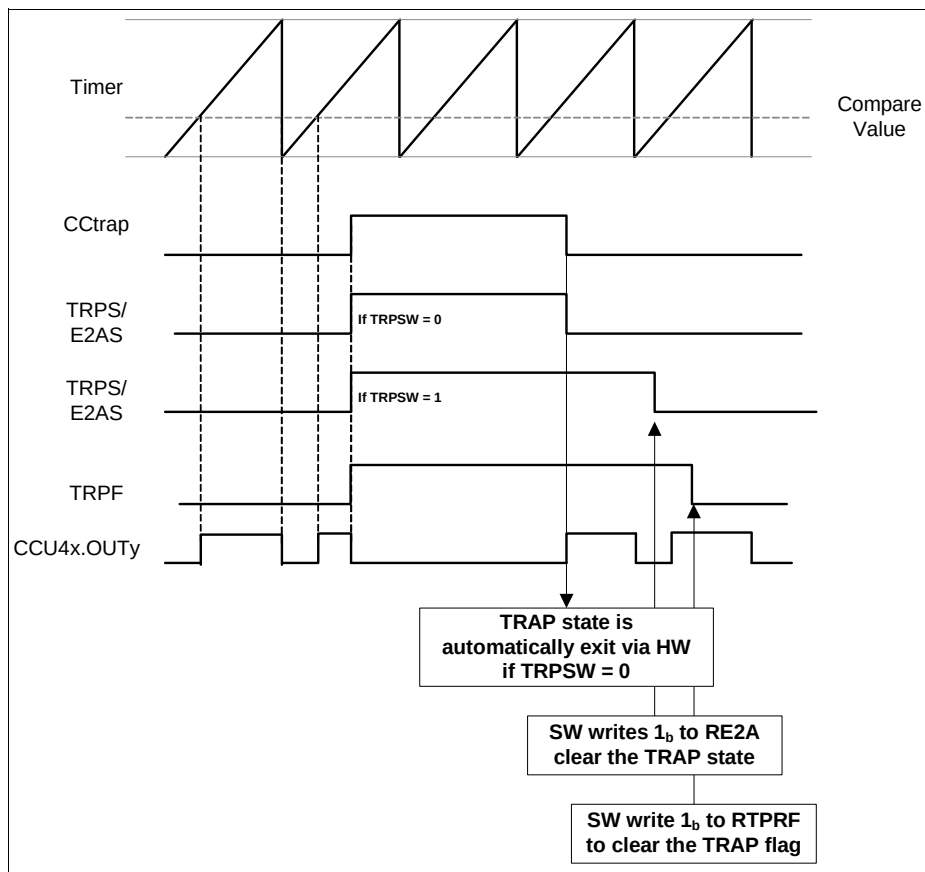


Figure 19-37 Trap timing diagram, **CC4yPSL.PSL = 0_B** (output passive level is 0_B)

It is also possible to synchronize the exiting of the TRAP state with the PWM signal, **Figure 19-38**. This function is enabled when the bitfield **CC4yTC**.TRPSE = 1_B .

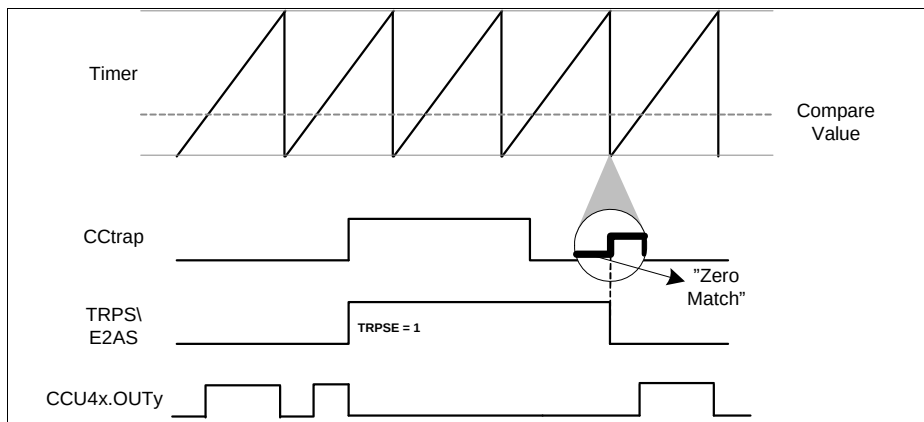


Figure 19-38 Trap synchronization with the PWM signal, **CC4yTC.TRPSE = 1_B**

19.2.7.10 Status Bit Override

For complex timed output control, each Timer Slice has a functionality that enables the override of the status bit (CC4yST) with a value passed through an external signal.

The override of the status bit, can then lead to a change on the output pin, CCU4xOUTy (from inactive to active or vice versa).

To enable this functionality, two signals are needed:

- One signal that acts as a trigger to override the status bit (edge active)
- One signal that contains the value to be set in the status bit (level active)

To use the status bit override functionality, one should map the signal that acts as trigger to the event number 1, by setting the required value in the **CC4yINS.EV1IS** register and indicating the active edge of the signal on the **CC4yINS.EV1EM** register.

The signal that carries the value to be set on the status bit, needs to be mapped to the event number 2, by setting the required value in the **CC4yINS.EV2IS** register. The **CC4yINS.EV2LM** register should be set to 0_B if no inversion on the signal is needed and to 1_B otherwise.

The events should be then mapped to the status bit functionality by setting the **CC4yCMC.OFS = 1_B**.

Figure 19-39 shows the functionality of the status bit override, when the external signal(1) was selected as trigger source (rising edge active) and the external signal(2) was selected as override value.

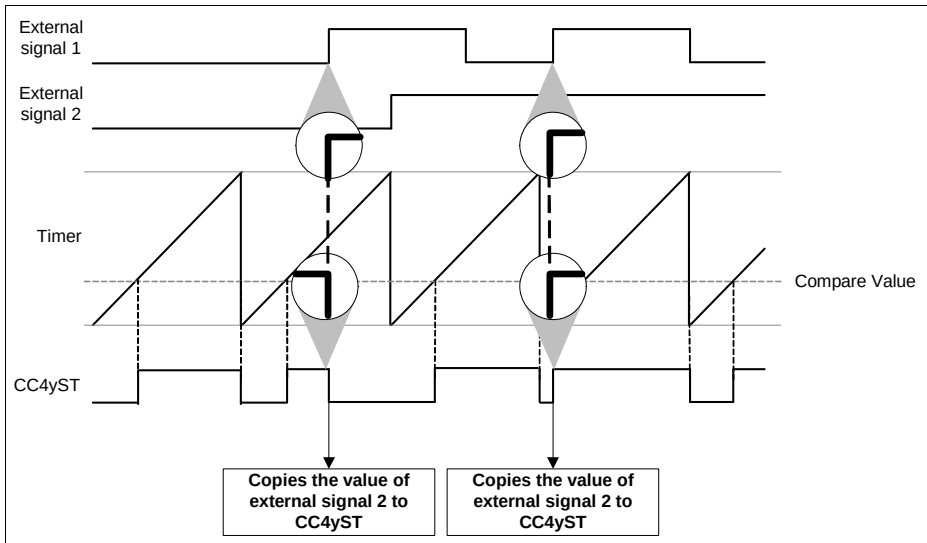


Figure 19-39 Status bit override

19.2.8 Multi-Channel Control

The multi channel control mode is selected individually in each slice by setting the **CC4yTC.MCME** = 1_B.

Within this mode, the output state of the Timer Slices (the ones set in multi channel mode) can be controlled in parallel by a single pattern.

The pattern is controlled via the CCU4 inputs, CCU4x.MCI0, CCU4x.MCI1, CCU4x.MCI2 and CCU4x.MCI3. Each of these inputs is connected directly to the associated slice input, e.g. CCU4x.MCI0 to CC40MCI, CCU4x.MCI1 to CC41MCI.

This pattern can be controlled directly by other module. The connectivity of each device may allow different control possibilities therefore one should address [Section 19.8](#) to check what modules are connected to these inputs.

When using the Multi Channel support of the CCU4, one can achieve a complete synchronicity between the output state update, CCU4x.OUTy, and the update of a new pattern, [Figure 19-40](#). This synchronicity feature can be enabled by using some specific modules and therefore one should address [Section 19.8](#) to check which module is controlling the CCU4x.MCIy inputs.

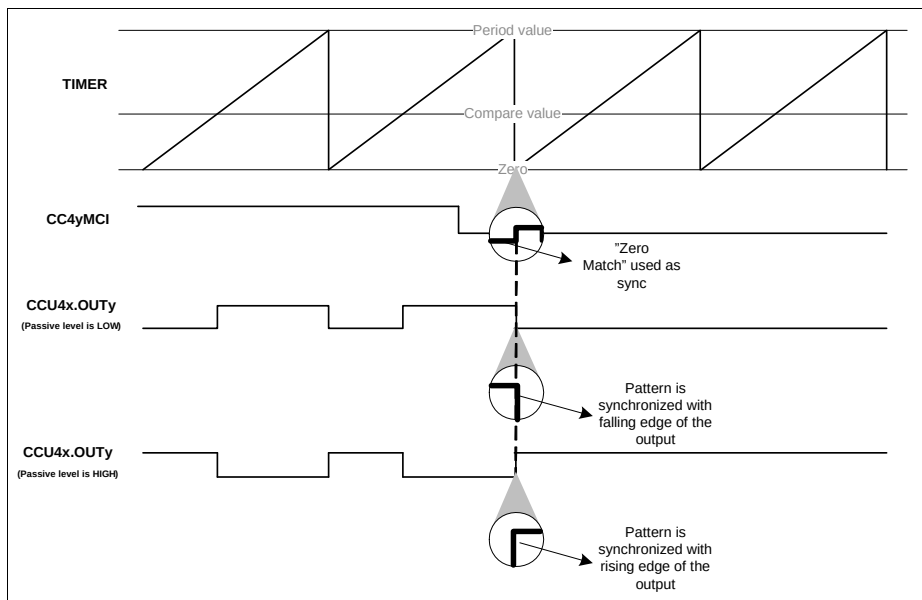


Figure 19-40 Multi channel pattern synchronization

Figure 19-41 shows the usage of the multi channel mode in conjunction with all four Timer Slices inside the CCU4.

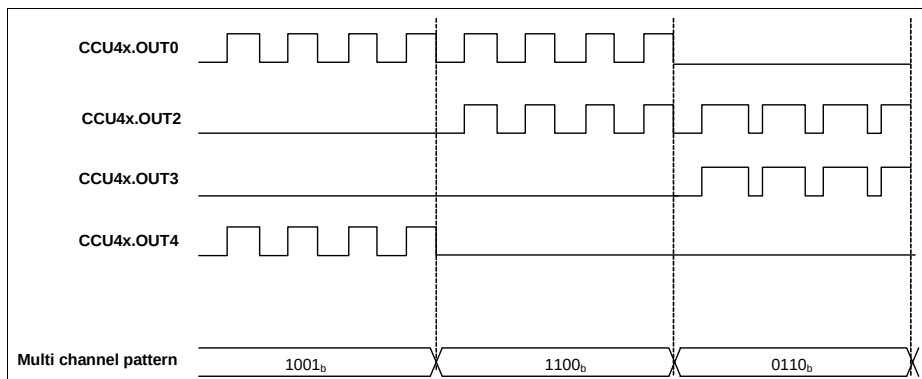


Figure 19-41 Multi Channel mode for multiple Timer Slices

The synchronization between the CCU4 and the module controlling the multi-channel pattern is achieved, by adding a 3 cycle delay on the output path of each Timer Slice

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(between the status bit, CC4yST and the direct control of the output pin). This path is only selected when **CC4yTC.MCME** = 1_B, see **Figure 19-42**.

The multi pattern input synchronization can be seen on **Figure 19-43**. To achieve a synchronization between the update of the status bit, the sampling of a new multi channel pattern input is controlled by the period match or one match signal.

In a straightforward utilization of this synchronization feature, the module controlling the multi channel pattern signals, receives a sync signal from the CCU4, the CCU4x.PSy. This signal is then used by this module to update the multi-channel pattern. Due to the structure of the synchronization scheme inside the CCU4, the module controlling the multi-channel pattern needs to update this pattern, within 4 clock cycles after the CCU4x.PSy signal is asserted, **Figure 19-43**.

In a normal operation, where no external signal is used to control the counting direction, the signal used to enable the sampling of the pattern is always the period match when in edge aligned and the one match when in center aligned mode. When an external signal is used to control the counting direction, depending if the counter is counting up or counting down, the period match or the one match signal is used, respectively.

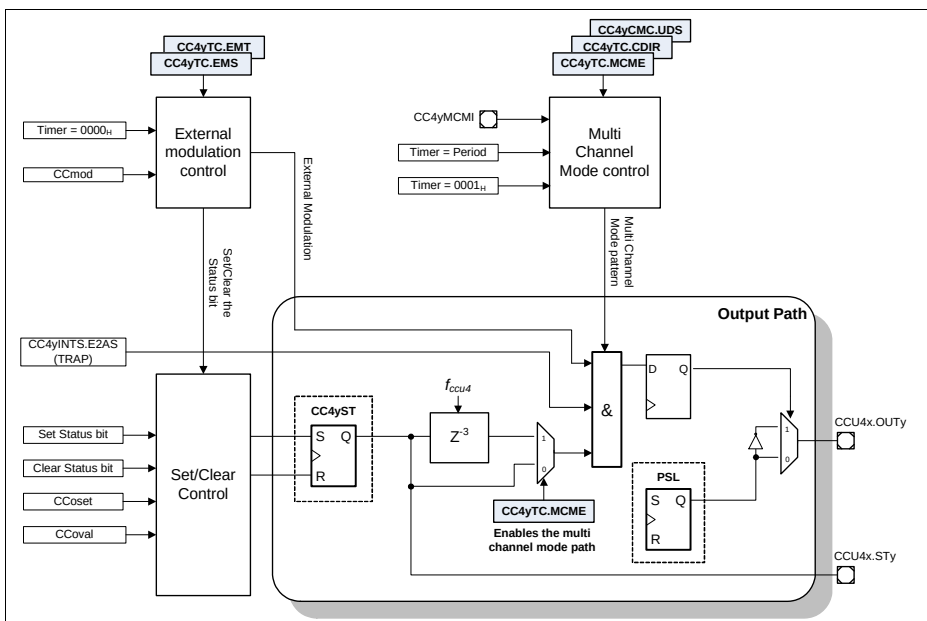


Figure 19-42 CC4y Status bit and Output Path

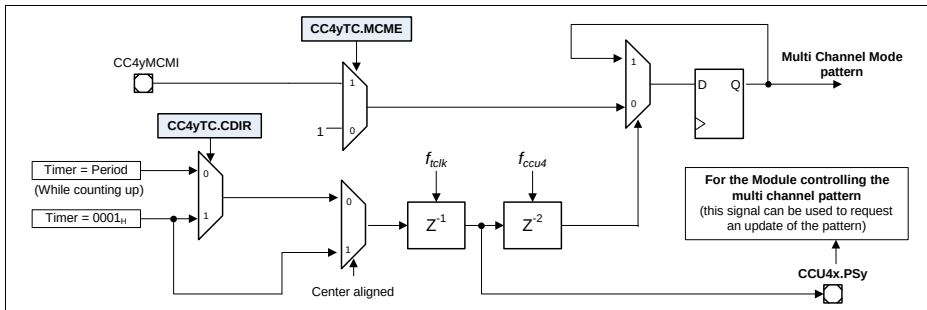


Figure 19-43 Multi Channel Mode Control Logic

19.2.9 Timer Concatenation

The CCU4 offers a very easy mechanism to perform a synchronous timer concatenation. This functionality can be used by setting the **CC4yCMC.TCE** = 1_B . By doing this the user is doing a concatenation of the actual CCU4 slice with the previous one, see [Figure 19-44](#).

Notice that it is not possible to perform concatenation with non adjacent slices and that timer concatenation automatically sets the slice mode into Edge Aligned. It is not possible to perform timer concatenation in Center Aligned mode.

To enable a 64 bit timer, one should set the **CC4yCMC.TCE** = 1_B in all the slices (with the exception of the CC40 due to the fact that it doesn't contain this control register).

To enable a 48 bit timer, one should set the **CC4yCMC.TCE** = 1_B in two adjacent slices and to enable a 32 bit timer, the **CC4yCMC.TCE** is set to 1_B in the slice containing the MSBs. Notice that the timer slice containing the LSBs should always have the TCE bitfield set to 0_B .

Several combinations for timer concatenation can be made inside a CCU4 module:

- one 64 bit timer
- one 48 bit timer plus a 16 timer
- two 32 bit timers
- one 32 bit timer plus two 16 bit timers

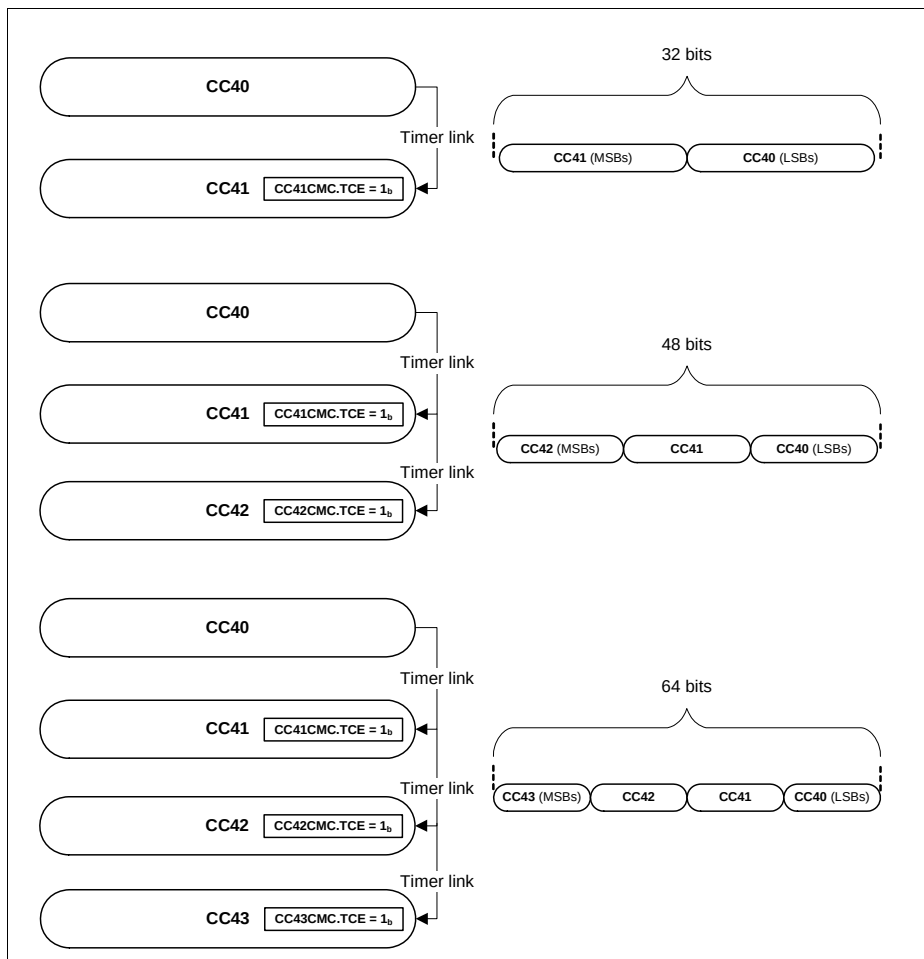


Figure 19-44 Timer Concatenation Example

Each Timer Slice is connected to the adjacent Timer Slices via a dedicated concatenation interface. This interface allows the concatenation of not only the Timer counting operation, but also a synchronous input trigger handling for capturing and loading operations, [Figure 19-45](#).

Note: For all cases CC40 and CC43 are not considered adjacent slices

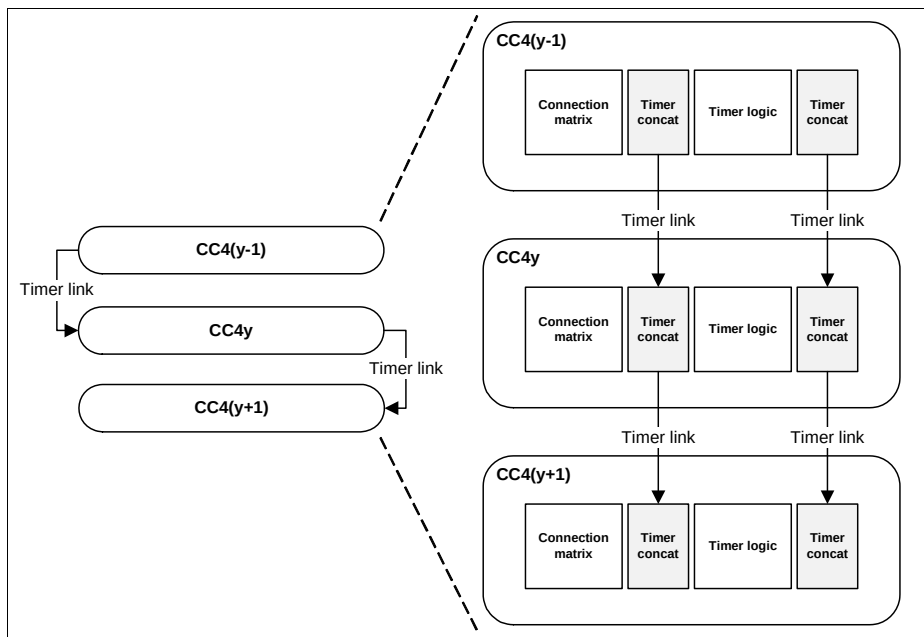


Figure 19-45 Timer Concatenation Link

Seven signals are present in the timer concatenation interface:

- Timer Period match (CC4yPM)
- Timer Zero match (CC4yZM)
- Timer Compare match (CC4yCM)
- Timer counting direction function (CCupd)
- Timer load function (CCload)
- Timer capture function for CC4yC0V and CC4yC1V registers (CCcap0)
- Timer capture function for CC4yC2V and CC4yC3V registers (CCcap1)

The first four signals are used to perform the synchronous timing concatenation at the output of the Timer Logic, like it is seen in [Figure 19-45](#). With this link, the timer length can be easily adjusted to 32, 48 or 64 bits (counting up or counting down).

The last three signals are used to perform a synchronous link between the capture and load functions, for the concatenated timer system. This means that the user can have a capture or load function programmed in the first Timer Slice, and propagate this capture or load trigger synchronously from the LSBs until the MSBs, [Figure 19-46](#).

The capture or load function only needs to be configured in the first Timer Slice (the one holding the LSBs). From the moment that [CC4yCMC.TCE](#) is set to 1_B, in the following Timer Slices, the link between these functions is done automatically by the hardware.

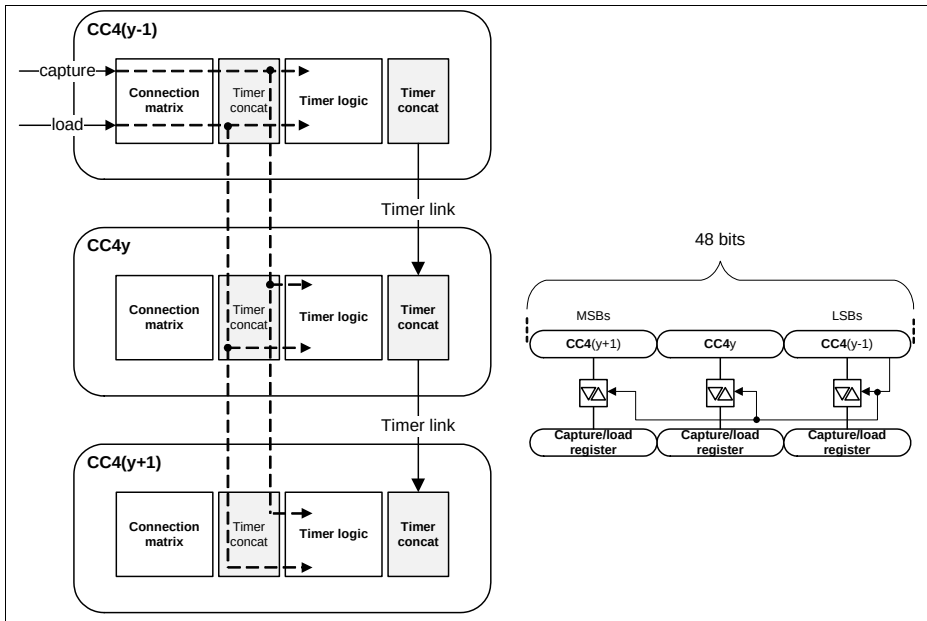


Figure 19-46 Capture/Load Timer Concatenation

The period match (CC4yPM) or zero match (CC4yZM) from the previous Timer Slice (with the immediately next lower index) are used in concatenated mode, as gating signal for the counter. This means that the counting operation of the MSBs only happens when a wrap around condition is detected, avoiding additional DSP operations to extract the counting value.

With the same methodology, the compare match (CC4yCM), zero match and period match are gated with the specific signals from the previous slice. This means that the timing information is propagated throughout all the slices, enabling a completely synchronous match between the LSB and MSB count, see [Figure 19-47](#).

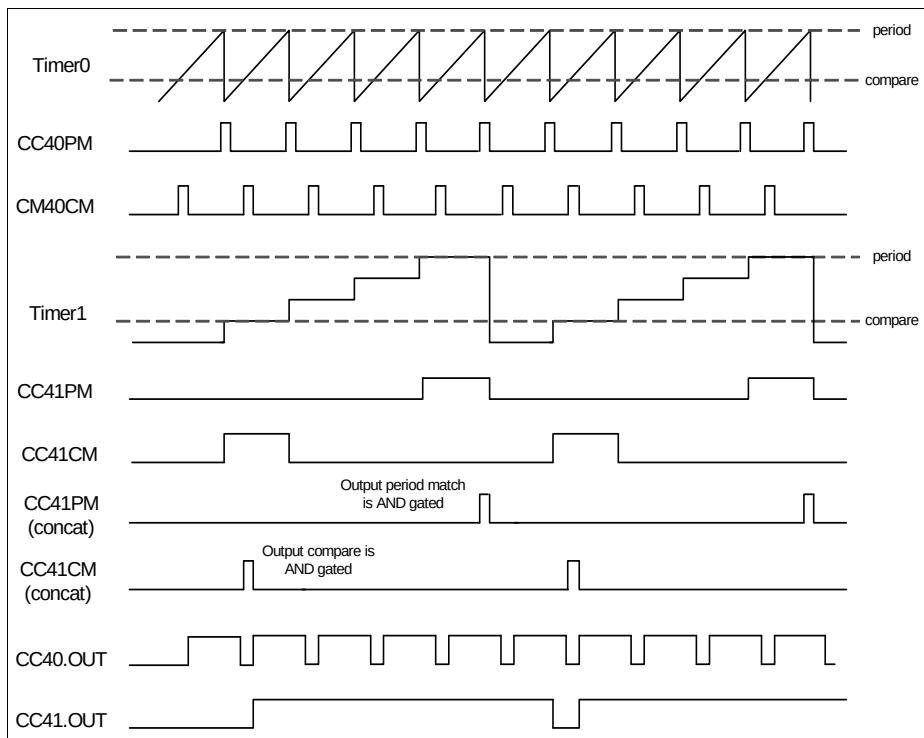


Figure 19-47 32 bit concatenation timing diagram

Note: The counting direction of the concatenated timer needs to be fixed. The timer can count up or count down, but the direction cannot be updated on the fly.

Figure 19-48 gives an overview of the timer concatenation logic. Notice that all the mechanism is controlled solely by the **CC4yCMC.TCE** bitfield.

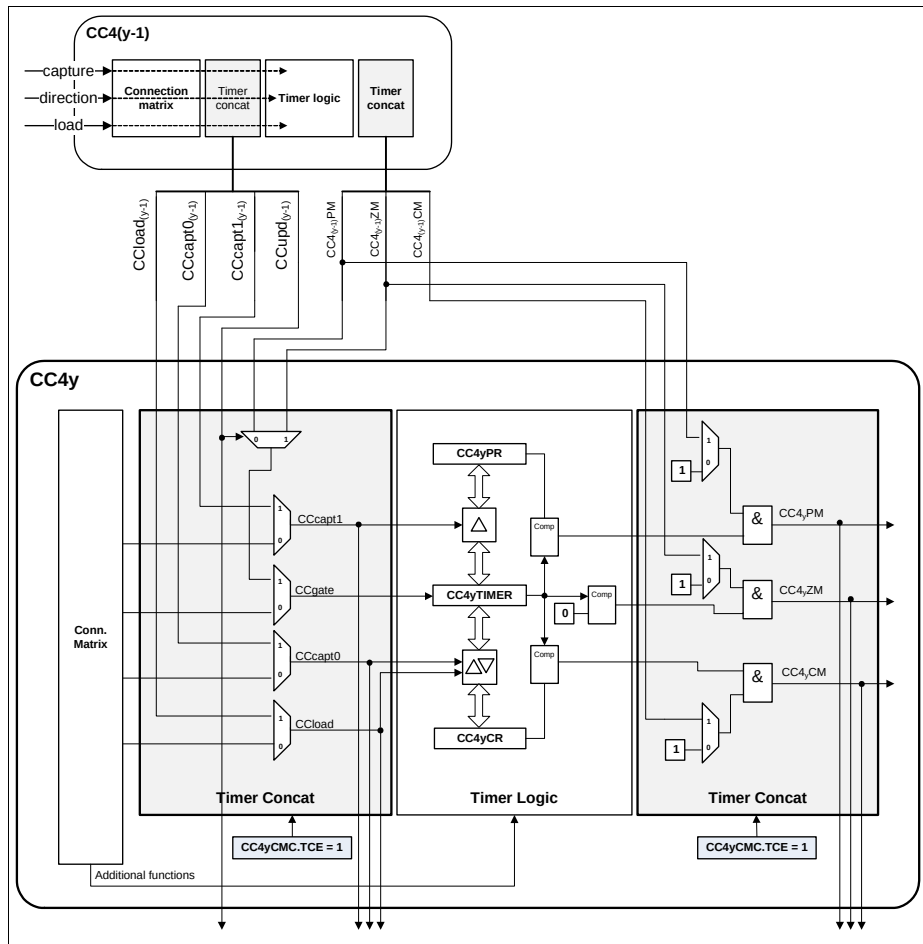


Figure 19-48 Timer concatenation control logic

19.2.10 PWM Dithering

The CCU4 has an automatic PWM dithering insertion function. This functionality can be used with very slow control loops that cannot update the period/compare values in a fast manner, and by that fact the loop can lose precision on long runs. By introducing dither on the PWM signal, the average frequency/duty cycle is then compensated against that error.

Each slice contains a dither control unit, see [Figure 19-49](#).

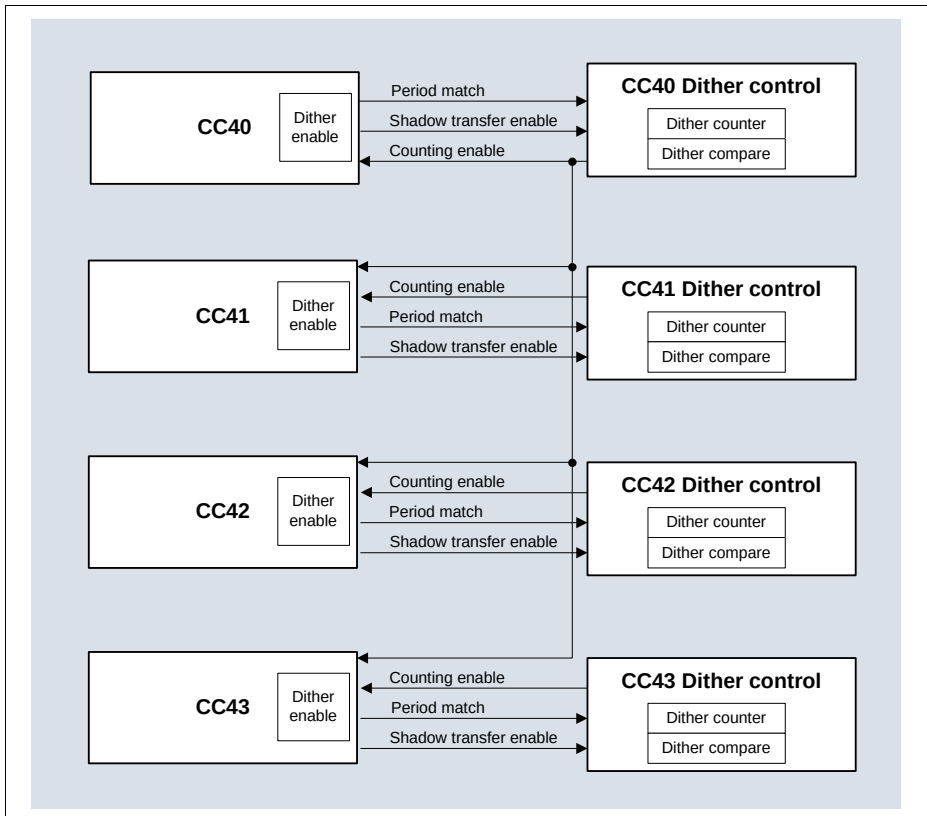


Figure 19-49 Dither structure overview

The dither control unit contains a 4 bit counter and a compare value. The four bit counter is incremented every time that a period match occurs. The counter works in a bit reverse mode so the distribution of increments stays uniform over 16 counter periods, see [Table 19-5](#).

Table 19-5 Dither bit reverse counter

counter[3]	counter[2]	counter[1]	counter[0]
0	0	0	0
1	0	0	0
0	1	0	0
1	1	0	0
0	0	1	0
1	0	1	0
0	1	1	0
1	1	1	0
0	0	0	1
1	0	0	1
0	1	0	1
1	1	0	1
0	0	1	1
1	0	1	1
0	1	1	1
1	1	1	1

The counter is then compared against a programmed value, **CC4yDIT.DCV**. If the counter value is smaller than the programmed value, a gating signal is generated that can be used to extend the period, to delay the compare or both (controlled by the **CC4yTC.DITHE** field, see [Table 19-6](#)) for one clock cycle.

Table 19-6 Dither modes

DITHE[1]	DITH[0]	Mode
0	0	Dither is disabled
0	1	Period is increased by 1 cycle
1	0	Compare match is delayed by 1 cycle
1	1	Period is increased by 1 cycle and compare is delayed by 1 cycle

The dither compare value also has an associated shadow register that enables concurrent update with the period/compare register of CC4y. The control logic for the dithering unit is represented on [Figure 19-50](#).

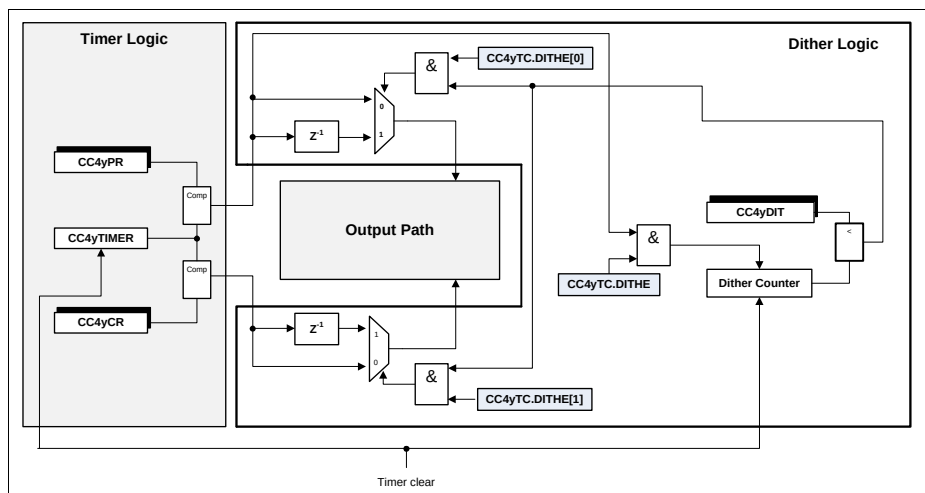


Figure 19-50 Dither control logic

Figure 19-51 to Figure 19-56 show the effect of the different configurations for the dithering function, **CC4yTC.DITHE**, for both counting schemes, Edge and Center Aligned mode. In each figure, the bit reverse scheme is represented for the dither counter and the compare value was programmed with the value 8_H . In each figure, the variable T , represents the period of the counter, while the variable d indicates the duty cycle (status bit is set HIGH).

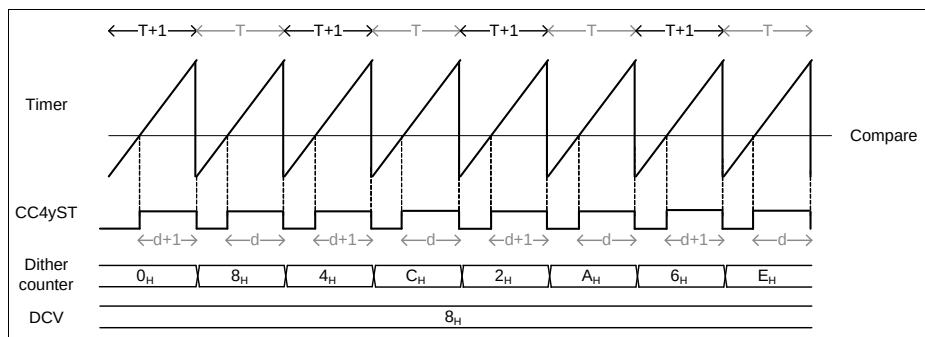


Figure 19-51 Dither timing diagram in edge aligned - **CC4yTC.DITHE** = 01_B

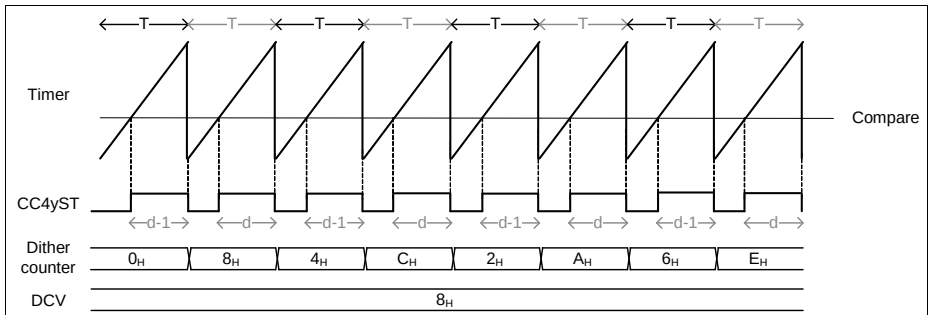


Figure 19-52 Dither timing diagram in edge aligned - $\text{CC4yTC.DITHE} = 10_{\text{b}}$

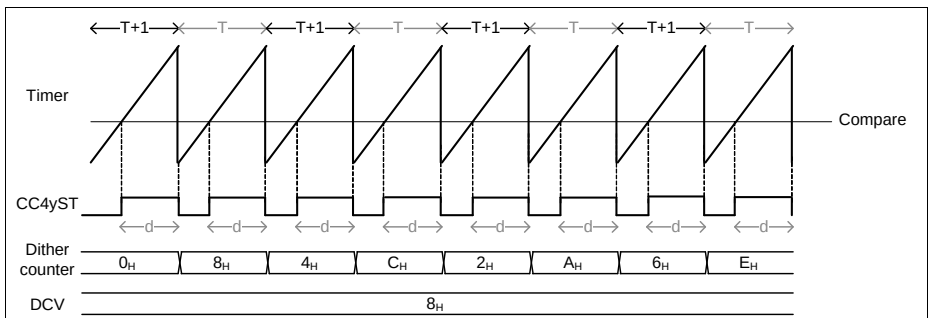


Figure 19-53 Dither timing diagram in edge aligned - $\text{CC4yTC.DITHE} = 11_{\text{b}}$

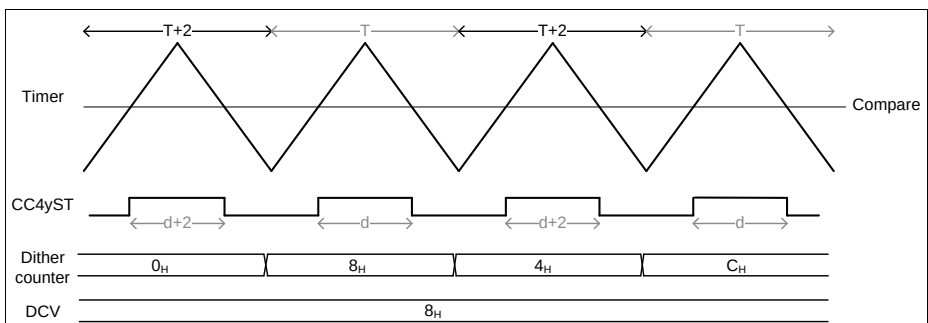


Figure 19-54 Dither timing diagram in center aligned - $\text{CC4yTC.DITHE} = 01_{\text{b}}$

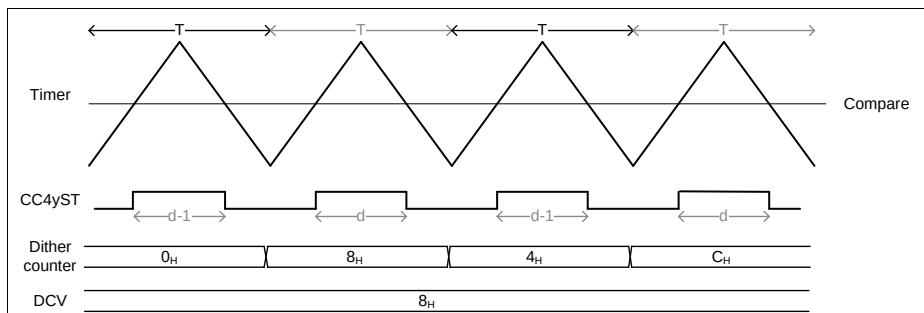


Figure 19-55 Dither timing diagram in center aligned - [CC4yTC.DITHE = 10_B](#)

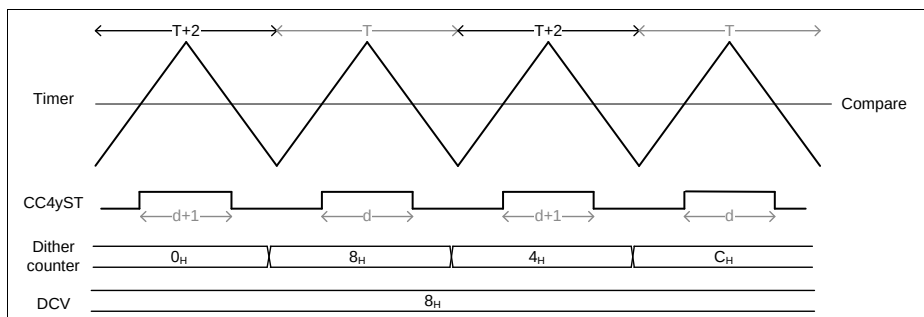


Figure 19-56 Dither timing diagram in center aligned - [CC4yTC.DITHE = 11_B](#)

Note: When using the dither, is not possible to select a period value of FS when in edge aligned mode. In center aligned mode, the period value must be at least FS - 2.

19.2.11 Prescaler

The CCU4 contains a 4 bit prescaler that can be used in two operating modes for each individual slice:

- normal prescaler mode
- floating prescaler mode

The run bit of the prescaler can be set/cleared by SW by writing into the registers, [GIDLC.SPRB](#) and [GIDLS.CPRB](#) respectively, and it can also be cleared by the run bit of a specific slice. With the last mechanism, the run bit of the prescaler is cleared one clock cycle after the clear of the run bit of the selected slice. To select which slice can perform this action, one should program the [GCTRL.PRBC](#) register.

19.2.11.1 Normal Prescaler Mode

In Normal prescaler mode the clock fed to the CC4y counter is a normal fixed division by N, accordingly to the value set in the **CC4yPSC**.PSIV register. The values for the possible division values are listed in **Table 19-7**. The **CC4yPSC**.PSIV value is only modified by a SW access. Notice that each slice has a dedicated prescaler value selector (**CC4yPSC**.PSIV), which means that the user can select different counter clocks for each Timer Slice (CC4y).

Table 19-7 Timer clock division options

CC4yPSC .PSIV	Resulting clock
0000 _B	f_{CCU4}
0001 _B	$f_{CCU4}/2$
0010 _B	$f_{CCU4}/4$
0011 _B	$f_{CCU4}/8$
0100 _B	$f_{CCU4}/16$
0101 _B	$f_{CCU4}/32$
0110 _B	$f_{CCU4}/64$
0111 _B	$f_{CCU4}/128$
1000 _B	$f_{CCU4}/256$
1001 _B	$f_{CCU4}/512$
1010 _B	$f_{CCU4}/1024$
1011 _B	$f_{CCU4}/2048$
1100 _B	$f_{CCU4}/4096$
1101 _B	$f_{CCU4}/8192$
1110 _B	$f_{CCU4}/16384$
1111 _B	$f_{CCU4}/32768$

19.2.11.2 Floating Prescaler Mode

The floating prescaler mode can be used individually in each slice by setting the register **CC4yTC**.FPE = 1_B. With this mode, the user can not only achieve a better precision on the counter clock for compare operations but also reduce the SW read access for the capture mode.

The floating prescaler mode contains additionally to the initial configuration value register, **CC4yPSC**.PSIV, a compare register, **CC4yFPC**.PCMP with an associated shadow register mechanism.

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Figure 19-57 shows the structure of the prescaler in floating mode when the specific slice is in compare mode (no external signal is used for capture). In this mode, the value of the clock division is incremented by 1_D every time that a timer overflow/underflow (overflow if in Edge Aligned Mode, underflow if in Center Aligned Mode) occurs.

In this mode, the Compare Match from the timer is AND gated with the Compare Match of the prescaler and every time that this event occurs, the value of the clock division is updated with the **CC4yPSC.PSIV** value in the immediately next timer overflow/underflow event.

The shadow transfer of the floating prescaler compare value, **CC4yFPC.PCMP**, is done following the same rules described on **Section 19.2.5.2**.

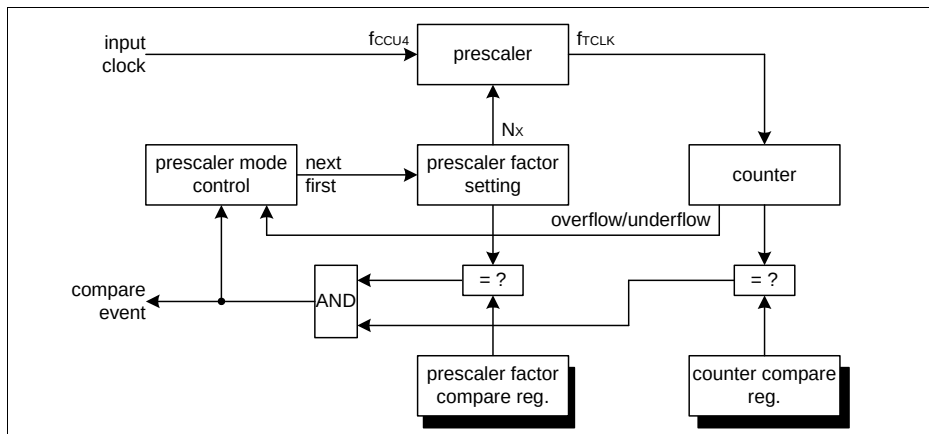


Figure 19-57 Floating prescaler in compare mode overview

When the specific CC4y is operating in capture mode (when at least one external signal is decoded as capture functionality), the actual value of the clock division also needs to be stored every time that a capture event occurs. The floating prescaler can have up to 4 capture registers (the maximum number of capture registers is dictated by the number of capture registers used in the specific slice).

The clock division value continues to be incremented by 1_D every time that a timer overflow (in capture mode, the slice is always operating in Edge Aligned Mode) occurs and it is loaded with the PSIV value every time that a capture triggers is detected.

See the **Section 19.2.12.2** for a full description of the usage of the floating prescaler mode in conjunction with compare and capture modes.

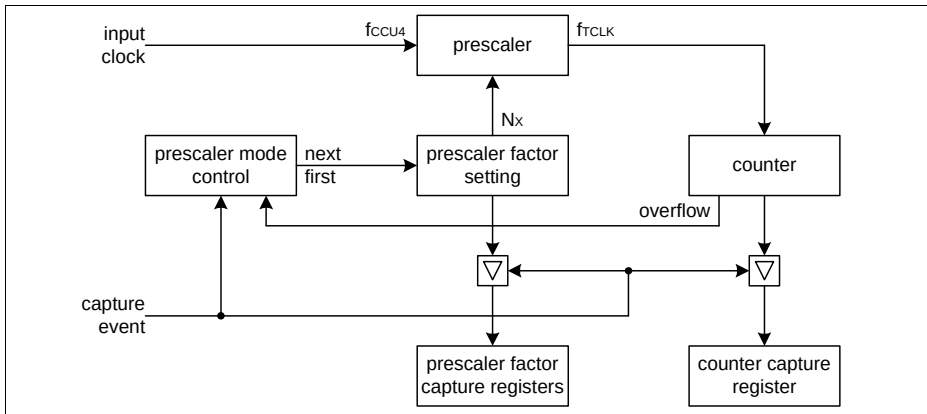


Figure 19-58 Floating Prescaler in capture mode overview

19.2.12 CCU4 Usage

19.2.12.1 PWM Signal Generation

The CCU4 offers a very flexible range in duty cycle configurations. This range is comprised between 0 to 100%.

To generate a PWM signal with a 100% duty cycle in Edge Aligned Mode, one should program the compare value, **CC4yCR.CR**, to 0000_H, see [Figure 19-59](#).

In the same manner a 100% duty cycle signal can be generated in Center Aligned Mode, see [Figure 19-60](#).

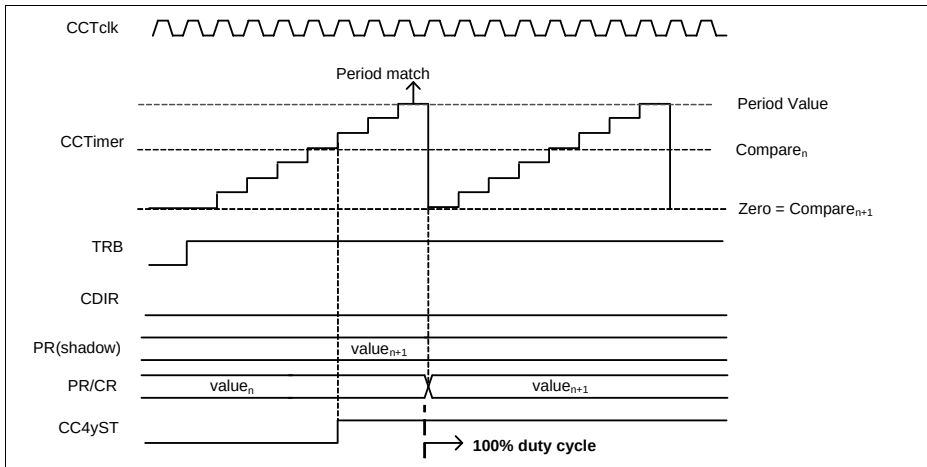


Figure 19-59 PWM with 100% duty cycle - Edge Aligned Mode

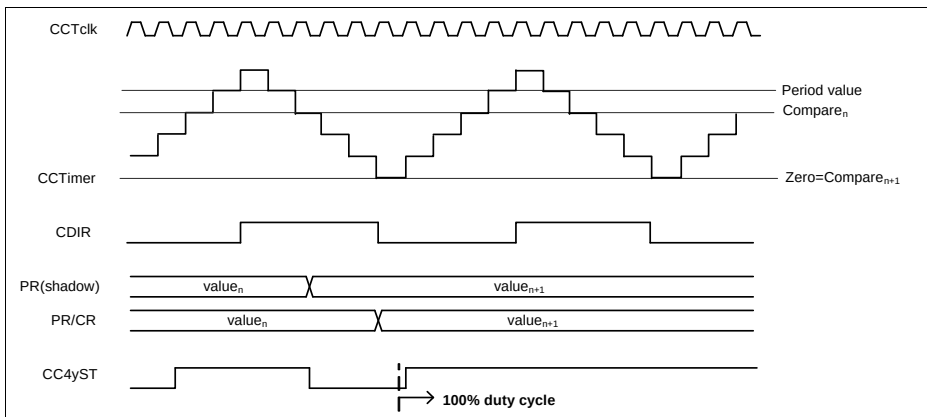


Figure 19-60 PWM with 100% duty cycle - Center Aligned Mode

To generate a PWM signal with 0% duty cycle in Edge Aligned Mode, the compare register should be set with the value programmed into the period value plus 1. In the case that the timer is being used with the full 16 bit capability (counting from 0 to 65535), setting a value bigger than the period value into the compare register is not possible and therefore the smallest duty cycle that can be achieved is 1/FS, see [Figure 19-61](#).

In Center Aligned Mode, the counter is never running from 0 to 65535_D, due to the fact that it has to overshoot for one clock cycle the value set in the period register. Therefore the user never has a FS counter, which means that generating a 0% duty cycle signal is

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always possible by setting a value in the compare register bigger than the one programmed into the period register, see [Figure 19-62](#).

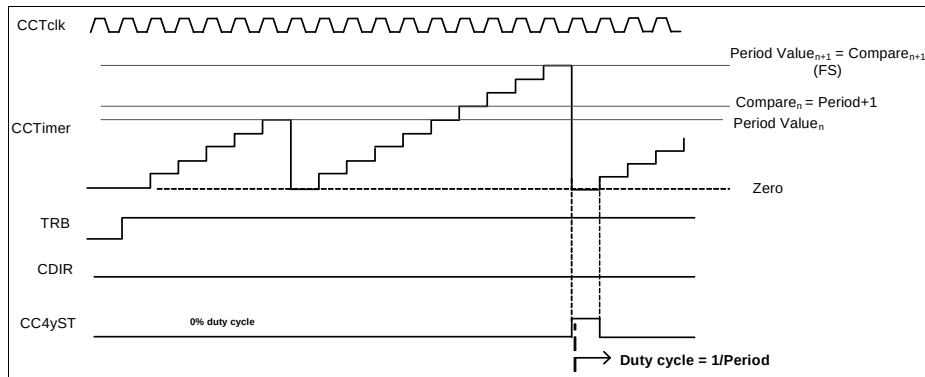


Figure 19-61 PWM with 0% duty cycle - Edge Aligned Mode

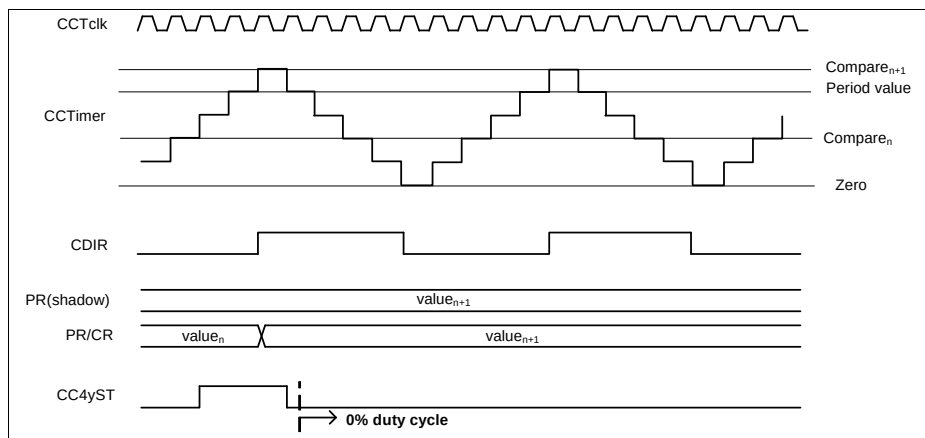


Figure 19-62 PWM with 0% duty cycle - Center Aligned Mode

19.2.12.2 Prescaler Usage

In Normal Prescaler Mode, the frequency of the f_{clk} fed to the specific CC4y is chosen from the [Table 19-7](#), by setting the **CC4yPSC.PSIV** with the required value.

In Floating Prescaler Mode, the frequency of the f_{clk} can be modified over a selected timeframe, within the values specified in [Table 19-7](#). This mechanism is specially useful if, when in capture mode, the dynamic of the capture triggers is very slow or unknown.

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In Capture Mode, the Floating Prescaler value is incremented by 1 every time that a timer overflow happens and it is set with the initial programmed value when a capture event happens, see [Figure 19-63](#).

When using the Floating Prescaler Mode in Capture Mode, the timer should be cleared each time that a capture event happens, **CC4yTC.CAPC** = 11_B. By operating the Capture mode in conjunction with the Floating Prescaler, even for capture signals that have a periodicity bigger than 16 bits, it is possible to use just a single CCU4 Timer Slice without monitoring the interrupt event of the timer overflow, cycle by cycle. For this the user just needs to know what is the timer captured value and the actual prescaler configuration at the time that the capture event occurred. These values are contained in each CC4yCxV register.

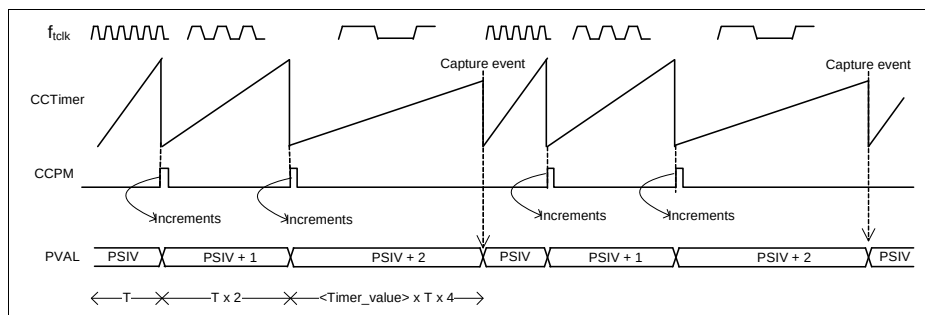


Figure 19-63 Floating Prescaler capture mode usage

When in Compare Mode, the Floating Prescaler function may be used to achieve a fractional PWM frequency or to perform some frequency modulation.

The same incrementing by 1_D mechanism is done every time that an overflow/underflow of the Timer occurs and the actual Prescaler value, doesn't match the one programmed into the **CC4yFPC.PCMP** register.

When a Compare Match from the Timer occurs and the actual Prescaler value is equal to the one programmed on the **CC4yFPC.PCMP** register, then the Prescaler value is set with the initial value, **CC4yPSC.PSIV**, when the next occurrence of a timer overflow/underflow.

In [Figure 19-64](#), the Compare value of the Floating Prescaler was set to PSIV + 2. Every time that a timer overflow occurs, the value of the Prescaler is incremented by 1, which means that if we give f_{tclk} as the reference frequency for the **CC4yPSC.PSIV** value, we have $f_{tclk}/2$ for **CC4yPSC.PSIV + 1** and $f_{tclk}/4$ for **CC4yPSC.PSIV + 2**.

The period over time of the counter becomes:

$$Period = (1/f_{tclk} + 2/f_{tclk} + 4/f_{tclk}) / 3 \quad (19.10)$$

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The same mechanism is used in Center Aligned Mode, but to keep the rising arcade and falling arcade always symmetrical, instead of the overflow of the timer, the underflow is used, see [Figure 19-65](#).

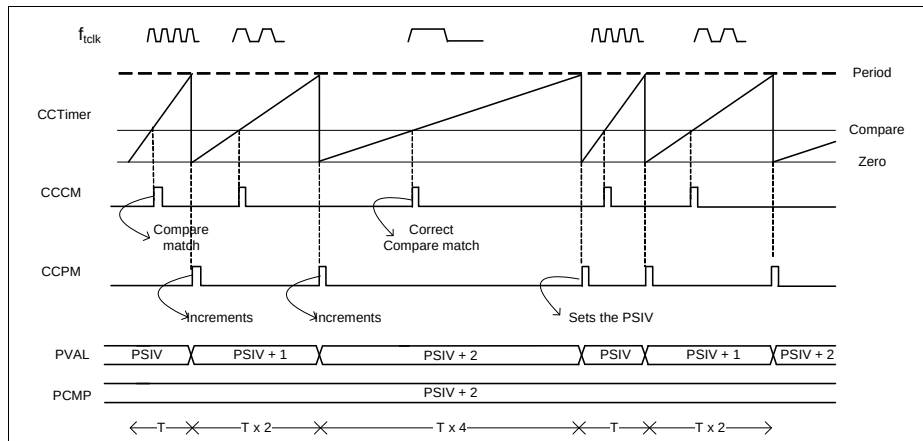


Figure 19-64 Floating Prescaler compare mode usage - Edge Aligned

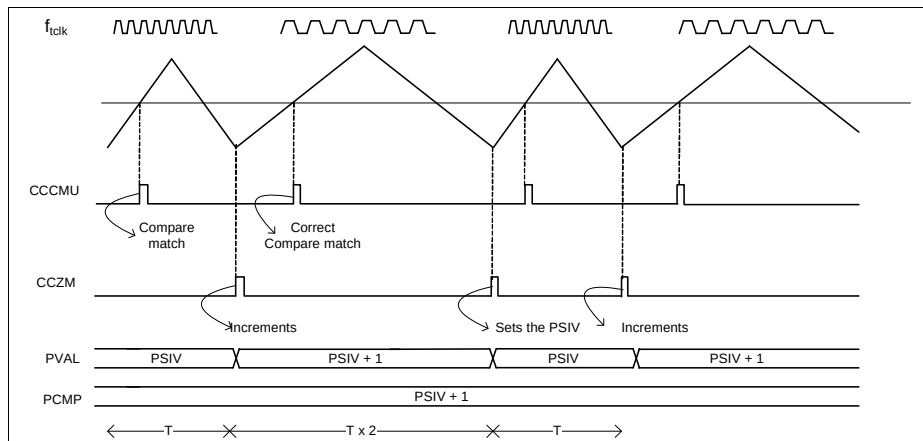


Figure 19-65 Floating Prescaler compare mode usage - Center Aligned

19.2.12.3 PWM Dither

The Dither functionality can be used to achieve a very fine precision on the periodicity of the output state in compare mode. The value set in the dither compare register, [CC4yDIT.DCV](#) is crosschecked against the actual value of the dither counter and every

Capture/Compare Unit 4 (CCU4)

time that the dither counter is smaller than the comparison value one of the follows actions is taken:

- The period is extended for 1 clock cycle - **CC4yTC.DITHE** = 01_B; in edge aligned mode
- The period is extended for 2 clock cycles - **CC4yTC.DITHE** = 01_B; in center aligned mode
- The comparison match while counting up (**CC4yTCST.CDIR** = 0_B) is delayed (this means that the status bit is going to stay in the SET state 1 cycle less) for 1 clock cycle - **CC4yTC.DITHE** = 10_B;
- The period is extended for 1 clock cycle and the comparison match while counting up is delayed for 1 clock cycle - **CC4yTC.DITHE** = 11_B; in edge aligned mode
- The period is extended for 2 clock cycles and the comparison match while counting up is delayed for 1 clock cycle; center aligned mode

The bit reverse counter distributes the number programmed in the **CC4yDIT.DCV** throughout a window of 16 timer periods.

Table 19-8 describes the bit reverse distribution versus the programmed value on the **CC4yDIT.DCV** field. The fields marked as '0' indicate that in that counter period, one of the above described actions, is going to be performed.

Table 19-8 Bit reverse distribution

	DCV															
Dither counter	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
4	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
6	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
E	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
5	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
B	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0

Table 19-8 Bit reverse distribution (cont'd)

	DCV															
Dither counter	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
7	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
F	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The bit reverse distribution versus the programmed **CC4yDIT.DCV** value results in the following values for the Period and duty cycle:

DITHE = 01_B

Period = [(16 - DCV) x T + DCV x (T + 1)]/16; in Edge Aligned Mode (19.11)

Duty cycle = [(16 - DCV) x d/T + DCV x (d+1)/(T + 1)]/16; in Edge Aligned Mode(19.12)

Period = [(16 - DCV) x T + DCV x (T + 2)]/16; in Center Aligned Mode (19.13)

Duty cycle = [(16 - DCV) x d/T + DCV x (d+2)/(T + 2)]/16; in Center Aligned Mode(19.14)

DITHE = 10_B

Period = T ; in Edge Aligned Mode (19.15)

Duty cycle = [(16 - DCV) x d/T + DCV x (d-1)/T]/16; in Edge Aligned Mode (19.16)

Period = T ; in Center Aligned Mode (19.17)

Duty cycle = [(16 - DCV) x d/T + DCV x (d-1)/T]/16; in Center Aligned Mode (19.18)

DITHE = 11_B

Period = [(16 - DCV) x T + DCV x (T + 1)]/16; in Edge Aligned Mode (19.19)

Duty cycle = [(16 - DCV) x d/T + DCV x d/(T + 1)]/16; in Edge Aligned Mode (19.20)

Period = [(16 - DCV) x T + DCV x (T + 2)]/16; in Center Aligned Mode (19.21)

Duty cycle = [(16 - DCV) x d/T + DCV x (d+1)/(T + 2)]/16; in Center Aligned Mode(19.22)

where:

T - Original period of the signal, see [Section 19.2.5.1](#)

d - Original duty cycle of the signal, see [Section 19.2.5.1](#)

19.2.12.4 Capture Mode Usage

Each Timer Slice can make use of 2 or 4 capture registers. Using only 2 capture registers means that only 1 Event was linked to a captured trigger. To use the four capture registers, both capture triggers need to be mapped into an Event (it can be the same signal with different edges selected or two different signals) or the **CC4yTC.SCE** field needs to be set to 1, which enables the linking of the 4 capture registers.

The internal slice mechanism for capturing is the same for the capture trigger 1 or capture trigger 0.

Different Capture Events - SCE = 0_B

Capture trigger 1 (CCcapt1) is appointed to the capture register 2, **CC4yC2V** and capture register 3, **CC4yC3V**, while trigger 0 (CCcapt0) is appointed to capture register 1, **CC4yC1V** and 0, **CC4yC0V**.

In each CCcapt0 event, the timer value is stored into **CC4yC1V** and the value of the **CC4yC1V** is transferred into the **CC4yC0V**.

In each CCcapt1 event, the timer value is stored into capture register **CC4yC3V** and the value of the capture register **CC4yC3V** is transferred into **CC4yC2V**.

The capture/transfer mechanism only happens if the specific register is not full. A capture register becomes full when receives a new value and becomes empty after the SW has read back the value.

The full flag is cleared every time that the SW reads back the **CC4yC0V**, **CC4yC1V**, **CC4yC2V** or **CC4yC3V** register. The SW can be informed of a new capture trigger by enabling the interrupt source linked to the specific Event. This means that every time that a capture is made an interrupt pulse is generated.

In the case that the Floating Prescaler Mode is being used, the actual value of the clock division is also stored in the capture register (CC4yCxV).

Figure 19-66 shows an example of how the capture/transfer may be used in a Timer Slice that is using an external signal as count function (to measure the velocity of a rotating device), and an equidistant capture trigger that is used to dictate the timestamp for the velocity calculation (two Timer waveforms are plotted, one that exemplifies the clearing of the timer in each capture event and another without the clearing function active).

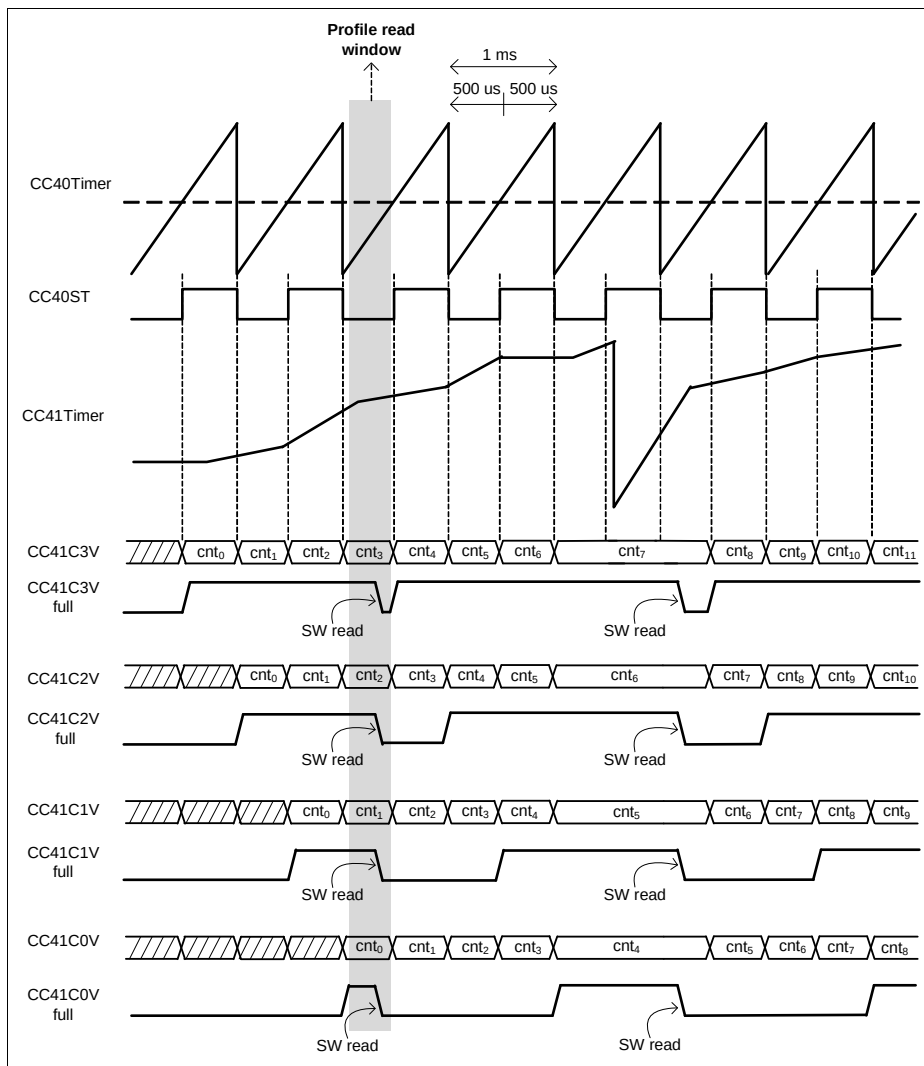


Figure 19-67 Three Capture profiles - CC4yTC.SCE = 1b

To calculate the three different profiles in [Figure 19-67](#), the 4 capture registers need to be read during the pointed read window. After that, the profile calculation is done:

$$\text{Profile 1} = \text{CC41C1V}_{\text{info}} - \text{CC41C0V}_{\text{info}}$$

$$\text{Profile 2} = \text{CC41C2V}_{\text{info}} - \text{CC41C1V}_{\text{info}}$$

Profile 3= $CC41C3V_{info} - CC41C2V_{info}$

Note: This is an example and therefore several Timer Slice configurations and software loops can be implemented.

High Dynamics Capturing

In some cases the dynamics of the capture trigger(s) may vary greatly over time. This will impose that the software needs to be prepared for the worst case scenario, where the frequency of the capture triggers may be very high. In applications where cycle-by-cycle calculation is needed (calculation in each capture trigger), then this constraints needs to be met by the software. Nevertheless for applications where a cycle-by-cycle calculation is not needed, the software can read back the FIFO data register in a periodic base and fetch all the data that has been captured so far, **Figure 19-68**.

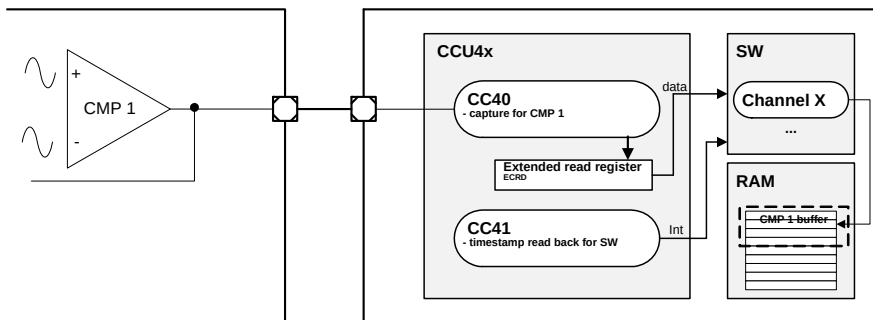


Figure 19-68 High dynamics capturing with software controlled timestamp

In this scenario, the software/CPU will read back the complete set of capture registers (2 or 4 depending on the chosen configuration), every time that an interrupt is triggered from the timestamp timer (the periodicity of this timer can also be adjusted on-the-fly).

Due to the fact that every capture register offers a full flag status bit, the software/CPU can always read back the complete set of registers. At the time of the data processing, this full flag is then checked, indicating if this value needs to be processed or not.

This FIFO read back functionality can also be used for applications that impose a heavy load on the system, which may not guarantee fixed access times to read back the captured data.

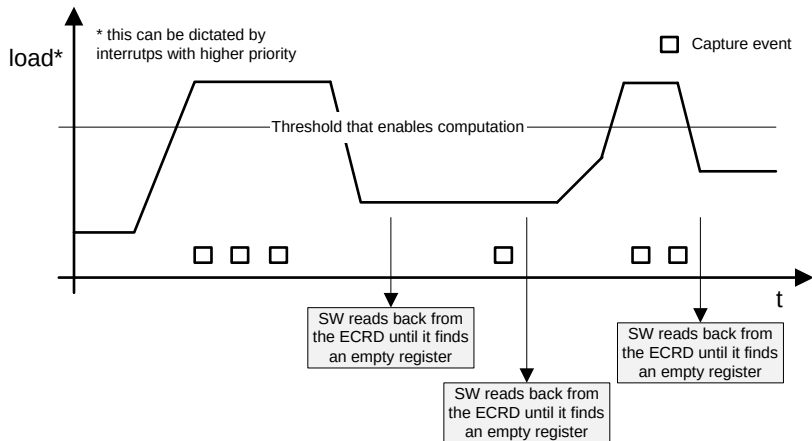


Figure 19-69 Extended read back during high load

Capture Grouping

In applications where multiple capture Timers are needed and the priority of the capture routines, does not imply that a cycle-by-cycle calculation needs to be done for every event, it may be suitable to group all the timers in the same CCU4x unit, [Figure 19-70](#).

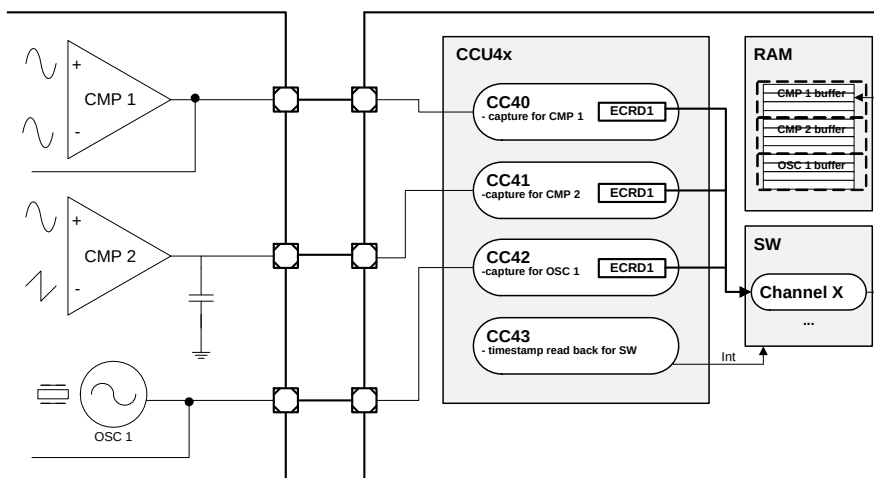


Figure 19-70 Capture grouping with extended read back

Capture/Compare Unit 4 (CCU4)

By setting the ECM bitfield for the Timer Slices used for capturing, the extended read back mode enables the reading back of data always in the proper capture order (from oldest to newest data). A timestamp timer is then used to trigger the Software/CPU to read back all the capture data present in the Timer Slices.

Every time that the interrupt is sensed, the Software/CPU (in this example) reads back the complete set of capture registers (via the ECRD address) for all Timer Slices. Due to the fact that each data read has a full flag indicator, the Software/CPU can read back the complete set of capture registers from all timers. This allows a fixed memory allocation that is as big as the number of captured registers, [Figure 19-71](#) (in this example 4 capture registers for each Timer Slice are being used).

The additional lost value bitfield (LCV) on the header of each ECRD data, will indicate if any capture trigger was lost between read operations (this can happen if the capture triggers are faster than the routine that is reading back the values).

Capture/Compare Unit 4 (CCU4)

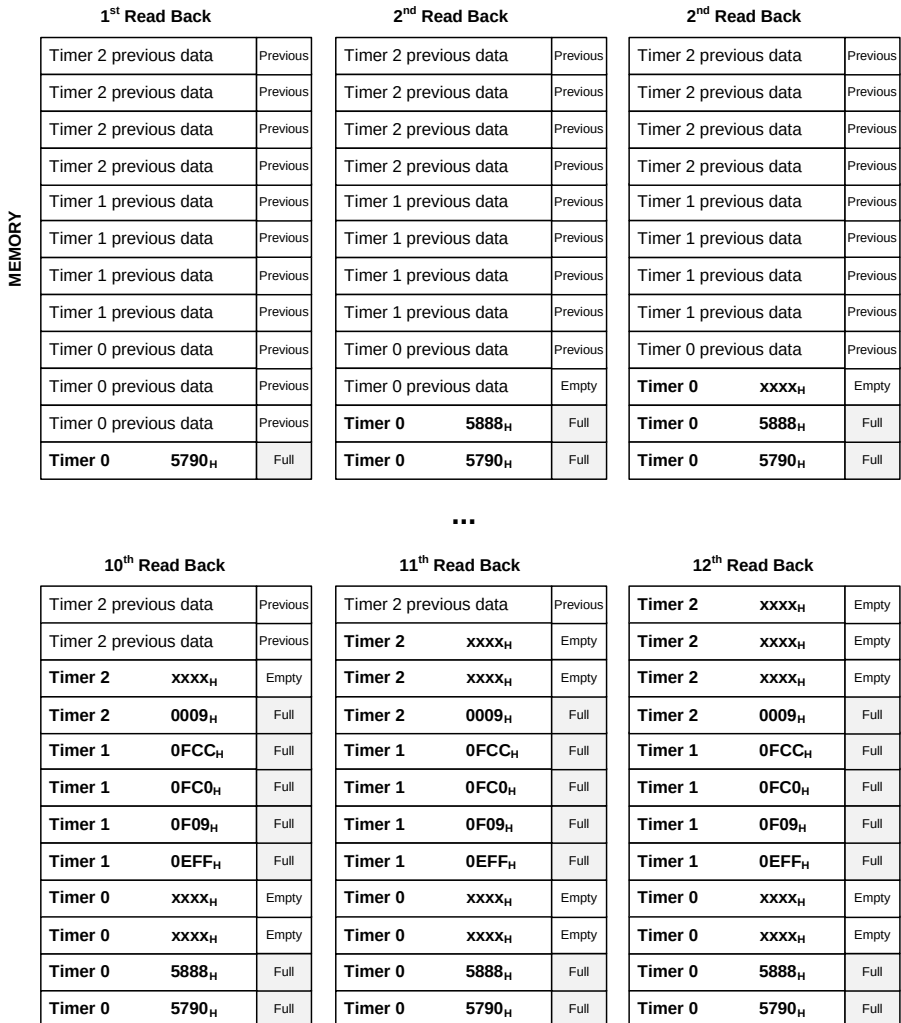


Figure 19-71 Memory structure for extended read back

19.3 Service Request Generation

Each CCU4 slice has an interrupt structure as the one in [Figure 19-72](#). The register **CC4yINTS** is the status register for the interrupt sources. Each dedicated interrupt

Capture/Compare Unit 4 (CCU4)

source can be set or cleared by SW, by writing into the specific bit in the **CC4ySWS** and **CC4ySWR** registers respectively.

Each interrupt source can be enabled/disabled via the **CC4yINTE** register. An enabled interrupt source will always generate a pulse on the service request line even if the specific status bit was not cleared. **Table 19-9** describes the interrupt sources of each CCU4 slice.

The interrupt sources, Period Match while counting up and one Match while counting down are ORed together. The same mechanism is applied to the Compare Match while counting up and Compare Match while counting down.

The interrupt sources for the external events are directly linked with the configuration set on the **CC4yINS.EVxEM**. If an event is programmed to be active on both edges, that means that service request pulse is going to be generated when any transition on the external signal is detected. If the event is linked with a level function, the **CC4yINS.EVxEM** still can be programmed to enable a service request pulse. The TRAP event doesn't need any of extra configuration for generating the service request pulse when the slice enters the TRAP state.

Table 19-9 Interrupt sources

Signal	Description
CCINEV0_E	Event 0 edge(s) information from event selector. Used when an external signal should trigger an interrupt.
CCINEV1_E	Event 1 edge(s) information from event selector. Used when an external signal should trigger an interrupt.
CCINEV2_E	Event 2 edge(s) information from event selector. Used when an external signal should trigger an interrupt.
CCPM_U	Period Match while counting up
CCCM_U	Compare Match while counting up
CCCM_D	Compare Match while counting down
CCOM_D	One Match while counting down
Trap state set	Entering Trap State. Will set the E2AS

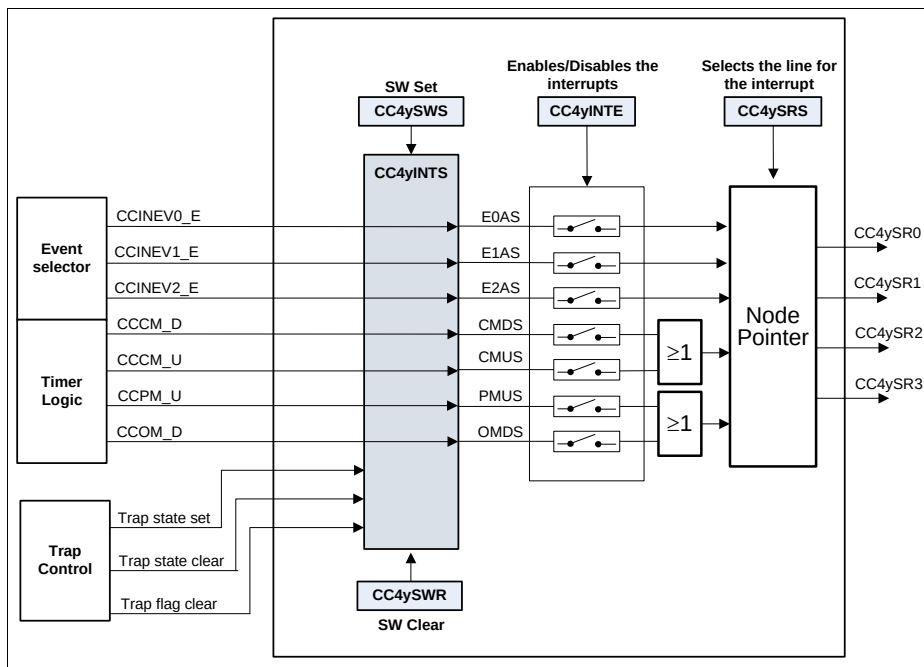


Figure 19-72 Slice interrupt structure overview

Each of the interrupt events can then be forwarded to one of the slice's four service request lines, [Figure 19-73](#). The value set on the **CC4ySRS** controls which interrupt event is mapped into which service request line.

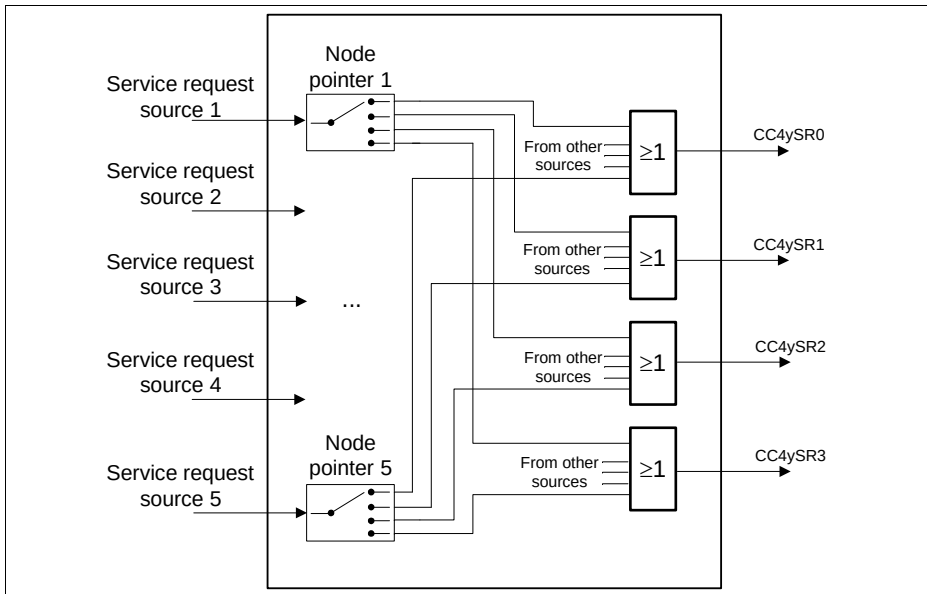


Figure 19-73 Slice Interrupt Node Pointer overview

The four service request lines of each slice are OR together inside the kernel of the CCU4, see [Figure 19-74](#). This means that there are only four service request lines per CCU4, that can have in each line interrupt requests coming from different slices.

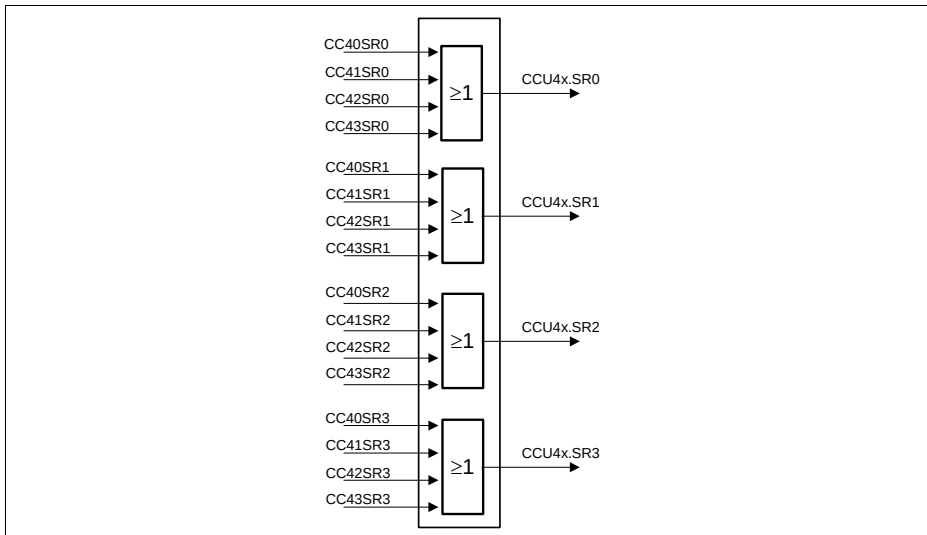


Figure 19-74 CCU4 service request overview

19.4 Debug Behavior

In suspend mode, the functional clocks for all slices as well the prescaler are stopped. The registers can still be accessed by the CPU (read only). This mode is useful for debugging purposes, e.g. where the current device status should be frozen in order to get a snapshot of the internal values. In suspend mode, all the slice timers are stopped. The suspend mode is non-intrusive concerning the register bits. This means register bits are not modified by hardware when entering or leaving the suspend mode.

Entry into suspend mode can be configured at the kernel level by means of the field **GCTRL.SUSCFG**.

The module is only functional after the suspend signal becomes inactive.

19.5 Power, Reset and Clock

The following sections describe the operating conditions, characteristics and timing requirements for the CCU4. All the timing information is related to the module clock, f_{CCU4} .

19.5.1 Clocks

Module Clock

The module clock of the CCU4 module is described in the SCU chapter as f_{PCLK} .

The bus interface clock of the CCU4 module is described in the SCU chapter as f_{MCLK} .

Capture/Compare Unit 4 (CCU4)

It is possible to disable the module clock for the CCU4 via the **GSTAT** register, nevertheless, there may be a dependency of the f_{CCU4} through the different CCU4 instances. One should address the SCU Chapter for a complete description of the product clock scheme.

If module clock dependencies exist through different IP instances, then one can disable the module clock internally inside the specific CCU4, by disabling the prescaler (**GSTAT.PRB** = 0_B).

External Clock

It is possible to use an external clock as source for the prescaler, and consequently for all the timer Slices, CC4y. This external source can be connected to one of the CCU4x.CLK[C...A] inputs.

This external source is nevertheless synchronized against f_{CCU4} .

Table 19-10 External clock operating conditions

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Frequency	f_{eclk}	—	—	$f_{\text{CCU4}}/4$	MHz	
ON time	ton_{eclk}	$2T_{\text{CCU4}}^{1)2)}$	—	—	ns	
OFF time	$toff_{\text{eclk}}$	$2T_{\text{CCU4}}^{1)2)}$	—	—	ns	Only the rising edge is used

1) Only valid if the signal was not previously synchronized/generated with the fccu4 clock (or a synchronous clock)

2) 50% duty cycle is not obligatory

19.5.2 Power

The CCU4 is inside the power core domain, therefore no special considerations about power up or power down sequences need to be taken. For an explanation about the different power domains, please address the SCU (System Control Unit) chapter.

An internal power down mode for the CCU4, can be achieved by disabling the clock inside the CCU4 itself. For this one should set the **GSTAT** register with the default reset value (via the idle mode set register, **GIDLS**).

19.6 Initialization and System Dependencies

19.6.1 Initialization Sequence

The initialization sequence for an application that is using the CCU4, should be the following:

1st Step: Enable the CCU4 clock via the specific SCU register, CGATCLR0.

2nd Step: Enable the prescaler block, by writing 1_B to the **GIDLC**.SPRB field.

3rd Step: Configure the global CCU4 register **GCTRL**

4th Step: Configure all the registers related to the required Timer Slice(s) functions, including the interrupt/service request configuration.

5th Step: If needed, configure the startup value for a specific Compare Channel Status, of a Timer Slice, by writing 1_B to the specific **GCSS**.SyTS.

6th Step: Enable the specific timer slice(s), CC4y, by writing 1_B to the specific **GIDLC**.CSyl.

7th Step: For all the Timer Slices that should be started synchronously via SW, the specific system register localized in the SCU, CCUCON, that enables a synchronous timer start should be addressed. The SCU.GSC4x input signal needs to be configured previously as a start function, see [Section 19.2.7.1](#).

19.6.2 System Dependencies

Each CCU4 may have different dependencies regarding module and bus clock frequencies. This dependencies should be addressed in the SCU and System Architecture Chapters.

Dependencies between several peripherals, regarding different clock operating frequencies may also exist. This should be addressed before configuring the connectivity between the CCU4 and some other peripheral.

The following topics must be taken into consideration for good CCU4 and system operation:

- CCU4 module clock must be at maximum two times faster than the module bus interface clock
- Module input triggers for the CCU4 must not exceed the module clock frequency (if the triggers are generated internally in the device)
- Module input triggers for the CCU4 must not exceed the frequency dictated in [Section 19.5.1](#)
- Frequency of the CCU4 outputs used as triggers/functions on other modules, must be crosschecked on the end point
- Applying and removing CCU4 from reset, can cause unwanted operations in other modules. This can occur if the modules are using CCU4 outputs as triggers/functions.

19.7 Registers

Registers Overview

The absolute register address is calculated by adding:
Module Base Address + Offset Address

Table 19-11 Registers Address Space

Module	Base Address	End Address	Note
CCU40	48040000 _H	4804FFFF _H	

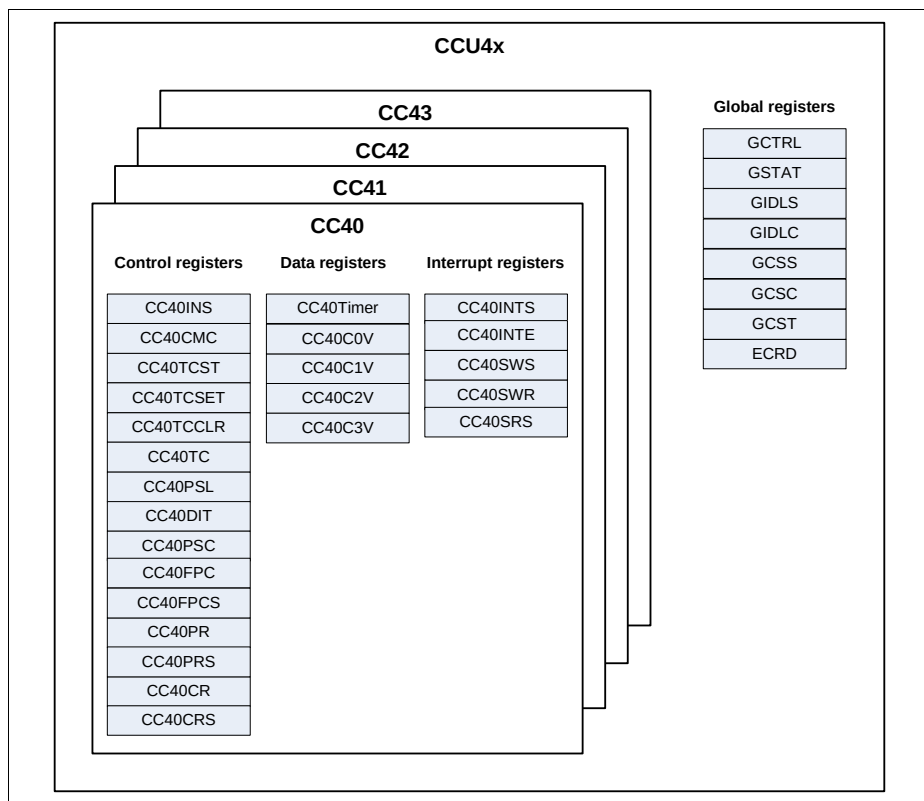


Figure 19-75 CCU4 registers overview

Table 19-12 Register Overview of CCU4

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	

CCU4 Global Registers

GCTRL	Module General Control Register	0000 _H	U, PV	U, PV	Page 19-86
GSTAT	General Slice Status Register	0004 _H	U, PV	BE	Page 19-89
GIDLS	General Idle Enable Register	0008 _H	U, PV	U, PV	Page 19-90
GIDLC	General Idle Disable Register	000C _H	U, PV	U, PV	Page 19-92
GCSS	General Channel Set Register	0010 _H	U, PV	U, PV	Page 19-93
GCSC	General Channel Clear Register	0014 _H	U, PV	U, PV	Page 19-95
GCST	General Channel Status Register	0018 _H	U, PV	BE	Page 19-98
MIDR	Module Identification Register	0080 _H	U, PV	BE	Page 19-101

CC40 Registers

CC40INS	Input Selector Unit Configuration	0100 _H	U, PV	U, PV	Page 19-101
CC40CMC	Connection Matrix Configuration	0104 _H	U, PV	U, PV	Page 19-103
CC40TST	Timer Run Status	0108 _H	U, PV	BE	Page 19-106
CC40TCSET	Timer Run Set	010C _H	U, PV	U, PV	Page 19-107
CC40TCCLR	Timer Run Clear	0110 _H	U, PV	U, PV	Page 19-108
CC40TC	General Timer Configuration	0114 _H	U, PV	U, PV	Page 19-109
CC40PSL	Output Passive Level Configuration	0118 _H	U, PV	U, PV	Page 19-114
CC40DIT	Dither Configuration	011C _H	U, PV	BE	Page 19-114
CC40DITS	Dither Shadow Register	0120 _H	U, PV	U, PV	Page 19-115
CC40PSC	Prescaler Configuration	0124 _H	U, PV	U, PV	Page 19-116
CC40FPC	Prescaler Compare Value	0128 _H	U, PV	U, PV	Page 19-117

Capture/Compare Unit 4 (CCU4)
Table 19-12 Register Overview of CCU4 (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
CC40FPCS	Prescaler Shadow Compare Value	012C _H	U, PV	U, PV	Page 19-118
CC40PR	Timer Period Value	0130 _H	U, PV	BE	Page 19-118
CC40PRS	Timer Period Shadow Value	0134 _H	U, PV	U, PV	Page 19-119
CC40CR	Timer Compare Value	0138 _H	U, PV	BE	Page 19-120
CC40CRS	Timer Compare Shadow Value	013C _H	U, PV	U, PV	Page 19-121
CC40TIMER	Timer Current Value	0170 _H	U, PV	U, PV	Page 19-122
CC40C0V	Capture Register 0 Value	0174 _H	U, PV	BE	Page 19-122
CC40C1V	Capture Register 1 Value	0178 _H	U, PV	BE	Page 19-123
CC40C2V	Capture Register 2 Value	017C _H	U, PV	BE	Page 19-124
CC40C3V	Capture Register 3 Value	0180 _H	U, PV	BE	Page 19-125
CC40INTS	Interrupt Status	01A0 _H	U, PV	BE	Page 19-126
CC40INTE	Interrupt Enable	01A4 _H	U, PV	U, PV	Page 19-128
CC40SRS	Interrupt Configuration	01A8 _H	U, PV	U, PV	Page 19-130
CC40SWS	Interrupt Status Set	01AC _H	U, PV	U, PV	Page 19-131
CC40SWR	Interrupt Status Clear	01B0 _H	U, PV	U, PV	Page 19-133
CC40ECD0	Extended Read Back 0	01B8 _H	U, PV	BE	Page 19-134
CC40ECD1	Extended Read Back 1	01BC _H	U, PV	BE	Page 19-136

CC41 Registers

CC41INS	Input Selector Unit Configuration	0200 _H	U, PV	U, PV	Page 19-101
CC41CMC	Connection Matrix Configuration	0204 _H	U, PV	U, PV	Page 19-103
CC41TST	Timer Run Status	0208 _H	U, PV	BE	Page 19-106
CC41TCSET	Timer Run Set	020C _H	U, PV	U, PV	Page 19-107
CC41TCCLR	Timer Run Clear	0210 _H	U, PV	U, PV	Page 19-108
CC41TC	General Timer Configuration	0214 _H	U, PV	U, PV	Page 19-109
CC41PSL	Output Passive Level Configuration	0218 _H	U, PV	U, PV	Page 19-114

Capture/Compare Unit 4 (CCU4)
Table 19-12 Register Overview of CCU4 (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
CC41DIT	Dither Configuration	021C _H	U, PV	BE	Page 19-114
CC41DITS	Dither Shadow Register	0220 _H	U, PV	U, PV	Page 19-115
CC41PSC	Prescaler Configuration	0224 _H	U, PV	U, PV	Page 19-116
CC41FPC	Prescaler Compare Value	0228 _H	U, PV	U, PV	Page 19-117
CC41FPCS	Prescaler Shadow Compare Value	022C _H	U, PV	U, PV	Page 19-118
CC41PR	Timer Period Value	0230 _H	U, PV	BE	Page 19-118
CC41PRS	Timer Period Shadow Value	0234 _H	U, PV	U, PV	Page 19-119
CC41CR	Timer Compare Value	0238 _H	U, PV	BE	Page 19-120
CC41CRS	Timer Compare Shadow Value	023C _H	U, PV	U, PV	Page 19-121
CC41TIMER	Timer Current Value	0270 _H	U, PV	U, PV	Page 19-122
CC41C0V	Capture Register 0 Value	0274 _H	U, PV	BE	Page 19-122
CC41C1V	Capture Register 1 Value	0278 _H	U, PV	BE	Page 19-123
CC41C2V	Capture Register 2 Value	027C _H	U, PV	BE	Page 19-124
CC41C3V	Capture Register 3 Value	0280 _H	U, PV	BE	Page 19-125
CC41INTS	Interrupt Status	02A0 _H	U, PV	BE	Page 19-126
CC41INTE	Interrupt Enable	02A4 _H	U, PV	U, PV	Page 19-128
CC41SRS	Interrupt Configuration	02A8 _H	U, PV	U, PV	Page 19-130
CC41SWS	Interrupt Status Set	02AC _H	U, PV	U, PV	Page 19-131
CC41SWR	Interrupt Status Clear	02B0 _H	U, PV	U, PV	Page 19-133
CC41ECD0	Extended Read Back 0	02B8 _H	U, PV	BE	Page 19-134
CC41ECD1	Extended Read Back 1	02BC _H	U, PV	BE	Page 19-136

CC42 Registers

CC42INS	Input Selector Unit Configuration	0300 _H	U, PV	U, PV	Page 19-101
CC42CMC	Connection Matrix Configuration	0304 _H	U, PV	U, PV	Page 19-103
CC42TST	Timer Run Status	0308 _H	U, PV	BE	Page 19-106
CC42TCSET	Timer Run Set	030C _H	U, PV	U, PV	Page 19-107

Capture/Compare Unit 4 (CCU4)
Table 19-12 Register Overview of CCU4 (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
CC42TCCLR	Timer Run Clear	0310 _H	U, PV	U, PV	Page 19-108
CC42TC	General Timer Configuration	0314 _H	U, PV	U, PV	Page 19-109
CC42PSL	Output Passive Level Configuration	0318 _H	U, PV	U, PV	Page 19-114
CC42DIT	Dither Configuration	031C _H	U, PV	BE	Page 19-114
CC42DITS	Dither Shadow Register	0320 _H	U, PV	U, PV	Page 19-115
CC42PSC	Prescaler Configuration	0324 _H	U, PV	U, PV	Page 19-116
CC42FPC	Prescaler Compare Value	0328 _H	U, PV	U, PV	Page 19-117
CC42FPCS	Prescaler Shadow Compare Value	032C _H	U, PV	U, PV	Page 19-118
CC42PR	Timer Period Value	0330 _H	U, PV	BE	Page 19-118
CC42PRS	Timer Period Shadow Value	0334 _H	U, PV	U, PV	Page 19-119
CC42CR	Timer Compare Value	0338 _H	U, PV	BE	Page 19-120
CC42CRS	Timer Compare Shadow Value	033C _H	U, PV	U, PV	Page 19-121
CC42TIMER	Timer Current Value	0370 _H	U, PV	U, PV	Page 19-122
CC42C0V	Capture Register 0 Value	0374 _H	U, PV	BE	Page 19-122
CC42C1V	Capture Register 1 Value	0378 _H	U, PV	BE	Page 19-123
CC42C2V	Capture Register 2 Value	037C _H	U, PV	BE	Page 19-124
CC42C3V	Capture Register 3 Value	0380 _H	U, PV	BE	Page 19-125
CC42INTS	Interrupt Status	03A0 _H	U, PV	BE	Page 19-126
CC42INTE	Interrupt Enable	03A4 _H	U, PV	U, PV	Page 19-128
CC42SRS	Interrupt Configuration	03A8 _H	U, PV	U, PV	Page 19-130
CC42SWS	Interrupt Status Set	03AC _H	U, PV	U, PV	Page 19-131
CC42SWR	Interrupt Status Clear	03B0 _H	U, PV	U, PV	Page 19-133
CC42ECD0	Extended Read Back 0	03B8 _H	U, PV	BE	Page 19-134
CC42ECD1	Extended Read Back 1	03BC _H	U, PV	BE	Page 19-136

CC43 Registers

CC43INS	Input Selector Unit Configuration	0400 _H	U, PV	U, PV	Page 19-101

Table 19-12 Register Overview of CCU4 (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
CC43CMC	Connection Matrix Configuration	0404 _H	U, PV	U, PV	Page 19-103
CC43TST	Timer Run Status	0408 _H	U, PV	BE	Page 19-106
CC43TCSET	Timer Run Set	040C _H	U, PV	U, PV	Page 19-107
CC43TCCLR	Timer Run Clear	0410 _H	U, PV	U, PV	Page 19-108
CC43TC	General Timer Configuration	0414 _H	U, PV	U, PV	Page 19-109
CC43PSL	Output Passive Level Configuration	0418 _H	U, PV	U, PV	Page 19-114
CC43DIT	Dither Configuration	041C _H	U, PV	BE	Page 19-114
CC43DITS	Dither Shadow Register	0420 _H	U, PV	U, PV	Page 19-115
CC43PSC	Prescaler Configuration	0424 _H	U, PV	U, PV	Page 19-116
CC43FPC	Prescaler Compare Value	0428 _H	U, PV	U, PV	Page 19-117
CC43FPCS	Prescaler Shadow Compare Value	042C _H	U, PV	U, PV	Page 19-118
CC43PR	Timer Period Value	0430 _H	U, PV	BE	Page 19-118
CC43PRS	Timer Period Shadow Value	0434 _H	U, PV	U, PV	Page 19-119
CC43CR	Timer Compare Value	0438 _H	U, PV	BE	Page 19-120
CC43CRS	Timer Compare Shadow Value	043C _H	U, PV	U, PV	Page 19-121
CC43TIMER	Timer Current Value	0470 _H	U, PV	U, PV	Page 19-122
CC43C0V	Capture Register 0 Value	0474 _H	U, PV	BE	Page 19-122
CC43C1V	Capture Register 1 Value	0478 _H	U, PV	BE	Page 19-123
CC43C2V	Capture Register 2 Value	047C _H	U, PV	BE	Page 19-124
CC43C3V	Capture Register 3 Value	0480 _H	U, PV	BE	Page 19-125
CC43INTS	Interrupt Status	04A0 _H	U, PV	BE	Page 19-126
CC43INTE	Interrupt Enable	04A4 _H	U, PV	U, PV	Page 19-128
CC43SRS	Interrupt Configuration	04A8 _H	U, PV	U, PV	Page 19-130
CC43SWS	Interrupt Status Set	04AC _H	U, PV	U, PV	Page 19-131
CC43SWR	Interrupt Status Clear	04B0 _H	U, PV	U, PV	Page 19-133

Table 19-12 Register Overview of CCU4 (cont'd)

Short Name	Description	Offset Addr. ¹⁾	Access Mode		Description See
			Read	Write	
CC43ECD0	Extended Read Back 0	04B8 _H	U, PV	BE	Page 19-134
CC43ECD1	Extended Read Back 1	04BC _H	U, PV	BE	Page 19-136

1) The absolute register address is calculated as follows:

Module Base Address + Offset Address (shown in this column)

19.7.1 Global Registers

GCTRL

The register contains the global configuration fields that affect all the timer slices inside CCU4.

GCTRL

Global Control Register

(0000_H)

Reset Value: 00000000_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
MSDE		MSE 3	MSE 2	MSE 1	MSE 0	SUSCFG		0		PCIS		0		PRBC	
rw		rw	rw	rw	rw	rw		r		rw		r		rw	

Field	Bits	Type	Description
PRBC	[2:0]	rw	Prescaler Clear Configuration This register controls how the prescaler Run Bit and internal registers are cleared. 000 _B SW only 001 _B GSTAT .PRB and prescaler registers are cleared when the Run Bit of CC40 is cleared. 010 _B GSTAT .PRB and prescaler registers are cleared when the Run Bit of CC41 is cleared. 011 _B GSTAT .PRB and prescaler registers are cleared when the Run Bit of CC42 is cleared. 100 _B GSTAT .PRB and prescaler registers are cleared when the Run Bit of CC43 is cleared.
PCIS	[5:4]	rw	Prescaler Input Clock Selection 00 _B Module clock 01 _B CCU4x.ECLKA 10 _B CCU4x.ECLKB 11 _B CCU4x.ECLKC
SUSCFG	[9:8]	rw	Suspend Mode Configuration This field controls the entering in suspend mode for all the CAPCOM4 slices. 00 _B Suspend request ignored. The module never enters in suspend 01 _B Stops all the running slices immediately. Safe stop is not applied. 10 _B Stops the block immediately and clamps all the outputs to PASSIVE state. Safe stop is applied. 11 _B Waits for the roll over of each slice to stop and clamp the slices outputs. Safe stop is applied.
MSE0	10	rw	Slice 0 Multi Channel shadow transfer enable When this field is set, a shadow transfer of slice 0 can be requested not only by SW but also via the CCU4x.MCSS input. 0 _B Shadow transfer can only be requested by SW 1 _B Shadow transfer can be requested via SW and via the CCU4x.MCSS input.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
MSE1	11	rw	Slice 1 Multi Channel shadow transfer enable When this field is set, a shadow transfer of slice 1 can be requested not only by SW but also via the CCU4x.MCSS input. 0_B Shadow transfer can only be requested by SW 1_B Shadow transfer can be requested via SW and via the CCU4x.MCSS input.
MSE2	12	rw	Slice 2 Multi Channel shadow transfer enable When this field is set, a shadow transfer of slice 2 can be requested not only by SW but also via the CCU4x.MCSS input. 0_B Shadow transfer can only be requested by SW 1_B Shadow transfer can be requested via SW and via the CCU4x.MCSS input.
MSE3	13	rw	Slice 3 Multi Channel shadow transfer enable When this field is set, a shadow transfer of slice 3 can be requested not only by SW but also via the CCU4x.MCSS input. 0_B Shadow transfer can only be requested by SW 1_B Shadow transfer can be requested via SW and via the CCU4x.MCSS input.
MSDE	[15:14]	rw	Multi Channel shadow transfer request configuration This field configures the type of shadow transfer requested via the CCU4x.MCSS input. The field CC4yTC.MSEy needs to be set in order for this configuration to have any effect. 00_B Only the shadow transfer for period and compare values is requested 01_B Shadow transfer for the compare, period and prescaler compare values is requested 10_B Reserved 11_B Shadow transfer for the compare, period, prescaler and dither compare values is requested

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
0	3, [7:6], [31:16]	r	Reserved A read always returns 0.

GSTAT

The register contains the status of the prescaler and each timer slice (idle mode or running).

GSTAT

Global Status Register (0004_H) **Reset Value: 000000F_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							PRB	0				S3I	S2I	S1I	S0I
r							rh	r				r	r	r	r

Field	Bits	Type	Description
S0I	0	r	CC40 IDLE status This bit indicates if the CC40 slice is in IDLE mode or not. In IDLE mode the clocks for the CC40 slice are stopped. 0 _B Running 1 _B Idle
S1I	1	r	CC41 IDLE status This bit indicates if the CC41 slice is in IDLE mode or not. In IDLE mode the clocks for the CC41 slice are stopped. 0 _B Running 1 _B Idle

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S2I	2	r	CC42 IDLE status This bit indicates if the CC42 slice is in IDLE mode or not. In IDLE mode the clocks for the CC42 slice are stopped. 0 _B Running 1 _B Idle
S3I	3	r	CC43 IDLE status This bit indicates if the CC43 slice is in IDLE mode or not. In IDLE mode the clocks for the CC43 slice are stopped. 0 _B Running 1 _B Idle
PRB	8	rh	Prescaler Run Bit 0 _B Prescaler is stopped 1 _B Prescaler is running
0	[7:4], [31:9]	r	Reserved Read always returns 0.

GIDLS

Through this register one can set the prescaler and the specific timer slices into idle mode.

GIDLS

Global Idle Set (0008_H) Reset Value: 00000000_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						PSIC	CPR B	0				SS3I	SS2I	SS1I	SS0I
r						w	w	r				w	w	w	w

Field	Bits	Type	Description
SS0I	0	w	CC40 IDLE mode set Writing a 1 _B to this bit sets the CC40 slice in IDLE mode. The clocks for the slice are stopped when in IDLE mode. When entering IDLE, the internal slice registers are not cleared. A read access always returns 0.
SS1I	1	w	CC41 IDLE mode set Writing a 1 _B to this bit sets the CC41 slice in IDLE mode. The clocks for the slice are stopped when in IDLE mode. When entering IDLE, the internal slice registers are not cleared. A read access always returns 0.
SS2I	2	w	CC42 IDLE mode set Writing a 1 _B to this bit sets the CC42 slice in IDLE mode. The clocks for the slice are stopped when in IDLE mode. When entering IDLE, the internal slice registers are not cleared. A read access always returns 0.
SS3I	3	w	CC43 IDLE mode set Writing a 1 _B to this bit sets the CC43 slice in IDLE mode. The clocks for the slice are stopped when in IDLE mode. When entering IDLE, the internal slice registers are not cleared. A read access always returns 0.
CPRB	8	w	Prescaler Run Bit Clear Writing a 1 _B into this register clears the Run Bit of the prescaler. Prescaler internal registers are not cleared. A read always returns 0.
PSIC	9	w	Prescaler clear Writing a 1 _B to this register clears the prescaler counter. It also loads the PSIV into the PVAL field for all Timer Slices. This performs a re alignment of the timer clock for all Slices. The Run Bit of the prescaler is not cleared. A read always returns 0.
0	[7:4], [31:10]	r	Reserved Read always returns 0.

Capture/Compare Unit 4 (CCU4)

GIDLC

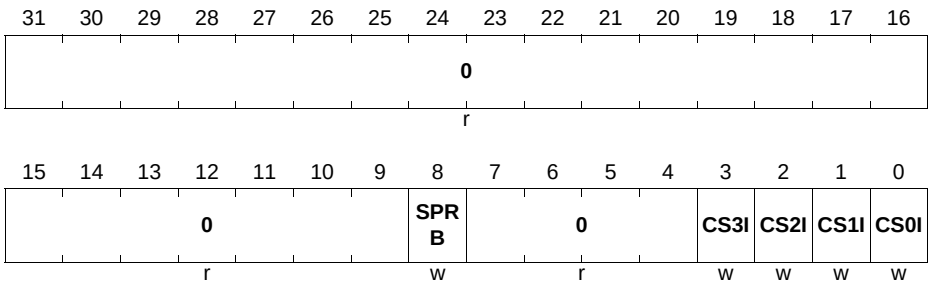
Through this register one can remove the prescaler and the specific timer slices from idle mode.

GIDLC

Global Idle Clear

(000C_H)

Reset Value: 00000000_H



Field	Bits	Type	Description
CS0I	0	w	CC40 IDLE mode clear Writing a 1 _B to this bit removes the CC40 from IDLE mode. A read access always returns 0.
CS1I	1	w	CC41 IDLE mode clear Writing a 1 _B to this bit removes the CC41 from IDLE mode. A read access always returns 0.
CS2I	2	w	CC42 IDLE mode clear Writing a 1 _B to this bit removes the CC42 from IDLE mode. A read access always returns 0.
CS3I	3	w	CC43 IDLE mode clear Writing a 1 _B to this bit removes the CC43 from IDLE mode. A read access always returns 0.
SPRB	8	w	Prescaler Run Bit Set Writing a 1 _B into this register sets the Run Bit of the prescaler. A read always returns 0.
0	[7:4], [31:9]	r	Reserved Read always returns 0.

GCSS

Through this register one can request a shadow transfer for the specific timer slice(s) and set the status bit for each of the compare channels.

GCSS

Global Channel Set

(0010_H)

Reset Value: 00000000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												S3S TS	S2S TS	S1S TS	S0S TS
r												w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	S3P SE	S3D SE	S3S E	0	S2P SE	S2D SE	S2S E	0	S1P SE	S1D SE	S1S E	0	S0P SE	S0D SE	S0S E
r	w	w	w	r	w	w	w	r	w	w	w	r	w	w	w

Field	Bits	Type	Description
S0SE	0	w	Slice 0 shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S0SS field, enabling then a shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S0DSE	1	w	Slice 0 Dither shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S0DSS field, enabling then a shadow transfer for the Dither compare value. A read always returns 0.
S0PSE	2	w	Slice 0 Prescaler shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S0PSS field, enabling then a shadow transfer for the prescaler compare value. A read always returns 0.
S1SE	4	w	Slice 1 shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S1SS field, enabling then a shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S1DSE	5	w	Slice 1 Dither shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S1DSS field, enabling then a shadow transfer for the Dither compare value. A read always returns 0.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S1PSE	6	w	Slice 1 Prescaler shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S1PSS field, enabling then a shadow transfer for the prescaler compare value. A read always returns 0.
S2SE	8	w	Slice 2 shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S2SS field, enabling then a shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S2DSE	9	w	Slice 2 Dither shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S2DSS field, enabling then a shadow transfer for the Dither compare value. A read always returns 0.
S2PSE	10	w	Slice 2 Prescaler shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S2PSS field, enabling then a shadow transfer for the prescaler compare value. A read always returns 0.
S3SE	12	w	Slice 3 shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S3SS field, enabling then a shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S3DSE	13	w	Slice 3 Dither shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S3DSS field, enabling then a shadow transfer for the Dither compare value. A read always returns 0.
S3PSE	14	w	Slice 3 Prescaler shadow transfer set enable Writing a 1 _B to this bit will set the GCST.S3PSS field, enabling then a shadow transfer for the prescaler compare value. A read always returns 0.
S0STS	16	w	Slice 0 status bit set Writing a 1 _B into this field sets the status bit of slice 0 (GCST.CC40ST) to 1 _B . A read always returns 0.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S1STS	17	w	Slice 1 status bit set Writing a 1 _B into this field sets the status bit of slice 1 (GCST .CC41ST) to 1 _B . A read always returns 0.
S2STS	18	w	Slice 2 status bit set Writing a 1 _B into this field sets the status bit of slice 2 (GCST .CC42ST) to 1 _B . A read always returns 0.
S3STS	19	w	Slice 3 status bit set Writing a 1 _B into this field sets the status bit of slice 3 (GCST .CC43ST) to 1 _B . A read always returns 0.
0	3, 7, 11, 15, [31:20]	r	Reserved Read always returns 0.

GCSC

Through this register one can reset a shadow transfer request for the specific timer slice and clear the status bit for each the compare channels.

GCSC

Global Channel Clear (0014_H) **Reset Value: 00000000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												S3S TC	S2S TC	S1S TC	S0S TC
r												w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	S3P SC	S3D SC	S3S C	0	S2P SC	S2D SC	S2S C	0	S1P SC	S1D SC	S1S C	0	S0P SC	S0D SC	S0S C
r	w	w	w	r	w	w	w	r	w	w	w	r	w	w	w

Field	Bits	Type	Description
S0SC	0	w	Slice 0 shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S0SS field, canceling any pending shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S0DSC	1	w	Slice 0 Dither shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S0DSS field, canceling any pending shadow transfer for the Dither compare value. A read always returns 0.
S0PSC	2	w	Slice 0 Prescaler shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S0PSS field, canceling any pending shadow transfer for the prescaler compare value. A read always returns 0.
S1SC	4	w	Slice 1 shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S1SS field, canceling any pending shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S1DSC	5	w	Slice 1 Dither shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S1DSS field, canceling any pending shadow transfer for the Dither compare value. A read always returns 0.
S1PSC	6	w	Slice 1 Prescaler shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S1PSS field, canceling any pending shadow transfer for the prescaler compare value. A read always returns 0.
S2SC	8	w	Slice 2 shadow transfer clear Writing a 1 _B to this bit will clear the GCST .S2SS field, canceling any pending shadow transfer for the Period, Compare and Passive level values. A read always returns 0.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S2DSC	9	w	Slice 2 Dither shadow transfer clear Writing a 1 _B to this bit will clear the GCST.S2DSS field, canceling any pending shadow transfer for the Dither compare value. A read always returns 0.
S2PSC	10	w	Slice 2 Prescaler shadow transfer clear Writing a 1 _B to this bit will clear the GCST.S2PSS field, canceling any pending shadow transfer for the prescaler compare value. A read always returns 0.
S3SC	12	w	Slice 3 shadow transfer clear Writing a 1 _B to this bit will clear the GCST.S3SS field, canceling any pending shadow transfer for the Period, Compare and Passive level values. A read always returns 0.
S3DSC	13	w	Slice 3 Dither shadow transfer clear Writing a 1 _B to this bit will clear the GCST.S3DSS field, canceling any pending shadow transfer for the Dither compare value. A read always returns 0.
S3PSC	14	w	Slice 3 Prescaler shadow transfer clear Writing a 1 _B to this bit will clear the GCST.S3PSS field, canceling any pending shadow transfer for the prescaler compare value. A read always returns 0.
S0STC	16	w	Slice 0 status bit clear Writing a 1 _B into this field clears the status bit of slice 0 (GCST.CC40ST) to 0 _B . A read always returns 0.
S1STC	17	w	Slice 1 status bit clear Writing a 1 _B into this field clears the status bit of slice 1 (GCST.CC41ST) to 0 _B . A read always returns 0.
S2STC	18	w	Slice 2 status bit clear Writing a 1 _B into this field clears the status bit of slice 2 (GCST.CC42ST) to 0 _B . A read always returns 0.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S3STC	19	w	Slice 3 status bit clear Writing a 1 _B into this field clears the status bit of slice 3 (GCST.CC43ST) to 0 _B . A read always returns 0.
0	3, 7, 11, 15, [31:20]	r	Reserved Read always returns 0.

GCST

This register holds the information of the shadow transfer requests and of each timer slice status bit.

GCST

Global Channel Status (0018_H) **Reset Value: 00000000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0												CC4 3ST	CC4 2ST	CC4 1ST	CC4 0ST
r												rh	rh	rh	rh
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	S3P SS	S3D SS	S3S S	0	S2P SS	S2D SS	S2S S	0	S1P SS	S1D SS	S1S S	0	S0P SS	S0D SS	S0S S
r	rh	rh	rh	r	rh	rh	rh	r	rh	rh	rh	r	rh	rh	rh

Field	Bits	Type	Description
S0SS	0	rh	Slice 0 shadow transfer status 0 _B Shadow transfer has not been requested 1 _B Shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S0DSS	1	rh	Slice 0 Dither shadow transfer status 0 _B Dither shadow transfer has not been requested 1 _B Dither shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.

Field	Bits	Type	Description
S0PSS	2	rh	Slice 0 Prescaler shadow transfer status 0_B Prescaler shadow transfer has not been requested 1_B Prescaler shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S1SS	4	rh	Slice 1 shadow transfer status 0_B Shadow transfer has not been requested 1_B Shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S1DSS	5	rh	Slice 1 Dither shadow transfer status 0_B Dither shadow transfer has not been requested 1_B Dither shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S1PSS	6	rh	Slice 1 Prescaler shadow transfer status 0_B Prescaler shadow transfer has not been requested 1_B Prescaler shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S2SS	8	rh	Slice 2 shadow transfer status 0_B Shadow transfer has not been requested 1_B Shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S2DSS	9	rh	Slice 2 Dither shadow transfer status 0_B Dither shadow transfer has not been requested 1_B Dither shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
S2PSS	10	rh	Slice 2 Prescaler shadow transfer status 0_B Prescaler shadow transfer has not been requested 1_B Prescaler shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S3SS	12	rh	Slice 3 shadow transfer status 0_B Shadow transfer has not been requested 1_B Shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S3DSS	13	rh	Slice 3 Dither shadow transfer status 0_B Dither shadow transfer has not been requested 1_B Dither shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
S3PSS	14	rh	Slice 3 Prescaler shadow transfer status 0_B Prescaler shadow transfer has not been requested 1_B Prescaler shadow transfer has been requested This field is cleared by HW after the requested shadow transfer has been executed.
CC40ST	16	rh	Slice 0 status bit
CC41ST	17	rh	Slice 1 status bit
CC42ST	18	rh	Slice 2 status bit
CC43ST	19	rh	Slice 3 status bit
0	3, 7, 11, 15, [31:20]	r	Reserved Read always returns 0.

MIDR

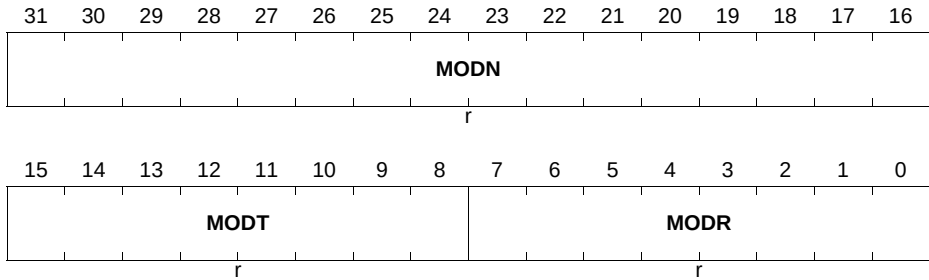
This register contains the module identification number.

MIDR

Module Identification

(0080_H)

Reset Value: 00A6C0XX_H



Field	Bits	Type	Description
MODR	[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.
MODT	[15:8]	r	Module Type
MODN	[31:16]	r	Module Number

19.7.2 Slice (CC4y) Registers

CC4yINS

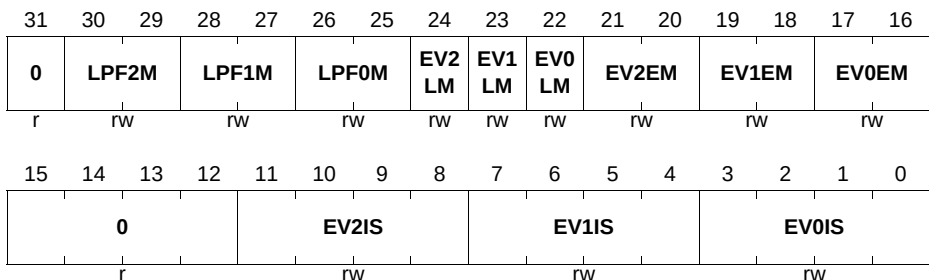
The register contains the configuration for the input selector.

CC4yINS (y = 0 - 3)

Input Selector Configuration

(0100_H + 0100_H * y)

Reset Value: 00000000_H



Field	Bits	Type	Description
EV0IS	[3:0]	rw	Event 0 signal selection This field selects which pins is used for the event 0. 0000 _B CCU4x.INyA 0001 _B CCU4x.INyB 0010 _B CCU4x.INyC 0011 _B CCU4x.INyD 0100 _B CCU4x.INyE 0101 _B CCU4x.INyF 0110 _B CCU4x.INyG 0111 _B CCU4x.INyH 1000 _B CCU4x.INyI 1001 _B CCU4x.INyJ 1010 _B CCU4x.INyK 1011 _B CCU4x.INyL 1100 _B CCU4x.INyM 1101 _B CCU4x.INyN 1110 _B CCU4x.INyO 1111 _B CCU4x.INyP
EV1IS	[7:4]	rw	Event 1 signal selection Same as EV0IS description
EV2IS	[11:8]	rw	Event 2 signal selection Same as EV0IS description
EV0EM	[17:16]	rw	Event 0 Edge Selection 00 _B No action 01 _B Signal active on rising edge 10 _B Signal active on falling edge 11 _B Signal active on both edges
EV1EM	[19:18]	rw	Event 1 Edge Selection Same as EV0EM description
EV2EM	[21:20]	rw	Event 2 Edge Selection Same as EV0EM description
EV0LM	22	rw	Event 0 Level Selection 0 _B Active on HIGH level 1 _B Active on LOW level
EV1LM	23	rw	Event 1 Level Selection Same as EV0LM description

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
EV2LM	24	rw	Event 2 Level Selection Same as EV0LM description
LPF0M	[26:25]	rw	Event 0 Low Pass Filter Configuration This field sets the number of consecutive counts for the Low Pass Filter of Event 0. The input signal value needs to remain stable for this number of counts (f_{CCU4}), so that a level/transition is accepted. 00 _B LPF is disabled 01 _B 3 clock cycles of f_{CCU4} 10 _B 5 clock cycles of f_{CCU4} 11 _B 7 clock cycles of f_{CCU4}
LPF1M	[28:27]	rw	Event 1 Low Pass Filter Configuration Same description as LPF0M
LPF2M	[30:29]	rw	Event 2 Low Pass Filter Configuration Same description as LPF0M
0	[15:12] , 31	r	Reserved Read always returns 0.

CC4yCMC

The register contains the configuration for the connection matrix.

CC4yCMC (y = 0 - 3)

Connection Matrix Control (0104_H + 0100_H * y) **Reset Value: 00000000_H**

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0											TCE	MOS	TS	OFS	
r											rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNTS		LDS		UDS		GATES		CAP1S		CAP0S		ENDS		STRTS	
rw		rw		rw		rw		rw		rw		rw		rw	

Field	Bits	Type	Description
STRTS	[1:0]	rw	External Start Functionality Selector Selects the Event that is going to be linked with the external start functionality. 00 _B External Start Function deactivated 01 _B External Start Function triggered by Event 0 10 _B External Start Function triggered by Event 1 11 _B External Start Function triggered by Event 2
ENDS	[3:2]	rw	External Stop Functionality Selector Selects the Event that is going to be linked with the external stop functionality. 00 _B External Stop Function deactivated 01 _B External Stop Function triggered by Event 0 10 _B External Stop Function triggered by Event 1 11 _B External Stop Function triggered by Event 2
CAP0S	[5:4]	rw	External Capture 0 Functionality Selector Selects the Event that is going to be linked with the external capture for capture registers number 1 and 0. 00 _B External Capture 0 Function deactivated 01 _B External Capture 0 Function triggered by Event 0 10 _B External Capture 0 Function triggered by Event 1 11 _B External Capture 0 Function triggered by Event 2
CAP1S	[7:6]	rw	External Capture 1 Functionality Selector Selects the Event that is going to be linked with the external capture for capture registers number 3 and 2. 00 _B External Capture 1 Function deactivated 01 _B External Capture 1 Function triggered by Event 0 10 _B External Capture 1 Function triggered by Event 1 11 _B External Capture 1 Function triggered by Event 2

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
GATES	[9:8]	rw	External Gate Functionality Selector Selects the Event that is going to be linked with the counter gating function. This function is used to gate the timer increment/decrement procedure. 00 _B External Gating Function deactivated 01 _B External Gating Function triggered by Event 0 10 _B External Gating Function triggered by Event 1 11 _B External Gating Function triggered by Event 2
UDS	[11:10]	rw	External Up/Down Functionality Selector Selects the Event that is going to be linked with the Up/Down counting direction control. 00 _B External Up/Down Function deactivated 01 _B External Up/Down Function triggered by Event 0 10 _B External Up/Down Function triggered by Event 1 11 _B External Up/Down Function triggered by Event 2
LDS	[13:12]	rw	External Timer Load Functionality Selector Selects the Event that is going to be linked with the timer load function. 00 _B - External Load Function deactivated 01 _B - External Load Function triggered by Event 0 10 _B - External Load Function triggered by Event 1 11 _B - External Load Function triggered by Event 2
CNTS	[15:14]	rw	External Count Selector Selects the Event that is going to be linked with the count function. The counter is going to be increment/decremented each time that a specific transition on the event is detected. 00 _B External Count Function deactivated 01 _B External Count Function triggered by Event 0 10 _B External Count Function triggered by Event 1 11 _B External Count Function triggered by Event 2
OFS	16	rw	Override Function Selector This field enables the ST bit override functionality. 0 _B Override functionality disabled 1 _B Status bit trigger override connected to Event 1; Status bit value override connected to Event 2

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
TS	17	rw	Trap Function Selector This field enables the trap functionality. 0_B Trap function disabled 1_B TRAP function connected to Event 2
MOS	[19:18]	rw	External Modulation Functionality Selector Selects the Event that is going to be linked with the external modulation function. 00_B - Modulation Function deactivated 01_B - Modulation Function triggered by Event 0 10_B - Modulation Function triggered by Event 1 11_B - Modulation Function triggered by Event 2
TCE	20	rw	Timer Concatenation Enable This bit enables the timer concatenation with the previous slice. 0_B Timer concatenation is disabled 1_B Timer concatenation is enabled <i>Note: In CC40 this field doesn't exist. This is a read only reserved field. Read access always returns 0.</i>
0	[31:21]	r	Reserved A read always returns 0

CC4yTCST

The register holds the status of the timer (running/stopped) and the information about the counting direction (up/down).

CC4yTCST (y = 0 - 3)

Slice Timer Status $(0108_H + 0100_H * y)$ **Reset Value: 00000000_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														CDIR	TRB
r														rh	rh

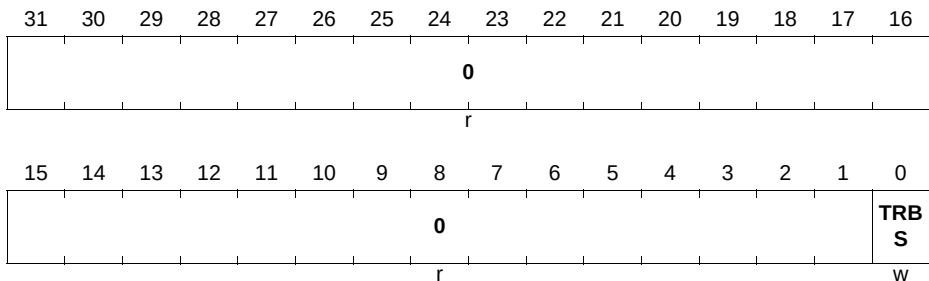
Field	Bits	Type	Description
TRB	0	rh	Timer Run Bit This field indicates if the timer is running. 0_B Timer is stopped 1_B Timer is running
CDIR	1	rh	Timer Counting Direction This field indicates if the timer is being increment or decremented 0_B Timer is counting up 1_B Timer is counting down
0	[31:2]	r	Reserved Read always returns 0

CC4yTCSET

Through this register it is possible to start the timer.

CC4yTCSET (y = 0 - 3)

Slice Timer Run Set (010C_H + 0100_H * y) **Reset Value: 00000000_H**



Field	Bits	Type	Description
TRBS	0	w	Timer Run Bit set Writing a 1_B into this field sets the run bit of the timer. Read always returns 0.
0	[31:1]	r	Reserved Read always returns 0

CC4yTCCLR

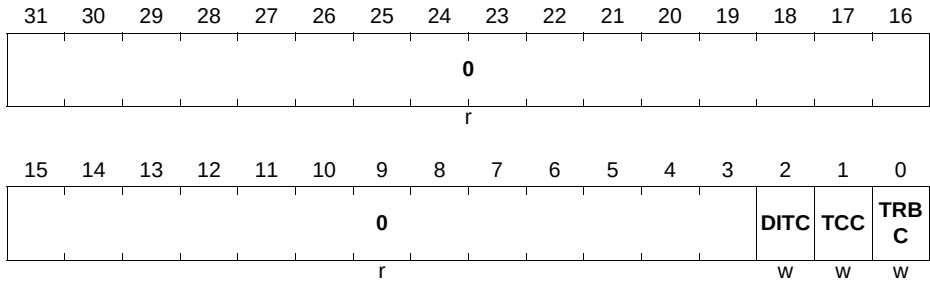
Through this register it is possible to stop and clear the timer, and clearing also the dither counter

CC4yTCCLR (y = 0 - 3)

Slice Timer Clear

(0110_H + 0100_H * y)

Reset Value: 00000000_H



Field	Bits	Type	Description
TRBC	0	w	Timer Run Bit Clear Writing a 1 _B into this field clears the run bit of the timer. The timer is not cleared. Read always returns 0.
TCC	1	w	Timer Clear Writing a 1 _B into this field clears the timer to 0000 _H . Read always returns 0.
DITC	2	w	Dither Counter Clear Writing a 1 _B into this field clears the dither counter to 0 _H . Read always returns 0.
0	[31:3]	r	Reserved Read always returns 0

CC4yTC

This register holds the several possible configurations for the timer operation.

CC4yTC (y = 0 - 3)

Slice Timer Control

(0114_H + 0100_H * y)

Reset Value: 00000000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						MCM E	EMT	EMS	TRP SW	TRP SE	0			TRA PE	FPE
r						rw	rw	rw	rw	rw	r			rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DIM	DITHE		CCS	SCE	STR M	ENDM		0	CAPC		ECM	CMO D	CLS T	TSS M	TCM
rw	rw		rw	rw	rw	rw		r	rw		rw	rh	rw	rw	rw

Field	Bits	Type	Description
TCM	0	rw	Timer Counting Mode This field controls the actual counting scheme of the timer. 0 _B Edge aligned mode 1 _B Center aligned mode <i>Note: When using an external signal to control the counting direction, the counting scheme is always edge aligned.</i>
TSSM	1	rw	Timer Single Shot Mode This field controls the single shot mode. This is applicable in edge and center aligned modes. 0 _B Single shot mode is disabled 1 _B Single shot mode is enabled
CLST	2	rw	Shadow Transfer on Clear Setting this bit to 1 _B enables a shadow transfer when a timer clearing action is performed. Notice that the shadow transfer enable bitfields on the GCST register still need to be set to 1 _B via software.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
CMOD	3	rh	Capture Compare Mode This field indicates in which mode the slice is operating. The default value is compare mode. The capture mode is automatically set by the HW when an external signal is mapped to a capture trigger. 0 _B Compare Mode 1 _B Capture Mode
ECM	4	rw	Extended Capture Mode This field control the Capture mode of the specific slice. It only has effect if the CMOD bit is 1 _B . 0 _B Normal Capture Mode. Clear of the Full Flag of each capture register is done by accessing the registers individually only. 1 _B Extended Capture Mode. Clear of the Full Flag of each capture register is done not only by accessing the individual registers but also by accessing the ECRD register. When reading the ECRD register, only the capture register register full flag pointed by the ECRD.VPTR is cleared.
CAPC	[6:5]	rw	Clear on Capture Control 00 _B Timer is never cleared on a capture event 01 _B Timer is cleared on a capture event into capture registers 2 and 3. (When SCE = 1 _B , Timer is always cleared in a capture event) 10 _B Timer is cleared on a capture event into capture registers 0 and 1. (When SCE = 1 _B , Timer is always cleared in a capture event) 11 _B Timer is always cleared in a capture event.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
ENDM	[9:8]	rw	Extended Stop Function Control This field controls the extended functions of the external Stop signal. 00 _B Clears the timer run bit only (default stop) 01 _B Clears the timer only (flush) 10 _B Clears the timer and run bit (flush/stop) 11 _B Reserved <i>Note: When using an external up/down signal the flush operation sets the timer with zero if the counter is counting up and with the Period value if the counter is being decremented.</i>
STRM	10	rw	Extended Start Function Control This field controls the extended functions of the external Start signal. 0 _B Sets run bit only (default start) 1 _B Clears the timer and sets run bit (flush/start) <i>Note: When using an external up/down signal the flush operation sets the timer with zero if the counter is being incremented and with the Period value if the counter is being decremented.</i>
SCE	11	rw	Equal Capture Event enable 0 _B Capture into CC4yC0V/CC4yC1V registers control by CCycapt0 and capture into CC4yC3V/CC4yC2V control by CCycapt1 1 _B Capture into CC4yC0V/CC4yC1V and CC4yC3V/CC4yC2V control by CCycapt1
CCS	12	rw	Continuous Capture Enable 0 _B The capture into a specific capture register is done with the rules linked with the full flags, described at Section 19.2.7.6 . 1 _B The capture into the capture registers is always done regardless of the full flag status (even if the register has not been read back).

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
DITHE	[14:13]	rw	Dither Enable This field controls the dither mode for the slice. See Section 19.2.10 . 00 _B Dither is disabled 01 _B Dither is applied to the Period 10 _B Dither is applied to the Compare 11 _B Dither is applied to the Period and Compare
DIM	15	rw	Dither input selector This fields selects if the dither control signal is connected to the dither logic of the specific slice of is connected to the dither logic of slice 0. Notice that even if this field is set to 1 _B , the field DITHE still needs to be programmed. 0 _B Slice is using its own dither unit 1 _B Slice is connected to the dither unit of slice 0.
FPE	16	rw	Floating Prescaler enable Setting this bit to 1 _B enables the floating prescaler mode. 0 _B Floating prescaler mode is disabled 1 _B Floating prescaler mode is enabled
TRAPE	17	rw	TRAP enable Setting this bit to 1 _B enables the TRAP action at the output pin. After mapping an external signal to the TRAP functionality, the user must set this field to 1 _B to activate the effect of the TRAP on the output pin. Writing a 0 _B into this field disables the effect of the TRAP function regardless of the state of the input signal. 0 _B TRAP functionality has no effect on the output 1 _B TRAP functionality affects the output
TRPSE	21	rw	TRAP Synchronization Enable Writing a 1 _B into this bit enables a synchronous exiting with the PWM signal of the trap state. 0 _B Exiting from TRAP state isn't synchronized with the PWM signal 1 _B Exiting from TRAP state is synchronized with the PWM signal

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
TRPSW	22	rw	TRAP State Clear Control 0_B The slice exits the TRAP state automatically when the TRAP condition is not present 1_B The TRAP state can only be exited by a SW request.
EMS	23	rw	External Modulation Synchronization Setting this bit to 1_B enables the synchronization of the external modulation functionality with the PWM period. 0_B External Modulation functionality is not synchronized with the PWM signal 1_B External Modulation functionality is synchronized with the PWM signal
EMT	24	rw	External Modulation Type This field selects if the external modulation event is clearing the CC4yST bit or if is gating the outputs. 0_B External Modulation functionality is clearing the CC4yST bit. 1_B External Modulation functionality is gating the outputs.
MCME	25	rw	Multi Channel Mode Enable 0_B Multi Channel Mode is disabled 1_B Multi Channel Mode is enabled
0	7, [20:18] , [31:26]	r	Reserved Read always returns 0

CC4yPSL

This register holds the configuration for the output passive level control.

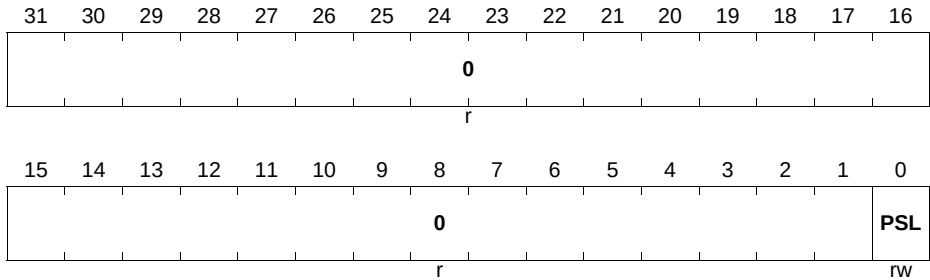
Capture/Compare Unit 4 (CCU4)

CC4yPSL (y = 0 - 3)

Passive Level Config

(0118_H + 0100_H * y)

Reset Value: 00000000_H



Field	Bits	Type	Description
PSL	0	rw	Output Passive Level This field controls the passive level of the output pin. 0 _B Passive Level is LOW 1 _B Passive Level is HIGH A write always addresses the shadow register, while a read always returns the current used value.
0	[31:1]	r	Reserved A read access always returns 0

CC4yDIT

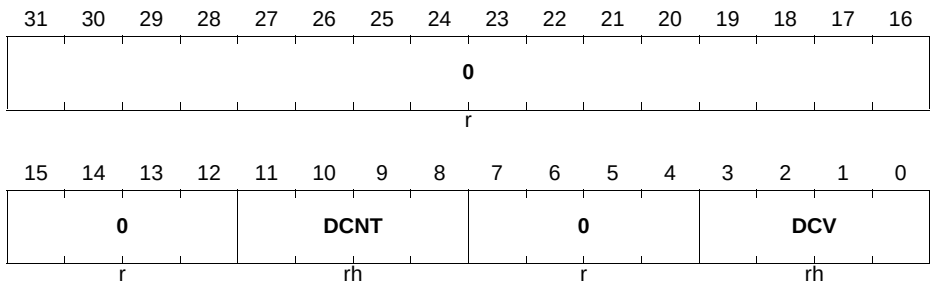
This register holds the current dither compare and dither counter values.

CC4yDIT (y = 0 - 3)

Dither Config

(011C_H + 0100_H * y)

Reset Value: 00000000_H



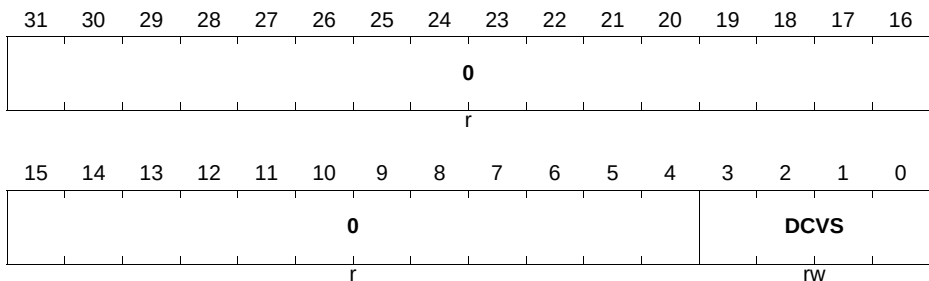
Field	Bits	Type	Description
DCV	[3:0]	rh	Dither compare Value This field contains the value used for the dither comparison. This value is updated when a shadow transfer occurs with the CC4yDITS.DCVS .
DCNT	[11:8]	rh	Dither counter actual value
0	[7:4], [31:12]	r	Reserved Read always returns 0.

CC4yDITS

This register contains the value that is going to be loaded into the **CC4yDIT.DCV** when the next shadow transfer occurs.

CC4yDITS (y = 0 - 3)

Dither Shadow Register **(0120_H + 0100_H * y)** **Reset Value: 00000000_H**



Field	Bits	Type	Description
DCVS	[3:0]	rw	Dither Shadow Compare Value This field contains the value that is going to be set on the dither compare value, CC4yDIT.DCV , within the next shadow transfer.
0	[31:4]	r	Reserved Read always returns 0.

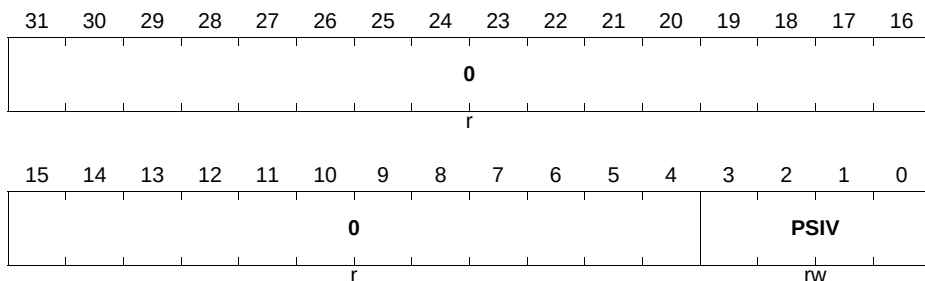
CC4yPSC

This register contains the value that is loaded into the prescaler during restart.

Capture/Compare Unit 4 (CCU4)

CC4yPSC (y = 0 - 3)

Prescaler Control $(0124_H + 0100_H * y)$ **Reset Value: 00000000_H**



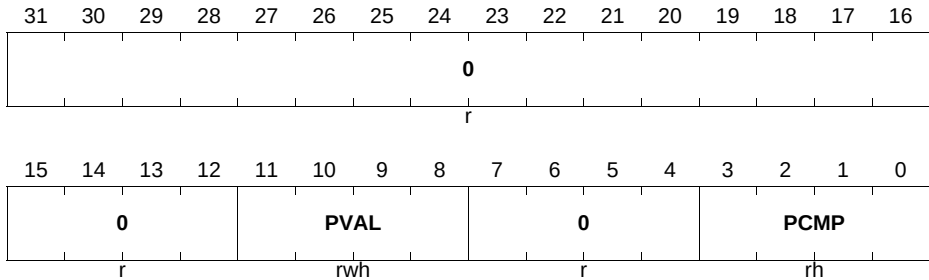
Field	Bits	Type	Description
PSIV	[3:0]	rw	Prescaler Initial Value This field contains the value that is applied to the Prescaler at startup. When floating prescaler mode is used, this value is applied when a timer compare match AND prescaler compare match occurs or when a capture event is triggered.
0	[31:4]	r	Reserved Read always returns 0.

CC4yFPC

This register contains the value used for the floating prescaler compare and the actual prescaler division value.

CC4yFPC (y = 0 - 3)

Floating Prescaler Control **(0128_H + 0100_H * y)** **Reset Value: 00000000_H**



Field	Bits	Type	Description
PCMP	[3:0]	rh	Floating Prescaler Compare Value This field contains comparison value used in floating prescaler mode. The comparison is triggered by the Timer Compare match event. See Section 19.2.11.2 .
PVAL	[11:8]	rwh	Actual Prescaler Value See Table 19-7 . Writing into this register is only possible when the prescaler is stopped. When the floating prescaler mode is not used, this value is equal to the CC4yPSC.PSIV .
0	[7:4], [15:12], [31:16]	r	Reserved Read always returns 0.

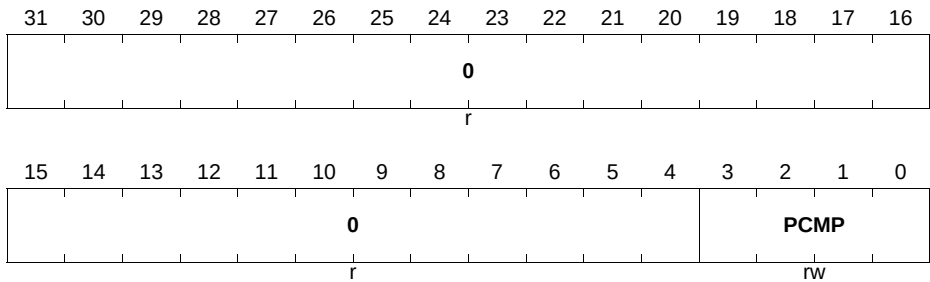
CC4yFPCS

This register contains the value that is going to be transferred to the [CC4yFPC.PCMP](#) field within the next shadow transfer update.

Capture/Compare Unit 4 (CCU4)

CC4yFPCS (y = 0 - 3)

Floating Prescaler Shadow ($012C_H + 0100_H * y$) **Reset Value: 00000000_H**



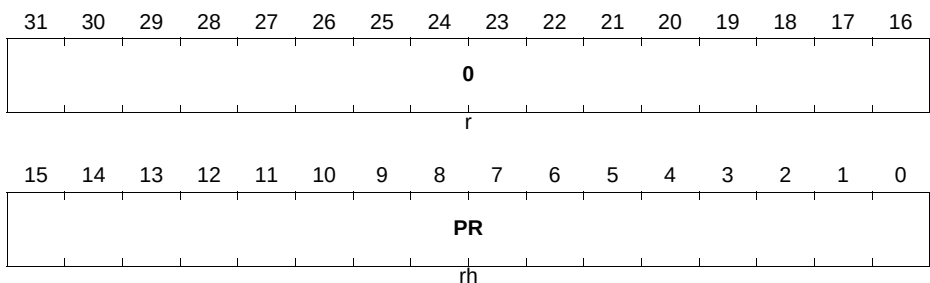
Field	Bits	Type	Description
PCMP	[3:0]	rw	Floating Prescaler Shadow Compare Value This field contains the value that is going to be set on the CC4yFPC .PCMP within the next shadow transfer. See Table 19-7 .
0	[31:4]	r	Reserved Read always returns 0.

CC4yPR

This register contains the actual value for the timer period.

CC4yPR (y = 0 - 3)

Timer Period Value ($0130_H + 0100_H * y$) **Reset Value: 00000000_H**



Capture/Compare Unit 4 (CCU4)

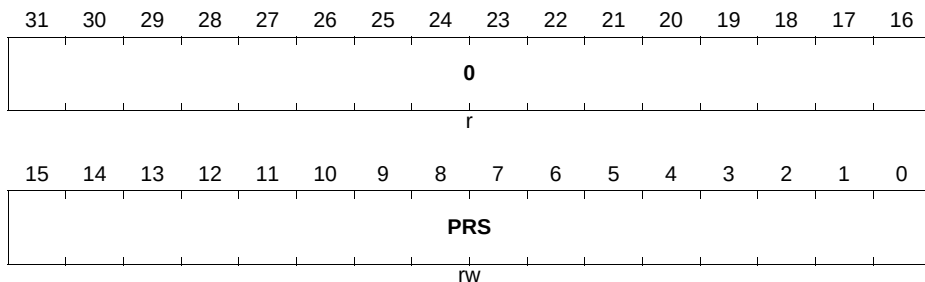
Field	Bits	Type	Description
PR	[15:0]	rh	Period Register Contains the value of the timer period. <i>Note: In Capture Mode when a external signal is selected for capturing the timer value into the capture registers 2 and 3, PR is not accessible for writing. A read always returns 0.</i>
0	[31:16]	r	Reserved A read always returns 0.

CC4yPRS

This register contains the value for the timer period that is going to be transferred into the **CC4yPR.PR** field when the next shadow transfer occurs.

CC4yPRS (y = 0 - 3)

Timer Shadow Period Value $(0134_H + 0100_H * y)$ Reset Value: 00000000_H



Field	Bits	Type	Description
PRS	[15:0]	rw	Period Register Contains the value of the timer period, that is going to be passed into the CC4yPR.PR field when the next shadow transfer occurs. <i>Note: In Capture Mode when a external signal is selected for capturing the timer value into the capture registers 2 and 3, the PRS is not accessible for writing. A read always returns 0.</i>

Capture/Compare Unit 4 (CCU4)

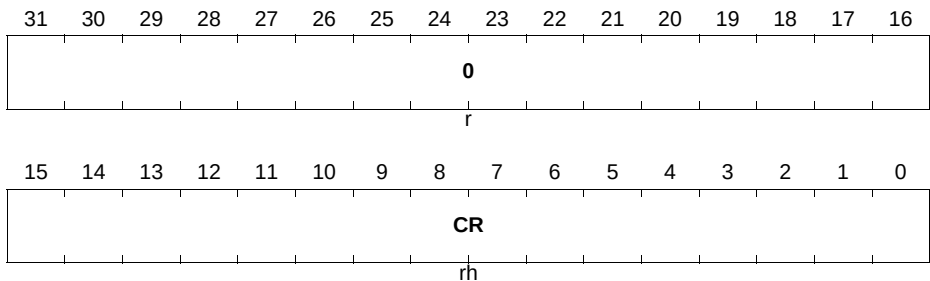
Field	Bits	Type	Description
0	[31:16]	r	Reserved A read always returns 0.

CC4yCR

This register contains the value for the timer comparison.

CC4yCR (y = 0 - 3)

Timer Compare Value (0138_H + 0100_H * y) **Reset Value: 00000000_H**



Field	Bits	Type	Description
CR	[15:0]	rh	Compare Register Contains the value for the timer comparison. <i>Note: In Capture Mode when a external signal is selected for capturing the timer value into the capture registers 0 and 1, a read always returns 0.</i>
0	[31:16]	r	Reserved A read always returns 0.

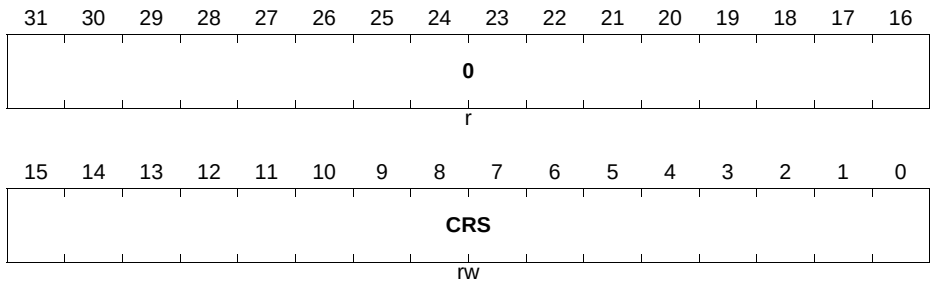
CC4yCRS

This register contains the value that is going to be loaded into the **CC4yCR.CR** field when the next shadow transfer occurs.

Capture/Compare Unit 4 (CCU4)

CC4yCRS (y = 0 - 3)

Timer Shadow Compare Value ($013C_H + 0100_H * y$) **Reset Value: 00000000_H**



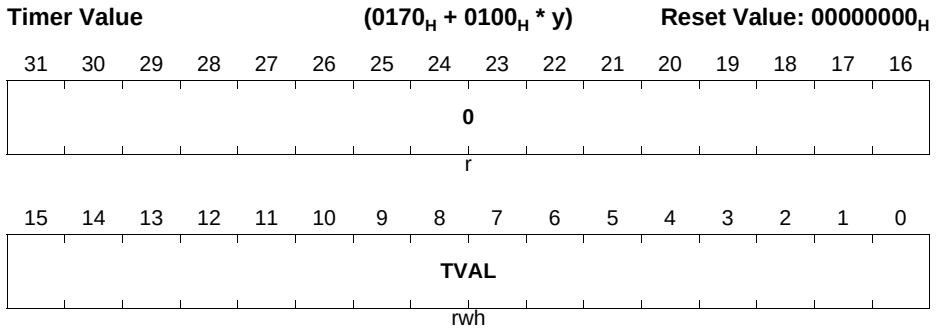
Field	Bits	Type	Description
CRS	[15:0]	rw	Compare Register Contains the value for the timer comparison, that is going to be passed into the CC4yCR.CR field when the next shadow transfer occurs. <i>Note: In Capture Mode when a external signal is selected for capturing the timer value into the capture registers 0 and 1, a read always returns 0.</i>
0	[31:16]	r	Reserved A read always returns 0.

CC4yTIMER

This register contains the current value of the timer.

Capture/Compare Unit 4 (CCU4)

CC4yTIMER (y = 0 - 3)

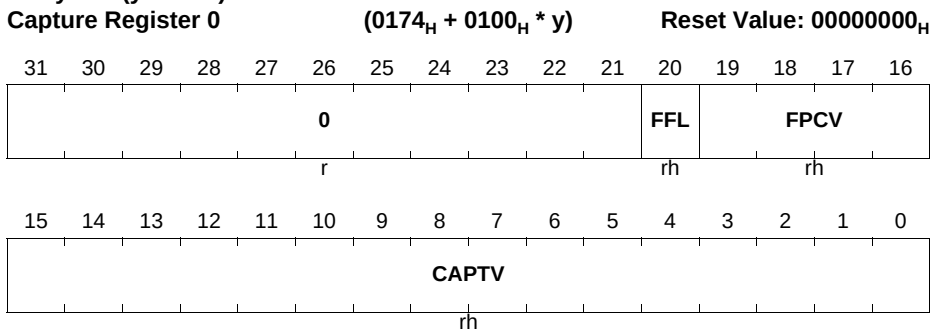


Field	Bits	Type	Description
TVAL	[15:0]	rwh	Timer Value This field contains the actual value of the timer. A write access is only possible when the timer is stopped.
0	[31:16]	r	Reserved A read access always returns 0

CC4yC0V

This register contains the values associated with the Capture 0 field.

CC4yC0V (y = 0 - 3)



Capture/Compare Unit 4 (CCU4)

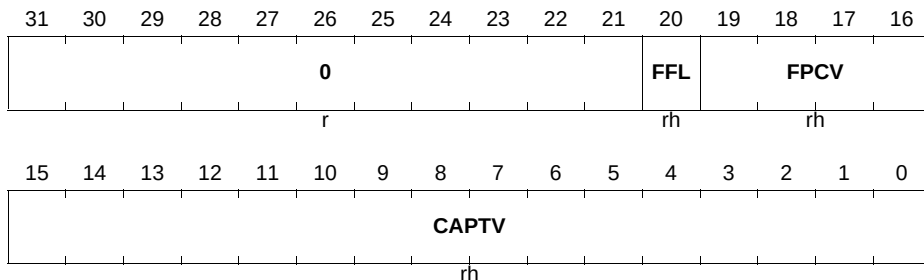
Field	Bits	Type	Description
CAPTV	[15:0]	rh	Capture Value This field contains the capture register 0 value. See Figure 19-26 . In compare mode a read access always returns 0.
FPCV	[19:16]	rh	Prescaler Value This field contains the prescaler value at the time of the capture event into the capture register 0. In compare mode a read access always returns 0.
FFL	20	rh	Full Flag This bit indicates if a new value was capture into the capture register 0 after the last read access. See Figure 19-26 . In compare mode a read access always returns 0. 0_B No new value was captured into the specific capture register 1_B A new value was captured into the specific register
0	[31:21]	r	Reserved A read always returns 0

CC4yC1V

This register contains the values associated with the Capture 1 field.

CC4yC1V (y = 0 - 3)

Capture Register 1 (0178_H + 0100_H * y) **Reset Value: 00000000_H**



Capture/Compare Unit 4 (CCU4)

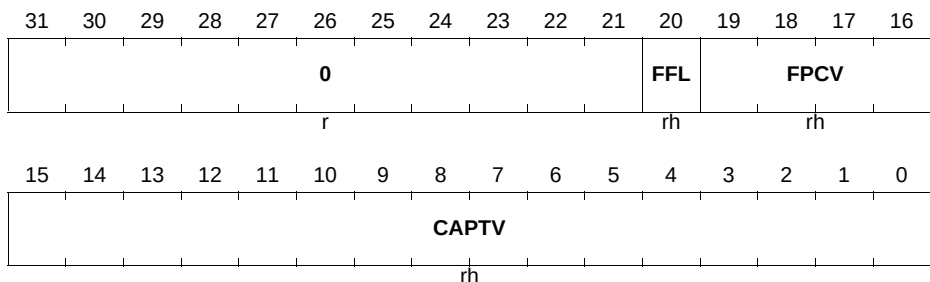
Field	Bits	Type	Description
CAPTV	[15:0]	rh	Capture Value This field contains the capture register 1 value. See Figure 19-26 . In compare mode a read access always returns 0.
FPCV	[19:16]	rh	Prescaler Value This field contains the prescaler value at the time of the capture event into the capture register 1. In compare mode a read access always returns 0.
FFL	20	rh	Full Flag This bit indicates if a new value was capture into the capture register 1 after the last read access. See Figure 19-26 . In compare mode a read access always returns 0. 0_B No new value was captured into the specific capture register 1_B A new value was captured into the specific register
0	[31:21]	r	Reserved A read always returns 0

CC4yC2V

This register contains the values associated with the Capture 2 field.

CC4yC2V (y = 0 - 3)

Capture Register 2 (017C_H + 0100_H * y) **Reset Value: 00000000_H**



Capture/Compare Unit 4 (CCU4)

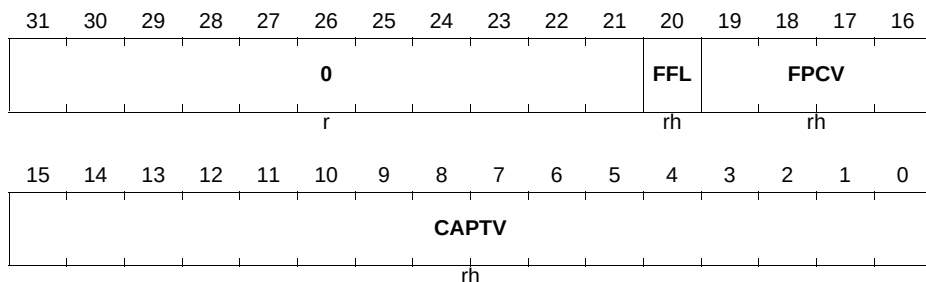
Field	Bits	Type	Description
CAPTV	[15:0]	rh	Capture Value This field contains the capture register 2 value. See Figure 19-26 . In compare mode a read access always returns 0.
FPCV	[19:16]	rh	Prescaler Value This field contains the prescaler value at the time of the capture event into the capture register 2. In compare mode a read access always returns 0.
FFL	20	rh	Full Flag This bit indicates if a new value was capture into the capture register 2 after the last read access. See Figure 19-26 . In compare mode a read access always returns 0. 0_B No new value was captured into the specific capture register 1_B A new value was captured into the specific register
0	[31:21]	r	Reserved A read always returns 0

CC4yC3V

This register contains the values associated with the Capture 3 field.

CC4yC3V (y = 0 - 3)

Capture Register 3 (0180_H + 0100_H * y) **Reset Value: 00000000_H**



Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
CAPTV	[15:0]	rh	Capture Value This field contains the capture register 3 value. See Figure 19-26 . In compare mode a read access always returns 0.
FPCV	[19:16]	rh	Prescaler Value This field contains the prescaler value at the time of the capture event into the capture register 3. In compare mode a read access always returns 0.
FFL	20	rh	Full Flag This bit indicates if a new value was capture into the capture register 3 after the last read access. See Figure 19-26 . In compare mode a read access always returns 0. 0 _B No new value was captured into the specific capture register 1 _B A new value was captured into the specific register
0	[31:21]	r	Reserved A read always returns 0

CC4yINTS

This register contains the status of all interrupt sources.

CC4yINTS (y = 0 - 3)

Interrupt Status (01A0_H + 0100_H * y) **Reset Value: 00000000_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				TRP	E2A	E1A	E0A	0				CMD	CMU	OMD	PMU
r				F	S	S	S	r				S	S	S	S
				rh	rh	rh	rh					rh	rh	rh	rh

Field	Bits	Type	Description
PMUS	0	rh	Period Match while Counting Up 0_B Period match while counting up not detected 1_B Period match while counting up detected
OMDS	1	rh	One Match while Counting Down 0_B One match while counting down not detected 1_B One match while counting down detected
CMUS	2	rh	Compare Match while Counting Up 0_B Compare match while counting up not detected 1_B Compare match while counting up detected
CMDS	3	rh	Compare Match while Counting Down 0_B Compare match while counting down not detected 1_B Compare match while counting down detected
E0AS	8	rh	Event 0 Detection Status Depending on the user selection on the CC4yINS.EV0EM , this bit can be set when a rising, falling or both transitions are detected. 0_B Event 0 not detected 1_B Event 0 detected
E1AS	9	rh	Event 1 Detection Status Depending on the user selection on the CC4yINS.EV1EM , this bit can be set when a rising, falling or both transitions are detected. 0_B Event 1 not detected 1_B Event 1 detected
E2AS	10	rh	Event 2 Detection Status Depending on the user selection on the CC4yINS.EV1EM , this bit can be set when a rising, falling or both transitions are detected. 0_B Event 2 not detected 1_B Event 2 detected <i>Note: If this event is linked with the TRAP function, this field is automatically cleared when the slice exits the Trap State.</i>
TRPF	11	rh	Trap Flag Status This field contains the status of the Trap Flag.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
0	[7:4], [31:12]	r	Reserved A read always returns 0.

CC4yINTE

Through this register it is possible to enable or disable the specific interrupt source(s).

CC4yINTE (y = 0 - 3)

Interrupt Enable Control (01A4_H + 0100_H * y) **Reset Value: 00000000_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					E2A E	E1A E	E0A E	0				CMD E	CMU E	OME	PME
r					rw	rw	rw	r				rw	rw	rw	rw

Field	Bits	Type	Description
PME	0	rw	Period match while counting up enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time a period match while counting up occurs. 0 _B Period Match interrupt is disabled 1 _B Period Match interrupt is enabled
OME	1	rw	One match while counting down enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time an one match while counting down occurs. 0 _B One Match interrupt is disabled 1 _B One Match interrupt is enabled

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
CMUE	2	rw	Compare match while counting up enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time a compare match while counting up occurs. 0 _B Compare Match while counting up interrupt is disabled 1 _B Compare Match while counting up interrupt is enabled
CMDE	3	rw	Compare match while counting down enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time a compare match while counting down occurs. 0 _B Compare Match while counting down interrupt is disabled 1 _B Compare Match while counting down interrupt is enabled
E0AE	8	rw	Event 0 interrupt enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time that Event 0 is detected. 0 _B Event 0 detection interrupt is disabled 1 _B Event 0 detection interrupt is enabled
E1AE	9	rw	Event 1 interrupt enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time that Event 1 is detected. 0 _B Event 1 detection interrupt is disabled 1 _B Event 1 detection interrupt is enabled
E2AE	10	rw	Event 2 interrupt enable Setting this bit to 1 _B enables the generation of an interrupt pulse every time that Event 2 is detected. 0 _B Event 2 detection interrupt is disabled 1 _B Event 2 detection interrupt is enabled
0	[7:4], [31:11]	r	Reserved A read always returns 0

CC4ySRS

Through this register it is possible to select to which service request line each interrupt source is forwarded.

Capture/Compare Unit 4 (CCU4)

CC4ySRS (y = 0 - 3)

Service Request Selector (01A8_H + 0100_H * y) **Reset Value: 00000000_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	E2SR		E1SR		E0SR		0				CMSR		POSR		
r	rw		rw		rw		r				rw		rw		

Field	Bits	Type	Description
POSR	[1:0]	rw	Period/One match Service request selector This field selects to which slice Service request line, the interrupt(s) generated by the Period match while counting up and One match while counting down are going to be forward. 00 _B Forward to CC4ySR0 01 _B Forward to CC4ySR1 10 _B Forward to CC4ySR2 11 _B Forward to CC4ySR3
CMSR	[3:2]	rw	Compare match Service request selector This field selects to which slice Service request line, the interrupt(s) generated by the Compare match while counting up and Compare match while counting down are going to be forward. 00 _B Forward to CC4ySR0 01 _B Forward to CC4ySR1 10 _B Forward to CC4ySR2 11 _B Forward to CC4ySR3
E0SR	[9:8]	rw	Event 0 Service request selector This field selects to which slice Service request line, the interrupt generated by the Event 0 detection is going to be forward. 00 _B Forward to CC4ySR0 01 _B Forward to CC4ySR1 10 _B Forward to CC4ySR2 11 _B Forward to CC4ySR3

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
E1SR	[11:10]	rw	Event 1 Service request selector This field selects to which slice Service request line, the interrupt generated by the Event 1 detection is going to be forward. 00 _B Forward to CC4ySR0 01 _B Forward to CC4ySR1 10 _B Forward to CC4ySR2 11 _B Forward to CC4ySR3
E2SR	[13:12]	rw	Event 2 Service request selector This field selects to which slice Service request line, the interrupt generated by the Event 2 detection is going to be forward. 00 _B Forward to CC4ySR0 01 _B Forward to CC4ySR1 10 _B Forward to CC4ySR2 11 _B Forward to CC4ySR3
0	[7:4], [31:14]	r	Reserved Read always returns 0.

CC4ySWS

Through this register it is possible for the SW to set a specific interrupt status flag.

CC4ySWS (y = 0 - 3)

Interrupt Status Set (01AC_H + 0100_H * y) **Reset Value: 00000000_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				STR PF	SE2 A	SE1 A	SE0 A	0				SCM D	SCM U	SOM	SPM
r				w	w	w	w	r				w	w	w	w

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
SPM	0	w	Period match while counting up set Writing a 1 _B into this field sets the CC4yINTS .PMUS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SOM	1	w	One match while counting down set Writing a 1 _B into this bit sets the CC4yINTS .OMDS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SCMU	2	w	Compare match while counting up set Writing a 1 _B into this field sets the CC4yINTS .CMUS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SCMD	3	w	Compare match while counting down set Writing a 1 _B into this bit sets the CC4yINTS .CMDS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SE0A	8	w	Event 0 detection set Writing a 1 _B into this bit sets the CC4yINTS .E0AS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SE1A	9	w	Event 1 detection set Writing a 1 _B into this bit sets the CC4yINTS .E1AS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
SE2A	10	w	Event 2 detection set Writing a 1 _B into this bit sets the CC4yINTS .E2AS bit. An interrupt pulse is generated if the source is enabled. A read always returns 0.
STRPF	11	w	Trap Flag status set Writing a 1 _B into this bit sets the CC4yINTS .TRPF bit. A read always returns 0.
0	[7:4], [31:12]	r	Reserved Read always returns 0

CC4ySWR

Through this register it is possible for the SW to clear a specific interrupt status flag.

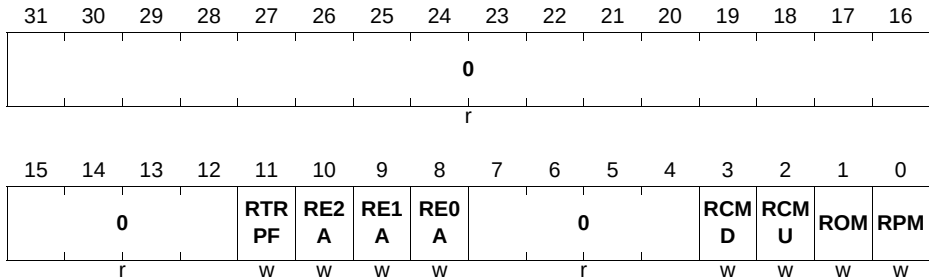
Capture/Compare Unit 4 (CCU4)

CC4ySWR (y = 0 - 3)

Interrupt Status Clear

(01B0_H + 0100_H * y)

Reset Value: 00000000_H



Field	Bits	Type	Description
RPM	0	w	Period match while counting up clear Writing a 1 _B into this field clears the CC4yINTS .PMUS bit. A read always returns 0.
ROM	1	w	One match while counting down clear Writing a 1 _B into this bit clears the CC4yINTS .OMDS bit. A read always returns 0.
RCMU	2	w	Compare match while counting up clear Writing a 1 _B into this field clears the CC4yINTS .CMUS bit. A read always returns 0.
RCMD	3	w	Compare match while counting down clear Writing a 1 _B into this bit clears the CC4yINTS .CMDS bit. A read always returns 0.
RE0A	8	w	Event 0 detection clear Writing a 1 _B into this bit clears the CC4yINTS .E0AS bit. A read always returns 0.
RE1A	9	w	Event 1 detection clear Writing a 1 _B into this bit clears the CC4yINTS .E1AS bit. A read always returns 0.
RE2A	10	w	Event 2 detection clear Writing a 1 _B into this bit clears the CC4yINTS .E2AS bit. A read always returns 0.

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
RTRPF	11	w	Trap Flag status clear Writing a 1 _B into this bit clears the CC4yINTS .TRPF bit. Not valid if CC4yTC .TRPEN = 1 _B and the Trap State is still active. A read always returns 0.
0	[7:4], [31:12]	r	Reserved Read always returns 0

CC4yECRD0

Through this register it is possible to read back the FIFO structure of the capture function that is linked with the capture trigger 0. The read back is only valid if the **CC4yTC**.ECM = 1_B.

CC4yECRD0 (y = 0 - 3)

Extended Read Back 0 (01B8_H + 0100_H * y) **Reset Value: 00000000_H**

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

Field	Bits	Type	Description
CAPV	[15:0]	rh	Timer Capture Value This field contains the timer captured value
FPCV	[19:16]	rh	Prescaler Capture value This field contains the value of the prescaler clock division associated with the specific CAPV field

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
SPTR	[21:20]	rh	Slice pointer This field indicates the slice index in which the value was captured. 00 _B CC40 01 _B CC41 10 _B CC42 11 _B CC43
VPTR	[23:22]	rh	Capture register pointer This field indicates the capture register index in which the value was captured. 00 _B Capture register 0 01 _B Capture register 1 10 _B Capture register 2 11 _B Capture register 3
FFL	24	rh	Full Flag This bit indicates if the associated capture register contains a new value. 0 _B No new value was captured into this register 1 _B A new value has been captured into this register
LCV	25	rh	Lost Capture Value This field indicates if between two reads of the ECRD0 a capture trigger occurred while the FIFO structure was full. If a capture trigger occurred between two reads than a capture value was lost. This field is automatically cleared by the HW whenever a read to the ECRD occurs. 0 _B No capture was lost 1 _B A capture was lost
0	[31:26]	r	Reserved Read always returns 0

CC4yECRD1

Through this register it is possible to read back the FIFO structure of the capture function that is linked with the capture trigger 1. The read back is only valid if the **CC4yTC.ECM** = 1_B.

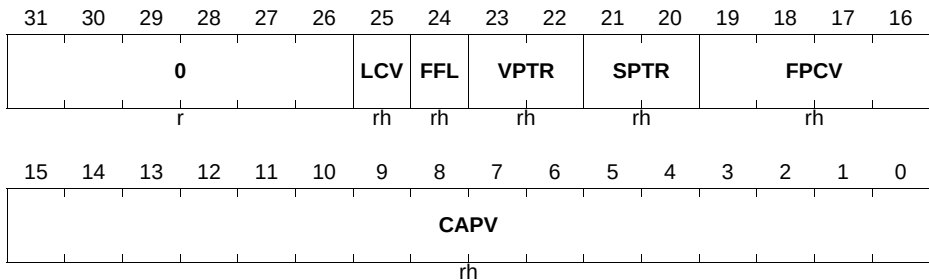
Capture/Compare Unit 4 (CCU4)

CC4yECDR1 (y = 0 - 3)

Extended Read Back 1

(01BC_H + 0100_H * y)

Reset Value: 00000000_H



Field	Bits	Type	Description
CAPV	[15:0]	rh	Timer Capture Value This field contains the timer captured value
FPCV	[19:16]	rh	Prescaler Capture value This field contains the value of the prescaler clock division associated with the specific CAPV field
SPTR	[21:20]	rh	Slice pointer This field indicates the slice index in which the value was captured. 00 _B CC40 01 _B CC41 10 _B CC42 11 _B CC43
VPTR	[23:22]	rh	Capture register pointer This field indicates the capture register index in which the value was captured. 00 _B Capture register 0 01 _B Capture register 1 10 _B Capture register 2 11 _B Capture register 3
FFL	24	rh	Full Flag This bit indicates if the associated capture register contains a new value. 0 _B No new value was captured into this register 1 _B A new value has been captured into this register

Capture/Compare Unit 4 (CCU4)

Field	Bits	Type	Description
LCV	25	rh	Lost Capture Value This field indicates if between two reads of the ECRD0 a capture trigger occurred while the FIFO structure was full. If a capture trigger occurred between two reads than a capture value was lost. This field is automatically cleared by the HW whenever a read to the ECRD occurs. 0 _B No capture was lost 1 _B A capture was lost
0	[31:26]	r	Reserved Read always returns 0

19.8 Interconnects

The tables that refer to the “global pins” are the ones that contain the inputs/outputs of each module that are common to all slices.

The GPIO connections are available at the Ports chapter.

19.8.1 CCU40 pins

Table 19-13 CCU40 Pin Connections

Global Inputs/Outputs	I/O	Connected To	Description
CCU40.MCLK	I	PCLK	Kernel clock
CCU40.CLKA	I	not connected	another count source for the prescaler
CCU40.CLKB	I	ERU0.IOUT0	another count source for the prescaler
CCU40.CLKC	I	ERU0.IOUT1	another count source for the prescaler
CCU40.MCSS	I	reserved	Multi pattern sync with shadow transfer trigger
CCU40.SR0	O	NVIC; ERU0.OGU01;	Service request line
CCU40.SR1	O	NVIC; ERU0.OGU11;	Service request line

Table 19-13 CCU40 Pin Connections (cont'd)

Global Inputs/Outputs	I/O	Connected To	Description
CCU40.SR2	O	NVIC; VADC0.BGREQTRA; VADC0.G0REQTRA; VADC0.G1REQTRA; ERU0.OGU21;	Service request line
CCU40.SR3	O	NVIC; VADC0.BGREQTRB; VADC0.G0REQTRB; VADC0.G1REQTRB; ERU0.OGU31;	Service request line

Table 19-14 CCU40 - CC40 Pin Connections

Input/Output	I/O	Connected To	Description
CCU40.IN0A	I	P0.12	General purpose function
CCU40.IN0B	I	P0.6	General purpose function
CCU40.IN0C	I	P0.0	General purpose function
CCU40.IN0D	I	ERU0.PDOUT1	General purpose function
CCU40.IN0E	I	reserved	General purpose function
CCU40.IN0F	I	reserved	General purpose function
CCU40.IN0G	I	reserved	General purpose function
CCU40.IN0H	I	reserved	General purpose function
CCU40.IN0I	I	SCU.GSC40	General purpose function
CCU40.IN0J	I	ERU0.PDOUT0	General purpose function
CCU40.IN0K	I	ERU0.IOUT0	General purpose function
CCU40.IN0L	I	USIC0_CH0.DX2INS	General purpose function
CCU40.IN0M	I	CCU40.GP10	General purpose function
CCU40.IN0N	I	CCU40.ST1	General purpose function
CCU40.IN0O	I	CCU40.ST2	General purpose function
CCU40.IN0P	I	CCU40.ST3	General purpose function
CCU40.MCI0	I	BCCU0.OUT2	Multi Channel pattern input

Capture/Compare Unit 4 (CCU4)

Table 19-14 CCU40 - CC40 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
CCU40.OUT0	O	P0.0; P0.5; P0.6; P1.0; P2.0; P2.0.HW1 direction control	Slice compare output
CCU40.GP00	O	CCU40.IN3M	Selected signal for event 0
CCU40.GP01	O	not connected	Selected signal for event 1
CCU40.GP02	O	reserved	Selected signal for event 2
CCU40.ST0	O	CCU40.IN1N; CCU40.IN2N; CCU40.IN3N; VADC0.BGREQGTD; VADC0.G0REQGTD; VADC0.G1REQGTD;	Slice status bit
CCU40.PS0	O	not connected	Multi channel pattern sync trigger: PM when counting UP (edge aligned) or OM when counting DOWN (center aligned)

Table 19-15 CCU40 - CC41 Pin Connections

Input/Output	I/O	Connected To	Description
CCU40.IN1A	I	P0.12	General purpose function
CCU40.IN1B	I	P0.7	General purpose function
CCU40.IN1C	I	P0.1	General purpose function
CCU40.IN1D	I	ERU0.PDOUT0	General purpose function
CCU40.IN1E	I	reserved	General purpose function
CCU40.IN1F	I	reserved	General purpose function
CCU40.IN1G	I	reserved	General purpose function
CCU40.IN1H	I	reserved	General purpose function
CCU40.IN1I	I	SCU.GSC40	General purpose function
CCU40.IN1J	I	ERU0.PDOUT1	General purpose function
CCU40.IN1K	I	ERU0.IOUT1	General purpose function

Capture/Compare Unit 4 (CCU4)
Table 19-15 CCU40 - CC41 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
CCU40.IN1L	I	USIC0_CH1.DX2INS	General purpose function
CCU40.IN1M	I	CCU40.GP20	General purpose function
CCU40.IN1N	I	CCU40.ST0	General purpose function
CCU40.IN1O	I	CCU40.ST2	General purpose function
CCU40.IN1P	I	CCU40.ST3	General purpose function
CCU40.MC11	I	BCCU0.OUT3	Multi Channel pattern input
CCU40.OUT1	O	P0.1; P0.4; P0.7; P1.1; P2.1; P2.1.HW1 direction control	Slice compare output
CCU40.GP10	O	CCU40.IN0M	Selected signal for event 0
CCU40.GP11	O	not connected	Selected signal for event 1
CCU40.GP12	O	reserved	Selected signal for event 2
CCU40.ST1	O	CCU40.IN0N; CCU40.IN2O; CCU40.IN3O; VADC0.BGREQGTC; VADC0.G0REQGTC; VADC0.G1REQGTC;	Slice status bit
CCU40.PS1	O	reserved	Multi channel pattern sync trigger: PM when counting UP (edge aligned) or OM when counting DOWN (center aligned)

Table 19-16 CCU40 - CC42 Pin Connections

Input/Output	I/O	Connected To	Description
CCU40.IN2A	I	P0.12	General purpose function
CCU40.IN2B	I	P0.8	General purpose function
CCU40.IN2C	I	P0.2	General purpose function
CCU40.IN2D	I	ERU0.PDOUT3	General purpose function
CCU40.IN2E	I	reserved	General purpose function

Capture/Compare Unit 4 (CCU4)
Table 19-16 CCU40 - CC42 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
CCU40.IN2F	I	reserved	General purpose function
CCU40.IN2G	I	reserved	General purpose function
CCU40.IN2H	I	reserved	General purpose function
CCU40.IN2I	I	SCU.GSC40	General purpose function
CCU40.IN2J	I	ERU0.PDOUT2	General purpose function
CCU40.IN2K	I	ERU0.IOOUT2	General purpose function
CCU40.IN2L	I	LEDS0.SR0	General purpose function
CCU40.IN2M	I	CCU40.GP30	General purpose function
CCU40.IN2N	I	CCU40.ST0	General purpose function
CCU40.IN2O	I	CCU40.ST1	General purpose function
CCU40.IN2P	I	CCU40.ST3	General purpose function
CCU40.MCI2	I	BCCU0.OUT4	Multi Channel pattern input
CCU40.OUT2	O	P0.2; P0.8; P1.2; P2.10; P2.8.HW1 pull control P2.9.HW1 pull control P2.10.HW1 direction control	Slice compare output
CCU40.GP20	O	CCU40.IN1M	Selected signal for event 0
CCU40.GP21	O	not connected	Selected signal for event 1
CCU40.GP22	O	reserved	Selected signal for event 2
CCU40.ST2	O	CCU40.IN0O; CCU40.IN1O; CCU40.IN3P; VADC0.BGREQGTB; VADC0.G0REQGTB; VADC0.G1REQGTB;	Slice status bit
CCU40.PS0	O	not connected	Multi channel pattern sync trigger: PM when counting UP (edge aligned) or OM when counting DOWN (center aligned)

Table 19-17 CCU40 - CC43 Pin Connections

Input/Output	I/O	Connected To	Description
CCU40.IN3A	I	P0.12	General purpose function
CCU40.IN3B	I	P0.9	General purpose function
CCU40.IN3C	I	P0.3	General purpose function
CCU40.IN3D	I	ERU0.PDOUT2	General purpose function
CCU40.IN3E	I	reserved	General purpose function
CCU40.IN3F	I	reserved	General purpose function
CCU40.IN3G	I	VADC0.G0ARBCNT	General purpose function
CCU40.IN3H	I	reserved	General purpose function
CCU40.IN3I	I	SCU.GSC40	General purpose function
CCU40.IN3J	I	ERU0.PDOUT3	General purpose function
CCU40.IN3K	I	ERU0.IOUT3	General purpose function
CCU40.IN3L	I	LEDTS1.SR0	General purpose function
CCU40.IN3M	I	CCU40.GP00	General purpose function
CCU40.IN3N	I	CCU40.ST0	General purpose function
CCU40.IN3O	I	CCU40.ST1	General purpose function
CCU40.IN3P	I	CCU40.ST2	General purpose function
CCU40.MCI3	I	BCCU0.OUT5	Multi Channel pattern input
CCU40.OUT3	O	P0.3; P0.9; P1.3; P2.11; P2.2.HW1 pull control P2.6.HW1 pull control P2.7.HW1 pull control P2.11.HW1 direction control	Slice compare output
CCU40.GP30	O	CCU40.IN2M	Selected signal for event 0
CCU40.GP31	O	not connected	Selected signal for event 1
CCU40.GP32	O	reserved	Selected signal for event 2

Capture/Compare Unit 4 (CCU4)

Table 19-17 CCU40 - CC43 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
CCU40.ST3	O	CCU40.IN0P; CCU40.IN1P; CCU40.IN2P; VADC0.BGREQGTA; VADC0.G0REQGTA; VADC0.G1REQGTA;	Slice status bit
CCU40.PS3	O	not connected	Multi channel pattern sync trigger: PM when counting UP (edge aligned) or OM when counting DOWN (center aligned)

20 Brightness and Color Control Unit (BCCU)

The BCCU is a dimming control peripheral for LED lighting applications that is capable of controlling multiple LED channels. A one-bit sigma-delta bit stream is provided for every channel that determines the brightness. The brightness can be changed gradually along an exponential curve to appear natural to the human eye by using dedicated dimming engines. The module supports color control by adjusting the relative intensity of selected channels using a linear walk scheme for smooth color changes, and it also supports high-power multi-channel LED lamps by optionally “packing” the bitstream to provide a defined ON-time at the output.

20.1 Overview

The BCCU in XMC1200 contains 3 identical dimming engines and 9 identical channels. Each channel can generate a one-bit flexible sigma-delta bit stream with a user-adjustable 12-bit average value. This average value can be provided manually or by any of the exponential dimming engines. The bit stream is generated by a 12-bit sigma-delta modulator, and an optional packer which decreases the average rate of output switching by enforcing a defined on-time. Although the primary target application is multi-channel LED dimming with special support for color control, the module can also be used as a multi-channel digital-analog converter with low-pass filters on the outputs.

20.1.1 Features

The BCCU provides the following functionality:

- 3 independent dimming engines
- 12-bit dimming levels
- Dimming along an exponential curve with adjustable dimming time
- 9 independent channels generating a 1-bit on-off signal each
- 12-bit channel intensities to define color
- Channels and dimming engines can be freely interconnected
- One input multiplier and one 12-bit sigma-delta modulator in every channel
- One bit-packer in every channel to decrease the average rate of output switching
- TRAP function
- Two ADC triggering modes

20.2 Functional Description

Each channel can operate independently from the others and can be freely interconnected with any one of the dimming engines. Triggering and TRAP control are globally handled for all channels.

Brightness and Color Control Unit (BCCU)

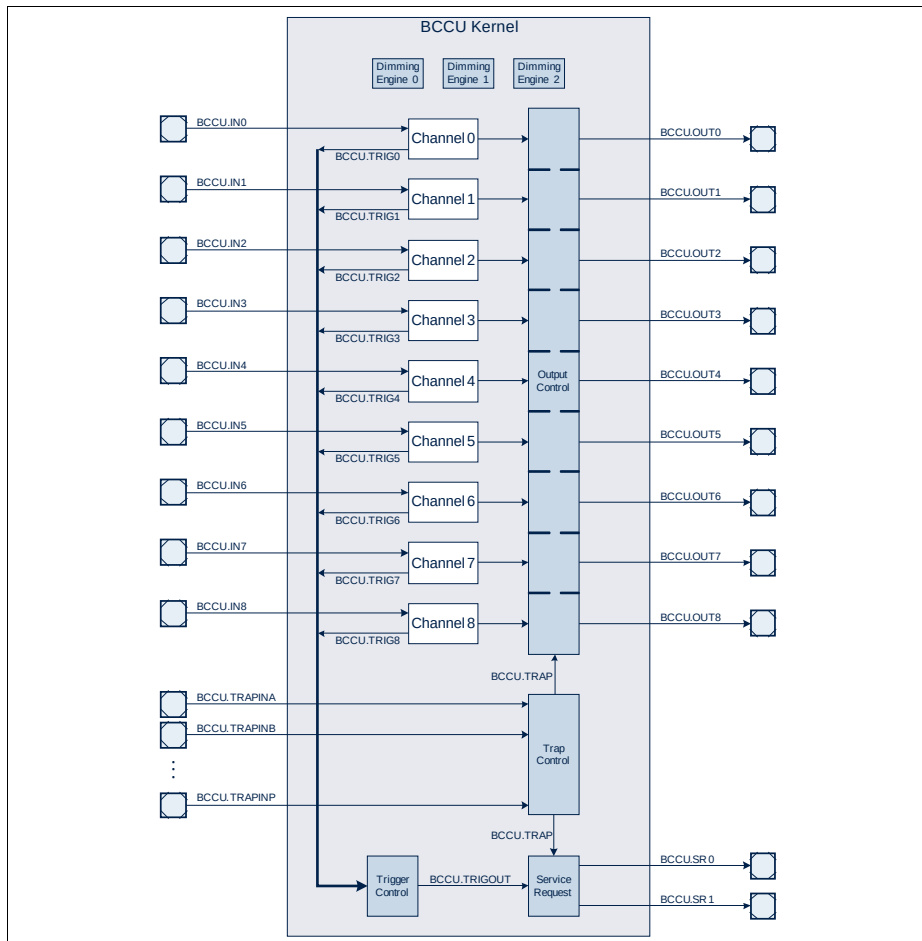


Figure 20-1 BCCU Kernel Block Diagram

Every dimming engine generates a 12-bit dimming level which can be routed to the input of any channel. Optionally a manually controllable 12-bit "Global Dimming Level" (BCCU_GLOBDIM.GLOBDIM) is also routable to the channels instead.

20.2.1 Channel Structure

Every active channel has a 12-bit intensity level (BCCU_INTy (y=0-8).CHINT). The brightness level (same as the average level of the output bit stream) is the product of the dimming level and the intensity level.

Brightness and Color Control Unit (BCCU)

Generally in multi-channel solutions, the intensity level is expected to determine the color and the dimming level is expected to be used for changes in overall brightness. E.g. in case of an RGB LED, 3 channels can be used; the individual intensity levels determine the color and a common dimming level (e.g. coming from one of the dimming engines) determines the overall brightness.

The 12-bit brightness level is the input to the sigma-delta modulator where it is converted into a fast changing 1-bit signal with the same average value. The average rate of switching of this signal is optionally decreased by a packer which generates a signal with fixed on-time or fixed off-time. This signal still has the same average value.

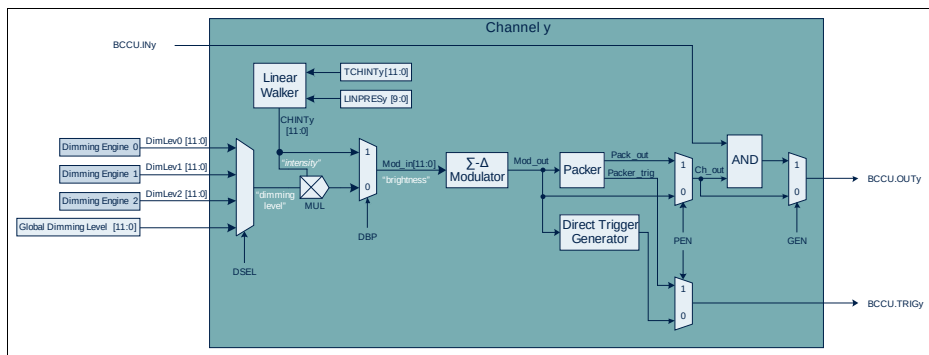


Figure 20-2 Channel Block Diagram

BCCU.INy is an asynchronous gating signal which can be used if BCCU_ **CHCONFIGY** (y=0-8).GEN is set. The gating connection is made of combinatorial logic only to enable fast control schemes, such as peak-current control.

If the packer is disabled, the trigger signal for the ADC is directly generated from the output of the sigma-delta modulator in the Trigger Generator block. The trigger pulse is generated on rising edge (transition from passive to active or passive to active or active to active state) if BCCU_ **CHCONFIGY** (y=0-8).TRED is 0 and on falling edge (transition from passive to active or passive to passive or active to active state) if BCCU_ **CHCONFIGY** (y=0-8).TRED is 1. If BCCU_ **CHCONFIGY** (y=0-8).ENFT is 1, forced trigger generation is enabled. A forced trigger is generated if the output signal (Mod_out) hasn't changed state for a long time (256 bit times for rising edge triggering, 257 bit times for falling edge triggering).

20.2.2 Exponential Dimming

The BCCU contains 3 dimming engines that are routable to all 9 channels. The dimming engine is capable of gradually changing the brightness level in order for the human eye to comfortably adapt to changes in light intensity. Since the human eye perceives light with logarithmic sensitivity, the gradual change of brightness is performed along a

Brightness and Color Control Unit (BCCU)

pseudo-exponential curve. The user has to set the target dimming level (BCCU_**DLSz** (**z=0-2**).TDLEV) and initiate the shadow transfer (by setting BCCU_**DESTRCON**.DEzS). The dimming level (BCCU_**DLz** (**z=0-2**).DIMLEV) is a time-varying signal. After shadow transfer, it will gradually reach the target dimming level along the pseudo-exponential curve. When the target is reached after the configured dimming period, BCCU_**DESTRCON**.DEzS is cleared by hardware. It is recommended to check BCCU_**DESTRCON**.DEzS before starting a new dimming process.

The dimming process can be aborted anytime by setting BCCU_**DESTRCON**.DEzA, which is recommended before starting a new dimming process if the actual one hasn't finished yet. This will also clear BCCU_**DESTRCON**.DEzS.

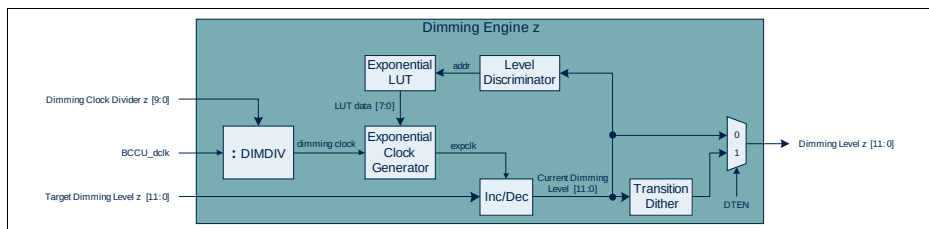


Figure 20-3 Dimming Engine Block Diagram

Above the level of 16, the ideal exponential dimming curve is described as:

$$\text{DimmingLevel} = 2^{\frac{\text{DimmingClocks} + 4096}{2048}} \quad (20.1)$$

The actual dimming curve approximates the ideal by combining straight lines forming a piecewise pseudo-exponential curve.

The module provides two curves to choose from, a coarse curve and a fine curve. The desired curve can be selected by BCCU_**DTTz** (**z=0-2**).CSEL. The difference is in the number of straight lines used to approximate the ideal exponential curve. Switching between the curves in the application is not supported.

As the dimming level increases along the coarse curve, the slope of the linear pieces doubles every time it passes one of the thresholds of 16, 32, 64, 128, 256, 512, 1024 or 2048.

Table 20-1 Coarse Piece-Wise Pseudo-Exponential Curve

Upper dimming threshold	Slope of the linear piece	Number of dimming clocks along the line
16	1/256	4096
32	1/128	2048
64	1/64	2048

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Table 20-1 Coarse Piece-Wise Pseudo-Exponential Curve

Upper dimming threshold	Slope of the linear piece	Number of dimming clocks along the line
128	$1/32$	2048
256	$1/16$	2048
512	$1/8$	2048
1024	$1/4$	2048
2048	$1/2$	2048
4095	1	2047

Brightness and Color Control Unit (BCCU)

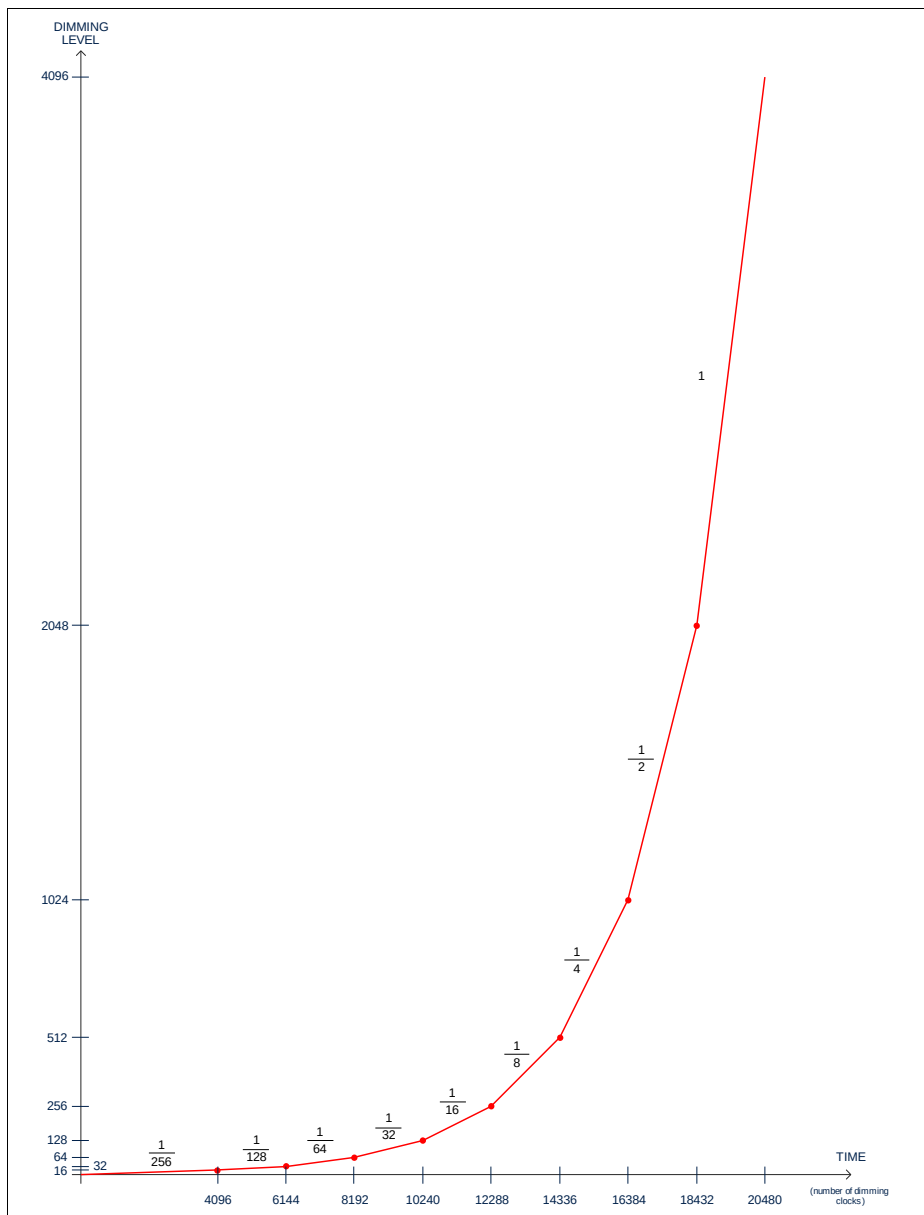


Figure 20-4 Coarse Piecewise pseudo-exponential curve

Brightness and Color Control Unit (BCCU)

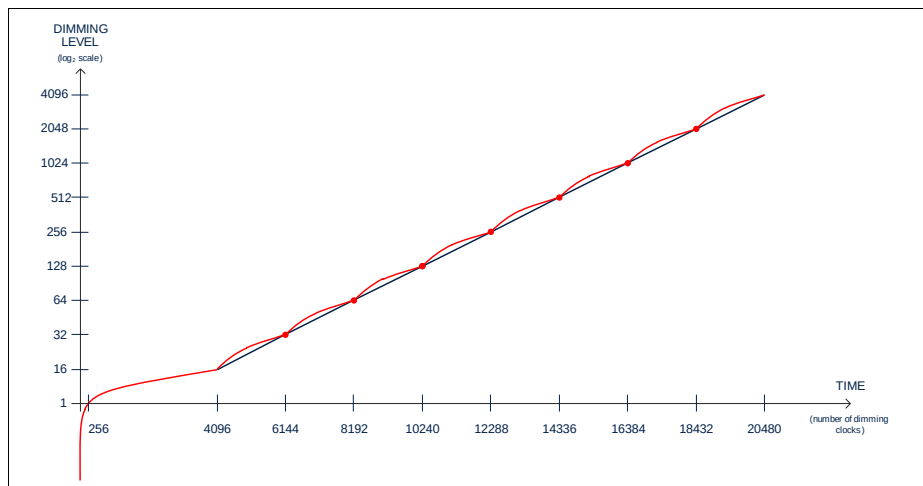


Figure 20-5 Coarse Piecewise pseudo-exponential curve with the dimming level on a logarithmic scale as the human eye sees it (real and ideal)

This piecewise pseudo-exponential curve is quantized into 4095 steps. When BCCU_ **DESTCON.DEzS** is set, the first step is immediately taken towards the target and at every dimming level, the dimming engine waits for a certain amount of dimming clocks ("waiting time") before taking the next step. This waiting time determines the slope of the linear piece. Once the target level has been reached and the appropriate amount of clocks have elapsed, BCCU_ **DESTCON.DEzS** is cleared by hardware signalling the end of the dimming process. Dimming up from 0 to 4095 takes 20479 dimming clocks (not counting synchronization and bus communication delays).

Table 20-2 Quantized CoarsePiece-Wise Pseudo-Exponential Curve

Dimming Levels	Clocks before the next step ("waiting time")	Slope of the linear piece
0..16	256	1/256
17..32	128	1/128
33..64	64	1/64
65..128	32	1/32
129..256	16	1/16
257..512	8	1/8
513..1024	4	1/4

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Table 20-2 Quantized CoarsePiece-Wise Pseudo-Exponential Curve

Dimming Levels	Clocks before the next step ("waiting time")	Slope of the linear piece
1025..2048	2	1/2
2049..	1	1

For example dimming from 0 to 18 along the coarse curve takes 4352 clocks ($16 \cdot 256$ clocks + $2 \cdot 128$ clocks) when measured as the time between setting and clearing BCCU_DESTRCON.DEzS (ignoring delays).

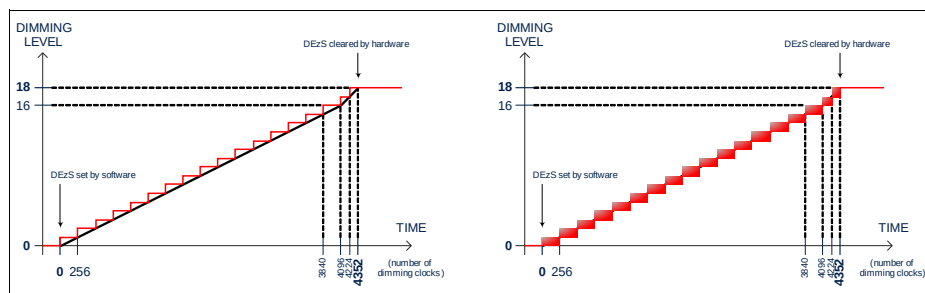


Figure 20-6 Dimming from 0 to 18 along the coarse curve without and with dither enabled

Exponential clock generation is the same regardless of the direction of the dimming so the waiting time before the next step is the same at a given dimming level whether the next step is an increment or a decrement. Because of this, dimming down takes longer than dimming up with the same settings. The extra time is equivalent to the waiting time of the target level minus the waiting time of the starting level. Dimming down from 4095 to 0 takes 20734 clocks ($20479 + 256 - 1$). Dimming down from 18 to 0 along the coarse curve takes 4480 clocks ($4352 + 256 - 128$).

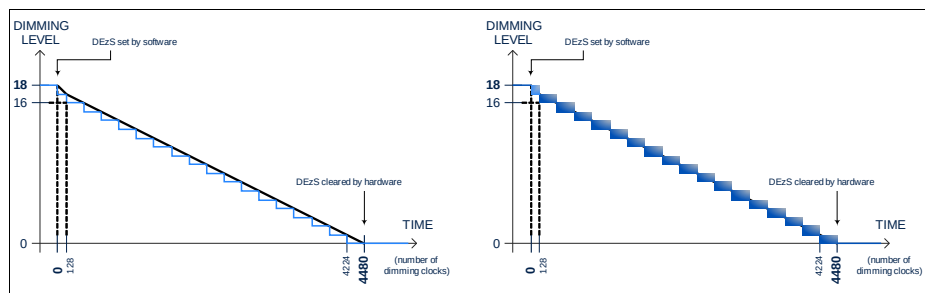


Figure 20-7 Dimming from 18 to 0 along the coarse curve without and with dither

Brightness and Color Control Unit (BCCU)

enabled

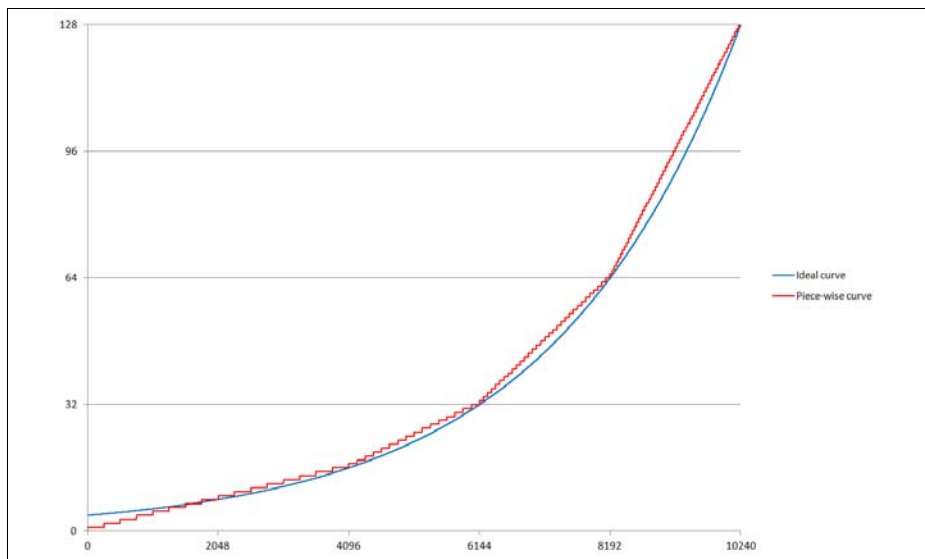


Figure 20-8 Lower section of the coarse curve (real and ideal)

The fine curve is similar to the coarse one but it has more pieces and different line slopes.

Table 20-3 Fine Piece-Wise Pseudo-Exponential Curve

Upper dimming threshold	Slope of the linear piece	Number of dimming clocks along the line
16	1/256	4096
18	1/196	392
25	1/132	924
34	1/102	918
41	1/81	567
48	1/64	448
69	1/51	1071
79	1/40	400
107	1/32	896
130	1/25	575

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Table 20-3 Fine Piece-Wise Pseudo-Exponential Curve

Upper dimming threshold	Slope of the linear piece	Number of dimming clocks along the line
167	1/20	740
203	1/16	576
253	1/13	650
343	1/10	900
512	1/7	1183
1024	1/4	2048
2048	1/2	2048
4095	1	2047

Table 20-4 Fine Piece-Wise Pseudo-Exponential Curve

Dimming Levels	Clocks before the next step ("waiting time")	Slope of the linear piece
0..16	256	1/256
17..18	196	1/196
19..25	132	1/132
26..34	102	1/102
35..41	81	1/81
42..48	64	1/64
49..69	51	1/51
70..79	40	1/40
80..107	32	1/32
108..130	25	1/25
131..167	20	1/20
168..203	16	1/16
204..253	13	1/13
254..343	10	1/10
334..512	7	1/7
513..1024	4	1/4
1025..2048	2	1/2
2049..4095	1	1

Brightness and Color Control Unit (BCCU)

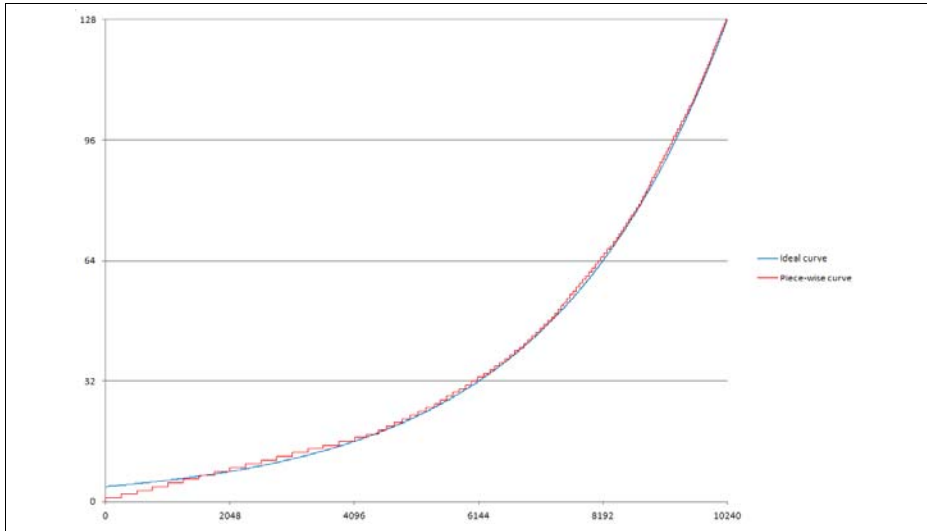


Figure 20-9 Lower section of the fine curve (real and ideal)

Dimming along the entire dimming curve takes 20479 dimming clocks when dimming up and 20734 clocks when dimming down. The fade time from 0 to 4095 (0% to 100%) is adjustable through the "dimming clock divider" bitfield (BCCU_ **DTTz (z=0-2)**.DIMDIV):

$$\text{FadeTime}_{0-100} = \frac{20479}{\left(\frac{f_{\text{BCCUclk}}}{\text{DCLKPS} \times \text{DIMDIV}}\right)} = \frac{20479}{\left(\frac{f_{\text{BCCUdclk}}}{\text{DIMDIV}}\right)} \quad (20.2)$$

$$\text{FadeTime}_{100-0} = \frac{20734}{\left(\frac{f_{\text{BCCUclk}}}{\text{DCLKPS} \times \text{DIMDIV}}\right)} = \frac{20734}{\left(\frac{f_{\text{BCCUdclk}}}{\text{DIMDIV}}\right)} \quad (20.3)$$

If BCCU_ **DTTz (z=0-2)**.DIMDIV is 0, the dimming level will instantly be the same as the target dimming level on shadow transfer, which means that the dimming engine is effectively bypassed.

At dimming levels below 128, where the human eye is potentially very sensitive to changes in brightness, the dimming steps can be dithered to avoid visible discrete steps in brightness. This function can be enabled by setting BCCU_ **DTTz (z=0-2)**.DTEN. Only the coarse curve can be used with dithering. Every time the dimming level (BCCU_ **DLz (z=0-2)**.DLEV) is supposed to increase or decrease by 1 ("dimming step"), a dither pattern is superimposed on it to make the transition appear smoother to the human eye. The pattern lasts 256 dimming clocks between dimming levels of 0 and 15, 128 dimming

Brightness and Color Control Unit (BCCU)

clocks between 16 and 31, 64 dimming clocks between 32 and 63 and 32 dimming clocks between 64 and 127.

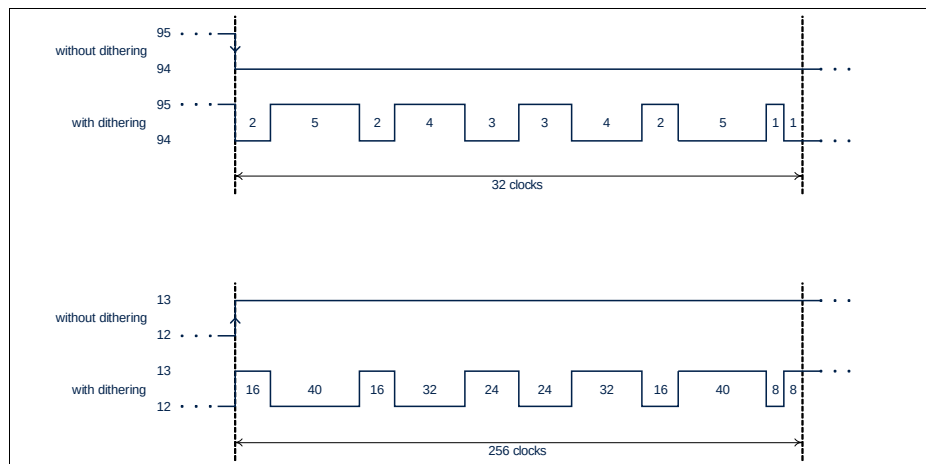


Figure 20-10 Dithering examples

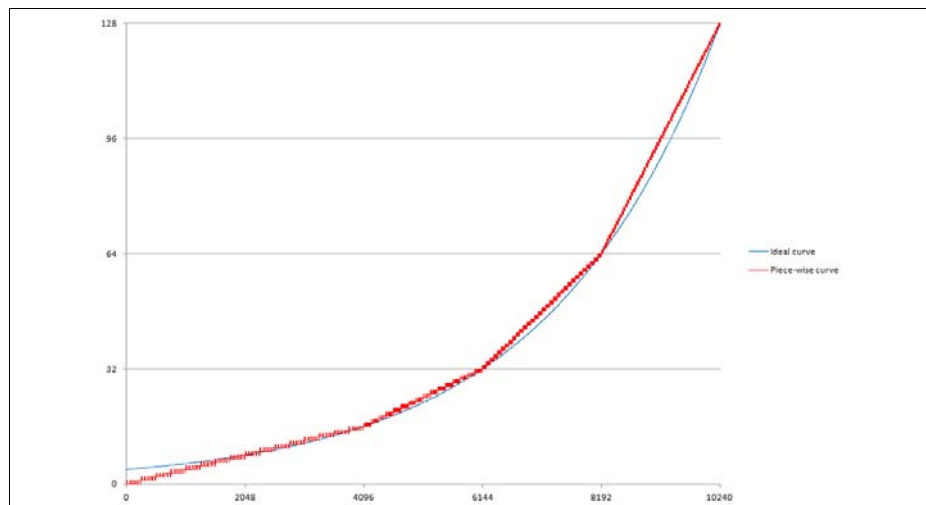


Figure 20-11 Lower section of the coarse curve with dithering enabled (real and ideal)

Brightness and Color Control Unit (BCCU)

Dithering the transition from dimming level of 0 to 1 may cause visible blinking. This can be avoided by enabling the flicker watchdog in the affected channels. The flicker watchdog can be enabled by setting bit **CHCONFIGy (y=0-8).WEN**.

20.2.3 Linear Color Walk

The intensity level (BCCU_**INTy (y=0-8).CHINT) can be changed using a linear walk. The transition time, aka linear walk time, is user adjustable by programming the (BCCU_**CHCONFIGy (y=0-8).LINPRES) bitfield. Reaching the target intensity level (BCCU_**INTSy (y=0-8).TCHINT) after shadow transfer (setting BCCU_**CHSTRCON.CHyS) will take the selected transition time which can be calculated by the following formula:

$$\text{LINEARWALKTIME} = \frac{\text{LINPRES} \times 2^{13}}{f_{\text{BCCUclk}}} \quad (20.4)$$

Once the linear walk is done, BCCU_**CHSTRCON.CHyS is cleared by hardware. Setting BCCU_**CHSTRCON.CHyA will abort the linear walk and will clear BCCU_**CHSTRCON.CHyS.

BCCU_**INTSy (y=0-8).TCHINT cannot be written while the linear walk is ongoing (BCCU_**CHSTRCON.CHyS is set). During this time, write accesses are ignored. The user either has to first wait until the walk is finished or has to manually abort the walk by setting BCCU_**CHSTRCON.CHyA.

If a linear walk is previously aborted, the subsequent linear walk starts with a miniscule delay. The maximum delay is one linear clock (LINPRES * 1 fclk cycle).

If BCCU_**CHCONFIGy (y=0-8).LINPRES is 0, the intensity level will be the same as the target intensity level on shadow transfer, which means that the linear walker is effectively bypassed.

Smooth color transition can be achieved by setting the same transition time for the respective channels and initiating shadow transfer at the same time. The delta intensity value is calculated as the difference between the channel intensity and the target channel intensity at the time of the channel shadow transfer.

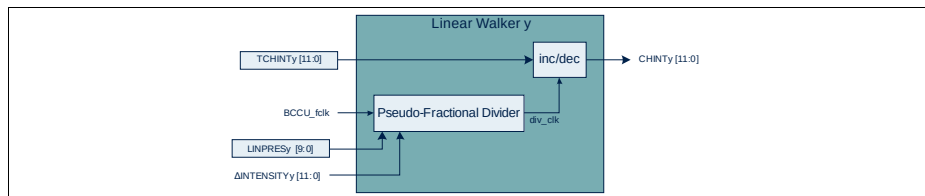


Figure 20-12 Linear Walker Block Diagram

20.2.4 Sigma-Delta Modulator

The sigma-delta modulator oversamples the slowly changing 12-bit brightness signal and changes it into a high bitrate single-bit signal. The average analog value of the single-bit signal is directly proportional to the 12-bit brightness value. Low-pass filtering is performed by the human eye.

The modulator contains a flicker watchdog which, if enabled, limits the number of consecutive off-bits (0) at the output to avoid visible flickering. The maximum number of off-bits allowed is determined by BCCU_GLOBCON.WDMBN. If the number of consecutive off-bits reaches this threshold, an on-bit (1) is inserted into the bitstream.

The minimum frequency of on bits is defined by the following formula:

$$f_{\min} = \frac{1}{\text{WDMBN}} \times f_{\text{BCCUclk}} \quad (20.5)$$

20.2.5 Packer

The main purpose of the packer is to decrease the average rate of switching of the output signal to decrease the load on external switching circuits and improve EMC behavior. The packer contains two 8-bit counters, a 4-stage FIFO and an output generator.

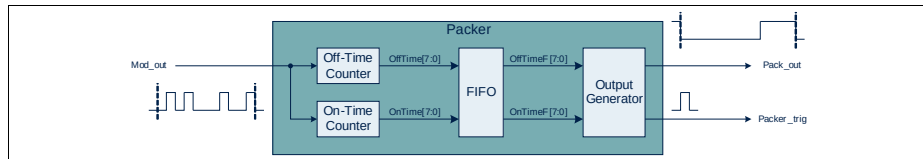


Figure 20-13 Packer Block Diagram

The on-time counter (BCU_PKCNTy (y=0-8).ONCNTVAL) counts the on-bits of the input bit stream (**Mod_out**) and the off-time counter (BCU_PKCNTy (y=0-8).OFFCNTVAL) counts the off bits. If the off-time counter or the on-time counter reaches the user adjustable compare level (BCCU_PKCMPy (y=0-8).ONCMP or BCCU_PKCMPy (y=0-8).OFFCMP), both timers reset and start counting again. Before the timers reset, their counts (BCCU_PKCNTy (y=0-8).ONCNTVAL and BCCU_PKCNTy (y=0-8).OFFCNTVAL) are loaded into a queue (FIFO). The counts are taken one by one from the queue in an alternating manner by the output generator and a packed off-on signal packet is generated (**Pack_out**). If the queue is empty, the output generator generates an off-bit (0) for one bit clock before checking the FIFO again. On microcontroller reset or if the channel has been disabled and enabled again, all queue stages are empty. When the packer becomes enabled (BCCU_CHCONFIGy (y=0-8).PEN), the output generator only starts taking the values from the queue once enough stages are filled (determined by BCCU_CHCONFIGy (y=0-8).PKTH). Until that, only off-bits are generated at the output.

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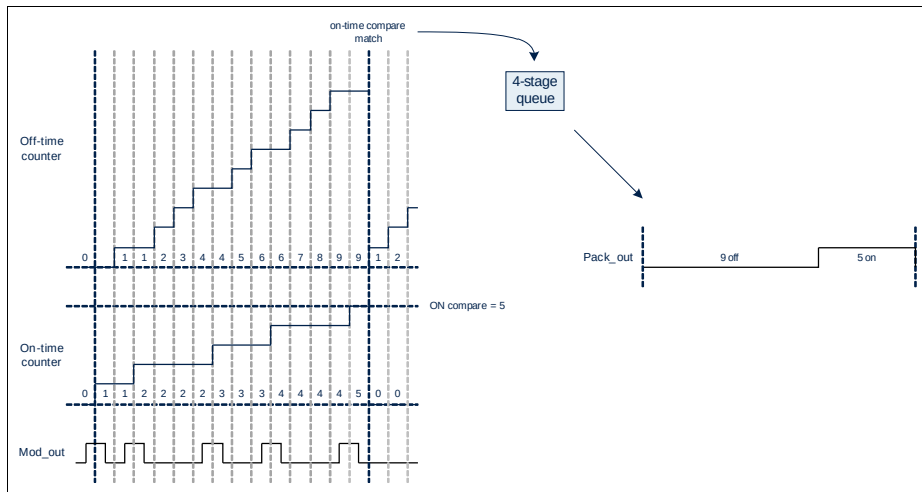


Figure 20-14 Signal Packing (example)

BCCU_PKCNTry (y=0-8).ONCNTVAL and BCCU_PKCNTry (y=0-8).OFFCNTVAL can be manually updated while the channel is not enabled (BCCU_CHEN.ECHy is 0). By putting a starting value other than zero in the counters, the user can introduce a “phase shift” between different channels to avoid identical behavior.

The packed signal has fixed on-time if the brightness level is high enough so that the on-time compare value is reached. Below a certain brightness level, the off-time compare value is reached before the on-time compare value. In this case the packed signal has a fixed off-time. The compare level determines the length of the packed signal packets which can be calculated with the following formulae:

$$\text{PacketTime}_{\min} = \text{ONCMP} \times \frac{1}{f_{\text{BCCUclk}}}$$

$$\text{PacketTime}_{\max} = (\text{ONCMP} + \text{OFFCMP}) \times \frac{1}{f_{\text{BCCUclk}}} \quad (20.6)$$

20.2.6 Global Trigger Control

The BCCU generates two trigger signals to the ADC (BCCU_TRIGOUT0 and BCCU_TRIGOUT1) to start conversions in a synchronized manner. In certain use cases, ADC samples are only meaningful if the respective control signal is active (e.g. the respective LED string is on). The output state of the BCCU channels when the last trigger occurred can be observed by checking the "Last Trigger Channel Output Level Register" (BCCU_LTCHOL). The channels can be individually enabled in the "Channel Enable

Brightness and Color Control Unit (BCCU)

Register" (BCCU_ **CHEN**.ECHy). Triggering can be individually enabled for every channel in the "Channel Trigger Register" (BCCU_ **CHTRIG**.ETy). Only enabled channels with enabled triggering participate in the triggering mechanism. Trigger occurs on a passive-to-active or active-to-passive transition of the channel output which can be individually selected for every channel (BCCU_ **CHCONFIGy** (y=0-8).TRED).

The BCCU offers two trigger modes (BCCU_ **GLOBCON**.TM). In mode 0, any channel trigger causes a trigger to the ADC on both trigger signals. When that happens, the ADC is expected to sample every channel and the user software has to decide which results are valid based on BCCU_ **LTCHOL**.

In mode 1, only one channel trigger generates an ADC trigger at a time. The channels take turns in trigger generation in a round robin manner starting from 0 and counting up. The trigger can be generated either on BCCU_TRIGOUT0 or on BCCU_TRIGOUT1 which is selectable for each channel individually by BCCU_ **CHTRIG**.TOSy. When a trigger has been generated, the channel pointer will point to the next participating channel to generate the next trigger. Every trigger will cause only one ADC measurement. Some additional user software may be necessary to control which ADC channel is triggered at a given time. BCCU_ **GLOBCON**.LTRS shows which BCCU channel generated the last trigger. The channel pointer is reset and will point to channel 0 if all channel trigger enable bits (BCCU_ **CHTRIG**.ETy) are 0.

The trigger can optionally be delayed by a quarter bit time or half a bit time to avoid sampling during switching noise. This is selectable by the BCCU_ **GLOBCON**.TRDEL bitfield. This delay is only functional if BCCU_bclk is generated in normal mode (BCCU_ **GLOBCLK**.BCS is 0).

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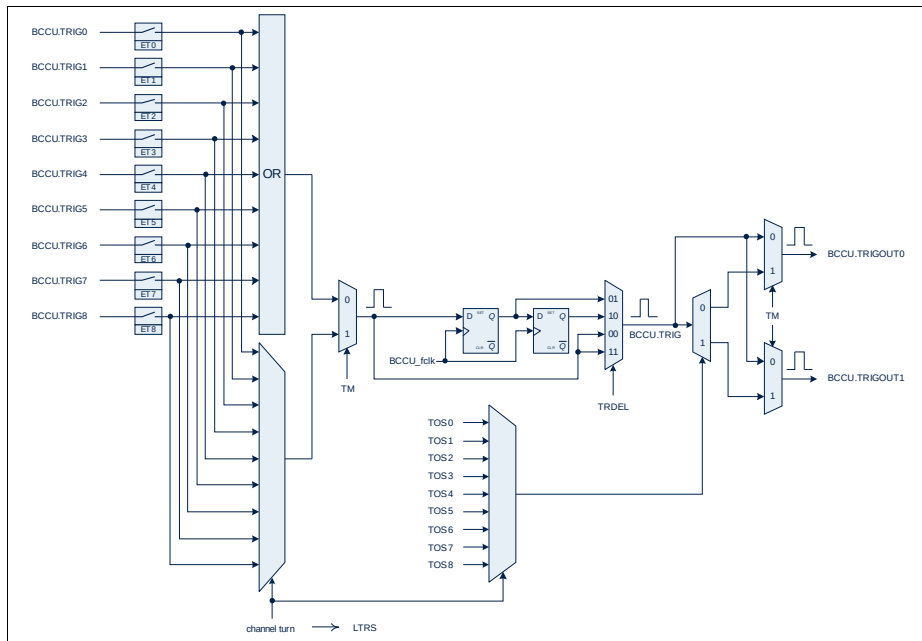


Figure 20-15 BCCU Trigger Generation

20.2.7 Trap Control

The trap functionality allows the BCCU outputs to react to a state of an input pin. This functionality can be used to switch off the connected power devices if the trap input becomes active (i.e. a trap occurs). A trap is a global event but trap functionality can be enabled for every channel individually by setting the BCCU_ [CHOCON](#).CHxTPE bits. If the corresponding bit is not set, the given channel will ignore the trap event.

A trap event occurs if a rising or a falling edge (user selectable via BCCU_ [GLOBCON](#).TRAPED) is detected on the BCCU.TRAPL signal. When a trap occurs, the affected channel outputs immediately¹⁾ go to their respective passive levels, determined by BCCU_ [CHOCON](#).CHyOP, while the event flag (BCCU_ [EVFR](#).TPF) and the trap state flag (BCCU_ [EVFR](#).TPSF) bits will be set.

BCCU_ [EVFR](#).TPF can be reset by writing 1 to BCCU_ [EVFCR](#).TPFC. This operation has no effect on the channel outputs. BCCU_ [EVFR](#).TPSF can be reset by writing 1 to BCCU_ [EVFCR](#).TPC. This will clear the trap and the channel outputs will go back to their respective output levels based on the channels' conditions. The user can monitor the

1) After a synchronization delay of 4 BCCU_clk cycles

Brightness and Color Control Unit (BCCU)

level of BCCU.TRAPL via bit BCCU_ **EVFR**.TPINL and may only want to exit the trap state once the trap signal is inactive.

BCCU_ **EVFR**.TPSF can also be set by writing 1 to BCCU_ **EVFSR**.TPS to generate a software trap.

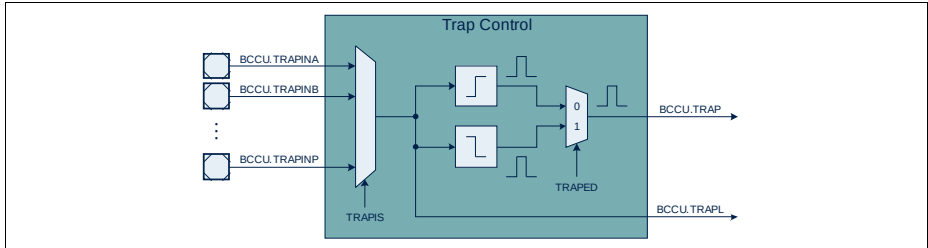


Figure 20-16 Trap Control

20.3 Power, Reset and Clock

BCCU is located in the core power domain. The module, including all registers other than the bit field BCCU_ **GLOBCON**.SUSCFG, can be reset to its default state by a system reset. The bit field BCCU_ **GLOBCON**.SUSCFG is reset to its default value only by a debug reset.

*Note: In XMC1200, as there is no separate debug reset, the bit field BCCU_ **GLOBCON**.SUSCFG will be reset to its default state by a system reset.*

The BCCU kernel is clocked (BCCU_clk) and accessible on the peripheral bus frequency (PCLK). Three main clocks are generated for the different blocks in the module:

- BCCU_bclk (bit clock) is the clock that determines the sampling rate of the sigma-delta converter and the bit time of the signal it generates. Depending on BCCU_ **GLOBCLK**.BCS, BCCU_bclk is generated from BCCU_fclk via a 4 divider or it is the same as BCCU_fclk.
- BCCU_fclk (fast clock) is used by the Trigger Control block to generate the trigger delay. It is generated from BCCU_clk by a prescaler. The frequency can be set by BCCU_ **GLOBCLK**.FCLK_PS.
- BCCU_dclk (dimming engine clock) is the input clock to the dimming engines. It is generated from BCCU_clk by a prescaler. The frequency can be set by BCCU_ **GLOBCLK**.DCLK_PS.

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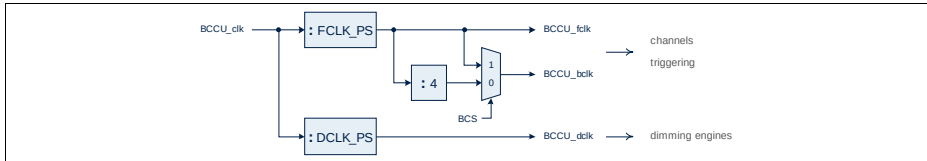


Figure 20-17 BCCU clocks

The clock frequencies in normal mode can be calculated with the following formulae:

$$f_{\text{BCCUfclk}} = \frac{1}{\text{FCLKPS}} \times f_{\text{BCCUclk}} \quad (20.7)$$

$$f_{\text{BCCUbclk}} = \frac{1}{\text{FCLKPS} \times 4} \times f_{\text{BCCUclk}} \quad (20.8)$$

$$f_{\text{BCCUdclk}} = \frac{1}{\text{DCLKPS}} \times f_{\text{BCCUclk}} \quad (20.9)$$

The kernel is only in operation in active mode.

20.4 Service Request Generation

The BCCU has one service request node and five interrupts. The five interrupts are 1) Trigger 0 event, 2) Trigger 1 event, 3) Packer FIFO full event, 4) Packer FIFO empty event and 5) Trap event.

A trigger 0/1 event occurs if there is a trigger pulse on BCCU.TRIGOUT0/1 to the ADC. A packer FIFO full/empty event occurs if any of the packer FIFOs is full/empty. A trap event occurs if a rising or a falling edge is detected on the BCCU.TRAPL signal.

The five interrupts can be generated by a hardware event or by setting the respective bit in BCCU_EVFSR. All five interrupts are assigned to node 0 and have their interrupt enable bit in BCCU_EVIER and their flag bit in BCCU_EVFR. The flag bits are set by the hardware event or by the respective set bits in BCCU_EVFSR and cleared by the respective clear bits in BCCU_EVFCR.

Additionally, the trigger events (BCCU.TRIGOUT0 and BCCU_TRIGOUT1) are connected to the trigger inputs of the ADC.

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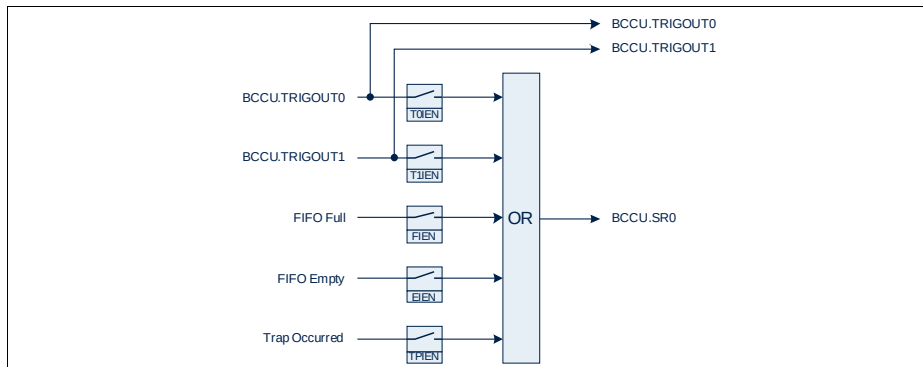


Figure 20-18 Service Request Nodes

The module clock is disabled by default and can be enabled via the SCU_CGATCLR0 register. Enabling and disabling the module clock could cause a load change and clock blanking could occur as described in the CCU (Clock Gating Control) section of the SCU chapter. It is strongly recommended to set up the module clock in the user initialization code to avoid clock blanking during runtime.

20.5 Debug Behaviour

The clocks to all channels, dimming engines and other functional blocks are stopped in suspend mode. The registers can still be accessed by the CPU as read-only. This mode is useful for debugging purposes as the current device status is frozen to get a snapshot of the internal values. As the clocks are stopped, all counters and timers are stopped and frozen.

Mode of entry into suspend mode can be configured by changing the BCCU_ **GLOBCON**.SUSCFG bitfield.

When debug suspend is revoked, the kernel resumes operation according to latest SFR settings.

*Note: In XMC1200, bit field BCCU_ **GLOBCON**.SUSCFG is reset to its default value by any reset. If the suspend function is required during debugging, it is recommended that it is enabled in the user initialization code. Before programming the bit field, the module clock has to be enabled and special care needs to be taken while enabling the module clock as described in the CCU (Clock Gating Control) section of the SCU chapter.*

20.6 Initialization

The BCCU registers are recommended to be programmed in a specific sequence.

Brightness and Color Control Unit (BCCU)

1. Program Global Registers

1. BCCU_ **CHOCN** to set output passive and active levels
2. BCCU_ **GLOBCLK** to set up the clocks
3. BCCU_ **GLOBCON** for general configuration
4. BCCU_ **EVIER** to set up interrupts
5. BCCU_ **GLOBDIM** for a user-defined dimming level when no dimming engine is used
6. BCCU_ **CHTRIG** to set up ADC triggering

2. Program Channel Registers

1. BCCU_ **CHCONFIGy (y=0-8)** for general channel configuration
2. BCCU_ **PKCMPy (y=0-8)** if the respective packer is used
3. BCCU_ **PKCNTRY (y=0-8)** to introduce a phase shift between channels. Ensure that the packer is already enabled (BCCU_ **CHCONFIGy (y=0-8)**.PEN is 1) before writing to packer counter register.

3. Program Dimming Engine Registers

1. BCCU_ **DTTz (z=0-2)** to adjust the dimming curve

4. Enable channels and dimming engines

1. BCCU_ **CHEN** to enable channels
2. BCCU_ **DEEN** to enable dimming engines

5. Set target intensities and start linear walk

1. BCCU_ **CHCONFIGy (y=0-8)**.LINPRES to set the linear walk time
2. BCCU_ **INTSy (y=0-8)** to set the target intensities
3. BCCU_ **CHSTRCON** to start linear walks
4. When the linear walks are finished, BCCU_ **CHSTRCON**.CHyS are cleared by hardware

6. Set target dimming levels and start dimming process (if at least one dimming engine is used)

1. BCCU_ **DTTz (z=0-2)**.DIMDIV to set the fade rate
2. BCCU_ **DLSz (z=0-2)** to set the target target dimming levels
3. BCCU_ **DESTRCON** to start dimming
4. When the dimming processes are completed, BCCU_ **DESTRCON**.DEzS are cleared by hardware

20.7 Digital-to-Analog Converter

The BCCU can be used as a simple multi-channel Digital-to-Analog Converter (DAC) with 12-bit resolution as well. The BCCU.OUTy signals can control the pull devices of certain port pins. An RC filter can be realized by adding an external capacitor.

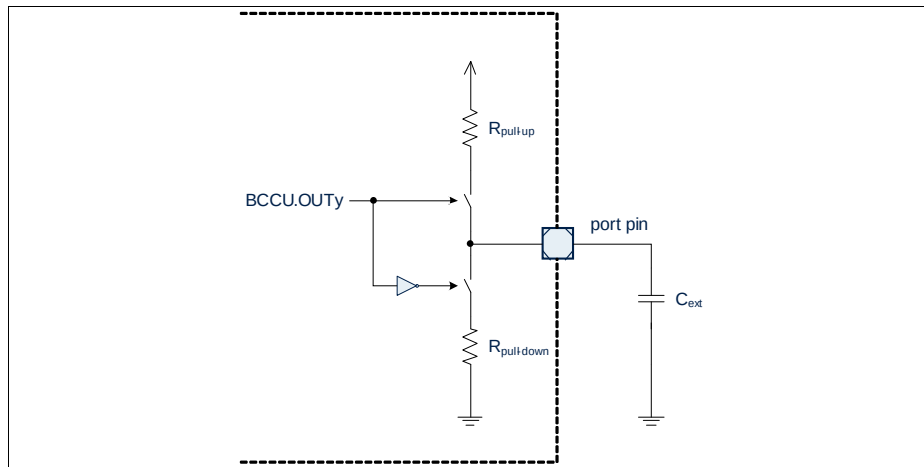


Figure 20-19 Simple DAC on one pin

To use the BCCU in a DAC configuration, the user must ensure that the HW0 control path is selected for the port pins used. This can be done by setting the selected Pn_HWSEL.HWx bitfields to 01_B. Additionally, the used pads need to be enabled by resetting the respective bits in register P2_PDISC. This will configure the port pins as digital input pins and can still be used by other modules. One example is generating an analog voltage reference for the in-built analog comparator.

It is recommended to select a high bit clock frequency by setting the fast clock prescaler (BCCU_GLOBCLK.FCLK_PS) to a low value and by selecting fast mode (BCCU_GLOBCLK.BCS to 1). The selected BCCU channels should bypass the dimming engines (BCCU_CHCONFIGy (y=0-8).DBP is 1) and the flicker watchdog should be disabled (BCCU_CHCONFIGy (y=0-8).WEN to 0).

The generated voltage level can be controlled with the 12-bit channel intensity value (BCCU_INTy (y=0-8).CHINT) by updating the target channel intensity (BCCU_INTSy (y=0-8).TCHINT) and initiating a shadow transfer (setting BCCU_CHSTRCON.CHyS to 1).

Brightness and Color Control Unit (BCCU)

20.8 Registers

All BCCU registers (except bit field BCCU_ [GLOBCON](#).SUSCFG) are reset by a system reset. Bit field BCCU_ [GLOBCON](#).SUSCFG is reset by a debug reset.

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 20-5 Registers Address Space

Module	Base Address	End Address	Note
BCCU	5003 0000 _H	5003 FFFF _H	

Table 20-6 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
BCCU Global Registers					
GLOBCON	Global Control Register	0000 _H	U, PV, 32	U, PV, 32	Page 20-25
GLOBCLK	Global Clock Register	0004 _H	U, PV, 32	U, PV, 32	Page 20-27
ID	Module Identification Register	0008 _H	U, PV, 32	BE	Page 20-29
CHEN	Channel Enable Register	000C _H	U, PV, 32	U, PV, 32	Page 20-29
CHOCON	Channel Output Control Register	0010 _H	U, PV, 32	U, PV, 32	Page 20-30
CHTRIG	Channel Trigger Register	0014 _H	U, PV, 32	U, PV, 32	Page 20-31
CHSTRCON	Channel Shadow Transfer Control Register	0018 _H	U, PV, 32	U, PV, 32	Page 20-32
LTCHOL	Last Trigger Channel Output Level Register	001C _H	U, PV, 32	BE	Page 20-33
DEEN	Dimming Engine Enable Register	0020 _H	U, PV, 32	U, PV, 32	Page 20-33
DESTRCON	Dimming Engine Shadow Transfer Control Register	0024 _H	U, PV, 32	U, PV, 32	Page 20-34

Brightness and Color Control Unit (BCCU)
Table 20-6 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
GLOBDIM	Global Dimming Level Register	0028 _H	U, PV, 32	U, PV, 32	Page 20-35
EVIER	Event Interrupt Enable Register	002C _H	U, PV, 32	U, PV, 32	Page 20-36
EVFR	Event Flag Register	0030 _H	U, PV, 32	BE	Page 20-37
EVFSR	Event Flag Set Register	0034 _H	U, PV, 32	U, PV, 32	Page 20-38
EVFCR	Event Flag Clear Register	0038 _H	U, PV, 32	U, PV, 32	Page 20-39

BCCU Channel Registers

INTSy	Channel Intensity Shadow Register y	003C _H + y*0014 _H	U, PV, 32	U, PV, 32	Page 20-41
INTy	Channel Intensity Register y	0040 _H + y*0014 _H	U, PV, 32	BE	Page 20-41
CHCONFIGy	Channel Configuration Register y	0044 _H + y*0014 _H	U, PV, 32	U, PV, 32	Page 20-42
PKCMPy	Packer Compare Register y	0048 _H + y*0014 _H	U, PV, 32	U, PV, 32	Page 20-44
PKCNTRY	Packer Counter Register y	004C _H + y*0014 _H	U, PV, 32	U, PV, 32	Page 20-45
Reserved	Reserved	00F0 _H - 0178 _H	BE	BE	

BCCU Dimming Engine Registers

DLSz	Dimming Level Shadow Register z	017C _H + z*000C _H	U, PV, 32	U, PV, 32	Page 20-46
DLz	Dimming Level Register z	0180 _H + z*000C _H	U, PV, 32	BE	Page 20-46
DTTz	Dimming Transition Time Register z	0184 _H + z*000C _H	U, PV, 32	U, PV, 32	Page 20-47
Reserved	Reserved	01A0 _H - FFFC _H	BE	BE	

Brightness and Color Control Unit (BCCU)

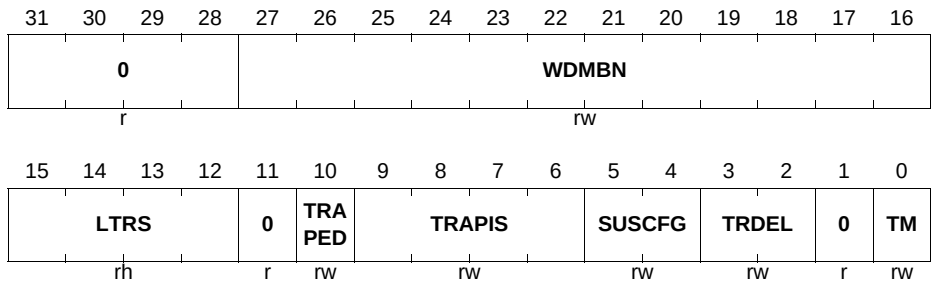
20.8.1 Global Registers

GLOBCON

Global Control

(0000_H)

Reset Value: 0320 0000_H



Field	Bits	Type	Description
TM	0	rw	Trigger Mode 0 _B Mode 0: BCCU trigger occurs if there is any channel trigger (OR logic) 1 _B Mode 1: BCCU trigger occurs if there is a channel trigger event on the active channel. When this happens, the next trigger-enabled channel will be active following the round robin.
0	1	r	Reserved Read as 0; should be written with 0.
TRDEL	[3:2]	rw	Trigger Delay 00 _B No delay 01 _B BCCU trigger occurs a quarter bit time after the channel trigger that caused it; only to be used if BCCU_GLOBCLK.BCS is 0 10 _B BCCU trigger occurs half a bit time after the channel trigger that caused it; only to be used if BCCU_GLOBCLK.BCS is 0 11 _B No delay

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
SUSCFG	[5:4]	rw	Suspend Mode Configuration This bitfield determines how the BCCU channels enter suspend mode. 00 _B Suspend request is ignored and the module cannot get suspended 01 _B All channels stop running immediately and freeze in the last state without any safe stop 10 _B All channels stop running immediately and freeze in the last state; all outputs go to passive state to achieve safe stop 11 _B Reserved
TRAPIS	[9:6]	rw	Trap Input Pin Selector Source of the trap input (BCCU.TRAPL) 0000 _B BCCU.TRAPINA 0001 _B BCCU.TRAPINB 0010 _B BCCU.TRAPINC 0011 _B BCCU.TRAPIND 0100 _B BCCU.TRAPINE 0101 _B BCCU.TRAPINF 0110 _B BCCU.TRAPING 0111 _B BCCU.TRAPINH 1000 _B BCCU.TRAPINI 1001 _B BCCU.TRAPINJ 1010 _B BCCU.TRAPINK 1011 _B BCCU.TRAPINL 1100 _B BCCU.TRAPINM 1101 _B BCCU.TRAPINN 1110 _B BCCU.TRAPINO 1111 _B BCCU.TRAPINP
TRAPED	10	rw	Trap Edge 0 _B Trap occurs (trap flag is set) on rising edge of the BCCU.TRAPL signal 1 _B Trap occurs (trap flag is set) on falling edge of the BCCU.TRAPL signal
0	11	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

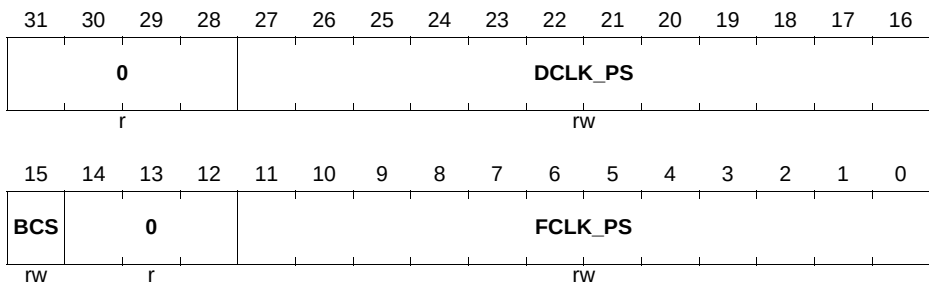
Field	Bits	Type	Description
LTRS	[15:12]	rh	Last Trigger Source Shows which channel generated the last trigger (the value is always 0 in Trigger Mode 0) 0000 _B The last trigger occurred in channel turn 0 0001 _B The last trigger occurred in channel turn 1 0010 _B The last trigger occurred in channel turn 2 0011 _B The last trigger occurred in channel turn 3 0100 _B The last trigger occurred in channel turn 4 0101 _B The last trigger occurred in channel turn 5 0110 _B The last trigger occurred in channel turn 6 0111 _B The last trigger occurred in channel turn 7 1000 _B The last trigger occurred in channel turn 8
WDMBN	[27:16]	rw	Watchdog Maximum Bitnumber The maximum number of consecutive zeroes allowed at the output of the sigma-delta modulators
0	[31:28]	r	Reserved Read as 0; should be written with 0.

GLOBCLK

Global Clock

(0004_H)

Reset Value: 00DB 0190_H



Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
FCLK_PS	[11:0]	rw	Fast Clock Prescaler Factor The constant clock input to the BCCU is prescaled according to this value to generate BCCU_fclk. BCCU_bclk is generated from BCCU_fclk by a division of 4. BCCU_bclk determines the bit-time at the output of the sigma-delta modulators. 0_D No clock 1_D Divide by 1 ... 4095_D Divide by 4095
BCS	15	rw	Bit-Clock Selector 0_B Normal Mode: BCCU_bclk is generated from BCCU_fclk by a division of 4 1_B Fast Mode: BCCU_bclk is the same as BCCU_fclk
0	[14:12]	r	Reserved Read as 0; should be written with 0.
DCLK_PS	[27:16]	rw	Dimmer Clock Prescaler Factor The constant clock input to the BCCU is prescaled according to this value to generate BCCU_dclk which is the clock input to the dimming engines. 0_D No clock 1_D Divide by 1 ... 4095_D Divide by 4095
0	[31:28]	r	Reserved Read as 0; should be written with 0.

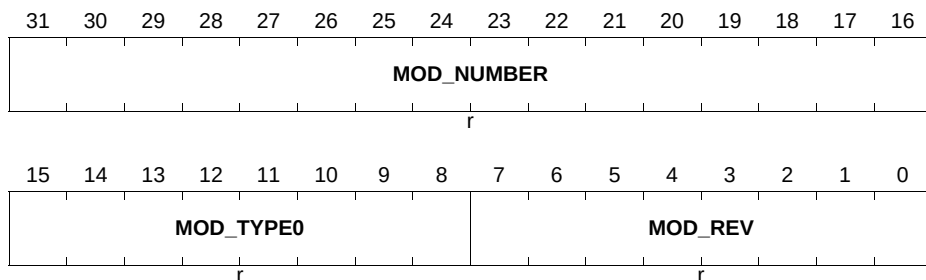
Brightness and Color Control Unit (BCCU)

ID

Module Identification

(0008_H)

Reset Value: 00F3 C0XX_H



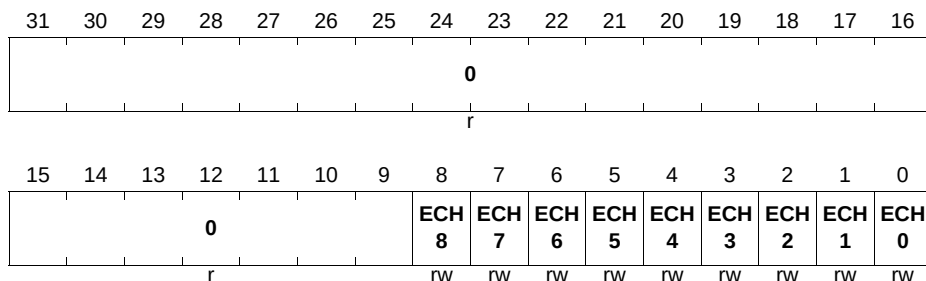
Field	Bits	Type	Description
MOD_REV	[7:0]	r	Module Revision Number MOD_REV defines the revision number. The value of a module revision starts with 01 _H (first revision).
MOD_TYPE0	[15:8]	r	Module Type This bit field is C0 _H . It defines the module as a 32-bit module.
MOD_NUMBER	[31:16]	r	Module Number Value This bit field defines the module identification number.

CHEN

Channel Enable

(000C_H)

Reset Value: 0000 0000_H



Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
ECHy (y=0-8)	y	rw	Channel y Enable 0_B Channel is disabled, the output level is passive; the Linear Walker and the Sigma-Delta Modulator are reset, the Packer FIFO is flushed; all internal logic and INTy are reset when the channel gets disabled 1_B Channel is enabled
0	[31:9]	r	Reserved Read as 0; should be written with 0.

CHOCON

Channel Output Control

(0010_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							CH8 TPE	CH7 TPE	CH6 TPE	CH5 TPE	CH4 TPE	CH3 TPE	CH2 TPE	CH1 TPE	CH0 TPE
r							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
0							CH8 OP	CH7 OP	CH6 OP	CH5 OP	CH4 OP	CH3 OP	CH2 OP	CH1 OP	CH0 OP
r							rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
CHyOP (y=0-8)	y	rw	Channel y Output Passive Level 0_B Active high 1_B Active low
0	[15:9]	r	Reserved Read as 0; should be written with 0.
CHyTPE (y=0-8)	y+16	rw	Channel y Trap Enable 0_B Trap function on channel is disabled 1_B Trap function on channel is enabled, the output goes to passive level when trap occurs
0	[31:25]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

CHTRIG

Channel Trigger

(0014_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							TOS 8	TOS 7	TOS 6	TOS 5	TOS 4	TOS 3	TOS 2	TOS 1	TOS 0
r							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
0							ET8	ET7	ET6	ET5	ET4	ET3	ET2	ET1	ET0
r							rw	rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
ETy (y=0-8)	y	rw	Channel y Trigger Enable 0 _B Channel trigger is disabled 1 _B Channel trigger is enabled If all Channel y Trigger Enable bits are 0, then the channel pointer is reset and points to channel 0.
0	[15:9]	r	Reserved Read as 0; should be written with 0.
TOSy (y=0-8)	y+16	rw	Channel y Trigger Output Select Only used in Trigger Mode 1 (GLOBON.TM=1), otherwise ignored 0 _B The channel trigger pulse will appear on BCCU_TRIGOUT0 1 _B The channel trigger pulse will appear on BCCU_TRIGOUT1
0	[31:25]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

CHSTRCON

Channel Shadow Transfer

(0018_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0							CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0
r							A	A	A	A	A	A	A	A	A
							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							CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0
r							S	S	S	S	S	S	S	S	S
							rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh	rwh

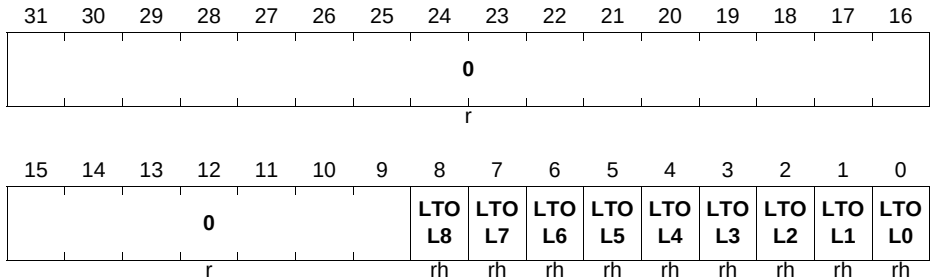
Field	Bits	Type	Description
CHyS (y=0-8)	y	rwh	Channel y Shadow Transfer 0 _B No action 1 _B Initiate channel y target intensity shadow transfer. The linear walk will start and channel y intensity will start to change towards the target. Cleared by hardware when the linear walk is complete and the target has been reached.
0	[15:9]	r	Reserved Read as 0; should be written with 0.
CHyA (y=0-8)	y+16	w	Channel y Linear Walk Abort 0 _B No action 1 _B Abort linear walk; CHyS is cleared, channel y intensity stops changing Always read as 0
0	[31:25]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

LTCHOL

Last Trigger Channel Output Level (001C_H)

Reset Value: 0000 0000_H

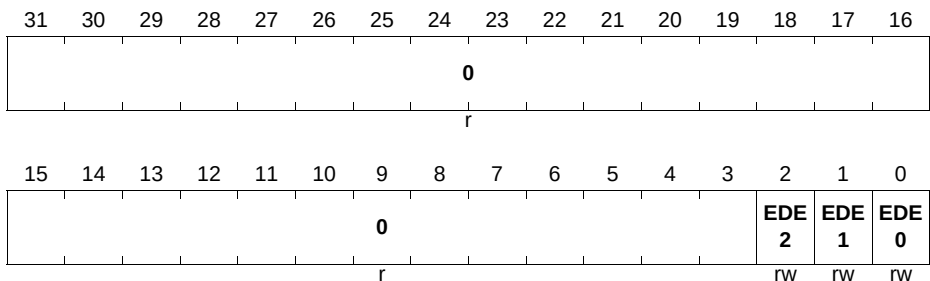


Field	Bits	Type	Description
LTOLy (y=0-8)	y	rh	Last Trigger Channel Output The output level of the channel when the last trigger occurred. The bit gets updated with every BCCU trigger in Trigger Mode 0. In Trigger Mode 1, the bit gets updated when a trigger occurs in the relevant channel turn. 0 _B Passive 1 _B Active
0	[31:9]	r	Reserved Read as 0; should be written with 0.

DEEN

Dimming Engine Enable (0020_H)

Reset Value: 0000 0000_H



Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
EDEz (z=0-2)	z	rw	Dimming Engine z Enable 0_B Dimming Engine is disabled; Channel brightness gets written with the value of channel intensity 1_B Dimming Engine is enabled
0	[31:3]	r	Reserved Read as 0; should be written with 0.

DESTRCON

Dimming Shadow Transfer

(0024_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0													DE2 A	DE1 A	DE0 A
r													w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0													DE2 S	DE1 S	DE0 S
r													rwh	rwh	rwh

Field	Bits	Type	Description
DEzS (z=0-2)	z	rwh	Dimming Engine z Shadow Transfer 0_B No action 1_B Initiate target dimming level shadow transfer. The dimming process will start and the dimming level will change towards the target. Cleared by hardware when the dimming process is complete and the target has been reached after the configured dimming period.
0	[15:3]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

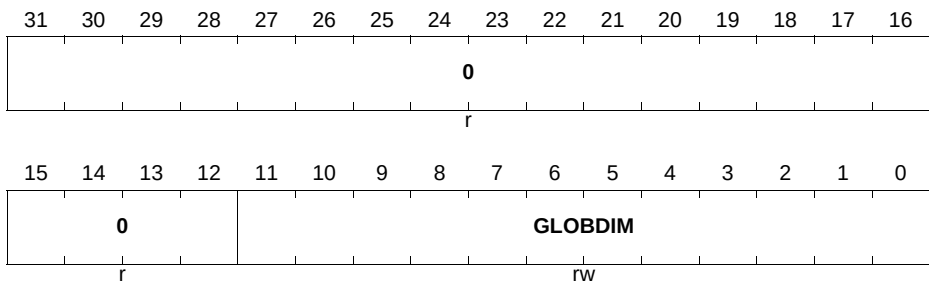
Field	Bits	Type	Description
DEzA (z=0-2)	z+16	w	Dimming Engine z Dimming Abort 0_B No action 1_B Abort dimming; DEzS is cleared, BCCU_DLz.DLEV stops changing Always read as 0
0	[31:19]	r	Reserved Read as 0; should be written with 0.

GLOBDIM

Global Dimming Level

(0028_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
GLOBDIM	[11:0]	rw	Global Dimming Level Can be used for software-controlled dimming
0	[31:12]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

EVIER

Event Interrupt Enable

(002C_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											TPIE N	EIEN	FIEN	T1IE N	T0IE N
r											rw	rw	rw	rw	rw

Field	Bits	Type	Description
T0IEN	0	rw	Trigger 0 Interrupt Enable 0 _B Trigger 0 interrupt generation is disabled 1 _B BCCU trigger 0 (BCCU_TRIGOUT0) generates an interrupt on SR0
T1IEN	1	rw	Trigger 1 Interrupt Enable 0 _B Trigger 1 interrupt generation is disabled 1 _B BCCU trigger 1 (BCCU_TRIGOUT1) generates an interrupt on SR0
FIEN	2	rw	FIFO Full Interrupt Enable 0 _B FIFO-full interrupt generation is disabled 1 _B An interrupt is generated on SR0 if any of the packer FIFOs is full when there is a write attempt by the on-time or off-time counter
EIEN	3	rw	FIFO Empty Interrupt Enable 0 _B FIFO-full interrupt generation is disabled 1 _B An interrupt is generated on SR0 if any of the packer FIFOs is empty when there is a read attempt by the output generator
TPIEN	4	rw	Trap Interrupt Enable 0 _B Trap interrupt generation is disabled 1 _B An interrupt is generated on SR0 if a trap occurs
0	[31:5]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

EVFR

Event Flag

(0030_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								TPIN	TPS	0	TPF	EF	FF	T1F	T0F
r								rh	rh	r	rh	rh	rh	rh	rh

Field	Bits	Type	Description
T0F	0	rh	Trigger 0 Flag 0 _B No trigger event has been detected on BCCU trigger line 0 (BCCU_TRIGOUT0) 1 _B A trigger event has been detected on BCCU trigger line 0 (BCCU_TRIGOUT0)
T1F	1	rh	Trigger 1 Flag 0 _B No trigger event has been detected on BCCU trigger line 1 (BCCU_TRIGOUT1) 1 _B A trigger event has been detected on BCCU trigger line 1 (BCCU_TRIGOUT1)
FF	2	rh	FIFO Full Flag 0 _B No FIFO full event has been detected 1 _B A FIFO full event has been detected because one of the packer FIFOs is full and there has been a write attempt by the on-time or off-time counter
EF	3	rh	FIFO Empty Flag 0 _B No FIFO full event has been detected 1 _B A FIFO full event has been detected because one of the packer FIFOs is empty and there has been a read attempt by the output generator
TPF	4	rh	Trap Flag 0 _B No trap event has been detected 1 _B A trap event has been detected

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
0	5	r	Reserved Read as 0; should be written with 0.
TPSF	6	rh	Trap State Flag 0 _B BCCU is not in a trap state 1 _B BCCU is in a trap state, the affected channel outputs are at their passive levels
TPINL	7	rh	Trap Input Level 0 _B The current level of BCCU.TRAPL is low 1 _B The current level of BCCU.TRAPL is high
0	[31:8]	r	Reserved Read as 0; should be written with 0.

EVFSR

Event Flag Set

(0034_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								TPS	0	TPFS	EFS	FFS	T1FS	T0FS	
r								w	r	w	w	w	w	w	

Field	Bits	Type	Description
T0FS	0	w	Trigger 0 Flag Set 0 _B No action 1 _B Sets the Trigger 0 Flag in EVFR and an interrupt will be generated if enabled in EVIER
T1FS	1	w	Trigger 1 Flag Set 0 _B No action 1 _B Sets the Trigger 1 Flag in EVFR and an interrupt will be generated if enabled in EVIER

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
FFS	2	w	FIFO Full Flag Set 0 _B No action 1 _B Sets the FIFO Full Flag in EVFR and an interrupt will be generated if enabled in EVIER
EFS	3	w	FIFO Empty Flag Set 0 _B No action 1 _B Sets the FIFO Empty Flag in EVFR and an interrupt will be generated if enabled in EVIER
TPFS	4	w	Trap Flag Set 0 _B No action 1 _B Sets the Trap Flag in EVFR and an interrupt will be generated if enabled in EVIER, no trap will occur
0	5	r	Reserved Read as 0; should be written with 0.
TPS	6	w	Trap Set 0 _B No action 1 _B Sets the Trap State Flag and Trap Flag in EVFR, a trap will be generated and an interrupt will be generated if enabled in EVIER
0	[31:7]	r	Reserved Read as 0; should be written with 0.

EVFCR

Event Flag Clear

(0038_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									TPC	0	TPF C	EFC	FFC	T1F C	T0F C
r									w	r	w	w	w	w	w

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
T0FC	0	w	Trigger 0 Flag Clear 0_B No action 1_B Clears the Trigger 0 Flag in EVFR
T1FC	1	w	Trigger 1 Flag Clear 0_B No action 1_B Clears the Trigger 1 Flag in EVFR
FFC	2	w	FIFO Full Flag Clear 0_B No action 1_B Clears the FIFO Full Flag in EVFR
EFC	3	w	FIFO Empty Flag Clear 0_B No action 1_B Clears the FIFO Empty Flag in EVFR
TPFC	4	w	Trap Flag Clear 0_B No action 1_B Clears the Trap Flag in EVFR
0	5	r	Reserved Read as 0; should be written with 0.
TPC	6	w	Trap Clear 0_B No action 1_B Clears the Trap State Flag in EVFR; trap state is exited, the affected channels will return to their normal output levels
0	[31:7]	r	Reserved Read as 0; should be written with 0.

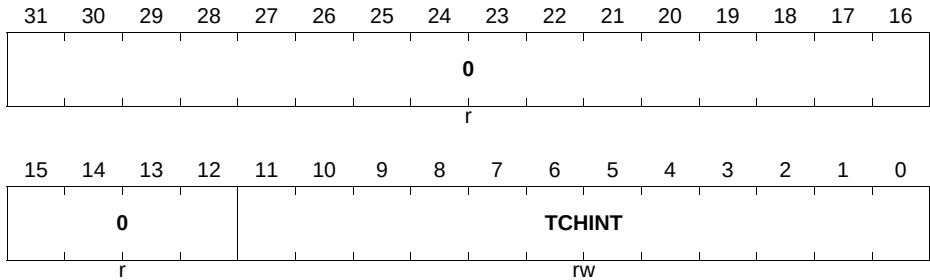
20.8.2 Channel Registers

There are 9 channels available on XMC1200. y denotes channel 0 through 8.

Brightness and Color Control Unit (BCCU)

INTSy (y=0-8)

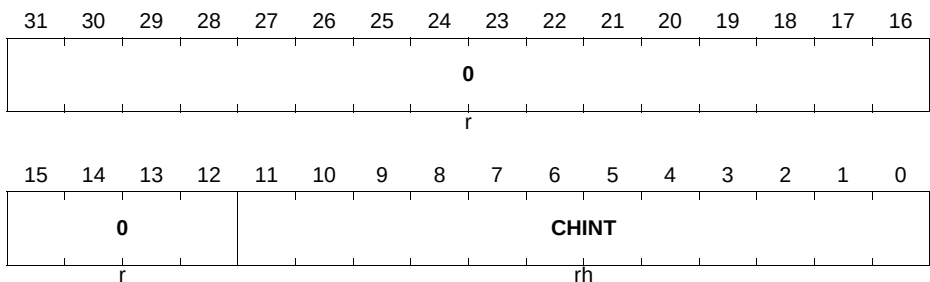
Channel Intensity Shadow **(003C_H + y*0014_H)** **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
TCHINT	[11:0]	rw	Target Channel Intensity Can only be written if CHSTRCON.CHyS is not set, otherwise the new value will be ignored.
0	[31:12]	r	Reserved Read as 0; should be written with 0.

INTy (y=0-8)

Channel Intensity **(0040_H + y*0014_H)** **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
CHINT	[11:0]	rh	Channel Intensity Actual channel intensity.

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
0	[31:12]	r	Reserved Read as 0; should be written with 0.

CHCONFIGy (y=0-8)

Channel Configuration

(0044_H + y*0014_H)

Reset Value: 0000 0002_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						LINPRES									
r						rw									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0				ENF T	TRE D	WEN	GEN	DBP	DSEL			PEN	PKTH		
r				rw	rw	rw	rw	rw	rw			rw	rw		

Field	Bits	Type	Description
PKTH	[2:0]	rw	Packer Threshold After being enabled, the packer will start generating the output based on the values stored in the FIFO (queue) once the number of full stages reaches this threshold (until that only zeros are generated). 000 _B Not allowed 001 _B Threshold value of 1 010 _B Threshold value of 2 011 _B Threshold value of 3 100 _B Threshold value of 4 101 _B Reserved 110 _B Reserved 111 _B Reserved
PEN	3	rw	Packer Enable 0 _B The packer is not used 1 _B On-time and off-time counters are running and the packed output bitstream with the packer trigger are generated.

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
DSEL	[6:4]	rw	Dimming Select Source of the dimming input 000 _B Dimming Engine 0 001 _B Dimming Engine 1 010 _B Dimming Engine 2 011 _B Reserved 100 _B Reserved 101 _B Reserved 110 _B Reserved 111 _B Global Dimming Level
DBP	7	rw	Dimming Input Bypass 0 _B Channel brightness is the product of the selected dimming input and the channel intensity 1 _B No dimming input is used, channel brightness is only determined by the channel intensity level
GEN	8	rw	Gating Enable 0 _B Gating function is disabled, the input signal (BCCU.INy) has no effect 1 _B Gating function is enabled, the output gating signal is BCCU.INy
WEN	9	rw	Flicker Watchdog Enable 0 _B The flicker watchdog is not used 1 _B The flicker watchdog is active and limits the number of consecutive zeroes at the sigma-delta modulator output according to GLOBCON.WDMBN
TRED	10	rw	Trigger Edge 0 _B Channel triggers occur on channel output transition from passive to active level 1 _B Channel triggers occur on channel output transition from active to passive level
ENFT	11	rw	Forced Trigger Enable 0 _B No forced trigger is generated 1 _B The trigger generator generates a trigger if the output of the sigma-delta modulator hasn't changed state for 256 bit times; only takes effect if the packer is disabled (PEN=0)

Brightness and Color Control Unit (BCCU)

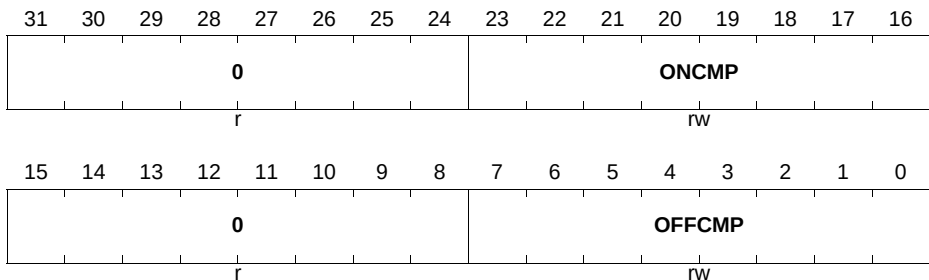
Field	Bits	Type	Description
0	[15:12]	r	Reserved Read as 0; should be written with 0.
LINPRES	[25:16]	rw	Linear Walker Clock Prescaler Determines how long it takes for the Channel Intensity to reach the Target Channel Intensity after shadow transfer (after CHSTRCON.CHyS is set). Necessary for smooth linear color transitions. If this value is 0, then the intensity level will become the same as the target intensity level on shadow transfer and the linear walker is bypassed.
0	[31:26]	r	Reserved Read as 0; should be written with 0.

PKCMPy (y=0-8)

Packer Compare

(0048_H + y*0014_H)

Reset Value: 0004 0060_H



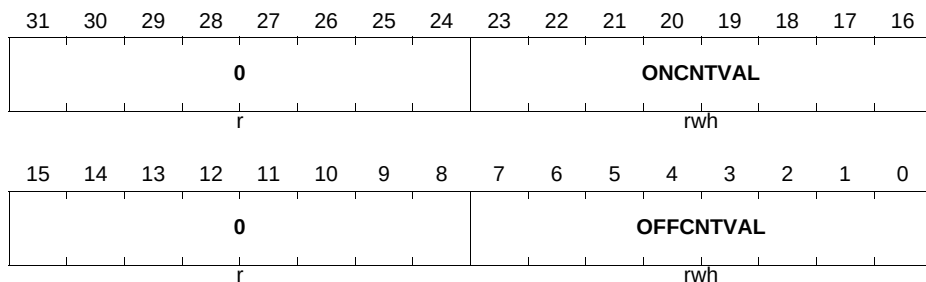
Field	Bits	Type	Description
OFFCMP	[7:0]	rw	Packer Off-Time Compare Level When the off-time counter in the packer reaches this value, the measured on-time and off-time of the output of the sigma-delta modulator are stored; and the counters reset to 0.
0	[15:8]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
ONCMP	[23:16]	rw	Packer On-Time Compare Level When the on-time counter in the packer reaches this value, the measured on-time and off-time of the output of the sigma-delta modulator are stored; and the counters reset to 0.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

PKCNTRY (y=0-8)

Packer Counter $(004C_H + y \cdot 0014_H)$ **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
OFFCNTVAL	[7:0]	rwh	Off-Time Counter Value Should be written when the channel is disabled (BCCU_ CHEN .ECHy is 0). Ensure that the packer is enabled (BCCU_ CHCONFIGy (y=0-8) .PEN is 1) before writing this bit field.
0	[15:8]	r	Reserved Read as 0; should be written with 0.
ONCNTVAL	[23:16]	rwh	On-Time Counter Value Should be written when the channel is disabled (BCCU_ CHEN .ECHy is 0). Ensure that the packer is enabled (BCCU_ CHCONFIGy (y=0-8) .PEN is 1) before writing this bit field.

Brightness and Color Control Unit (BCCU)

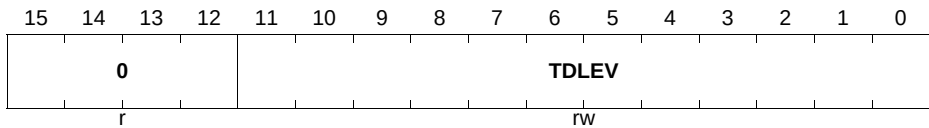
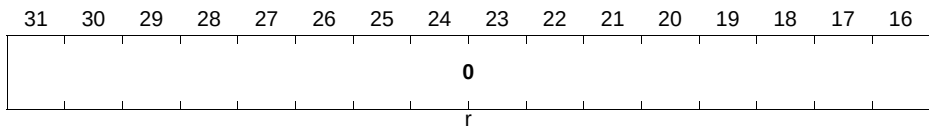
Field	Bits	Type	Description
0	[31:24]	r	Reserved Read as 0; should be written with 0.

20.8.3 Dimming Engine Registers

There are 3 dimming engines available on XMC1200. z denotes engine 0 through 2.

DLSz (z=0-2)

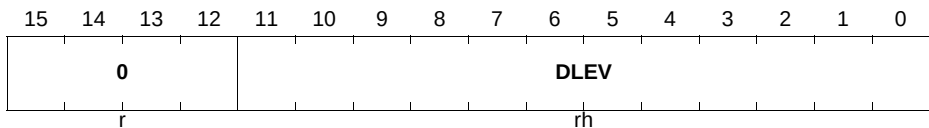
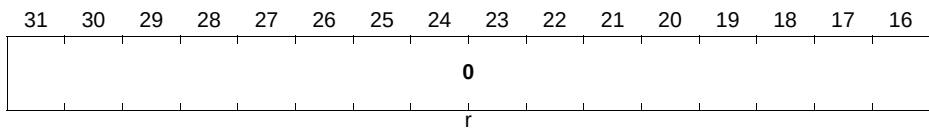
Dimming Level Shadow (017C_H + z*000C_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
TDLEV	[11:0]	rw	Target Dimming Level
0	[31:12]	r	Reserved Read as 0; should be written with 0.

DLz (z=0-2)

Dimming Level (0180_H + z*000C_H) **Reset Value: 0000 0000_H**

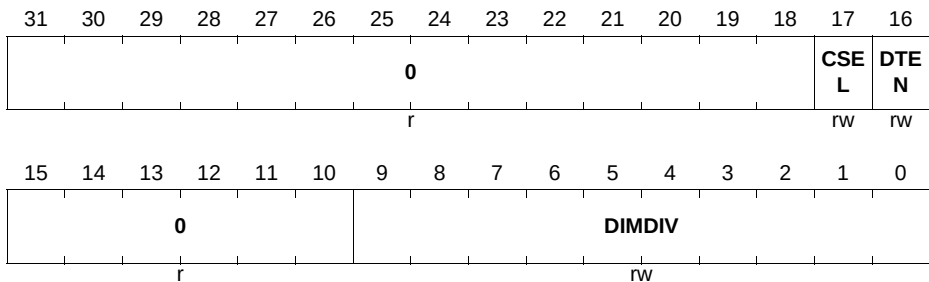


Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
DLEV	[11:0]	rh	Dimming Level
0	[31:12]	r	Reserved Read as 0; should be written with 0.

DTTz (z=0-2)

Dimming Transition Time (0184_H + z*000C_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
DIMDIV	[9:0]	rw	Dimming Clock Divider BCCU_dclk is prescaled according to this value to generate the dimming clock; this value can be used to adjust the fade rate of the dimming engine. If this value is 0, then the dimming level will become the same as the target dimming level on shadow transfer and the dimming engine is bypassed.
0	[15:10]	r	Reserved Read as 0; should be written with 0.
DTEN	16	rw	Dither Enable 0 _B No dithering 1 _B Dithering is added to every dimming step if the dimming level is below 128; the coarse curve is used for the entire dimming range

Brightness and Color Control Unit (BCCU)

Field	Bits	Type	Description
CSEL	17	rw	Curve Select 0_B Coarse curve 1_B Fine curve If dithering is enabled (DTEN=1), this bit is ignored and the coarse curve is used. Switching between curves in application is not supported.
0	[31:18]	r	Reserved Read as 0; should be written with 0.

Brightness and Color Control Unit (BCCU)

20.9 Interconnects

BCCU0 is connected to the ports, the ERU, the analog comparator, the ADC, the NVIC, CCU4, the suspend signal and the kernel clock.

Table 20-7 Pin Connections

Input/Output	I/O	Connected To	Description
BCCU0_clk	I	PCLK	BCCU kernel clock
SUSPEND	I	CPU Halted	Suspend signal
BCCU0.IN0	I	ACMP1.OUT	Gating Input of channel 0
BCCU0.IN1	I	not connected (1)	Gating Input of channel 1
BCCU0.IN2	I	not connected (1)	Gating Input of channel 2
BCCU0.IN3	I	ACMP2.OUT	Gating Input of channel 3
BCCU0.IN4	I	not connected (1)	Gating Input of channel 4
BCCU0.IN5	I	ACMP0.OUT	Gating Input of channel 5
BCCU0.IN6	I	not connected (1)	Gating Input of channel 6
BCCU0.IN7	I	not connected (1)	Gating Input of channel 7
BCCU0.IN8	I	not connected (1)	Gating Input of channel 8
BCCU0.TRAPINA	I	P0.12	Trap input A
BCCU0.TRAPINB	I	P0.0	Trap input B
BCCU0.TRAPINC	I	not connected (0)	Trap input C
BCCU0.TRAPIND	I	not connected (0)	Trap input D
BCCU0.TRAPINE	I	ERU0.IOUT0	Trap input E
BCCU0.TRAPINF	I	ERU0.IOUT1	Trap input F
BCCU0.TRAPING	I	ERU0.IOUT2	Trap input G
BCCU0.TRAPINH	I	ERU0.IOUT3	Trap input H
BCCU0.TRAPINI	I	SCU.SR2	Trap input I
BCCU0.TRAPINJ	I	not connected (0)	Trap input J
BCCU0.TRAPINK	I	not connected (0)	Trap input K
BCCU0.TRAPINL	I	not connected (0)	Trap input L
BCCU0.TRAPINM	I	not connected (0)	Trap input M
BCCU0.TRAPINN	I	not connected (0)	Trap input N
BCCU0.TRAPINO	I	not connected (0)	Trap input O
BCCU0.TRAPINP	I	not connected (0)	Trap input P

Brightness and Color Control Unit (BCCU)
Table 20-7 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
BCCU0.OUT0	O	P0.4 P1.0 P2.2.HW0 pull control	Output of channel 0
BCCU0.OUT1	O	P0.5 P1.5 P2.0.HW0 pull control P2.8.HW0 pull control	Output of channel 1
BCCU0.OUT2	O	P0.6 P1.6 CCU40.MCI0 P1.0.HW0 pull control P2.6.HW0 pull control	Output of channel 2
BCCU0.OUT3	O	P0.7 CCU40.MCI1 P1.1.HW0 pull control	Output of channel 3
BCCU0.OUT4	O	P0.8 CCU40.MCI2 P1.2.HW0 pull control P2.10.HW0 pull control	Output of channel 4
BCCU0.OUT5	O	P0.9 CCU40.MCI3 P1.3.HW0 pull control P2.11.HW0 pull control	Output of channel 5
BCCU0.OUT6	O	P0.10 P0.12 P1.4.HW0 pull control P2.1.HW0 pull control	Output of channel 6
BCCU0.OUT7	O	P0.11 P0.14 P1.5.HW0 pull control P2.9.HW0 pull control	Output of channel 7

Brightness and Color Control Unit (BCCU)

Table 20-7 Pin Connections (cont'd)

Input/Output	I/O	Connected To	Description
BCCU0.OUT8	O	P0.1 P0.15 P1.6.HW0 pull control P2.4.HW0 pull control P2.7.HW0 pull control	Output of channel 8
Service Request Connectivity			
BCCU0.SR0	O	NVIC	Service Request Node 0: Interrupt
BCCU0.TRIGOUT0	O	VADC0.BGREQTRF VADC0.G0REQTRF	ADC trigger signal 0
BCCU0.TRIGOUT1	O	VADC0.G1REQTRF	ADC trigger signal 1

General Purpose I/O Ports

21 General Purpose I/O Ports (Ports)

The XMC1200 has 35 digital General Purpose Input/Output (GPIO) port lines which are connected to the on-chip peripheral units.

21.1 Overview

The Ports provide a generic and very flexible software and hardware interface for all standard digital I/Os. Each Port slice has individual interfaces for the operation as General Purpose I/O and it further provides the connectivity to the on-chip periphery and the control for the pad characteristics. [Table 21-1](#) gives an overview of the available PORTS and other pins in the different packages of the XMC1200:

Table 21-1 Port/Pin Overview

Port	VQFN-40	TSSOP-38	TSSOP-28	VQFN-24	TSSOP-16	Note
P0	16	16	12	10	8	Standard bi-directional pad
P1	7	6	4	4	-	High current and Standard bi-directional pad
P2	12	12	10	8	6	Analog/Digital input and bi-directional pad
Supply VDD, ADC / ORC Reference Voltage	1	1	1	1	1	VDD
Supply GND, ADC Reference Ground	1	1	1	1	1	VSS
I/O Port Supply	1	1	-	-	-	VDDP
I/O Port Ground	1	1	-	-	-	VSSP

21.1.1 Features

This is a list of the main features of the Ports:

- same generic register interface for each port pin, [Chapter 21.8](#)

General Purpose I/O Ports (Ports)

- simple and robust software access for general purpose I/O functionality, [Chapter 21.2](#)
- direct input connections to on-chip peripherals, [Chapter 21.2.1](#)
- dedicated hardware interface for BCCU, CCU, LEDTS and USIC, [Chapter 21.3](#)
- defined power-up/power-fail behavior, [Chapter 21.6](#).
- up to seven alternate output paths from peripherals selectable, [Chapter 21.8.1](#)
- programmable open-drain or push-pull output driver stage, [Chapter 21.8.1](#)
- programmable weak pull-up and pull-down devices, [Chapter 21.8.1](#)
- programmable input inverter, [Chapter 21.8.1](#)
- programmable pad hysteresis, [Chapter 21.8.2](#)
- disabling of digital input stage on shared analog inputs, [Chapter 21.8.3](#)
- separate set and clear output control to avoid read-modify-write operations, [Chapter 21.8.5](#)
- programmable power-save behavior in Deep-Sleep mode, [Chapter 21.8.7](#)
- Privileged Mode restricted access to configuration registers to avoid accidental modification

21.1.2 Block Diagram

Below is a figure with the generic structure of a digital port pin, split into the port slice with the control logic and the pad with the pull devices and the input and output stages, [Figure 21-1](#).

General Purpose I/O Ports (Ports)

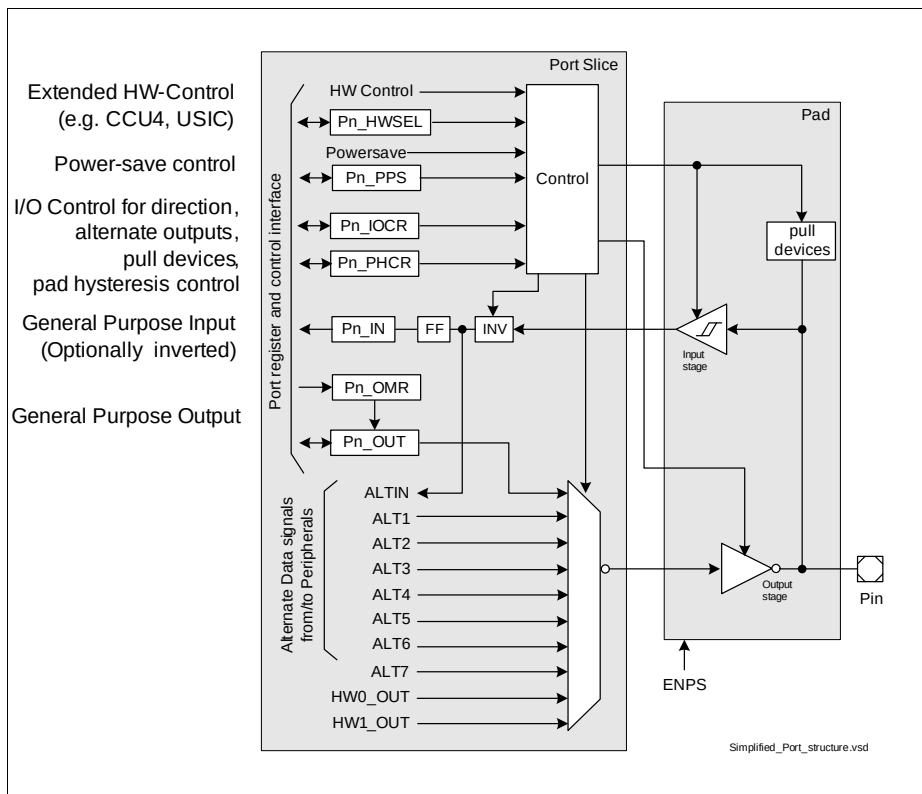


Figure 21-1 General Structure of a digital Port Pin

21.1.3 Definition of Terms

Some specific terms are used throughout this chapter:

- **Pin/Ball:** External connection of the device to the PCB.
- **Dedicated Pin:** A Pin with a dedicated function that is not under the control of the port logic (i.e. supply pins).
- **Port Pin:** A pin under the control of the port logic (P0.1).
- **Port:** A group of up to 16 Port Pins sharing the same generic register set (P0).
- **Port Slice:** The “sum” of register bits and control logic used to control a port pin.
- **Pad:** Analog component containing the output driver, pull devices and input Schmitt-Trigger. Also interfaces the internal logic operating on V_{DDC} to the pad supply domain V_{DDP} .

General Purpose I/O Ports (Ports)

- **GPIO:** General Purpose Input/Output. A port pin with the input and/or output function controlled by the application software.
- **Alternate Function:** Direct connection of a port pin with an on-chip peripheral.

21.2 GPIO and Alternate Functions

The Ports can be operated as General Purpose Input/Output (GPIO) and with Alternate Functions of the on-chip peripheral, configured by the Port Input/Output Control Register (Pn_IOC, [Chapter 21.8.1](#)). It selects between

- Direct or Inverted Input
 - with or without pull device
- Push-pull or Open-Drain Output driven by
 - Pn_OUT (GPIO)
 - selected peripheral output connections.

As GPIO the port pin is controlled by the application software, reading the input value by the Port Input register Pn_IN ([Chapter 21.8.6](#)) and/or defining the output value by the Output Modification Register Pn_OMR ([Chapter 21.8.5](#)). Output modification by Pn_OMR is preferred over the direct change of the output value with the Output register Pn_OUT ([Chapter 21.8.4](#)), as Pn_OMR allows the manipulation of individual port pins in a single access without “disturbing” other pins controlled by the same Pn_OUT register. If an application uses a GPIO as a bi-directional I/O line, register Pn_IOC has to be written to switch between input and output functionality.

For the operation with Alternate Functions, the port pins are directly connected to input or output functions of the on-chip peripheral. This allows the peripheral to directly evaluate the input value or drive the output value of the port pin without further application software interaction after the initial configuration. The connection of alternate functions is used for control and communication interfaces, like a PWM from a CAPCOM unit or a SPI communication of a USIC channel. A detailed connectivity list of the peripherals to the port pins is given in the [Port I/O Function Description](#) chapter. For specific functions, certain peripherals may also take direct control of “their” port pins, see [Hardware Controlled I/Os](#).

21.2.1 Input Operation

As an input, the actual voltage level at the port pin is translated into a logical 0_B or 1_B via a Schmitt-Trigger device within the pad. The resulting input value can be optionally inverted. As general purpose input, the signal is synchronized and can be read with the Input register (Pn_IN, [Chapter 21.8.6](#)). Alternatively, the input can be connected to the multiple on-chip peripherals via the ALTIN signal. Where necessary, these peripherals have internal controls to select the appropriate port pin with an input multiplexer stage, and will take care of synchronization and further processing of the input signals. (See respective peripheral chapters for more details on the input selection and handling). With the Pn_IOC register ([Chapter 21.8.1](#)), it is also possible to activate an internal weak

pull-up or pull-down device in the pad.

The input register Pn_IN and ALTIN signal always represent the state of the input, independent whether the port pin is configured as input or output. This means that even if the port is in output mode, the level of the pin can be read by software via Pn_IN and/or a peripheral can use the pin level as an input.

Pad Hysteresis Control

The pad hysteresis can be configured according to the application needs via the Pad Hysteresis Control register (Pn_PHCR, [Chapter 21.8.2](#)). Selecting the appropriate pad hysteresis allows optimized pad oscillation behaviour for touch-sensing applications.

21.2.2 Output Operation

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_IOCRR register ([Chapter 21.8.1](#)), which

- enables or disables the output driver,
- selects between open-drain and push-pull mode,
- selects the general purpose or alternate function outputs.

The output multiplexer selects the signal source of the output with

- Pn_IOCRR
 - general purpose output (Pn_OUT, [Chapter 21.8.4](#))
 - alternate peripheral functions, ALT1...ALT7
- hardware control, Pn_HWSEL
 - HW0_OUT
 - HW1_OUT

Note: It is recommended to complete the Port and peripheral configuration with respect to operating mode and initial values before the port pin is switched to output mode.

The output function is exclusive, meaning that only one peripheral has control of the output path at any one time.

Used as general purpose output, software can directly modify the content of Pn_OUT to define the output value on the pin. A write operation to Pn_OUT updates all port pins of that port (e.g. P0) that are configured as general purpose output. Updating just one or a selected few general purpose output pins via Pn_OUT requires a masked read-modify-write operation to avoid disturbing pins that shall not be changed. Direct writes to Pn_OUT will also affect Pn_OUT bits configured for use with the Pin Power-save function, [Chapter 21.4](#).

Because of that, it is preferred to modify Pn_OUT bits by the Output Modification Register Pn_OMR ([Chapter 21.8.5](#)). The bits in Pn_OMR allow to individually set, clear or toggle the bits in the Pn_OUT register and only update the “addressed” Pn_OUT bits.

General Purpose I/O Ports (Ports)

The data written by software into the output register Pn_OUT can also be used as input data to an on-chip peripheral. This enables, for example, peripheral tests and simulation via software without external circuitry.

Output lines of on-chip peripherals can directly control the output value of the output driver if selected via ALT1 to ALT7 as well as HW0_OUT and HW1_OUT. After initialization, this allows the connected peripherals to directly drive complex control and communication patterns without further software interaction with the ports.

The actual logic level at the pin can be examined through reading Pn_IN and compared against the applied output level (either applied by 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 by external circuitry. In addition, software-supported arbitration schemes between different “masters” 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_B) is output, but a low level (0_B) is seen when reading the pin value via the input register Pn_IN or directly by a peripheral (via ALTIN, for example a USIC channel in IIC mode).

There are two pad types in XMC1200 providing different drive strength:

- Standard pad
- High Current pad

The assignment of each port pin to one of these pad types is listed in the Package Pin Summary table. Further details about pad properties are summarized in the Data Sheet.

21.3 Hardware Controlled I/Os

Some ports pins are overlaid with peripheral functions for which the connected peripheral needs direct hardware control, e.g. for the direction of a bi-directional data bus. There is a dedicated hardware control interface for these functions. As multiple peripherals need access to this interface, the Pn_HWSEL register ([Chapter 21.8.8](#)) allows to select between the hardware “masters”.

Depending on the operating mode, the peripheral can take control of various functions:

- Pin direction, input or output, e.g. for bi-directional signals
- Driver type, open-drain or push-pull
- Pull devices under peripheral control or under standard control via Pn_IOCR

Some configurations remain under control by the standard configuration interface, the pad hysteresis by Pn_PHCR and the direct or inverted input path by Pn_IOCR.

Pn_HWSEL.HWx just pre-assigns the hardware-control of the pin to a certain peripheral, but the peripheral itself decides when to take control over it. As long as the peripheral does not take control of a given pin via HWx_EN, the configuration of this pin is still defined by the configuration registers and it is available as GPIO or for other alternate functions. This might be because the selected peripheral has controls to just activate a subset of its pins, or because the peripheral is not active at all.

General Purpose I/O Ports (Ports)

This mechanism can also be used to prohibit the hardware control of certain pins to a peripheral, in case the application does not need the respective functionality and the peripheral has no controls to disable the hardware control selectively.

The default hardware input configuration and the pull devices are controlled by Pn_IOCR.

If configured accordingly, the LEDTS module can also control the internal pull devices and change between push-pull and open-drain output drivers. The outputs of BCCU, CCU4 and ACMP modules can be used to control the internal pull devices via direct hardware control. A detailed connectivity list of the hardware I/O and pull control of the peripherals to the port pins is given in the **Hardware Controlled I/O Function Description** chapter.

Note: Do not enable the Pin Power Save function for pins configured for Hardware Control (Pn_HWSEL.HWx != 00_B). Doing so may result in an undefined behavior of the pin when the device enters the Deep Sleep state.

21.4 Power Saving Mode Operation

In Deep-Sleep mode, the behavior of a pin depends on the setting of the Pin Power save register (Pn_PPS, **Chapter 21.8.7**). Basically, each pin can be configured to react to the Power Save Mode Request or to ignore it. In case a pin is configured to react to a Power Save Mode Request, the output driver is switched to tri-state, the input Schmitt-Trigger and the pull devices are switched off (see **Figure 21-2**). The input signal to the on-chip peripherals is optionally driven statically high or low, software-defined by a value stored in Pn_OUT or by the last input value sampled to the Pn_OUT register during normal operation. The actual reaction is configured with the Pn_IOCR register under power save conditions, see **Table 21-8**.

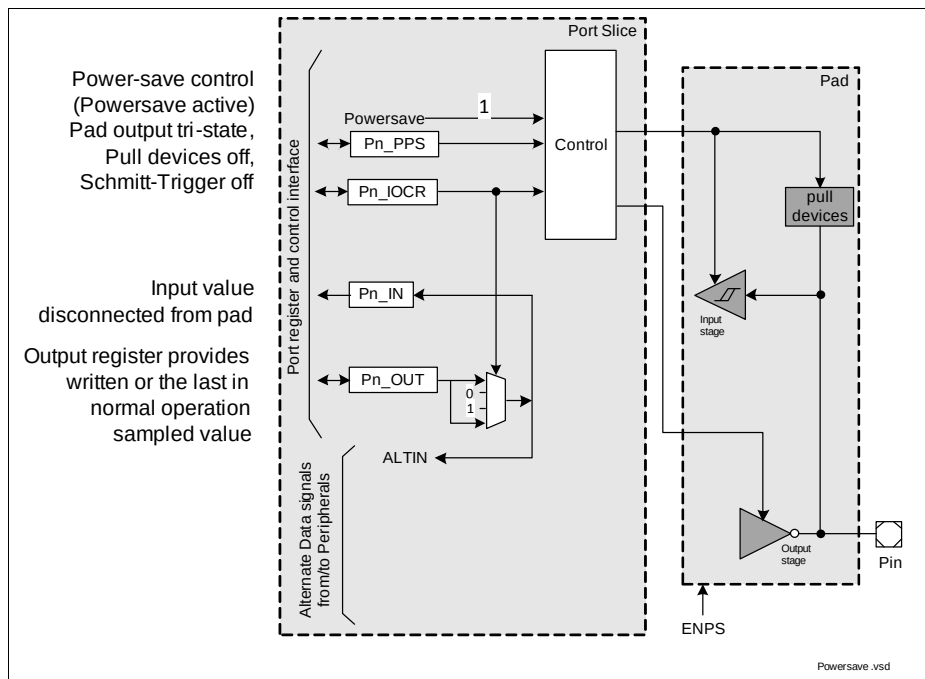


Figure 21-2 Port Pin in Power Save State

Note: Do not enable the Pin Power Save function for pins configured for Hardware Control ($Pn\_HWSEL.HWx \neq 00_B$). Doing so may result in an undefined behavior of the pin when the device enters the Deep Sleep state.

21.5 Analog Ports

P2.2 - P2.9 is the analog and digital input port with a simplified port and pad structure, see [Figure 21-3](#). The analog pads have no output drivers and the digital input Schmitt-Trigger can be controlled by the Pn_PDISC ([Chapter 21.8.3](#)) register. Accordingly, the port control interface is reduced in its functionality. The Pn_IOCRR register controls the pull devices, the optional input inversion and the input source in power-save mode. The Pn_OUT has only its power-save functionality, as described in [Chapter 21.4](#).

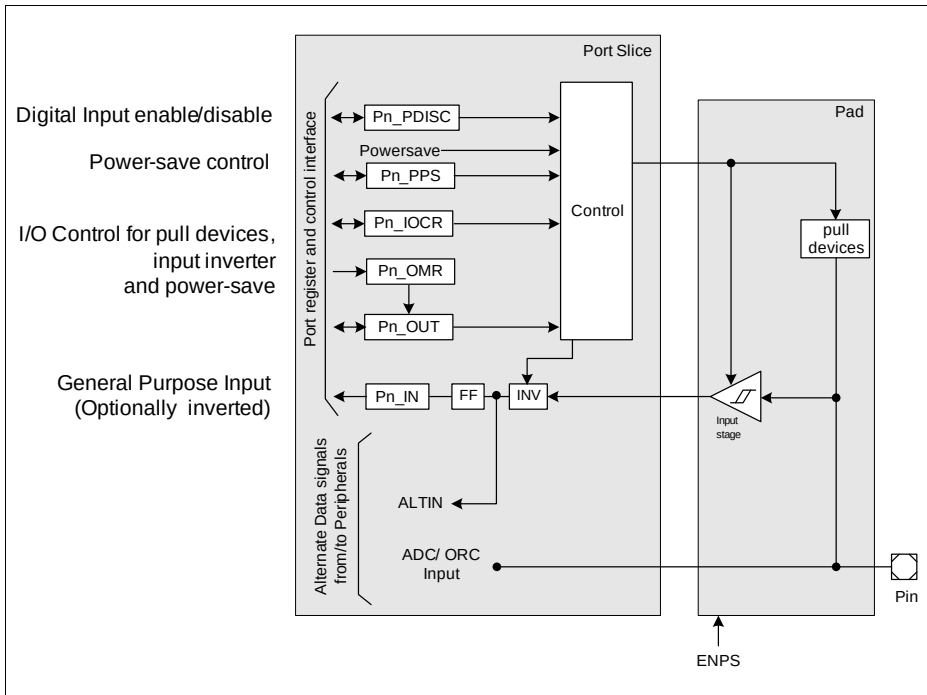


Figure 21-3 Analog Port Structure

21.6 Power, Reset and Clock

All digital I/O pads are held in a defined state, tristate, with output driver disabled and no pull devices active when one of the following occurs:

- During power-up, until V_{DDC} and V_{DDP} voltage levels are stable and within limits
- During power-fail, one or more voltage levels are outside the limits

Refer to the EVR section in the SCU chapter and Data Sheet for details on the power-up, supply monitoring and voltage limits.

All Port registers are reset with the System Reset (see Reset Control Unit chapter in the System Control Unit). The standard reset values are defined such that the port pins are configured as tri-state inputs, output driver disabled and no pull devices active. Exceptions from these standard values are related to special interfaces or the analog input channels.

All registers of the Ports are clocked with f_{MCLK} .

21.7 Initialization and System Dependencies

It is recommended to follow pre-defined routines for the initialization of the port pins.

Input

When a peripheral shall use a port pin as input, the actual pin levels may immediately trigger an unexpected peripheral event (e.g. clock edge at SPI). This can be avoided by forcing the "passive" level via pull-up/down programming.

The following steps are required to configure a port pin as an input:

- Pn_IOCR
input configuration with pull device and/or power-save mode configuration
- Pn_PHCR
pad hysteresis configuration (if applicable)
- Hardware Control (if applicable)
 - Pn_HWSEL
switch hardware control to peripheral
- Pin Power Save (if applicable)
 - Pn_OMR/Pn_OUT
default value in power save mode (if applicable)
 - Pn_PPS
enable power save control

Output

When a port pin is configured as output for an on-chip peripheral, it is important that the peripheral is configured before the port switches the control to the peripheral in order to avoid spikes on the output.

The following steps are required to configure a port pin as an output:

- Pn_OMR/Pn_OUT
Initial output value (as general purpose output)
- GPIO or Alternate Output
 - Pn_IOCR
Output multiplexer select
Push-pull or open-drain output driver mode
Activates the output driver!
- Hardware Control
 - Pn_IOCR
depending on the hardware function Pn_IOCR can enable the internal pull devices
 - Pn_HWSEL
Switch hardware control to peripheral

Transitions

If a port pin is used for different functions that require a reconfiguration of the port registers, it is recommended to do this transition via an intermediate "neutral" tri-state input configuration.

- **Pn_HWSEL**
disable hardware selection; can be omitted if no hardware control is used on the port pin
- **Pn_PPS**
disable power save mode control of the pin; can be omitted if no power save configuration is used on the port pin
- **Pn_IOCRR**
tri-state input and no pull device active

21.8 Registers

Registers Overview

The absolute register address is calculated by adding:

Module Base Address + Offset Address

Table 21-2 Registers Address Space

Module	Base Address	End Address	Note
P0	4004 0000 _H	4004 00FF _H	
P1	4004 0100 _H	4004 01FF _H	High current bi-directional pad
P2	4004 0200 _H	4004 02FF _H	Analog/Digital input and bi-directional pad

Table 21-3 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
Pn_OUT	Port n Output Register	0000 _H	U, PV	U, PV	Page 21-27
Pn_OMR	Port n Output Modification Register	0004 _H	U, PV	U, PV	Page 21-30
–	Reserved	0008 _H –000C _H	BE	BE	–
Pn_IOCRO	Port n Input/Output Control Register 0	0010 _H	U, PV	PV	Page 21-15
Pn_IOCRR4	Port n Input/Output Control Register 4	0014 _H	U, PV	PV	Page 21-16
Pn_IOCRR8	Port n Input/Output Control Register 8	0018 _H	U, PV	PV	Page 21-17
Pn_IOCRR12	Port n Input/Output Control Register 12	001C _H	U, PV	PV	Page 21-17
–	Reserved	0020 _H	BE	BE	–
Pn_IN	Port n Input Register	0024 _H	U, PV	R	Page 21-33
–	Reserved	0028 _H –003C _H	BE	BE	–

General Purpose I/O Ports (Ports)

Table 21-3 Register Overview (cont'd)

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
Pn_PHCR0	Port n Pad Hysteresis Control Register 0	0040 _H	U, PV	PV	Page 21-20
Pn_PHCR1	Port n Pad Hysteresis Control Register 1	0044 _H	U, PV	PV	Page 21-22
–	Reserved	0048 _H -005C _H	BE	BE	–
P0_PDISC P1_PDISC	Port n Pin Function Decision Control Register (non-ADC ports)	0060 _H	U, PV	BE	Page 21-24
P2_PDISC	Port n Pin Function Decision Control Register (ADC ports)	0060 _H	U, PV	PV	Page 21-25
–	Reserved	0064 _H -006C _H	BE	BE	–
Pn_PPS	Port n Pin Power Save Register	0070 _H	U, PV	PV	Page 21-35
Pn_HWSEL	Port n Hardware Select Register	0074 _H	U, PV	PV	Page 21-38
–	Reserved	0078 _H -00FC _H	BE	BE	–

General Purpose I/O Ports (Ports)

Table 21-4 Registers Access Rights and Reset Classes

Register Short Name	Access Rights		Reset Class
	Read	Write	
Pn_IN	U, PV	R	System Reset
Pn_OUT		U, PV	
Pn_OMR			
Pn_IOCRO		PV	
Pn_IOCRO4			
Pn_IOCRO8			
Pn_IOCRO12			
Pn_PDISC (ADC ports)			
Pn_PH0			
Pn_PH1			
Pn_PPS			
Pn_PDISC (non-ADC ports)		BE	

21.8.1 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=0-1)

Port n Input/Output Control Register 0

(4004 0010_H + n*100_H)

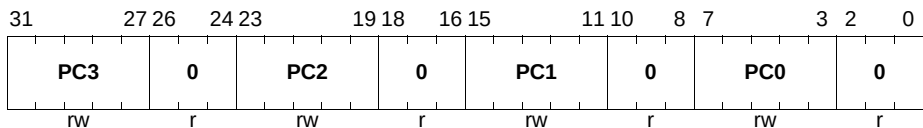
Reset Value: 0000 0000_H

P2_IOCR0

Port 2 Input/Output Control Register 0

(0010_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
PC0, PC1, PC2, PC3	[7:3], [15:11], [23:19], [31:27]	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 21-5).
0	[2:0], [10:8], [18:16], [26:24]	r	Reserved Read as 0; should be written with 0.

General Purpose I/O Ports (Ports)

P0_IOC4

Port 0 Input/Output Control Register 4

(0014_H)

Reset Value: 0000 0000_H

P2_IOC4

Port 2 Input/Output Control Register 4

(0014_H)

Reset Value: 0000 0000_H

31	27	26	24	23	19	18	16	15	11	10	8	7	3	2	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	[7:3], [15:11], [23:19], [31:27]	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 21-5).
0	[2:0], [10:8], [18:16], [26:24]	r	Reserved Read as 0; should be written with 0.

P1_IOC4

Port 1 Input/Output Control Register 4

(0014_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		PC6	0		PC5	0		PC4	0																	
					r		rw	r		rw	r		rw	r																	

Field	Bits	Type	Description
PC4, PC5, PC6	[7:3], [15:11], [23:19]	rw	Port Control for Port n Pin 4 to 6 This bit field determines the Port n line x functionality (x = 4-6) according to the coding table (see Table 21-5).

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
0	[2:0], [10:8], [18:16], [26:24], [31:27]	r	Reserved Read as 0; should be written with 0.

P0_IOC8

Port 0 Input/Output Control Register 8

(0018_H)

Reset Value: 0000 0000_H

P2_IOC8

Port 2 Input/Output Control Register 8

(0018_H)

Reset Value: 0000 0000_H

31	27	26	24	23	19	18	16	15	11	10	8	7	3	2	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	[7:3], [15:11], [23:19], [31:27]	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 21-5).
0	[2:0], [10:8], [18:16], [26:24]	r	Reserved Read as 0; should be written with 0.

P0_IOC12

Port 0 Input/Output Control Register 12

(001C_H)

Reset Value: 0000 0000_H¹⁾

31	27	26	24	23	19	18	16	15	11	10	8	7	3	2	0			
PC15			0		PC14			0		PC13			0		PC12		0	
rw			r		rw			r		rw			r		rw		r	

1) Upon reset, the value of PC14 (P0.14) is 00000_B. The Startup Software (SSW) will change the PC14 value to input pull-up device active, 00010_B. Refer to the Startup chapter for more information.

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
PC12, PC13, PC14, PC15	[7:3], [15:11], [23:19], [31:27]	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 21-5).
0	[2:0], [10:8], [18:16], [26:24]	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.

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 21-5](#) describes the coding of the PCx bit fields that determine the port line functionality.

The Pn_IOCry PCx bit field is also used to control the pin behavior in Deep-Sleep mode if the Pin Power Save option is enabled, see [Chapter 21.8.7](#).

Table 21-5 Standard PCx Coding¹⁾

PCx[4:0]	I/O	Output Characteristics	Selected Pull-up / Pull-down / Selected Output Function
0X000 _B	Direct Input	—	No internal pull device active
0X001 _B			Internal pull-down device active
0X010 _B			Internal pull-up device active
0X011 _B			No internal pull device active; Pn_OUTx continuously samples the input value
0X100 _B	Inverted Input	—	No internal pull device active
0X101 _B			Internal pull-down device active
0X110 _B			Internal pull-up device active
0X111 _B			No internal pull device active; Pn_OUTx continuously samples the input value

General Purpose I/O Ports (Ports)

Table 21-5 Standard PCx Coding¹⁾ (cont'd)

PCx[4:0]	I/O	Output Characteristics	Selected Pull-up / Pull-down / Selected Output Function
10000 _B	Output (Direct Input)	Push-pull	General-purpose output
10001 _B			Alternate output function 1
10010 _B			Alternate output function 2
10011 _B			Alternate output function 3
10100 _B			Alternate output function 4
10101 _B			Alternate output function 5
10110 _B			Alternate output function 6
10111 _B			Alternate output function 7
11000 _B		Open-drain	General-purpose output
11001 _B			Alternate output function 1
11010 _B			Alternate output function 2
11011 _B			Alternate output function 3
11100 _B			Alternate output function 4
11101 _B			Alternate output function 5
11110 _B			Alternate output function 6
11111 _B			Alternate output function 7

1) For the analog and digital input port P2.2 - P2.9, the combinations with PCx[4]=1_B is reserved.

21.8.2 Pad Hysteresis Control Register

The pad structure of the XMC1200 GPIO lines offers the possibility to select the pad hysteresis. These two parameters are controlled by the bit fields in the pad hysteresis control registers Pn_PHCR0/1, independently from input/output and pull-up/pull-down control functionality as programmed in the Pn_IOCRR register. Pn_PHCR0 and Pn_PHCR1 registers are assigned to each port.

The 1-bit pad hysteresis selection bit field PHx in the pad hysteresis control registers Pn_PHCR make it possible to select the port line functionality as shown in [Table 21-6](#). Note that the pad hysteresis control registers are specific for each port.

Table 21-6 Pad Hysteresis Selection

PHx	Functionality
0	Standard hysteresis
1	Large hysteresis

General Purpose I/O Ports (Ports)

Note: Refer to Input/Output Characteristics table in the XMC1200 Data Sheet for hysteresis parameter values.

Pad Hysteresis Control Registers

This is the general description of the PHCR registers. Each port contains its own specific PHCR registers, described additionally at each port, that can contain between one and eight PHx fields for PHCR0 and PHCR1 registers, respectively. Each field controls 1 pin. For coding of PHx, see [Page 21-19](#).

P0_PHCR0

Port 0 Pad Hysteresis Control Register 0

(0040_H)

Reset Value: 0000 0000_H

P2_PHCR0

Port 2 Pad Hysteresis Control Register 0

(0040_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PH7		0		PH6		0		PH5		0		PH4		0
r	rW		r		rW		r		rW		r		rW		r

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PH3		0		PH2		0		PH1		0		PH0		0
r	rW		r		rW		r		rW		r		rW		r

Field	Bits	Type	Description
PH0	2	rW	Pad Hysteresis for Pn.0
PH1	6	rW	Pad Hysteresis for Pn.1
PH2	10	rW	Pad Hysteresis for Pn.2
PH3	14	rW	Pad Hysteresis for Pn.3
PH4	18	rW	Pad Hysteresis for Pn.4
PH5	22	rW	Pad Hysteresis for Pn.5
PH6	26	rW	Pad Hysteresis for Pn.6
PH7	30	rW	Pad Hysteresis for Pn.7

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
0	[1:0], [5:3], [9:7], [13:11], [17:15], [21:19], [25:23], [29:27], 31	r	Reserved Read as 0; should be written with 0.

P1_PHCR0

Port 1 Pad Hysteresis Control Register 0

(0040_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0					PH6	0			PH5	0			PH4	0	
r					rw	r			rw	r			rw	r	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PH3	0			PH2	0			PH1	0			PH0	0	
r	rw	r			rw	r			rw	r			rw	r	

Field	Bits	Type	Description
PH0	2	rw	Pad Hysteresis for P1.0
PH1	6	rw	Pad Hysteresis for P1.1
PH2	10	rw	Pad Hysteresis for P1.2
PH3	14	rw	Pad Hysteresis for P1.3
PH4	18	rw	Pad Hysteresis for P1.4
PH5	22	rw	Pad Hysteresis for P1.5
PH6	26	rw	Pad Hysteresis for P1.6

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
0	[1:0], [5:3], [9:7], [13:11], [17:15], [21:19], [25:23], [31:27]	r	Reserved Read as 0; should be written with 0.

P0_PHCR1

Port 0 Pad Hysteresis Control Register 1

(0044_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0	PH1 5		0		PH1 4		0		PH1 3		0		PH1 2		0
r	rW		r		rW		r		rW		r		rW		r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	PH1 1		0		PH1 0		0		PH9		0		PH8		0
r	rW		r		rW		r		rW		r		rW		r

Field	Bits	Type	Description
PH8	2	rW	Pad Hysteresis for P0.8
PH9	6	rW	Pad Hysteresis for P0.9
PH10	10	rW	Pad Hysteresis for P0.10
PH11	14	rW	Pad Hysteresis for P0.11
PH12	18	rW	Pad Hysteresis for P0.12
PH13	22	rW	Pad Hysteresis for P0.13
PH14	26	rW	Pad Hysteresis for P0.14
PH15	30	rW	Pad Hysteresis for P0.15

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
0	[1:0], [5:3], [9:7], [13:11], [17:15], [21:19], [25:23], [29:27], 31	r	Reserved Read as 0; should be written with 0.

P2_PHCR1

Port 2 Pad Hysteresis Control Register 1

(0044_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	PH1 1	0		PH1 0		0		PH9		0		PH8		0	
r	rW	r		rW		r		rW		r		rW		r	

Field	Bits	Type	Description
PH8	2	rW	Pad Hysteresis for P2.8
PH9	6	rW	Pad Hysteresis for P2.9
PH10	10	rW	Pad Hysteresis for P2.10
PH11	14	rW	Pad Hysteresis for P2.11
0	[1:0], [5:3], [9:7], [13:11], [31:15]	r	Reserved Read as 0; should be written with 0.

21.8.3 Pin Function Decision Control Register

Pin Function Decision Control Register

The primary use for this register is to disable/enable the digital pad structure in shared analog and digital ports, see the dedicated description for [P2_PDISC](#).

For “normal” digital I/O ports (P0-P1) this register is read-only and the read value corresponds to the available pins in the given package.

P0_PDISC

Port 0 Pin Function Decision Control Register (0060_H)

Reset Value: 0000 XXXX_H¹⁾

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
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
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

1) The reset value is package dependent.

Field	Bits	Type	Description
PDISx (x = 0-15)	x	r	Pad Disable for Port 0 Pin x 0 _B Pad P0.x is enabled. 1 _B Pad P0.x is disabled.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

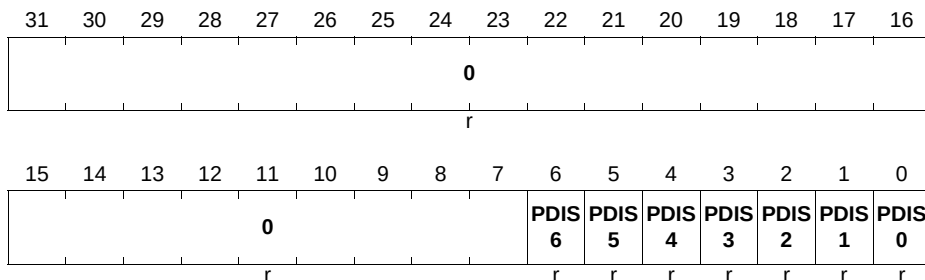
General Purpose I/O Ports (Ports)

P1_PDISC

Port 1 Pin Function Decision Control Register

(0060_H)

Reset Value: 0000 00XX_H¹⁾



1) The reset value is package dependent.

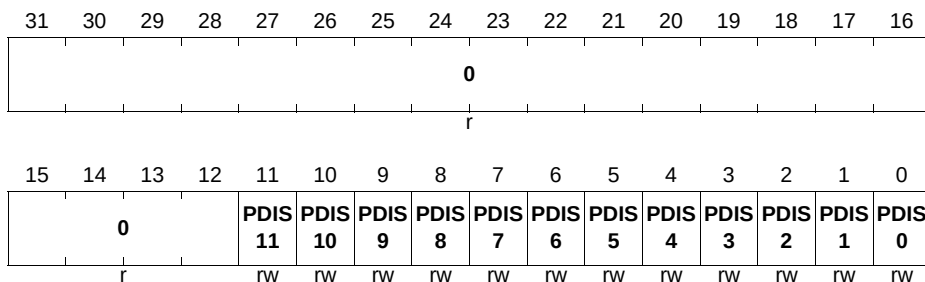
Field	Bits	Type	Description
PDISx (x = 0-6)	x	r	Pad Disable for Port 1 Pin x 0 _B Pad P1.x is enabled. 1 _B Pad P1.x is disabled.
0	[31:7]	r	Reserved Read as 0; should be written with 0.

P2_PDISC

Port 2 Pin Function Decision Control Register

(0060_H)

Reset Value: 0000 0XXX_H¹⁾



1) The reset value is package dependent.

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
PDIS0, PDIS1	0, 1	rw	Pad Disable for Port 2 Pin 0 to 1 This bit disables or enables the digital pad function. 0 _B Digital Pad input is enabled. Analog and digital input/output path active. 1 _B Digital Pad input is disabled. Analog input path active. (default)
PDISx (x = 2-9)	x	rw	Pad Disable for Port 2 Pin 2 to 9 This bit disables or enables the digital pad function. 0 _B Digital Pad input is enabled. Analog and digital input path active. 1 _B Digital Pad is disabled. Analog input path active. (default)
PDIS10, PDIS11	10, 11	rw	Pad Disable for Port 2 Pin 10 to 11 This bit disables or enables the digital pad function. 0 _B Digital Pad input is enabled. Analog and digital input/output path active. 1 _B Digital Pad input is disabled. Analog input path active. (default)
0	[31:12]	r	Reserved Read as 0; should be written with 0.

21.8.4 Port Output Register

The port output register determines the value of a GPIO pin when it is selected by Pn_IOC Rx as output. Writing a 0 to a Pn_OUT.Px (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.Px can be individually set/reset by writing appropriate values into the port output modification register Pn_OMR, avoiding read-modify-write operations on the Pn_OUT, which might affect other pins of the port.

The Pn_OUT is also used to store/drive a defined value for the input in Deep-Sleep mode. For details on this, see the [Port Pin Power Save Register](#). That is also the only use of the Pn_OUT register in the analog and digital input port P2.2 - P2.9.

P0_OUT

Port 0 Output Register

(0000_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
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 0 Output Bit x This bit determines the level at the output pin P0.x if the output is selected as GPIO output. 0 _B The output level of P0.x is 0. 1 _B The output level of P0.x is 1. P0.x can also be set/reset by control bits of the P0_OMR register.
0	[31:16]	r	Reserved Read as 0; should be written with 0.

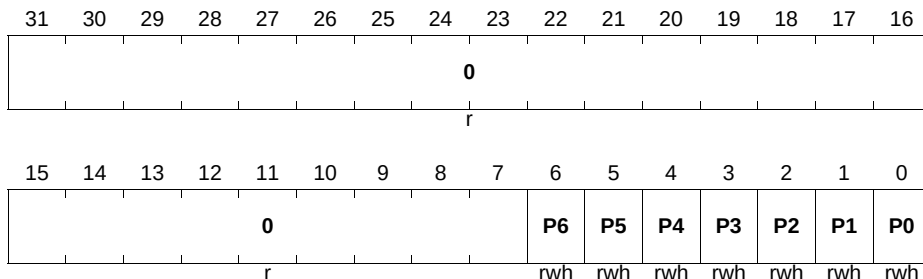
General Purpose I/O Ports (Ports)

P1_OUT

Port 1 Output Register

(0000_H)

Reset Value: 0000 0000_H



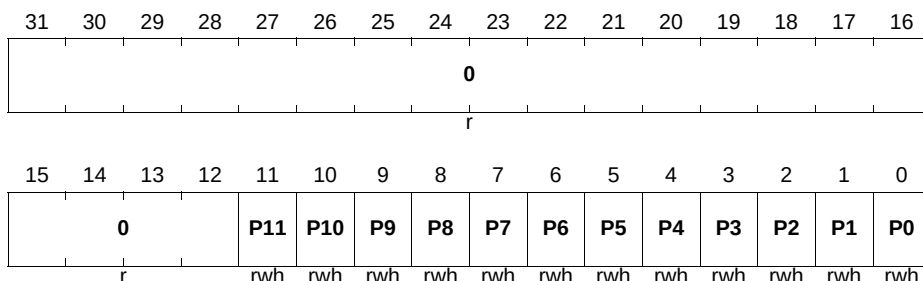
Field	Bits	Type	Description
Px (x = 0-6)	x	rwh	Port 1 Output Bit x This bit determines the level at the output pin P1.x if the output is selected as GPIO output. 0 _B The output level of P1.x is 0. 1 _B The output level of P1.x is 1. P1.x can also be set/reset by control bits of the P1_OMR register.
0	[31:7]	r	Reserved Read as 0; should be written with 0.

P2_OUT

Port 2 Output Register

(0000_H)

Reset Value: 0000 0000_H



General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
Px (x = 0-11)	x	rwh	Port 2 Output Bit x This bit determines the level at the output pin P2.x if the output is selected as GPIO output. 0 _B The output level of P2.x is 0. 1 _B The output level of P2.x is 1. P2.x can also be set/reset by control bits of the P2_OMR register.
0	[31:12]	r	Reserved Read as 0; should be written with 0.

21.8.5 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.

P0_OMR

Port 0 Output Modification Register

(0004_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PR1	PR1	PR1	PR1	PR1	PR1	PR9	PR8	PR7	PR6	PR5	PR4	PR3	PR2	PR1	PR0
5	4	3	2	1	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
PS15	PS14	PS13	PS12	PS11	PS10	PS9	PS8	PS7	PS6	PS5	PS4	PS3	PS2	PS1	PS0
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 0 Set Bit x Setting this bit will set or toggle the corresponding bit in the port output register P0_OUT. The function of this bit is shown in Table 21-7 .
PRx (x = 0-15)	x + 16	w	Port 0 Reset Bit x Setting this bit will reset or toggle the corresponding bit in the port output register P0_OUT. The function of this bit is shown in Table 21-7 .

General Purpose I/O Ports (Ports)

P1_OMR

Port 1 Output Modification 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									PR6	PR5	PR4	PR3	PR2	PR1	PR0
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									PS6	PS5	PS4	PS3	PS2	PS1	PS0
r									w	w	w	w	w	w	w

Field	Bits	Type	Description
PSx (x = 0-6)	x	w	Port 1 Set Bit x Setting this bit will set or toggle the corresponding bit in the port output register P1_OUT. The function of this bit is shown in Table 21-7 .
PRx (x = 0-6)	x + 16	w	Port 1 Reset Bit x Setting this bit will reset or toggle the corresponding bit in the port output register P1_OUT. The function of this bit is shown in Table 21-7 .
0	[15:7], [31:23]	r	Reserved Read as 0; should be written with 0.

P2_OMR

Port 2 Output Modification 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				PR1 1	PR1 0	PR9	PR8	PR7	PR6	PR5	PR4	PR3	PR2	PR1	PR0
r				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				PS11	PS10	PS9	PS8	PS7	PS6	PS5	PS4	PS3	PS2	PS1	PS0
r				w	w	w	w	w	w	w	w	w	w	w	w

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
PSx (x = 0-11)	x	w	Port 2 Set Bit x Setting this bit will set or toggle the corresponding bit in the port output register P2_OUT. The function of this bit is shown in Table 21-7 .
PRx (x = 0-11)	x + 16	w	Port 2 Reset Bit x Setting this bit will reset or toggle the corresponding bit in the port output register P2_OUT. The function of this bit is shown in Table 21-7 .
0	[15:12], [31:28]	r	Reserved Read as 0; should be written with 0.

Note: Register Pn_OMR is virtual and does not contain any flip-flop. A read action delivers the value of 0. A 8 or 16-bits write behaves like a 32-bit write padded with zeros.

Table 21-7 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.

21.8.6 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, synchronized to avoid meta-stabilities, independently whether the pin is selected as input or output.

P0_IN

Port 0 Input Register

(0024_H)

Reset Value: 0000 XXXX_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
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

Field	Bits	Type	Description
Px (x = 0-15)	x	rh	Port 0 Input Bit x This bit indicates the level at the input pin P0.x. 0 _B The input level of P0.x is 0. 1 _B The input level of P0.x is 1.
0	[31:16]	r	Reserved Read as 0.

P1_IN

Port 1 Input Register

(0024_H)

Reset Value: 0000 00XX_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									P6	P5	P4	P3	P2	P1	P0
r									rh	rh	rh	rh	rh	rh	rh

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
Px (x = 0-6)	x	rh	Port 1 Input Bit x This bit indicates the level at the input pin P1.x. 0 _B The input level of P1.x is 0. 1 _B The input level of P1.x is 1.
0	[31:7]	r	Reserved Read as 0.

P2_IN

Port 2 Input Register (0024_H) **Reset Value: 0000 0XXX_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				P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0
r				rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh	rh

Field	Bits	Type	Description
Px (x = 0-11)	x	rh	Port 2 Input Bit x This bit indicates the level at the input pin P2.x. 0 _B The input level of P2.x is 0. 1 _B The input level of P2.x is 1.
0	[31:12]	r	Reserved Read as 0.

21.8.7 Port Pin Power Save Register

When the XMC1200 enters Deep-Sleep mode, pins with enabled Pin Power Save option are set to a defined state and the input Schmitt-Trigger as well as the output driver stage are switched off.

Note: Do not enable the Pin Power Save function for pins configured for Hardware Control (Pn_HWSEL.HWx != 00_B). Doing so may result in an undefined behavior of the pin when the device enters the Deep Sleep state.

P0_PPS

Port 0 Pin Power Save Register

(0070_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
PPS 15	PPS 14	PPS 13	PPS 12	PPS 11	PPS 10	PPS 9	PPS 8	PPS 7	PPS 6	PPS 5	PPS 4	PPS 3	PPS 2	PPS 1	PPS 0
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Field	Bits	Type	Description
PPSx (x = 0-15)	x	rW	Port 0 Pin Power Save Bit x 0 _B Pin Power Save of P0.x is disabled. 1 _B Pin Power Save of P0.x is enabled.
0	[31:16]	r	Reserved Read as 0.

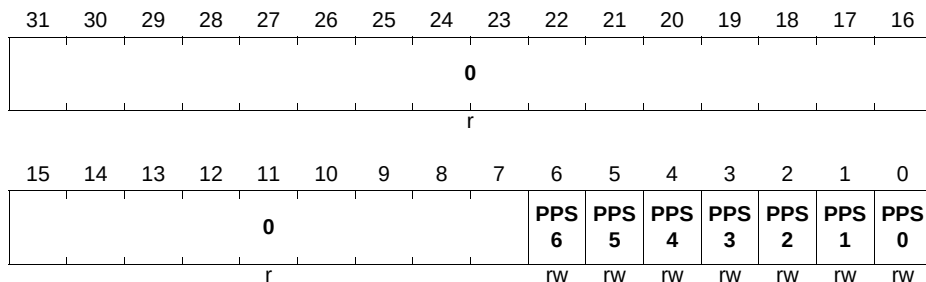
General Purpose I/O Ports (Ports)

P1_PPS

Port 1 Pin Power Save Register

(0070_H)

Reset Value: 0000 0000_H



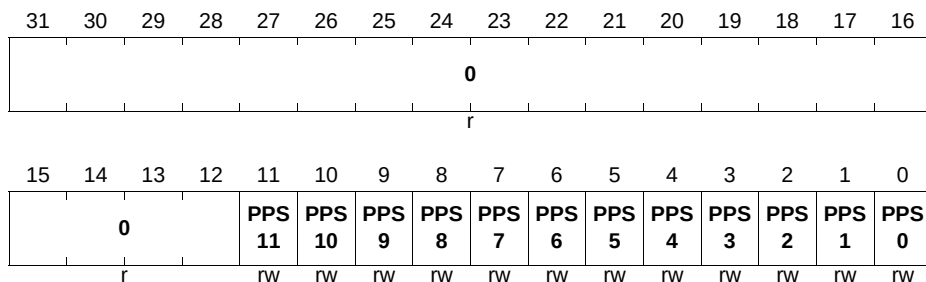
Field	Bits	Type	Description
PPS_x (x = 0-6)	x	rw	Port 1 Pin Power Save Bit x 0 _B Pin Power Save of P1.x is disabled. 1 _B Pin Power Save of P1.x is enabled.
0	[31:7]	r	Reserved Read as 0.

P2_PPS

Port 2 Pin Power Save Register

(0070_H)

Reset Value: 0000 0000_H



General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
PPSx (x = 0-11)	x	rw	Port 2 Pin Power Save Bit x 0 _B Pin Power Save of P2.x is disabled. 1 _B Pin Power Save of P2.x is enabled.
0	[31:12]	r	Reserved Read as 0.

Deep-Sleep Pin Power Save behavior

The actual behavior in Deep-Sleep mode with enabled Pin Power Save is controlled by the Pn_IOCry.PCx bit field ([Page 21-15](#)) of the respective pin. [Table 21-8](#) shows the coding.

Table 21-8 PCx Coding in Deep-Sleep mode

PCx[4:0]	I/O	Normal Operation or PPSx=0 _B	Deep-Sleep mode and PPSx=1 _B
0X000 _B	Direct Input	See Table 21-5	Input value=Pn_OUTx
0X001 _B			Input value=0 _B ; pull-down deactivated
0X010 _B			Input value=1 _B ; pull-up deactivated
0X011 _B			Input value=Pn_OUTx, storing the last sampled input value
0X100 _B	Inverted Input	See Table 21-5	Input value= $\overline{\text{Pn\_OUTx}}$
0X101 _B			Input value=1 _B ; pull-down deactivated
0X110 _B			Input value=0 _B ; pull-up deactivated
0X111 _B			Input value= $\overline{\text{Pn\_OUTx}}$, storing the last sampled input value
1XXXX _B	Output	See Table 21-5	Output driver off, Input Schmitt-Trigger off, no pull device active, Input value=Pn_OUTx

21.8.8 Port Pin Hardware Select Register

Some peripherals require direct hardware control of their I/Os. As multiple such peripheral I/Os are mapped on some pins, the register Pn_HWSEL is used to select which peripheral has the control over the pin.

Note: Pn_HWSEL.HWx just pre-assigns the hardware-control of the pin to a certain peripheral, but the peripheral itself decides when to take control over it. As long as the peripheral does not take control of a given pin via HWx_EN, the configuration of this pin is still defined by the configuration registers and it is available as GPIO or for other alternate functions. This might be because the selected peripheral has provisions to just activate a subset of its pins, or because the peripheral is not active at all.

This mechanism can also be used to prohibit the hardware control of certain pins to a peripheral, in case the application does not need the respective functionality and the peripheral has no provisions to disable the hardware control selectively.

P0_HWSEL

Port 0 Pin Hardware Select Register (0074_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
HW15		HW14		HW13		HW12		HW11		HW10		HW9		HW8	
rw		rw		rw		rw		rw		rw		rw		rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
HW7		HW6		HW5		HW4		HW3		HW2		HW1		HW0	
rw		rw		rw		rw		rw		rw		rw		rw	

Field	Bits	Type	Description
HWx (x = 0-15)	[2*x+1: 2*x]	rw	Port 0 Pin Hardware Select Bit x 00 _B Software control only. 01 _B HW0 control path can override the software configuration. 10 _B HW1 control path can override the software configuration. 11 _B Reserved.

General Purpose I/O Ports (Ports)

P1_HWSEL

Port 1 Pin Hardware Select Register (0074_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	HW6		HW5		HW4		HW3		HW2		HW1		HW0		
r	rw		rw		rw		rw		rw		rw		rw		

Field	Bits	Type	Description
HWx (x = 0-6)	[2*x+1: 2*x]	rw	Port 1 Pin Hardware Select Bit x 00 _B Software control only. 01 _B HW0 control path can override the software configuration. 10 _B HW1 control path can override the software configuration. 11 _B Reserved.
0	[31:14]	r	Reserved Read as 0; should be written with 0.

P2_HWSEL

Port 2 Pin Hardware Select Register (0074_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0								HW11		HW10		HW9		HW8	
r								rw		rw		rw		rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
HW7		HW6		HW5		HW4		HW3		HW2		HW1		HW0	
rw		rw		rw		rw		rw		rw		rw		rw	

General Purpose I/O Ports (Ports)

Field	Bits	Type	Description
HWx (x = 0-11)	[2*x+1: 2*x]	rw	Port 2 Pin Hardware Select Bit x 00 _B Software control only. 01 _B HW0 control path can override the software configuration. 10 _B HW1 control path can override the software configuration. 11 _B Reserved.
0	[31:24]	r	Reserved Read as 0; should be written with 0.

21.9 Package Pin Summary

The following general building block is used to describe each pin:

Table 21-9 Package Pin Mapping Description

Function	Package A	Package B	...	Pad Type
Px.y	N	N		Pad Class

The table is sorted by the “Function” column, starting with the regular Port pins (Px.y), followed by the supply pins.

The following columns, titled with the supported package variants, lists the package pin number to which the respective function is mapped in that package.

The “Pad Type” indicates the employed pad type:

- STD_INOUT (standard bi-directional pads)
- STD_INOUT/AN (standard bi-directional pads with analog input)
- High Current (high current bi-directional pads)
- STD_IN/AN (standard input pads with analog input)
- Power (power supply)

Details about the pad properties are defined in the Datasheet.

Table 21-10 Package Pin Mapping

Function	VQFN 40	TSSOP 38	TSSOP 28	VQFN 24	TSSOP 16	Pad Type	Notes
P0.0	23	17	13	15	7	STD_INOUT	
P0.1	24	18	-	-	-	STD_INOUT	
P0.2	25	19	-	-	-	STD_INOUT	
P0.3	26	20	-	-	-	STD_INOUT	
P0.4	27	21	14	-	-	STD_INOUT	
P0.5	28	22	15	16	8	STD_INOUT	
P0.6	29	23	16	17	9	STD_INOUT	

General Purpose I/O Ports (Ports)
Table 21-10 Package Pin Mapping

Function	VQFN 40	TSSOP 38	TSSOP 28	VQFN 24	TSSOP 16	Pad Type	Notes
P0.7	30	24	17	18	10	STD_INO UT	
P0.8	33	27	18	19	11	STD_INO UT	
P0.9	34	28	19	20	12	STD_INO UT	
P0.10	35	29	20	-	-	STD_INO UT	
P0.11	36	30	-	-	-	STD_INO UT	
P0.12	37	31	21	21	-	STD_INO UT	
P0.13	38	32	22	22	-	STD_INO UT	
P0.14	39	33	23	23	13	STD_INO UT	
P0.15	40	34	24	24	14	STD_INO UT	
P1.0	22	16	12	14	-	High Current	
P1.1	21	15	11	13	-	High Current	
P1.2	20	14	10	12	-	High Current	
P1.3	19	13	9	11	-	High Current	
P1.4	18	12	-	-	-	High Current	
P1.5	17	11	-	-	-	High Current	
P1.6	16	-	-	-	-	STD_INO UT	
P2.0	1	35	25	1	15	STD_INO UT/AN	

General Purpose I/O Ports (Ports)
Table 21-10 Package Pin Mapping

Function	VQFN 40	TSSOP 38	TSSOP 28	VQFN 24	TSSOP 16	Pad Type	Notes
P2.1	2	36	26	2	-	STD_INO UT/AN	
P2.2	3	37	27	3	-	STD_IN/A N	
P2.3	4	38	-	-	-	STD_IN/A N	
P2.4	5	1	-	-	-	STD_IN/A N	
P2.5	6	2	28	-	-	STD_IN/A N	
P2.6	7	3	1	4	16	STD_IN/A N	
P2.7	8	4	2	5	1	STD_IN/A N	
P2.8	9	5	3	5	1	STD_IN/A N	
P2.9	10	6	4	6	2	STD_IN/A N	
P2.10	11	7	5	7	3	STD_INO UT/AN	
P2.11	12	8	6	8	4	STD_INO UT/AN	
VSS	13	9	7	9	5	Power	Supply GND, ADC reference GND
VDD	14	10	8	10	6	Power	Supply VDD, ADC reference voltage/ ORC reference voltage
VDDP	15	10	8	10	6	Power	When VDD is supplied, VDDP has to be supplied with the same voltage.

General Purpose I/O Ports (Ports)

Table 21-10 Package Pin Mapping

Function	VQFN 40	TSSOP 38	TSSOP 28	VQFN 24	TSSOP 16	Pad Type	Notes
VSSP	31	25	-	-	-	Power	I/O port ground
VDDP	32	26	-	-	-	Power	I/O port supply
VSSP	Exp. Pad	-	-	Exp. Pad	-	Power	Exposed Die Pad The exposed die pad is connected internally to VSSP. For proper operation, it is mandatory to connect the exposed pad to the board ground. For thermal aspects, please refer to the Package and Reliability chapter.

21.10 Port I/O Functions

21.10.1 Port Pin for Boot Modes

Port functions can be overruled by the boot mode selected. The type of boot mode is selected via BMI. [Table 21-11](#) shows the port pins used for the various boot modes.

Table 21-11 Port Pin for Boot Modes

Pin	Boot	Boot Description
P0.13	CS(O)	SSC BSL mode
P0.14	SWDIO_0	Debug mode (SWD)
	SPD_0	Debug mode (SPD)
	RX/TX	ASC BSL half-duplex mode
	RX	ASC BSL full-duplex mode
	SCLK(O)	SSC BSL mode
P0.15	SWDCLK_0	Debug mode (SWD)
	TX	ASC BSL full-duplex mode
	DATA(I/O)	SSC BSL mode
P1.2	SWDCLK_1	Debug mode (SWD)
	TX	ASC BSL full-duplex mode
P1.3	SWDIO_1	Debug mode (SWD)
	SPD_1	Debug mode (SPD)
	RX/TX	ASC BSL half-duplex mode
	RX	ASC BSL full-duplex mode

21.10.2 Port I/O Function Description

The following general building block is used to describe the I/O functions of each PORT pin:

Table 21-12 Port I/O Function Description

Function	Outputs		Inputs	
	ALT1	ALTn	Input	Input
P0.0		MODA.OUT	MODC.INA	
Pn.y	MODA.OUT		MODA.INA	MODC.INB

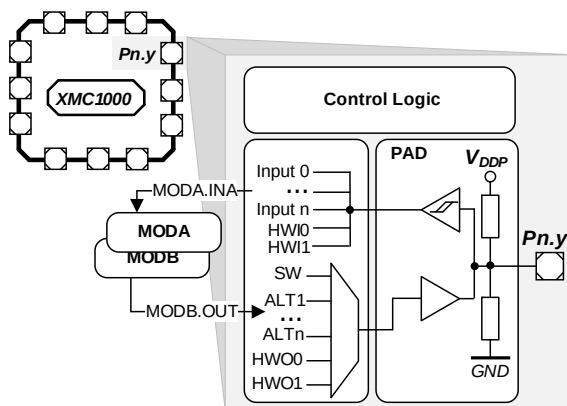


Figure 21-4 Simplified Port Structure

Pn.y is the port pin name, defining the control and data bits/registers associated with it. As GPIO, the port is under software control. Its input value is read via Pn_IN.y, Pn_OUT defines the output value.

Up to seven alternate output functions (ALT1/2/3/4/5/6/7) can be mapped to a single port pin, selected by Pn_IOC.R.PC. The output value is directly driven by the respective module, with the pin characteristics controlled by the port registers (within the limits of the connected pad).

The port pin input can be connected to multiple peripherals. Most peripherals have an input multiplexer to select between different possible input sources.

The input path is also active while the pin is configured as output. This allows to feedback an output to on-chip resources without wasting an additional external pin.

Please refer to the [Port I/O Functions](#) table for the complete Port I/O function mapping.

21.10.3 Hardware Controlled I/O Function Description

The following general building block is used to describe the hardware I/O and pull control functions of each PORT pin:

Table 21-13 Hardware Controlled I/O Function Description

Function	Outputs	Inputs	Pull Control	
	HWO0	HWI0	HW0_PD	HW0_PU
P0.0	MODB.OUT	MODB.INA		
Pn.y			MODC.OUT	MODC.OUT

By Pn_HWSEL ([Chapter 21.8.8](#)) it is possible to select between different hardware “masters” (HWO0/HWI0, HWO1/HWI1). The selected peripheral can take control of the pin(s). Hardware control overrules settings in the respective port pin registers. Additional hardware signals HW0_PD/HW1_PD and HW0_PU/HW1_PU controlled by the peripherals can be used to control the pull devices of the pin.

Please refer to the [Hardware Controlled I/O Functions](#) table for the complete hardware I/O and pull control function mapping.

Table 21-14 Port I/O Functions

Function	Outputs							Inputs							
	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	Input	Input	Input	Input	Input	Input	Input	Input
P0.0	ERU0. P0OUT0	LEDTS0. LINE7	ERU0. GOUT0	CCU40. OUT0		USIC0_CH 0.SELO0	USIC0_CH 1.SELO0	BCCU0. TRAPINB	CCU40.IN0 C			USIC0_CH 0.DX2A	USIC0_CH 1.DX2A		
P0.1	ERU0. P0OUT1	LEDTS0. LINE6	ERU0. GOUT1	CCU40. OUT1		BCCU0. OUT8	SCU. VDROP		CCU40.IN1 C						
P0.2	ERU0. P0OUT2	LEDTS0. LINE5	ERU0. GOUT2	CCU40. OUT2		VADC0. EMUX02			CCU40.IN2 C						
P0.3	ERU0. P0OUT3	LEDTS0. LINE4	ERU0. GOUT3	CCU40. OUT3		VADC0. EMUX01			CCU40.IN3 C						
P0.4	BCCU0. OUT0	LEDTS0. LINE3	LEDTS0. COL3	CCU40. OUT1		VADC0. EMUX00	WWDT. SERVICE_ OUT								
P0.5	BCCU0. OUT1	LEDTS0. LINE2	LEDTS0. COL2	CCU40. OUT0		ACMP2. OUT									
P0.6	BCCU0. OUT2	LEDTS0. LINE1	LEDTS0. COL1	CCU40. OUT0		USIC0_CH 1.MCLKOU T	USIC0_CH 1.DOUT0		CCU40.IN0 B			USIC0_CH 1.DX0C			
P0.7	BCCU0. OUT3	LEDTS0. LINE0	LEDTS0. COL0	CCU40. OUT1		USIC0_CH 0.SCLKOU T	USIC0_CH 1.DOUT0		CCU40.IN1 B			USIC0_CH 0.DX1C	USIC0_CH 1.DX0D	USIC0_CH 1.DX1C	
P0.8	BCCU0. OUT4	LEDTS1. LINE0	LEDTS0. COLA	CCU40. OUT2		USIC0_CH 0.SCLKOU T	USIC0_CH 1.SCLKOU T		CCU40.IN2 B			USIC0_CH 0.DX1B	USIC0_CH 1.DX1B		
P0.9	BCCU0. OUT5	LEDTS1. LINE1	LEDTS0. COL6	CCU40. OUT3		USIC0_CH 0.SELO0	USIC0_CH 1.SELO0		CCU40.IN3 B			USIC0_CH 0.DX2B	USIC0_CH 1.DX2B		
P0.10	BCCU0. OUT6	LEDTS1. LINE2	LEDTS0. COL5	ACMP0. OUT		USIC0_CH 0.SELO1	USIC0_CH 1.SELO1					USIC0_CH 0.DX2C	USIC0_CH 1.DX2C		
P0.11	BCCU0. OUT7	LEDTS1. LINE3	LEDTS0. COL4	USIC0_CH 0.MCLKOU T		USIC0_CH 0.SELO2	USIC0_CH 1.SELO2					USIC0_CH 0.DX2D	USIC0_CH 1.DX2D		
P0.12	BCCU0. OUT6	LEDTS1. LINE4	LEDTS0. COL3	LEDTS1. COL3		USIC0_CH 0.SELO3		BCCU0. TRAPINA	CCU40.IN0 A	CCU40.IN1 A	CCU40.IN2 A	CCU40.IN3 A	USIC0_CH 0.DX2E		
P0.13	WWDT. SERVICE_ OUT	LEDTS1. LINE5	LEDTS0. COL2	LEDTS1. COL2		USIC0_CH 0.SELO4						USIC0_CH 0.DX2F			
P0.14	BCCU0. OUT7	LEDTS1. LINE6	LEDTS0. COL1	LEDTS1. COL1		USIC0_CH 0.DOUT0	USIC0_CH 0.SCLKOU T					USIC0_CH 0.DX0A	USIC0_CH 0.DX1A		

Table 21-14 Port I/O Functions (cont'd)

Function	Outputs							Inputs							
	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	Input	Input	Input	Input	Input	Input	Input	Input
P0.15	BCCU0. OUT8	LEDTS1. LINE7	LEDTS0. COL0	LEDTS1. COL0		USIC0_CH 0.DOUT0	USIC0_CH 1.MCLKOUT					USIC0_CH 0.DX0B			
P1.0	BCCU0. OUT0	CCU40. OUT0	LEDTS0. COL0	LEDTS1. COLA		ACMP1. OUT	USIC0_CH 0.DOUT0					USIC0_CH 0.DX0C			
P1.1	VADC0. EMUX00	CCU40. OUT1	LEDTS0. COL1	LEDTS1. COL0		USIC0_CH 0.DOUT0	USIC0_CH 1.SELO0					USIC0_CH 0.DX0D	USIC0_CH 0.DX1D	USIC0_CH 1.DX2E	
P1.2	VADC0. EMUX01	CCU40. OUT2	LEDTS0. COL2	LEDTS1. COL1		ACMP2. OUT	USIC0_CH 1.DOUT0					USIC0_CH 1.DX0B			
P1.3	VADC0. EMUX02	CCU40. OUT3	LEDTS0. COL3	LEDTS1. COL2		USIC0_CH 1.SCLKOUT	USIC0_CH 1.DOUT0					USIC0_CH 1.DX0A	USIC0_CH 1.DX1A		
P1.4	VADC0. EMUX10	USIC0_CH 1.SCLKOUT	LEDTS0. COL4	LEDTS1. COL3		USIC0_CH 0.SELO0	USIC0_CH 1.SELO1					USIC0_CH 0.DX5E	USIC0_CH 1.DX5E		
P1.5	VADC0. EMUX11	USIC0_CH 0.DOUT0	LEDTS0. COLA	BCCU0. OUT1		USIC0_CH 1.SELO1	USIC0_CH 1.SELO2					USIC0_CH 1.DX5F			
P1.6	VADC0. EMUX12	USIC0_CH 1.DOUT0	LEDTS0. COL5	USIC0_CH 0.SCLKOUT	BCCU0. OUT2	USIC0_CH 0.SELO2	USIC0_CH 1.SELO3			USIC0_CH 0.DX5F					
P2.0	ERU0. PDUOT3	CCU40. OUT0	ERU0. GOUT3	LEDTS1. COL5		USIC0_CH 0.DOUT0	USIC0_CH 0.SCLKOUT		VADC0. G0CH5		ERU0.0B0	USIC0_CH 0.DX0E	USIC0_CH 0.DX1E	USIC0_CH 1.DX2F	
P2.1	ERU0. PDUOT2	CCU40. OUT1	ERU0. GOUT2	LEDTS1. COL6		USIC0_CH 0.DOUT0	USIC0_CH 1.SCLKOUT	ACMP2.INP	VADC0. G0CH6		ERU0.1B0	USIC0_CH 0.DX0F	USIC0_CH 1.DX3A	USIC0_CH 1.DX4A	
P2.2								ACMP2.INN	VADC0. G0CH7		ERU0.0B1	USIC0_CH 0.DX3A	USIC0_CH 0.DX4A	USIC0_CH 1.DX5A	ORC0.AIN
P2.3									VADC0. G1CH5		ERU0.1B1	USIC0_CH 0.DX5B	USIC0_CH 1.DX3C	USIC0_CH 1.DX4C	ORC1.AIN
P2.4									VADC0. G1CH6		ERU0.0A1	USIC0_CH 0.DX3B	USIC0_CH 0.DX4B	USIC0_CH 1.DX5B	ORC2.AIN
P2.5									VADC0. G1CH7		ERU0.1A1	USIC0_CH 0.DX5D	USIC0_CH 1.DX3E	USIC0_CH 1.DX4E	ORC3.AIN
P2.6								ACMP1.INN	VADC0. G0CH0		ERU0.2A1	USIC0_CH 0.DX3E	USIC0_CH 0.DX4E	USIC0_CH 1.DX5D	ORC4.AIN
P2.7								ACMP1.INP	VADC0. G1CH1		ERU0.3A1	USIC0_CH 0.DX5C	USIC0_CH 1.DX3D	USIC0_CH 1.DX4D	ORC5.AIN

Table 21-14 Port I/O Functions (cont'd)

Function	Outputs							Inputs							
	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	Input	Input	Input	Input	Input	Input	Input	Input
P2.8								ACMP0.INN	VADC0.G0CH1	VADC0.G1CH0	ERU0.3B1	USIC0_CH0.DX3D	USIC0_CH0.DX4D	USIC0_CH1.DX5C	ORC6.AIN
P2.9								ACMP0.INP	VADC0.G0CH2	VADC0.G1CH4	ERU0.3B0	USIC0_CH0.DX5A	USIC0_CH1.DX3B	USIC0_CH1.DX4B	ORC7.AIN
P2.10	ERU0.PDOUT1	CCU40.OUT2	ERU0.GOUT1	LEDTS1.COL4		ACMP0.OUT	USIC0_CH1.DOUT0		VADC0.G0CH3	VADC0.G1CH2	ERU0.2B0	USIC0_CH0.DX3C	USIC0_CH0.DX4C	USIC0_CH1.DX0F	
P2.11	ERU0.PDOUT0	CCU40.OUT3	ERU0.GOUT0	LEDTS1.COL3		USIC0_CH1.SCLKOUT	USIC0_CH1.DOUT0	ACMP.REF	VADC0.G0CH4	VADC0.G1CH3	ERU0.2B1	USIC0_CH1.DX0E	USIC0_CH1.DX1E		

Table 21-15 Hardware Controlled I/O Functions

Function	Outputs		Inputs		Pull Control			
	HWO0	HWO1	HWI0	HWI1	HW0_PD	HW0_PU	HW1_PD	HW1_PU
P0.0	LEDTS0. EXTENDED7		LEDTS0.TSIN7	LEDTS0. TSIN7	Reserved for LEDTS Scheme A: pull-down disabled always	Reserved for LEDTS Scheme A: pull-down enabled always	Reserved for LEDTS Scheme B: pull-up enabled and pull-down disabled, and vice versa	
P0.1	LEDTS0. EXTENDED6		LEDTS0.TSIN6	LEDTS0. TSIN6				
P0.2	LEDTS0. EXTENDED5		LEDTS0.TSIN5	LEDTS0. TSIN5				
P0.3	LEDTS0. EXTENDED4		LEDTS0.TSIN4	LEDTS0. TSIN4				
P0.4	LEDTS0. EXTENDED3		LEDTS0. TSIN3	LEDTS0. TSIN3				
P0.5	LEDTS0. EXTENDED2		LEDTS0. TSIN2	LEDTS0. TSIN2				
P0.6	LEDTS0. EXTENDED1		LEDTS0. TSIN1	LEDTS0. TSIN1				
P0.7	LEDTS0. EXTENDED0		LEDTS0. TSIN0	LEDTS0. TSIN0				
P0.8	LEDTS1. EXTENDED0		LEDTS1. TSIN0	LEDTS1. TSIN0				
P0.9	LEDTS1. EXTENDED1		LEDTS1. TSIN1	LEDTS1. TSIN1				
P0.10	LEDTS1. EXTENDED2		LEDTS1. TSIN2	LEDTS1. TSIN2				
P0.11	LEDTS1. EXTENDED3		LEDTS1. TSIN3	LEDTS1. TSIN3				
P0.12	LEDTS1. EXTENDED4		LEDTS1. TSIN4	LEDTS1. TSIN4				
P0.13	LEDTS1. EXTENDED5		LEDTS1. TSIN5	LEDTS1. TSIN5				
P0.14	LEDTS1. EXTENDED6		LEDTS1. TSIN6	LEDTS1. TSIN6				
P0.15	LEDTS1. EXTENDED7		LEDTS1. TSIN7	LEDTS1. TSIN7				
P1.0		USIC0_CH0.DOUT0		USIC0_CH0.HWIN0	BCCU0.OUT2	BCCU0.OUT2		
P1.1		USIC0_CH0.DOUT1		USIC0_CH0.HWIN1	BCCU0.OUT3	BCCU0.OUT3		
P1.2		USIC0_CH0.DOUT2		USIC0_CH0.HWIN2	BCCU0.OUT4	BCCU0.OUT4		

Table 21-15 Hardware Controlled I/O Functions (cont'd)

Function	Outputs		Inputs		Pull Control			
	HWO0	HWO1	HWI0	HWI1	HW0_PD	HW0_PU	HW1_PD	HW1_PU
P1.3		USIC0_CH0.DOUT3		USIC0_CH0.HWIN3	BCCU0.OUT5	BCCU0.OUT5		
P1.4					BCCU0.OUT6	BCCU0.OUT6		
P1.5					BCCU0.OUT7	BCCU0.OUT7		
P1.6					BCCU0.OUT8	BCCU0.OUT8		
P2.0					BCCU0.OUT1	BCCU0.OUT1		
P2.1					BCCU0.OUT6	BCCU0.OUT6		
P2.2					BCCU0.OUT0	BCCU0.OUT0	CCU40.OUT3	CCU40.OUT3
P2.3					ACMP2.OUT	ACMP2.OUT		
P2.4					BCCU0.OUT8	BCCU0.OUT8		
P2.5					ACMP1.OUT	ACMP1.OUT		
P2.6					BCCU0.OUT2	BCCU0.OUT2	CCU40.OUT3	CCU40.OUT3
P2.7					BCCU0.OUT8	BCCU0.OUT8	CCU40.OUT3	CCU40.OUT3
P2.8					BCCU0.OUT1	BCCU0.OUT1	CCU40.OUT2	CCU40.OUT2
P2.9					BCCU0.OUT7	BCCU0.OUT7	CCU40.OUT2	CCU40.OUT2
P2.10					BCCU0.OUT4	BCCU0.OUT4		
P2.11					BCCU0.OUT5	BCCU0.OUT5		

Boot and Startup, Bootstrap Loaders, and User Routines

22 Boot and Startup

The startup sequence of the XMC1200 is a process taking place before user application software takes control of the system and is comprising of two major phases (see [Figure 22-1](#)), split in several distinctive steps:

Hardware Controlled Startup Phase

The hardware controlled startup phase gets performed automatically after power up of the microcontroller. This part is generic and it ensures basic configuration common to most applications. The hardware setup needs to ensure fulfillment of requirements specified in Data Sheet in order to enable reliable start up of the microcontroller before control is handed over to the user software. The sequence where boot code gets executed is considered a part of the hardware controlled phase of the startup sequence.

For details of the setup requirements, please refer to Data Sheet.

Software Controlled Startup Phase

The software controlled startup phase is the part where the application specific configuration gets applied with user software. It involves several steps that are critical for proper operation of the microcontroller in the application context and may also involve some optional configuration actions in order to improve system performance and stability in the application context.

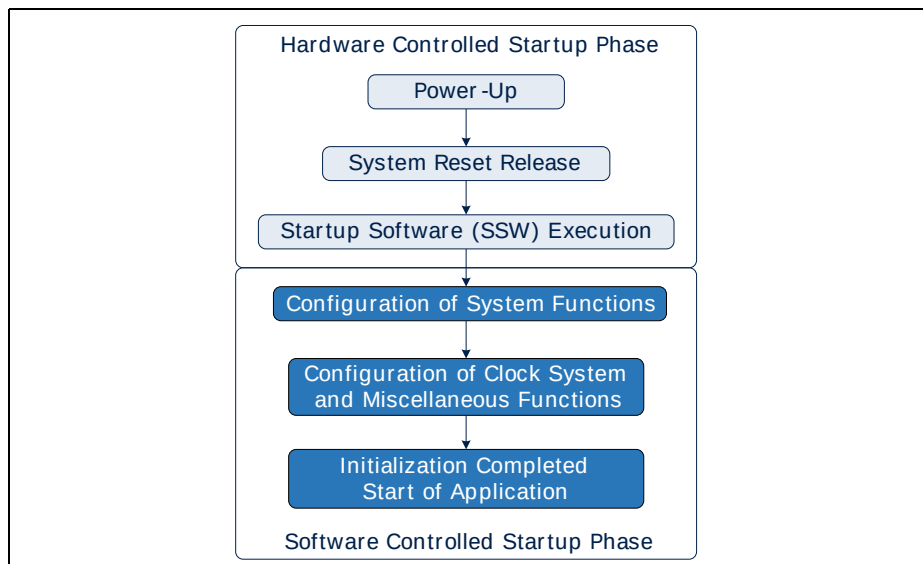


Figure 22-1 Startup sequence

22.1 Startup Sequence and System Dependencies

A more detailed description of the startup sequence is available in the following sub-chapters.

22.1.1 Power-Up

Power up of the microcontroller gets performed by applying V_{DDP} supply (for details of the supply requirements, please refer to Data Sheet). Once V_{DDP} reaches a threshold, the internal core voltage, V_{DDC} , is generated automatically by the EVR.

22.1.2 System Reset Release

The internal power-on reset generation is based on the supply and core voltage validation. When V_{DDP} and V_{DDC} reaches a stable threshold level, the power-on reset is released. Next, after the on-chip oscillators generate a stable clock output, the system reset is released automatically and the SSW code starts to run.

The system reset can be triggered from various sources like software controlled CPU reset register or a watchdog time-out-triggered reset. For more details on reset control details, please refer to the Reset Control Unit (RCU) section in the SCU chapter.

The cause of the last reset gets automatically stored in the SCU_RSTSTAT register and can be checked by user software to determine the state of the system and for debug purpose. The reset status in the SCU_RSTSTAT register shall be reset with SCU_RSTCLR register after each startup in order to ensure consistent source indication after the next reset.

After reset release, MCLK and PCLK are running at 8MHz and most of the peripherals' clocks are disabled except for CPU, memories and PORT. It is recommended to disable the clock of the unused modules in order to reduce power consumption.

22.1.3 Startup Software (SSW) Execution

After the reset is deasserted, CPU starts to execute the SSW code from the ROM memory. To indicate the start of the SSW execution, the pullup device in P0.14 is enabled. Pullup device is disabled during reset.

Another important task that is done by SSW is to read the Boot Mode Index (BMI) stored in Flash and decide the startup mode (such as User Productive mode and Bootstrap Loader) selected by the user. For more details about the various startup modes and handling of BMI, please refer to [Section 22.2](#).

To handle the initial hardfault error during the SSW execution, SSW installs "jump to itself" instruction at SRAM location $2000'000C_H$ as temporary HardFault handler - until the user code installs its own. It is installed upon master reset only.

During SSW execution, the SRAM area between 2000'00C0_H and 2000'0200_H is reserved for usage by XMC1200 SSW, therefore the user software should not store in this area data which must be preserved throughout (non-power) resets.

The MCLK and PCLK frequency that is used to execute the SSW and to start the user code can be configured by user. In addition, some of the peripheral clock can also be enabled (default disabled) by the SSW. Detailed description can be found in the [Section 22.1.3.1](#).

22.1.3.1 Clock system handling by SSW

XMC1200 SSW is able to change device clock settings to allow flexibility of device performance e.g. speed vs. power consumption optimization during start-up.

The clock handling by SSW is user configurable by installing values in Flash. For this purpose two word locations - CLK_VAL1 and CLK_VAL2 - are assigned in Flash (refer to [Table 22-1](#)), the values from these locations are processed by SSW as follows:

- if CLK_VAL1[31]=0 - CLK_VAL1[19:0] bits are installed into SCU_CLKCR[19:0] register - this configures clock dividers and selection
- if CLK_VAL2[31]=0 - CLK_VAL2[10:0] bits are installed into SCU_CGATCLR0[10:0] - this enables the clock of the selected peripherals

In case some CLK_VALx location is not programmed by the user - like in device delivery state - its bit[31]=1 and no installation is done into the respective register(s).

Limited device frequency change

To avoid big jumps/drops in power consumption, the user-configurable value to be installed during start-up from CLK_VAL1 into CLKCR.IDIV is limited to the range 1..16, resulting in possible range of MCLK after re-configuration 2..32 MHz from initial 8MHz - i.e. MCLK frequency can be increased or decreased no more than 4 times (rounded, ignoring potential FDIV influence).

In case CLK_VAL1 (refer to [Table 22-1](#)) contains IDIV value out of the 1..16 range:

- if IDIV=0 - SSW installs IDIV=1 instead
- if IDIV>16 - SSW install IDIV=16 instead

22.1.4 Configuration of Special System Functions as part of User code initialization

Special system functions may be required to perform actions that improve system stability and robustness. The following special system functions or modules require initialization as part of the User code initialization before the actual user application starts:

- Start Address and Initial Stack Pointer Value
- Setup the Interrupt handler

- Supply Voltage Brown-out Detection
- Watchdog Timer (WDT)

Start Address and Initial Stack Pointer Value

The start address and the initial stack pointer values in [Table 22-1](#) need to be defined by the user. It can be done together with the downloading of the user code into the flash memory.

Setup the Interrupt Handler

The vector table is remapped to the SRAM based on the remapped vector table in CPU chapter. The interrupt service routine can be placed in these SRAM address or user can also have a branch instruction to the routine that is placed in other memory location. For details, please refer to CPU chapter.

V_{DDP} Brown Out Detection

V_{DDP} brown out detection mechanism allows active monitoring of the supply voltage and a corrective reaction in case the voltage level is below a programmed threshold. An interrupt request will be flagged if a programmed condition is detected. For details, please refer to the Power Control Unit (PCU) section in the SCU chapter.

Watchdog Timer

The Watchdog Timer requires a clock source selection and activation. It is highly recommended to use a reliable clock source, preferably independent from the system clock source in order to ensure corrective action in case of a system failure which will bring the microcontroller into a safe operation state. In XMC1200, the default WDT clock is the standby clock. For more details, please refer to WDT chapter. For details of the WDT module configuration, please refer to the “Initialization and Control Sequence” section of the WDT chapter.

22.1.5 Configuration of Clock System and Miscellaneous Functions

The following functions are available and may require configuration in the user code:

- Clock System Configuration
- System Reset Configuration
- Debug Suspend Configuration

Clock System Configuration

MCLK and PCLK frequency can be configured to be different from the user settings during SSW execution as described in [Section 22.1.3.1](#). The SCU_CRCLK.IDIV/FDIV bits are used to program the target clock frequency. The ratio between MCLK and PCLK is also selectable via bit SCU_CRCLK.PCLKSEL. In addition, some of the peripheral

clocks can be enable/disable via the SCU_CGATCLR0/SCU_CGATSET0 register respectively. It is also recommended to enable the oscillator watchdog for loss of clock detection.

System Reset Configuration

Several events such as Flash ECC error or SRAM parity error can be used to trigger a system reset using the SCU_RSTCON register. For details, please refer to the reset control unit (RCU) section in the SCU chapter.

Debug Suspend Configuration

The XMC1200 device supports a suspend capability for peripherals, if the program execution of the CPU is stopped by the debugger, e.g. with a breakpoint, or with the C_HALT. This allows the debugging of critical states of the whole microcontroller. The suspend function has to be enabled or disabled locally at the peripheral based on the application and the debugging approach. Refer to Debug System chapter for details.

22.2 Start-up Modes

Startup Software (short name SSW) is the first software executed by CPU after any device leaves reset state.

SSW is stored in the ROM memory, but nevertheless its flow is influenced by other “flexible” factors as:

- type of the event triggering SSW execution
- start-up configuration as selected by the user in so called Boot Mode Index (short notation BMI)

22.2.1 Start-up modes in XMC1200

Start-up mode selection in XMC1200 is done by the SSW after reset. It is based on **Boot Mode Index (BMI)** stored in flash configuration sector 0 (CS0) meaning no device pin is used for configuration purpose. To program a new BMI, user need to call the user function “Request BMI installation” as described in the BSL and User Routines chapter. The selection and handling of BMI by SSW is described in **Section 22.2.3**. The default start-up mode in device delivery state is the ASC BSL mode.

A summary of the supported start-up modes follows.

22.2.1.1 User productive mode

User code is started from Flash memory, no debugging is possible in this mode.

The address of the first user instruction - to where SSW jumps at its end - is taken from Flash location 1000'1004_H.

SSW does not check either the target address is inside user Flash. Therefore HardFault will be generated if it's outside and the execution will jump to exception handler in SRAM (upon master reset an endless loop is installed by SSW).

22.2.1.2 User mode with debug enabled

User code is started from Flash memory, the first address is determined as in [User productive mode](#) (see [Section 22.2.1.1](#)).

Debug interface is configured according to [Boot Mode Index \(BMI\)](#) value and enabled.

22.2.1.3 User mode with debug enabled and Halt After Reset (HAR)

User code is started from Flash memory as in the two modes above.

Debug interface is configured according to BMI value and enabled, the CPU is stalled upon exit from SSW and before the first user instruction (for the handling refer to [Section 22.2.3.2](#)).

22.2.1.4 Standard Bootstrap Loader modes

In this mode (short notation Standard BSL):

- user code is downloaded into SRAM
- at the SSW end the execution jumps to SRAM
- no debugging is possible

The Standard BSL mode supported in XMC1200 uses USIC0 module for communication with the host:

- ASC - using channel 0 or 1 (auto-detection by firmware) of USIC0 module and ASC (UART) protocol for download
This is the default start-up mode - selected by BMI value in device delivery state.
- SSC - using USIC0 channel 0 and SSC (SPI) standard protocol for download
In this mode SPI-compatible serial EEPROM is supposed to be connected as slave device to XMC1200.

The functionality of standard BSL routines is described in the BSL chapter.

22.2.1.5 Bootstrap Loader modes with time-out

These modes are using the Standard BSL routines for downloading, but the functionality is different:

- SSW first checks either an external device is connected/active, meaning SSW waits to receive Start and Header Bytes from the host - either via USIC channel 0 or 1 - for time-out which duration is taken from BMI.BLSTO (refer to [Section 22.2.2](#)):

- if yes
 - * user code is downloaded into SRAM
 - * at the SSW end the execution jumps to SRAM
- if not - at the SSW end the execution jumps to Flash as in **User productive mode**
- no debugging is possible in this mode, independently either code execution starts from Flash or SRAM

Two BSL modes with time-out are supported in XMC1200, both using USIC0 module for communication with the host. Besides the difference in interface selection, also the check performed as part from the above sequence is different:

- ASC mode
 - SSW configures USIC0 channels 0 and 1 in ASC (UART) mode
 - SSW waits to receive Start and Header Bytes from the host - either via channel 0 or 1 - for time-out which duration is taken from BMI.BLSTO (refer to [Section 22.2.2](#))
 - if Start+Header Bytes are received - Standard ASC BSL is further executed for downloading and starting user code from SRAM; otherwise execution from Flash will be taken
- SSC mode
 - SSW configures USIC0 channel 0 as Master in SSC (SPI) mode
 - SSW initiates communication with SPI-compatible serial EEPROM supposed to be connected as slave device
 - if data received upon Read Command sent by SSW corresponds to the expected (serial EEPROM) protocol - Standard SSC BSL is further executed for downloading and starting user code from SRAM; otherwise execution from Flash will be taken

Note: If BSLTO=0 is configured in BMI - SSW at all does not perform any BSL check but directly takes User Productive Mode.

22.2.2 Boot Mode Index (BMI)

The Boot Mode Index is 2 Byte value stored in Flash (refer to [Table 22-1](#)) and holding information about start-up mode and debug configuration of the device. Additionally to BMI at 1000'0E00_H its inverse value is stored at 1000'0E10_H for check purposes.

BMI

Boot Mode Index				CS0 offset 0E00 _H				Delivery state: FFC0 _H							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BSLTO				1	DAPIS		DAP TYP	1	HWCFCG						
r				r	r		r	r	r						

Field	Bits	Typ	Description
HWCFCG	[5:0]	r	Start-up mode selection: 000000 _B ASC Bootstrap Loader mode (ASC_BSL) 000001 _B User productive Mode (UPM) 000011 _B User mode with debug enabled (UMD) 000111 _B User mode with debug enabled and HAR (UMHAR) 001000 _B SSC Bootstrap Loader mode (SSC_BSL) 010000 _B ASC BSL mode with time-out (ASC_BSLTO) 011000 _B SSC BSL mode with time-out (SSC_BSLTO) 101010 _B Secure Bootstrap Loader mode (SBSL) ¹⁾ else Not defined ²⁾
DAPTYP	8	r	DAP Type Selection Coding as of SCU_DAPCON.DAPTYP
DAPDIS	[10:9]	r	SWD/SPD Input/Output Selection Coding as of SCU_DAPCON.DAPDIS
BSLTO	[15:12]	r	ASC BSL Time-out value The time-out duration is BSLTO*2664000 MCLK cycles, the supported time-out range is 0.3-5s (333...4995ms)
1	[7:6], 11	r	Reserved, must be programmed to 1

1) Only in device versions supporting it

2) ATTENTION: Installing one of these values will cause device delivery state to be restored upon the next reset - refer to [Section 22.2.3](#)

22.2.3 Start-up mode selection

The start-up modes in XMC1200 are selected and handled according to Boot Mode Index (BMI) value read from Flash - refer to [Section 22.2.1](#).

The BMI evaluation can lead to:

- taking User mode - SSW will jump at its end into User Flash and start execution from the location which address is stored at 1000'1004_H if:
 - a kind of User Mode is selected in BMI
 - ASC BSL with time-out is selected but no valid Start+Header Bytes are received within the selected time frame
- taking Bootstrap Loader mode - executing ASC BSL then jumping into SRAM at 2000'0200_H
- taking Secure Bootstrap Loader (SBSL) mode - if SBSL is selected in BMI and supported for the device
- executing (endless) loop - waiting for valid Start+Header Bytes to be received via ASC upon ASC BSL mode selected without time-out
- erasing the complete user Flash and installing ASC BSL (or SBSL if supported) mode as new BMI value - upon invalid BMI value or if Secure BSL is selected but not supported for the device. Afterwards master reset is triggered and device is started in a mode according to the new BMI.

22.2.3.1 BMI handling by SSW

This SSW part is intended to be executed after the user function (in ROM) "Request BMI installation" (described in the BSL and User Routines chapter) has been called and has triggered a system reset. Therefore the conditions under which this handling is performed are:

- the last reset was a system reset requested by CPU
- the two half words of SSW0 register are inverse to each other

If all the above conditions are true, the SSW considers SSW0[15:0] content as new BMI value to be installed and executes the following:

- check either the current BMI (in CS0) is User_Productive AND the new value is NOT User_Productive:
 - if yes - erase the complete user Flash and install ASC_BSL (or SBSL if supported) mode as new BMI value
 - if not - install the new BMI value from SSW0[15:0]
- instal all zero in SSW0 to indicate no BMI-programming upon the next reset
- request master reset to be triggered

Upon the last action, a master reset is triggered and a next SSW execution will start with the new BMI value installed in CS0.

22.2.3.2 Debug system handling

If debug system must be enabled - start-up mode with debug support is selected in Boot Mode Index (refer to [Section 22.2.2](#)) - SSW performs the following:

- configure the debug interface from BMI value
- enable the debug interface
- if start-up mode with Halt After Reset request (UMHAR) is selected in BMI upon master reset - enter an endless NOP (no operation) loop. From this point on, an external tool (debugger) can take over the control of the device, in particular:
 - if/when a debugger connects to device, it can halt the CPU and check BMI and/or the core program counter (PC) register
 - if HAR is selected, this can be identified by BMI value (refer to [Section 22.2.2](#)) and the PC value will point inside the ROM. The debugger can then manipulate PC and start the user code as desired - the default start address (taken without HAR) is according to the content at location 1000'1004_H in user Flash (refer to [Table 22-1](#))

22.3 Data in Flash for SSW and User SW

[Table 22-1](#) shows the data in Flash which is relevant for SSW execution and can be used by user software in XMC1200.

Table 22-1 Flash data for SSW and user SW in XMC1200

Address	Length	Function	Target location
Start-up mode selection:			
1000'0E00 _H	2 B	Boot Mode Index (BMI)	---
1000'0E10 _H	2 B	Inverse BMI	---
Chip Identification:			
1000'0F00 _H	4 B	Chip ID	SCU_IDCHIP
1000'0F04 _H	28 B	Chip Variant Identification Number	---
1000'0FF0 _H	16 B	Unique Chip ID	---
Temperature-sensor and DCO related data:			
1000'0F20 _H	16 B	Temperature-sensor constant data 1	---
1000'0F30 _H	1 B	ANA_TSE_T1	---
1000'0F31 _H	1 B	ANA_TSE_T2	---
1000'0F32 _H	1 B	DCO_ADJLO_T1	---
1000'0F33 _H	1 B	DCO_ADJLO_T2	---
1000'0F34 _H	161 B	Temperature-sensor constant data 2	---

Table 22-1 Flash data for SSW and user SW in XMC1200

Address	Length	Function	Target location
Application software related data:			
1000'1000 _H	4 B	Initial Stack Pointer value after SSW	SP_main
1000'1004 _H	4 B	Start address after SSW in User modes	PC
Clock system related data:			
1000'1010 _H	4 B	Clock configuration value CLK_VAL1	If bit[31]=0: bits[19:0] into SCU_CLKCR[19:0]
1000'1014 _H	4 B	Clock gating configuration value CLK_VAL2	If bit[31]=0: bits[10:0] into SCU_CGATCLR0[10:0]

23 Bootstrap Loaders (BSL) and User Routines

This chapter describes the Bootstrap Loaders (BSL) and the user-accessible routines in the ROM memory.

The ASC (UART) BSL ([Section 23.1](#)) and the SSC BSL ([Section 23.2](#)) is entered with the BMI settings as described in the Boot and Startup Chapter. The main purpose of BSL Mode is to allow easy and quick programming/erasing of the Flash.

[Section 23.3](#) describes 5 user-accessible routines that can be called by application software. These routines are located in the ROM memory.

23.1 ASC (UART) Bootstrap Loader

ASC (UART) Standard Bootstrap Loader (ASC BSL) in XMC1200 uses USIC0 module to download code/data into SRAM starting at address 2000'0200H.

After the last code/data Byte is received and stored, the Startup Software starts user code from address 20000'0200H.

23.1.1 Pin usage

ASC BSL in XMC1200 is selected by a single BMI value but it allows to download user code/data via several variants of pins, modes and USIC0 channels:

- Channel 0
 - full duplex mode with RxD at P0.14 and TxD at P0.15
 - half duplex mode with RxD/TxD at P0.14
- Channel 1
 - full duplex mode with RxD at P1.3 and TxD at P1.2
 - half duplex mode with RxD/TxD at P1.3

Note: The above set of pins also accommodate all the assignments for SWD/SPD (debug) interfaces.

23.1.2 ASC BSL execution flow

The complete ASC Bootstrap Loader procedure consists of two parts as described below.

23.1.2.1 ASC BSL entry check sequence

Downloading is only initiated after a Start (zero) and a Header (described below) Bytes are received through one of the channels whereas both the channels are active ("listening") until the selection is done by the routine itself as follows:

- Channel selection - based on the fact at which RxD pin (see the above assignments) first Start+Header Bytes are received
- Full/half duplex selection - based on the Header Byte received

Bootstrap Loaders (BSL) and User Routines

Note: For definitions of header/acknowledge byte values exchanged with the host - refer to [Section 23.1.3](#).

The ASC bootloader functionality includes:

1. enable and configure the both USIC0 communication channels 0 and 1 as follows:
 - a) ASC mode, 8 data bits, 1 stop bit, no parity
2. configure ASC clock-generation circuitry for measurement
3. perform continuously the following sequence for both USIC0 channels one after another
 - a) check either Start zero Byte has been received
if yes - then:
 - b) reconfigure ASC clock-generating circuitry for normal operation according to the baudrate measured from the Start Byte, then:
 - c) check either Header Byte has been received
if yes - then:
 - d) check the Header Byte received
 - * if equal to BSL_ASC_F or BSL_ENC_F - full duplex mode is selected - continue with step 4.
 - * if equal to BSL_ASC_H or BSL_ENC_H - half duplex mode is selected - continue with step 4.
 - * otherwise - go to sequence for the other channel
4. select the current (Cy) channel for further handling; restore default configuration for the channel C(y-1) which is not selected
5. for the selected channel and mode (full/half duplex) :
 - a) configure TxD pin and ASC transmitter
 - b) adapt (in case) RxD pin settings
 - c) enable transmission, single shot mode
6. check which Header byte was received:
 - a) BSL_ASC_F or BSL_ASC_H - standard BSL entry sequence was executed, the communication will use further the baudrate detected - continue with [ASC BSL download sequence](#) (see [Section 23.1.2.2](#))
 - b) BSL_ENC_F or BSL_ENC_H - the communication during [ASC BSL download sequence](#) will potentially use different (e.g. higher) baudrate than the initially detected - continue with the [Enhanced ASC BSL entry sequence](#) (see below))

The above check sequence is executed

- in ASC BSL mode without time-out - until valid Start+Header Bytes are received
- otherwise - only for some time according to BMI.BSLTO

Note: If mode with time-out is selected but BMI.BSLTO=0 - User mode with start from Flash is directly taken.

Enhanced ASC BSL entry sequence

This is an extension of the standard [ASC BSL entry check sequence](#) and will be used when higher baudrates are required for the communication channel.

It includes the following steps:

1. Send BSL_ENC_ID to acknowledge the establishment of the initial baud rate and entry into enhanced ASC BSL
2. Send current PDIV divider from USIC0_CHy_BRG register - the 10-bit value is sent in 2 bytes (most significant byte first)
3. Receive from host the 10-bit value to be written into the STEP bit field in USIC0_CHy_FDR register
4. Send BSL_BR_OK to acknowledge the establishment of the new baud rate
5. Configure USIC baud rate generator accordingly
6. Receive from host BSL_BR_OK to indicate that the communication channel has been successfully established
 - If no or wrong acknowledge value is received, a device software reset will be triggered

Figure 23-1 shows the outline of the sequence to configure the baud rate.

Requirements for Host

For the host to support enhanced ASC BSL, the host additionally has to:

- Receive from XMC1200 device, the current 10-bit PDIV value in USIC0_CHy_BRG register
- Calculate the MCLK that the device is running on based on the received PDIV through the formula:

(23.1)

$$\text{MCLK} = \text{Initial Baud Rate} \times (\text{PDIV} + 1) \times 8$$

- Select a new baud rate that is supported by the enhanced ASC BSL given the MCLK (see [Table 23-1](#))
- Calculate the scaling factor, i.e. ratio of the new baud rate to the initial baud rate. Some examples are given in [Table 23-2](#). The scaling factor is rounded to the nearest integer in order to meet a frequency deviation of +/- 3%.

Table 23-1 Supported Baud Rates

MCLK (MHz)	Standard baud rates supported with ASC BSL (kHz)		Max. baud rate supported with Enhanced ASC BSL (MHz)
	Min.	Max.	
8	1.2	28.8	0.999
16	2.4	57.6	1.998
32	4.8	115.2	3.996

Table 23-2 Scaling Factor Examples

Initial standard baud rates (kHz) ---A	Targeted higher baud rates (kHz) ---B	Scaling factor rounded to the nearest integer (B/A)
9.6	1500	156
19.2	1500	78
57.6	1500	26
115.2	1500	13

- Calculate the 10-bit value to be written into the STEP bit field of USIC0_CHy_FDR register through the formula:

(23.2)

$$\text{STEP (in fractional divider mode)} = \frac{1024 \times \text{Scaling Factor}}{\text{PDIV} + 1}$$

- Send the 10-bit STEP value to the device
- Wait until the BSL_BR_OK is received from the device
- Echo the BSL_BR_OK back to the device

Bootstrap Loaders (BSL) and User Routines

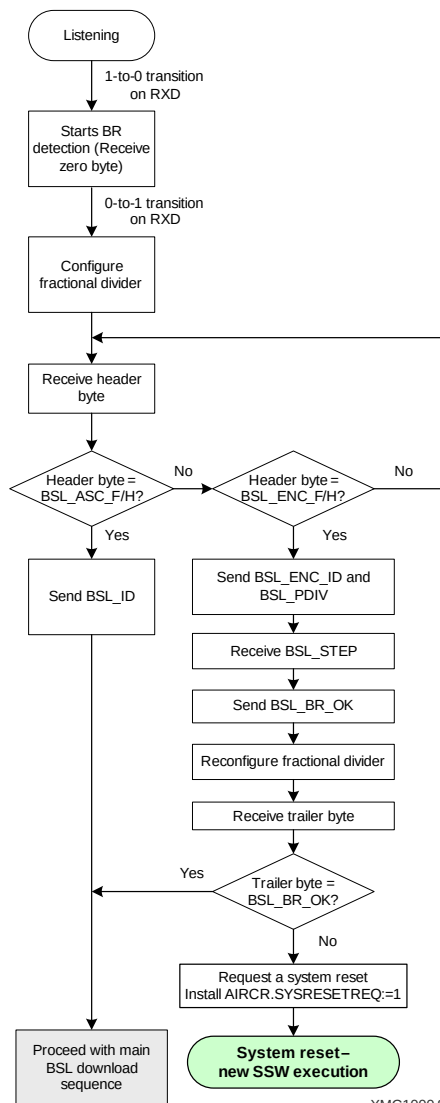


Figure 23-1 Baud Rate configuration sequence during XMC1200 ASC BSL entry

Bootstrap Loaders (BSL) and User Routines

23.1.2.2 ASC BSL download sequence

After the baud rate has been detected/configured and channel/mode (full/half duplex) selected, ASC BSL awaits 4 bytes describing the length of the application from the host (refer to [Figure 23-2](#)). The least significant byte is received first.

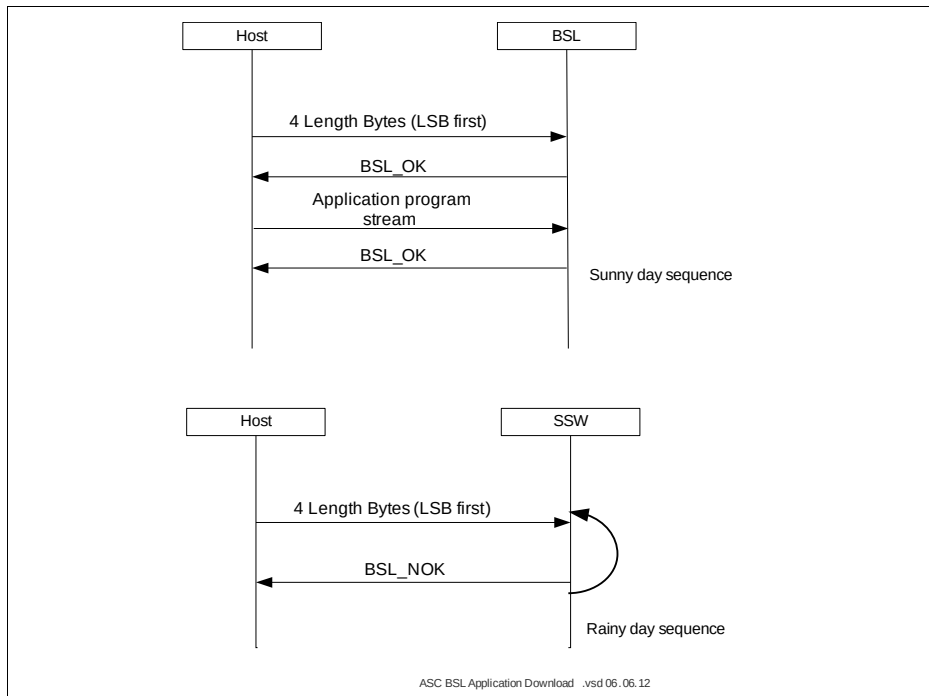


Figure 23-2 XMC1200 Standard ASC BSL: Application download protocol

If application length is found alright by SSW, a BSL_OK byte is sent to the host following which the latter sends the byte stream belonging to the application. After the byte stream has been received, SSW terminates the protocol by sending a final OK byte and then cedes control to the downloaded application.

If application length is found to be in error (application length greater than device SRAM size), a BSL_NOK byte is transmitted back to the host and the SSW resumes awaiting the length bytes.

Bootstrap Loaders (BSL) and User Routines

23.1.3 ASC BSL protocol data definitions

The interaction between XMC1200 ASC Bootstrap Loader routine and the host implements handshake protocol based on [Figure 23-3](#) and request/acknowledge/data Bytes defined in [Table 23-3](#).

Table 23-3 Handshake protocol data definitions in XMC1200 ASC BSL

Name	Length, Byte	Value	Description
Requests/data/acknowledge sent by the Host:			
BSL_ASC_F	1	6CH	Header requesting full duplex ASC mode with the current baud rate
BSL_ASC_H	1	12H	Header requesting half duplex ASC mode with the current baud rate
BSL_ENC_F	1	93 _H	Header requesting full duplex ASC mode with a request to switch the baud rate
BSL_ENC_H	1	ED _H	Header requesting half duplex ASC mode with a request to switch the baud rate
BSL_STEP	2	0XXX _H	10-bit value (LSB aligned) to be programmed into selected USIC channel's FDR.STEP bit field. Most significant 6 bits should contain all 0.
BSL_BR_OK	1	F0 _H	Final baud rate is established in enhanced ASC BSL
Acknowledges sent by XMC1200 firmware:			
BSL_ID	1	5DH	Start and header bytes are received, baud rate is established
BSL_ENC_ID	1	A2 _H	Start and header byte(s) are received in enhanced ASC BSL, initial baud rate is established
BSL_PDIV	2	0XXX _H	10-bit value (LSB aligned) containing the selected USIC channel's BRG.PDIV bit field value. Most significant 6 bits should contain all 0.
BSL_BR_OK	1	F0 _H	Final baud rate is established in enhanced ASC BSL.
BSL_OK	1	01H	Data received is OK
BSL_NOK	1	02H	Failure encountered during data reception

Bootstrap Loaders (BSL) and User Routines

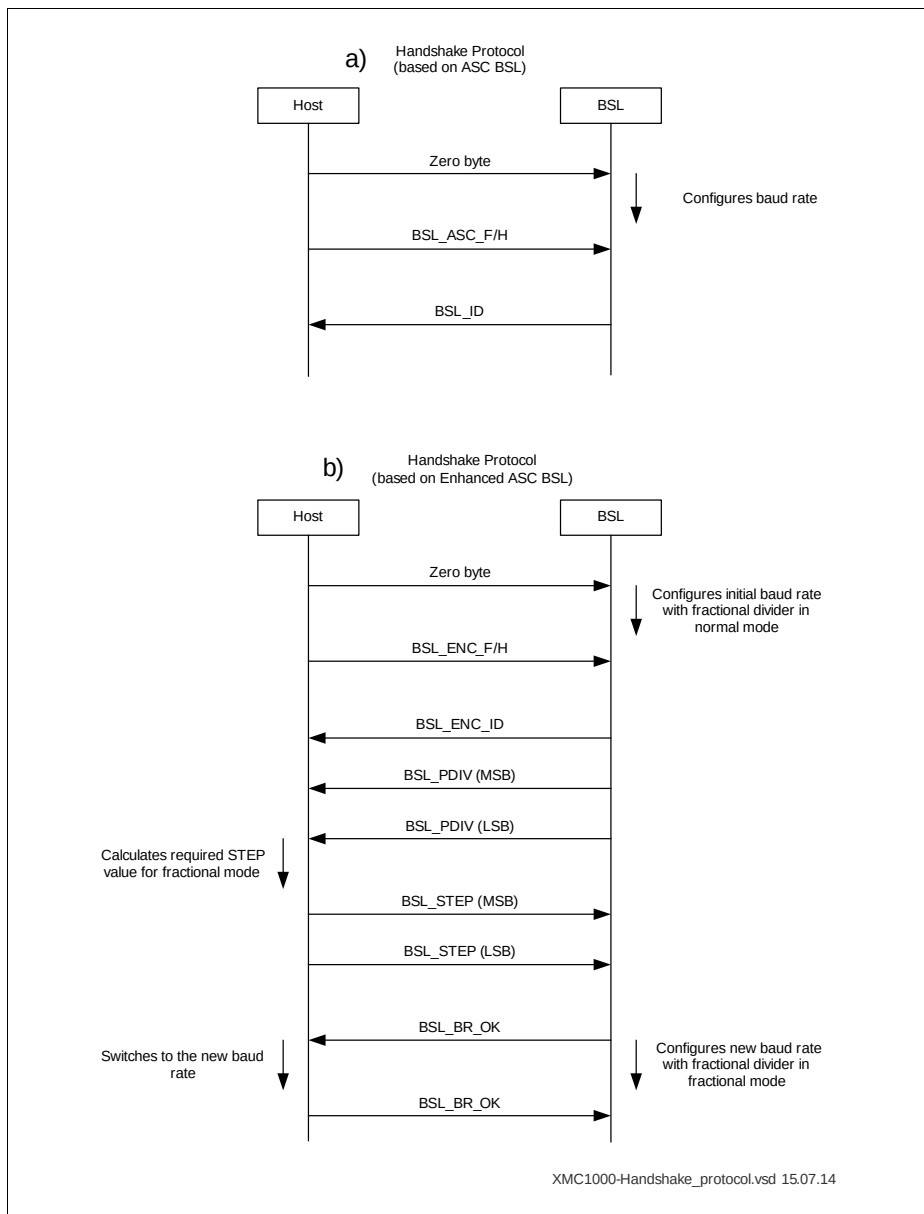


Figure 23-3 Handshake protocol for XMC1200 ASC BSL entry

Bootstrap Loaders (BSL) and User Routines

23.2 SSC Bootstrap loader

This procedure downloads code from a SPI-compatible serial EEPROM into SRAM starting at address 2000'0200H using Channel 0 of USIC0 Module. The length of the code can be arbitrary up to the user-available SRAM size.

XMC1200 is the master SPI-device, following pins are used by the bootloader:

- MRST (master data input) and MTSR (master data output) - on the same P0.15, half-duplex mode used
- SCLK (clock signal) - P0.14, open drain
- SLS (chip-select CS to the EEPROM) - P0.13, open drain

Note: Due to the specific functionality of the bootloader - performing one Sequential Read operation only - there is no need of a dedicated SLS-control.

Note: Due to XMC1200 pin configured as open drain, external pull-up resistors need to be added on the bus

A SPI-compatible serial EEPROM of type 25xxx must be connected to the pins as above defined. The clock signal is configured at MCLK/10 frequency upon device startup.

The SSC bootloader in XMC1200 is able to communicate with a very broad range on serial-EEPROM types: from such using 8-bit addressing (size up to 2K bit, quite outdated already) up to devices using 24-bit addressing (1M bit and above). The connected EEPROM type is determined by examining the received header bytes, as indicated in

Table 23-4.

Note: Besides the bootloader supports all the device-types, the code/data length which can be downloaded is limited by the size of available SRAM.

Table 23-4 SSC BL: Determining the EEPROM Type and data-flow

SSC Frame		EEPROM with 8-bit addressing connected		EEPROM with 16-bit addressing connected		EEPROM with 24-bit addressing connected	
N	data	P11-send	P11-receive	P11-send	P11-receive	P11-send	P11-receive
1	03 _H	Read command	XX _H default level	Read command	XX _H default level	Read command	XX _H default level
2	00 _H	Address	XX _H	Address _H	XX _H	Address _H	XX _H
3	00 _H	dummy	Identification	Address _L	XX _H	Address _M	XX _H

Bootstrap Loaders (BSL) and User Routines

Table 23-4 SSC BL: Determining the EEPROM Type and data-flow

SSC Frame		EEPROM with 8-bit addressing connected		EEPROM with 16-bit addressing connected		EEPROM with 24-bit addressing connected	
4	00 _H	dummy	Size	dummy	Identification	Address_L	XX _H
5	00 _H	dummy	Data Byte 1	dummy	Size, High B	dummy	Identification
6	00 _H	dummy	Data Byte 2	dummy	Size, Low B	dummy	Size, High B
7	00 _H	dummy	Data Byte 3	dummy	Data Byte 1	dummy	Size, Mid B
8	00 _H	dummy	Data Byte 4	dummy	Data Byte 2	dummy	Size, Low B
9	...	dummy	Data Byte 5	dummy	Data Byte 3	dummy	Data Byte 1
...			...n		...n		...n

The EEPROM connected for downloading must contain:

- identification Byte D5H at the first address (0000H)
- the length of the code (Code_Length) in Bytes as follows:
 - in case of an EEPROM with 8-bit addressing - in one Byte at address 0001H
 - in case of an EEPROM with 16-bit addressing - in two Bytes at addresses 0001H/0002H ordered high/low
 - in case of an EEPROM with 24-bit addressing - in three Bytes at addresses 0001H/0002H/0003H ordered high/middle/low
- the code of defined length follows sequentially

The SSC bootloader functionality includes:

1. enable the communication channel by setting USIC0_C0_KSCFG.MODEN:=1
2. assure clock gating for USIC0 module is de-asserted
3. configure the USIC0_C0 channel as follows:
 - a) SSC mode, 8 data bits, MSB first
 - b) SCLK frequency = MCLK/10
 - c) no SLS activated
 - d) pin-configuration as defined above
 - e) enable transmission
4. de-select EEPROM by setting CS=1
5. enable EEPROM (CS=0) and send Read command (03h)
6. send two zero Bytes to request data from address 0000h
7. Upon any next Byte transfer as long as the EEPROM is still selected (CS=0) - data from then next following address will be read out.
8. the last Byte received is checked:

Bootstrap Loaders (BSL) and User Routines

- a) if equal to the Identification Byte (D5H) - the EEPROM uses 8-bit addressing:
 - SSW reads one more Byte and saves it as Code_Length - 1B only effective
 - continue with p.10
- 9. read one more Byte:
 - a) if equal to the Identification Byte (D5H) - the EEPROM uses 16-bit addressing:
 - SSW reads two Bytes in order High/Low to determine Code_length (2 Bytes)
 - continue with p.10
- 10. read one more Byte:
 - a) if equal to the Identification Byte (D5H) - the EEPROM uses 24-bit addressing:
 - SSW reads three more Bytes in order High/Middle/Low to determine Code_length (3 Bytes)
 - continue with p.10
 - b) if Not - directly exit the sequence
- 11. check the value of Code_length:
 - a) if 0 or greater than allowed in XMC1200- directly exit the sequence
- 12. read [Code_Length] Bytes and store them sequentially from the beginning of SRAM (address 2000'0200H) on
- 13. disable EEPROM (CS=1)
- 14. disable the communication channel by resetting USIC0_C0_KSCFG.MODEN:=0
- 15. set SSW flag BSL_act=1 and exit the sequence

After the last Byte is received and stored, the Startup Software starts the code downloaded from address 20000'0200H.

23.3 Firmware routines available for the user

Several user routines (refer to [Table 23-5](#)) are available inside ROM so they can be called by application software.

Table 23-5 User routines' in XMC1200 ROM

XMC1200 ROM		Description
Address	Content	
0000'0100H	_NvmErase	Pointer to Erase Flash Page routine
0000'0104H	_NvmProgVerify	Pointer to Erase, Program & Verify Flash Page routine
0000'0108H	_BmiInstallationReq	Pointer to Request BMI installation routine
0000'010CH	_CalcTemperature	Pointer to Calculate chip temperature routine
0000'0110H	_NvmEraseSector	Pointer to Erase Flash Sector routine

Bootstrap Loaders (BSL) and User Routines

Table 23-5 User routines' in XMC1200 ROM

XMC1200 ROM		Description
Address	Content	
0000'0114H	_NvmProgVerifyBlock	Pointer to Program & Verify Flash Block routine
0000'0120H	_CalcTSEVAR	Pointer to Calculate target level for temperature comparison routine

NVM-related functions (see [Section 23.3.1](#) and [Section 23.3.2](#)) return status indication as shown in [Table 23-6](#).

Table 23-6 Status indicators returned by NVM routines in XMC1200 ROM

Status Indicator		Description
Symbolic name	Value	
NVM_PASS	0001'0000H	Function succeeded
NVM_E_FAIL	8001'0001H	Generic error
NVM_E_SRC_AREA_EXCEEDED	8001'0003H	Source data is not in RAM
NVM_E_SRC_ALIGNMENT	8001'0004H	Source data is not 4 Byte aligned
NVM_E_NVM_FAIL	8001'0005H	NVM module can not be physically accessed
NVM_E_VERIFY	8001'0006H	Verification of the written page not successful
NVM_E_DST_AREA_EXCEEDED	8001'0009H	Destination data is not (completely) located in NVM
NVM_E_DST_ALIGNMENT	8001'0010H	Destination data is not properly aligned

The description below provides an overview of the features.

23.3.1 Erase Flash Page

XMC1200 Flash can be erased with granularity of one page = 16 blocks of 16 Bytes = 256 Bytes using this routine.

- Input parameter
 - logical address of the Flash Page to be erased, must be page aligned and in NVM address range (pageAddr)
- Return status (refer to [Table 23-6](#))
 - OK (NVM_PASS)

Bootstrap Loaders (BSL) and User Routines

- invalid address (NVM_E_DST_AREA_EXCEEDED, NVM_E_DST_ALIGNMENT)
- operation failed (NVM_E_FAIL, NVM_E_NVM_FAIL, NVM_E_VERIFY)
- Prototype
NVM_STATUS XMC1000_NvmErasePage (unsigned long pageAddr)

23.3.2 Erase, Program & Verify Flash Page

This function performs erase (skipped if not necessary), program and verify of selected Flash page.

- Input parameters
 - logical address of the target Flash Page (dstAddr)
 - address in SRAM where the data starts (srcAddr)
- Return status (refer to [Table 23-6](#))
 - OK (NVM_PASS)
 - invalid addresses (NVM_E_SRC_AREA_EXCEEDED, NVM_E_SRC_ALIGNMENT, NVM_E_DST_AREA_EXCEEDED, NVM_E_DST_ALIGNMENT)
 - operation failed (NVM_E_FAIL, NVM_E_NVM_FAIL, NVM_E_VERIFY)
- Prototype
NVM_STATUS XMC1000_NvmProgVerify (unsigned long srcAddr, unsigned long dstAddr)

23.3.3 Request BMI installation

This procedure initiates installation of a new BMI value. In particular, it can be used as well as to restore the state upon delivery for a device already in User Productive mode.

- Input parameter
 - BMI value to be installed (requestedBmiValue)
- Return status - only upon error, if OK the procedure triggers a reset respectively does not return to calling routine
 - wrong input BMI value (0001H)
- Prototype
unsigned long XMC1000_BmiInstallationReq (unsigned short requestedBmiValue)

23.3.4 Calculate chip temperature

This procedure calculates the current chip temperature as measured by the XMC1200 built-in sensor, based on data from Flash including trimming values and pre-calculated constants (refer to [Table 23-7](#)) and data from the actual measurement (read from Temperature Sensor Counter2 Monitor Register ANATSEMON).

- Input parameter
 - none
- Return status
 - chip temperature in degree Kelvin

Bootstrap Loaders (BSL) and User Routines

- Prototype
 unsigned long XMC1000_CalcTemperature (void)

23.3.5 Erase Flash Sector

XMC1200 Flash can be erased with granularity of one sector = 16 pages of (16 blocks of 16 Bytes) = 4K Bytes using this routine.

- Input parameter
 - logical address of the Flash Sector to be erased, must be in NVM address range (sectorAddr)
- Return status (refer to [Table 23-6](#))
 - OK (NVM_PASS)
 - invalid address (NVM_E_DST_AREA_EXCEEDED, NVM_E_DST_ALIGNMENT)
 - operation failed (NVM_E_FAIL, NVM_E_NVM_FAIL, NVM_E_VERIFY)
- Prototype
 NVM_STATUS XMC1000_NvmEraseSector (unsigned long sectorAddr)

23.3.6 Program & Verify Flash Block

XMC1200 Flash can be programmed and verified with granularity of one block (4 words of 4 Bytes) = 16 Bytes using this routine.

- Input parameter
 - logical address of the target Flash Block (dstAddr)
 - address in SRAM where the data starts (srcAddr)
- Return status (refer to [Table 23-6](#))
 - OK (NVM_PASS)
 - invalid addresses (NVM_E_SRC_AREA_EXCEEDED, NVM_E_SRC_ALIGNMENT, NVM_E_DST_AREA_EXCEEDED, NVM_E_DST_ALIGNMENT)
 - operation failed (NVM_E_FAIL, NVM_E_NVM_FAIL, NVM_E_VERIFY)
- Prototype
 NVM_STATUS XMC1000_NvmProgVerifyBlock (unsigned long srcAddr, unsigned long dstAddr)

23.3.7 Calculate target level for temperature comparison

This procedure - a kind of reverse of [Calculate chip temperature](#) - calculates the value which must be installed in ANATSEVAR register to get indication in ANATSESTATUS.TSE_CP_VAR_STAT bit when the chip temperature is above/below some target/threshold.

- Input parameter
 - threshold temperature in degree Kelvin - allowed range 223...423 (temperature)
- Return status
 - equivalent sensor threshold value for the temperature provided as input parameter

Bootstrap Loaders (BSL) and User Routines

- Prototype
unsigned long XMC1000_CalcTSEVAR (unsigned long temperature)

23.4 Data in Flash used by the User Routines

Table 23-7 shows the data in Flash which is used by the user routines in XMC1200.

Table 23-7 Basic Flash data for SSW and user SW in XMC1200

Address	Length	Function	Target location
Start-up mode selection:			
1000'0E00 _H	2 B	Boot Mode Index (BMI)	---
1000'0E10 _H	2 B	Inverse BMI	---
Temperature-sensor related data:			
1000'0F20 _H	16 B	Temperature-sensor constant data 1	---
1000'0F30 _H	1 B	ANA_TSE_T1	---
1000'0F31 _H	1 B	ANA_TSE_T2	---
1000'0F34 _H	161 B	Temperature-sensor constant data 2	---

Debug System

24 Debug System (DBG)

The debug system is an extension to the regular processor architecture. The XMC1200 Series Microcontrollers provide a complete hardware debug solution, with hardware breakpoint and watchpoint options. This allows high system visibility of the processor, memory and available peripherals. The debug functions are implemented with a standard ARM Cortex M0 configuration. Debug functions are integrated into the ARM Cortex-M0 processor architecture. The debug system supports serial wire debug and single pin debug interfacing.

References

- [9] Cortex-M0 Technical Reference Manual
- [10] Cortex-M0 Integration and Implementation Manual
- [11] Cortex-M0 User Guide
- [12] ARMv6-M Architecture Reference Manual
- [13] ARM Debug Interface V5
- [14] CoreSight Components Technical Reference Manual
- [15] CoreSight DAP-Lite

24.1 Overview

The basic debug functionality of the Cortex-M0 debug system is limited to invasive debug and includes processor halt, single step, processor core register access, Reset and HardFault Vector Catch. Besides the hardware debug components unlimited software breakpoints are available. The Debugger can connect to the debug system via the Serial Wire Debug (SWD) or Single Pin Debug (SPD) interface port and uses CoreSight infrastructure and the regular access flow. This permits debugger to identify the processor and its debug capabilities. The debug system allows a full system memory access and access to zero-wait state system slaves via the internal debug access port (DAP) connected to the system bus matrix. This access is non-intrusive and a debugger can access the devices, including memory when the processor is halted or running. Core register full access is available, if the processor is halted. The System Control Space (SCS) provides debug through registers available. The Data Watchpoint Unit (DWT) provides two watchpoint register sets, each implement data address and PC based watchpoint functionality including comparator address masking. The processor BreakPoint Unit (BPU) provides four PC based breakpoint register. The system is accessible by the tool through DAP. DAP permits access to debug resources when the processor is running, halted, or held in reset. A processor enters Debug state if it is

configured to halt on a debug event, and a debug event occurs. The supported debug infrastructure can be identified by checking the ROM table.

24.1.1 Features

The accurate Debug and Trace System provides the following functionality:

- Serial Wire Debug Port (SWD) provides Serial Wire Debug, which allows to debug via 2 pins.
- Single Pin Debug (SPD) provides a debug capability via 1 pin.
- Processor halt, single-step, processor core register access
- Reset and HardFault Vector Catch.
- Software breakpoints
- Full system memory access
- 4 Hardware breakpoints supported
- 2 watchpoints supported

Note: Please refer to [ARMv6-M Architecture Reference Manual](#) for more detailed informations on the debug functionality.

24.1.2 Block Diagram

The Debug system block diagram is shown in [Figure 24-1](#).

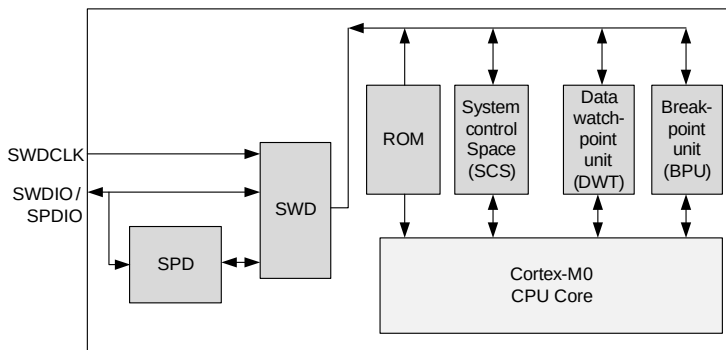


Figure 24-1 Debug and Trace System block diagram

24.2 Debug System Operation

The Debug System provides general debug options. Debug options are based on break points and CPU halt. Debug resources available are Data Watchpoint and Trace, Breakpoint unit, ROM table and the SCS system control block and debug control block. Debug capabilities can be accessed by a debug tool via Serial Wire Debug interface

(SWD) or Single Pin Debug (SPD). The selection of the access protocol (SWD or SPD) is done by BMI mode setting.

24.2.1 System Control Space (SCS)

The SCS is the area where the debugger can have direct access to the memory mapped register debug register. The debug resources together with the debug register in the SCS are accessible through the DAP interface. Accessible resources are for example system control and ID registers including system control block. Additionally the system timer and the interrupt controller (NVIC) can be accessed via the SCS.

24.2.2 Data Watchpoint and Trace (DWT)

The DWT unit provides an external Program Counter (PC) sampling capability based on PC sample register and comparators, that support watchpoints for address matching and PC watchpoints for instruction address matching. The PC sampling feature and watchpoint support operate independently of each other and a watchpoint event is asynchronous to the instruction that caused it. The XMC1200 supports two watchpoints, each supporting compare, mask and function registers. Watchpoint events result in a processor halt and enters the processor system into debug state. Data address matching results in a creation of a watchpoint event. Instruction address matching in a creation of a PC watchpoint event. The DWT register are accessible through the DAP interface.

A DWT program counter sample register permits a debugger to periodically sample the PC without halting the processor and allows coarse grained profiling. The PC sampling feature and the watchpoint support operate independently of each other. The register is defined so that a debugger can access it without changing the behavior of any code currently executing on the device.

The recommended mechanism for generating a breakpoint on a single instruction address is to use the BPU. The DWT based mechanism must be used to generate a PC matching event on a range of addresses. The debug return address value for a watchpoint event must be that of an instruction to be executed after the instruction responsible for generating the watchpoint.

24.2.3 Break Point Unit (BPU)

The Breakpoint (BKPT) instruction provides software breakpoints. It can cause a running system to halt depending on the debug configuration. A BKPT is a synchronous debug event, caused by execution of a BKPT instruction or by a match in the BPU. A BKPT causes the processor to enter debug state. The Debug tool can use this situation to investigate the system state when the instruction at a particular address is reached. The BPU provides support for breakpoint functionality on instruction fetches, based on instruction address comparator. The M0 provides four breakpoint comparator registers. Each breakpoint comparator register includes its own enable bit. The comparators match

instruction fetches from the Code memory region and operate only on instruction read accesses. The comparators do not match data read or data write access. Address matching is available on the upper half word, lower half word or both half words. Potential reasons for a debug event are a debug halt, a BKPT, a DWT trap and Vector CATCH.

24.2.4 ROM Table

To identify the Cortex-M0 processor with the respective Debug System components the debugger locates and identifies the ROM table. ROM table Identification values are predefined and contain pointers to the SCS, BPU and DWT. Each of the debug modules requires its own ROM table and indicate whether the block is present. The ROM table can be accessed through the DAP interface.

24.2.5 Debug tool interface access - SWD

The tool access based on SWD must use a connection sequence, to ensure that hot-plugging the serial connection does not result in unintentional transfer. The connection sequence ensures that the SWD is synchronized correctly to the header. The sequence consists of a sequence of 50 clock cycles data = 1s. This connection sequence is also used as a line reset sequence. The protocol requires that any run of 50 consecutive 1s on the data input is detected as line reset, regardless of the state of the protocol. After the line reset the debugger reads IDCODE register, which gives confirmation that correct packet frame alignment has been achieved.

24.2.5.1 SWD based transfers

The SWD interface requires to continue the clock for a number of cycles after the data phase of any data transfer. This ensures the transfer is completely clocked through the SWD. The transfer completion can be achieved by an immediate start of a new SWD operation, continuous clocking of SWD interface until the host starts a new SWD operation or after the data parity bit the clock is continued for at least 8 more clock rising edges, before stopping the clock.

Each sequence of operation on the serial wire consists of two or three phases and is defined from debugger point of view. The package request and acknowledge response phases are always there. The data transfer phase is only present when either data read or data write request is followed by a valid acknowledge response or the Overrun Detect flag is set.

The SWD protocol applies a simple parity check to all packet request and data transfer phases. On a packet request the parity check is made over the four bit header. On a data transfer the parity check is made over the complete 32 data bits. The parity is added directly after the packet request and after the data transfers. The parity bits are not included in the parity calculation.

Serial Wire Debug protocol operation

The SWD protocol supports the following operations:

- **Write operation** including OK response (3-Phases: 8-bit write packet request, 3-bit OK ACK, 33-bit data write including 1-bit parity at the end)
- **Read operation** including OK response (3-Phases: 8-bit read packet request, 3-bit OK ACK, 33-bit data read including a 1-bit parity at the end).
- **WAIT response** to read or write operation request (2 Phases: 8-bit read or write packet request, 3-bit WAIT ACK response)
- **FAULT response** Read or Write operation (2-Phases: 8-bit read or write packet request, 3bit FAULT ACK response)
- **Protocol error** sequence occurs when target failed to return a ACK response (1 Phase: 8-bit Packet request - line not driven by target for 32 bit cycles)

Note: A single-cycle turnaround period between the operation phases is required, for the transfer direction change only. If there is no transfer direction change, no turnaround period is introduced. If the protocol ends with a data transfer towards the debugger a turnaround period is introduced. After the single-cycle turnaround time the protocol must be proceeded.

24.2.5.2 SWD based errors

On the SWD interface protocol errors can occur. These errors might be detected by the parity checks on the data. A message header error can be detected by a parity error. A debugger not receiving a response or a port does not respond to the message, the debugger must back off. During the back off mechanism the debugger does read the IDCODE register and ensures the Debug Port is responsive and then retries the original access.

Errors can be returned by the DAP itself or might come from a debug resource. When an error occurs the error bit remains sticky until cleared. A debugger must check the error status after performing a series of transaction to be aware of an error.

Error conditions within the SWD interface are recorded using sticky flags. Potential errors are read and write errors, overrun detection, protocol errors. When the sticky bit is set to 1 it remains set until it is explicitly cleared to 0. When an error is flagged the current transaction is completed and any additional access port access transaction is discarded until the sticky flag is cleared to 0. A debugger must check periodically the Control/Status register after performing a series of transactions to detect the error.

A read and write error might occur within the DAP or come from the resource being accessed. Additionally a read or write error might be generated if the debugger makes an access port transaction request while the debugger power domain is powered down.

An overrun error might be detected on a sequence of transactions. Therefore the debugger must check after each sequence. The Overrun detection mode can be left by clearing the STICKYORUN and ORUNDETECT.

On the Serial Wire Interface protocol errors can occur, for example because of wire-level errors. These errors might be detected by the parity checks of data. If the SWD interface detects a parity error in a message header of the debug message the error is reflected. If the interface does not receive a response to a message, the debugger must back off. It must then requires a read of the IDCODE register, to ensure the debug port is responsive, before retrying the original access, again. If the SWD detects a parity error in the data phase of a write transaction, it sets the sticky write data error flag (WDATAERR) in the control and status register. Subsequent accesses from the debugger, other than IDCODE, CTRL/STAT or ABORT, result in a FAULT response.

24.2.6 Debug tool interface access - Single Pin Debug (SPD)

The SPD protocol based tool interface access allows to debug the system using a single pin only. The bit frequency is 2 MHz and allows an effective SWD telegram of 1.4 Mbits/s. The protocol is very robust against clock deviations between tool and device.

The SPD protocol encodes the SWD protocol bits with the distance between the SPD signal edges. A SWD value of '0' is encoded with a short distance of 0.5 μ s, a value of '1' with a distance of 1 μ s. This encoding is used in both transfer directions. Initially the SPD signal level always start with a positive SPD signal pulse with 1 μ s width, encoded SPD start bit, which is not part of the SWD protocol. The transmission of the rest of the telegram will be independent of the edge direction. As the protocol starts with a logic one start bit detection it is recommended to finish the protocol with a logic 0 signaling level. If the SPD signal level is high after the last bit of the telegram, that tool to add at '0' bit with a negative edge after 0.5 μ s. This can be achieved by the tool transferring an odd number of bits.

SWD has a clean request response protocol, where the tool is always the requestor and the device executes and sends a response. So the SWD module will change the direction as defined by the SWD protocol operations ([Section 24.2.5.1](#)).

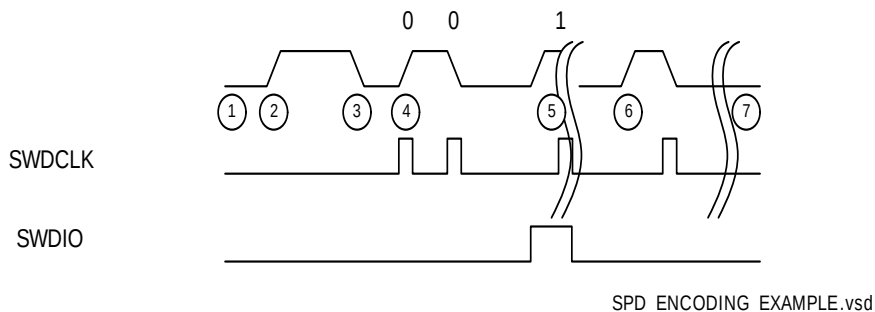


Figure 24-2 SPD Encoding Example

As a basic example a simple transfer is described in Figure before. Initially (1) the SPD module is in IDLE state. During IDLE state the SPD module does not generate a clock to the SWD module. At point (2) the SPD detects a rising edge and moves to a receive state. The first rising edge of the protocol is a start bit for the SPD module only and is not transferred to the SWD module. The following bits are the SWD header information and transferred to the SWD module. At point (5) a logic 1 shown and at (6) a logic zero. At the time the protocol direction is changed (which means for the implementation to go through IDLE state) the clock to SWD is switched off as shown in state (7). The SPD module requires to end on a Low signal value therefore it is required to have an odd number of bits moved into the interface.

Protocol transfer requirements between SWD and SPD module

The data transfer to and from SWD protocol is single bit based on the SWD clock. The SWD clock is generated by the SPD module and directly derived from the transferred bit. In RECEIVE direction the SPD module transfers the data to the SWD module bit wise, with one clock cycle per bit received.

The SPD module switches off SWD clock when going through module IDLE.

The Debugger adds a SPD start bit in front of the SWD telegram when it writes data to the device (form SPD point of view, RECEIVE). The SPD RECEIVE start bit is not transferred to the SWD module. The RECEIVE start bit is in front of the original SWD protocol on every new RECEIVE start, which is in front of the SWD header and again in front of debugger write data. Additionally the SPD module requires in RECEIVE direction a protocol to end with a logic zero signal level, which is achieved by an odd number of bits transferred by the tool. Based on the SWD protocol this is already achieved in the header phase by adding the described SPD start bit. During acknowledge phase as this phase does have 3 bits only. During the protocol data phase the Debugger has to add one more zero bit. (SPD Start bit, 32-bit data, parity bit, SPD odd bit as logic Zero).

As the SWD protocol requires in RECEIVE direction at least 8 clocks at the end of the data transferred to finish the protocol operation the Debugger has to add 9 logic zeros to the protocol (8 for this requirement and 1 to have an odd number).

SPD protocol based tool Interaction

All SPD communication is initiated by the tool. The tool will send a SWD header encoded to a SPD telegram (header) and then switches the SPD signal direction to input and wait for the acknowledge from the device.

SPD Receive:

Based on a low level the tool starts the protocol with SPD start bit. The start bit is indicated with a rising edge and a signal duration of 1 μ s. The following bits are based on the SWD protocol sequence.

The start sequence: SPD start bit + SWD HEADER + 0 Bit + 0 Bit (the two additional 0 bits at the end are required to achieve a low level at the signaling line.).

After receiving the header, the SWD will output his acknowledge response. Thus, SPD will change from RECEIVE to IDLE to SEND and ACKto IDLE again.

Leaving IDLE to RECEIVE state to transfer write data the start bit from tool is also required.

The SPD start bit must be a logic one with the defined time duration of a logic one. Is the signal duration longer it turns into a timeout situation. Is the signal duration shorter the start bit is not recognized.

The debug tool not sending data continuously in SPD RECEIVE direction, generates a Timeout in SPD module, which brings it to IDLE mode again. Starting from IDLE state the tool is required to provide SPD start bit for a new communication. A timeout is recognized after 1.4 μ s.

A permanent write (SPD RECEIVE) allows to proceed the protocol without SPD start bit. In this case the SPD interface remains in RECEIVE state and only the SWD receive protocol has to be performed. In this case the SWD header has to start with a logic 1 as defined by the SWD protocol.

SPD SEND:

The tool is required to end a RECEIVE at low level. Based on the low level the SEND start is indicated by a rising edge. SEND has to end with a signal low level, too.

IDLE:

From RECEIVE to IDLE - driven by SPD or by timeout.

From SEND to IDLE - driven by SWD module caused by direction change .

Time to switch from RECEIVE to SEND is between 375 and 500 ns and always goes through IDLE phase. The tool must change from write (SPD RECEIVE) to read (SPD SEND) direction within 375 ns. SEND always starts with a rising edge.

24.2.7 Debug accesses and Flash protection

The XMC1200 Flash implements read protection for sector 0 only. All other sectors can be read. Additionally a user configuration erase and write protection is available, which allows to protect Flash content from unintended writes or erase. Special care is taken, that the debugger can't bypass this protection.

Because of this, per default and after a system reset the debug interface is disabled. The Boot Mode Index (BMI) determines if the debug mode can be entered and the debug interface enabled at the end of the SSW.

Before the BMI is configured to user productive mode a change of BMI to arbitrary value is supported, afterwards BMI can only be restored to its default value, which does not enable debug access.

Besides the BMI configuration the Debug system supports a protection mechanism which prevents a debug access to the system address area during the time startup software (SSW) is running. Firmware controls the debug access, based on register setting.

Software based Breakpoints are supported, but prevented during SSW.

24.2.8 Halt after reset

There are two possibilities to perform a halt after reset. The first possibility is Infineon specific and allows to perform a CPU halt after "power on"/"master" reset (HAR) at the very first instruction of the Application code. The HAR activation is based on BMI settings and SSW executing endless loop, allowing a debugger to take control over the device. A defined configuration sequence driven by the connected debug tool is required in this case. The second possibility is the regular ARM flow halt after reset, which is based on breakpoints and a system reset. This halt after reset is also named "Warm Reset". In both cases the ARM system can not be accessed for security reasons from the debug port during the time SSW is running, as the physical pins are not available during that time. Based on the BMI setting the debug capability can be enabled at the end of the SSW by firmware. The default BMI configuration does not enable debug access.

24.2.8.1 HAR

The BMI can be configured to allow a HAR (UMHAR) at the end of the SSW, which always requires a power on reset to be executed. A new BMI configuration to BMI.UMHAR (User Mode with debug enabled and HAR) requires to perform a master reset to boot in UMHAR mode.

At a HAR (Cold Reset situation), the system comes from a PORST (or Master Reset) . To achieve a HAR, the tool has to register (CDBGPWRUPREQ) and enable (DHSCR.C_DEBUGEN) the debug system. Additionally it has to halt (DHCSR.C_HALT) the CPU and manipulate the PC (Program Counter) to point to the start address of the user code. The debugger registration and debug system enable is possible at the end of

Debug System (DBG)

the firmware, where firmware is waiting for a tool registration. During SSW execution the debugger as no access capability and cannot set the enabling bits CDBGPWRUPREQ, C_DEBUGEN or halt the CPU. The address of the user code start address can be read from address 0x10001004 in user Flash. It is recommended to check the Boot Mode Index BMI.HWCFG bit for UMHAR before manipulating the PC.

The following Figure (Figure HAR - Halt After Reset) shows the software flow based on the modules participating to the HAR.

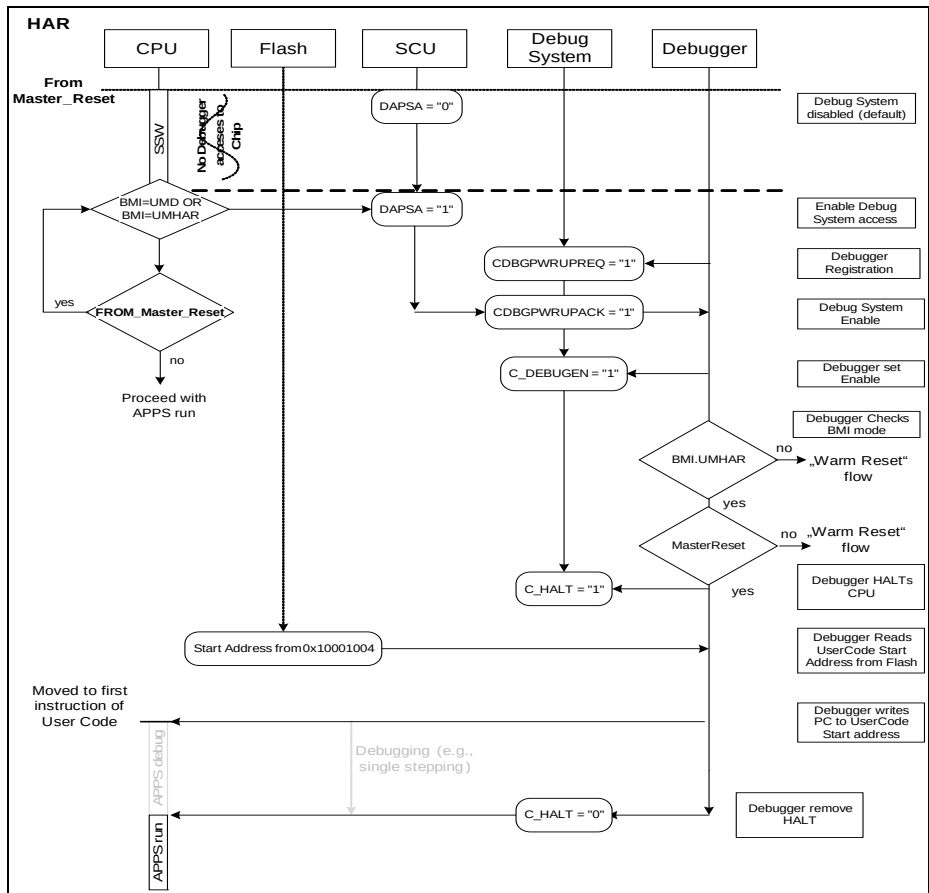


Figure 24-3 HAR - Halt After Reset Flow

24.2.8.2 Warm Reset

A halt after system reset (Warm Reset) can be achieved by programming a break point at the first instruction of the application code. Additionally the CDBGPWRUPREQ (tool registration) and the C_DEBUGEN has to be set by the debugger. After a system reset, the HAR situation is not considered, as the reset is not coming from PORST (Master_Reset).

Note: The CDBGPWRUPREQ and C_DEBUGEN does not have to be set after a system reset, if they have already been set before and the debugger remains registered. The bits are not affected by the system reset.

A tool hot plug situation allows to debug the system by enabling the CDBGPWRUPREQ and the C_DEBUGEN register. It is recommended to check the Boot Mode Index BMI.HWCFG. The Warm Reset flow can be done in both BMI modes, UMD (User mode with debug enabled) and UM HAR. In both cases the "Warm Reset" flow is based on breakpoint setting and system reset afterwards.

In general after a tool hot plug break points can be set or the CPU can directly be HALTED and stops at the actual program stage. To stop at the very first instruction of the user code the tool has to fire a system reset after setting the breakpoint there.

The following Figure (Figure Hot Plug and Warm Reset) illustrates the debug tool HOT PLUG situation or the Halt after Warm Reset (system reset) and how to proceed to come to a Halt situation.

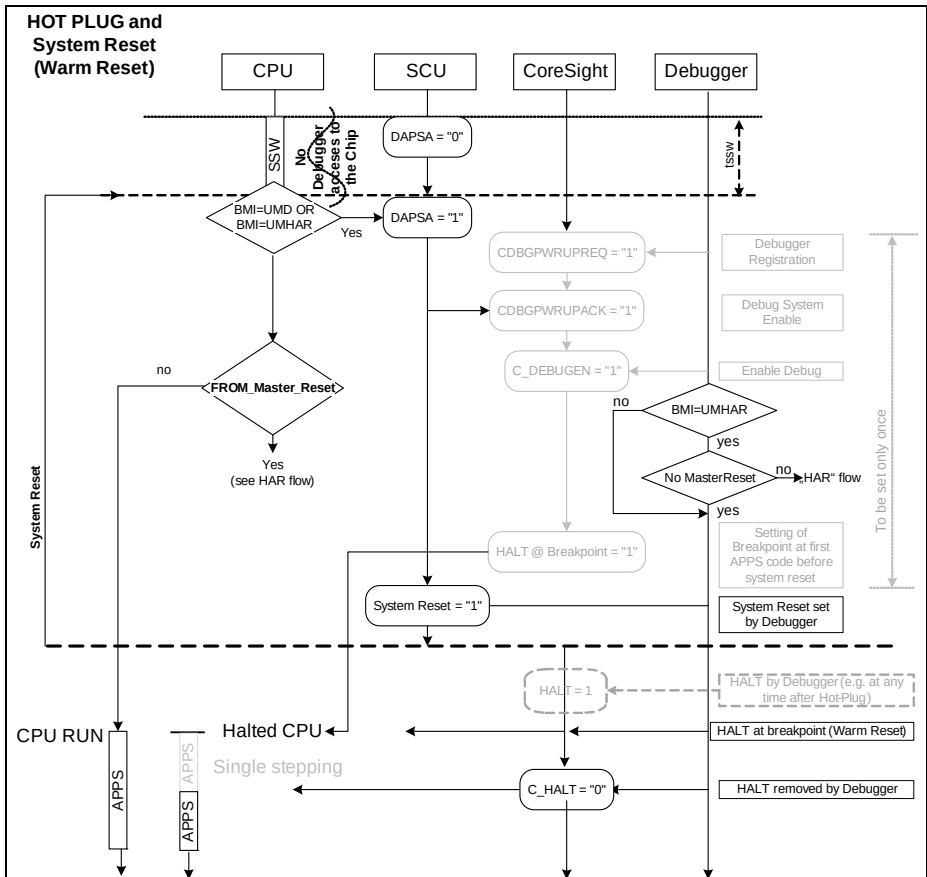


Figure 24-4 HOT PLUG or Warm Reset Flow

24.2.9 Halting Debug and Peripheral Suspend

The XMC1200 device supports a suspend capability for peripherals, if the program execution of the CPU is stopped by the debugger, e.g. with a breakpoint, or with the C_HALT. This allows to debug critical states of the whole microcontroller. Whether the suspend function is supported or not has to be configured locally at the peripheral.

In some cases it is important to keep certain peripherals running, e.g. a PWM or a CAN node, to avoid system errors or even critical damage to the application. Because of this, the peripheral allows to configure how it behaves, when the CPU enters halt debug

mode. Per default a peripheral is not sensitive on a suspend request. Sensitivity can be configured based on the system use case.

It can be decided at the peripheral to support a Hard Suspend or a Soft Suspend. At a Hard Suspend situation the clock at the peripheral is switched off immediately, without waiting on acknowledge from the module. At a soft suspend the peripheral can decide when to suspend. Usually at the end of the actual active transfer.

A Watchdog timer is only running when the suspend bus is not active. This is particularly useful as it can't be serviced by a halted CPU. A configuration option is available, which allows to enable the Watchdog timer also during suspend. This allows to debug Watchdog behavior, if a debugger is connected.

The user has to ensure, that always only those peripherals are sensitive to suspend, which are intended to be. To address this, each peripheral supporting suspend does have an enable register which allows to enable the suspend feature. The following table ([Table 24-1](#)) shows the peripherals, supporting or not supporting peripheral suspend or detailed information on the peripheral suspend behavior during soft suspend can be found at the respective peripheral chapter.

Table 24-1 Peripheral Suspend support

Peripheral	supported	default mode	Hard Suspend	Soft Suspend
RTC	yes	not active	yes	no
USIC	yes	not active	no	yes
CCU4	yes	not active	yes	yes
BCCU	yes	not active	yes	no
WDT	yes	active	yes	no
VADC	yes	not active	yes	yes
LEDTS	yes	not active	yes	no
PRNG	no	- - -	- - -	- - -

Note: Enable debug suspend function in the user initialization code after every reset. In addition the user has to consider debug suspend register at peripherals can only be configured after the clock of the module is enabled via CGATCLR0 register.

Important tool provider note:

The peripheral suspend logic is connected to the system reset. A system reset activation results in a peripheral suspend configuration loss. Therefore the suspend configuration at the peripherals "outlasting" a system reset, requires the tool to reconfigure the suspend configuration after system reset. This is achieved by shadowing the user peripheral suspend configuration in the tool and set a HW breakpoint at the first

instruction of use code, if the suspend function is activated. After the CPU halts at that breakpoint the tool has to reconfigure the suspend configuration at the peripheral, as it has been configured before the system reset.

Note: Suspend activation results in losing one HW breakpoint, as it is used by the tool to handle the suspend reconfiguration after system reset.

A debug tool should offer the peripheral suspend reconfiguration after system reset with an option to proceed Usercode without an user interaction requirement after tool reconfiguration or remain stopped at first line of user code and wait for user action.

(The user configures the desired suspend behavior only once and the tool stores the configuration to have it present for a automatic reconfiguration after a system reset.)

24.2.10 Debug System based processor wake-up

The debugger can wake-up a processor in sleep mode (sleep and deep sleep mode). The wake-up is based on a new pending interrupt event from the debug system, which is a HALT. The interrupt event does also wake-up the processor, if the interrupt is disabled or has insufficient priority to cause exception entry. The interrupt wake-up mode is derived by the NVIC (Programmable Multiple Priority Interrupt System) available in the processor system. The debugger is able to register, enable the Debug System and HALT the CPU also in sleep and deep sleep mode.

Note: The wake-up from deep-sleep mode via debugger halt is only supported using SWD interface. A wake-up from deep-sleep based on SPD interface is not supported.

24.2.11 Debug Access Server (DAS)

The DAS API provides an abstraction of the physical device interface for tool access. The key paradigm of DAS is to read or write data in one or several address spaces of the target device.

DAS Features

- Standard interface for all types of tools
- Efficient and robust methods for data transfer
- Several independent tools can share the same physical interface
- Infineon's DAS miniWiggler support SWD and SPD.

Note: DAS is not XMC1200 specific. It can be used for all Infineon 8-, 16, and 32-bit microcontrollers with DAP, SWD, SPD or JTAG interface. For more information refer to www.infineon.com/DAS.

24.2.12 Debug Signals

XMC1200 MC product family provides debug capability using ARM M0 Debug port SWD or the Infineon proprietary SPD. The SWD Port has 2 interface signals (Clock + Bidirectional data). The SPD port has one interface signal (SPDIO - bidirectional data) with an overlay of SWD interface SWDIO pin.

Table 24-2 SWD toplevel IO signal

Signal	Direction	Function
SWDCLK	I	Serial Wire Clock. This pin is the clock for debug module when running in Serial Wire debug mode.
SWDIO	I / O	Serial Wire debug data IO. Used by an external debug tool to communicate with and control the Cortex-M0 debug system.

The HALTED and EDBGREQ signals can be used to halt the CPU based on an external event. This allows to halt an external hardware synchronously with the CPU. The halt can be recognized by the external hardware based on the HALTED output. This can be used for example to synchronize with an logic analyzer and request a breakpoint or in a multi CPU scenario.

24.2.12.1 Internal pull-up and pull-down on SWD/SPD pins

It is a requirement to ensure none floating SWD/SPD input pins, as they are directly connected to flip-flops controlling the debug function. To avoid any uncontrolled I/O voltage levels internal pull-up and pull-downs on SWD/SPD input pins are provided.

- SWDIO/SPD: Internal pull-up
- SWCLK: Internal pull-down

24.2.13 Reset

The debug system register bits are reset by Power-on reset. Other reset in the system do not have an effect on the debug register, if the tool is registered.

24.3 Debug System Power Save Operation

The Debug System is in the “always-on” power domain, which allows to connect the debugger to the device. The Debug System does not support any special power mode or power save operation. The power supply of the Debug System is directly connected to the main chip part including the system components.

24.4 Service Request Generation

The debugger can set `DHCSR.C_MASKINTS` to 1 to prevent `PendSV`, `SysTick` and external configured interrupts from occurring.

24.5 Debug behavior

The Debug System is based on events. Whereas events are an entry to debug state, if halting debug is enabled. Debug events available are:

- Internal halt request
- Breakpoint
- Watchpoint
- Vector catch
- External debug request based on

The following events are synchronous debug events:

- Breakpoint debug events, caused by execution of a `BKPT` instruction
- Breakpoint debug events, caused by execution of a match in the BPU
- Vector catch debug events
- Step debug events (`DHCSR.C_STEP`)

The following events are asynchronous debug events:

- Watchpoint debug events, including PC match watchpoints
- Halt request debug event (`DHCSR.C_HALT`)
- External signal based debug request event (EDBGRQ signal)

Asynchronous debug events do have a lower prioritization than synchronous generated events. An instruction can generate a number of synchronous debug events. It also can generate a number of asynchronous exceptions.

The Debug Fault Status register (DFSR) contains a status bit for each debug event. The bits are write-one-to-clear. These bits are set to 1 when a debug event causes the processor to halt or generate an exception. The bits are also updated if the event is ignored.

Software must write `0xA05F` to the `DHCSR.DBGKEQ` register in order to be able to have debug support available from CPU side.

24.6 Power, Reset and Clock

The requirements for power, reset and clock are derived from ARM.

24.6.1 Power management

There is no power management implemented for the debug system. . Nevertheless the tool does has to follow the regular tool flow by setting the CDBGPWRUPREQ in order to register the tool.

24.6.2 Debug System reset

The SWD register are in the power on reset (PORST) domain.

The Debug logic is reset by system reset, if no tool is connected to chip and therefore not registered, which is indicated by **CDBGPWRUPREQ** not set.

Processor reset

A processor or warm reset (SYSRESETn) initializes the majority of the processor, excluding debug logic, BKPT unit, DWT unit and SCS.

PowerOn reset

PORESETn reset initializes the SWD access port, the AHB-AP logic and all other debug system related functions.

Normal operation

During normal operation the resets PORESETn and SYSRESETn are deasserted.

Processor reset affects Debug System

A System reset also affects the Debug System, if a tool is not registered. The tool registration is reflected by an activation of the register bit CDBGPWRUPACK, which activates by a debugger enabling the CDBGPWRUPREQ. .

24.6.3 Debug System Clocks

The Debug system clock is called DCLK and is derived directly from SCLK (free running clock). DCLK must always be driven while a debugger is connected.

24.7 Initialization and System Dependencies

24.7.1 ID Code

Available ID Code is used by a debug tool to identify the available debug components during tool setup.

Table 24-3 ARM CoreSight™ Component ID code

ID	Value	Description
SW_DP	0BB1 1477 _H	The ARM SW-DP ID

24.7.2 ROM Table

To identify Infineon as manufacturer and XMC1200 as device, the ROM table has to be read out. The format of the ROM table is illustrated in [Table 24-4](#).

Table 24-4 Peripheral ID Values of XMC1200 ROM Table

Name	Offset	Value ¹⁾	Bits	Reference	Infineon JTAG ID Code
PID0	FE0 _H	XXXXXXXX _B	[7:0]	Part Number [7:0]	DBGROMID [19:12]
PID1	FE4 _H	0001XXXX _B	[7:4] [3:0]	JEP106 ID code [3:0] Part Number [11:8]	DBGROMID [4:1] DBGROMID [23:20]
PID2	FE8 _H	XXXX1100 _B	[7:4] [3] [2:0]	Revision JEDEC assigned ID fields JEP106 ID code [6:4]	DBGROMID [31:28] '1' DBGROMID [7:5]
PID3	FEC _H	00000000 _B	[7:4] [3:0]	RevAnd, minor revision field Customer-modified block (if non-zero)	
PID4	FD0 _H	00000000 _B	[7:4] [3:0]	4KB count JEP106 continuation code	4KB count DBGROMID [11:8]

1) For "X" values please refer to Data Sheet

The ROM table values representing Infineon Part Number, JEP106 and Revision number can be checked in the SCU chapter.

24.8 Debug System Registers

Registers Overview

The absolute register address is calculated by adding:

The DWT, BPU, ROM table, DCB and debug register in the SCS are accessible memory mapped by the debugger and also from the CPU.

Table 24-5 Registers Address Space

Module	Base Address	End Address	Note
DWT	E000 1000 _H	E000 1FFF _H	Data Watchpoint
BP	E000 2000 _H	E000 2FFF _H	Breakpoint Unit
SCS	E000 E000 _H	E000 EFFF _H	SCS (here DBG CTRL)
ROM	E00F F000 _H	E00F FFFF _H	ROM table area

Table 24-6 Register Overview

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
SCS_DFSR	Debug Fault Status Register	D30 _H			Page 24-20
SCS_DHCSR	Debug Halting Control and Status Register	DF0 _H			Page 24-22
SCS_DCRSR	Debug Core Register Selector Register	DF4 _H			Page 24-28
SCS_DCRDR	Debug Core Register Data Register	DF8 _H			Page 24-29
SCS_DEMCR	Debug Exception and Monitor Control Register	DFC _H			Page 24-30
DWT_CTRL	DWT Control Register	000 _H			Page 24-31
DWT_PCSR	DWT program Counter Sample Register	01C _H			Page 24-32
DWT_COMP0	DWT Comparator register	020 _H			Page 24-32
DWT_COMP1	DWT Comparator register	030 _H			Page 24-32
DWT_MASK0	DWT MASK register	024 _H			Page 24-33
DWT_MASK1	DWT MASK register	034 _H			Page 24-33

Table 24-6 Register Overview (cont'd)

Short Name	Description	Offset Addr.	Access Mode		Description See
			Read	Write	
DWT_FUNCTION0	DWT Comparator Function register	028 _H			Page 24-34
DWT_FUNCTION1	DWT Comparator Function register	038 _H			Page 24-34
BP_CTRL	Breakpoint Control register	000 _H			Page 24-35
BP_COMP0	Breakpoint Comparator register	008 _H			Page 24-36
BP_COMP1	Breakpoint Comparator register	008C			Page 24-36
BP_COMP2	Breakpoint Comparator register	010 _H			Page 24-36
BP_COMP3	Breakpoint Comparator register	014 _H			Page 24-36

24.8.1 DFSR - Debug Fault Status Register

SCS_DFSR

The DFSR registers provides the top level reason why a debug event has occurred. Writing 1 to a register bit clears the bit to 0. A read of the HALTED bit by an instruction executed by stepping returns an UNKNOWN value.

SCS_DFSR

Debug Fault Status Register (D30_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											EXT ERN AL	VCA TCH	DWT TRA P	BKP T	HAL TED
r											rW	rW	rW	rW	rW

Field	Bits	Type	Description
HALTED	0	rw	HALTED Indicates a debug event generated by a C_HALT or C_STEP request, triggered by a write to the DHCSR. 0 _B no active halt request debug event. 1 _B halt request debug event active.
BKPT	1	rw	BKPT Indicates a debug event generated by BKPT instruction execution or a breakpoint match in the BPU. 0 _B no breakpoint debug event. 1 _B at least one breakpoint debug event.
DWTTRAP	2	rw	DWTTRAP Indicates a debug event generated by the DWT. 0 _B no debug events generated by the DWT. 1 _B at least one debug event generated by the DWT.
VCATCH	3	rw	VCATCH Indicates whether a vector catch debug event was generated. 0 _B no vector catch debug event generated. 1 _B vector catch debug event generated. <i>Note: The corresponding FSR shows the primary cause of the exception.</i>
EXTERNAL	4	rw	EXTERNAL Indicates an asynchronous debug event generated because of EDBGRRQ being asserted. 0 _B no EDBGRRQ debug event. 1 _B EDBGRRQ debug event.
0	[31:5]	r	Reserved

24.8.2 DHCSR - Debug Halting Control and Status Register

SCS_DHCSR

Controls halting debug. When C_DEBUGEN is set to 1, C_STEP and C_MASKINTS must not be modified when the processor is running (S_HALT is 0 when the processor is running). When C_DEBUGEN is set to 0, the processor ignores the values of all other bits in this register.

Debug System (DBG)

A separate register is represented below for read and write as the function changes at some bits access based.

SCS_DHCSR

Debug Halting Control and Status Register [Read Mode]

(DF0_H)

Reset Value: 0000 0000_H

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
0						S_R ESE T_ST	S_R ETIR E_S T	0				S_L OCK KUP	S_S LEE P	S_H ALT	S_R EGR DY
r						r	r	r				r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0												C_M ASKI NTS	C_S TEP	C_H ALT	C_D EBU GEN
r												r	r	r	r

Field	Bits	Type	Description
C_DEBUGEN	0	r	Halting debug enable bit 0 _B Halting debug disabled. 1 _B Halting debug enabled. <i>Note: If a debugger writes to DHCSR to change the value of this bit from 0 to 1, it must also write 0 to the C_MASKINTS bit, otherwise behavior is UNPREDICTABLE. This bit can only be written from the DAP Access to the DHCSR from Software running on the processor it cannot be set. This bit is 0 after Power-on reset.</i>
C_HALT	1	r	Processor halt bit. The effects of writes to this bit are: 0 _B Request a halted processor to run. 1 _B Request a running processor to halt. <i>Note: This bit is unknown after power-on reset</i>

Field	Bits	Type	Description
C_STEP	2	r	Processor step bit. The effects of writes to this bit are: 0_B Single-stepping disabled. 1_B Single-stepping enabled. <i>Note: This bit is unknown after power-on reset</i>
C_MASKINTS	3	r	Mask PEDSV, SysTick and external configurable interrupts. The effects of writes to this bit are: 0_B Do not mask 1_B Mask PendSV, SysTick and external configurable interrupts. The effect of any attempt to change the value of this bit is UNPREDICTABLE unless both: • before the write to DHCSR, the value of the C_HALT bit is 1 • the write to the DHCSR that changes the C_MASKINTS bit also writes 1 to the C_HALT bit. This means that a single write to DHCSR cannot set the C_HALT to 0 and change the value of the C_MASKINTS bit. When DHCSR.C_DEBUGEN is set to 0, the value of this bit is UNKNOWN. This bit is UNKNOWN after Power-on reset.
S_REGRDY	16	r	S_REGRDY status - a handshake flag for transfers through DCRDR How to work with: • Writing to DCRSR clears the bit to 0. • Completion of the DCRDR transfer then sets the bit to 1 Check DCRDR for more information. 0_B There has been a wrote to the DCRDR, but the transfer is not complete. 1_B The transfer to or from the DCRDR is complete. <i>Note: This bit is only valid when the processor is in Debug State, otherwise the bit is UNKONWN.</i>

Field	Bits	Type	Description
S_HALT	17	r	S_HALT indicates whether the processor is in Debug state. 0_B Not in Debug State. 1_B In Debug State.
S_SLEEP	18	r	S_SLEEP indicates whether the processor is sleeping. 0_B Not sleeping. 1_B Sleeping. <i>Note: The debugger must set the DHCSR.C_HALT bit to 1 to gain control, or wait for an interrupt or other wake-up event to wake-up the system.</i>
S_LOCKUP	19	r	S_LOCKUP indicates whether the processor is locked up because of an unrecoverable exception. 0_B Not locked up. 1_B Locked up. <i>Note: This bit is only read as 1 when accessed by a remote debugger using the DAP. The value of 1 indicates that the processor is running, but locked up due to an unrecoverable exception case.</i>

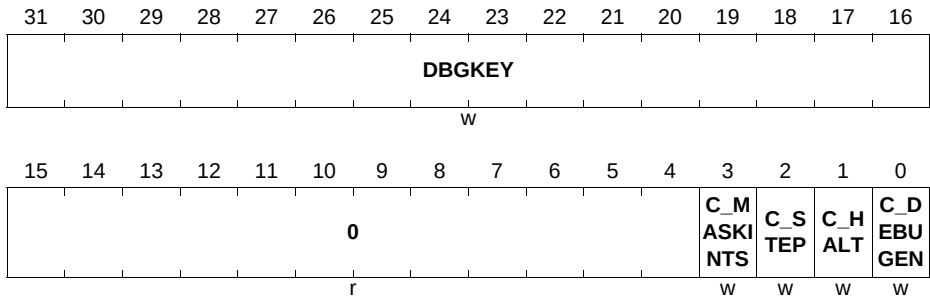
Field	Bits	Type	Description
S_RETIRE_ST	24	r	S_RETIRE_ST - When not in Debug state, indicates whether the processor has completed the execution of an instruction since the last read of DHCSR: 0_B No instruction has completed since the last DHCSR read. 1_B At least one instructions has completed since last DHCSR read. This is a sticky bit, that clears to 0 on a read of DHCSR. This bit is UNKNOWN: • after a Local reset, but is set to 1 as soon as the processor completes execution of an instruction • when S_LOCKUP is set to 1 • when S_HALT is set to 1 <i>Note: When the processor is not in Debug state, a debugger can check this bit to determine if the processor is stalled on a load store or fetch access.</i>
S_RESET_ST	25	r	S_RESET_ST indicates whether the processor has been reset since the last read of DHCSR. 0_B No reset since last DHCSR read. 1_B At least one rest since last DHCSR read. <i>Note: This is a sticky bit, that clears to 0 on a read of DHCSR.</i>
0	[15:4], [23:20], [31:26]	r	Reserved

SCS_DHCSR

Debug Halting Control and Status Register [Write Mode]

(DF0_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
C_DEBUGEN	0	w	Halting debug enable bit 0 _B Halting debug disabled. 1 _B Halting debug enabled. <i>Note: If a debugger writes to DHCSR to change the value of this bit from 0 to 1, it must also write 0 to the C_MASKINTS bit, otherwise behavior is UNPREDICTABLE. This bit can only be written from the DAP Access to the DHCSR from Software running on the processor it cannot be set. This bit is 0 after Power-on reset.</i>
C_HALT	1	w	Processor halt bit. The effects of writes to this bit are: 0 _B Request a halted processor to run. 1 _B Request a running processor to halt. <i>Note: This bit is unknown after power-on reset</i>
C_STEP	2	w	Processor step bit. The effects of writes to this bit are: 0 _B Single-stepping disabled. 1 _B Single-stepping enabled. <i>Note: This bit is unknown after power-on reset</i>

Field	Bits	Type	Description
C_MASKINTS	3	w	Mask PEDSV, SysTick and external configurable interrupts. The effects of writes to this bit are: 0_B Do not mask 1_B Mask PendSV, SysTick and external configurable interrupts. The effect of any attempt to change the value of this bit is UNPREDICTABLE unless both: • before the write to DHCSR, the value of the C_HALT bit is 1 • the write to the DHCSR that changes the C_MASKINTS bit also writes 1 to the C_HALT bit. This means that a single write to DHCSR cannot set the C_HALT to 0 and change the value of the C_MASKINTS bit. When DHCSR.C_DEBUGEN is set to 0, the value of this bit is UNKNOWN. This bit is UNKNOWN after Power-on reset.
DBGKEY	[31:16]	w	DEBUG Key Bits [31:16]!!! Software must write 0xA05F to this field to enable write access to bits [15:0], otherwise the processor ignores the write access
0	[15:4]	r	Reserved

24.8.3 DCRSR - Debug Core Register Selector Register

SCS_DCRSR

The DCRSR together with DCRDR (Debug Core Register Data Register) provides debug access to the ARM core register and special-purpose registers. A write to DCRSR specifies the register to transfer, whether the transfer is a read or a write, and starts the transfer. This register is only accessible in Debug state.

SCS_DCRSR

Debug Core Register Selector Register (DF4_H)

Reset Value: 0000 0000_H

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

Field	Bits	Type	Description
REGSEL	[4:0]	rw	REGSEL - Specifies the ARM core register or special-purpose register to transfer 00000 _B - 01100 _B ARM core register R0-R12. For example, 0b00000 specifies R0 and 0b00101 specifies R5 01101 _B The current SP. See also values 0b10001 and 0b10010. 01110 _B LR. 01111 _B Debug Return Address. 10000 _B xPSR. 10001 _B Main stack pointer, MSP. 10010 _B Process stack pointer, PSP. 10100 _B Bits[31:24] Control; Bits[23:8] Reserved; Bits[7:0] PRIMASK. In each field, the valid bits are packed with leading zeros. For example DCRDR [31L26] is 0b000000.
REGWnR	16	rw	REGWnR specifies the type of access for the transfer 0 _B read. 1 _B write.
0	[31:17], [15:5]	r	Reserved

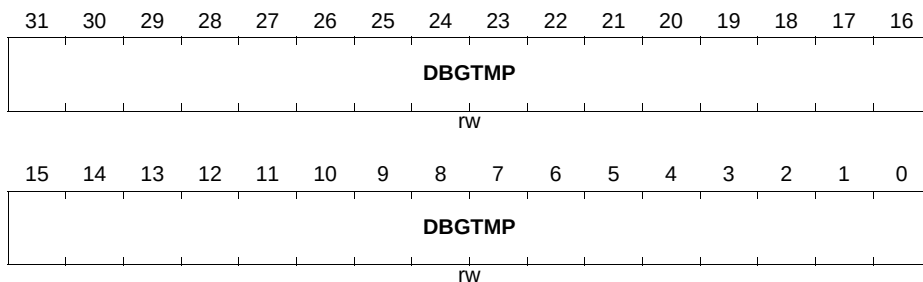
24.8.4 DCRDR - Debug Core Register Data Register

SCS_DCRDR

The DCRDR works with the DCRSR (Debug Core Register Selector Register). The DCRDR provides debug access to the ARM core registers and special-purpose registers. The DCRDR is the data register for these accesses.

SCS_DCRDR

Debug Core Register Data Register (DF8_H) **Reset Value: xxxx xxxx_H**



Field	Bits	Type	Description
DBGTMP	[31:0]	rw	DBGTMP - Data temporary cache, for reading and writing register. This register is UNKONWN: • on reset • when DHCSR.S_HALT = 0 • when DHCSR.S_REGRDY = 0 during execution of a DCRSR based transaction that updates the register.

24.8.5 DEMCR - Debug Exception and Monitor Control Register

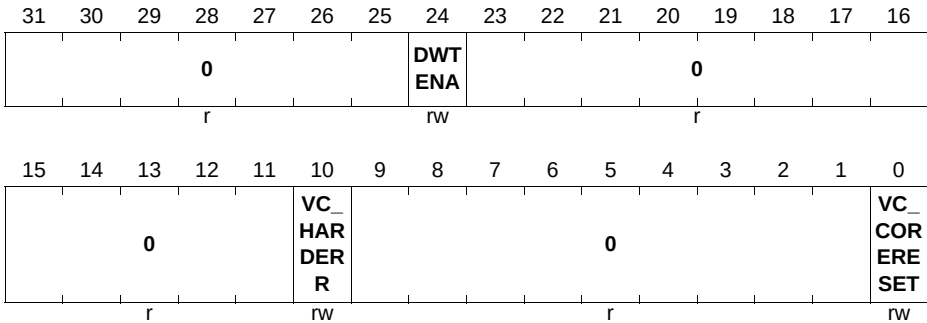
SCS_DEMCR

The DEMCR purpose is to manage vector catch behavior and enable the DWT.

A Power-on reset sets all register bits to 0. A local reset sets DWTENA to 0 but does not affect VC-HARDERR or VC_CORERESSET.

SCS_DEMCR

Debug Exception and Monitor Control Register (DFC_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
VC_CORERES ET	0	rw	VC_CORERESSET - Enable Reset Vector Catch. This causes a Local reset to handle a running system 0 _B Reset Vector Catch disabled. 1 _B Reset Vector Catch enabled. <i>Note: If DHCSR.C_DEBUGEN is set to 0, the processor ignores the value of this bit.</i>
VC_HARDERR	10	rw	VC_CORERESSET - Enable Reset Vector Catch. This causes a Local reset to halt a running system. 0 _B halting debug trap disabled. 1 _B halting debug trap enabled. <i>Note: If DHCSR.C_DEBUGEN is set to 0, the processor ignores the value of this bit.</i>
DWTENA	24	rw	DWTENA - Global enable for all features configured by the DWT unit. 0 _B DWT disabled. 1 _B DWT enabled. <i>Note: When DWTENA is set to 0 DWT registers return UNKNOWN values on reads. In addition the processor ignores writes to the DWT while DWTENA is 0.</i>

Field	Bits	Type	Description
0	[31:25], [23:16], [15:11], [9:1]	r	Reserved

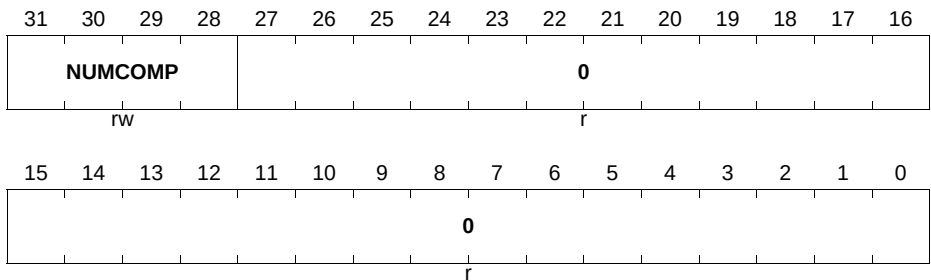
24.8.6 DWT_CTRL - Data Watchpoint Control Register

DWT_CTRL

The DWT_CTRL register defines the number of comparators implemented.

DWT_CTRL

Debug Halting Control and Status Register (000_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
NUMCOMP	[31:28]	rw	Number of comparators available 0000 _B No comparator support.
0	[27:0]	r	Reserved

24.8.7 DWT_PCSR - Program Counter Sample Register

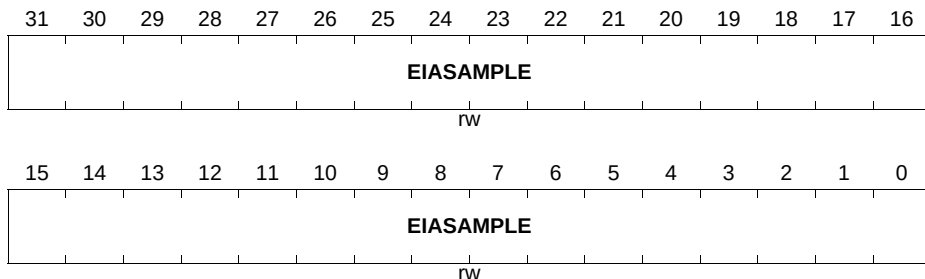
DWT_PCSR

The DWT_PCSR register samples the current value of the program counter. The register is UNKNOWN on reset.

DWT_PCSR

Program Counter Sample Register (01C_H)

Reset Value: xxxx xxxx_H



Field	Bits	Type	Description
EIASAMPLE	[31:0]	rw	EIASAMPLE Executed instruction address sample register

24.8.8 DWT_COMPx - DWT Comparator register

DWT_COMPx

The DWT_COMPx register provides a reference value for use by comparator x. The value is UNKNOWN on reset. DWT_CTRL.NUMCOMP defines the number of implemented DWT_COMPx register, from 0 to (NUMCOMP-1).

The DWT_COMP [1 .. 0] register are implemented.

DWT_COMP0

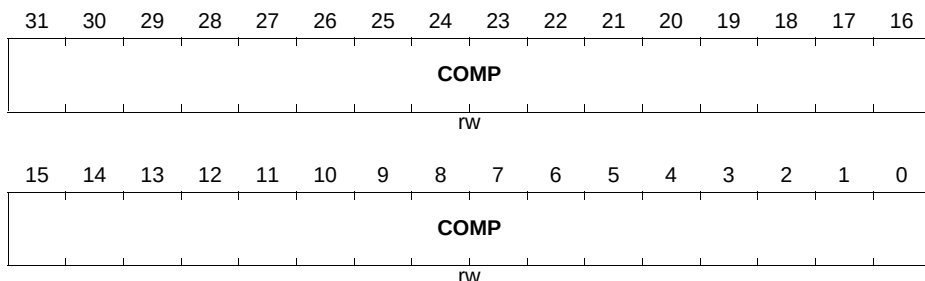
DWT Comparator register 0 (020_H)

Reset Value: xxxx xxxx_H

DWT_COMP1

DWT Comparator register 1 (030_H)

Reset Value: xxxx xxxx_H



Field	Bits	Type	Description
COMP	[31:0]	rw	COMP Reference value for comparison

24.8.9 DWT_MASKx - DWT Comparator Mask Register

DWT_MASKx

The DWT_MASKx register provides the size of the ignore mask applied to the access address range matching by comparator x. The value is UNKONWN on reset. DWT_CTRL.NUMCOMP defines the number of implemented DWT_COMPx register, from 0 to (NUMCOMP-1).

The DWT_MASK [1 .. 0] register are implemented.

DWT_MASK0

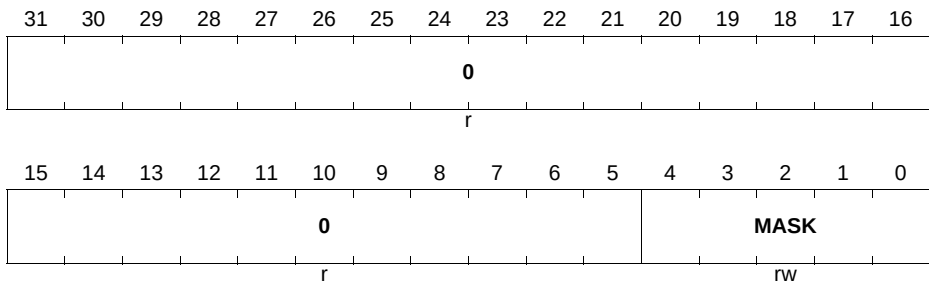
Debug Halting Control and Status Register (24_H)

Reset Value: 0000 0000_H

DWT_MASK1

Debug Halting Control and Status Register (34_H)

Reset Value: 0000 0000_H



Field	Bits	Type	Description
MASK	[4:0]	rw	MASK The size of the ignore mask applied to address range matching. Writing all ones to this field and reading it back can be used to determine the maximum mask size supported (not all mask bit must be implemented).
0	[31:5]	r	Reserved

24.8.10 DWT_FUNCTIONx - Comparator Function Register

DWT_FUNCTIONx

The DWT_FUNCTIONx register controls the operation of the comparator DWT_COMPx register. DWT_CTRL.NUMCOMP defines the number of implemented DWT_FUNCTIONx registers, from 0 to (NUMCOMP-1).

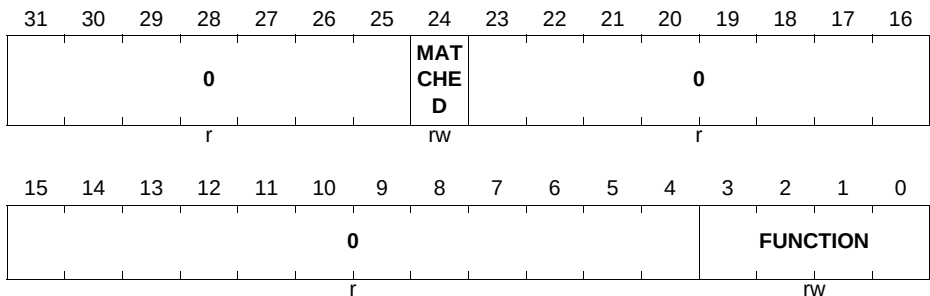
The DWT_FUNCTION [1 .. 0] register are implemented.

DWT_FUNCTION0

Comparator Function Register (28_H) **Reset Value: 0000 0000_H**

DWT_FUNCTION1

Comparator Function Register (38_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
FUNCTION	[3:0]	rw	FUNCTION Select action on comparator match- 0000 _B Disabled. 0001 _B Reserved. 0010 _B Reserved. 0011 _B Reserved. 0100 _B PC watchpoint event - input laddr. 0101 _B Watchpoint event - input Daddr (read only) 0110 _B Watchpoint event - input Daddr (write only) 0111 _B Watchpoint event - input Daddr (read/write) 1xxx _B reserved <i>Note: This field is set to 0 on a Power-on reset.</i>

Field	Bits	Type	Description
MATCHED	24	rw	MATCHED Comparator match. It indicates that the operation defined by FUNCTION has occurred since the bit was last read. 0_B the associated comparator has matched. 1_B the associated comparator has not matched. <i>Note: Reading the register clears this bit to 0.</i>
0	[31:25], [23:16], [15:4]	r	Reserved

24.8.11 BP_CTRL - Breakpoint Control Register

BP_CTRL

The Breakpoint Control Register provides BPU implementation information and the global enable for the BPU.

BP_CTRL

Breakpoint Control Register (000_H) Reset Value: 0000 0040_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								NUM_CODE				0		KEY	EN BLE
r								r				r	rw	rw	

Field	Bits	Type	Description
ENABLE	0	rw	ENABLE the BPU 0_B BPU is disabled. 1_B BPU is enabled. <i>Note: This bit is set to 0 on Power-on reset.</i>
KEY	1	rw	KEY reads as 0 on reads, should be 1 for writes. If written as zero, the write to the register is ignored.

Field	Bits	Type	Description
NUM_CODE	[7:4]	r	NUM_CODE, the number of breakpoint comparators.
0	[31:8], [3:2]	r	Reserved

24.8.12 Breakpoint Comparator Registers

BP_COMPx

The BP_COMPx register holds a breakpoint address for comparison with instruction addresses in the Code memory region. A comparator can only be enabled when BP_CTRL.ENABLE is set to 1. BP_CTRL.NUM_CODE defines the number of implemented BP_COMPx registers, from 0 to (NUM_CODE-1).

The BP_COMP [3 .. 0] register are implemented.

BP_COMP0

Breakpoint Comparator X Register (008_H) **Reset Value: 0000 0000_H**

BP_COMP1

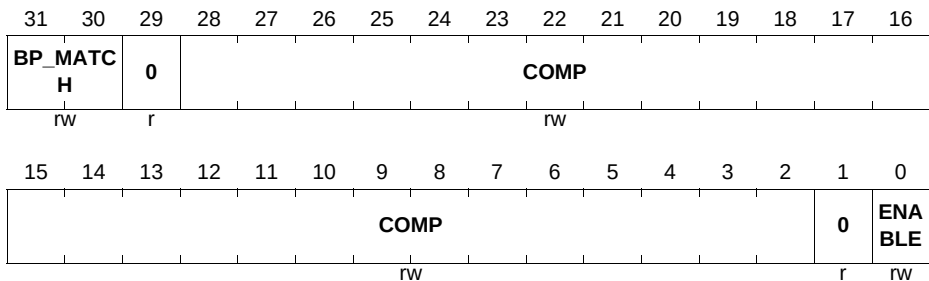
Breakpoint Comparator X Register (00C_H) **Reset Value: 0000 0000_H**

BP_COMP2

Breakpoint Comparator X Register (010_H) **Reset Value: 0000 0000_H**

BP_COMP3

Breakpoint Comparator X Register (014_H) **Reset Value: 0000 0000_H**



Field	Bits	Type	Description
ENABLE	0	rw	ENABLE the comparator 0 _B Comparator is disabled. 1 _B Comparator is enabled. <i>Note: This bit is set to 0 on a Power-on reset. BP_CTRL:ENABLE must also be set to 1 to enable a comparator.</i>
COMP	[28:2]	rw	Stores bits [28:0] of the comparison address. The comparison address is compared with the address from the Code memory region. Bits [31:29] and [1:0] of the comparison address are zero. <i>Note: The field is UNKNOWN on Power-on reset.</i>
BP_MATCH	[31:30]	rw	BP_MATCH defines the behavior when the COMP address is matched. 00 _B no breakpoint matching. 01 _B breakpoint on lower halfword, upper is unaffected. 10 _B breakpoint on upper halfword, lower is unaffected. 11 _B breakpoint on both lower and upper halfwords. <i>Note: The field is UNKNOWN on reset.</i>
0	29, 1	r	Reserved

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