Application Note FLASH Programming TriCore

Release 09.2023

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TRACE32 Online Help

TRACE32 Directory

TRACE32 Index

TRACE32 Documents ....

ICD In-Circuit Debugger ....

Processor Architecture Manuals ....

TriCore ....

TriCore Application Notes ....

Application Note FLASH Programming TriCore 1

Introduction 4

FLASH Programming Commands 5

Organization of TriCore FLASH Scripts 6

FLASH Declaration Scripts 6

FLASH Feature Scripts 7

FLASH Demo Scripts 7

TC2xx Devices 11

Erased FLASH 11

TRACE32 Methods for Safe FLASH Programming 13

NOP Sectors 13

Protecting Boot Mode Headers 14

Recommended Procedures 15

Boot Mode Headers 15

User Configuration Blocks 16

HSM 18

OTP and WOP Sectors 21

TC3xx Devices 22

Erased FLASH 22

TRACE32 Mechanisms for Safe FLASH Programming 24

NOP Sectors 24

Recommended Procedures 25

User Configuration Blocks 25

HSM 30

OTP and WOP Sectors 33

DFLASH Single-Ended and Complement Sensing Mode 34

Support for SOTA 35

FLASH Programming with SWAP Enabled 35
The SWAP Feature Script 36

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Version 10-Oct-2023

Introduction

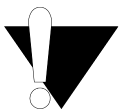
TriCore AURIX devices have many configurations that are located in FLASH (e.g., User Configurations Blocks). For security and safety reasons, the chip offers the possibility, e.g., to install intended locking of the debug access, or prohibit programming of specific FLASH sectors. But programming invalid content to the FLASH may result in locking the device forever.

TRACE32 provides several methods to minimize the risks of accidentally writing wrong content to FLASH and consequently locking the device without recovering possibilities. To fully benefit from these mechanisms, it is mandatory to understand the TRACE32 FLASH programming strategies for TriCore AURIX devices and to learn about recommended procedures and good practices when writing FLASH scripts. This is the intention of this document.

This document is only discussing peculiarities of TRACE32 internal FLASH programming for TriCore AURIX devices. The document **"Onchip/NOR FLASH Programming User's Guide"** (norflash.pdf) covers TRACE32 internal FLASH programming in general and is recommended as basic knowledge for this application note.

The first section summarizes the TRACE32 FLASH programming commands and which methods have to be used or avoided according to the TriCore specificities. The second section presents different types of TRACE32 FLASH scripts for TriCore, their location in the TRACE32 installation and their intended usage. The last two sections are separately covering FLASH programming for TC2xx and TC3xx. Chip specific behaviors, protection mechanisms, practical use-cases and scripting examples are provided.

In this document, the term AURIX is used to designate all TC2xx and TC3xx devices.

	The procedures and scripts presented in this document are designed to avoid common risks and mistakes resulting in a locked device. TRACE32 FLASH scripts consider critical content as valid when it passes number of formal checks. Formal checks are, e.g., correct address alignment, presence of magic patterns matching CRCs, etc. When formal checks have passed, the Startup Software (SSW) will consider the content as valid and will evaluate it. The TRACE32 FLASH scripts are continuously improved and extended to cover a maximum of protection but there is no guarantee that all cases are covered. For example, the scripts may not warn if a user actively enables locking. In no case using TRACE32 FLASH scripts will replace reading the TriCore User Manuals and Errata Sheets.

FLASH Programming Commands

TRACE32 offers three FLASH programming methods. Each method uses different groups of FLASH programming commands:

- **FLASH.Erase / FLASH.Program**
- **FLASH.ReProgram**
- **FLASH.AUTO**

Details on how these commands work and information about their parameters and option are explained in **"Onchip/NOR FLASH Programming User's Guide"** (norflash.pdf).

For TriCore, the commands **FLASH.Erase** and **FLASH.Program** have to be used with care. Using these commands might result in incorrect ECC and erroneous FLASH content. This especially happens when the programmed file format fragmentation does not cover the entire ECC line.

The command **FLASH.ReProgram** is the convenient choice when programming a content that will make big changes to many FLASH sectors. Loading an application ELF file is a typical example.

The command **FLASH.AUTO** is the best fit when making small patches or changing some bytes in the FLASH.

Organization of TriCore FLASH Scripts

Three categories of FLASH scripts for the TriCore architecture are available in the TRACE32 installation:

- FLASH declaration scripts
- FLASH feature scripts
- FLASH demo scripts

This section presents their organization and intended usage for writing user's FLASH scripts.

FLASH Declaration Scripts

Internal FLASH programming for AURIX devices is using a target-controlled method, where the FLASH programming algorithm (or FLASH driver) is executed from the device RAM under control of TRACE32 PowerView. Every AURIX device has a different FLASH structure and consequently a different FLASH mapping. Thus it is necessary to specify the FLASH mapping before the FLASH programming commands can be used.

The FLASH mapping declaration is done via the TRACE32 FLASH declaration scripts located in the installation directory under "**`~~/demo/tricore/flash`**". Each device series has a FLASH declaration script. For example, the script **`tc39x.cmm`** is intended to be used for all TC39x devices. Obviously, the script **`tc27x.cmm`** is for all TC27x devices.

The FLASH declaration scripts are intended as "library" scripts and have to be used as-is. Those scripts must not be modified or partly copied to the user's FLASH scripts. Instead, they have to be called from the user's FLASH scripts with the appropriate arguments.

Example:

```
DO ~~/demo/tricore/flash/tc39x.cmm CPU=TC397XE PREPAREONLY DUALPORT=1
```

The ***"PREPAREONLY"*** argument instructs the FLASH declaration script to declare the FLASH and exit without FLASH programming.

The argument ***"CPU=<cpu>"*** selects the used CPU derivative. This argument is optional if the debugger to target communication is already established.

The argument ***"DUALPORT=1"*** enables data transfer via dual-port memory access and ensures a continuous running of the FLASH algorithm until the FLASH programming is finished. This results in a higher FLASH programming performance.

Other important information and details about all the script arguments can be found in the script header.

Some devices, using the same CPU selection, might be available with different FLASH sizes and consequently require different FLASH declarations. This is handled transparently if the device is already supported by the used FLASH declaration script version. A TRACE32 software update can be requested

from ***support@lauterbach.com*** if the device is not supported by the used TRACE32 software version (i.e. the CPU selection is missing) and/or by the FLASH declaration script (an error ***"Unsupported Pflash Size"*** is thrown by the script).

NOTE:	Do not move the FLASH declaration scripts from their default location. This leads to problems when performing a TRACE32 software update, since the copied scripts won't be updated to the newest version. This prevents to benefit from eventual script improvements and support of new devices.

FLASH Feature Scripts

Like FLASH declaration scripts, FLASH feature scripts are located in the installation directory under "**`~~/demo/tricore/flash`**". They have to be used as-is by calling them from the user's FLASH scripts using appropriate arguments.

The feature scripts are used to help programming various features including checks for valid content.

Examples of FLASH feature scripts for TC2xx:

- **`tc2xx-ucb.cmm`**
- **`tc2xx-bmhd.cmm`**
- **`tc2xx-hsm-config.cmm`**
- **`tc23x-hsm.cmm, tc27x-hsm.cmm, tc29x-hsm.cmm`**

Examples of FLASH feature scripts for TC3xx:

- **`tc3xx-ucb.cmm`**
- **`tc3xx-hsm-config.cmm`**
- **`tc3xx-swap.cmm`**

Details about the scripts' arguments and intended usage are documented in the script headers. Use-cases and examples will be detailed later in this document.

FLASH Demo Scripts

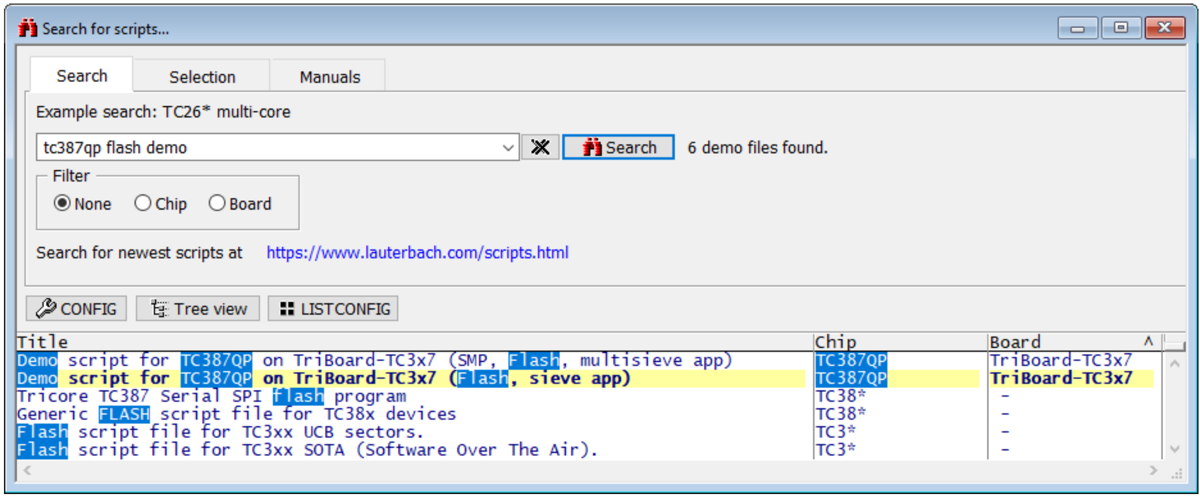
The TRACE32 demo directory for the TriCore architecture includes FLASH demo scripts for Infineon reference boards. These demo scripts are located in the installation under "**`~~/demo/tricore/hardware`**" and are organized by board name and chip derivative.

Example:

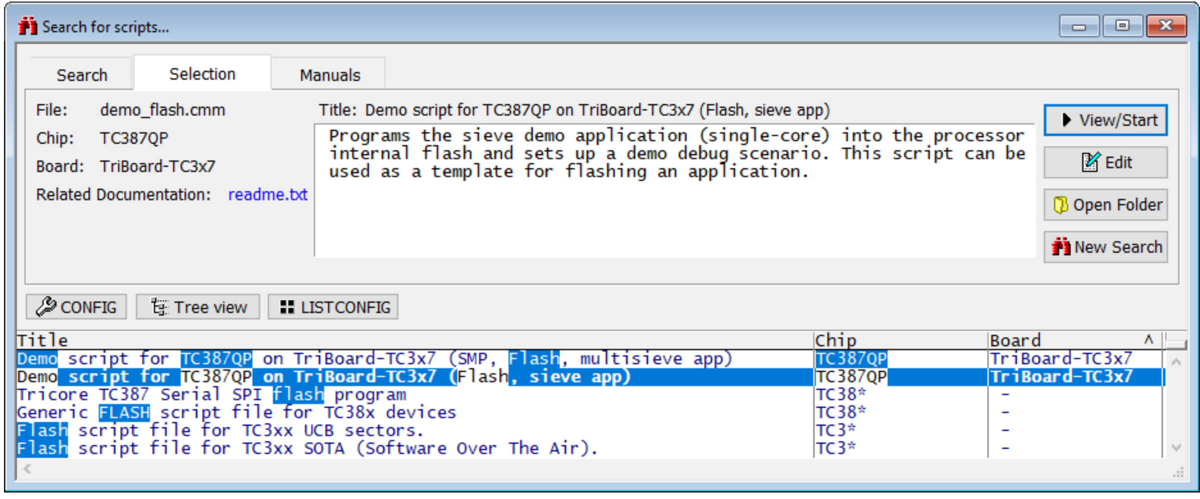
```
PEDIT ~~/demo/tricore/hardware/triboard-tc3x7/tc387qp/demo_flash.cmm
```

These scripts are intended to be copied and used as templates to create customised users' scripts.

TRACE32 script search dialog can be used to search an appropriate FLASH demo script. The dialog can be opened from the menu ***"Help -> Demo Scripts..."***. Using the chip name and appropriate keywords to refine the search, the matching scripts from the TRACE32 installation are listed.

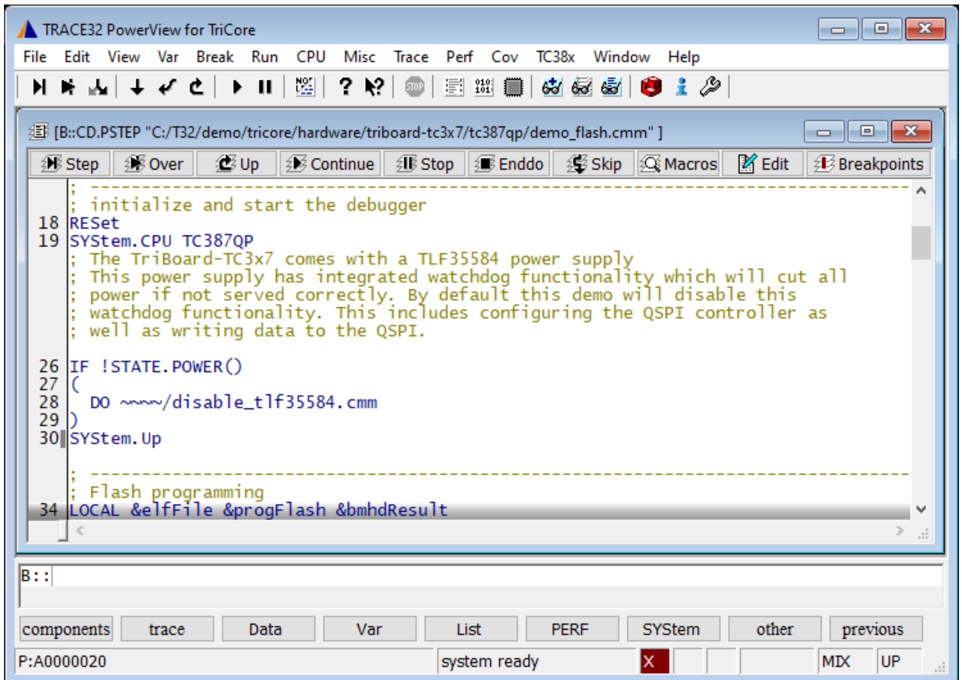


In this example, the matching FLASH demo script is entitled ***"Demo script for TC387QP on TriBoard-TC3x7 (Flash, sieve app)"***. By selecting the script, a more detailed description is displayed.



The FLASH demo scripts have a unified layout with three main parts.

The first part of the script initiates the debugger/target communication. This includes setting the CPU selection and setting up all the required configurations to start the debugger/target communication successfully.

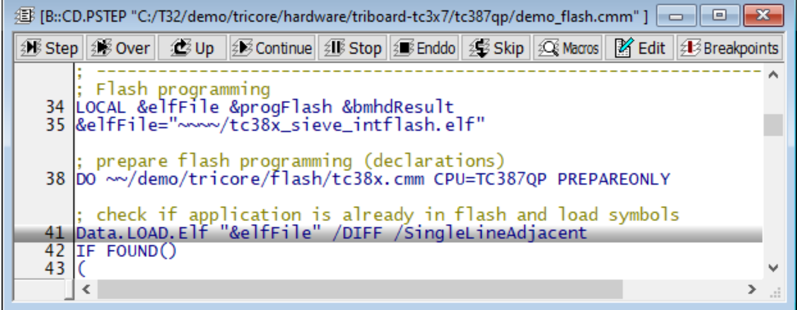


Before starting the FLASH programming, it is very important to disable all external (and internal) watchdogs to avoid resetting the target while the FLASH programming is in progress. It is also very important to start FLASH programming from a “clean” known state of the target. In this example, the command **SYStem.Up** is used to reset the target and halt the CPU at the reset vector.

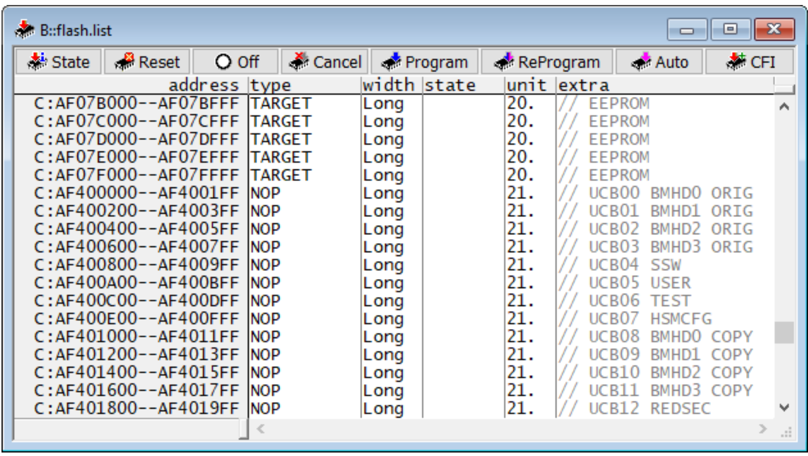
After a successful startup of the debugger/target communication, the state ***“system ready”*** is displayed in the status bar.

The second part is the FLASH preparation. This is done by calling the FLASH declaration script with the ***“PREPAREONLY”*** argument.

```
DO ~~/demo/tricore/flash/tc38x.cmm CPU=TC387QP PREPAREONLY
```



After the FLASH preparation the command **FLASH.List** can be used to examine the declared FLASH mapping.



B::flash.list

address	type	width	state	unit	extra
C:AF07B000--AF07BFFF	TARGET	Long		20.	// EEPROM
C:AF07C000--AF07CFFF	TARGET	Long		20.	// EEPROM
C:AF07D000--AF07DFFF	TARGET	Long		20.	// EEPROM
C:AF07E000--AF07EFFF	TARGET	Long		20.	// EEPROM
C:AF07F000--AF07FFFF	TARGET	Long		20.	// EEPROM
C:AF400000--AF4001FF	NOP	Long		21.	// UCB00 BMHD0 ORIG
C:AF400200--AF4003FF	NOP	Long		21.	// UCB01 BMHD1 ORIG
C:AF400400--AF4005FF	NOP	Long		21.	// UCB02 BMHD2 ORIG
C:AF400600--AF4007FF	NOP	Long		21.	// UCB03 BMHD3 ORIG
C:AF400800--AF4009FF	NOP	Long		21.	// UCB04 SSW
C:AF400A00--AF400BFF	NOP	Long		21.	// UCB05 USER
C:AF400C00--AF400DFF	NOP	Long		21.	// UCB06 TEST
C:AF400E00--AF400FFF	NOP	Long		21.	// UCB07 HSMCFG
C:AF401000--AF4011FF	NOP	Long		21.	// UCB08 BMHD0 COPY
C:AF401200--AF4013FF	NOP	Long		21.	// UCB09 BMHD1 COPY
C:AF401400--AF4015FF	NOP	Long		21.	// UCB10 BMHD2 COPY
C:AF401600--AF4017FF	NOP	Long		21.	// UCB11 BMHD3 COPY
C:AF401800--AF4019FF	NOP	Long		21.	// UCB12 REDSEC

The third part of a FLASH demo script is the FLASH programming. The command **FLASH.ReProgram ALL** enables the FLASH programming for all ***"TARGET"*** sectors, then the ELF file of the demo application (or any other binary format) is loaded using the appropriate **Data.LOAD** command.

[B::CD.PSTEP "C:/T32/demo/tricore/hardware/triboard-tc3x7/tc387qp/demo_flash.cmm"]

```
42 IF FOUND()
43 (
     ; ==== Step 1: Program TriCore code ====

46   DIALOG.YESNO "Program Lauterbach demo into flash memory?"
47   ENTRY &progFlash
48   IF (&progFlash)
49   (
       ; enable flash programming
51     FLASH.ReProgram ALL

       ; load demo application
54     Data.LOAD.Elf "&elfFile"

56     FLASH.ReProgram OFF
57   )
```

After executing **FLASH.ReProgram OFF** the effective FLASH programming to the device is started.

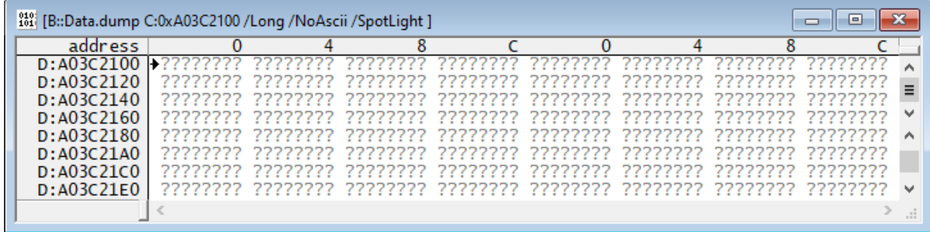
The rest of this demo script shows the FLASH programming of the BMHDs. This part will be detailed in the following sections.

Erased FLASH

For TriCore AURIX devices the data is stored in FLASH with error correcting codes “ECC” in order to protect against data corruption. These ECC can correct a certain amount of bit errors.

For PFLASH, the ECC are calculated over the data and the address bits. After an erase, the state of the data as well as the state of the ECC is “all-0”. As the ECC of 0x0 is not 0x0, the stored ECC does not match with the ECC of the actual data. Thus, an erased PFLASH range is resulting in ECC errors.

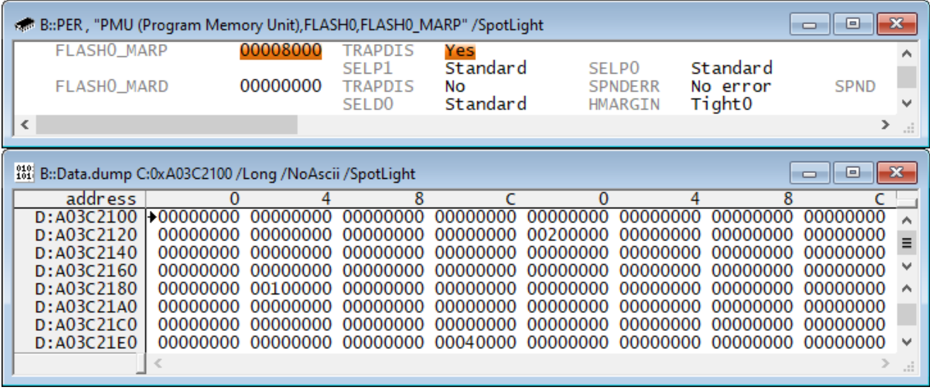
The ECC is automatically evaluated by the chip when reading data. Thus, reading from an erased PFLASH sector returns “bus error” indicated as “????????” in, e.g., a **Data.dump** window.



For DFLASH, a different ECC algorithm is used. ECC are calculated over the data bits only and the “all-0” state for data and checksums do not result in “bus errors” when reading from erased DFLASH sectors.

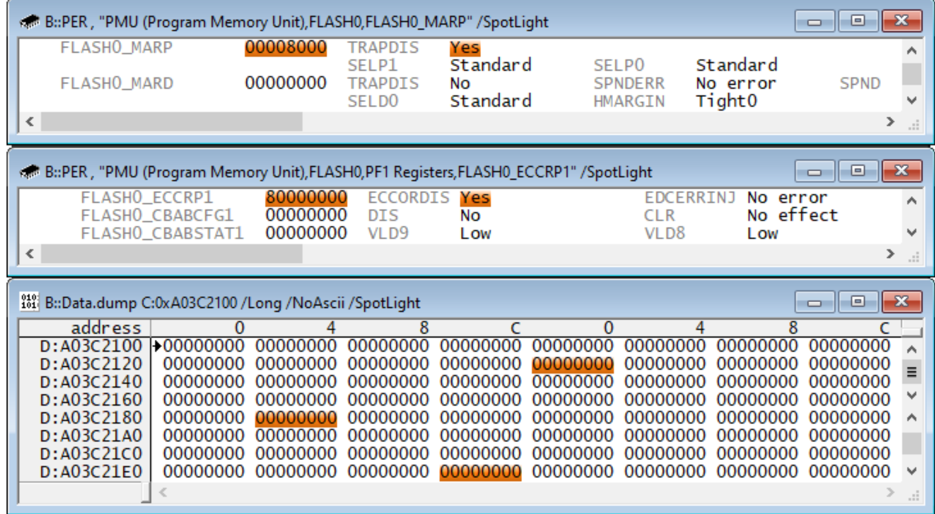
Bus errors that are caused by uncorrectable ECC errors can be disabled by configuring ***FLASH0_MARP.TRAPDIS*** and ***FLASH0_MARD.TRAPDIS*** register fields.

After changing the configuration of ***FLASH0_MARP.TRAPDIS*** field to disable the uncorrectable ECC error reporting, the erased range is displayed like in the following screenshot.



Some bits still show the value 1. The displayed values don’t reflect the real physical FLASH content, but this reflects the content obtained after applying the ECC correction. The result is not the same for all the PFLASH lines because for PFLASH, the address of the ECC line is used for calculating the ECC.

The real PFLASH content can be displayed by additionally disabling the ECC correction in the corresponding PFLASH register filed ***FLASH0_ECCRPp.ECCORDIS*** like the example in the following screenshot.



NOTE:	Configuring ***FLASH0_MARP*** and ***FLASH0_MARD*** to mask the bus error traps or disabling the ECC correction in ***FLASH0_ECCRPp*** are not presented here as programming options***.*** These are only mentioned for better understanding of the chip behavior.

To ensure that all PFLASH and ECCs are initialized, the command **FLASH.ReProgram** can be used with the option ***"/FILL"*** to fill all erase sectors with 0.

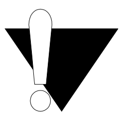
Example:

```
FLASH.ReProgram ALL /Erase /FILL
Data.LOAD.Elf application.elf
FLASH.ReProgram OFF
```

NOP Sectors

TRACE32 FLASH declaration scripts declare sensitive sectors as ***"NOP"*** to protect them against unwanted FLASH programming. TRACE32 PowerView silently discards all erase and write operations to ***"NOP"*** sectors.

When it is required to make changes to ***"NOP"*** sectors, the command **FLASH.CHANGEtype** has to be used to modify the FLASH sector type to ***"TARGET"***. Only then, FLASH operations for that range are performed by TRACE32 PowerView.

	FLASH sectors that are declared by TRACE32 FLASH scripts as ***"NOP"*** need to be handled with special care. Before making any changes to these sectors, it is mandatory to read the Infineon documentation for understanding the effects of the modifications.

To prevent unintended bricking of the device the FLASH declaration scripts for TC2xx declare the tuning protection configurations and the HSM code as ***"NOP"*** sectors. The following is an extract from ***`tc27x.cmm`*** FLASH declaration script.

```
FLASH.Create 1. 0xA0014000++0x3FFF 0x4000 NOP Long /INFO "Tuning Protec."
FLASH.Create 1. 0xA0018000++0x3FFF 0x4000 NOP Long /INFO "HSM code sect."
```

These sectors can safely be used for the application if the user makes sure that the code he is programming will not lock the device.

The FLASH programming scripts for TC2xx does not provide checks to ensure that the code programmed to the tuning protection sectors or HSM code sectors is safe. For the tuning protection sectors, the user has to ensure this by himself. For the HSM code sectors it is strongly recommended to use the checks provided by the HSM feature scripts e.g. **`tc29x-hsm.cmm`**. Details and scripting examples are provided in the recommended procedures paragraph for **HSM**.

NOTE:	It is strongly recommended to use the command **FLASH.CHANGEtype** to change a sector from ***"NOP"*** to ***"TARGET"***. After programming, change the sector back to ***"NOP"*** to avoid unintended programming with invalid content.

Protecting Boot Mode Headers

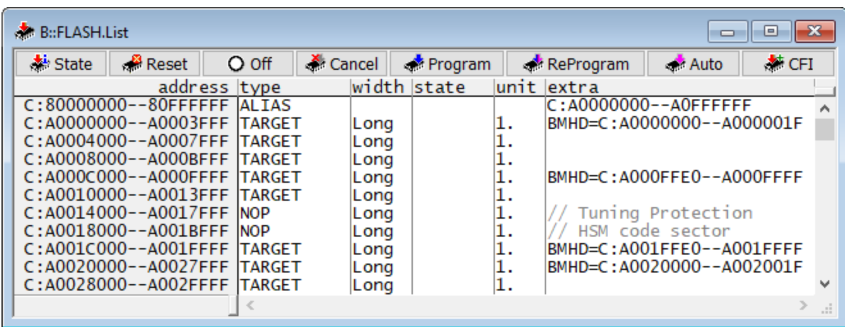
For TC2xx devices, the option ***"/BootModeHeaDer"*** is used with the command **FLASH.Create** to make TRACE32 PowerView aware of the boot mode header regions. TRACE32 will then ensure that the old content of the boot mode headers will be preserved if nothing is programmed to them after an erase.

Example:

```
&s0_s2="0xA0000000--0xA000BFFF"           ; PS0, S0..S2
&bmhd0="0xA0000000--0xA000001F"           ; Range of BMHD0
FLASH.Create 1. &s0_s2 0x4000 TARGET Long /BootModeHeaDer &bmhd0
```

The resulting FLASH declaration can be viewed using the command **FLASH.List**. The following FLASH declaration is obtained after executing the FLASH declaration script for TC277TF device using the parameter ***"PREPAREONLY"***.

```
DO ~~/demo/tricore/flash/tc27x.cmm CPU=TC277TF PREPAREONLY
```



address	type	width	state	unit	extra
C:80000000--80FFFFFF	ALIAS				C:A0000000--A0FFFFFF
C:A0000000--A0003FFF	TARGET	Long		1.	BMHD=C:A0000000--A000001F
C:A0004000--A0007FFF	TARGET	Long		1.	
C:A0008000--A000BFFF	TARGET	Long		1.	
C:A000C000--A000FFFF	TARGET	Long		1.	BMHD=C:A000FFE0--A000FFFF
C:A0010000--A0013FFF	TARGET	Long		1.	
C:A0014000--A0017FFF	NOP	Long		1.	// Tuning Protection
C:A0018000--A001BFFF	NOP	Long		1.	// HSM code sector
C:A001C000--A001FFFF	TARGET	Long		1.	BMHD=C:A001FFE0--A001FFFF
C:A0020000--A0027FFF	TARGET	Long		1.	BMHD=C:A0020000--A002001F
C:A0028000--A002FFFF	TARGET	Long		1.	

Recommended Procedures

In order to prevent unwanted locking of a device the following procedures must be followed. They combine the FLASH declaration script and the FLASH feature scripts.

NOTE:	The procedures and script examples presented in this document requires TRACE32 release **2020/02** or newer.

Boot Mode Headers

When booting an AURIX device, at least one boot mode header should contain valid data. For some early TC2xx devices, having no valid boot mode header is fatal. This will lock the device with no recovering possibilities.

The FLASH declaration scripts can be used to check if at least one valid Boot Mode Header is going to be programmed to the device. The script needs to be called using the argument ***“CHECKBMHD”*** as follows:

```
DO ~~/demo/tricore/flash/tc27x.cmm CHECKBMHD
```

This check has to be performed before the effective FLASH programming is started via the command **FLASH.ReProgram OFF**.

If at least one valid boot mode header is found, the script execution returns the result ***“BMHD_OK”***. Then the user script can continue the FLASH programming. If no valid boot mode header is found, the check will return ***“BMHD_MISSING”*** and the user script must abort the FLASH programming.

Here is the script example with the full programming flow:

```
; Enable FLASH programming
FLASH.ReProgram ALL

; Load the demo application
Data.LOAD.Elf application.elf

; Check if there is at least one valid BMHD
DO ~~/demo/tricore/flash/tc27x.cmm CHECKBMHD
ENTRY &bmhdResult
IF ("&bmhdResult"=="BMHD_OK")
(
  ; At least one valid BMHD is detected => make the changes to the device
  FLASH.ReProgram OFF
)
ELSE
(
  DIALOG.OK "No valid Boot Mode Header found!" "Reverting loaded data"
  FLASH.ReProgram CANCEL
  ENDDO
)
```

The FLASH feature script **tc2xx-ucb.cmm** is used to help programming UCBs and test for valid content.

The following example shows how the PFLASH UCB can be programmed when it is in a confirmed state (indicated by the register field ***FPRO.PROINP***). The main steps to achieve this are the following:

1. Perform the FLASH declaration using the appropriate FLASH declaration script.

2. Activate UCB_PFLASH programming by calling the UCB programming script using the argument ***“ACTIVATE”***. This combines the following steps:

   - Unlocking the UCB_PFLASH password protection. This is only required if UCB_PFLASH password protection is active.

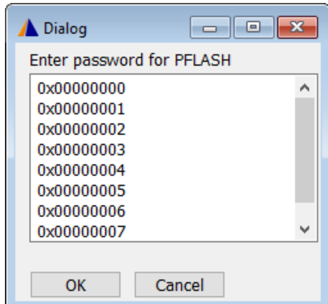
   - Changing the UCB_PFLASH sector type from ***“NOP”*** to ***“TARGET”*** to allow FLASH programming by TRACE32 PowerView.

   - Enabling FLASH programming for UCB_PFLASH using **FLASH.AUTO** command. The latter is used to preserve the unchanged content of the affected FLASH sector.

   Unlocking the UCB password protection requires the unlock password to be provided. This is achieved by additionally providing the argument ***“PWD=<password>”*** like in the following example:

```
&pwd="0x0_0x1_0x2_0x3_0x4_0x5_0x6_0x7"
DO ~~/demo/tricore/flash/tc2xx-ucb.cmm UCB=PFLASH ACTIVATE PWD=&pwd
```

   Alternatively, a dialog can be used to enter the password manually. This is done by using the argument ***“DIALOG”*** instead of ***“PWD=<password>”***.



3. Make the desired changes to the UCB via, e.g., **Data.Set** commands for both original and copy UCB contents.

4. Program the modifications by calling the UCB programming script using the argument ***“PROGRAM”***. This will perform the following:

   - Do a formal verification of the UCB_PFLASH content.

   - If the provided content is formally correct the changes are programmed to the device and the script returns “***UCBOK”***.

   - If the formal checks detected invalid content the FLASH programming is aborted and the script returns the result ***“UCBFAIL”***.

   In both cases the NOP protection of UCB_PFLASH sector is restored.

Here is the script example with the full programming flow:

```
; Perform the FLASH declaration
DO ~~/demo/tricore/flash/tc27x.cmm PREPAREONLY CPU=TC277TF
; Activate UCB modification:
; - Unlock password protection to allow programming of UCB_PFLASH
; - Allow FLASH programming by changing the sector type from NOP to
;   TARGET
; - Enable FLASH programming for UCB_PFLASH using FLASH.AUTO command
DO ~~/demo/tricore/flash/tc2xx-ucb.cmm UCB=PFLASH ACTIVATE DIALOG
; Disable all write protections in PROCONP0 original and copy content
Data.Set 0xAF100000 %Long 0x0
Data.Set 0xAF100010 %Long 0x0
; Program the modifications:
; - Formal verification of the UCB_PFLASH content
; - The content is formally correct => Program the changes to the device
; - The check detected invalid content => Abort FLASH programming
; - In any case restore NOP protection for UCB_PFLASH range
DO ~~/demo/tricore/flash/tc2xx-ucb.cmm UCB=PFLASH PROGRAM
ENTRY &result
IF ("&result"=="UCBOK")
(
  PRINT "UCB_PFLASH programming successful"
)
```

Enabling HSM boot when no valid HSM code is present will lock the device permanently. Series-specific HSM FLASH scripts can be used to program with maximum safety.

Example 1:

This example shows how the following HSM feature scripts can be used to check for valid HSM code and enable the HSM boot.

- ***tc23x-hsm.cmm***
- ***tc27x-hsm.cmm***
- ***tc29x-hsm.cmm***

Assuming that the TriCore application is already programmed to the device, the recommended FLASH programming flow for HSM programming is the following:

1. Disable NOP protection of HSM code and configuration sectors:

   Per default, the FLASH declaration scripts declare HSM code sectors as ***"NOP"***. It is necessary to change these sectors types to ***"TARGET"*** to allow their programming by TRACE32 PowerView. HSM FLASH scripts can be used to achieve this using the script argument ***"PREPAREONLY"***.

```
DO ~~/demo/tricore/flash/tc27x-hsm.cmm CPU=TC277TF PREPAREONLY
```

2. Program the HSM application code:

   The FLASH programming of HSM application can be done via, e.g., HSM specific ELF file or any other binary format. The FLASH programming commands **FLASH.ReProgram** have to be used.

```
FLASH.ReProgram ALL
Data.LOAD.Elf hsm_app.elf /NoClear /NoRegister /NosYmbol
FLASH.ReProgram OFF
```

3. Check for valid HSM code and enable HSM boot:

   After programming the HSM code, a post programming check could be done to verify if the application is correctly programmed to the target FLASH using the command **Data.LOAD** with the option ***"/DIFF"***.

   If any difference is found, HSM boot needs to be disabled by calling the HSM FLASH script with the argument ***"DISABLE"***.

If the HSM application file is correctly programmed the HSM FLASH script can safely be called with the argument ***"ENABLE"***. This will verify if the HSM programmed boot vectors are valid and enable HSM by programming the register ***UCB_HSMCOTP***. Otherwise, the HSM is kept disabled.

```
Data.LOAD.Elf hsm_app.elf /NoClear /NoRegister /NosYmbol /DIFF
IF FOUND()
(
  ; Ensure that HSM is kept disabled to avoid locking the device!
  DO ~~/demo/tricore/flash/tc27x-hsm.cmm DISABLE
  ENDDO
)
ELSE
(
  ; Check HSM code area and enable HSM
  DO ~~/demo/tricore/flash/tc27x-hsm.cmm ENABLE
)
```

4. Restore the NOP protection of HSM code and configuration sectors: After HSM FLASH programming is finished, restore the NOP protection of HSM sectors by calling the HSM FLASH script using the argument ***"FINISH"***.

```
DO ~~/demo/tricore/flash/tc27x-hsm.cmm FINISH
```

Here is the script example with the full programming flow:

```
DO ~~/demo/tricore/flash/tc27x-hsm.cmm CPU=TC277TF PREPAREONLY

FLASH.ReProgram ALL
Data.LOAD.Elf hsm_app.elf /NoClear /NoRegister /NosYmbol
FLASH.ReProgram OFF

; Check the HSM Elf file is correctly programmed to the device
Data.LOAD.Elf hsm_app.elf /NoClear /NoRegister /NosYmbol /DIFF
IF FOUND()
(
  ; Ensure that HSM is kept disabled to avoid locking the device!
  DO ~~/demo/tricore/flash/tc27x-hsm.cmm DISABLE
  ENDDO
)
ELSE
(
  ; Check HSM code area and enable HSM
  DO ~~/demo/tricore/flash/tc27x-hsm.cmm ENABLE
)

DO ~~/demo/tricore/flash/tc27x-hsm.cmm FINISH
```

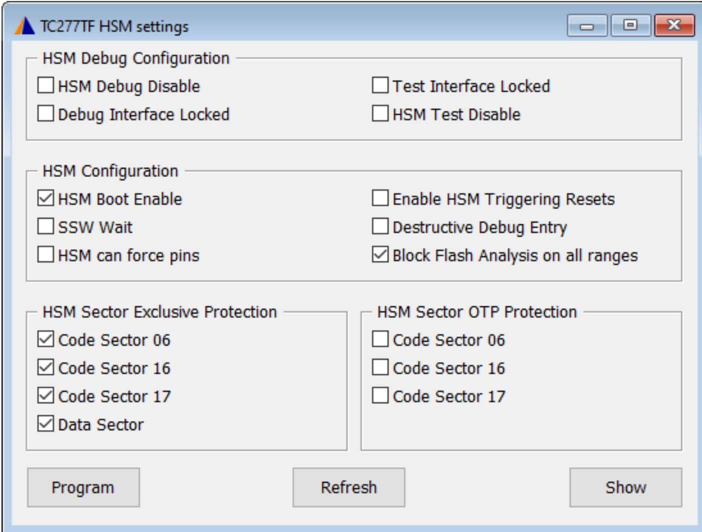
Example 2:

This example shows how the HSM feature script ***tc2xx-hsm-config.cmm*** can be used for an easier configuration of the HSM related chip setting.

The script can be started in dialog mode as follows.

```
DO ~~/demo/tricore/flash/tc2xx-hsm-config.cmm
```

The HSM related setups are configured via various check-boxes. The ***"Refresh"*** button reloads the currently programmed configuration. After selecting the desired HSM configurations the button ***"Program"*** stores the new configuration to the device. If the selected setup enables the HSM boot, the script will first check if the HSM boot vectors are valid, otherwise the FLASH programming is aborted to prevent permanent locking of the device.



The button ***"Show"*** generates a script snippet with all the settings to be made, that can be copied to the user's FLASH script.

OTP and WOP Sectors

For TriCore AURIX devices, beside write protection with password, two types of sector specific programming protection can be distinguished.

- FLASH sectors that are configured with OTP (One-Time Programmable) protection can not be erased or programmed. Otherwise, FLASH programming errors will be reported by the hardware.
- FLASH sectors that are configured with WOP (Write-page Once Protection) can be programmed once. These sectors can only be programmed if they are in erased state. Erasing these sectors is prevented by hardware after the protection is activated. The hardware will report an error when trying to erase them.

TRACE32 defines the FLASH sectors that must not be erased or programmed as ***"NOP"*** sectors. Thus OTP protected sectors (as defined by Infineon) are declared by TRACE32 FLASH declaration scripts as NOP sectors.

TRACE32 uses the ***"OTP"*** term to designate FLASH sectors that can be programmed once because erase is prohibited. Thus, the FLASH sectors that are protected with WOP (as defined by Infineon) are declared by TRACE32 FLASH declaration scripts using the option ***"/OTP"***.

Sectors declared with ***"/OTP"*** can only be programmed with the command **FLASH.Program** and the option ***"/OTP"*** must be specified.

Example:

```
FLASH.Program 0xA0000000++0x3FFF /OTP
Data.Set ...
FLASH.Program OFF
```

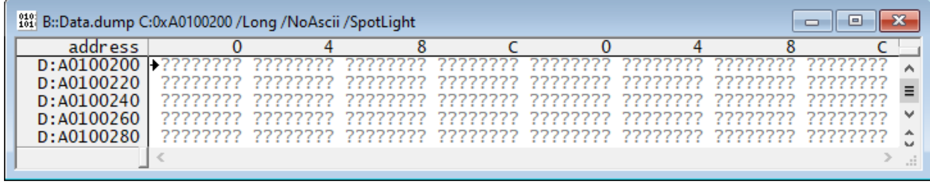
More details about FLASH programming of TRACE32 OTP sectors can be found in **"Onchip/NOR FLASH Programming User's Guide"** (norflash.pdf).

Erased FLASH

For TriCore AURIX devices the data is stored in FLASH with error correcting codes “ECC” in order to protect against data corruption. These ECC can correct a certain amount of bit errors.

For PFLASH, the ECCs are calculated over the data and the address bits. After an erase, the state of the data as well as the state of the ECC is “all-0”. As the ECC of 0x0 is not 0x0, the stored ECC does not match with the ECC of the actual data. Thus, an erased PFLASH range is resulting in ECC errors.

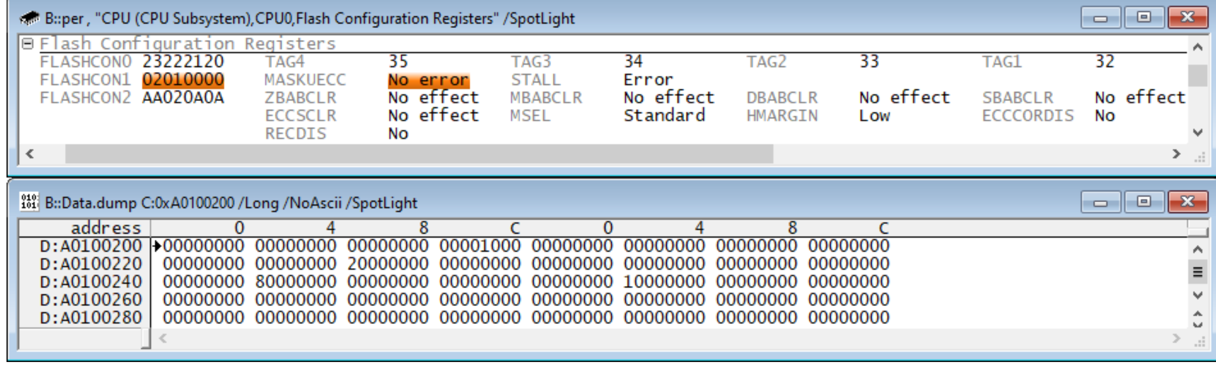
The ECC is automatically evaluated by the chip when reading data. Thus, reading from an erased PFLASH sector returns “bus error” indicated as “????????” in, e.g., a **Data.dump** window.



For DFLASH, a different ECC algorithm is used. ECC are calculated over the data bits only and the “all-0” state for data and checksums do not result in “bus errors” when reading from erased DFLASH sectors.

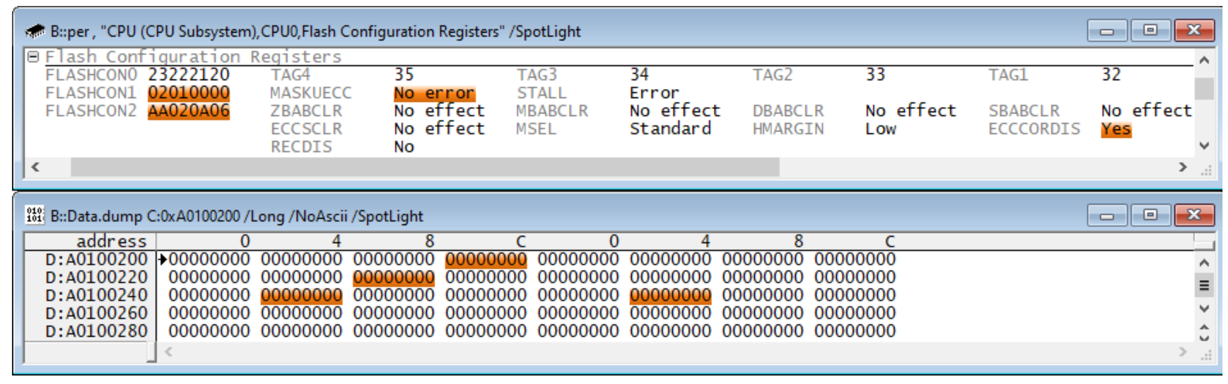
Bus errors that are caused by uncorrectable ECC errors can be masked by changing the register field ***FLASHCON1.MASKUECC*** of the CPU associated to the corresponding PFLASH unit.

After changing the configuration in the CPU0 register field ***FLASHCON1.MASKUECC*** for disabling the ECC error reporting, the erased range is displayed like in the following screenshot.



Some bits still show the value 1. The displayed values don’t reflect the real physical FLASH content, but this reflects the content obtained after applying the ECC correction. The result is not the same for all the FLASH cells because the ECC is calculated from the data values and the corresponding address.

The real erased FLASH content can be displayed by additionally disabling the ECC correction in ***FLASHCON2.ECCCORDIS*** like in the following screenshot.



NOTE:	Configuring ***FLASHCON1*** to mask the bus error traps or disabling the ECC correction in ***FLASHCON2*** are not presented here as programming options. These are only mentioned for better understanding of the chip behavior.

To ensure that all PFLASH and ECCs are initialized, the command **FLASH.ReProgram** can be used with the option ***"/FILL"*** to fill all erase sectors with 0.

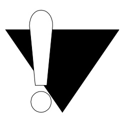
Example:

```
FLASH.ReProgram ALL /Erase /FILL
Data.LOAD.Elf application.elf
FLASH.ReProgram OFF
```

NOP Sectors

TRACE32 FLASH declaration scripts declare sensitive sectors as ***"NOP"*** to protect them against unwanted FLASH programming. TRACE32 PowerView silently discards all erase and write operations to ***"NOP"*** sectors.

When it is required to make changes to ***"NOP"*** sectors, the command **FLASH.CHANGEtype** has to be used to modify the FLASH sector type to ***"TARGET"***. Only then, FLASH operations for that range are performed by TRACE32 PowerView.

	FLASH sectors that are declared by TRACE32 FLASH scripts as ***"NOP"*** need to be handled with special care. Before making any changes to these sectors, it is mandatory to read the Infineon documentation for understanding the effects of the modifications.

FLASH declaration scripts for TC3xx declare the User Configuration Blocks (UCBs) and Configuration Sector Layout (CFS) as ***"NOP"*** sectors.

Example:

```
FLASH.Create 21. 0xAF400000++0x1FF  0x0200 NOP Long /INFO "BMHD0 ORIG"
FLASH.Create 22. 0xAF800000++0xFFFF 0x0200 NOP Long /INFO "CFS"
```

More safety in FLASH programming can be achieved by using the FLASH declaration scripts and the FLASH feature scripts in the recommended way.

For TC3xx devices, more automation of FLASH pre-checks was introduced starting from TRACE32 release **2018/02**. The FLASH declaration scripts install automatic checkers for the FLASH programming commands to warn the user about dangerous operations and to block fatal operations.

The pre-check has configuration options to control the user confirmation. These options are documented in the header of the FLASH declaration scripts.

To benefit from these automatic checks, the user's FLASH script must call the device-specific FLASH declaration script using the parameter ***"PREPAREONLY"***.

```
DO ~~/demo/tricore/flash/tc39x.cmm CPU=TC397XE PREPAREONLY
```

From the user's FLASH script, no call to check scripts is required before effective FLASH programming. For TC3xx these checks are performed automatically by TRACE32 PowerView.

The FLASH feature scripts for TC3xx are used to help programming the UCBs. Also, they are used as an additional check against unwanted device locking.

NOTE:	The procedures and script examples presented in this document requires TRACE32 release **2020/02** or newer.

User Configuration Blocks

The FLASH feature script **`tc3xx-ucb.cmm`** is used to help programming different UCBs and to test the UCB content. Details about the supported UCBs are documented in the script header.

Example 1: BMHD UCBs

This example shows how the **`tc3xx-ucb.cmm`** script is used for programming the UCB_BMHD when they are in a confirmed state. This is indicated by the fields ***PROINBMHDxO*** and ***PROINBMHDxC*** of the register ***DMU_HF_CONFIRM0***.

The recommended strategy is to start by programming the COPY UCBs first and the ORIG UCBs second. Please refer to the Infineon documentation for details on the recommended strategy.

The main steps to achieve this are the following:

1. Perform the FLASH declaration using the appropriate FLASH declaration script.

2. Activate UCB_BMHD0_COPY programming by calling the UCB programming script using the ***"ACTIVATE"*** argument. This combines the following steps:

- Unlocking the UCB_BMHD password protection. This is only required if the password protection for BMHDs is active.

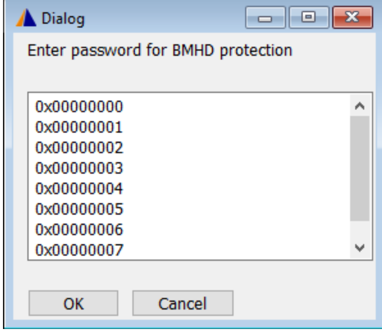
- Changing the UCB_BMHD0_COPY sector type from ***"NOP"*** to ***"TARGET"*** to allow FLASH programming by TRACE32 PowerView.

- Enabling FLASH programming for UCB_BMHD0_COPY using **FLASH.AUTO** command. The latter is used to preserve the unchanged content of the affected FLASH sector.

Unlocking the UCB password protection requires the unlock password to be provided. This is achieved by additionally providing the argument ***"PWD=<password>"*** like in the following example:

```
&pwd="0x0_0x1_0x2_0x3_0x4_0x5_0x6_0x7"
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=BMHD0_COPY ACTIVATE PWD=&pwd
```

Alternatively, a dialog can be used to enter the password manually. This is done by calling the UCB programming script using the argument ***"DIALOG"*** instead of ***"PWD=<password>"***.



3. Make the desired changes to the UCB_BMHD0_COPY via, e.g., **Data.LOAD** command.

4. Program the modifications by calling the UCB programming script using the argument ***"PROGRAM"***. This will perform the following:

   - Do a formal verification of the UCB_BMHD0_COPY content.

   - If the provided content is formally correct the changes are programmed to the device and the script returns ***"UCBOK"***.

   - If the formal checks detected invalid content the FLASH programming is aborted and the script returns the result ***"UCBFAIL"***.

   In both cases the NOP protection of UCB_BMHD0_COPY sector is restored.

```
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=BMHD0_COPY PROGRAM
```

After BMHD0_COPY is programmed, repeat steps 2 to 4 to program BMHD0_ORIG. For this, in step 2 and step 4 the script **tc3xx-ucb.cmm** must be called with the argument ***"UCB=BMHD0_ORIG"*** instead of ***"UCB=BMHD0_COPY"***. Also the address range of UCB_COPY must be replaced by the one for UCB_ORIG as parameter of the **Data.LOAD** command.

The following example summarizes the full programming flow for BMHD0_COPY.

```
; Perform the FLASH declaration
DO ~~/demo/tricore/flash/tc39x.cmm PREPAREONLY CPU=TC397XE
; Activate UCB modification:
; - Unlock password protection to allow programming of BMHDs
; - Allow FLASH programming by changing the sector type from NOP to
; TARGET
; - Enable FLASH programming for UCB_BMHD0_COPY using FLASH.AUTO command
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=BMHD0_COPY ACTIVATE DIALOG
ENTRY &result
IF ("&result"=="UCBFAIL")
(
  PRINT "UCB_BMHD unlock failed"
  ENDDO
)
; Load data of UCB_BMHD0_COPY
Data.LOAD.S3record bmhds.s3 0xAF401000++0x1FF
; Program the modifications:
; - Formal verification of the UCB_BMHD0_COPY content
; - The content is formally correct => Program the changes to the device
; - The check detected invalid content => Abort FLASH programming
; - In any case restore NOP protection for UCB_BMHD0_COPY range
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=BMHD0_COPY PROGRAM
ENTRY &result
IF ("&result"=="UCBOK")
(
  PRINT "UCB_BMHD0_COPY programming successful"
)
```

Example2: PFLASH UCBs

This example shows how the **`tc3xx-ucb.cmm`** script is used for programming the PFLASH UCBs when they are in a confirmed state (indicated by the fields ***PROINPO*** and ***PROINPC*** of the register ***DMU_HF_CONFIRM1***).

The recommended strategy is to start by programming the COPY UCB then the ORIG UCB.

This example is only showing the steps for programming PFLASH_COPY.

1. Perform the FLASH declaration using the appropriate FLASH declaration script.
2. Activate the UCB modification: This includes unlocking the password protection of the UCB, changing the UCB sector type from ***"NOP"*** to ***"TARGET"*** and enabling FLASH programming of UCB_PFLASH_COPY.
3. Make the desired changes to the UCB.
4. Program the modifications: A formal verification of UCB_PFLASH_COPY content will be performed and the changes are programmed to the device only if the formal check passes.

Here is an example script with the full programming flow of the UCB_PFLASH_COPY:

```
; Perform the FLASH declaration
DO ~~/demo/tricore/flash/tc39x.cmm PREPAREONLY CPU=TC397XE

; Activate UCB modification:
; - Unlock password protection to allow programming of PFLASH UCBs
; - Allow FLASH programming by changing the sector type from NOP to
; TARGET
; - Enable FLASH programming for UCB_PFLASH_COPY using FLASH.AUTO command
&pwd="0x0_0x1_0x2_0x3_0x4_0x5_0x6_0x7"
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=PFLASH_COPY ACTIVATE PWD=&pwd
ENTRY &result
IF ("&result"=="UCBFAIL")
(
  PRINT "UCB PFLASH unlock failed"
  ENDDO
)

; Load data of the PFLASH_COPY UCB
Data.LOAD.S3record ucbs.s3 0xAF403000++0x1FF

; Program the modifications:
; - Formal verification of the UCB_PFLASH_COPY content
; - The content is formally correct => Program the changes to the device
; - The check detected invalid content => Abort FLASH programming
; - In any case restore NOP protection for UCB_PFLASH_COPY range
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm UCB=PFLASH_COPY PROGRAM
ENTRY &result
IF ("&result"=="UCBOK")
(
  PRINT "UCB_PFLASH_COPY programming successful"
)
```

To extend the script for programming PFLASH_ORIG, the steps 2 to 4, need to be repeated using the address range of the ORIG UCB. Additionally the argument ***"UCB=PFLASH_ORIG"*** needs to be used instead of ***"UCB=PFLASH_COPY"*** when calling the script **`tc3xx-ucb.cmm`**.

The script **`tc3xx-ucb.cmm`** is also used to unlock sector specific write protection of different PFLASHs. In this case the script needs to be called with the argument ***"UNLOCK"*** and the corresponding ***"PRO=PFLASHx"*** (x in [0..5]).

Example:

```
; Unlock write protection of PFLASH0 enabled in the PFLASH UCBS
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm PRO=PFLASH0 UNLOCK DIALOG

; Unlock write protection of PFLASH5 enabled in the PFLASH UCBS
DO ~~/demo/tricore/flash/tc3xx-ucb.cmm PRO=PFLASH5 UNLOCK DIALOG
```

The arguments ***"PRO=PFLASHx"*** are not to be confused with ***"PRO=PFLASH"***. The latter is used, to disable global write protection for all PFLASHs, and to unlock the programming of PFLASH UCBs when they are in confirmed state.

For more details, please refer to the description of the register ***DMU_HF_PROTECT*** in the **AURIX™ TC3xx User's Manual** from Infineon.

When enabling HSM boot it is very important to verify that the HSM contains valid code in its FLASH area and that the boot configuration register ***PROCONHSMCBS*** is correctly initialized. Otherwise the device gets locked forever and there is no way for the debugger to recover the chip from this state.

TRACE32 FLASH scripts for TC3xx offer two ways to do this safely. The HSM feature script **`tc3xx-hsm-config.cmm`** can be used for easier configuration of the HSM boot. The FLASH declaration scripts install automatic pre-checks for the HSM boot vectors to warn about dangerous operations. The FLASH declaration scripts block any detected fatal operation that may result, e.g., in enabled HSM with invalid boot code and HSM boot settings.

Assuming that the TriCore application is already programmed to the device, the main programming flow is as follows:

1. Perform the FLASH declaration using the appropriate FLASH declaration script.
2. Enable FLASH programming of the HSM code sectors via the FLASH programming command **FLASH.ReProgram**.
3. Load the HSM code using the appropriate **Data.LOAD** command.
4. Perform FLASH programming via the command **FLASH.ReProgram OFF**.
5. Program the HSM boot configuration via the HSM feature script **`tc3xx-hsm-settings.cmm`**.

Example:

```
; Prepare FLASH programming
DO ~~/demo/tricore/flash/tc39x.cmm CPU=TC397XE PREPAREONLY

; HSM boot address
&bootaddr=0x80090000
; Enable FLASH programming of the address range reserved for HSM
FLASH.ReProgram &bootaddr++0xFFFF

; Load HSM application code
Data.LOAD.Elf hsm_app.elf /NoClear /NoRegister /NosYmbol

FLASH.ReProgram OFF

; Set the HSM boot configuration
&hsm_cfg="UCBHSM_COTP0 BOOTADDR=&bootaddr BOOTINDEX=0 HSMBOOT=ENABLE"
DO ~~/demo/tricore/flash/tc3xx-hsm-config.cmm PROGRAM_SETTINGS &hsm_cfg
```

The HSM feature script is called either using the argument ***“PROGRAM_SETTING”*** or ***“PROGRAM_REGISTER”***.

In both cases the argument ***“UCBHSM_COTP0”*** or ***“UCBHSM_COTP1”*** is used to specify whether the settings are to be programmed to the UCBs HSMCOTP0 or HSMCOTP1.

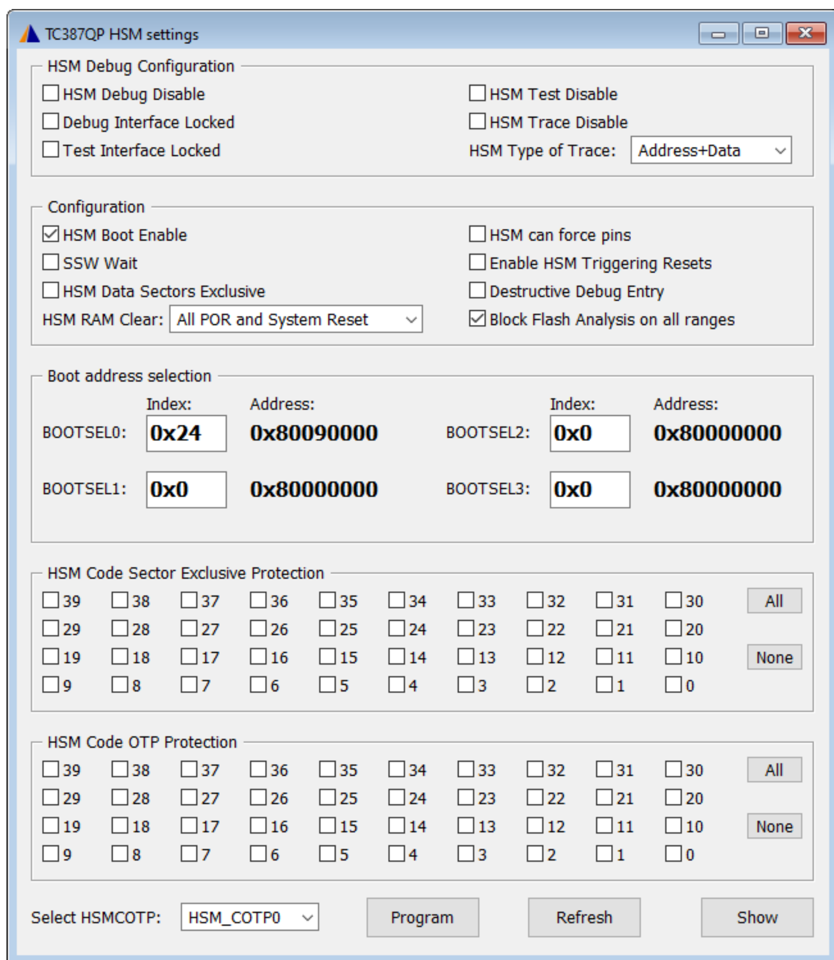
The argument ***"PROGRAM_SETTING"*** is for programming some of the HSM settings by human readable arguments:

- The arguments "***BOOTINDEX=<value> BOOTADDR=<value>***" are to be set together. ***"BOOTINDEX"*** selects the index [0..3] of the ***PROCONHSMCBS*** to be programmed, ***"BOOTADDR"*** sets the boot sector address for the HSM.
- ***"HSMBOOT=ENABLE|DISABLE"*** is used to enable or disable HSM booting.

Using the argument ***"PROGRAM_REGISTER"***, the calling script needs to supply the registers values to be programmed to the HSM UCBs. The script **`tc3xx-hsm-config.cmm`** starts an HSM configuration dialog to calculate these registers values:

```
; Open the TC3xx HSM configuration programming dialog
DO ~~/demo/tricore/flash/tc3xx-hsm-config.cmm
```

The dialog can also be started from the PowerView using the ***"HSM configuration"*** menu in the chip specific menu.



- The combo-box ***“Select HSMCOTP”*** needs to be configured first depending whether HSMCOTP0 or HSMCOTP1 shall be programmed.
- The button ***“Program”*** is used to apply the changes to the device. This will automatically check if the new configuration is valid according to the HSM code programmed to the device. The changes are discarded otherwise.
- The button ***“Refresh”*** updates the dialog with the current configuration of the HSM UCBs as programmed in the chip.
- The button ***“Show”*** generates a script snippet with all the changed settings. The snippet can be copied to the user’s FLASH script.

OTP and WOP Sectors

For TriCore AURIX devices, beside write protection with password, two types of sector specific programming protection can be distinguished.

- FLASH sectors that are configured with OTP (One-Time Programmable) protection can not be erased or programmed. Otherwise, FLASH programming errors will be reported by the hardware.
- FLASH sectors that are configured with WOP (Write-page Once Protection) can be programmed once. These sectors can only be programmed if they are in erased state. Erasing these sectors is prevented by hardware after the protection is activated. The hardware will report an error when trying to erase them.

TRACE32 defines the FLASH sectors that must not be erased or programmed as ***"NOP"*** sectors. Thus OTP protected sectors (as defined by Infineon) are declared by TRACE32 FLASH declaration scripts as NOP sectors.

TRACE32 uses the ***"OTP"*** term to designate FLASH sectors that can be programmed once because erase is prohibited. Thus, the FLASH sectors that are protected with WOP (as defined by Infineon) are declared by TRACE32 FLASH declaration scripts using the option ***"/OTP"***.

Sectors declared with ***"/OTP"*** can only be programmed with the command **FLASH.Program** and the option ***"/OTP"*** must be specified.

Example:

```
FLASH.Program 0xA0000000++0x3FFF /OTP
Data.Set ...
FLASH.Program OFF
```

More details about FLASH programming of TRACE32 OTP sectors can be found in **"Onchip/NOR FLASH Programming User's Guide"** (norflash.pdf).

DFLASH Single-Ended and Complement Sensing Mode

The DFLASH of TC3xx devices supports two operation modes.

- The single-ended mode is the normal operation mode were the full DFLASH size is available.
- The complement sensing mode is a redundant mode were only half the DFLASH size is available and the other, invisible part is used to store the redundancy information as bit-complement.

FLASH programming for the complement sensing mode is supported since TRACE32 release **2019/09**. Whether DFLASH is configured to operate in single ended or complement sensing mode is transparently handled by TRACE32. No special handling by the user's FLASH script is required. As usual, the FLASH declaration is to be done by calling the corresponding FLASH declaration script using the option ***"PREPAREONLY"***. Depending on the current device configuration, the corresponding FLASH mapping is declared.

Example:

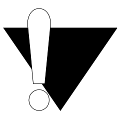
```
DO ~~/demo/tricore/flash/tc39x.cmm CPU=TC397XE PREPAREONLY
```

In complement-sensing mode, erased DFLASH is flickering. The **Data.dump** window shows random values, including bus errors. This is a chip behavior. Only a programmed DFLASH will show stable and correct values.

Support for SOTA

The majority of the TC3xx devices support a product feature named "Software Updates Over The Air (SOTA)". This designates the ability of the device to integrate received software updates by supporting the SWAP mechanism. The basic idea of SWAP is to split the PFLASH into two groups of banks, ***“A”*** and ***“B”***, allowing the application to program a new version to the inactive banks while the current version of the application is executing from the active banks. When programming has been completed, the banks are switched. After the next reboot of the chip, the previously inactive banks will become the active banks and the new version of the application will start. The SWAP mechanism ensures that the application will always execute from the same addresses, no matter which physical banks it was programmed to.

When SWAP is enabled, a chip-internal remapping redirects all read-and-fetch accesses to the active address map while the FLASH programming operations (erase/write) keep using the physical system address of PFLASH.

	Before enabling the SWAP mechanism on your chip, it is essential to read and understand the Infineon related documentation including the application note AP32404: “AURIX™ TC3xx Using the SWAP mechanism for Software Updates Over The Air (SOTA)”. Understanding the underlying concepts is mandatory to avoid unintended bricking of the chip.

NOTE:	The SOTA feature allows the application to update itself by receiving an update over the air. TRACE32 SWAP support is only required during the SOTA development phase where FLASH programming and bank switching is implemented and tested.

FLASH Programming with SWAP Enabled

TC3xx FLASH programming with SWAP enabled needs special handling. This is only supported with TRACE32 release **2020/09** or newer.

TRACE32 SWAP support ensures that the address mapping (Standard Address Map or Alternate Address Map) is always displayed as seen by the application, depending on the current configuration.

TRACE32 ensures that FLASH is programmed according to the currently selected address map. FLASH declaration is to be done by calling the corresponding FLASH declaration script using the option ***“PREPAREONLY”***.

Example:

```
DO ~~/demo/tricore/flash/tc39x.cmm CPU=TC397XE PREPAREONLY
```

When performing the FLASH declaration, the ***SWAPEN*** status of the device and the currently selected address map is checked and the FLASH declaration is performed according to the current setup of the device. The user does not need to know about the current mapping. The user just needs to know if he wants to load the application to the currently active or inactive banks.

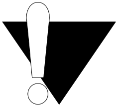
If the application has to be programmed to the inactive banks, then it has to be relocated by the user. To achieve this, TRACE32 internal debugger address translation must be configured and enabled using the **TRANSlation** command group.

The following example configures the relocation for tc37x devices:

```
TRANSlation.RESet
TRANSlation.Create C:0x80000000--0x802FFFFF A:0x80300000
TRANSlation.Create C:0xA0000000--0xA02FFFFF A:0xA0300000
TRANSlation.ON
```

SWAP demo scripts are located in the installation directory under "**~~/demo/tricore/etc/swap**".

NOTE:	After FLASH programming to the currently inactive banks is performed the relocation must be disabled before loading the debug symbols. This can be achieved using the command **TRANSlation.RESet**.

	The mapping between the banks is not linear. For example, for TC39x: • PF0 and PF1 are mapped to PF2 and PF3 • PF4 is mapped to PF5 • The upper 2 Mbytes of PF4 are not accessible when the alternate address map is installed.

The SWAP Feature Script

For convenience, TRACE32 offers the FLASH feature script **tc3xx-swap.cmm**. This script can be used to easily configure the SWAP related chip setting. Calling the script with the appropriate arguments results in programming the corresponding UCBs. The changes become effective with the next device reset after the UCBs are re-evaluated by the microcontroller's firmware (SSW).

Example:

```
DO ~~/demo/tricore/flash/tc3xx-swap.cmm SWAPEN=ON OTP=OTP1 MAP=SWITCH
```

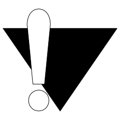
The argument ***"SWAPEN=ON"*** enables swapping in ***PROCONTP*** register of the OTPx UCB (COPY and ORIG) specified by the argument ***"OTP=<otp>"***. If not specified, OTP0 is used per default.

Note that ***"SWAPEN=OFF"*** is only performed for the selected OTP (or OTP0 if no "***OTP=<otp>***" argument is specified). For completely disabling the swapping feature the user needs to make sure that swapping is disabled in all the remaining OTPs.

"MAP=" parameter results in programming UCB_SWAP as follows:

- ***"MAP=ALTERNATE"*** results in activating the alternate address map after the device reset.
- ***"MAP=STANDARD"*** results in activating the standard address map after the device reset.
- ***"MAP=SWITCH"*** results in activating the currently inactive banks after the device reset. The alternate address map will become active when the standard address map was active before reset and vice versa.
- ***"MAP=KEEP"*** results in preserving the current configuration. Note that disabling the swapping feature automatically switches back to the standard address map.

More details about all the script arguments and other important information are documented in the script header.

	When changing any of the SWAP configurations, the FLASH declaration scripts must be called again after the next chip reboot to adjust the FLASH declaration according to the new FLASH mapping. The FLASH declaration script detects the chip configuration and declares FLASH accordingly.