TLE984x

Microcontroller with LIN and Power Switches for Automotive Applications

Firmware User Manual (AD/AE-step)

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Automotive Power

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1 Introduction

This document specifies the BootROM firmware behavior for the TLE984x microcontroller family.

The specification is organized into the following major sections:

Table 1-1 Document Content Description

Topic	Description
Startup procedure	**BootROM Startup procedure**: An overview on the Startup procedure: the first steps executed by the BootROM after a reset
LIN and Fast LIN BSL features	**Boot Strap Loader (BSL)**: An overview on the BSL : the module used to download and to run code from NVM and RAM
	BSL commands - Protocol (Version 2.0) : Details and Commands description
	BSL via LIN (Local Interconnected Network) **BSL via FastLIN** (UART via LIN)
NVM structure	**NVM**: An overview on the NVM : the module used to initialize and program the NVM sectors and pages
User routines description	**User Routines** : User routines description

1.1 Purpose

The document describes the functionality of the BootROM firmware.

1.2 Scope

The BootROM firmware for the TLE984x family will provide the following features

- Startup procedure for stable operation of TLE984x chip
- Debugger connection for proper code debug
- BSL mode for users to download and run code from NVM and RAM
- NVM operation handling, e.g. program and erase

1.3 Abbreviations and Special Terms

A list of terms and abbreviations used throughout the document is provided in **“Terminology” on Page 103**.

2 Overview

This specification includes the description of all firmware features including the operations and tasks defined to support the general startup behaviour and various boot options.

2.1 Firmware architecture

The BootROM in the TLE984x consists of a firmware image located inside the device's ROM. It consists of the startup procedure, the bootstrap loader via LIN, the bootstrap loader via Fast- LIN, NVM user routines and NVM integrity handling routines.

The BootROM in TLE984x is located at the address 00000000_H, and so represents the standard reset handler routine. The BootROM firmware is executed in the ARM Cortex CPU core and uses the SRAM for variables and software stack.

Figure 2-1 shows the TLE984x components used during execution of the BootROM.

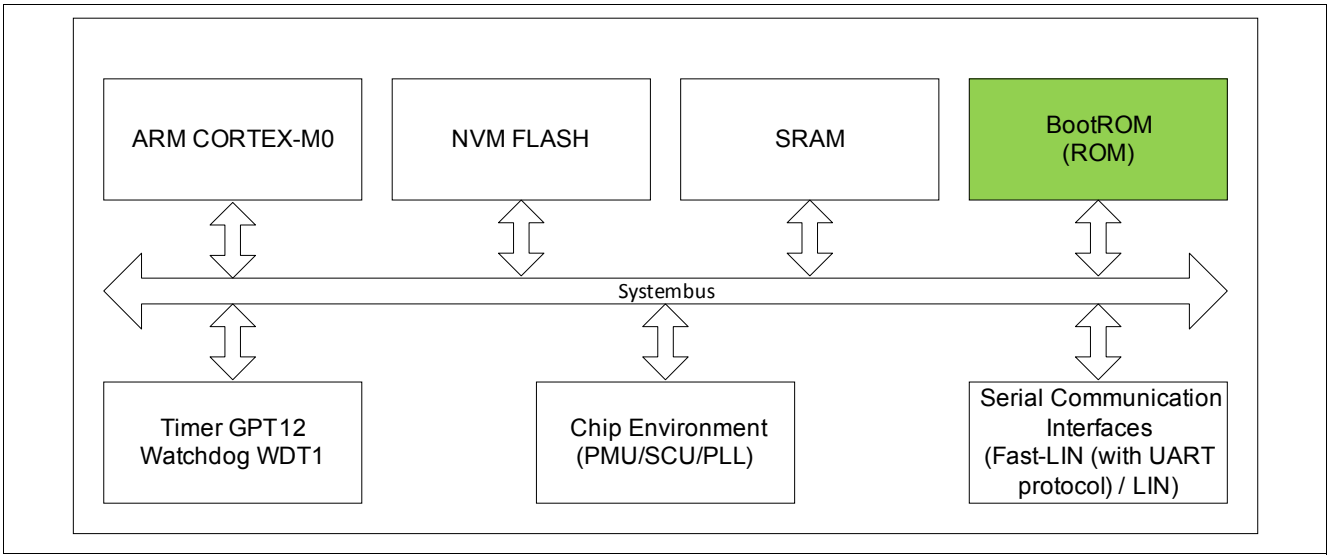


Figure 2-1 Block Diagram of the BootROM and its Interaction with other TLE984x Components

The startup procedure is the first software-controlled operation in the BootROM that is automatically executed after every reset. Certain startup submodules are skipped depending on the type of reset (more details are provided in **"Reset Types" on Page 14**) and the error which might occur (more details are provided in **"Startup Error Handling" on Page 17**).

The startup procedure includes the NVM initialisation, PLL configuration, enabling of NVM protection, branching to the different modes and other startup procedure steps.

There are two (2) operation modes in the BootROM :

- User/BSL mode
- Debug Support mode

The deciding factor will be on the latch values of TMS and P0.0 upon a reset. During reset, these signals are latched at the rising edge of RESET pin. Details are provided in **"Boot Modes" on Page 10**.

2.2 Program Structure

The different sections of the BootROM provide the following basic functionality.

Startup procedure

The startup procedure is the main control program in the BootROM. It is the first software-controlled operation in the BootROM that is executed after any reset.

The startup procedure performs initialization steps and decode the pin-latched values of the TMS and P0.0 to determine which mode to execute.

User mode

It is used to support user code execution in the NVM address space. However, if the NVM is not protected and the Bytes at address 11000004_H-11000007_H are erased (FF_H), then device enters sleep mode.

If a valid user reset vector was found at 11000004_H (values at 11000004_H - 11000007_H not equal to $FFFFFFFF_H$) and a proper NAC value is found then the BootROM proceeds into user mode.

In case an invalid No Activity Counter value is found (see also **“NAC Definition” on Page 11**), the device waits indefinitely for a FastLIN BSL communication.

LIN BSL mode

It is used to support BSL via LIN like protocol. Downloading of code/data to RAM and NVM related programming is supported in this mode.

FastLIN BSL mode

It is used to support BSL via FastLIN protocol. Downloading of code/data to RAM and NVM is supported in this mode.

2.3 RAM Structure for User

With user mode entry, the entire RAM is available to the user, but upon a reset the BootROM uses parts of the RAM for variables and for its program stack. For a reset type with no RAMBIST execution (e.g. softreset), user data outside the BootROM reserved RAM range will not get changed.

The BootROM RAM range is defined to go from 0x1800.0000 - 0x1800.03FF

3 BootROM Startup procedure

This chapter describes the BootROM startup procedure in TLE984x.

The startup procedure is the first software-controlled operation in the BootROM that is automatically executed after every reset.

There are 2 operation modes in the BootROM :

- User/BSL mode
- Debug Support mode

The operation modes get selected dependent on the latch values of two (2) pins upon reset. Details are provided in **“Boot Modes” on Page 10**.

For each HW module a HW abstaction layer (HAL) is implemented with its associated module specific firmware functions called by the BootROM startup procedure.

Figure 3-1gives an overview by showing the startup code partitioning into firmware modules and the corresponding dataflow.

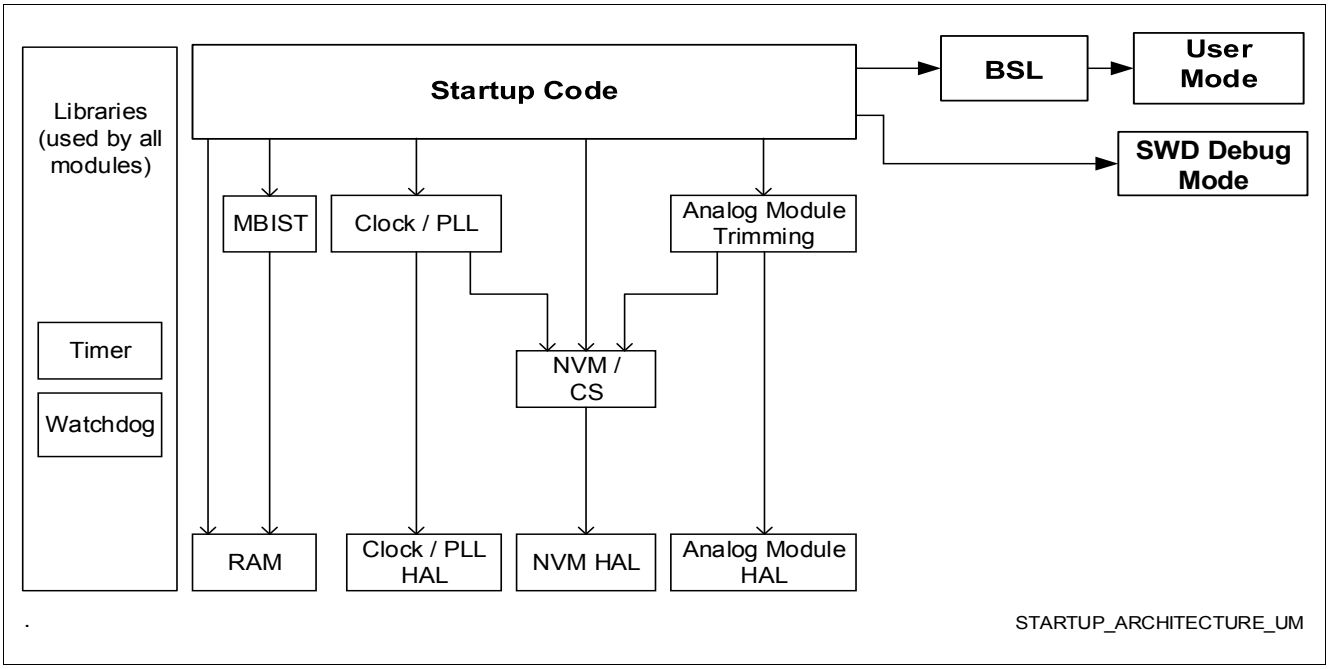


Figure 3-1 Startup Procedure Architecture Overview

The startup code performs different device initialization steps.

After initialization, the BootROM either starts BSL communication (according to configuration) or jumps to user mode code execution.

For user mode, BootROM will execute the startup procedure, redirect the vector table to the beginning of the NVM in user accessible space (by proper setting of the VTOR register) and jump to the customer defined reset handler routine (jump to the address pointed by the address 11000004_H) to execute the user program.

3.1 Startup Program Structure

The first task executed by the BootROM startup procedure is to check the reset type.

The BootROM also reads the logical state of certain external Pins (see **“Boot Modes” on Page 10**) to decide which initialization sub modules to be executed or to be skipped during the startup sequence.

A list of supported boot mode pin selections is given in **“Boot Modes” on Page 10**.

Many of the called initialization parts require further configuration parameters which are stored in the NVM CS (Configuration Sector).

The initialization process differs slightly between each selected boot mode. Each boot mode has a different set of initialization steps to be performed. For instance, some initialization steps might be skipped for one mode but carried out for another mode.

The functional blocks are listed in **Table 3-1**.

Table 3-1 Functional Blocks

Block	Description	Reference
Watchdog Disable	The WDT1 is disabled, depending to the boot mode.	**Section 3.8.1**
RAM MBIST	Performs RAM MBIST (optional).	**Section 3.8.2**
RAM Init	Inits RAM to zero (mandatory).	
MapRAM Init	Inits MapRAM based on MapBlock data	**Section 5.3**
Analog Module Trimming	Analog module NVM CS trimming values are configured in the hardware.	**Section 3.8.3**
PLL Init	Switch system clock to PLL	**Section 3.5**
Start NAC Timer	Start a timer which is dedicated to the user mode / BSL “no activity count timeout” calculation.	**Section 3.8.5**
BSL	BSL communication	**Chapter 4**

3.2 Boot Modes

The different BootROM-supported boot modes are listed in **Table 3-2 “BootROM Boot Modes” on Page 10**. These boot modes are pin-latched during reset release. The mode decides which initialization parts are to be executed by BootROM.

Table 3-2 BootROM Boot Modes

TMS / SWD_IO	P0.0 / SWD_CLK	Mode / Comment
0	X	**USER_BSL_MODE** User Mode / BSL Mode
1	1	**SWD_DEBUG_MODE** Debug Support Mode with SWD port
All other values		Reserved for internal use

3.3 Debug Support Mode entry (with SWD port)

Debug support mode is available for SWD. The BootROM starts the overall device initialization as described in **“Startup Program Structure” on Page 9**.

The BootROM then enters a waiting loop to synchronize with the debugger connected to the Serial Wire Debug (SWD) interface. After that, the BootROM finishes the boot process and starts to execute user code under control of the debugger.

Firmware ensures that jumping to user code in user mode entry or customer debug entry is performed with identical RAM and SFR content, except WDT1.

The watchdog is always disabled in debug support mode, except when the debug error loop is entered after a boot error.

3.4 NAC Definition

The No Activity Counter (NAC) value defines the time window after reset release within the firmware is able to receive BSL connection messages. If no BSL messages are received on the selected BSL interface during the NAC window and NAC time has expired the firmware code proceeds to user mode.

NAC is a byte value which describes the timeout delay with a granularity of 5 ms. The NAC timeout supports a maximum of 140 ms.

For example:

- NAC = 05_H indicates a timeout delay of 25 ms (5_D x 5 ms) before jumping to user mode
- NAC = 16_H indicates a timeout delay of 110 ms (22_D x 5 ms) before jumping to user mode

After ending the start up procedure, the program will detect any activity on the LIN/ FastLIN interface for the remaining NAC window. When noactivity is detected, the program will jump to user mode. To determine the minimum required NAC value, the baudrate, the interframe gap and the BSL passphrase requirements need to be taken into account. For more details, refer to **“LIN / FastLIN Passphrase” on Page 20**

In case a valid BSL passphrase is detected during the BSL window the firmware suspends the counting of the WDT1 in order to avoid that requested BSL communication is broken by a WDT1 reset. The firmware will then re-enable WDT1 before jumping to user code.

If NAC is 00_H, the BSL window is closed, no BSL connection is possible and the user mode is entered without delay.

If NAC is FF_H , no timeout is used, BootROM code will switch off WDT1 and wait indefinitely for a BSLconnection attempt.

3.5 User and BSL Mode Entry (UM)

Entry to user mode is determined by the No Activity Count (NAC) value,see **“NAC Definition” on Page 11**.

After waiting the time defined by the current NAC value, the startup procedure sets the VTOR register to point to the beginning of the NVM (11000000_H) and jumps to the reset handler. If a NVM double Bit error occurs when reading the NAC value, the system goes into an endless loop waiting for BSL communication. Before entering User mode (except for Hot Reset, see **Figure 3-2 “Flowchart – Start BootROM” on Page 13**), the system clock frequency is switched to PLL output and to the max. frequency as stated in the datasheet. In case PLL has not locked within 1 ms, the clock source fINTOSC/4 (20 MHz) will be used.

User mode is entered by jumping to the reset handler. This can happen directly from startup routine, after a waiting time for possible BSL communication, or as a result of BSL commands. In all these cases, a jump to user mode will only occur if the NVM content at 11000004_H-11000007_H is not $FFFFFFFF_H$. Otherwise, the BootROM executes an endless loop.

3.5.1 Unlock BSL Communications

The BootROM locks the BSL LIN and FastLIN communication after reset to avoid unexpected BSL communication on the customer side. The host needs to unlock the communication by sending a passphrase sequence to the BootROM.

Details about this passphrase and how it influences the NAC timeout are given in **“LIN / FastLIN Passphrase” on Page 20**.

3.5.2 Post User Mode Entry Recommendations

Upon USER MODE entry, it is highly recommended to to perform the following checks and actions:

Prior to any NVM operation, it is recommended to implement a test of SYS_STRTUP_STS.Bit1.
If the bit is clear then the data flash mapping is consistent NVM write/erase operation can be performed. To see if the Service Algorithm might have been active the user has to check the MEMSTAT register. If the Service Algorithm was active the user has to expect that expected logical data flash pages are not present anymore. The user has to take care of this and reconstruct any missing page. Furthermore it might be possible that the Service Algorithm reports an unrecoverable failure inside the Data Flash, then the same corrective actions shall be applied as described in the following paragraph for the case that SYS_STRTUP_STS.Bit1 is set.
If the SYS_STRTUP_STS.Bit1 is set, then the data flash mapping is inconsistent, the mapping might not be complete and any NVM operation like write or erase is not safe and might cause further inconsistencies inside the data flash. As corrective actions the user might reset the device (cold reset) in order to give the Service Algorithm a chance to repair the data flash sector. If this attempt fails again, then a sector erase is needed to reinitialize the data flash sector and to remove any mapping inconsistency. After the data flash sector has been erased the user has to take care of reconstructing the expected logical data flash pages.

The reset source should get read from the PMU Reset Status Register (PMU_RESET_STS). Clearing PMU_RESET_STS is strongly recommended in the user startup code, as uncleared bits can cause a wrong reset source interpretation in the BootROM firmware after the next reset (e.g. handling a warm reset as a cold reset)

The system startup status register SCU.SYS_STRTUP_STS should get checked for any startup fails. The bit INIT_FAIL which is a logical or of all modul status bits should get checked at least. See the TLE984xQX User's Manual for a detailed register description

3.6 Flowcharts for User BSL / Debug Modes

This section provides the firmware flow charts that are relevant for user and debug boot modes.

BootROM Startup procedure

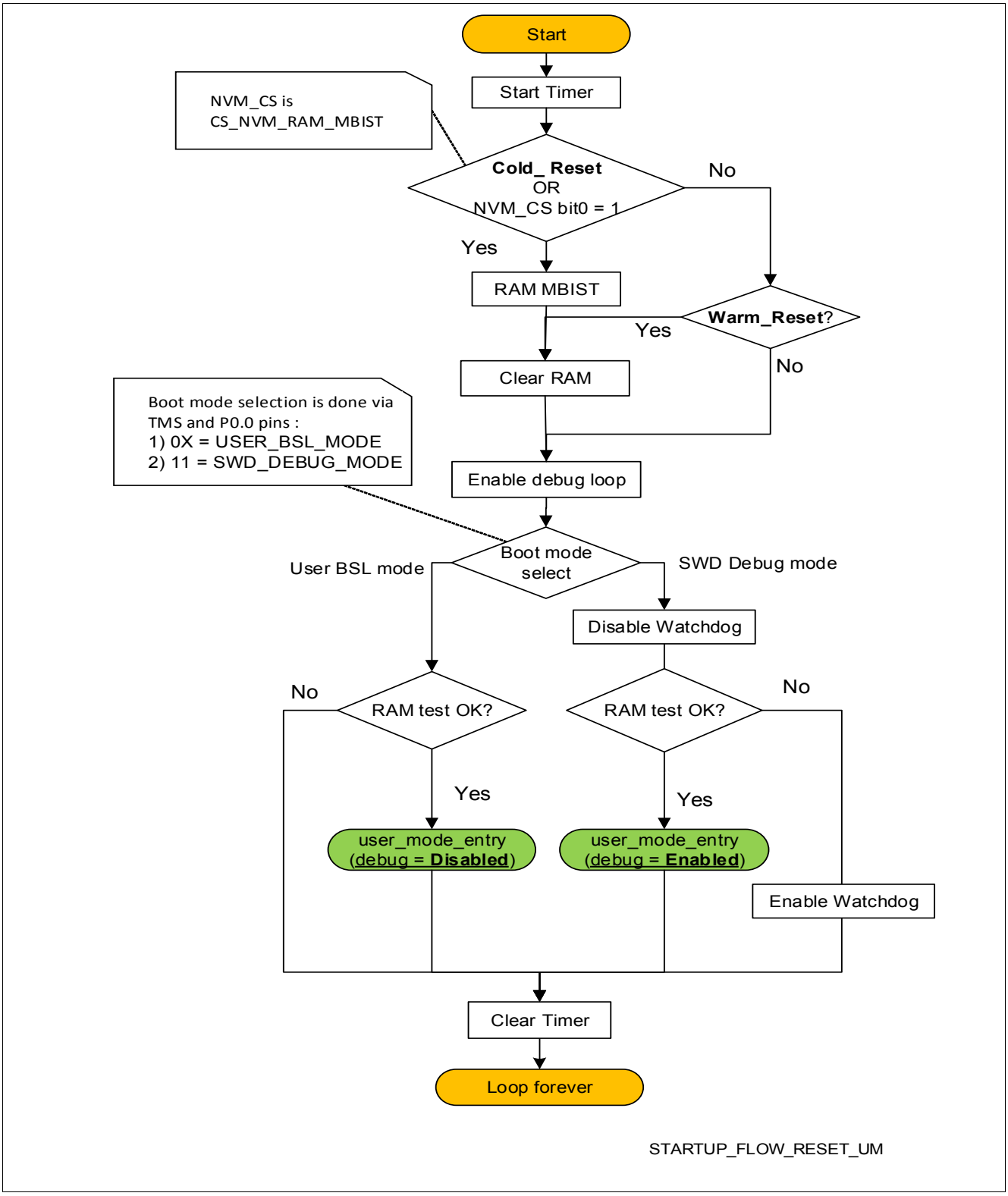


Figure 3-2 Flowchart – Start BootROM

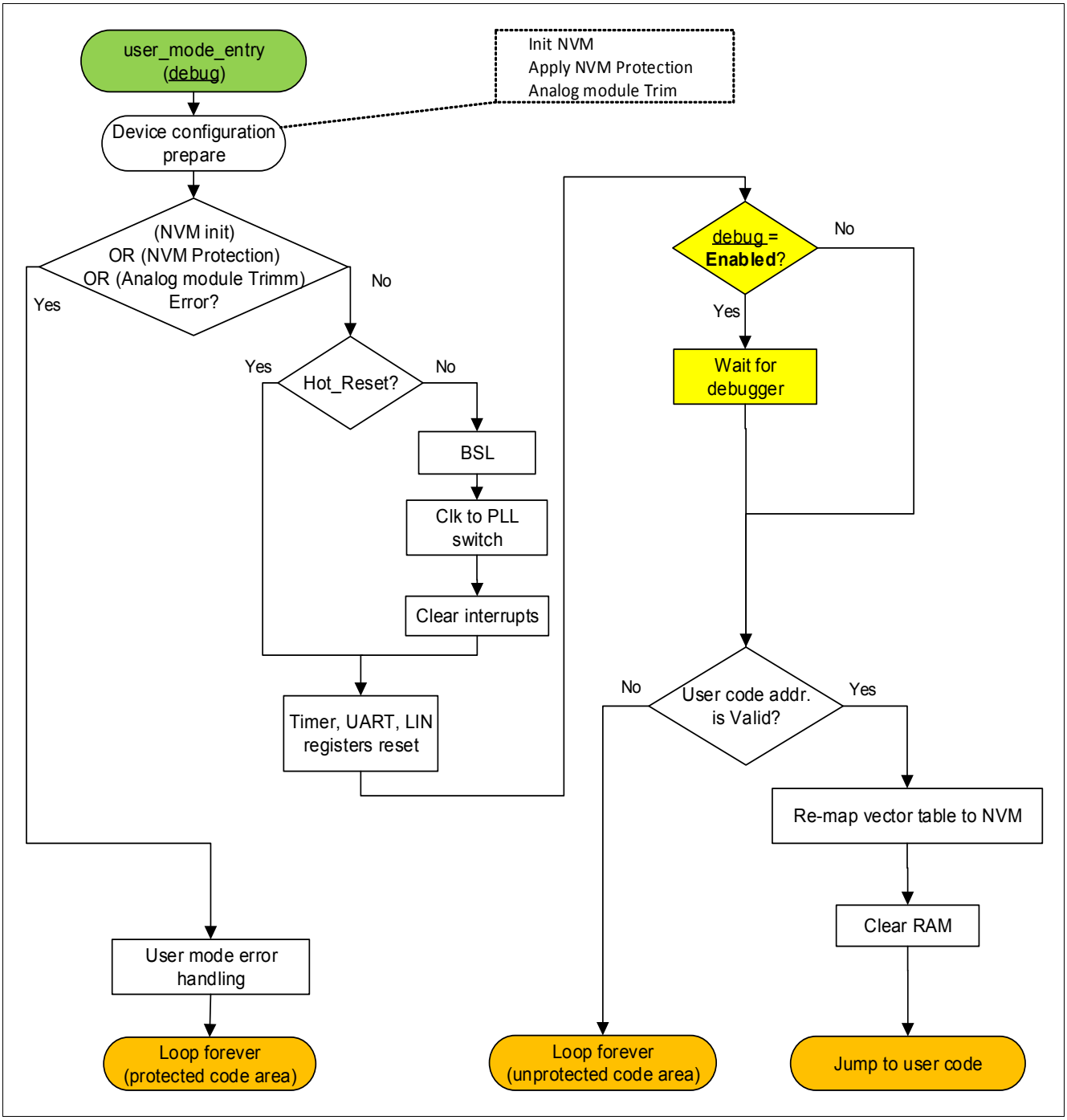


Figure 3-3 Flowchart – User BSL Mode

3.7 Reset Types

The BootROM classifies the different hardware resets according to the following reset types:

- Cold reset
- Warm reset
- Hot reset

Cold reset

The reset events generated from the following sources, are classified as cold resets :

- POR : Power-on reset
- Pin reset
- Watchdog reset
- System fail

After a cold reset, all initialization steps, listed in **Table 3-1 “Functional Blocks” on Page 10**, are processed in accordance with the boot mode.

Warm Reset

The reset events generated from the following sources, are classified as Warm resets :

- Sleep-exit reset
- Stop-exit reset

After a warm reset, the following initialization steps, listed in **Table 3-1**, are processed, except :

- RAM memory test - MBIST - (only executed if forced by NVM CS configuration, as described in **“RAM Test (MBIST) and RAM Initialization” on Page 16**)

Hot Reset

The reset events generated from the following sources, are classified as Hot resets :

- Software reset
- Lock-up reset

After a Hot reset, the following initialization steps, listed in **Table 3-1**, are processed, except :

- RAM memory test - MBIST - (only executed if forced by NVM CS configuration, as described in **“RAM Test (MBIST) and RAM Initialization” on Page 16**)
- NVM map-RAM initialization
- Download of analog module trimming parameters (incl. oscillator and PLL settings)
- Switch system clock to PLL output

Reset priority

In case more than one reset event occur, the post reset initialization procedure with the highest priority type is executed. The priority is evaluated according to this priority order (where “1” is the highest priority):

1. Cold reset
2. Warm reset
3. Hot reset

Attention: The reset source is read from the PMU Reset Status Register (PMU_RESET_STS). Clearing PMU_RESET_STS is strongly recommended in the user startup code, as uncleared bits can cause a wrong reset source interpretation in the BootROM firmware after the next reset (e.g. handling a warm reset as a cold reset)
See also “Post User Mode Entry Recommendations” on Page 12..

3.8 Startup Procedure Submodules

The following submodules are described in this section.

- Watchdog configuration
- RAM Test (MBIST) and RAM initialization
- Analog module trimming
- Startup Error Handling
- No Activity Counter (NAC) Configuration
- Node Address for Diagnostics (NAD) Configuration

3.8.1 Watchdog Configuration

After a reset, the watchdog WDT1starts with a long open window. For all the reset types, firmware startup in user mode enables WDT1 before jumping to user code, and the watchdog cannot be disabled while user code is being executed.

The watchdog WDT1is disabled before entering into debug mode. WDT1 continues running while waiting for the first BSL frame. If host synchronisation is completed during the BSL waiting time (defined by NAC), WDT1 is disabled and its status is frozen.

WDT1 is re-enabled when entering user mode from BSL mode.

3.8.2 RAM Test (MBIST) and RAM Initialization

The RAM memory test is performed for cold reset type.

The RAM initialization is performed for cold and warm reset types.

It is possible to force a RAM test and the RAM initialization for the whole RAM range during startup regardless of reset type. This can be done by enabling the feature using the user API function **“user_mbist_set” on Page 81**. Exception for the forced test is that for WARM reset the first 1kB of the RAM will not be checked. User_ram_mbist() must therefore be called by the user on the first 1kB RAM range to make sure RAM test and RAM initialization is performed and no errors exist (user_ram_mbist(0x18000000, 0x180003FF)).

When executed, the RAM MBIST test destroys the contents of the tested RAM. It consists of a linear write/read algorithm using alternating data. RAM MBIST execution is user configurable for all reset types, see **“user_mbist_set” on Page 81**.

Prior to calling MBIST to test the first 1kB of RAM, stack and variables must be moved to the already tested RAM range above 1kB.

In case an error is detected in the RAM MBIST, the appropriate error status is captured and the device enters an endless loop. As the watchdog is enabled when entering the endless error loop after a boot in user or debugmode, a WDT1 cold reset is asserted after timeout and the RAM test is re-executed.

After five (5) consecutive watchdog resets, the device enters SLEEP mode (by hardware function).

The RAM initialization writes the whole RAM to zero with the proper ECC status. This is needed to prevent an ECC error during user code execution due to a write operation to a non initialized location (with invalid ECC code).

Note: The standard RAM interface is disabled during MBIST test execution.

3.8.3 Analog Module Trimming

During analog module trimming, the trimming values of PMU, voltage regulators, LIN module, temperature sensor, oscillator, PLLand other analog modules are read from the NVM configuration sector and written into

the respective SFR registers. In case 100TP pages with data for the trimming process contains CRC errors, the predefined ones are used.

- 100 Time Programmable data (user data)
  - User has eight 100 time programmable pages. The values of the first (page 0) and second (page 1) pages are automatically copied into the dedicated SFR registers after every COLD or WARM reset thus replacing the registers default reset values. The user can check them by reading the dedicated SFRs or by reading directly the content of the page.
  - This procedure allows the user to configure the ADC1 . The complete list of SFR registers is provided in **“Appendix D – Analog Module Trimming (100TP Pages)” on Page 110**
  - In case the first and second 100TP NVM CS (Configuration Sector) pages do not contain valid trimming data (CRC failure), the BootROM reports error and downloads alternative backup trimming values.

For BootROM reported error handling see **“Post User Mode Entry Recommendations” on Page 12**.

3.8.4 Startup Error Handling

To ensure that the device is properly booted, error checking and error handling are added to the startup procedure

For USER_BSL_MODE, the overall startup sequence ends up in an endless loopor SLEEP mode in the event that any called submodule returns an error.

If a startup error occurs – except for double-bit errors for NVM reading – and the boot option is USER_BSL_MODE, the device is set to a safe mode with limited access to HW resources. If the errors persist after five (5) WDT1 triggered timeouts, the device enters SLEEP mode.

Regardless of the boot mode, the system enters an endless loop in the case of NVM double-bit errors when reading the NVM contents.

For BootROM reported error handling see **“Post User Mode Entry Recommendations” on Page 12**.

Note: MON inputs must not be floating in order to prevent an unintended wakeup.

3.8.5 No Activity Counter (NAC) Configuration

A NAC timeout value is stored in the NVM CS. It is stored as a value and bit-inverted value in a dedicated NVM CS page.

During user mode, this parameter is read from the NVM CS (Configuration Sector) and verified against the stored inverted value. This parameter is provided as an API parameter when calling the BSL module. For details, refer to **Section 3.4**.

If the NVM CS does not contain a valid NAC, a “wait forever” NAC (NAC=FF_H) is given to the BSL module .

The BootROM offers 2 user API functions to read and write NAC parameter:

- **user_nac_get**
- **user_nac_set**

3.8.6 LIN Node Address for Diagnostics (NAD) Configuration

For LIN, a NAD is stored in the NVM CS (Configuration Sector). It is stored as a value and bit-inverted value in a dedicated NVM CS (Configuration Sector) page.

During user mode, this parameter is read from the NVM CS (Configuration Sector) and verified against the stored inverted value. The parameter is provided as an API parameter when calling the LIN BSL module. For details, please refer to **“Node Address for Diagnostic (NAD)” on Page 33**.

If the NVM CS (Configuration Sector) does not contain a valid NAD, a “broadcast” NAD (NAD=FF_H) is given to the LIN BSL module .

The BootROM offers user APIs for reading and writing NAD parameter:

- **user_nad_get**
- **user_nad_set**

4 Boot Strap Loader (BSL)

The BSL (Boot Strap Loader) module supports handling of message-based command request and response communication over the serial LIN interface. The received command messages are parsed and executed according to the LIN or FastLIN protocol. Details about this message protocol are given in **“BSL commands - Protocol (Version 2.0)” on Page 38**.

The device supports the following serial interfaces :

- LIN
- Fast-LIN (LIN interface using the UART protocol)

Figure 4-1 shows the various software submodules in the BSL module. The shared protocol is handled on a single protocol level that processes all messages described in **“BSL commands - Protocol (Version 2.0)” on Page 38**.

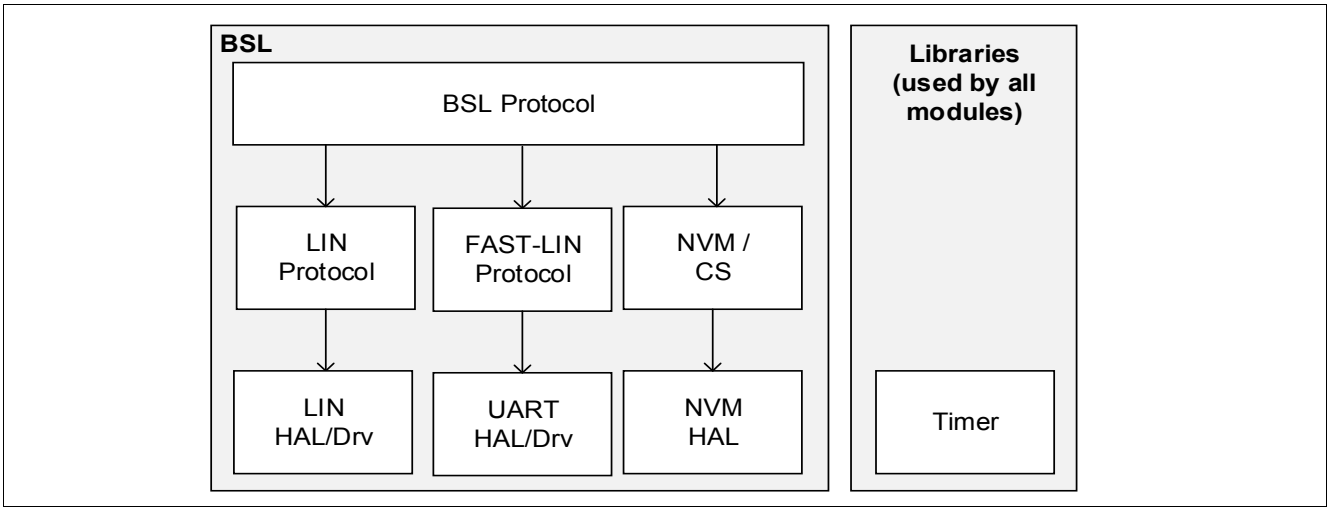


Figure 4-1 BSL Architecture

All command messages are encapsulated in an interface-specific frame format. This format includes specified parameters, such as a checksum calculation and overall message size. Also specified on this level is whether the interface is used as a peer-to-peer connection or as a master-slave-bus communication, which includes device node addressing. This interface-specific frame handling is implemented in the interface-specific protocol layer (e.g. LIN protocol).

The BSL protocol layer performs the command execution based on the parsed BSL commands. This results in programming of the NVM, NVM CS (Configuration Sector), downloading to RAM or execution of NVM/RAM code. It also includes the aspect that some commands are blocked based on applied hardware protection or boot mode selection.

4.1 BSL overview

In this chapter, more details about the BSL mechanisms are provided.

4.1.1 BSL Selector

The BootROM supports specification of a BSL interface selector in the NVM CS for user-/debug mode. This selector parameter is read and verified by the startup routine and provided as an API call parameter to the software module.

This interface selector can be read with the user API routine **user_bsl_config_get**, and can be modified with the routine **user_bsl_config_set**.

4.1.2 BSL Interframe Timeout

The interframe timeout is a configuration parameter read by BootROM startup code from the NVM CS (Configuration Sector).

Interframe timeout parameter has the same format as NAC value (1 = 1x5ms, 2 = 2x5ms ...).

The paramter value is set to 0x38, which results in a timeout value of 280ms (0x38 x 5ms).

4.1.3 NVM / RAM Range Access

Some BSL commands allow access to the NVM and some to the RAM. In BSL mode the following memory ranges are accessible for read and write operations:

- All user accessible NVM and NVM CS pages.
- The 100TP pages
- The RAM area , apart from the BootROM global variables and stack648 bytes from 18000178H to 180003FFH)

4.1.4 LIN / FastLIN Passphrase

The BootROM locks the BSL LIN and FastLIN communication after reset to avoid unexpected BSL communication on the customer side. The host needs to unlock the communication by sending a passphrase sequence to the BootROM.

A passphrase consists of two (2) consecutive frames, where each frame contains a set pattern. To unlock the BSL communication, both passphrase frames have to be sent by the host. Any other received message within the passphrase sequence stops the unlock sequence. The unlock procedure always restarts on receiving the first passphrase frame.

The contents of both passphrase frames are described in **Figure 4-2**.

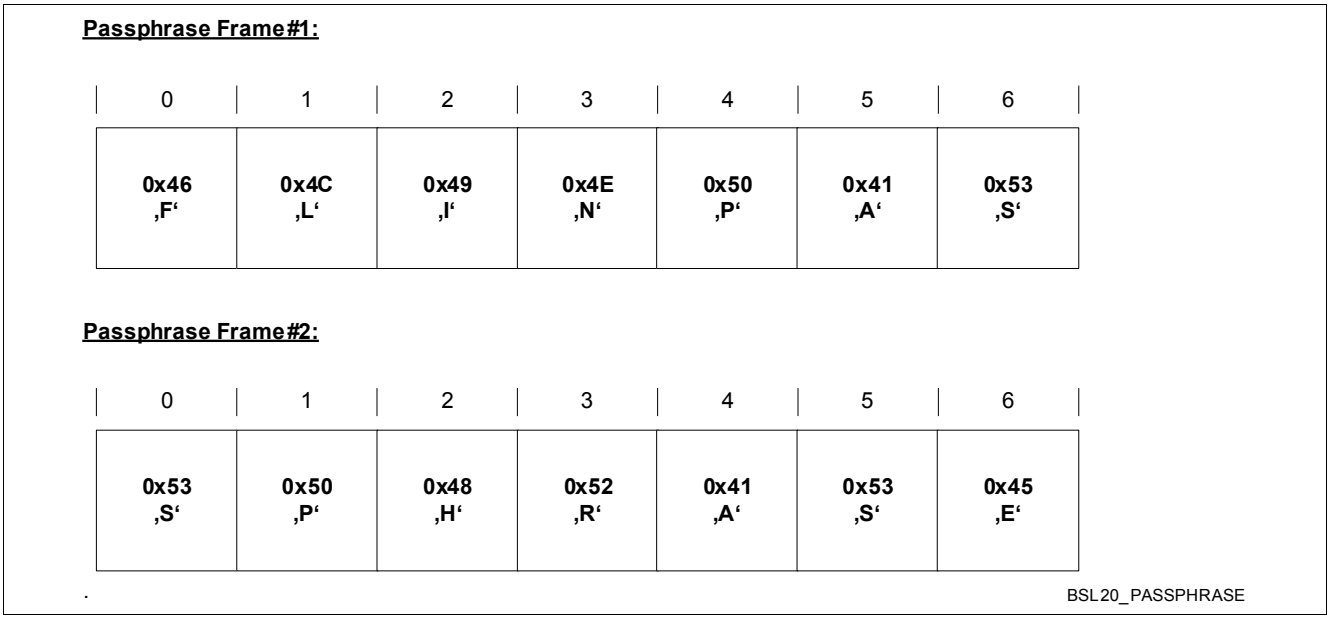


Figure 4-2 Passphrase Content

For LIN communication, the passphrase frames are encapsulated by sync break, sync char, protected ID, NAD and checksum byte fields. A passphrase frame is rejected in case of incorrect received NAD or checksum bytes. For FastLIN communication, the frames are extended by the checksum byte. Details about the encapsulation are given in **Section 4.2**.

The BootROM ignores and rejects all received LIN and FastLIN frames if the communication is still locked. This rejection includes frames with valid NAD and checksum fields. It does not reply to any received passphrase frames.

The NAC timeout stops when the communication is unlocked after receiving the second valid passphrase frame. For more details about NAC timout, refer to **Section 3.4**.

4.1.5 BSL Message Parsing & Responses

The BSL protocol provides single message commands and multimessage commands. A message state machine is implemented, which first collects all command-related messages before executing the command. It periodically polls the underlying interface protocol layer (e.g. LIN protocol layer) to collect all frames belonging to a BSL command.

Command Message State Machine

Figure 4-3 gives an overview of the BSL command message state machine.

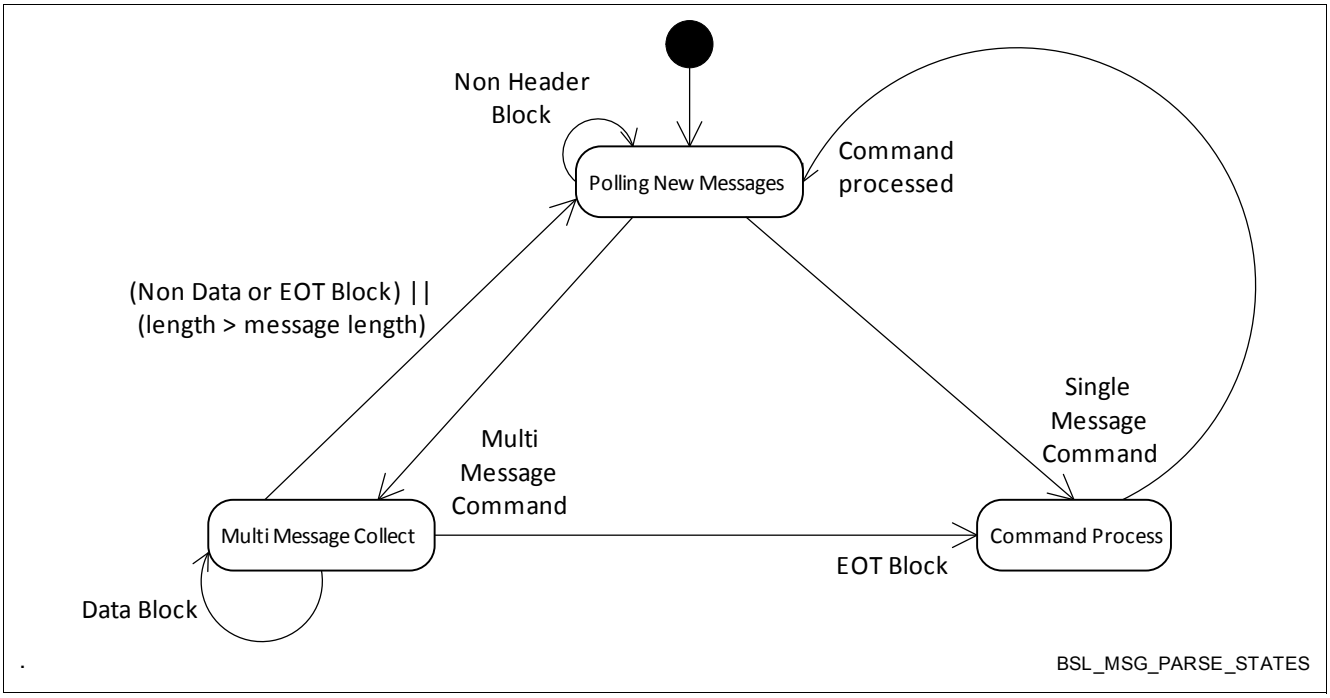


Figure 4-3 BSL Command Message State Machine

The state machine starts to wait for the header block. This could be either a command which consists of a single header block (the message type MSB bit is set) or a command that consists of multiple messages (the message type MSB bit is zero).

For multimessage commands, all message data is collected by receiving data block messages. The last message data is always received by an EOT block message.

The EOT block message reception initiates command parsing and execution.

The command processing includes message validation, where the message parameters are checked for boundaries, any hardware applied protection and if this message is supported for this boot mode.

The state machine aborts the multimessage collection if the overall data bytes of all collected messages have exceeded the maximum message data buffer length of 137 bytes (7 bytes in the header block message + 130 EOT data bytes).

For single message commands, all command-related information is already available in the header block message. The command parsing and execution start right after receiving the message.

After command execution and after a response has been sent, the state machine returns to the header block polling state in order to wait for the next command.

Any received message which does not fit the current state or state transmission leads to an exit from the current state and restarting of the whole state machine.

Response Message State Machine

The command response is specific to the used serial interface. For instance, LIN slave devices only send out response frames if a slave response header was received from the LIN bus master. Further details are described in the interface specific protocol layer part.

Figure 4-4 gives an overview of the LIN response message state machine.

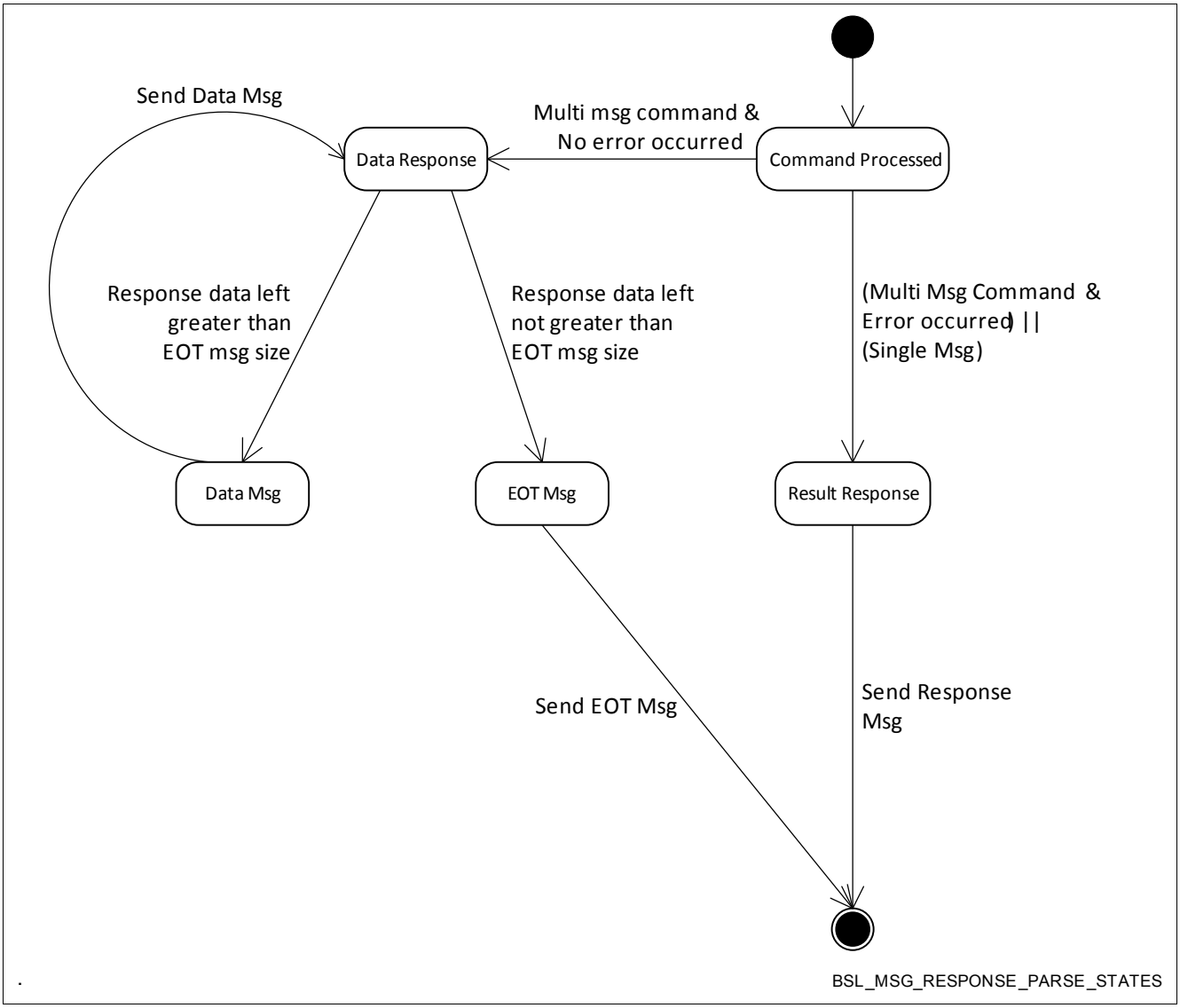


Figure 4-4 LIN Response Message State Machine

Some BSL messages request read-out of data from the device. These messages expect multimessage responses. The responses are sent out using data block and EOT block messages, where the data block messages are only used for the data that does not fit in the EOT block message. The EOT block message is the last message for such responses.

Other BSL messages download data or initiate code execution. They do not request reading out of any data. These messages only reply with a status response message.

A BSL command execution replies with a status response message in the event that the command execution fails.

Attention: The BootROM responds to each incoming command. This is either the requested data or the response block (e.g. success or error code). Only the code execution command does not reply with a response message.

4.1.6 Command Execution

The command data is checked and validated after all the message data is received. This includes that the message parameters are checked for boundaries, any hardware-applied protection (e.g. NVM protection) and if this message is supported for this boot mode.

The following command classes are supported:

- **RAM access** – RAM accesses are directly done by the BSL protocol without the use of any other submodule.
- **NVM access** – NVM accesses (read/write) are performed using the NVM API.
- **100TP access** – 100TP accesses are performed using the NVM CS (Configuration Sector) API.
- **NVM CS (Configuration Sector) access** – NVM CS (Configuration Sector) accesses are performed using the NVM CS (Configuration Sector) API.

4.1.7 Timing Constraints

The host needs to add a delay between all sent BSL command header and EOT messages. Same delay must be add between EOT and DATA block messages.

The BootROM also requires an additional waiting time to process the full received BSL command. The BootROM is not able to provide the response messages or able to receive new commands before this period expires. The host must wait this length of time before sending a new command or requesting the command response (e.g. by sending a LIN slave response header).

To give BootROM time to process each byte and CMD/DATA/EOT frame, byte and frame timing must comply to the values shown in **Table 4-1**.

Table 4-1 BSL Byte and Frame Timing Limits and Highest Transfer Rate

Delay type	LIN (min.)	FastLIN (min.)
Between bytes	4.1 µs	3.7 µs
Between end of CMD to start of DATA or EOT frame	20 µs	20 µs
Interframe Timeout	280 ms	280 ms
Host waiting time for message processing before asking for response	100 µs *	n/a
Host waiting time after response is received until a new frame can be sent	20 µs	20 µs

* There are certain BSL commands that need longer processing time. These involve NVM write/erase operations. The host waiting time is longer before a command response can be requested or before a result is sent back. Changing a value in an already programmed NVM page, which happen if a setting is changed, requires the following NVM steps:

- Read the full page into the HW buffer
- Update the HW buffer with new data
- Program the page from the HW buffer
- Erase the old page

Total time: 8 ms

The processing time must always be taken into account.

4.1.8 BSL Interframe timeout behavior

To keep track of BSL frame transmission violations, interframe timeout is used (described also in **Chapter 4.1.2**). This chapter summarizes the different use-case scenarions where BSL frame timeouts are applied.

BSL frame transmission timeout is handled differently and depends on:

- BSL has not received any valid host synchronization yet. In this case NAC timeout value is used for all timeout calculations. If timeout is reached this means NAC timer expired.
- BSL has completed host synchronization. All timeouts are based on interframe timeout value. This means wait forever for frame start and once frame reception has started, time measurement against interframe timeout are performed.

Once host synchronization is done there are different scenarios how timeout is used.

More details are provided in **Figure 4-5** related LIN communication (same concept for FastLIN) .

Note: When a LIN frame is received, its PID and NAD numbers are checked. If one of them doesn't match, the current frame is discarded and frame reception process is restarted with detection of break/sync sequence.

Note: Valid host synchronization: For FLIN/LIN the full passphrase has been received before NAC expires.

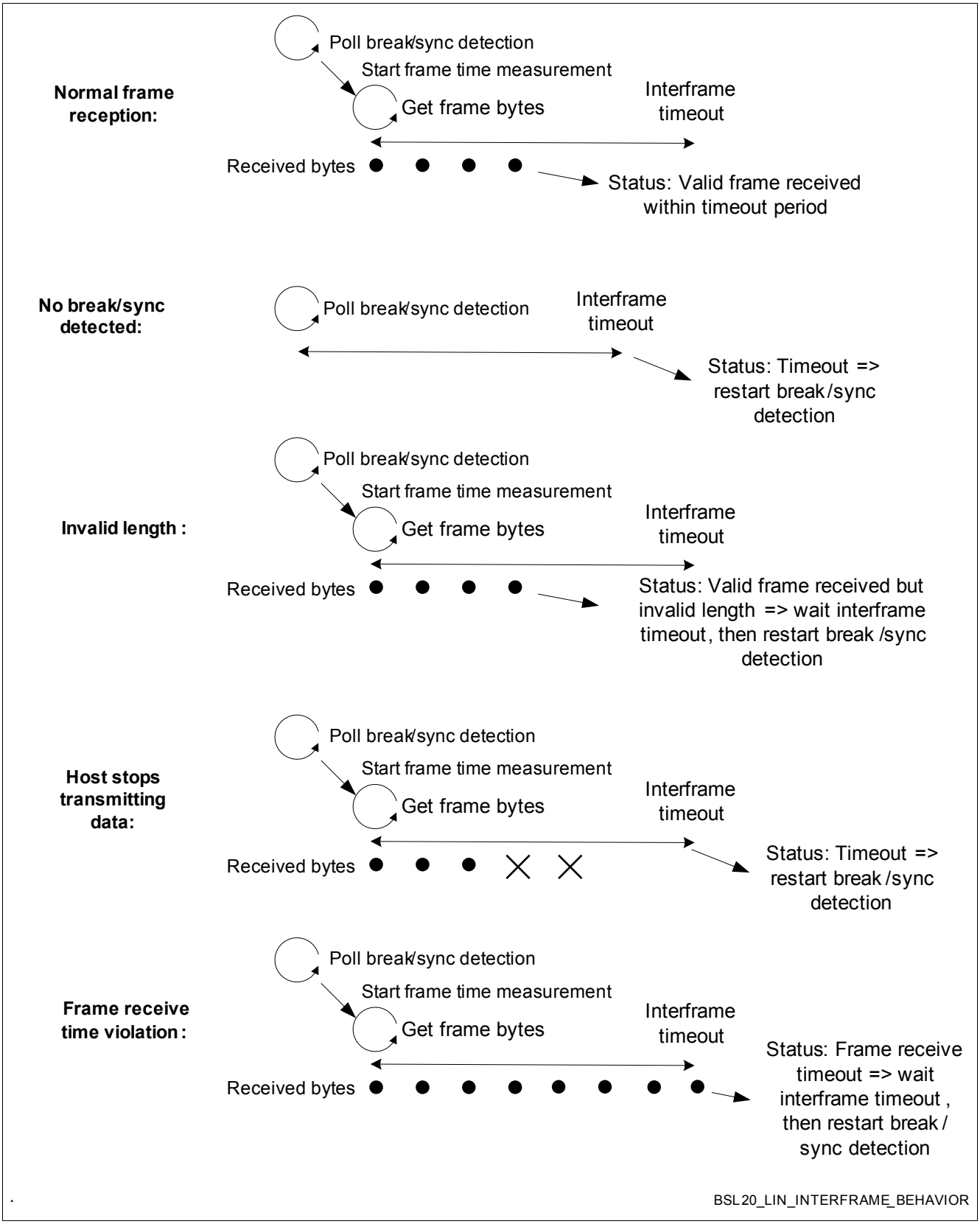


Figure 4-5 Handling of LIN frame timeouts

4.2 BSL via LIN

The LIN BSL is a LIN-like protocol based on LIN 2.0 (refer to LIN Specification Package documentation, Revision 2.0, 23 September 2003).

The LIN protocol layer module handles incoming LIN frames. It forwards the given commands and requests to the BSL protocol layer and is responsible for response message handling.

This layer calls the LIN HAL API to access the LIN hardware module for baud rate management and LIN frame exchange (transmission & reception).

The LIN interface supports baud rate detection including the standard rates from 9.6 kbit/s to 57.6 kbit/s.

The LIN HAL is described in **“LIN HAL” on Page 36**.

The BSL software module periodically polls the LIN protocol layer to receive incoming frames and send out available response frames.

The LIN protocol layer parses all incoming LIN frames, it rejects frames with wrong checksum calculation or invalid NAD values. The checksum calculation algorithm is done according to the LIN 2.0 standard. All received messages are given to the BSL protocol layer, which concatenates it to complete commands.

Some BSL commands are shorter than the expected LIN frame. Those frames are filled up with dummy bytes. BootROM reads such dummy bytes during checksum validation, but it ignores them during command processing. The dummy Bytes in both directions are always set to zero.

Figure 4-6 shows the LIN protocol layer and its interaction with other software modules.

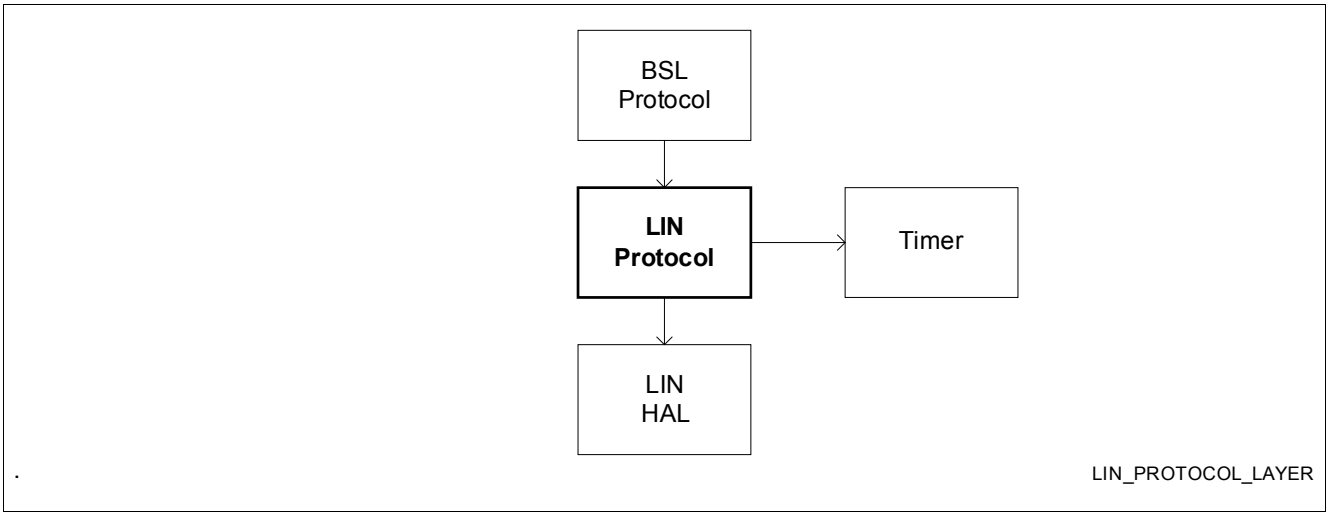


Figure 4-6 LIN Protocol Layer

Figure 4-7 shows the interaction between Hardware and software layers for the BSL LIN mode .

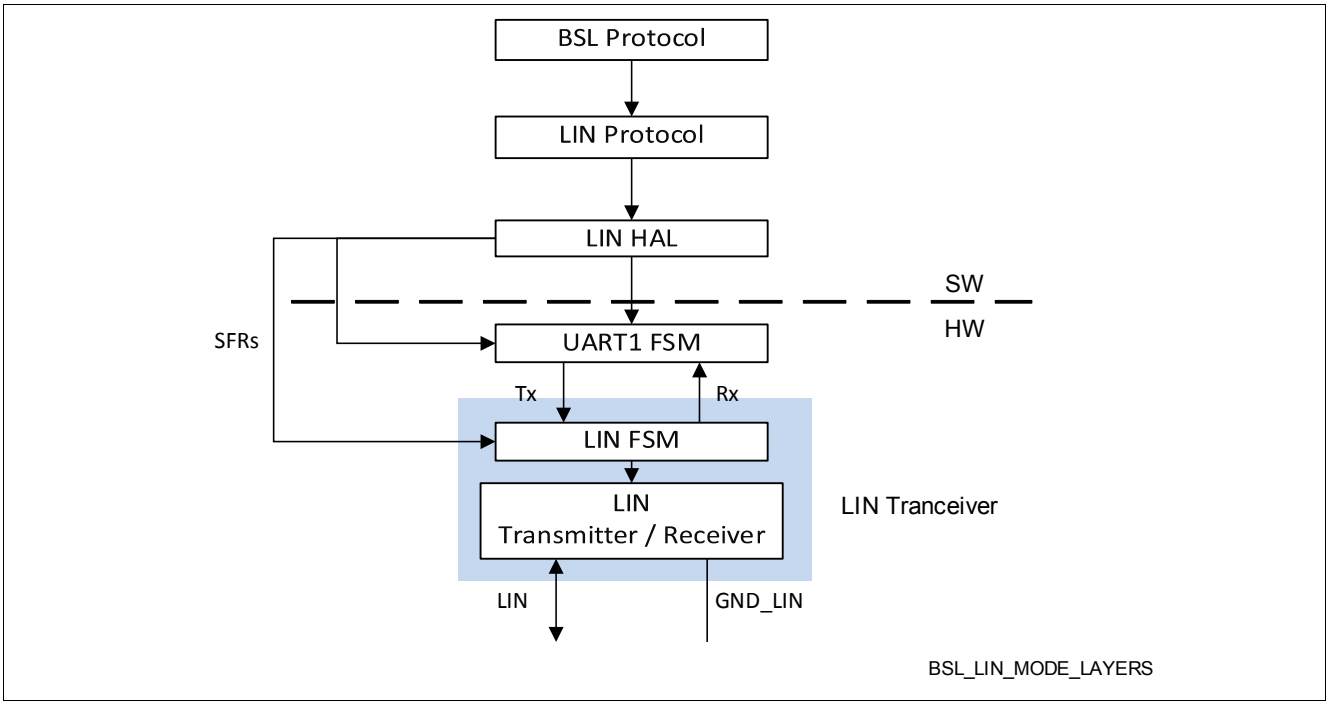


Figure 4-7 BSL LIN Mode HW/SW Layers

4.2.1 LIN frame format

For all supported modes, the command messages (see **Command Message Protocol**) are transmitted from the host to the BootROM, requesting the commands to be executed. The response request messages (see **Response Message Protocol**) are transmitted to check the status of the operation and to read out the data requested (e.g. read RAM command).Upon a response request message, the requested data is sent from the BootROM to the host.

Figure 4-8 shows the Master Request Header, Slave Response Header, Command and Response LIN frames. The command and response LIN frames are identified as diagnostic LIN frames which have a standard 9-byte structure.

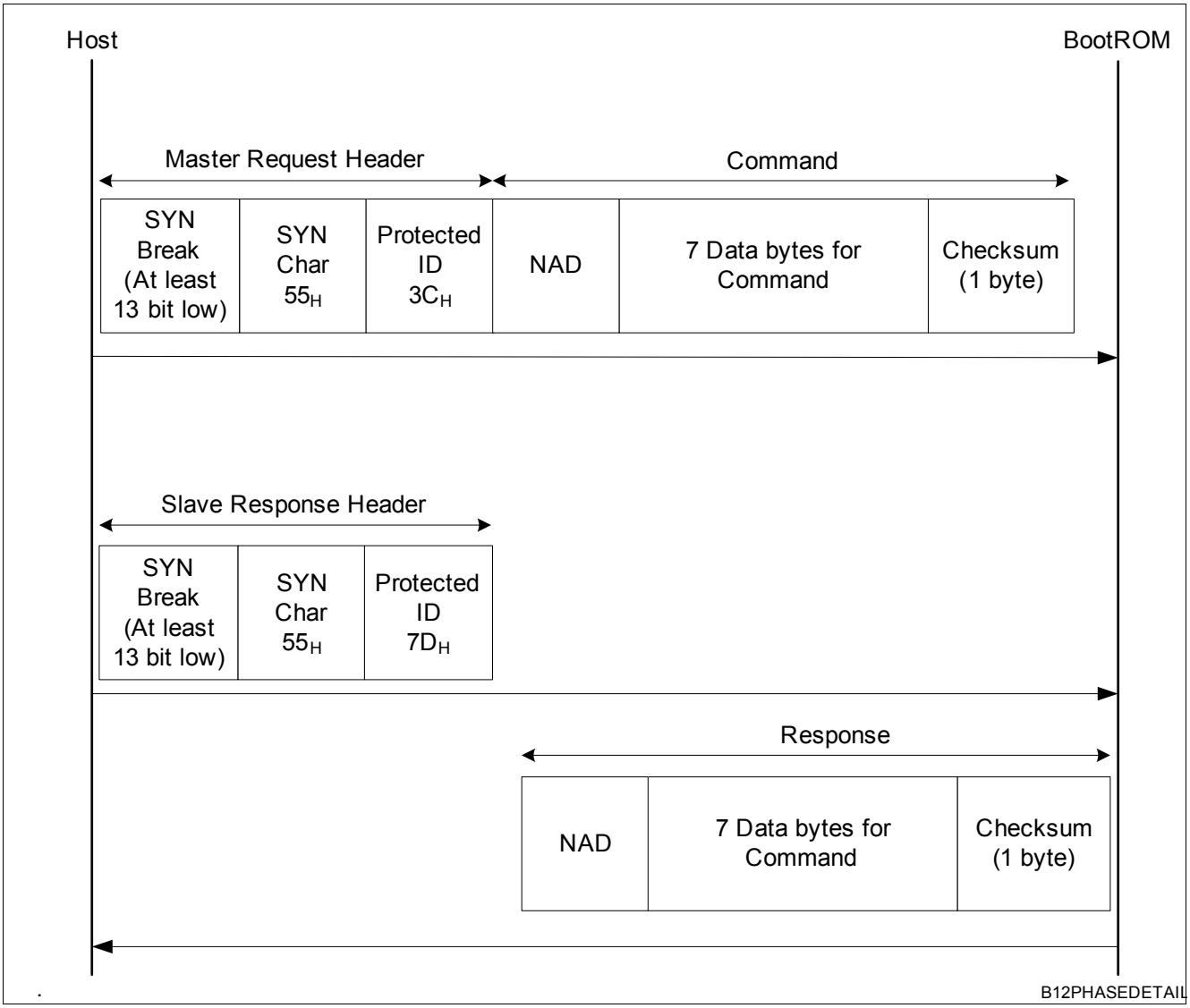


Figure 4-8 LIN mode - LIN Frames

The Master Request Header is transmitted from the host to the BootROM, followed by the command, which is the header block. The Slave Response Header is transmitted to check the status of the operation. To save protocol overhead, the BootROM supports multiple data block transfers, sending a Slave Response Header is only allowed after the EOT block has been sent. Sending a Slave Response Header between data blocks will result in a communication error. As the commands are sent one after another without waiting for any status indication, a certain delay is required (as shown in **Figure 4-9**) to ensure sufficient time is provided for the BootROM to execute the desired operations.

Figure 4-9 shows the LIN frame communication for BSL commands, where no data blocks and EOT blocks are involved.

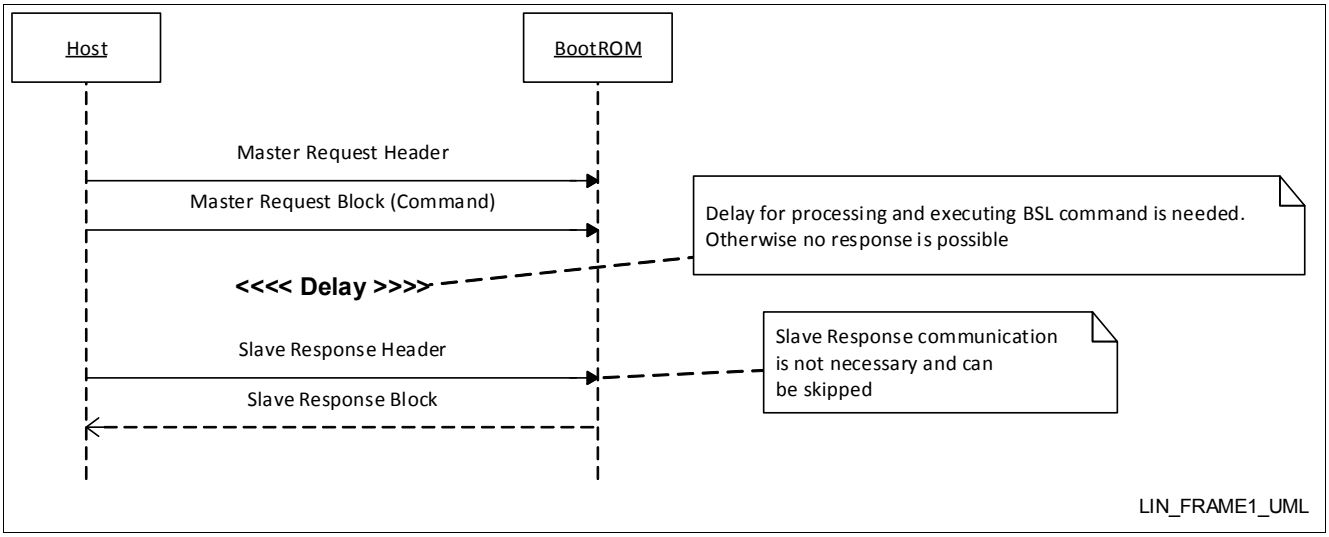


Figure 4-9 LIN Communication: Command and Response

Figure 4-10 shows the LIN frame communication for BSL commands, where data are downloaded over data blocks and EOT blocks.

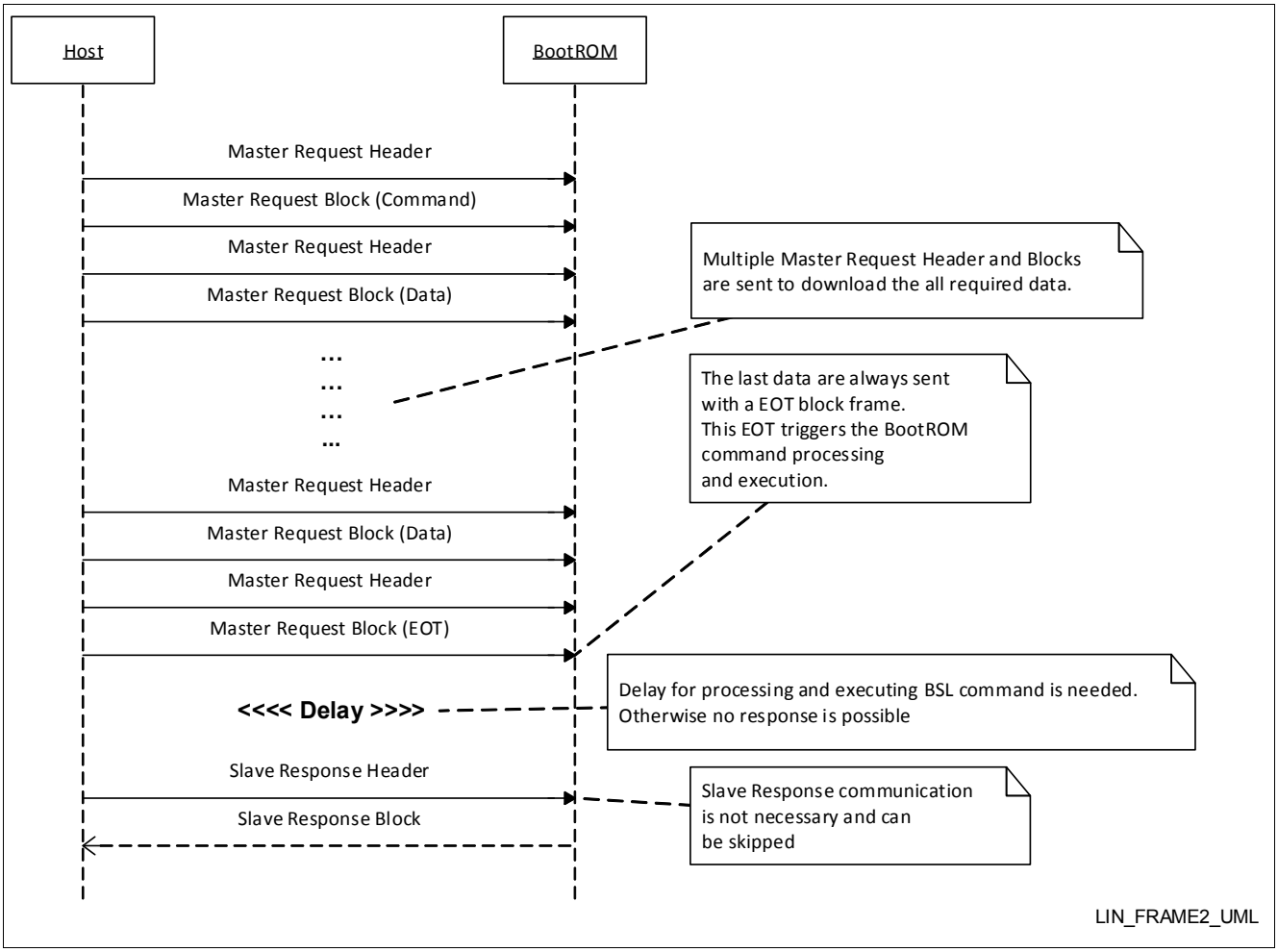


Figure 4-10 LIN Communication: Data Command and Response

Figure 4-11 shows the LIN frame communication for BSL commands, where data are read from the device. BootROM provides such data over data blocks and EOT blocks.

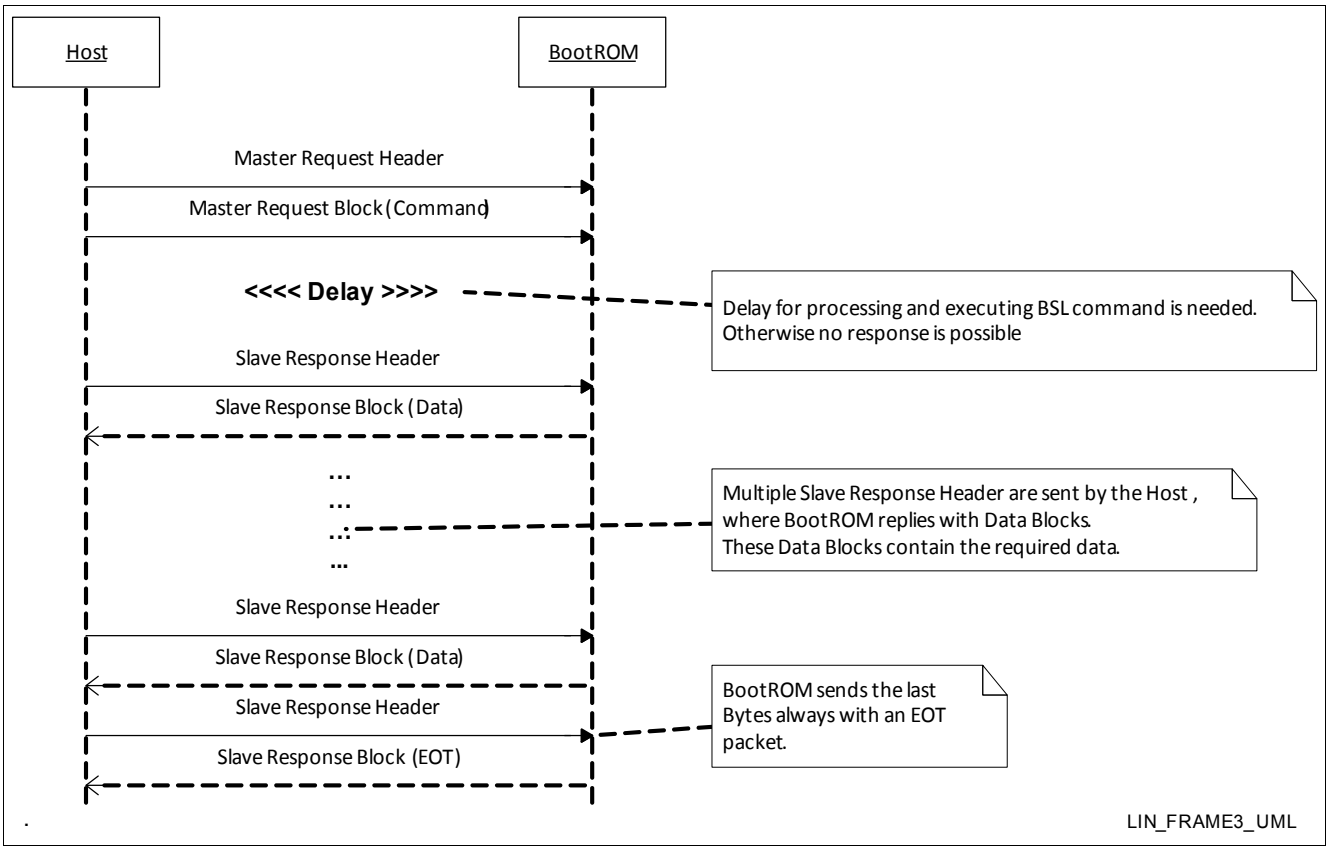


Figure 4-11 LIN Communication: Request Command and Data Response

4.2.1.1 Command Message Protocol

This section describes the **Master Request Header** and the **Master Request Block** which are sent by the the host for each LIN command frame. The **Master Request Header** contains synchronization bytes to detect the start of a frame and to detect the baud rate.

Master Request Header

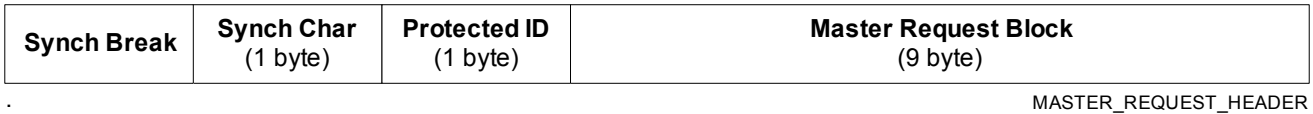
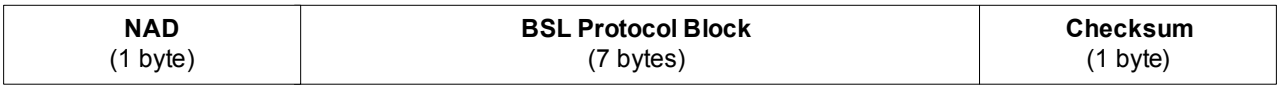


Table 4-2 Master Request Header Field Description

Field	Description
Synch Break	At least 13 bits must be low
Synch Char	Always 55_H
Protected ID	Always $3C_H$
Master Request Block	Commands as described in **"Master Request Block" on Page 32**.

Master Request Block

A simple protocol is defined for the communication between the the host and BootROM. The **Master Request Header** is followed by the Master Request Block.



LIN_FRAME_FORMAT

Table 4-3 Master Request Block Field Description

Field	Description
NAD	Node Address for Diagnostic, specifies the address of the active slave node. See **Chapter 4.2.1.3**.
BSL Protocol Block	This field determines the type of the BSL message. The size of this block is always 7 Bytes. The block is filled up with dummy Bytes (zeros) in case the BSL message is smaller.
Checksum	This checksum is calculated based on the NAD and BSL protocol block. See **Chapter 4.2.1.4**.

4.2.1.2 Response Message Protocol

The BootROM reply is sent to the the host only when a Slave Response Header frame is received. The BootROM reply is always sent in a transfer block of 9 bytes (consisting of Slave Response Header and Slave Response Block).

Slave Response Header

This header is sent by the the host to initiate that the BootROM sends a Slave Response Block.



SLAVE_RESPONSE_HEADER

Table 4-4 Slave Response Header Field Description

Field	Description
Synch Break	At least 13 bits must be low
Synch Char	Always 55_H
Protected ID	Always $7D_H$

Slave Response Block



LIN_RESPONSE_FORMAT

Table 4-5 Slave Response Block Field Description

Field	Description
NAD	Node address for diagnostics, specifies the address of the active slave node.
BSL Protocol Data/EOT/Response Block	This field determines the type of the BSL message. Depending on the BSL command used, it could be either a data block, an EOT block or a response block.
Checksum	The checksum is calculated based on NAD, Response and Response Data bytes. All responses sent by the BootROM adopts the classic checksum. See **Section 4.2.1.4**.

4.2.1.3 Node Address for Diagnostic (NAD)

This field specifies the address of the active slave node (only slave nodes have a NAD address). Each **Master Request Block** contains a NAD field. **Table 4-6** lists the BootROM-supported NAD address range.

The used NAD parameter is given as a BSL API parameter (for details see also **"User and BSL Mode Entry (UM)" on Page 11**).

Table 4-6 NAD Address Range

NAD Value	Description
00_H to $7F_H$	Invalid slave address
80_H to FF_H	Valid slave address
FF_H	Broadcast address. Default address (NAD value is invalid or it is not programmed)

Note: The LIN block with the standard LIN broadcast NAD ($7F_H$) is ignored.

The firmware treats a received BSL message with NAD value of FF_H as 'broadcast' message. BSL responds to this no matter which NAD value is stored inside the NVM CS. A device with an invalid NAD value in NVM CS only responds to a BSL 'broadcast' message.

4.2.1.4 Checksum

The checksum contains the inverted eight-bit sum with a carry over all data bytes. Data bytes are defined as all bytes in the LIN frame excluding the protected ID byte.

Checksum calculation over the data bytes only is referred to as a classic checksum. An eight-bit sum with carry is equivalent to the sum of all values, subtracted by 255 every time the sum is greater than or equal to 256.

Enhanced checksums are normally used for LIN 2.x devices, but frame identifiers (PID) $3C_H$ always uses the classic checksum.

The checksum is the last field of Command and Response LIN frames.

4.2.2 LIN Message Examples

Figure 4-12 and **Figure 4-13** provide some examples of how to write and read RAM using LIN BSL commands.



Figure 4-12 BSL RAM Write Access Frame Examples



Figure 4-13 BSL RAM Read Access Frame Examples

4.2.3 LIN HAL

The LIN HAL handles all SFR register accesses to the LIN hardware modules . These accesses include timing critical register accesses and status polling mechanism.

Functionality

The following features are provided by the LIN HAL:

- BREAK condition detection on the LIN interface, used as indication for incoming packets.
- Baud rate detection
- Data reception
- Data transmission

LIN HW slope control is dependent on LIN or FastLIN mode selection:

For LIN **fastslope** is used.

For FastLIN **flashmode** slope is used.

The device requires some delay to process each received byte from header or EOT block or when transmitting a response back.

4.3 BSL via FastLIN

FastLIN is a LIN enhancement supporting higher baud rates of up to 230.4 kBd. This rate is higher than the standard LIN. FastLIN is especially useful during back-end programming, where faster programming time is desirable.

The FastLIN BSL protocol supports baud rates of 38.4 kBd, 115.2 kBd and 230.4 kBd via the internal LIN TrxHW module using the UART BSL protocol.

The FastLIN checksum calculation algorithm is the same algorithm used for the LIN interface (see **“BSL via LIN” on Page 27**). The checksum is the last field of Command and Response FastLIN frames.

The FastLIN passphrase frame format is the same as used for the LIN see **“LIN / FastLIN Passphrase” on Page 20**.

For user mode, the default FastLIN baudrate is 115.2 kBd. The actual session baud rate can be changed with the BSL command **“Command 93H – FastLIN: Set Session Baudrate” on Page 68**.

Figure 4-14 shows the interaction between Hardware and software layers for the BSL FastLIN mode .

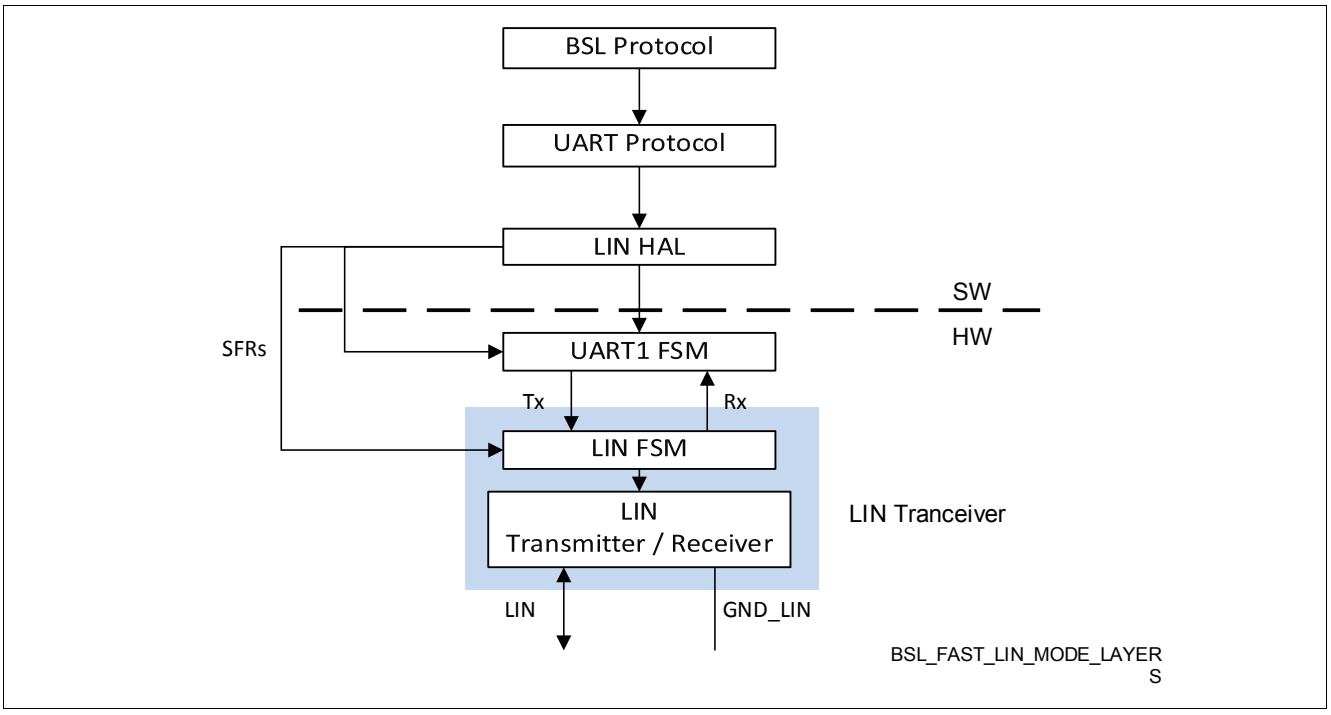


Figure 4-14 BSL FastLIN Mode HW/SW Layers

4.4 BSL commands - Protocol (Version 2.0)

This section describes the boot strap loader messages that are used by the LIN and FastLIN protocols. The physical layer encapsulation of these messages is described in

- **BSL via LIN** Page 27
- **BSL via Fast LIN** Page 37

All commands support acknowledge response message, which contain an error code with the result of the executed command. Some messages return a response message with the result of the executed command and some messages also return requested data. For messages that return data, the data should be treated as a response with no errors and the acknowledge response message will in this case not be sent. The messages will either return an error code of a detected error or return the requested data. Data response messages are described together with the command messages. The response and error code messages are described in **“Acknowledge Response Message (81H)” on Page 69**.

Some commands do not intend to send any response message. For instance, the code execution command messages directly jump to the requested code location. These messages will only send a response message if the requested command could not be executed.

Each incoming message is verified. Inconsistent frames or messages (e.g. invalid checksum or length) are rejected. Unknown messages and message types are also rejected. Discarding an invalid message is done without any acknowledgement or notification.

Whether the host waiting time before response is sent back or whether a response can be asked for is defined for each of the messages if it deviates from the definition given in **Section 4.1.7**.

The following BSL commands are supported:

- **Command 02H – RAM: Write Data/Program**
- **Command 83H – RAM: Execute**
- **Command 84H – RAM: Read Data**
- **Command 05H – NVM: Write Data/Program**
- **Command 86H – NVM: Execute**
- **Command 87H – NVM: Read Data**
- **Command 88H – NVM: Erase**
- **Command 89H – NVM: Protection Set / Clear**
- **Command 0DH – NVM: 100TP Write**
- **Command 8EH – NVM: 100TP Read**
- **Command 8FH – BSL: Option Set**
- **Command 90H – BSL: Option Get**
- **Command 91H – LIN: NAD Set**
- **Command 92H – LIN: NAD Get**
- **Command 93H – FastLIN: Set Session Baudrate**

Dummy Bytes

Depending on the BSL frame data fill level, some frame data bytes are not used. Those bytes are filled with dummy bytes, which are set to zero. The BootROM ignores dummy bytes, independent of their values.

Padding Bytes

For FastLIN:

If the customer adds padding bytes, although this is not regular it is still supported by the firmware. Padding bytes up to a data field size of 128 bytes are possible. The firmware will accept the real data and will find the checksum byte after the last padding byte.

RAM Access Limitation

Access to the BootROM RAM is limited for the BSL commands **Command 84H – RAM: Read Data** and **Command 02H – RAM: Write Data/Program**. In all boot modes, the full RAM range can be read but global variables/data and stack area cannot be written to. Trying to write to these areas will result in an error.

RAM and NVM Address Range Checks

All commands reading or writing the NVM or RAM check the address range and return an error if it is exceeded. The number of bytes to be read or written must be greater than zero.

Blocking of BSL commands due to NVM protection

With any command, the BSL applies checks to determine if the command can get executed. BSL commands accessing the NVM also check the applied read or write NVM HW protection scheme against the NVM access request. Details are given specifically with each BSL command description. An errror is returned upon any access violation. **Table 4-7** states which NVM protection group is checked before a given BSL command is executed.

Definitions of NVM protection groups:

- **Group 1** = NVM HW read or write protection applied to any NVM region. Reason for this: BSL download is blocked in case any protection is set. This is done to avoid BSL download of code into any region (even 100TP pages).
- **Group 2** = NVM HW read protection applied to any NVM region. Reason for this: BSL download is blocked in case any protection is set. This is done to avoid BSL download of code into any region (even 100TP pages).
- **Group 3** = NVM HW read protection applied to any NVM region and no write protection to NVM code region. Reason for this: When in user mode, instead, the concept is that for CS accessible page (e.g. 100TP pages) the FW should apply the same protection set for the user code region. This means that the 100TP write via User API should be blocked only in case the write protection of the code region (checked by looking at the NVM_PROT_STS bits) is set.
- **Group 4** = NVM HW read and write protection for all regions are ignored. Reason for this: For a command that can change protection, must be allowed access independently of protection.

Table 4-7 NVM Protection Check for BSL Commands

NVM protection group (condition to block)	BSL Command
Group 1 NVM HW read or write protection applied to any NVM region	**Command 02H – RAM: Write Data/Program** **Command 05H – NVM: Write Data/Program** **Command 88H – NVM: Erase**
Group 2 NVM HW read protection applied to any NVM region	**Command 83H – RAM: Execute** **Command 86H – NVM: Execute** **Command 87H – NVM: Read Data** **Command 84H – RAM: Read Data** **Command 8EH – NVM: 100TP Read** **Command 90H – BSL: Option Get** **Command 92H – LIN: NAD Get** **Command 93H – FastLIN: Set Session Baudrate**
Group 3 NVM HW read protection applied to any NVM region and no write protection to NVM code region	**Command 0DH – NVM: 100TP Write** **Command 8FH – BSL: Option Set** **Command 91H – LIN: NAD Set**
Group 4 NVM HW read and write protection for all regions are ignored.	**Command 89H – NVM: Protection Set / Clear**

4.4.1 Command 02_H – RAM: Write Data/Program

Firmware supports downloading of data and code to the device's internal RAM via command 02_H .

The host initiates the RAM download by sending a header block message. This message contains information about the RAM location (offset address based on RAM start address). The data bytes are followed by Data Block messages and the last data bytes are sent by an EOT block message.

The overall download must be terminated with an EOT block message. The Data Block messages are used if the downloaded data exceed the Data field size of the EOT block message.

This command does not support to write RAM locations which BootROM uses for global variable and stack storage.

This command rejects the write operation if any NVM read or write protection is applied to any NVM region, the offset is out of range, or offset plus count is out of range. Details about the NVM access protection are given in **"Command 89H – NVM: Protection Set / Clear" on Page 56**. It returns an error code in the response message.

This message supports downloading of a maximum of 128 bytes into the RAM. Larger memory blocks need to be split into multiple **Command 02H – RAM: Write Data/Program** messages.

Header Block

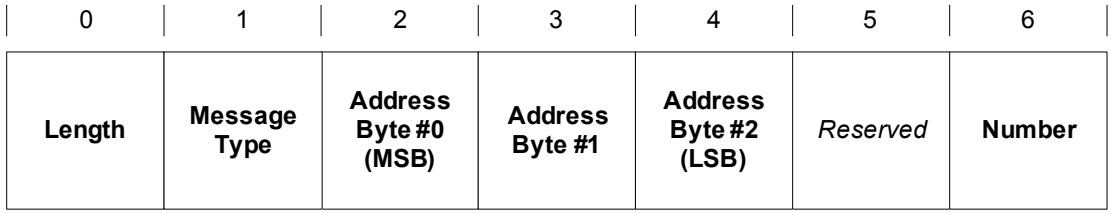
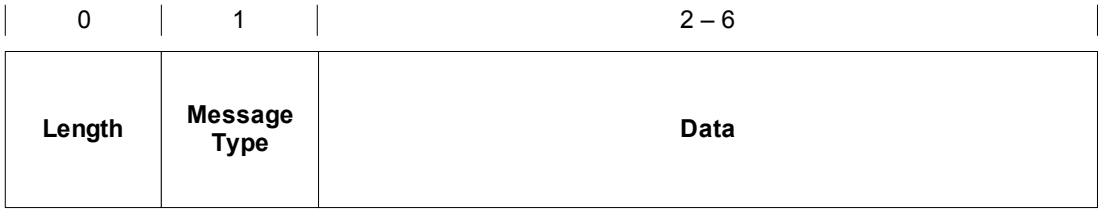


Table 4-8 "Command 02_H – RAM: Write Data/Program" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	RAM write command. Always set to 02_H
Address Byte #0 (MSB)	24-bit RAM address offset where to store the download data. The offset starts counting from the RAM start address 1800.0000_H
Address Byte #1	
Address Byte #2 (LSB)	
Number	8-bit number of data bytes to write with the whole message. The BootROM expects to receive these bytes in data blocks and an EOT block. Maximum supported length: 128 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.

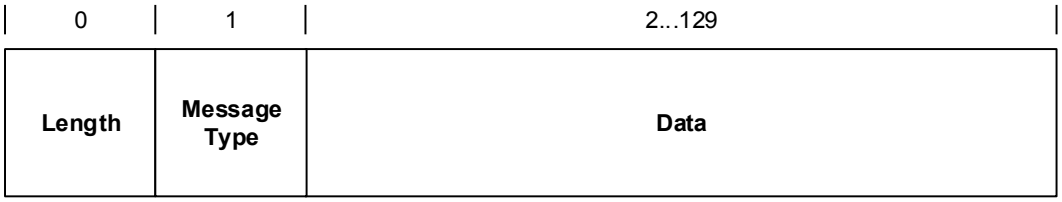


BSL20_MODE_DATA

Table 4-9 “Command 02_H – RAM: Write Data/Program” Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06_H
Message Type	Data block. Always set to 00_H
Data	It contains the downloaded data (no dummy data to fill up the packet).

EOT Block



BSL20_MODE_EOT

Table 4-10 “Command 02_H – RAM: Write Data/Program” EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the “Data” field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 129 bytes
Message Type	EOT block. Always set to 80_H
Data	The maximum size of the field depends on the BSL interface that is used: • LIN – 5 bytes • FastLIN – 128 bytes Contains the downloaded data. The EOT block message is the last message for a download and contains the last downloaded bytes. The data download process does not use data block messages if the overall data size is equal to or smaller than the “Data” field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_ERROR (RAM range is invalid)
- ERR_LOG_CODE_MEM_READWRITE_PARAMS_INVALID

4.4.2 Command 83_H – RAM: Execute

Firmware triggers execution of a RAM user program by the Host via command 83_H. This code can be previously downloaded by the BSL **Command 02H – RAM: Write Data/Program**.

The host initiates the RAM code execution by sending the header block message. This messages contains the RAM address offset where to jump for code execution.

This command does not check if any valid code is placed in RAM before jumping to the given code location. The watchdog timer got disabled when entering the BSL communication and stays disabled when jumping to RAM.

Before jumping to RAM the following steps are done:

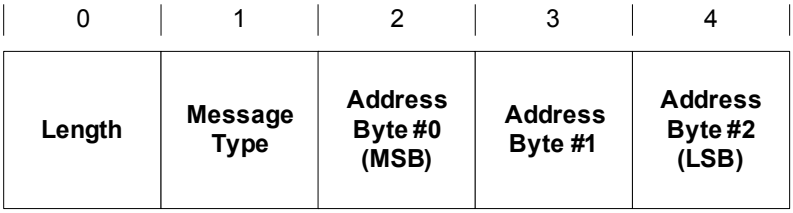
- The BootROM configures the stack pointer to 1800.0400_H. It is recommended that the RAM code adapts the stack pointer on demand.
- The system clock is switched to PLL at the device default or user defined frequency from NVM CS settings.
- All interrupts are cleared.
- The timer is cleared.
- In the SCU_VTOR.VTOR register,VTOR_BYP is set to 01b (RAM).

It is not allowed for the RAM code to make a return call. ARM LR register has been set to zero when jumping to RAM. If BSL should be re-entered a system reset must be performed.

This command does not support any Slave Response Header. It performs the RAM code execution right after receiving the header block.

Command is rejected if there is any NVM HW read protection applied to any NVM region. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**.

Header Block



BSL20_MODE01_HEADER

Table 4-11 "Command 83_H – RAM: Execute" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 04_H
Message Type	RAM execute command. Always set to 83_H
Address Byte #0(MSB)	24-bit RAM address offset where to jump for code execution. The offset starts counting from the RAM start address 1800.0000_H
Address Byte #1	
Address Byte #2(LSB)	

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_ERROR (RAM range is invalid)
- ERR_LOG_CODE_NVM_RAM_EXEC_PARAMS_INVALID

4.4.3 Command 84_H – RAM: Read Data

Firmware supports reading of data and code from the device's internal RAM via command 84_H.

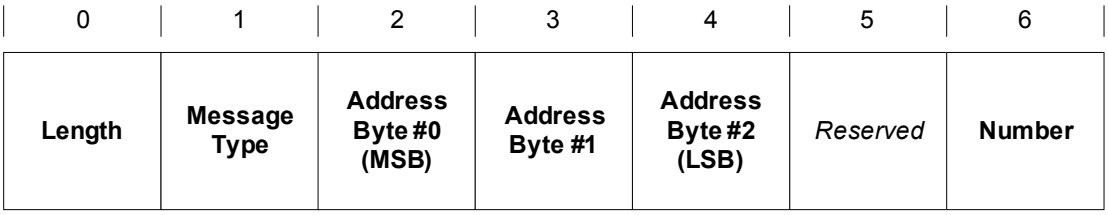
The host initiates the RAM read by sending a header block message. This message contains information about the RAM location (offset address based on RAM start address) and the number of read data bytes.

BootROM sends back the requested data by Data Block message and by a terminating EOT block message. The Data Block messages are used if the amount of read data exceed the Data field size of the EOT block message.

This command rejects the read operation if there is NVM HW read protection applied to any NVM region, the offset is out of range, or offset plus count is out of range. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**. It returns an error code in the response message.

This message supports reading of a maximum of 128 bytes from the RAM. Larger memory blocks need to be split into multiple **Command 84H – RAM: Read Data** messages.

Header Block



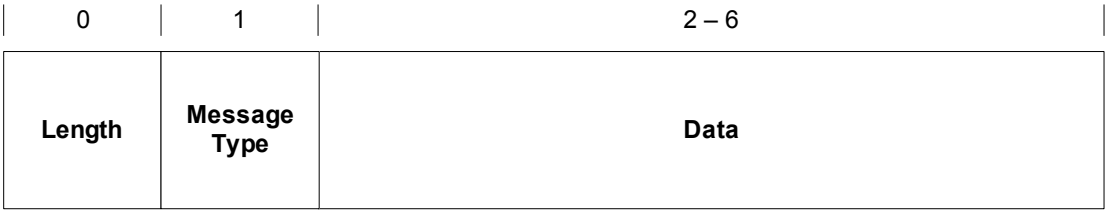
BSL20_MODE02_HEADER

Table 4-12 "Command 84_H – RAM: Read Data" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	RAM read data command. Always set to 84_H
Address Byte #0(MSB)	24-bit RAM address offset where to read the data. The offset starts counting from the RAM start address 1800.0000_H
Address Byte #1	
Address Byte #2(LSB)	
Number	8-bit number of data bytes to read. The BootROM will send these bytes in Data Blocks and an EOT block. Maximum supported length: 128 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.



BSL20_MODE_DATA

Table 4-13 “Command 84_H – RAM: Read Data” Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06_H
Message Type	Data block. Always set to 00_H
Data	It contains the read data.

EOT Block

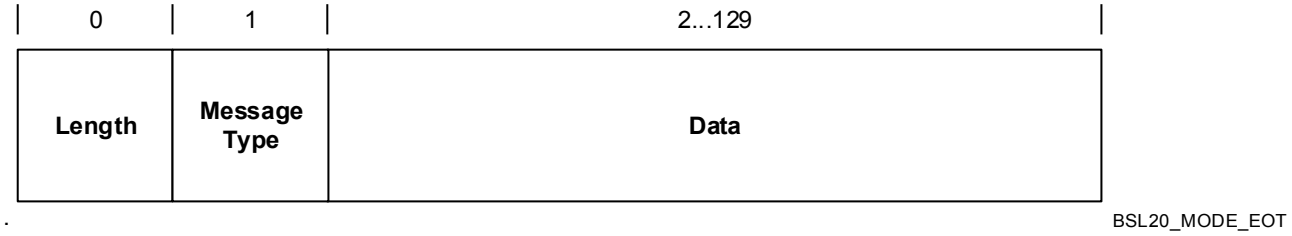


Table 4-14 “Command 84_H – RAM: Read” Data EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the Data field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 128 bytes
Message Type	EOT block. Always set to 80_H
Data	The maximum size of the field depends on the used BSL interface: • LIN – 5 bytes • FastLIN – 128 bytes Contains the read data. The EOT block message is the last message for a read byte. The data read process does not use Data Block messages if the overall data size is equal to or smaller than the “Data” field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_ERROR (RAM range is invalid)
- ERR_LOG_CODE_MEM_READWRITE_PARAMS_INVALID

4.4.4 Command 05_H – NVM: Write Data/Program

Firmware supports programming of data and code to the device's internal NVM via command 05_H.

The host initiates the NVM program by sending a header block message. This message contains information about the NVM location (offset address based on NVM start address). The data bytes follow by Data Block messages and the last data bytes are sent by an EOT block message.

The overall download must be terminated with an EOT block message. The Data Block messages are used if the downloaded data exceeds the Data field size of the EOT block message.

BootROM does not support NVM cross page boundary programming. It stops the programming when it reaches a NVM page boundary. No bytes are programmed if the data does not fit the page size.

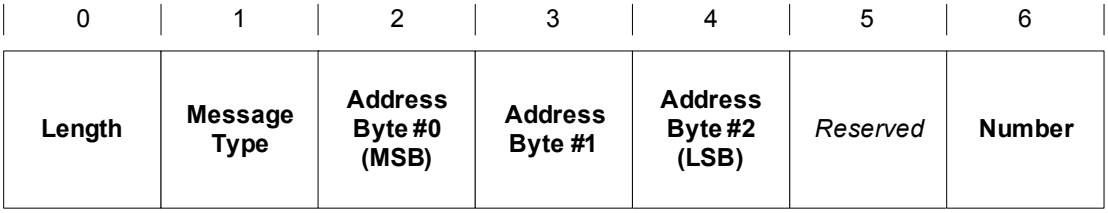
NVM pages can only be written if there is no NVM read or write protection applied to any NVM region. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**.

This message supports downloading of a maximum of 128 bytes into the NVM. Larger memory blocks need to be split into multiple **Command 05H – NVM: Write Data/Program**.

The host waiting time before response is sent back/can be asked for:

- 8 ms

Header Block



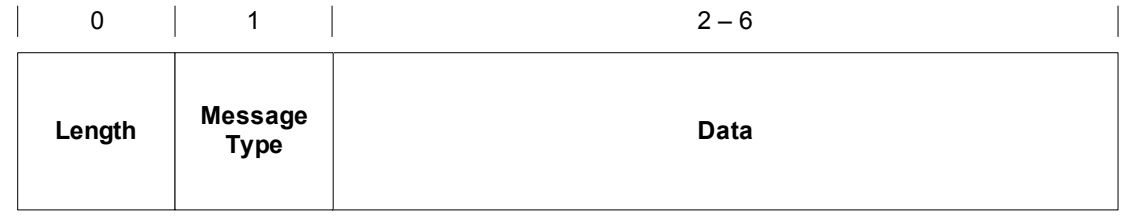
BSL20_MODE03_HEADER

Table 4-15 "Command 05_H – NVM: Write Data/Program" Header Block Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	NVM write data/program command. Always set to 05_H
Address Byte #0(MSB)	24-bit NVM address offset where to store the download data. The offset starts counting from the NVM start address 1100.0000_H
Address Byte #1	
Address Byte #2(LSB)	
Number	8-bit number of data bytes to write with the whole message. The BootROM expects to receive these bytes in Data Blocks and an EOT block. Maximum supported length: 128 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.

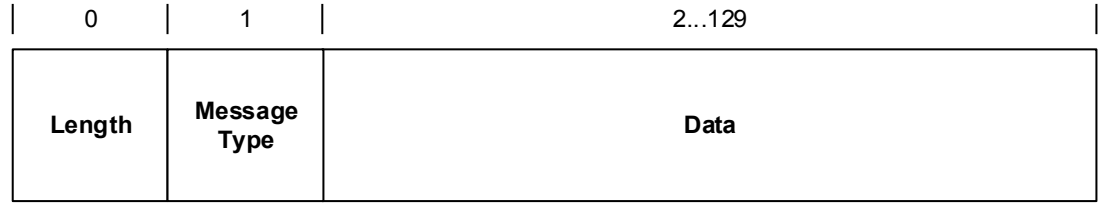


BSL20_MODE_DATA

Table 4-16 "Command 05_H – NVM: Write Data/Program" Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06_H
Message Type	Data block. Always set to 00_H
Data	It contains the downloaded data (no dummy data to fill up the packet).

EOT Block



BSL20_MODE_EOT

Table 4-17 "Command 05_H – NVM: Write Data/Program" EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the Data field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 129 bytes
Message Type	EOT block. Always set to 80_H
Data	The maximum size of the field depends on the used BSL interface: • LIN – 5 bytes • FastLIN – 128 bytes Contains the downloaded data. The EOT block message is the last message for a download and contains the last downloaded bytes. The data download process does not use Data Block messages if the overall data size is equal to or smaller than the "Data" field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_ERROR (NVM range is invalid)
- ERR_LOG_CODE_MEM_READWRITE_PARAMS_INVALID
- ERR_LOG_CODE_USER_CROSS_PAGE_PRG_NOT_SUPPORTED
- ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_ACCESS_AB_MODE_ERROR
- ERR_LOG_CODE_NVM_MAPRAM_UNKNOWN_TYPE_USAGE
- ERR_LOG_CODE_NVM_VER_ERROR
- ERR_LOG_CODE_NVM_PROG_MAPRAM_INIT_FAIL
- ERR_LOG_CODE_NVM_PROG_VERIFY_MAPRAM_INIT_FAIL

4.4.5 Command 86_H – NVM: Execute

Firmware triggers execution of a NVM user program by the Host via command 86_H. This code could be previously downloaded by the BSL **Command 05H – NVM: Write Data/Program**.

The host initiates the NVM code execution by sending the header block message. This messages contains the NVM address offset where to jump for code execution.

This command does not check if any valid code is placed in NVM before jumping to the given code location. The watchdog timer got disabled when entering the BSL communication and stays disabled when jumping to NVM.

Before jumping to NVM the following steps are done:

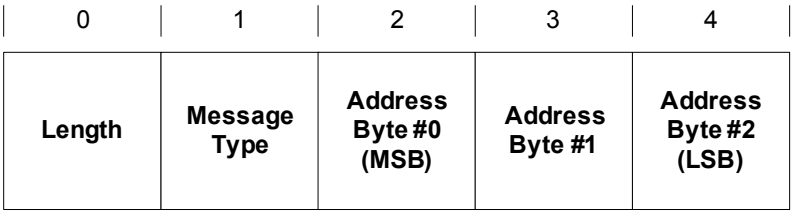
The BootROM configures the stack pointer to 1800.0400_H. It is recommended that the NVM code adapts the stack pointer on demand. The System clock is switched to PLL, interrupts are cleared, the GPT12E timer is cleared, the SCU_VTOR.VTOR register is set to NVM (SCU.VTOR.VTOR_BYP = 10b).

It is not allowed for the NVM code to make a return call. ARM LR register has been set to zero when jumping to NVM. If BSL should be re-entered a system reset must be performed.

This command does not support any Slave Response Header. It performs the NVM code execution right after receiving the header block.

Command is rejected if there is NVM HW read protection applied to any NVM region. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**.

Header Block



BSL20_MODE04_HEADER

Table 4-18 "Command 86_H – NVM: Execute" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 04_H
Message Type	NVM execute command. Always set to 86_H
Address Byte #0 (MSB)	24-bit NVM address offset where to jump for code execution. The offset starts counting from the NVM start address 1100.0000_H
Address Byte #1	
Address Byte #2 (LSB)	

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID
- ERR_LOG_CODE_NVM_RAM_EXEC_PARAMS_INVALID

4.4.6 Command 87_H – NVM: Read Data

Firmware supports reading of data and code from the device's internal NVM via command 87_H.

The host initiates the NVM read by sending a header block message. This message contains information about the NVM location (offset address based on NVM start address) and the number of read data bytes.

BootROM sends back the requested data by Data Block message and by a terminating EOT block message. The Data Block messages are used if the amount of read data exceeds the Data field size of the EOT block message.

NVM pages can only be read if there is no NVM HW read protection applied to any NVM region. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**. If reading from an address, which belongs to the non-linear NVM region and the page is not mapped (previous programmed), the read is rejected.

This message supports reading of a maximum of 128 bytes from the NVM. Larger memory blocks need to be split into multiple **Command 87_H – NVM: Read Data** messages.

The host waiting time before response is sent back/can be asked for:

- 8 ms

Header Block

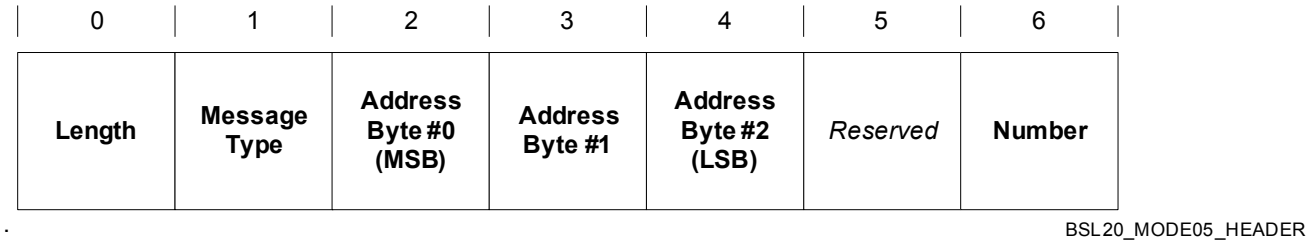
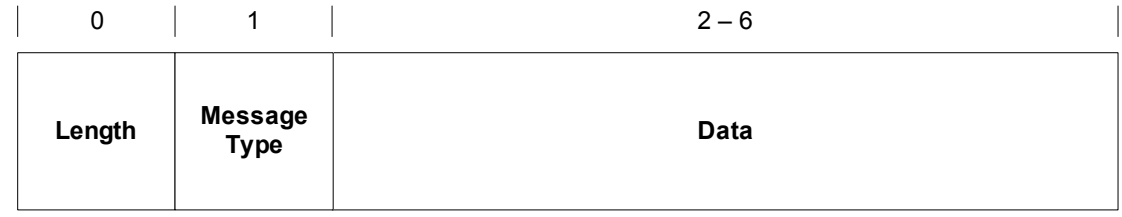


Table 4-19 "Command 87_H – NVM: Read Data" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	NVM read data command. Always set to 87_H
Address Byte #0(MSB)	24-bit NVM address offset where to read the data. The offset starts counting from the NVM start address 1100.0000_H
Address Byte #1	
Address Byte #2(LSB)	
Number	8-bit number of data bytes to read. The BootROM will send these bytes in Data Blocks and an EOT block. Maximum supported length: 128 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.

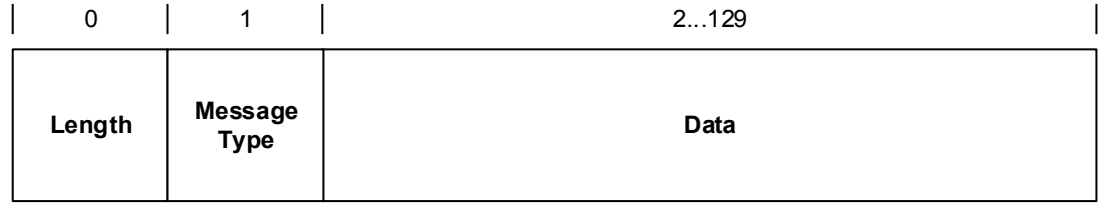


BSL20_MODE_DATA

Table 4-20 “Command 87_H – NVM: Read Data” Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06_H
Message Type	Data block. Always set to 00_H
Data	It contains the read data.

EOT block



BSL20_MODE_EOT

Table 4-21 “Command 87_H – NVM: Read Data” EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the Data field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 128 bytes
Message Type	EOT block. Always set to 80_H
Data	The maximum size of the field depends on the used BSL interface: • LIN – 5 bytes • FastLIN – 128 bytes Contains the read data. The EOT block message is the last message for read bytes. The data read process does not use Data Block messages if the overall data size is equal to or smaller than the “Data” field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID
- ERR_LOG_CODE_MEM_READWRITE_PARAMS_INVALID
- ERR_LOG_CODE_NVM_PAGE_NOT_MAPPED
- ERR_LOG_CODE_ECC2READ_ERROR

4.4.7 Command 88_H – NVM: Erase

88_H

This command supports the erasure of NVM pages and NVM sectors.

The host initiates the NVM erase operation by sending a header block message. This message contains information about the NVM location (offset address based on NVM start address) and selects the erase granularity.

The BootROM rejects the erase operation if the given NVM location is not page-aligned for page erase operation, or not sector-aligned for sector erase operation.

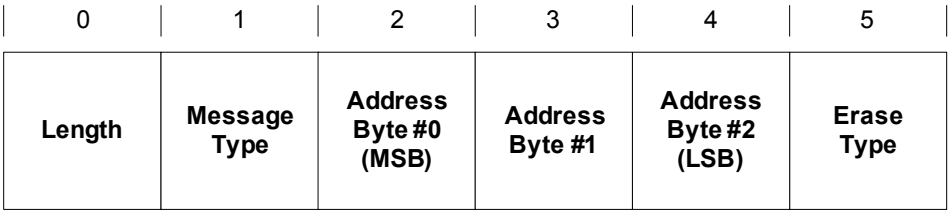
Any NVM erase operation is rejected in case any NVM read or write protection is applied to any NVM region. Details about the NVM access protection are given in **Command 89H – NVM: Protection Set / Clear**.

This erase command does not erase any NVM CS (Configuration Sector) pages.

The host waiting time before response is sent back/can be asked for:

- Page erase (128 bytes) / sector erase (4 KB): 5 ms

Header Block



BSL20_MODE06_HEADER

Table 4-22 "Command 88_H – NVM: Erase" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 05_H
Message Type	NVM erase command. Always set to 88_H
Address Byte #0(MSB)	24-bit NVM address offset for page or sector erase selection. The offset starts counting from the NVM start address 1100.0000_H
Address Byte #1	
Address Byte #2(LSB)	
Erase Type	Supported erase type field values: • **0 -** NVM page erase • **1 -** NVM sector erase

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID
- ERR_LOG_CODE_NVM_ERASE_PARAMS_INVALID (includes NVM write protection check)
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED

- ERR_LOG_CODE_NVM_ERASE_ADDR_INVALID
- ERR_LOG_CODE_NVM_SECT_ERASE_ADDR_INVALID
- ERR_LOG_CODE_NVM_INIT_MAPRAM_SECTOR

4.4.8 Command 89_H – NVM: Protection Set / Clear

Firmware supports setting and clearing of NVM protection for different NVM regions via command 89_H. These regions are the customer Bootloader NVM sector, code and data NVM sectors (multiple sector regions).

NVM region protection includes access protection for read and/or write/erase.

Any NVM protection clear operation ignores the password parameter if there is currently no protection password installed for that region.

A valid password must be not equal to 0000.0000_H or $3FFF.FFFF_H$. The password is checked during startup. Only if the password is valid, the given protection gets applied to the HW. This command only updates the specified NVM CS region password and does not apply it to the HW. This is done at the next device boot.

It is only possible to set a new password if one is not installed for the region. An error is returned otherwise. To update an existing password, the current one must be cleared first and then a new one can be set. When the password has been successfully cleared, the password specified for the region in the options field will get set to 0xFFFFFFFF. If the password used for clearing doesn't match the one installed, all region passwords and the whole NVM are erased. Clearing of the password for the customer Bootloader (CBSL) region is not supported.

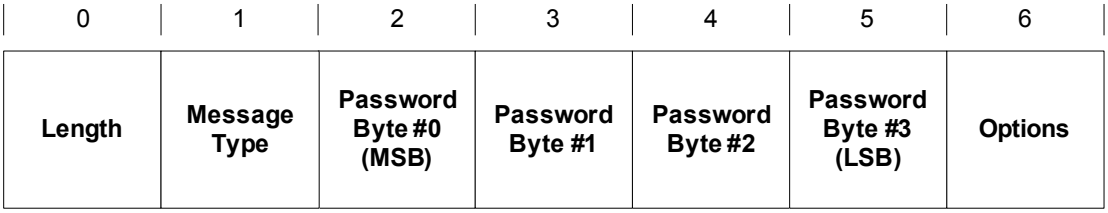
When comparing a given password with one installed, the protection part of the password is ignored.

This command can be used regardless of the current applied NVM HW protection for any region.

The host waiting time before a response is sent back/can be asked for:

- 8 ms

Header Block



BSL20_MODE07_HEADER

Table 4-23 "Command 89_H – NVM: Protection Set / Clear" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	NVM protection set/clear command. Always set to 89_H
Password Byte #0(MSB)	32-bit password parameter. (see also **"NVM Password Format" on Page 70**)
Password Byte #1	
Password Byte #2	
Password Byte #3(LSB)	
Options	The options field is described in **Table 4-24**.

Table 4-24 “Command 89_H – NVM: Protection Set / Clear” Header Block Options Field Description

Field	Bits	Description
Res	7:3	**Reserved**
Password Selector	2:1	**Password Selector** Password selection to set or reset. 00_B **Customer Bootloader Password**, 01_B **Code Segment Password**, 10_B **Data Segment Password**, 11_B **Reserved**,
Operation	0	**Set/Clear the password protection** 0_B **Clear**, The password protection is cleared if the provided password matches the installed password for the region. 1_B **Set**, Password protection is installed for the region if the selected password protection is currently not installed.

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID
- ERR_LOG_CODE_USER_PROTECT_PWD_INVALID
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_CS_PAGE_CHECKSUM
- ERR_LOG_CODE_CS_PAGE_ECC2READ
- ERR_LOG_CODE_USER_PROTECT_NO_CBSL_PWD_CLEAR
- ERR_LOG_CODE_USER_PROTECT_NO_PASSWORD_EXISTS
- ERR_LOG_CODE_NVM_ERASE_ADDR_INVALID
- ERR_LOG_CODE_NVM_SECT_ERASE_ADDR_INVALID
- ERR_LOG_CODE_NVM_PROTECT_REMOVE_PASSWORD_FAILED
- ERR_LOG_CODE_USER_PROTECT_NVM_AND_PWD_ERASED
- ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID
- ERR_LOG_CODE_NVM_ERASE_PARAMS_INVALID (includes NVM write protection check)
- ERR_LOG_CODE_USER_PROTECT_PWD_EXISTS

4.4.9 Command $0D_H$ – NVM: 100TP Write

Firmware supports programming of data in the customer-specific 100TP pages via command $0D_H$.

Any page programming is rejected if the page specific programming limit (100 times) is exceeded.

The header block message contains parameter about the 100TP page index, the offset inside that page. The data bytes follow by Data Block messages and the last data bytes are sent by an EOT block message.

This command rejects the page write operation if the offset is out of range, or offset plus count is out of range. NVM 100TP pages can only be written if there is no NVM read protection applied to any NVM region and write protection to code segment (linear sectors). It returns an error code in the response message. It supports partial page programming, preserving the page data not passed as an input

After successful write operation, the page write counter and checksum parameter are updated. These two bytes are stored at the end of the page. These two internal bytes reduce the usable page size (126 bytes instead of 128 bytes).

The host waiting time before response is sent back/can be asked for:

- 8 ms

Header Block

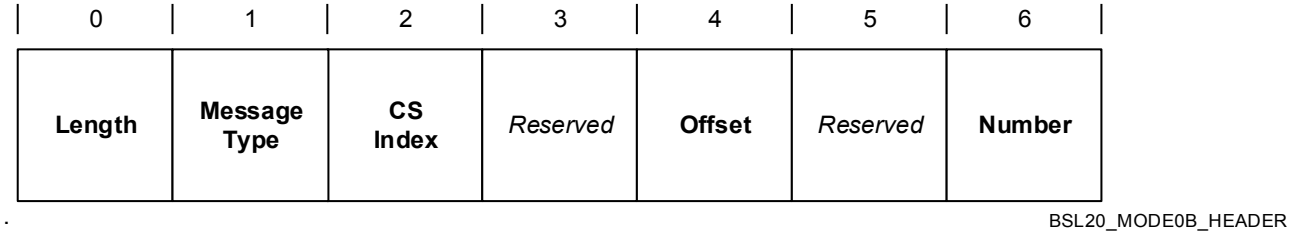
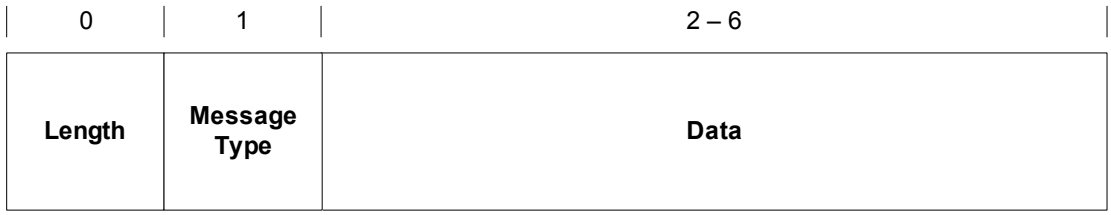


Table 4-25 "Command $0D_H$ – NVM: 100TP Write" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	NVM 100TP write command. Always set to $0D_H$
CS Index	100TP Selector. Supported range: 0 ... 7
Offset	Byte offset within page, valid range 0...125
Number	8-bit number of data bytes to write with the whole message. The BootROM expects to receive these bytes in Data Blocks and an EOT block. Maximum supported length: 126 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.

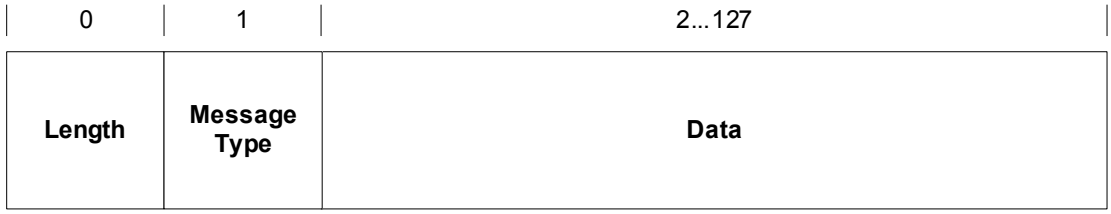


BSL20_MODE_DATA

Table 4-26 "Command 0D$_H$ – NVM: 100TP Write" Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06$_H$
Message Type	Data block. Always set to 00$_H$
Data	It contains the downloaded data (no dummy data to fill up the packet).

EOT Block



BSL20_BSL_NVM_100TP_WRITE_EOT

Table 4-27 "Command 0D$_H$ – NVM: 100TP Write" EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the Data field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 127 bytes
Message Type	EOT block. Always set to 80$_H$
Data	The maximum size of the field depends on the used BSL interface: • LIN – 5 bytes • FastLIN – 126 bytes Contains the read data. The EOT block message is the last message for read bytes. The data read process does not use Data Block messages if the overall data size is equal to or smaller than the "Data" field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED

- ERR_LOG_CODE_100TP_WRITE_ADDRESS_INVALID
- ERR_LOG_CODE_100TP_WRITE_COUNT_EXCEEDED
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

4.4.10 Command $8E_H$ – NVM: 100TP Read

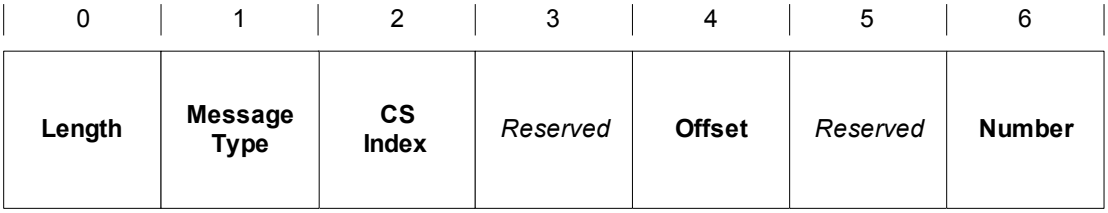
Firmware supports reading of data from the customer-specific 100TP page via command $8E_H$.

The header block message contains parameter about the 100TP page index, the offset inside that page and the number of read data bytes. The BootROM sends the data bytes by Data Block messages and the last data bytes by an EOT block message.

This command rejects the read operation if the 100TP page checksum is invalid, the offset is out of range, or offset plus count is out of range. NVM 100TP pages can only be read if there is no NVM HW read protection applied to any NVM region

The read command allows reading the internal used page programming counter. Those parameters are set during the write operation. Details can be found in **Command 0DH – NVM: 100TP Write**.

Header Block



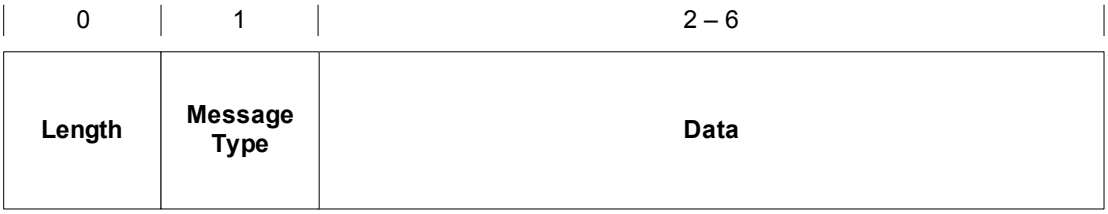
BSL20_MODE0C_HEADER

Table 4-28 "Command $8E_H$ – NVM: 100TP Read" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 06_H
Message Type	NVM 100TP read command. Always set to $8E_H$
CS Index	100TP Selector. Supported range: 0 ... 7
Offset	Byte offset within page, valid range 0...126.
Number	Number of data bytes to read. The BootROM will send these bytes in Data Blocks and an EOT block. Maximum supported length: 127 bytes.

Data Block

This block is only used for LIN communication, because the LIN frame length is too short to place the maximum supported data length into the EOT block.



BSL20_MODE_DATA

Table 4-29 “Command 8E$_H$ – NVM: 100TP Read” Data Block Field Description

Field	Description
Length	Number of following bytes in the data block. Always set to 06$_H$
Message Type	Data block. Always set to 00$_H$
Data	It contains the read data.

EOT Block

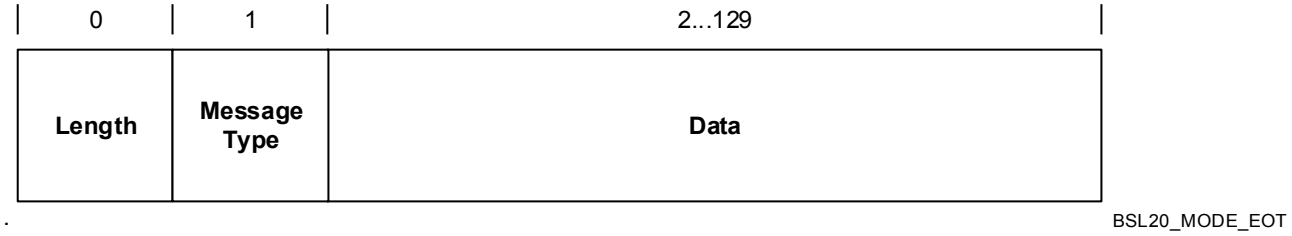


Table 4-30 “Command 8E$_H$ – NVM: 100TP Read” EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. The value depends on the size of the Data field: • LIN – always 2 to 6 bytes • FastLIN – 2 ... 128 bytes
Message Type	EOT block. Always set to 80$_H$
Data	The maximum size of the field depends on the used BSL interface: • LIN – 5 bytes • FastLIN – 127 bytes. Contains the read data. The EOT block message is the last message for read bytes. The data read process does not use Data Block messages if the overall data size is equal to or smaller than the "Data" field.

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_100TP_READ_ADDRESS_INVALID
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_CS_PAGE_CHECKSUM
- ERR_LOG_CODE_CS_PAGE_ECC2READ

4.4.11 Command $8F_H$ – BSL: Option Set

Firmware supports setting of some BSL option data, including BSL timeout (NAC) and BSL interface selector, via command $8F_H$.

The header block message contains the selected BSL interface and the NAC value.

The given configuration is stored in the device NVM CS and is used for the next startup.

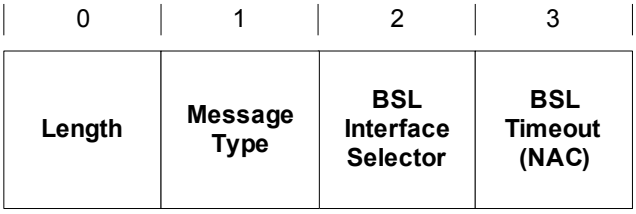
The current BSL option can be read by the **Command 90H – BSL: Option Get** command.

The command can only be used if there is no NVM read protection applied to any NVM region and write protection to code segment (linear sectors).

The host waiting time before response is sent back/can be asked for:

- 8 ms

Header Block



BSL20_BSL_OPTION_SET_HEADER

Table 4-31 "Command $8F_H$ – BSL: Option Set" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 03_H
Message Type	BSL option set. Always set to $8F_H$
BSL Interface Selector	BSL Interface Selector to be used for the next startup: • **0 -** LIN • **1 -** FastLIN
BSL Timeout (NAC)	BSL Timeout before jumping to the User Mode Code execution. The timeout starts counting from device reset release. A maximum of 140 ms is supported. The BSL timeout parameter counts the amount of 5 ms (01_H = 5 ms, 02_H = 10 ms and so on). The value FF_H waits forever. A value = 00_H disables the BSL mode and the BootROM directly jumps to user mode.

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED
- ERR_LOG_CODE_USERAPI_CONFIG_SET_PARAMS_INVALID
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

4.4.12 Command 90_H – BSL: Option Get

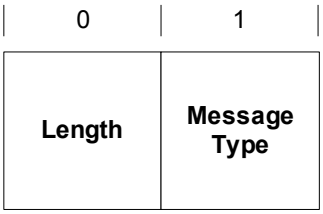
Firmware supports reading the current configured BSL option data from the NVM CS, including BSL timeout (NAC) and BSL interface selector, via command 90_H.

The header block message contains the information request. The BootROM sends the selected BSL interface and the NAC parameter by an EOT block message.

The command is rejected if NVM HW read protection is applied to any NVM region.

The BSL option can be changed by the **Command 8FH – BSL: Option Set**.

Header Block

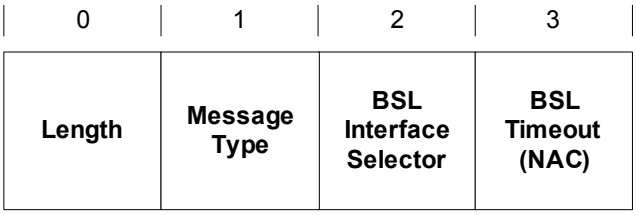


BSL20_BSL_OPTION_GET_HEADER

Table 4-32 "Command 90_H – BSL: Option Get" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 01_H
Message Type	BSL option set. Always set to 90_H

EOT block



BSL20_BSL_OPTION_GET_EOT

Table 4-33 "Command 90_H – BSL: Option Get" EOT Block Description

Field	Description
Length	Number of following bytes in the EOT block. Always set to 03_H
Message Type	EOT block. Always set to 80_H

Table 4-33 "Command 90_H – BSL: Option Get" EOT Block Description (cont'd)

Field	Description
BSL Interface Selector	BSL Interface Selector to be used for the next startup: • **0 -** LIN • **1 -** FastLIN
BSL Timeout (NAC)	BSL Timeout before jumping to the User Mode Code execution. The timeout starts counting from device reset release. A maximum of 140 ms is supported. The BSL timeout parameter counts the amount of 5 ms (01_H = 5 ms, 02_H = 10 ms and so on). The value FF_H waits forever. A value = 00_H disables the BSL mode and the BootROM directly jumps to user mode.

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED

4.4.13 Command 91_H – LIN: NAD Set

Firmware supports setting of the LIN NAD via command 91_H.

The header block message contains as a parameter the LIN NAD value.

The given NAD address is stored in the device NVM CS and is used for the next startup.

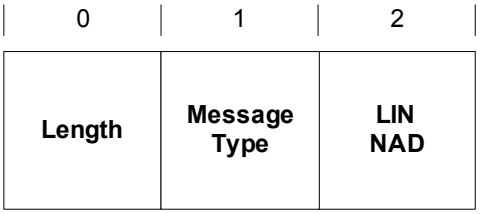
The command can only be used if there is no NVM read protection applied to any NVM region and write protection to code segment (linear sectors).

The current NAD value can be read by the **Command 92H – LIN: NAD Get** command.

The host waiting time before response is sent back/can be asked for:

- 8 ms

Header Block



BSL20_BSL_NAD_SET_HEADER

Table 4-34 "Command 91_H – LIN: NAD Set" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 02_H
Message Type	BSL option set. Always set to 91_H
LIN NAD	New NAD value to be stored in the NVM CS

Returned error codes

The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED
- ERR_LOG_CODE_NAD_VALUE_INVALID
- ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED
- ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

4.4.14 Command 92_H – LIN: NAD Get

Firmware supports reading the currently configured LIN NAD value via command 92_H.

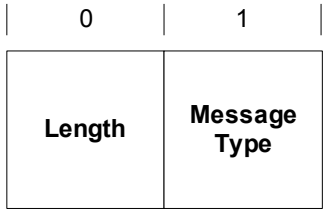
The header block message contains the information request. The BootROM sends the current LIN NAD value by an EOT block message.

The command is rejected if NVM HW read protection is applied to any NVM region.

The given NAD address is read from the NVM CS.

The NAD value can be changed by the **Command 91H – LIN: NAD Set** command.

Header Block

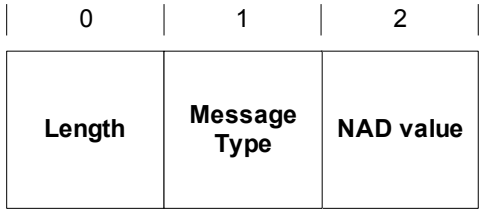


BSL20_BSL_NAD_GET_HEADER

Table 4-35 "Command 92_H – LIN: NAD Get" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 01_H
Message Type	BSL option set. Always set to 92_H

EOT Block



BSL20_BSL_NAD_GET_EOT

Table 4-36 "Command 92_H – LIN: NAD Get" EOT Block Field Description

Field	Description
Length	Number of following bytes in the EOT block. Always set to 02_H
Message Type	EOT block. Always set to 80_H
NAD value	The configured LIN NAD value

Returned error codes

The message can return the following error codes:

- ERR_LOG_CODE_NVM_IS_READ_PROTECTED

4.4.15 Command 93_H – FastLIN: Set Session Baudrate

Firmware supports changing the FastLIN baudrate for the current FastLIN BSL session via command 93_H.

The header block message contains the new FastLIN baud rate selection for the current FastLIN session. The given parameter is not stored inside the NVM CS, and the FastLIN default baud rate takes effect when the response has been sent back to the host.

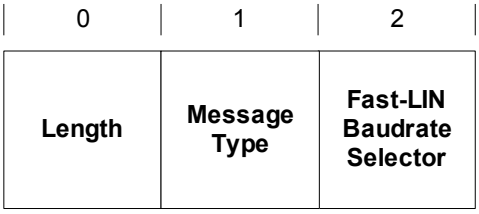
This command is rejected if the BSL communication currently uses a different interface than FastLIN. The command is also rejected if NVM HW read protection is applied to any NVM region.

The host waiting time before response is sent back/can be asked for:

- 8 ms

NOTE:

When sending this command, the response to the command will use the old baudrate. The new baudrate will be set only after the response has been transmitted.



BSL20_BSL_FAST_LIN_BAUDRATE_SET_HEADER

Table 4-37 "Command 93_H – FastLIN: Set Session Baudrate" Header Block Field Description

Field	Description
Length	Number of following bytes in the header block. Always set to 02_H
Message Type	BSL Set session baud rate. Always set to 93_H
FastLIN Baudrate Selector	Baud rate to be used, starting from the next frame: • **0 -** 38.4 kBd • **1 -** 115.2 kBd • **2 -** 230.4 kBd

Returned error codes

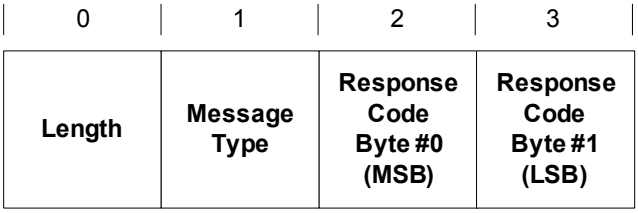
The message can return the following error codes:

- ERR_LOG_SUCCESS
- ERR_LOG_CODE_NVM_IS_READ_PROTECTED
- ERR_LOG_CODE_FASTLIN_BAUDRATE_SET_FAIL

4.4.16 Acknowledge Response Message (81_H)

Firmware supports sending back acknowledge response message (81_H) if the requested BSLcommand does not retrieve any data or the requested data cannot be provided. It is also sent if a problem occurred during processing the requested command data.

Response Block



BSL20_MODE_RESPONSE

Table 4-38 Acknowledge Response Block Field Description

Field	Description
Length	Number of following bytes in the Response Block. Always set to 03_H
Message Type	Response Block. Always set to 81_H
Response Code Byte #0 (MSB)	Signed 16-bit command response code. The value is set to zero if the requested command could be executed without any problems.
Response Code Byte #1 (LSB)	

5 NVM

5.1 NVM Overview

The NVM module consists of three regions, the Config Sector, the user code region and the user data region. The Config Sector holds device specific information as well the eight 100TP pages. The Config Sector is not directly addressable by the user. To access the 100TP pages dedicated user API functions are provided.

USER CODE Region

The user code region is intended to store the user application and/or constant user configurations. The user code area is divided into two parts. The first 4KB are called customer BSL region. It is a user code area which can be protected separately from the remaining user code. The customer BSL region is provided to store a user defined boot up code. The remaining user code is used to store the user application code. The entire user code area is directly addressable for read accesses. For writing/erasing data to the user code area dedicated user API functions are provided.

USER DATA Region

The last 4KB of the NVM module are the user data flash region. For this sector an EEPROM emulation is implemented. It is intended to store dynamical application data inside this NVM region. Constant data is recommended to be stored inside the user code area.

The EEPROM emulation is being achieved by the implementation of an address translation table, the so called MapRAM. All accesses to the data flash, read or write, the user given address (logical) is being translated to the physical address by using the MapRAM. The data flash is directly addressable for read accessed (through the MapRAM), but only mapped pages return data. The read access to an unmapped page causes a NMI, to signal to the user application the attempt of reading not existing data. For writing/erasing data to the user data area dedicated user API functions are provided.

NVM Password Protection

Firmware supports setting and clearing of NVM protection for different NVM regions. These regions are the customer Bootloader NVM sector, code and data NVM sectors. NVM region protection includes access protection for read and/or write/erase. NVM protection passwords are 32-bit in lenght, the two MSBs are reserved for read/write protection handling.

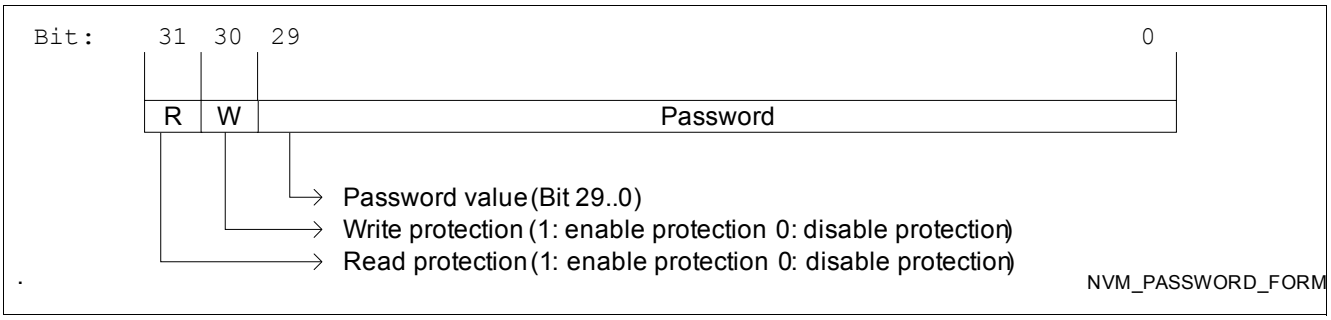


Figure 5-1 NVM Password Format

See also **“Command 89H – NVM: Protection Set / Clear” on Page 56** for details on how to set or clear the NVM protection password

5.2 NVM Write

It is strongly recommended to the user that no flash operations which modify the content of the flash, like write and erase, get interrupted at any time.

In order to write/modify data to a NVM page inside the user code or user data area, several user API functions are provided. From a user point of view there is no need to differentiate between the two major user NVM areas by using the API functions. The called user API functions are identifying by the given address the target user NVM region.

For writing a NVM page two scenarios are considered:

1.Writing a new page (erased or unmapped)

2.Writing a used page

The handling of these two scenarios, differ slightly between user code area and user data area. All the following described actions are performed by the user API functions, it does not describe user activities.

For writing a new code flash page the assembly buffer (AB) is opened. The AB is a small portion of SRAM inside the NVM hardware module to buffer the content of a NVM page for write activities. The AB is filled with 0xFF, the content of an erased page. The AB is updated with the data provided by the user along with the calling of the user API function. Then the content of the AB is written to the erased page addressed by the address provided by the user as parameter for the user API function.

For writing a used code flash area the AB is opened and the data inside the used page is copied into the assembly buffer. The AB is updated with the data provided by the user along with the calling of the user API function. The addressed NVM page is being erased afterwards the content of the AB is written to the erased page.

For writing a new data flash page, the user API function checks the content of the MapRAM for the given address. Since the page is not used, the MapRAM entry is marked unused. An internally maintained spare page points to a randomly selected erased physical data flash page. The assembly buffer (AB) is opened for the selected physical data flash page. The AB is updated with the data provided by the user along with the calling of the user API function. Then the content of the AB is written to the page addresses by the spare page. The link to the physical page is entered into the MapRAM and a new spare page is randomly selected.

For writing a used data flash page, the user API function checks the content of the MapRAM for the given address. The AB is opened and the data of the used (still mapped) page is copied into the AB. The AB is updated with the data provided by the user along with the calling of the user API function. Then the content of the AB is written to the page addresses by the spare page. The link to the new physical page is entered into the MapRAM. Now the old data flash page is being erased and a new spare page is randomly selected.

For all of these four scenarios the data just written is verified against the content of the AB. The user can select whether a retry (erase-write) is performed in case the verify failed.

For the data flash along with the enabled retry feature also the Disturb Handling (DH) feature gets enabled. The goal of the Disturb Handling is to compensate for retention losses of pages long time not updated by the user. Retry and Disturb Handling are executed exclusively, either of the two can be executed with one user API call but not both. In case no retry is performed and based on a pseudo-random number generator the DH is called (in average on every 1000th write operation), a copying of a used page (not the one which was just

written) is triggered. The actions performed by copying a used page inside the data flash sector are the same as for writing a used data flash page.

5.3 Data Flash Initialization

After a reset the volatile memory, MapRAM, has to be recovered in order to be able to perform the address translation for data flash accesses. The content of the MapRAM is being recovered out of the MapBlock, control information stored along with each data flash page. If during the initialization of the MapRAM an error occurred, i.e. a MapBlock of a data flash page contains ECC failures or if two pages are pointing to the same MapRAM entry (double mapping) then a repair function is called, the Service Algorithm (SA).

The Service Algorithm (SA) is executed only during startup, by the MapRAM initialization function and only if failures occurred during the MapRAM initialization. The Service Algorithm scans the entire data flash sector and tries to repair as much as possible faulty pages, pages with ECC failures in the MapBlock. The SA further scans for double mappings, pages which point to the same MapRAM entry. Up to one double mapping can be resolved by deleting one of the two pages. If more than one double mapping is existent the SA is not able to repair.

The result of the Service Algorithm is being reflected in the register MEMSTAT. The user shall read this register upon user code entry and in case unrecoverable failures in the data flash are signaled appropriate data flash recovery has to be performed by the user, such as erase of the entire data flash sector. It is not recommended to perform any write/erase action to the data flash if the mapping integrity is not given, the status of the mapping integrity is stored inside MEMSTAT and shall be evaluated by the user upon user code entry.

6 User Routines

The BootROM exports some library functions to the user mode software. These library functions allow to configure the device boot parameter and access the NVM.

6.1 List of Supported Features

- Read and write the various 100TP pages inside the NVM.
- Read, write and erase the NVM pages and sectors.
- Configure the BSL parameter (e.g. Interface selection, timeout configuration, LIN address).
- Retrieve the customer identification number.
- Perform a RAM MBIST test.
- Check for ECC single- and double-errors on NVM and RAM.

All library functions are accessible over a branch table, where the user mode software can directly jump to. The branch table is stored at a fix location and in return branches to the function implementation.

An API reference to the user routines is given in **“User API Routines” on Page 75**.

6.2 Reentrance Capability and Interrupts

With the exception of a few functions, **no** support is provided for reentrance of user API routines – user calls must be atomic (i.e., they must not be interrupted and reentered before completion). The customer application must not call these routines from different multitask levels (e.g. different thread/interrupt levels). As user API routines are potentially timimg dependent, it is recommended to disable interrupts prior to calling API routines.

6.3 Parameter Checks

Some of the user API implementations use pointers to exchange data with the API. All pointers must point to a valid RAM address range. If the address points outside the valid RAM area, an error code is returned.

Other routines support branching or callbacks. If the callback is different from zero, it must point to a valid NVM or RAM range. Otherwise an error is returned.

6.4 NVM Region Write Protection Check

The user API functions writing to a page in NVM or NVM-CS check for NVM region write protection, and return an error code if the protection is set for that page.

6.5 Watchdog handling when using NVM functions

The execution time of all user API functions is given in **“Appendix F – Execution time of BootROM User API Functions” on Page 114**. This has to be observed for watchdog timeout calculations, especially when NVM operations are involved (programming or erase). Prior to invoking NVM write routines, it is recommended to do the following:

- Perform a short-open-window trigger to WDT1 before a NVM operation is called
- Invoke NVM write routine
- Reconfigure watchdog for normal operation

Doing this ensures that the watchdog will not expire and cause reset during NVM operations.

6.6 Interrupts

System interrupts are not used by any BootROM functions during startup or when any user APIs are executed. Customer software must service system interrupts in a normal fashion, which means installing interrupt vectors at the correct locations for the system CPU.

6.7 Resources used by user API functions

Listed below is a list of user API functions with what kind of HW resources they use.

Stack usage of the functions are listed in **Appendix B – Stack Usage of User API Functions**

Table 6-1 Resources used by User API functions

User API function	Non Re-entrance	NVM HW	GPT12 timer
user_nvm_mapram_init	X	X (HW init)	
user_bsl_config_get		X (read)	
user_bsl_config_set	X	X (write)	
user_ecc_events_get	X		
user_ecc_check	X	X (read)	
user_mbist_set	X	X (write)	
user_nac_get		X (read)	
user_nac_set	X	X (write)	
user_nad_get		X (read)	
user_nad_set	X	X (write)	
user_nvm_100tp_read	X	X (read)	
user_nvm_100tp_write	X	X (write)	
user_nvm_config_get		X (read)	
user_nvm_password_clear	X	X (write)	
user_nvm_password_set	X	X (write)	
user_nvm_protect_get			
user_nvm_protect_set	X	X (write)	
user_nvm_protect_clear	X	X (write)	
user_nvm_ready_poll			
user_nvm_page_erase / user_nvm_page_erase_branch / user_nvm_sector_erase	X	X (write)	
user_nvm_write / user_nvm_write_branch	X	X (write)	
user_ram_mbist			X
user_nvm_clk_factor_set			
user_vbg_temperature_get		X (read)	

6.8 User API Routines

These routines are exported by the BootROM to the customer user mode software.

User API Routines support features like accessing memory resources like NVM and 100TP pages. They also support to configure some protection mechanism and BSL parameters. The API functions check the valid parameter range, which is depending on the device.

Table 6-2 User API Routines Function Overview

Name	Description
user_bsl_config_get	This user API function reads the user BSL interface selection value.
user_bsl_config_set	This user API function writes the user BSL interface selection value. This function returns an error in case the NVM code segment is write protected.
user_ecc_check	This user API function checks for single and double ECC checking over the entire NVM (all NVM linear and NVM non-linear sectors). Any existing ECC errors are cleared before the read starts.
user_ecc_events_get	This user API function checks if any single or double ECC events have occurred during runtime. It reports any single or double ECC event coming from NVM. The corresponding last double ECC failure address is returned via modified pointer.
user_mbist_set	This user API function enables a separate MBIST for all possible reset sources, except POR reset and pin reset. The MBIST is always performed for POR reset and pin reset. This function rejects with an error in case the NVM code segment is write protected.
user_nac_get	This user API function reads out the NAC value that is currently configured in the non volatile device configuration memory.
user_nac_set	This user API function configures the NAC value in the non volatile device configuration memory.
user_nad_get	This user API function reads out the LIN NAD value that is currently configured in the non volatile device configuration memory.
user_nad_set	This user API function configures the LIN NAD value in the non volatile device configuration memory.
user_nvm_100tp_read	This user API function reads data from the customer accessible configuration pages (100TP), address is relative inside the configuration NVM area (8x one page, 1024 bytes). It stops reading at page boundary. In case the offset plus count is out of range or if count is zero it returns an error and does not perform any read operation.

Table 6-2 User API Routines Function Overview (cont'd)

Name	Description
user_nvm_100tp_write	This user API function writes data to the configuration NVM, address is relative inside the configuration NVM area (8x one page, 1024 bytes). It stops writing at page boundary. The function shall support partial page programming, preserving the page data not passed as an input. The function shall perform an implicit update of the page checksum and write counter. The function does not allow the customer to change the page checksum or write counter. In case the offset plus count is out of range or if count is zero it returns an error and does not perform any program operation. The function also returns an error in case the NVM code segment is write protected. The write counter and the page checksum are the last two bytes of the page.
user_nvm_clk_factor_set	This user API function sets the SCU_SYSCON0.NVMCLKFAC divider
user_nvm_config_get	This user API function allows to gather the NVM configuration, this is the number of sectors for user code, user data and user bsl.
user_nvm_mapram_init	This user API function triggers NVM FSM mapRAM update sequence from mapped sector.
user_nvm_page_erase	This user API function erases a given NVM page (address). This function rejects with an error in case the accessed NVM page is write protected. In case of an unsused (new) page in non-linear sector, the function does nothing and returns success. In case of erasing a page in linear sector, the function should always perform the erase.
user_nvm_page_erase_branch	This user API function erases a given NVM page (address) and branches to an address (branch_address) for code execution during the NVM operation.
user_nvm_password_clear	This user API function clears the NVM protection password for a given NVM code or data segment (not supported for the BSL segment). The password is only removed in case the correct password is provided.
user_nvm_password_set	This user API function sets a read and/or write protection for any NVM region individually. The API does not change the protection state for a region where password protection is currently installed.
user_nvm_protect_clear	This user API function clears a read and/or write protection for any NVM region individually. The API changes the protection state for a region, but does not update the installed password (config sector).
user_nvm_protect_get	This user API function checks for the hardware current applied NVM protection status.

Table 6-2 User API Routines Function Overview (cont'd)

Name	Description
user_nvm_protect_set	This user API function sets a read and/or write protection for any NVM region individually. The API changes the protection state for a region, but does not update the installed password in configuration sector.
user_nvm_ready_poll	This user API function checks for the readiness of the NVM module. The API is called within the NVM programming or erase branch callback operation. It checks if the NVM operation has finished and the callback could return to the NVM routine.
user_nvm_sector_erase	This user API function erases the NVM sector-wise. It operates on user code and data NVM region.
user_nvm_write	This user API function programs the NVM. It operates on the user NVM, as well as on the user data NVM. The API shall write a number of bytes (count) from the source (data) to the NVM location (address) with the programming options (options). The options provide parameters like DH and fail scenario handling.
user_nvm_write_branch	This user API function programs the NVM. It operates on the user NVM, as well as on the user data NVM. The API shall write a number of bytes (count) from the source (data) to the NVM location (address) with the programming options (options). During the NVM operation the program execution branches to a given SRAM location (branch_address) and continues code execution from there. The options provide parameters like DH and fail scenario handling.
user_ram_mbist	This user API function performs a MBIST on the integrated SRAM. The range to check is provided as parameter. The function rejects the call in case the parameter exceeds the RAM address range.
user_vbg_temperature_get	This user API function returns the V bandgap temperature Hot or Cold The customer can do temperature compensation in software based on these values (as the VBG is the reference for the ADC). In case the parameter "temperature" is not correct, the function returns the value 0xFFFFFFFF.

6.8.1 user_nvm_mapram_init

Description

This user API function triggers NVM FSM mapRAM update sequence from mapped sector.In case of mapping errors (double or multiple mapping or faulty pages) the initialization of the MapRAM is stopped on the first error found and the routine is exited reporting an error indication.
In case of fail, the content of the MapRAM might be only partial and the mapping information might be corrupted.

Prototype

```
int32_t user_nvm_mapram_init (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
int32_t	Zero in case the function has been called successfully, otherwise a negative error code. The returned code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_ERROR, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_NVM_INIT_MAPRAM_SECTOR

6.8.2 user_bsl_config_get

Description

This user API function reads the user BSL interface selection value.

Prototype

```
BSL_INTERFACE_SELECT_t user_bsl_config_get (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
BSL_INTERFACE_SELECT_t	The currently selected BSL interface. It returns the default BSL_FAST_LIN interface in case no configuration is given in the NVM CS.

6.8.3 user_bsl_config_set

Description

This user API function writes the user BSL interface selection value. This function returns an error in case the NVM code segment is write protected.

Prototype

```
int32_t user_bsl_config_set (
  BSL_INTERFACE_SELECT_t ser_if
)
```

Parameters

Data Type	Name	Description	Dir
BSL_INTERFACE_SELECT_t	ser_if	BSL interface selection	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of success, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED, ERR_LOG_CODE_USERAPI_CONFIG_SET_PARAMS_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

Remarks

It is not allowed to be called by NVM callback routines.

6.8.4 user_ecc_events_get

Description

This user API function checks if any single or double ECC events have occurred during runtime. It reports any single or double ECC event coming from NVM. The corresponding last double ECC failure address is returned via modified pointer. Upon exit, the function will clear the current ECC status in the NVM module.

Prototype

```
int32_t user_ecc_events_get (
  uint32_t * pNVM_Addr
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t *	pNVM_Addr	Pointer to NVM Address variable where the double ECC error is stored. This pointer stays untouched in case no NVM double ECC errors was detected. The double ECC error address points to an 8-byte NVM block where the error occurred. Pointer must be within valid RAM range (0x18000000 + device RAM size) or an error code is returned.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case no single or double ECC event have occurred, A negative error code for single, double or single and double ECC errors A negative error code if the NVM semaphore is not free. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_SINGLE_ECC_EVENT_OCCURRED, ERR_LOG_CODE_DOUBLE_ECC_EVENT_OCCURRED, ERR_LOG_CODE_SINGLE_AND_DOUBLE_ECC_EVENT_OCCURRED

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.5 user_ecc_check

Description

This user API function checks for single and double ECC checking over the entire NVM (all NVM linear sectors and all mapped pages inside the mapped NVM sector). Any existing ECC errors are cleared before the read starts. Upon exit, the function will clear the current ECC status in the NVM module.

Prototype

```
int32_t user_ecc_check (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case no single or double ECC event have occurred, otherwise a negative error code for single, double or single and double ECC errors. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_SINGLE_ECC_EVENT_OCCURRED, ERR_LOG_CODE_DOUBLE_ECC_EVENT_OCCURRED, ERR_LOG_CODE_SINGLE_AND_DOUBLE_ECC_EVENT_OCCURRED

Remarks

This routine does not provide the ECC error address. Please use the **user_ecc_events_get** routines to retrieve the addresses.

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.6 user_mbist_set

Description

This user API function enables a separate MBIST for all possible reset sources, except POR reset and pin reset. The MBIST is always performed for POR reset and pin reset. This function rejects with an error in case the NVM code segment is write protected.

Prototype

```
int32_t user_mbist_set (
  bool bEnable
)
```

Parameters

Data Type	Name	Description	Dir
bool	bEnable	Enable the MBIST test execution if the boolean parameter is set to TRUE, otherwise disable the MBIST test execution	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case the configuration is set successfully, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.7 user_nac_get

Description

This user API function reads out the NAC value that is currently configured in the non volatile device configuration memory.

Prototype

```
uint8_t user_nac_get (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
uint8_t	NAC value that is found in the configuration memory. It returns "wait forever" (0xFF) in case no NAC value is currently configured in the configuration memory.

6.8.8 user_nac_set

Description

This user API function configures the NAC value in the non volatile device configuration memory.

This function rejects with an error in case the NVM code segment is write protected.

Prototype

```
int32_t user_nac_set (
  uint8_t nac
)
```

Parameters

Data Type	Name	Description	Dir
uint8_t	nac	NAC value to be stored in the device configuration memory.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful write operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR

Remarks

Any NAC value larger than 28 gets clipped to 28

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.9 user_nad_get

Description

This user API function reads out the LIN NAD value that is currently configured in the non volatile device configuration memory.

Prototype

```
uint8_t user_nad_get (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
uint8_t	The LIN NAD value which is found in the configuration memory. It returns the default broadcast address in case no LIN NAD value is currently configured in the configuration memory.

6.8.10 user_nad_set

Description

This user API function configures the LIN NAD value in the non volatile device configuration memory.

This function rejects with an error in case the NVM code segment is write protected.

Prototype

```
int32_t user_nad_set (
  uint8_t nad
)
```

Parameters

Data Type	Name	Description	Dir
uint8_t	nad	LIN NAD value to be stored in the device configuration memory. Valid range is from 0x80-0xFF.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful write operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NAD_VALUE_INVALID

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.11 user_nvm_100tp_read

Description

This user API function reads data from the customer accessible configuration pages (100TP), the read address is relative inside the configuration NVM area (8x one page, 1024 bytes). An invalid parameter setup (page number out of range, offset plus count larger than page boundary, count is 0) returns an error, no read operation is performed. In case of a checksum error, the function also returns an error.

A maximum number of 127 bytes can be read by this function (including the page counter, which is contained in the last byte of the page).

Prototype

```
int32_t user_nvm_100tp_read (
  uint32_t page_num
  uint32_t offset
  void * data
  uint32_t count
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	page_num	Page number where to read from. Valid range: 0 to 7	-
uint32_t	offset	Byte offset inside the selected page address, where to start reading. Maximum is 127 bytes. If count plus offset is larger than 127, an error code is returned.	-

Data Type	Name	Description	Dir
void *	data	Data pointer where to store the read data. Pointer plus valid count must be within valid RAM range or an error code is returned	-
uint32_t	count	Amount of data bytes to read. If count is zero, there is no operation and an error code is returned. Maximum is 127 bytes.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful read operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_100TP_PARAM_INVALID, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID, ERR_LOG_CODE_100TP_READ_ADDRESS_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_CS_PAGE_CHECKSUM, ERR_LOG_CODE_CS_PAGE_ECC2READ

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.12 user_nvm_100tp_write

Description

This user API function writes data to the configuration NVM, the write address is relative inside the configuration NVM area (8x one page, 1024 bytes). The function supports partial page programming, preserving page data not passed as new input. The function performs an implicit update of the page checksum and the write counter. The write counter is increased by 1 at each write operation, when 99 is reached, an error is reported. The function does not allow the customer to change the page checksum or write counter. An invalid parameter setup (page number out of range, offset plus count larger than page boundary, count is 0) returns an error, no write operation is performed. The function also returns an error in case the NVM code segment is write protected. The write counter and the page checksum are located in the last two bytes of the page.

The maximum value for writing is 126 bytes.

Prototype

```
int32_t user_nvm_100tp_write (
  uint32_t page_num
  uint32_t offset
  const void * data
  uint32_t count
```

)

Parameters

Data Type	Name	Description	Dir
uint32_t	page_num	Page number where to write to. Valid range: 0 to 7	-
uint32_t	offset	Byte offset inside the selected page address, where to start writing. Maximum is 126 bytes.	-
const void *	data	Data pointer where to read the data to write. Pointer plus valid count must be within valid RAM range or an error code is returned	-
uint32_t	count	Amount of data bytes to write. If count is zero, there is no operation and an error code is returned. Maximum is 126 bytes.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful write operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_100TP_PARAM_INVALID, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID, ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED, ERR_LOG_CODE_100TP_WRITE_ADDRESS_INVALID, ERR_LOG_CODE_100TP_WRITE_COUNT_EXCEEDED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NVM_VER_ERROR

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.13 user_nvm_config_get

Description

This user API function allows to gather the NVM configuration, this is the number of sectors for user code, user data and user bsl.

Pointer must be within valid RAM range or an error code is returned.

Prototype

```
int32_t user_nvm_config_get (
  uint8_t * cbsl_nvm_size
  uint8_t * code_nvm_size
```

```
  uint8_t * data_nvm_size
)
```

Parameters

Data Type	Name	Description	Dir
uint8_t *	cbsl_nvm_size	Pointer where to store the retrieved NVM cbsl size. Valid RAM range is 0x18000000 + device RAM size.	-
uint8_t *	code_nvm_size	Pointer where to store the retrieved NVM code size. Valid RAM range is 0x18000000 + device RAM size.	-
uint8_t *	data_nvm_size	Pointer where to store the retrieved NVM data size. Valid RAM range is 0x18000000 + device RAM size.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful configuration retrieve operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_NVM_CONFIG_NOT_READY, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID

6.8.14 user_nvm_password_clear

Description

This user API function clears the NVM protection password for a given NVM code or data segment (not supported for the BSL segment). The password is only removed in case the correct password is provided.

This function only removes the protection password from the device NVM configuration sector. It does not remove the currently applied NVM HW access protection. The protection will not be applied until the next system reboot, in case the password got removed successfully.

All NVM segment data (BSL-, Code- and Data- regions) and all passwords are erased in case a wrong password is provided. Before erasing starts, all interrupts including NMI are temporarily disabled and any NVM and NVM CS protection is disabled. Once erase is completed, protection and interrupts are restored to their original state. The current protection status is not touched. The function rejects with an error in case the NVM code segment is write protected.

Prototype

```
int32_t user_nvm_password_clear (
  uint32_t password
  NVM_PASSWORD_SEGMENT_t segment
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	password	Current active password for the segment . A valid password parameter consists of a 30-bit password (bits 0...29), bits 30 and 31 are ignored.	-
NVM_PASSWORD_SEGMENT_t	segment	Segment where password should be cleared	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case the password could be successfully applied, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USER_PROTECT_NO_CBSL_PWD_CLEAR, ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_CS_PAGE_CHECKSUM, ERR_LOG_CODE_CS_PAGE_ECC2READ, ERR_LOG_CODE_USER_PROTECT_NO_PASSWORD_EXISTS, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NVM_PROTECT_REMOVE_PASSWORD_FAILED, ERR_LOG_CODE_USER_PROTECT_NVM_AND_PWD_ERASED, ERR_LOG_CODE_NVM_VER_ERROR

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.15 user_nvm_password_set

Description

This user API function sets a read and/or write protection for any NVM region individually. The API does not change the protection state for a region where password protection is currently installed.

The password parameter consists of a 30-bit password (bit 0...29) and two additional protection bits (bit 30 + bit 31).

A valid password must be different from 0x3FFFFFFF and 0x00000000 (bit 0...29). The two MS bits in the password contain the protection type, where setting bit 31 activates the read protection and setting bit 30 activates the write protection. A non-compliant password is rejected. The function rejects with an error in case the NVM code segment is write protected.

A password can only be applied in case no valid password is currently set for the requested region.

Prototype

```
int32_t user_nvm_password_set (
```

```
  uint32_t password
  NVM_PASSWORD_SEGMENT_t segment
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	password	Protection password to apply on the given segment	-
NVM_PASSWORD_SEGMENT_t	segment	Segment which should be password protected	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case the password could be successfully applied, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID, ERR_LOG_CODE_USER_PROTECT_PWD_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_CS_PAGE_CHECKSUM, ERR_LOG_CODE_CS_PAGE_ECC2READ, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NVM_VER_ERROR ERR_LOG_CODE_USER_PROTECT_PWD_EXISTS

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.16 user_nvm_protect_get

Description

This user API function checks for the currently applied NVM hardware protection status.

Prototype

```
uint32_t user_nvm_protect_get (
  NVM_PASSWORD_SEGMENT_t segment
)
```

Parameters

Data Type	Name	Description	Dir
NVM_PASSWORD_SEGMENT_t	segment	Which NVM segment to retrieve the current password protection status	-

Return Values

Data Type	Description
uint32_t	Current protection status of the NVM segment selected: Protection disabled: 0x00000000 read protection enabled: 0x80000000 Write protection enabled: 0x40000000 Read and write protection enabled: 0xC0000000 Segment not recognized: 0xFFFFFFFF

6.8.17 user_nvm_protect_set

Description

This user API function sets a read and/or write protection for any NVM region individually. The API changes the protection state for a region, but does not update the installed password in configuration sector.

A valid password must be provided in case any valid NVM protection password is installed for this region.

All NVM segment data (BSL-, Code- and Data- regions) and all passwords are erased in case a wrong password is provided. Before erasing starts, all interrupts including NMI are temporarily disabled and any NVM and NVM CS protection is disabled. Once erase is completed, protection and interrupts are restored to their original state.

Set bit 31 of the password parameter to enable read protection, set bit 30 of the password parameter to enable write protection. The bits (0...29) of the password parameter shall match the password installed before. In case no valid protection password is currently installed, bits (0...29) are ignored.

Prototype

```
int32_t user_nvm_protect_set (
  uint32_t password
  NVM_PASSWORD_SEGMENT_t segment
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	password	Protection password to apply on the given segment	-
NVM_PASSWORD_SEGMENT_t	segment	Segment which should be password protected	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case the password could be successfully applied, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_CS_PAGE_CHECKSUM, ERR_LOG_CODE_CS_PAGE_ECC2READ, ERR_LOG_CODE_USER_PROTECT_NVM_AND_PWD_ERASED, ERR_LOG_CODE_NVM_PROTECT_REMOVE_PASSWORD_FAILED,

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.18 user_nvm_protect_clear

Description

This user API function clears a read and/or write protection for any NVM region individually. The API changes the protection state for a region, but does not update the installed password (config sector).

A valid password must be provided in case any valid NVM protection password is installed for this region.

All NVM segment data (BSL-, Code- and Data- regions) and all passwords are erased in case a wrong password is provided. Before erasing starts, all interrupts including NMI are temporarily disabled and any NVM and NVM CS protection is disabled. Once erase is completed, protection and interrupts are restored to their original state.

Set bit 31 of the password parameter to enable read protection, set bit 30 of the password parameter to enable write protection. The bits (0...29) of the password parameter shall match the password installed before. In case no valid protection password is currently installed, bits (0...29) are ignored.

Prototype

```
int32_t user_nvm_protect_clear (
  uint32_t password
  NVM_PASSWORD_SEGMENT_t segment
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	password	Protection password to apply on the given segment	-
NVM_PASSWORD_SEGMENT_t	segment	Segment which should be password protected	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case the password could be successfully applied, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_CS_PAGE_CHECKSUM, ERR_LOG_CODE_CS_PAGE_ECC2READ, ERR_LOG_CODE_USER_PROTECT_NVM_AND_PWD_ERASED, ERR_LOG_CODE_NVM_PROTECT_REMOVE_PASSWORD_FAILED,

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.19 user_nvm_ready_poll

Description

This user API function checks for the readiness of the NVM module. The API is called within the NVM programming or erase branch callback operation. It checks if the NVM operation has finished and the callback could return to the NVM routine.

Prototype

```
bool user_nvm_ready_poll (void)
```

Parameters

```
void
```

Return Values

Data Type	Description
bool	True in case the requested NVM operation is already finished, otherwise false.

6.8.20 user_nvm_page_erase

Description

This user API function erases a given NVM page (address). In case of an unsused (new) page in non-linear sector, the function does nothing and returns success. In case of erasing a page in linear sector, the function should always perform the erase.

This function rejects with an error in case the accessed NVM page is write protected.

Prototype

```
int32_t user_nvm_page_erase (
  uint32_t address
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	address	Address of the NVM page to erase. Non-aligned address is accepted. Range is 0x11000000 + device NVM size.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful erase operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID, ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED,

Remarks

This function does not support erasing any 100TP pages.

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.21 user_nvm_page_erase_branch

Description

This user API function erases a given NVM page (address) and branches to an address (branch_address) for code execution during the NVM operation.

This function rejects with an error in case the accessed NVM page is write protected.

Prototype

```
int32_t user_nvm_page_erase_branch (
  uint32_t address
  user_callback_t branch_address
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	address	Address of the NVM page to erase. Non-aligned address is accepted. Range is 0x11000000 + device NVM size.	-
user_callback_t	branch_address	Function callback address where to jump while waiting for the NVM module to finish the erase operation. Address must be within valid RAM range (0x18000000 + device RAM size). RAM end address - 4 is the upper limit.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful erase operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID, ERR_LOG_CODE_USER_API_BRANCH_ADDRESS_INVALID, ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED,

Remarks

This function does not support to erase any 100TP pages.

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.22 user_nvm_sector_erase

Description

This user API function erases the NVM sector-wise. It operates on user code and data NVM region.

This function rejects with an error in case the accessed NVM page is write protected.

Prototype

```
int32_t user_nvm_sector_erase (
  uint32_t address
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	address	Address of the NVM sector to erase. Non-aligned address is accepted. Range is 0x11000000 + device NVM size.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful erase operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID, ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_NVM_INIT_MAPRAM_SECTOR

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

In case of non linear sector, the sector erase function has to run mapram init starting from a random position to get a random spare page (for the next programming).

6.8.23 user_nvm_write

Description

This user API function programs the NVM. It operates on the user NVM, as well as on the user data NVM. The API shall write a number of bytes (count) from the source (data) to the NVM location (address) with the programming options (options). The options provide parameters like DH and fail scenario handling.

Supported option parameters:

- NVM_PROG_CORR_ACT (Disturb handling & retry enabled)
- NVM_PROG_NO_FAILPAGE_ERASE

The page programming stops at page boundary. If data is lost due to page boundary, an error code informs that crossing page boundary is not supported. The firmware preserves the non-programmed page data.

This function rejects with an error in case the accessed NVM page is write protected.

Prototype

```
int32_t user_nvm_write (
  uint32_t address
  const void * data
  uint8_t count
  uint8_t options
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	address	NVM address where to program the data. Range is 0x11000000 + device NVM size.	-
const void *	data	Pointer to the data where to read the programming data. Pointer must be within valid RAM range (0x18000000 + device RAM size) or an error code is returned.	-
uint8_t	count	Amount of bytes to program. Range from 1-127 bytes.	-
uint8_t	options	NVM programming options (e.g. NVM_PROG_CORR_ACT | NVM_PROG_NO_FAILPAGE_ERASE)	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful write operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_PARAM_INVALID, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID, ERR_LOG_CODE_USER_CROSS_PAGE_PRG_NOT_SUPPORTED, ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NVM_MAPRAM_UNKNOWN_TYPE_USAGE, ERR_LOG_CODE_NVM_VER_ERROR, ERR_LOG_CODE_NVM_PROG_MAPRAM_INIT_FAIL, ERR_LOG_CODE_NVM_PROG_VERIFY_MAPRAM_INIT_FAIL, ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID,

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.24 user_nvm_write_branch

Description

This user API function programs the NVM. It operates on the user NVM, as well as on the user data NVM. The API shall write a number of bytes (count) from the source (data) to the NVM location (address) with the programming options (options). During the NVM operation the program execution branches to a given SRAM location (branch_address) and continues code execution from there. The options provide parameters like DH and fail scenario handling.

Supported option parameters:

- NVM_PROG_CORR_ACT (Disturb handling & retry enabled)
- NVM_PROG_NO_FAILPAGE_ERASE

The page programming stops at page boundary. The firmware preserves the non-programmed page data. This function rejects with an error in case the accessed NVM page is write protected.

Prototype

```
int32_t user_nvm_write_branch (
  uint32_t address
  const void * data
  uint8_t count
  uint8_t options
  user_callback_t branch_address
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	address	NVM address where to program the data. Range is 0x11000000 + device NVM size.	-
const void *	data	Pointer to the data where to read the programming data. Pointer must be within valid RAM range (0x18000000 + device RAM size) or an error code is returned.	-
uint8_t	count	Amount of bytes to program. Range from 1-127 bytes.	-
uint8_t	options	NVM programming options (e.g. NVM_PROG_CORR_ACT | NVM_PROG_NO_FAILPAGE_ERASE)	-
user_callback_t	branch_address	Function callback address where to jump while waiting for the NVM module to finish the program operation. Address must be within RAM range (0x18000000 + device RAM size). RAM end address - 4 is the upper limit.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful write operation, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_PARAM_INVALID, ERR_LOG_CODE_USER_API_BRANCH_ADDRESS_INVALID, ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID, ERR_LOG_CODE_USER_CROSS_PAGE_PRG_NOT_SUPPORTED, ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED, ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED, ERR_LOG_CODE_ACCESS_AB_MODE_ERROR, ERR_LOG_CODE_NVM_MAPRAM_UNKNOWN_TYPE_USAGE, ERR_LOG_CODE_NVM_VER_ERROR, ERR_LOG_CODE_NVM_PROG_MAPRAM_INIT_FAIL, ERR_LOG_CODE_NVM_PROG_VERIFY_MAPRAM_INIT_FAIL, ERR_LOG_CODE_NVM_PROG_MAPRAM_INIT_FAIL, ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID,

Remarks

It is not allowed to be called by NVM callback routines or any interrupt or multi-threaded environment in a re-entrant context.

6.8.25 user_ram_mbist

Description

This user API function performs a MBIST on the integrated SRAM. The range to check is provided as parameter. The function rejects the call in case the parameter exceeds the RAM address range.

Prototype

```
int32_t user_ram_mbist (
  uint32_t start_address
  uint32_t end_address
)
```

Parameters

Data Type	Name	Description	Dir
uint32_t	start_address	RAM memory address where to start the MBIST test. Range is 0x18000000 + device RAM size.	-
uint32_t	end_address	RAM memory address till where to perform the MBIST test. Range is 0x18000000 + device RAM size.	-

Return Values

Data Type	Description
int32_t	ERR_LOG_SUCCESS in case of successful MBIST execution, otherwise a negative error code. Returned error code can be one of the following: ERR_LOG_SUCCESS, ERR_LOG_CODE_MBIST_RAM_RANGE_INVALID, ERR_LOG_CODE_MBIST_FAILED, ERR_LOG_CODE_MBIST_TIMEOUT

Remarks

Customer needs to make attention to not destroy the BootROM stack pointer.

6.8.26 user_nvm_clk_factor_set

Description

This user API function sets the SCU_SYSCON0.NVMCLKFAC divider

Prototype

```
void user_nvm_clk_factor_set (
  uint8_t clk_factor
)
```

Parameters

Data Type	Name	Description	Dir
uint8_t	clk_factor	Sets the clock factor directly to the value specified. No checks are done on the value. It is the responsibility of the user to know the range based on device technical data sheet.	-

6.8.27 user_vbg_temperature_get

Description

This user API function returns the V bandgap temperature Hot or Cold The customer can do temperature compensation in software based on these values (as the VBG is the reference for the ADC). In case the parameter "temperature" is not correct, the function returns the value 0xFFFFFFFF.

Prototype

```
uint32_t user_vbg_temperature_get (
  VBG_TEMP_SELECT_t temperature
)
```

Parameters

Data Type	Name	Description	Dir
VBG_TEMP_SELECT_t	temperature	Select the temperatuare requested .	-

Return Values

Data Type	Description
uint32_t	Vbg value corresponding to the selected temperature. In case the parameter "temperature" is not correct, the function returns the value 0xFFFFFFFF.

6.9 NVM Protection API types

6.9.1 user_callback_t

Description

User NVM callback function

Prototype

```
typedef void(* user_callback_t) (void)
```

6.10 Data Types and Structure Reference

This chapter contains the reference of data types and structures of all modules.

6.10.1 Enumerator Reference

This chapter contains the Enumerator reference.

Table 6-3 Enumerator Overview

Name	Description
BSL_INTERFACE_SELECT_t	User API BSL interface selection.
NVM_PASSWORD_SEGMENT_t	NVM protection API password segment
VBG_TEMP_SELECT_t	VBG Temperature selection.

6.10.1.1 BSL_INTERFACE_SELECT_t

Description

User API BSL interface selection.

Prototype

```
typedef enum
{
```

```
  BSL_IF_LIN = 0,
  BSL_IF_FAST_LIN = 1,
}BSL_INTERFACE_SELECT_t;
```

Parameters

Name	Value	Description
BSL_IF_LIN	0	LIN used as BSL interface.
BSL_IF_FAST_LIN	1	Fast-LIN used as BSL interface.

6.10.1.2 NVM_PASSWORD_SEGMENT_t

Description

NVM protection API password segment

Prototype

```
typedef enum
{
  NVM_PASSWORD_SEGMENT_BOOT = 0,
  NVM_PASSWORD_SEGMENT_CODE = 1,
  NVM_PASSWORD_SEGMENT_DATA = 2,
}NVM_PASSWORD_SEGMENT_t;
```

Parameters

Name	Value	Description
NVM_PASSWORD_SEGMENT_BOOT	0	NVM password for customer segment, used for customer bootloader
NVM_PASSWORD_SEGMENT_CODE	1	NVM password for customer code segment, which is not used by the customer bootloader.
NVM_PASSWORD_SEGMENT_DATA	2	NVM password for customer data segment.

6.10.1.3 VBG_TEMP_SELECT_t

Description

VBG Temperature selection.

Prototype

```
typedef enum
{
  VBG_TEMP_HOT = 0,
  VBG_TEMP_COLD = 1,
}VBG_TEMP_SELECT_t;
```

Parameters

Name	Value	Description
VBG_TEMP_HOT	0	VBG Temperature selection Hot
VBG_TEMP_COLD	1	VBG Temperature selection Cold

6.10.2 Constant Reference

This chapter contains the Constant reference.

Table 6-4 Constant Overview

Name	Value	Description
NVM_PASSWORD_PROTECTION_NONE	0x00000000u	NVM protection API password protection status NVM segment no protection enabled
NVM_PASSWORD_PROTECTION_READ	0x80000000u	NVM segment read protection enabled
NVM_PASSWORD_PROTECTION_WRITE	0x40000000u	NVM segment write protection enabled
NVM_PROG_FLAG_NULL	0x00u	NVM programming options No options provided
NVM_PROG_CORR_ACT	0x02u	Disturb handling enabled
NVM_PROG_NO_FAILPAGE_ERASE	0x04u	Programmed data erased/not erased in case of fail

Terminology

#

100-Time Programming (100TP)	The BootROM offers eight 100-time programmable pages to the user mode software. The size of a 100TP page is 128 bytes. The last two bytes of each 100TP page store the programming counter, followed by the page checksum byte.

A

API	Application Programming Interface

B

BootROM	Device-internal ROM code that the CPU executes directly after reset release
BSL	Boot Strap Loader
BSL command message	The BootROM receives these messages via LIN. A message of this kind contains commands and related data. A complete command could consist of multiple messages. The BootROM processes and execute these commands.
BSL response message	The BootROM replies to BSL command messages by BSL response messages. A response message contains requested data or an error code. The response message format and content depend on the given command.

C

CS	Configuration sector, see also NVM CS

D

Data block	Part of the BSL command message. This block follows a header block for data download commands.A data block could also be part of a BSL response message if the header block message requests read-out of some data from the device. The last data block is always followed by an EOT block.

E

EOT block	End of Transmission (EOT) block, part of the BSL command message or BSL response message. This block follows a data block to terminate a larger data download message.

F

FastLIN	FastLIN is a LIN enhancement supporting higher baud rates of up 230.4 kBd. This rate is higher than the standard LIN. This mode is especially useful during back-end programming, where faster programming time is desirable.
f_{INTOSC}	Internal oscillator (80MHz)

G

H

HAL	Hardware Abstraction Layer. This software layer abstracts all module-specific hardware registers by API functions. It performs all device hardware register (SFR) accesses, which includes timing of critical register accesses and polling mechanisms. This layer exports its functionality to other software modules by means of API functions.

Header block	Part of the BSL command message. The host initiates a command by sending the header block. Some commands require further data transmission, during which the header block is followed by one or multiple data blocks and a terminating EOT block.
Host	The host communicates with the BootROM device over the LIN interface. The host sends BSL command messages and receives BSL response messages.

I

J

K

L

LIN	Local Interconnect Network

M

MBIST	Memory Built-In Self-Test (MBIST writes and reads all locations of the RAM to ensure that its cells are operating correctly)

N

NAC	No Activity Counter (millisecond timeout counter polling BSL LIN before jumping to user mode code execution)
NAD	Node Address for Diagnostics (LIN protocol parameter)
NVM	Non-Volatile Memory (device-internal)
NVM CS	NVM configuration sector. The BootROM uses one NVM sector to store device-specific calibration and trimming values. It configures such values on the device during startup. This sector also contains the One Time programmable and 100 Time programmable sectors, which are offered to the user mode software. The configuration sector is not directly accessible by user mode software.

O

OSC	Oscillator

P

POR	Power-On Reset
PLL	Phase-Locked Loop

Q

R

Response block	Part of the BSL response message, in which the corresponding BSL command message does not request read-out of data. This block reports the command execution status.
ROM	Read Only Memory

S

SA	Service Algorithm
SCU	System Control Unit

SFR	Special Function Register (CPU memory-mapped device hardware registers)
SWD	Serial Wire Debug
T	
Tearing Safe Programming	The mapping mechanism of the NVM module is intended to be used like a log-structured file system: When a page is programmed in the cell array, the old values are not physically overwritten, but a different physical page (the spare page) in the same sector is programmed in fact. If the programming fails (e.g. because of power loss during the erase or write procedure), either the old values are still present in the cell array or the verified new values are present in the cell array. The firmware therefore can program a single page in a tearing safe way.
U	
User mode code	Customer application code for download and execution in NVM.
UART	Universal asynchronous receiver/transmitter
V	
VTOR	Vector Table Offset Register
W	
WDT	WatchDog Timer

Appendix A – Error Codes

This chapter provides a list of all available error codes.

Table 6-5 List of Possible Errors during Startup

Error Name	Codes	Description
ERR_LOG_SUCCESS	0_D	Successful execution, no error occured
ERR_LOG_ERROR	-1_D	Standard Error
ERR_LOG_CODE_NVM_ADDR_RANGE_INVALID	-21_D	NVM address range is invalid
ERR_LOG_CODE_NVM_SEMAPHORE_RESERVED	-24_D	NVM semaphore already reserved
ERR_LOG_CODE_NVM_VER_ERROR	-30_D	2 or more bit errors detected in NVM page when verifying NVM data after linear/mappped page programming
ERR_LOG_CODE_NVM_PROG_MAPRAM_INIT_FAIL	-31_D	NVM mapRAM update failed after mapped page programming or after execution of DH
ERR_LOG_CODE_NVM_PROG_VERIFY_MAPRAM_INIT_FAIL	-32_D	NVM programming and mapRAM init update failed after mapped page programming
ERR_LOG_CODE_NVM_MAPRAM_UNKNOWN_TYPE_USAGE	-33_D	MAPRAM physical page number for a given logical sector/page is larger than the number of physical pages in a sector
ERR_LOG_CODE_NVM_INIT_MAPRAM_SECTOR	-35_D	Mapped page has double mapping or ECC2 error when trying to init mapRAM
ERR_LOG_CODE_ACCESS_AB_MODE_ERROR	-37_D	Error when setting the assembly buffer to mode 1 or 2
ERR_LOG_CODE_NVM_PROTECT_REMOVE_PASSWORD_FAILED	-39_D	Removing region password(s) failed when trying to remove all region passwords
ERR_LOG_CODE_100TP_READ_ADDRESS_INVALID	-43_D	Attempt to read NVM 100TP address outside of the valid range
ERR_LOG_CODE_100TP_WRITE_COUNT_EXCEEDED	-44_D	NVM 100TP page write count was exceeded
ERR_LOG_CODE_100TP_WRITE_ADDRESS_INVALID	-45_D	Attempt to write NVM 100TP address outside of the valid range
ERR_LOG_CODE_CS_PAGE_CHECKSUM	-46_D	NVM config sector checksum calculation failed
ERR_LOG_CODE_CS_PAGE_ECC2READ	-47_D	NVM config sector checksum calculation failure based on NVM ECC2 error
ERR_LOG_CODE_MBIST_FAILED	-62_D	MBIST test detected an error
ERR_LOG_CODE_MBIST_TIMEOUT	-63_D	MBIST test failed due to timeout
ERR_LOG_CODE_USERAPI_CONFIG_SECTOR_WRITE_PROTECTED	-64_D	Not allowed to change values in write protected config sector

Table 6-5 List of Possible Errors during Startup (cont'd)

Error Name	Codes	Description
ERR_LOG_CODE_USERAPI_CONFIG_SET_PARAMS_INVALID	-65_D	Invalid parameters given to user_bsl_config_set
ERR_LOG_CODE_NAD_VALUE_INVALID	-66_D	Invalid NAD value given in user_nad_set()
ERR_LOG_CODE_100TP_PARAM_INVALID	-67_D	user_nvm_100tp_read/write(): Bad data parameter
ERR_LOG_CODE_NVM_CONFIG_NOT_READY	-68_D	Data for user_nvm_config_get() is not available
ERR_LOG_CODE_PARAM_INVALID	-69_D	user_nvm_write/branch(): data parameter is invalid
ERR_LOG_CODE_USER_CROSS_PAGE_PRG_NOT_SUPPORTED	-70_D	user_nvm_write/branch cross-page programming is not supported
ERR_LOG_CODE_USER_PROTECT_NVM_WRITE_PROTECTED	-71_D	user_nvm_write/branch operation not allowed when NVM is write protected
ERR_LOG_CODE_MBIST_RAM_RANGE_INVALID	-72_D	user_ram_mbist() RAM range for MBIST is invalid
ERR_LOG_CODE_USER_PROTECT_NO_PASSWORD_EXISTS	-74_D	user_nvm_password_clear() no password installed when trying to clear password
ERR_LOG_CODE_USER_PROTECT_NVM_AND_PWD_ERASED	-75_D	user_nvm_password_clear() wrong password given, all NVM sections + NVM passwords are erased
ERR_LOG_CODE_USER_PROTECT_NO_CBSL_PWD_CLEAR	-76_D	user_nvm_password_clear() clear password for CBSL not supported
ERR_LOG_CODE_USER_PROTECT_PWD_INVALID	-77_D	user_protect_password_set() provided password not valid
ERR_LOG_CODE_USER_PROTECT_PWD_EXISTS	-78_D	nvm_protect_password_set() segment password already exists when trying to set a new one in
ERR_LOG_CODE_USER_NVM_PROTECT_SEGMENT_INVALID	-79_D	Provided segment to change protection is invalid
ERR_LOG_CODE_SINGLE_ECC_EVENT_OCCURRED	-80_D	user_ecc_events_get()/user_ecc_get() single ECC event has occurred
ERR_LOG_CODE_DOUBLE_ECC_EVENT_OCCURRED	-81_D	user_ecc_events_get()/user_ecc_get() double ECC event has occurred
ERR_LOG_CODE_SINGLE_AND_DOUBLE_ECC_EVENT_OCCURRED	-82_D	user_ecc_events_get()/user_ecc_get() single and double ECC events have occurred
ERR_LOG_CODE_USERAPI_POINTER_RAM_RANGE_INVALID	-83_D	Provided pointer doesn't point to a valid RAM range
ERR_LOG_CODE_USER_API_BRANCH_ADDRESS_INVALID	-84_D	Provided callback branch address is not within a valid RAM range

Appendix B – Stack Usage of User API Functions

The following table lists the maximum used stack for each user API function.

Table 6-6 Maximum used stack for user API functions

User API function	Maximum stack usage (bytes)
user_bsl_config_get	8_D
user_bsl_config_set	104_D
user_ecc_check	72_D
user_ecc_events_get	72_D
user_mbist_set	104_D
user_nac_get	8_D
user_nac_set	104_D
user_nad_get	8_D
user_nad_set	104_D
user_nvm_100tp_read	96_D
user_nvm_100tp_write	136_D
user_nvm_config_get	48_D
user_nvm_mapram_init	48_D
user_nvm_page_erase	128_D
user_nvm_page_erase_branch	128_D
user_nvm_password_clear	160_D
user_nvm_password_set	152_D
user_nvm_protect_clear	184_D
user_nvm_protect_get	16_D
user_nvm_protect_set	184_D
user_nvm_sector_erase	128_D
user_nvm_write	224_D
user_nvm_write_branch	208_D
user_ram_mbist	64_D
user_vbg_temperature_get	0_D
user_nvm_ready_poll	0_D
user_nvm_clk_factor_set	0_D

Appendix C – BootROM User API Functions

This appendix provides a table that lists all exported BootROM functions and their addresses that can be called by user code.

Table 6-7 User API Functions adresses

User API Function	BootROM Thumb Address
user_bsl_config_get	00000101_H
user_bsl_config_set	00000103_H
user_nvm_protect_clear	00000105_H
user_nvm_protect_set	00000107_H
user_nvm_protect_get	00000109_H
user_ecc_events_get	$0000010D_H$
user_ecc_check	$0000010F_H$
user_mbist_set	00000111_H
user_nac_get	00000113_H
user_nac_set	00000115_H
user_nad_get	00000117_H
user_nad_set	00000119_H
user_nvm_100tp_read	$0000011B_H$
user_nvm_100tp_write	$0000011D_H$
user_nvm_config_get	$0000011F_H$
user_nvm_page_erase	00000121_H
user_nvm_page_erase_branch	00000123_H
user_nvm_ready_poll	00000125_H
user_nvm_sector_erase	00000127_H
user_nvm_write	00000129_H
user_nvm_write_branch	$0000012B_H$
user_ram_mbist	$0000012D_H$
user_nvm_mapram_init	00000131_H
user_nvm_clk_factor_set	00000133_H
user_nvm_password_set	00000135_H
user_nvm_password_clear	00000137_H
user_vbg_temperature_get	00000139_H

Appendix D – Analog Module Trimming (100TP Pages)

The TLE984x contains 8 x 100TP (100 Time Programmable) pages and each page has a size of 128 bytes but only the first 126 Bytes are usable. The last two Bytes of each 100TP page store the programming counter followed by the page checksum Byte.

The first page is 100TP_Page0 and the latest one is Pges are counted

User could read and write into the 100TP pages using the user API functions :

- user_nvm_100tp_read

- user_nvm_100tp_write

In case the checksum of any page is incorrect, the whole content of the 100TP pages is ignored and considered as unsafe.

Each user_nvm_100tp_write page programming operation leads to a programming counter increase. user_nvm_100tp_write returns with an error in case the user tries to program one page where the counter has reached 100 programming cycles. Page programming counter range is from 0 - 99.

The first and second 100TP pages contain customer specific analog module trimming values.

Table 6-8 100TP page 0 and page 1 : Analog Module Trimming registers

Data Offset	**100 TP Page 0** SFR Registers to TRIM	**100 TP Page 1** SFR Register to TRIM
0x00	ADC1_DUIN_SEL	ADC1_SQ2_3
0x04	ADC1_MMODE0_11	ADC1_SQ0_1
0x08	ADC1_DCHCNT1_4_UPPER	ADC1_OFFSETCALIB
0x0C	ADC1_CNT8_11_UPPER	
0x10	ADC1_CNT4_7_UPPER	
0x14	ADC1_CNT0_3_UPPER	
0x18	ADC1_DCHCNT1_4_LOWER	
0x1C	ADC1_CNT8_11_LOWER	
0x20	ADC1_CNT4_7_LOWER	
0x24	ADC1_CNT0_3_LOWER	
0x28	ADC1_DCHTH1_4_UPPER	
0x2C	ADC1_TH8_11_UPPER	
0x30	ADC1_TH4_7_UPPER	
0x34	ADC1_TH0_3_UPPER	
0x38	ADC1_TH8_11_LOWER	
0x3C	ADC1_CTRL2	
0x40	ADC1_TH4_7_LOWER	
0x44	ADC1_TH0_3_LOWER	
0x48	ADC1_FILT_LO_CTRL	

Table 6-8 100TP page 0 and page 1 : Analog Module Trimming registers

0x4C	ADC1_FILT_UP_CTRL	
0x50	ADC1_FILTCOEFF0_11	
0x54	ADC1_CAL_CH10_11	
0x58	ADC1_CAL_CH8_9	
0x5C	ADC1_CAL_CH6_7	
0x60	ADC1_CAL_CH4_5	
0x64	ADC1_CAL_CH2_3	
0x68	ADC1_CAL_CH0_1	
0x6C	ADC1_SQ10_11	
0x70	ADC1_SQ8_9	
0x74	ADC1_SQ6_7	
0x78	ADC1_SQ4_5	

Example

Table 6-9 100TP Analog Module Trimming example

Code example

```
#define PAGE0                   (uint32_t 0)
#define ADC1_CNT_UPPER_OFFSET (uint32_t 0x0C)
#define ADC1_CNT_UPPER_LEN     (uint32_t sizeof(ADC1_TRIM_Data_table))

uint32_t ADC1_TRIM_Data_table[]= {0x11111111, 0x12121212, 0x13131313};

int32_t User_Trimming_100TP(void)
{
 int32_t status=0;
 status = user_nvm_100tp_write(PAGE0,
                               ADC1_CNT_UPPER_OFFSET,
                               ADC1_TRIM_Data_table,
                               ADC1_CNT_UPPER_LEN);

 return status;
}
```

Description

This function write into the 100TP page 0 at the offset 0x0C, which correspond to the address allowed for ADC1_CNT8_11_UPPER. The length of the data to write is 12 bytes, which means 3 words : ADC1_CNT8_11_UPPER, then ADC1_CNT4_7_UPPER and finally ADC1_CNT0_3_UPPER.
This function trims the following registers :
ADC1_CNT8_11_UPPER = 0x11111111
ADC1_CNT4_7_UPPER = 0x12121212
ADC1_CNT0_3_UPPER = 0x13131313

Table 6-10 Alternative predefined values to trim in case 100TP page 0 and page 1 CRC is incorrect

100 TP Page 0		
Data Offset	**SFR registers**	**Alternative Back up values**
0x00	ADC1_DUIN_SEL	0x00000000
0x04	ADC1_MMODE0_11	0x00000000
0x08	ADC1_DCHCNT1_4_UPPER	0x00000000
0x0C	ADC1_CNT8_11_UPPER	0x00000000
0x10	ADC1_CNT4_7_UPPER	0x00000000
0x14	ADC1_CNT0_3_UPPER	0x12131b1a
0x18	ADC1_DCHCNT1_4_LOWER	0x00000000
0x1C	ADC1_CNT8_11_LOWER	0x00000000
0x20	ADC1_CNT4_7_LOWER	0x00000000
0x24	ADC1_CNT0_3_LOWER	0x12131312
0x28	ADC1_DCHTH1_4_UPPER	0x00000000
0x2C	ADC1_TH8_11_UPPER	0x00000000
0x30	ADC1_TH4_7_UPPER	0x00000000
0x34	ADC1_TH0_3_UPPER	0xab8dc5c0
0x38	ADC1_TH8_11_LOWER	0x00000000
0x3C	ADC1_TH8_11_LOWER	0x00000000
0x40	ADC1_TH4_7_LOWER	0x00000000
0x44	ADC1_TH0_3_LOWER	0x1d2f423a
0x48	ADC1_FILT_LO_CTRL	0x0000ffff
0x4C	ADC1_FILT_UP_CTRL	0x0000ffff
0x50	ADC1_FILTCOEFF0_11	0x00aaaaaa
0x54	ADC1_CAL_CH10_11	0x00000000
0x58	ADC1_CAL_CH8_9	0x00000000
0x5C	ADC1_CAL_CH6_7	0x00000000
0x60	ADC1_CAL_CH4_5	0x00000000
0x64	ADC1_CAL_CH2_3	0x00000000
0x68	ADC1_CAL_CH0_1	0x00000000
0x6C	ADC1_SQ10_11	0x00000000
0x70	ADC1_SQ8_9	0x00000000
0x74	ADC1_SQ6_7	0x00000000
0x78	ADC1_SQ4_5	0x00000000
100 TP Page 1		
0x00	ADC1_SQ2_3	0x00000000
0x01	ADC1_SQ0_1	0x00000000

Appendix E – Device settings in NVM CS

The BootROM uses pre-configured settings written to NVM CS, which all are used to perform various tasks inside the device. This section show the settings used for different modules.

Table 6-11 BSL module configuration

NVM CS entry	Value	Description
CS_CUST_BSLSIZE	0x00	Size definition of Customer BSL region. 0x00 = CBSL Size is 4K, 0x01 = CBSL Size is 8K, 0x02 = CBSL Size is 12K, 0x03 = CBSL Size is 16K
CS_NVM_BSL_INTERFACE	0x01	BSL Interface Selection. 0x00 = LIN, 0x01 =FastLIN
CS_NVM_BSL_NAD	0xFF	BSL LIN NAD value
CS_NVM_BSL_INTERFRAME_TO	0x0038	BSL FastLIN and LIN interface timeout. 1 step is 5ms.
CS_NVM_BSL_NAC	0xFF	BSL NAC value. 1 step is 5ms up to 140ms. 0xFF: no timeout used, wait forever

Table 6-12 Startup module configuration

NVM CS entry	Value	Description
CS_SCU_APCLK_CFG	0x02000B00 or 0x02001301	PLL divider settings , depends on device variant: 0x02000B00 (25 MHz), 0x02001301 (40 MHz) Analog Module Clock Factor (APCLK1FAC)[1:0] 0x00 = divide by 1, 0x01 = divide by 2, 0x02 = divide by 3, 0x03 = divide by 4 Slow Down Clock Divider for TFILT_CLK Generation (APCLK2FAC) [12:8] 0x01 = fsys/2 to 0x12 = fsys/12, 0x1E = fsys/31, 0x1F = fsys/32 Bandgap Clock Selection (BGCLK_SEL)[24] 0 = LP_CLK is selected, 1 = fsys is selected Bandgap Clock Divider (BGCLK_DIV)[25] 0= divide by 2, 1 = divide by 1
CS_SCU_PLL_DIVIDER_CFG	0x006E or 0x004A	PLL divider settings , depends on device variant: 0x6E (25 MHz), 0x4A (40 MHz) PLL PDIV-Divider [7:6] = Register SCU_CMCON1.PDIV 0x00: 4, 0x01: 5, 0x02: 6, 0x03: 6 PLL K2-Divider [5:4] = Register SCU_CMCON1.K2DIV 0x00 K2 = 2, 0x01 K2 = 3, 0x02 K2 = 4, 0x03 K2 = 5 PLL N-Divider [3:0] = Register SCU_PLL_CON.NDIV 0x00 N = 48, 0x01 N = 50, 0x02 N = 51, 0x03 N = 52, 0x04 N = 54, 0x05 N = 60, 0x06 N = 67
CS_NVM_RAM_MBIST	0x0000	RAM test (MBIST) performed during bootup besides POR. 0 = disabled, 1 = enabled.

Appendix F – Execution time of BootROM User API Functions

This appendix provides a table that lists the execution Time of BootROM User API functions.

Table 6-13 User API execution time

User API function	Execution time [ms]			
	Worst case operation [1]		Normal operation [2]	
	25MHz	40MHz	25MHz	40MHz
user_bsl_config_get	0.0055	0.0034	0.0055	0.0034
user_bsl_config_set	7.6140	7.5905	7.2771	7.2837
user_ecc_events_get	0.0120	0.0075	0.0120	0.0075
user_ecc_check	4.3929	2.7580	4.3980	2.7524
user_mbist_set	7.6132	7.5958	7.2798	7.2824
user_nac_get	0.0055	0.0034	0.0055	0.0034
user_nac_set	7.6129	7.5949	7.2798	7.2809
user_nad_get	0.0055	0.0034	0.0055	0.0034
user_nad_set	7.6133	7.5948	7.2823	7.2833
user_nvm_100tp_read	0.1235	0.0774	0.1234	0.0774
user_nvm_100tp_write	7.7469	7.6796	7.4167	7.3657
user_nvm_config_get	0.0159	0.0099	0.0159	0.0099
user_nvm_password_clear	7.6547	7.6216	7.3220	7.3090
user_nvm_password_set	7.6550	7.6222	7.3198	7.3092
user_nvm_protect_get	0.0060	0.0038	0.0060	0.0038
user_nvm_protect_set	0.0473	0.0296	0.0473	0.0296
user_nvm_protect_clear	0.0462	0.0289	0.0461	0.0289
user_nvm_ready_poll	N.A.	N.A.	N.A.	N.A.
user_nvm_page_erase	4.0914	4.0852	3.9142	3.9174
user_nvm_sector_erase	4.0827	4.0801	3.9062	3.9123
user_nvm_write[3]	3.8392	3.7077	3.6844	3.5645
user_ram_mbist	0.0462	0.0290	0.0462	0.0290
user_nvm_mapram_init	0.0260	0.0163	0.0260	0.0163
user_nvm_clk_factor_set	0.0044	0.0028	0.0044	0.0028
user_vbg_temperature_get	0.0046	0.0029	0.0046	0.0029

1) Execution time relative to the following conditions : 3V, 150°C
2) Execution time relative to the following conditions : 12V, 25°C
3) Execution time values when writing to an erased page

Appendix G – Change of register reset values

Before the BootROM is executing user code, the startup boot sequence has been executed. This means configuring the device with user parameters, setting up NVM to be ready for the user and other important system settings. **Table 6-14** lists the registers, which will be having a different default value than what is defined in the specification.

Fields marked bold are part of trimming phase.

Table 6-14 Registers with changed default values done by bootROM

Module name	Register name	Default reset value	Reconfigured value
T21	CON1	0x00000003	0x00000000
T2	CON1	0x00000003	0x00000000
ADC1	CTRL3	0x401	0x400
LS	LS1_TRIM	0	Trimming value
	LS2_TRIM	0	Trimming value
HS	HS1_TRIM	0	Trimming value
	HS2_TRIM	0	Trimming value
MF	TEMPSENSE_CTRL	0x03	Trimming value
ADC2	CTRL1	0	Trimming value
LIN	CTRL	0x180007	0x180207
SCU	VTOR	0	0x02
	PLL_CON	0xA4	Device variant dependent
	APCLK	0	0x1001301
	SYSCON0	0x80	0
	SYS_STRTUP_STS	0	0x10
	OSC_CON	0x10	0x18
	NVM_PROT_STS	0	0x403F
SCUPM	SYS_SUPPLY_IRQ_CTRL	0xFF	0

Table 6-15 Registers with changed default values done by hardware

Module name	Register name	Default reset value	Reconfigured value
PMU	RESET_STS	0	0x80

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