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How to populate and boot a board with OP-TEE

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Contents

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Contents

1 Introduction

OP-TEE overview can be found in OP-TEE_overview wiki page.

OP-TEE is a combined feature from Open Embedded point of view.
A combined feature is a combination of 2 Yocto variables MACHINE_FEATURES and DISTRO_FEATURES.
So a combined feature is activated only after these two variables are set.

Once the machine is defined with **MACHINE_FEATURES += "optee"** and the distro is set with **DISTRO_FEATURES_append = " optee "**, building the OpenSTLinux distribution will provide all necessary binaries to populate and boot with OP-TEE feature.
As a reminder, STMicroelectronics machine configuration files are located here:

- meta-st/meta-st-stm32mp/conf/machine/*.conf

and STMicroelectronics distribution configuration file here:

- meta-st/meta-st-openstlinux/conf/distro/include/openstlinux.inc

2 Usage

2.1 Programming the built image with OP-TEE

Inside the build-<distro>-<machine>/tmp-glibc/deploy/images/stm32mp1/flashlayout_st-image-weston folder, one of the OP-TEE Flash layout file must be selected:

```
Flashlayout_*-optee.tsv
```

Several devices to program (microSD, e•MMC...) are available on the board.

Once the Flash layout file has been selected, the STM32CubeProgrammer tool can be used as usual.

Information

For microSD card and Evaluation board, the correct Flash layout file to use is: **FlashLayout_sdcard_stm32mp157c-ev1-optee.tsv**

2.2 Booting the built image with OP-TEE

During boot sequence, the OP-TEE integration trace should be displayed on the UART console log. The OP-TEE core boot stage trace should look like this:

```
I/TC:  Pager is enabled. Hashes: 1184 bytes
I/TC:  OP-TEE version: openstlinux-18-06-01
I/TC:  Initialized
```

The Linux kernel boot trace should show the successful probing of the OP-TEE Linux kernel driver:

```
optee: probing for conduit method from DT.
optee: initialized driver
```

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MultimediaCard

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Device Tree

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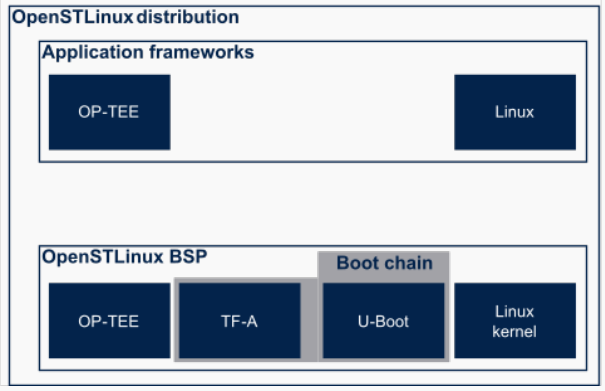
Contents

1 Overview of the OP-TEE open source project

OP-TEE allows the development and integration of secure services and applications under trusted execution environments, that is execution environments isolated from the Linux® -based OS .



Zoom out to OpenSTLinux distribution

Description extracted from the OP-TEE site[1]:

> *"OP-TEE is an open source project, which contains a full implementation to make up a complete Trusted Execution Environment using the ARM®TrustZone®. technology. OP-TEE meets the GlobalPlatform TEE System Architecture specification. It also provides the TEE Internal core API v1.1 as defined by the GlobalPlatform TEE Standard for the development of Trusted Applications. OP-TEE Trusted OS is accessible from the Linux based OS using the GlobalPlatform TEE Client API Specification v1.0, which also is used to trigger secure execution of applications within the TEE."*

OP-TEE is delivered under a BSD style license and can run secure (trusted) applications without restriction on their licensing model.

The OP-TEE project is maintained by the Linaro Security Working Group.

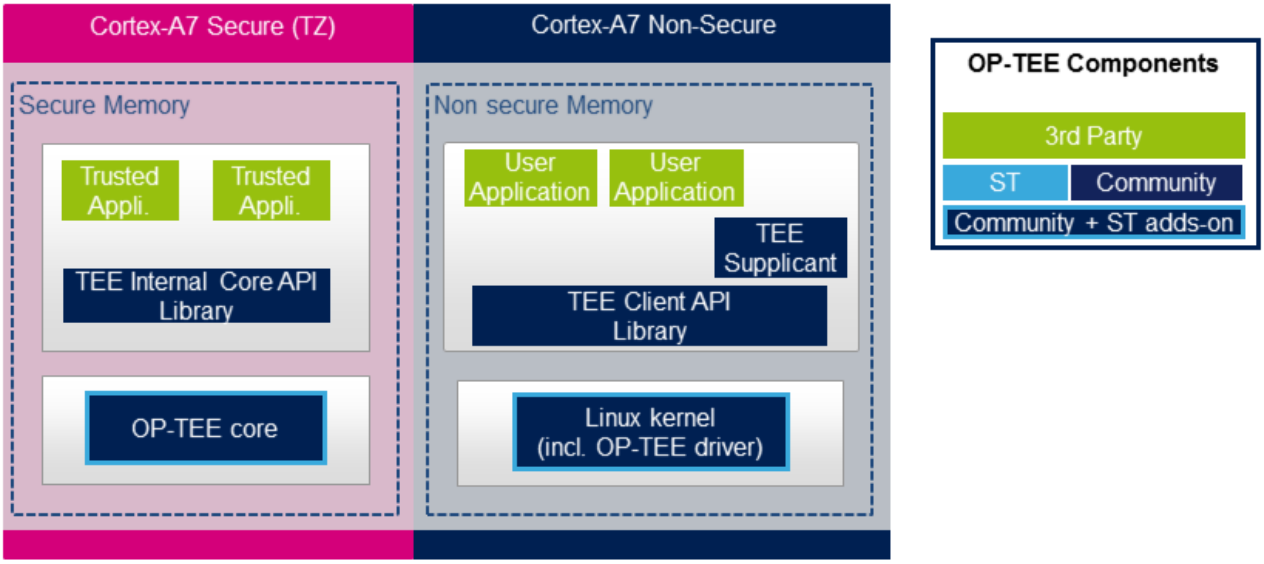
- OP-TEE official site[1]
- OP-TEE source repositories [2][3][4]
- OP-TEE documentation[5]

GlobalPlatform Device TEE specifications (TEE Client API, TEE Internal Core API and few more) is available from the GlobalPlatform site[6].

2 Architecture

The OP-TEE project includes several secure and non-secure embedded components, as well as some tools for development and debugging purposes.

The figure below shows the main OP-TEE embedded components, namely the OP-TEE core and trusted application standard libraries on the secure side, and the Client API library, the OP-TEE supplicant daemon and the OP-TEE Linux kernel driver on the non-secure side.



2.1 OP-TEE core

The main OP-TEE component is the OP-TEE core. The OP-TEE core execution is done in Arm®Cortex®-A secure state while the non-secure world (likely a Linux based OS) is done in the non-secure state of the processor. The OP-TEE core executes in secure privileged (kernel) mode, while trusted applications are executed in secure user mode.

OP-TEE can load signed trusted applications stored in the Linux OS file system or embedded in the OP-TEE core boot image.

On devices with secure external memory, the OP-TEE core runs as a monolithic image in the secure memory. On devices with a small secure memory, the OP-TEE core can run in paging-on-demand configuration: a small resident agent is loaded in the small secure memory and can securely page-in/page-out data from/to the non-secure (or less secure) external memory.

OP-TEE core source files can be found from optee_os repository [2].

2.2 OP-TEE trusted libraries

OP-TEE embeds utility libraries for trusted application development including the GlobaPlatform Device TEE Internal Core API Library, which provides the standard services a trusted application can expect from the TEE. OP-TEE supports the loading of static and dynamic libraries in the TEE.

The OP-TEE standard trusted application libraries source files can be found in the optee_os repository[2].

2.3 TEE Linux driver

The OP-TEE Linux driver is part of the Linux kernel since release 4.12.

The OP-TEE Linux driver is enabled via the CONFIG_OPTEE configuration directive through the usual Linux kernel configuration means. The driver can be probed thanks to a device tree node.

2.4 TEE Client API

The OP-TEE project embeds an implementation of the GlobaPlatform Device TEE Client API specification for Linux based OS. This TEE Client API specification is partly implemented as a userland library and partly as a Linux kernel OP-TEE driver. The API allows userland clients to invoke trusted applications and the OP-TEE core services exported to non-secure world with a standard API.

The OP-TEE Client API library source files can be found in the optee_client repository[3].

2.5 TEE supplicant

The OP-TEE core can rely on non-secure remote services. OP-TEE embeds an implementation of a non-secure userland supplicant, that can be invoked by the OP-TEE core through the OP-TEE Linux kernel driver. An example of such service is the access to a non-volatile media device that is controlled in the non-secure world.

The OP-TEE supplicant source files can be found in the optee_client repository[3].

2.6 Host tools

The OP-TEE optee_os component, once built, generates a so-called Trusted Application Development Kit to ease the development and integration of trusted applications on a target system. The Trusted Application Development Kit includes the libraries, with their header files and makefile scripts, that allow the generation of signed trusted applications from their respective source files.

Optee_os package also provides a tool to analyse call stack backtraces in case of trusted application and/or OP-TEE core crash. Refer to script **symbolize.py** in optee_os source tree[2].

3 Booting with OP-TEE

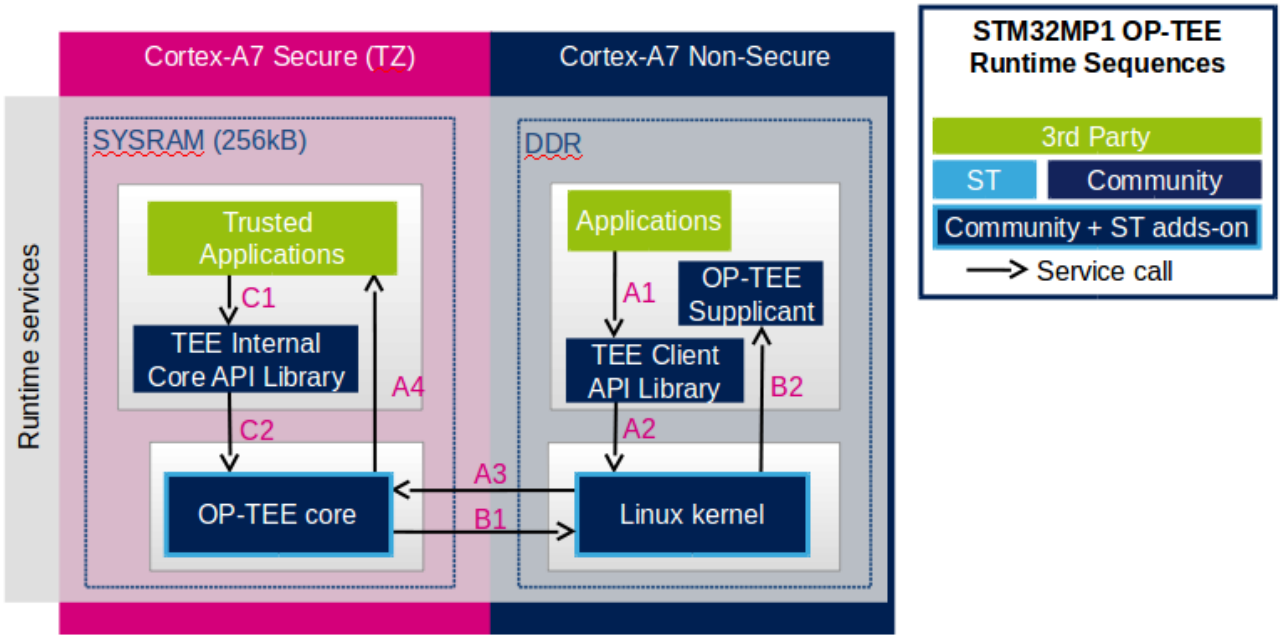
The OP-TEE core is a secure firmware. It must be booted prior to the non-secure world on Arm Cortex-A core(s). The secure bootloader must therefore load the OP-TEE core images in memory and run its initialization prior to executing the first booted non-secure image.

Refer to the target system boot sequences for more details.

4 Invoking the OP-TEE services from Linux based OS

Once the Linux kernel is booted, the OP-TEE core is already initialized and ready to serve.

The figure below shows the main run time sequences in which the OP-TEE can be involved.



Sequence A: an non-secure application invokes a service from a trusted application.

The non-secure application calls the TEE Client API library (**A1**), which in turns invokes (**A2**) the Linux kernel OP-TEE driver. The OP-TEE driver invokes the secure world (**A3**) and reaches the OP-TEE core. The last OP-TEE core transfers the request (**A4**) to the target trusted application. Once the trusted application has completed the request, the system branches back to the calling application with the request status.

If an invoked trusted application is not yet loaded into the TEE, the OP-TEE core loads it by calling remote services through the non-secure TEE supplicant as described in **sequence B** below.

In addition, any invocation of the TEE from the non-secure world must go through the Linux kernel OP-TEE driver.

Sequence B: the OP-TEE core must invoke a non-secure remote service.

The OP-TEE core invokes (**B1**) the Linux kernel OP-TEE driver which in turns notifies the TEE supplicant daemon (**B2**) for a request. Once the supplicant has completed the request, the system branches back to the OP-TEE core with the request status.

Sequence C: a trusted application invokes an OP-TEE core service.

Most of the services defined by the GlobaPlatform Device TEE Internal Core API must be executed in OP-TEE core privileged mode. The trusted application calls the corresponding service from the TEE Internal Core API library (**C1**), which issues a system call (**C2**) to the OP-TEE core. Once the core has completed the request, the system branches back to the calling trusted application with the request status.

5 Experiencing OP-TEE on a target

First make sure your setup includes OP-TEE in the boot sequence. If the OP-TEE core console traces are enabled, you should see the OP-TEE banner after secure bootloader traces and before non-secure bootloader traces. The OP-TEE core banner looks like this:

```
I/TC:  OP-TEE version: <some-reference-version-info> #1 Mon Jun 25 08:59:21 UTC 2018 arm
I/TC:  Initialized
```

The Linux kernel boot traces also show the successful probing of the OP-TEE Linux kernel driver:

```
optee: probing for conduit method from DT.
optee: initialized driver
```

The OP-TEE non-secure components are stored in the file system:

- By default the TEE supplicant is installed at **/usr/bin/tee-supplicant**.
- By default, the TEE Client API library is installed at **/usr/lib/teec.so**.
- By default the TEE regression test tool is installed at **/usr/bin/xtest**.

In the default OP-TEE configuration, trusted applications are stored in the non-secure filesystem at **/lib/optee_armtz/*.ta**.

OP-TEE provides means to protect the trusted application binary images from corruption as image signature or installation in the OP-TEE secure storage. In any case, it is likely that Othe P-TEE core needs to invoke a non-secure service to retrieve the trusted application(s) from some non-secure filesystem data in order to load trusted application(s) in the TEE. This service requires the availability of the OP-TEE supplicant.

Therefore, once the non-secure OS has booted, it must launch the OP-TEE supplicant as a background daemon. Use the following shell command to start the OP-TEE supplicant from a booted Linux system, :

```
sh> tee-supplicant &
```

The OP-TEE package comes with some examples and regression tests. Use the following embedded shell command to run the regression tests:

```
sh> xtest
```

or to run only selective tests:

```
sh> xtest 1002     # Invokes some OP-TEE internal core services
sh> xtest 1004     # Invokes a trusted application loaded from the non-secure filesystem
```

6 References

- 1.01.1 https://op-tee.org
- 2.02.12.22.3 https://github.com/OP-TEE/optee_os
- 3.03.13.2 https://github.com/OP-TEE/optee_client
- https://github.com/OP-TEE/optee_test
- https://optee.readthedocs.io/
- https://globalplatform.org/

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Device Tree

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This article gives a short introduction to the official STM32CubeProgrammer tool: What are the flashing principles? Where to download the software? How to install it? How to use it?

Contents

1 STM32CubeProgrammer overview

STM32CubeProgrammer is the official STMicroelectronics tool for creating partitions into any Flash device available on STM32 platforms.
Once created, STM32CubeProgrammer allows populating and updating the partitions with the prebuilt binaries.

The connection between the host PC and the board can be done through UART or USB serial links.

Any Flash device supported on STM32MPU boards can be flashed using STM32CubeProgrammer. For example, for the STM32MP157 Evaluation board:

1. microSD™ card
2. eMMC
3. NAND Flash memory
4. NOR Flash memory

Information

During development, it is recommended to use a microSD card; you can then switch to eMMC or NAND Flash memory.

More details on supported Flash memory technologies and mapping can be found in Flash mapping articles, e.g. STM32MP15 Flash mapping.

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2 STM32CubeProgrammer installation

2.1 Installing the STM32CubeProgrammer tool

	STM32CubeProgrammer for Linux® host PC	STM32CubeProgrammer for Windows® host PC
Download	**Version 2.7.0** • Browse SetupSTM32CubeProgrammer link and follow instructions to download the package, you need a myST account. • Download the archive file on your host PC in a temporary directory • Uncompress the archive file to get the STM32CubeProgrammer installers: **PC $>**unzip en.stm32cubeprog.zip	
Installation	• Execute the Linux installer, which guides you through the installation process. `$> ./SetupSTM32CubeProgrammer-2.7.0.linux` • The path to the STM32CubeProgrammer binary must be added to the PATH environment variable • either in each Terminal program in which the STM32CubeProgrammer binary needs to be used, using the following command:	• Execute the Windows installer, which guides you through the installation process.

	STM32CubeProgrammer for Linux® host PC	STM32CubeProgrammer for Windows® host PC

	`$> export PATH=<my STM32CubeProgrammer install directory>/bin:$PATH`
	• or once for all by creating a link to the STM32CubeProgrammer binary in a directory already present in PATH. For example, if "/home/bin" is in the PATH environment variable, run the following command:
	`$> ln -s <my STM32CubeProgrammer install directory>/bin/STM32_Programmer_CLI /home/bin/STM32_Programmer_CLI`	

User manual	• Instructions to follow for using the STM32CubeProgrammer can be found in user manual, UM2237 available from ST web site, or in STM32CubeProgrammer#How to flash with STM32CubeProgrammer article.	
Detailed release note	• Details about the content of this tool version are available from ST web site at Release Note .	

2.2 Preparing the USB serial link for flashing

It is recommended to use the USB (in DFU mode) for flashing rather than the UART, which is too slow.

Below indications on how to install the USB in DFU mode under Linux and Windows OS, respectively.

- **For Linux host PC** or Windows host PC with VMWare:

The libusb1.0 package (including USB DFU mode) must be installed to be able to connect to the board via the USB port. This is achieved by typing the following command from the host PC terminal:

```
PC $> sudo apt-get install libusb-1.0-0
```

To allow STM32CubeProgrammer to access the USB port through low-level commands, proceed as follows:

```
PC $> cd <your STM32CubeProgrammer install directory>/Drivers/rules
PC $> sudo cp *.* /etc/udev/rules.d/
```

- **For Windows host PC**:

Run the “STM32 Bootloader.bat” file to install the STM32CubeProgrammer DFU driver and activate the STM32 microprocessor device in USB DFU mode. This driver (installed by STM32 Bootloader.bat) is provided within the STM32CubeProgrammer release package. It is located in the DFU driver folder, \Drivers\DFU_Driver.

In case of issue, refer to How to proceed when the DFU driver installation fails on Windows host PC.

To validate the installation, the DFU driver functionality can be verified by following the FAQ instructions provided in how to check if the DFU driver is functional.

STM32CubeProgrammer is now ready to use: to know more about this tool, please continue reading; otherwise, jump to the Starter or Distribution Package article corresponding to your board: Category:Starter Package or Category:Distribution Package.

3 Flash programming principles

Flash programming consists in transferring the binaries stored on the host computer into the platform Flash memory(ies), via a serial interface.
This operation requires a communication interface between the **STM32CubeProgrammer** and an **embedded programming service**.

The selection of the binaries to download and the Flash memory destination is done through the flashlayout.tsv file.
The STM32Cubeprogrammer tool uses the Flashlayout.tsv file as an input.
The Flashlayout includes a formal description of the partitions (ID, naming, type, offset) as well as the identification of the Flash memory to be populated.

Some default "tsv" files aligned with the STM32 Flash memory mapping (e.g.STM32MP15_Flash_mapping) are provided in the STM32Cubeprogrammer tool. They can be used as a starting point and can be further adapted to specific application needs.

More examples as well as information on the description format are available in STM32CubeProgrammer flashlayout.

See AN5275: USB DFU/USART protocols used in STM32MP1 Series bootloaders for protocol details.

4 How to flash with STM32CubeProgrammer

Once the STM32CubeProgrammer has been installed, complete flashing procedures for STM32 boards are available in Starter Package and Distribution Package articles. Select the article corresponding to your STMicroelectronics platform.

The generic syntax of the STM32CubeProgrammer command is explained below.

- **With Linux host PC**, the main command is:

```
PC $> ./bin/STM32_Programmer_CLI  + options given below
```

- **With Windows host PC**, the main command is:

```
PC $> ./bin/STM32_Programmer_CLI.exe + options given below
```

The Linux related information provided below can be extrapolated for other host PC operating systems:

- **Complete flashing command (for Linux host PC):**

```
PC $>  STM32_Programmer_CLI -c port=<DEVICE_PORT_LOCATION> -w [<file.tsv>]
where
 w:
     Write
 <file.tsv>:PathToFlashlayout/flashlayout.tsv file (see above)
         if Flashlayout and binaries are not in the same directory, then the path to the
Flashlayout files must be precised.
 <DEVICE_PORT_LOCATION>:
         e.g. usb1 (case sensitive): for other options, please refer to How to find the
DEVICE_PORT_LOCATION parameter value for the USB link.
```

Populating all partitions can take a few minutes (depending mainly on the rootfs size).

5 FAQs

5.1 Where to find the STM32CubeProgrammer user manual

The user manual is available in ST deliveries under <STM32CubeProgrammer installation directory>/doc/UM2336.pdf (see Installing the STM32CubeProgrammer tool).

5.2 How to check if the DFU driver is functional

Prerequisites: STM32CubeProgrammer installation completed and STM32 board connected to the host PC.

First, activate the USB driver on Ubuntu on VMware Workstation Player (use VM Player menu "removable devices" to connect to STMicroelectronics DFU in HS mode), then execute the following command and check the result:

```
PC $> STM32_Programmer_CLI -l usb
```

- If the DFU is functional, the result is similar to the following

```
    -------------------------------------------------------------------
                    STM32CubeProgrammer <tool version>
    -------------------------------------------------------------------

Total number of available STM32 device in DFU mode: 1

 Device Index           : USB1
 USB Bus Number         : 002
 USB Address Number     : 008
 Product ID             : USB download gadget@Device ID /0x500, @Revision ID /0x0000
 Serial number          : 0000000000
 Firmware version       : 0x0110
 Device ID              : 0x0500
```

- Otherwise, the DFU is not functional and the result is the following:

```
-------------------------------------------------------------------
                    STM32CubeProgrammer <tool version>
-------------------------------------------------------------------


 Warning: No STM32 device in DFU mode connected
```

5.3 How to proceed when the DFU driver installation fails on Windows host PC

Prerequisites: STM32CubeProgrammer installation completed.

The STM32 Bootloader.bat allows to install the DFU driver on a Windows PC (see Preparing the USB serial link for flashing). In case of failure, here is a typical error log:

```
c:\demo\MPU\stm32_programmer_package_v1.0.3_MPU\Drivers\DFU_Driver>"STM32 Bootloader.bat"
c:\demo\MPU\stm32_programmer_package_v1.0.3_MPU\Drivers\DFU_Driver>echo off Microsoft PnP
Utility
Processing inf :            DFU_in_HS_Mode.inf
Failed to install the driver on any of the devices on the system : No more data is
available.
Total attempted:              1
Number successfully imported: 0
```

This error occurs either because the STM32CubeProgrammer DFU driver is already installed or because the DFUSE driver is installed.

To verify if the STM32CubeProgrammer DFU driver is correctly installed on your Windows host PC, please proceed as follow:

1. Connect the board to the Windows host PC.
2. Launch the Device Manager utility and execute the below action depending on your use case:
   - The STM32CubeProgrammer DFU driver is not installed:

     Execute the STM32 Bootloader.bat script to install it (see Preparing the USB serial link for flashing).

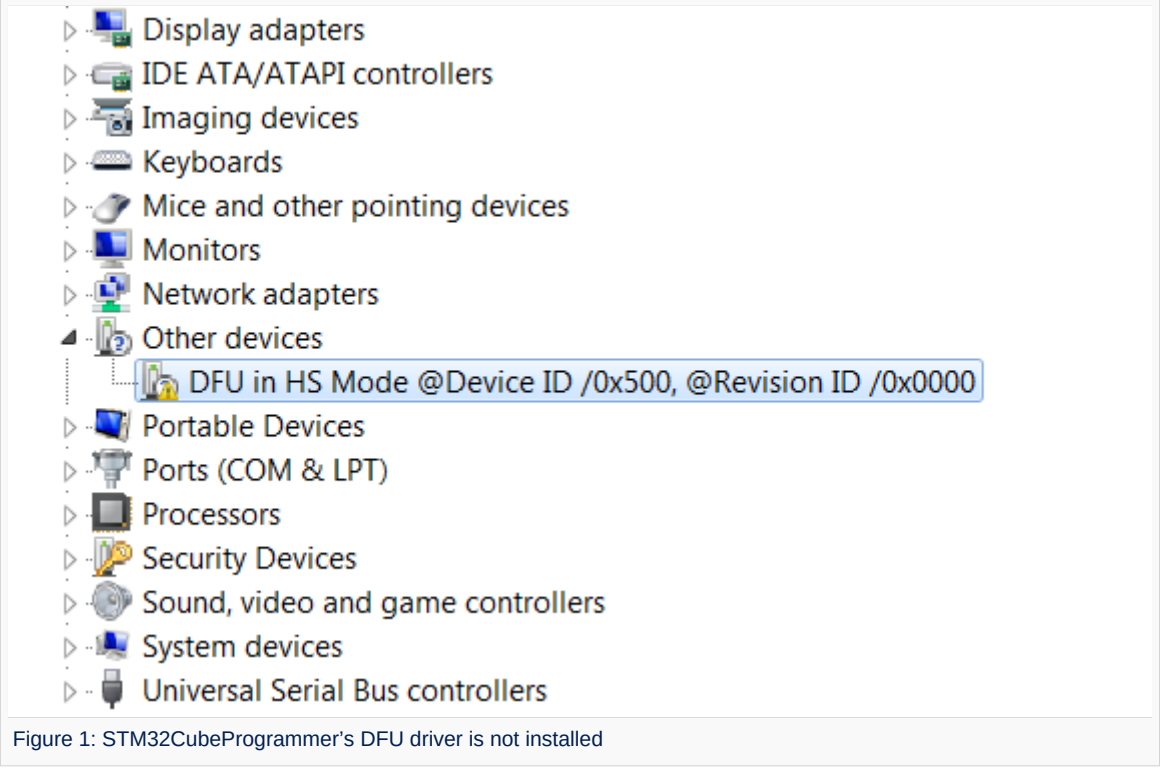


Figure 1: STM32CubeProgrammer's DFU driver is not installed

   - The DfuSe driver is installed and you must uninstall it.

     Right click **STM Device in DFU Mode** and select **Uninstall**.

Figure 1: STM32 DFU Device with DfuSe Driver

- The STM32CubeProgrammer DFU driver is installed and ready to be used.

Figure 2: STM32 DFU Device with STM32_Programmer Driver

5.4 How to find the DEVICE_PORT_LOCATION parameter value for the USB link

Prerequisites: STM32CubeProgrammer installation completed and STM32 board connected to the host PC.

To find the value of the DEVICE_PORT_LOCATION corresponding to the USB link, use the following command:

```
PC $> STM32_Programmer_CLI -l usb
     -------------------------------------------------------------------
                    STM32CubeProgrammer <tool version>
     -------------------------------------------------------------------

Total number of available STM32 device in DFU mode: 1

 Device Index           : USB1
 USB Bus Number         : 002
```

```
USB Address Number     : 008
Product ID             : USB download gadget@Device ID /0x500, @Revision ID /0x0000
Serial number          : 0000000000
Firmware version       : 0x0110
Device ID              : 0x0500
```

You can then report the value returned by the command line as explained in the How to flash with STM32CubeProgrammer chapter. Pay attention that the value must be written in **lower case**.

5.5 How to explore all the partitions of a populated microSD card

A populated microSD card can contain more than eight partitions, exceeding the number of partitions allowed by default in a Linux system.
At insertion step, you may get an 'Error mounting /dev/mmcblk0p9' or 'mount: cannot mount /dev/mmcblk0p9 read-only' error message.

By adding some options to modprobe, it is possible to allow more than eight partitions on a storage device:

```
PC $> echo 'options mmc_block perdev_minors=16' > /tmp/mmc_block.conf
PC $> sudo mv /tmp/mmc_block.conf /etc/modprobe.d/mmc_block.conf
```

5.6 How to update partitions

For partial Flash memory update, the flashlayout.tsv must be edited to select only the partition that needs to be updated (first column =1).
See STM32CubeProgrammer_flashlayout#Updating partitions for details and example, the rest of the procedure is the same.

On ST boards, if FSBL or SSBL partitions need to be updated, the Bin2boot fields must be configured with **ST binaries**, as described in STM32CubeProgrammer_flashlayout#Updating partitions using official ST bootloaders.

5.7 How to populate a microSD card inserted in a Linux host PC

STMicroelectronics distribution is delivered with the *create_sdcard_from_flashlayout.sh* script that allows to prepare and flash a microSD card image.

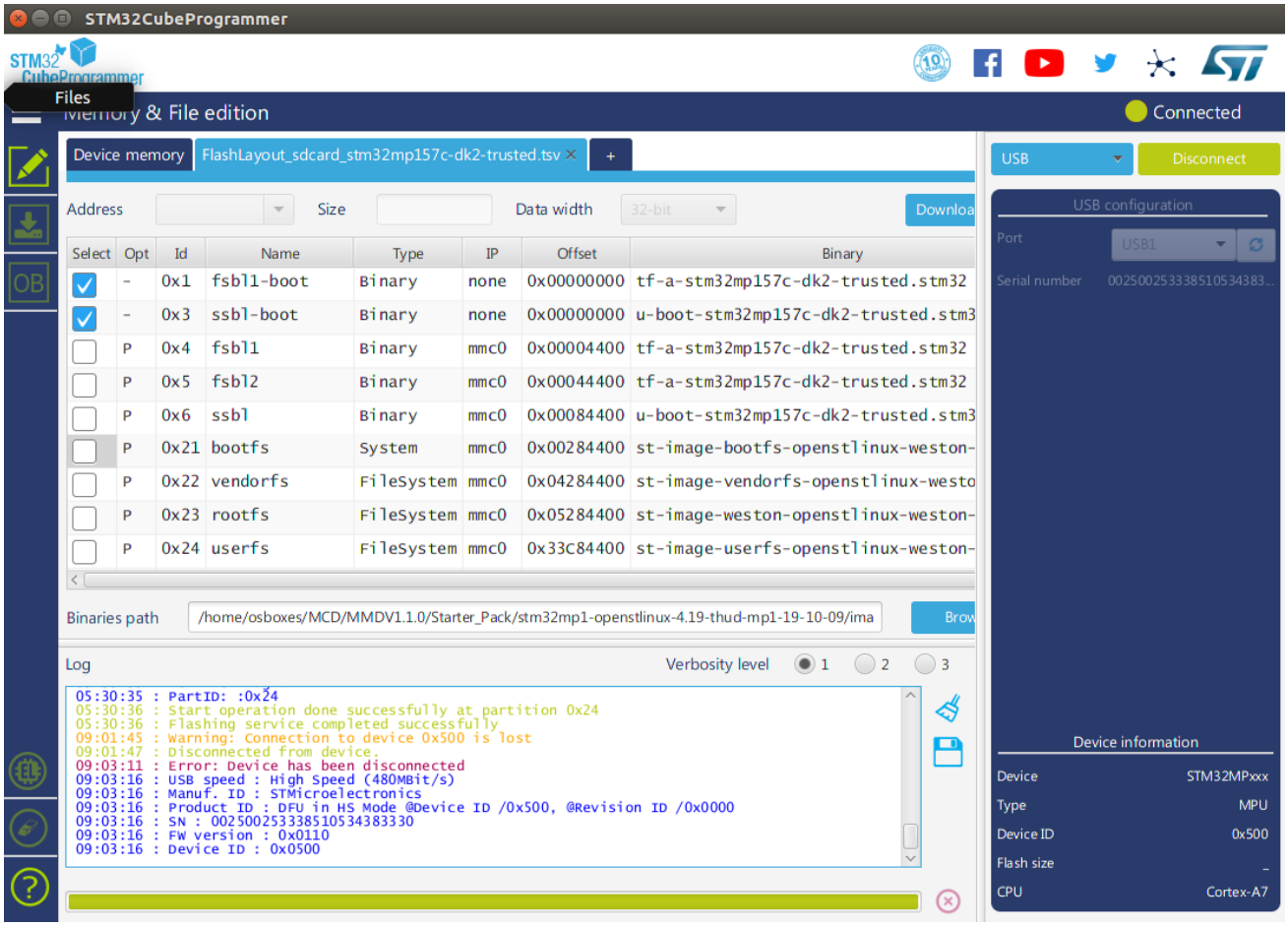
5.8 How to fuse STM32MP15x OTP

5.8.1 Connection

STM32CubeProgrammer requires to be connected to U-Boot in order to access OTP alternate.

To do it, you have to initiate a flash process but selecting only the 2 first "boot" partitions TF-A(0x1) and U-Boot(0x03) of a .tsv.

Using STM32CubeProgrammer GUI this can done without editing by using any available .tsv but selecting only the 2 first partitions thanks to "Select" column tick boxes on the left, as follow:



Perform the "Download" till success popup then disconnect from the GUI and switch to CLI in a terminal without rebooting the board:

```
PC $> STM32_Programmer_CLI -c port=usb1
```

5.8.2 Display status

It will also displayed the status for each OTP words (Shadow lock read/write, program stick lock, permanent write lock):

- All lower OTP
- Only upper that are available for non secure (defined in TF-A device tree).

To display the OTP:

```
PC $>  STM32_Programmer_CLI -c port=usb1 -otp displ

-------------------------------------------------------------------
                  STM32CubeProgrammer v2.3.0
-------------------------------------------------------------------
```

```
USB speed   : High Speed (480MBit/s)
Manuf. ID   : STMicroelectronics
Product ID  : USB download gadget@Device ID /0x500, @Revision ID /0x0000
SN          : 00250025333851053438333O
FW version  : 0x0110
Device ID   : 0x0500
Device name : STM32MPxxx
Device type : MPU
Device CPU  : Cortex-A7


UPLOADING OTP STRUCTURE ...
  Partition     : 242
  Size          : 1024 Bytes

Uploading OTP data:
[==================================================] 100%

OTP Partition read successfully


OTP STRUCTURE VERSION          :0x00000001

BSEC CONTROL REGISTERS:

BSEC_OTP_CONFIG                :0x0000000e
                                |_[08] TR[1]                    : 0
                                |_[07] TR[0]                    : 0
                                |_[06] PRGWIDTH[3]              : 0
                                |_[05] PRGWIDTH[2]              : 0
                                |_[04] PRGWIDTH[1]              : 0
                                |_[03] PRGWIDTH[0]              : 1
                                |_[02] FRC[1]                   : 1
                                |_[01] FRC[0]                   : 1
                                |_[00] PWRUP                    : 0

BSEC_OTP_Status                :0x00000041
                                |_[07] BIST2LOCK                : 0
                                |_[06] BIST1LOCK                : 1
                                |_[05] PWRON                    : 0
                                |_[04] PROGFAIL                 : 0
                                |_[03] BUSY                     : 0
                                |_[02] INVALID                  : 0
                                |_[01] FULLDBG                  : 0
                                |_[00] SECURE                   : 1

BSEC_OTP_LOCK                  :0x00000002
                                |_[04] GPLOCK                   : 0
                                |_[03] FENREG                   : 0
                                |_[02] DENREG                   : 0
                                |_[00] OTP                      : 0

BSEC_DENABLE                   :0x0000047f
                                |_[10] DBGSWENABLE              : 1
                                |_[09] CFGSDISABLE              : 0
                                |_[08] CP15SDISABLE[1]          : 0
                                |_[07] CP15SDISABLE[0]          : 0
                                |_[06] SPNIDEN                  : 1
                                |_[05] SPIDEN                   : 1
                                |_[04] HDPEN                    : 1
                                |_[03] DEVICEEN                 : 1
                                |_[02] NIDEN                    : 1
                                |_[01] DBGEN                    : 1
                                |_[00] DFTEN                    : 1

BSEC_FENABLE                   :0x00000000
```

```
                                |_[03] CAN_disable                : 0
                                |_[02] GPU_disable                : 0
                                |_[01] Dual_A7_disable            : 0
                                |_[00] Crypto_disable             : 0


OTP LOWER SHADOW REGISTERS:

ID     value     disturbed     error     R_SLock     W_SLock     Prog_SL     Perm_L

00  0x00000017       0           0           1           1           0           0
01  0x00008000       0           0           0           1           0           1
02  0x00000000       0           0           0           1           1           0
03  0x00000000       0           0           0           0           0           0
04  0x00000000       0           0           0           0           0           0
05  0x00000000       0           0           0           0           0           0
06  0x00000000       0           0           0           0           0           0
07  0x00000000       0           0           0           0           0           0
08  0x00000000       0           0           0           1           0           0
09  0x00000000       0           0           0           0           0           0
10  0x00000000       0           0           0           0           0           0
11  0x00000000       0           0           0           0           0           0
12  0x7ce7f0ee       0           0           0           0           0           1
13  0x00250025       0           0           0           0           0           1
14  0x33385105       0           0           0           0           0           1
15  0x34383330       0           0           0           0           0           1
16  0x125575aa       0           0           0           1           1           1
17  0x1f41185b       0           0           0           0           0           1
18  0x7a200140       0           0           1           1           0           0
19  0x0690147c       0           0           0           0           0           1
20  0x5de00048       0           0           0           0           0           1
21  0x00000000       0           0           0           0           0           1
22  0x00000000       0           0           0           0           0           1
23  0x3fec2fd7       0           0           0           0           0           1
24  0x00000000       0           0           0           1           0           0
25  0x00000000       0           0           0           1           0           0
26  0x00000000       0           0           0           1           0           0
27  0x00000000       0           0           0           1           0           0
28  0x00000000       0           0           0           1           0           0
29  0x00000000       0           0           0           1           0           0
30  0x00000000       0           0           0           1           0           0
31  0x00000000       0           0           0           1           0           0

OTP UPPER SHADOW REGISTERS:

ID     value     disturbed     error     R_SLock     W_SLock     Prog_SL     Perm_L

32  0x00000000       0           0           1           1           1           1
33  0x00000000       0           0           1           1           1           1
34  0x00000000       0           0           1           1           1           1
35  0x00000000       0           0           1           1           1           1
36  0x00000000       0           0           1           1           1           1
37  0x00000000       0           0           1           1           1           1
38  0x00000000       0           0           1           1           1           1
39  0x00000000       0           0           1           1           1           1
40  0x00000000       0           0           0           1           1           1
41  0x00000000       0           0           0           1           1           1
42  0x00000000       0           0           0           1           1           1
43  0x00000000       0           0           0           1           1           1
44  0x00000000       0           0           0           1           1           1
45  0x00000000       0           0           0           1           1           1
46  0x00000000       0           0           0           1           1           1
47  0x00000000       0           0           0           1           1           1
48  0x00000000       0           0           0           1           1           1
49  0x00000000       0           0           0           1           1           1
50  0x00000000       0           0           0           1           1           1
51  0x00000000       0           0           0           1           1           1
```

```
52  0x00000000      0           0           0           1           1           1
53  0x00000000      0           0           0           1           1           1
54  0x00000000      0           0           0           1           1           1
55  0x00000000      0           0           0           1           1           1
56  0x00000000      0           0           1           1           0           0
57  0x42e18000      0           0           0           0           0           0
58  0x0000fd51      0           0           0           0           0           0
59  0x12722301      0           0           0           0           0           0
60  0x00000000      0           0           0           0           0           0
61  0x00000000      0           0           0           0           0           0
62  0x00000000      0           0           0           0           0           0
63  0x00000000      0           0           0           0           0           0
64  0x00000000      0           0           0           0           0           0
65  0x00000000      0           0           0           0           0           0
66  0x00000000      0           0           0           0           0           0
67  0x00000000      0           0           0           0           0           0
68  0x00000000      0           0           0           0           0           0
69  0x00000000      0           0           0           0           0           0
70  0x00000000      0           0           0           0           0           0
71  0x00000000      0           0           0           0           0           0
72  0x00000000      0           0           0           0           0           0
73  0x00000000      0           0           0           0           0           0
74  0x00000000      0           0           0           0           0           0
75  0x00000000      0           0           0           0           0           0
76  0x00000000      0           0           0           0           0           0
77  0x00000000      0           0           0           0           0           0
78  0x00000000      0           0           0           0           0           0
79  0x00000000      0           0           0           0           0           0
80  0x00000000      0           0           0           0           0           0
81  0x00000000      0           0           0           0           0           0
82  0x00000000      0           0           0           0           0           0
83  0x00000000      0           0           0           0           0           0
84  0x00000000      0           0           0           0           0           0
85  0x00000000      0           0           0           0           0           0
86  0x00000000      0           0           0           0           0           0
87  0x00000000      0           0           0           0           0           0
88  0x00000000      0           0           0           0           0           0
89  0x00000000      0           0           0           0           0           0
90  0x00000000      0           0           0           0           0           0
91  0x00000000      0           0           0           0           0           0
92  0x00000000      0           0           0           0           0           0
93  0x00000000      0           0           0           0           0           0
94  0x00000000      0           0           0           0           0           0
95  0x00000000      0           0           0           0           0           0

BSEC_HWCFGR                     :0x00000014
                                |_[07] ECC_USE[3]               : 0
                                |_[06] ECC_USE[2]               : 0
                                |_[05] ECC_USE[1]               : 0
                                |_[04] ECC_USE[0]               : 1
                                |_[03] SAFMEM_SIZE[3]           : 0
                                |_[02] SAFMEM_SIZE[2]           : 1
                                |_[01] SAFMEM_SIZE[1]           : 0
                                |_[00] SAFMEM_SIZE[0]           : 0


BSEC IP REV                     :1.1

BSEC IP ID                      :0x00100032

BSEC IP MAGIC ID                :0xa3c5dd04
```

5.8.3 Update value

It is now possible to use programmer to manage new fuses values: bit to bit for Lower, only programmable once for Upper.

For example: Set the value 0x21458000 into the word 57 (0x39)

```
PC $> STM32_Programmer_CLI -c port=usb1 -otp program wordID=0x39 value=0x21458000
```

Words are written as a 32bit word. It is important to take care of the bit order once using the value in software.

Example: Mac address 00:80:e1:42:45:e5 must be written as:

- Word 57 : 0x42e18000
- Word 58 : 0x0000e545

Warning

MAC address / board Id OTP write should not be performed on ST boards ! They are written and protected by ECC during factory production. Any further write will break the board with no way to recover if these OTP are not locked

5.8.4 Update lock

Lock (no other programmation could occured) could be added per word; the permanent lock access will only be refreshed after boot.

For example: permanent lock (pl=1) the word 57 (0x39)

```
PC $> STM32_Programmer_CLI -c port=usb1 -otp program wordID=0x39 value=0x21458000 pl=1
```

5.9 How to program STPMIC NVM

STM32CubeProgrammer require to be connected to U-Boot in order to access STPMIC NVM alternate (0xF4).

Refer to previous Chapter 5.8.1 and follow same procedure to flash only the 2 first "boot" partition with GUI. Then disconnect from GUI and switch to CLI in a terminal.

This is procedure to modify NVM values.

- Read partition of pmic and load it into a .bin file

```
PC $> STM32_Programmer_CLI -c port=usb1  -rp 0xf4 0x0 0x8 $MySelectedPATH\PMIC_NVM_read.
bin
```

- Backup it by creating a copy PMIC_NVM_write.bin
- Use a binary editor in HEX format (eg "vi -b file.bin" then :%!xxd) to edit the copy PMIC_NVM_write.bin with new values.

The binary format display the shadow register from 0xF8 to 0XFF. Refer to STPMIC1 DataSheet DS12792.

```
00000000: EE92 C002 F280  0233                     .......3
respectively SHR address :  F8F9 FAFB FCFD FEFF
```

- Program back the STPMIC1 with modified NVM using following command:

```
PC $> STM32_Programmer_CLI -c port=usb1 -pmic "PMIC_NVM_write.bin"
```

Universal Asynchronous Receiver/Transmitter

former spelling for e•MMC ('e' in italic)

Flash memories combine high density and cost effectiveness of EPROMs with the electrical erasability of EEPROMs. For this reason, the Flash memory market is one of the most exciting areas of the semiconductor industry today and new applications requiring in system reprogramming, such as cellular telephones, automotive engine management systems, hard disk drives, PC BIOS software for Plug & Play, digital TV, set top boxes, fax and other modems, PC cards and multimedia CD-ROMs, offer the prospect of very high volume demand.

Linux® is a registered trademark of Linus Torvalds.

Device Firmware Upgrade

Operating System

High Speed (MIPI® Alliance DSI standard)

Microprocessor Unit

System Trace Module

First Stage Boot Loader

Second Stage Boot Loader

One Time Programmed

Das U-Boot -- the Universal Boot Loader (see U-Boot_overview)

Trusted Firmware for Arm Cortex-A

Graphical User Interface

Central processing unit

Cortex®

Boot and Security and OTP control

Controller Area Network (robust bus mainly used for automotive applications)

Graphics Processing Units

Elliptic curve cryptography

Error Correction Capability

media access control address (https://en.wikipedia.org/wiki/MAC_address)

Non Volatile Memory, like a flash memory

Power Management Integrated Circuit