Introduction

STM32CubeMX is a graphical tool for STM32 products. It is part of the STM32Cube initiative (see Section 1), and is available as a standalone application as well as in the STM32CubeIDE toolchain.

STM32CubeMX has the following key features:

- **Easy microcontroller selection** covering the whole STM32 portfolio
- **Board selection** from a list of STMicroelectronics boards
- **Easy microcontroller configuration** (pins, clock tree, peripherals, middleware) and generation of the corresponding initialization C code
- **Easy switching to another microcontroller** by importing a previously-saved configuration to a new MCU project
- **Easy exporting of current configuration to a compatible MCU**
- **Generation of configuration reports**
- **Generation of embedded C projects** for a selection of integrated development environment tool chains (STM32CubeMX projects include the generated initialization C code, MISRA 2004 compliant STM32 HAL drivers, the middleware stacks required for the user configuration, and all the relevant files for opening and building the project in the selected IDE)
- **Power consumption calculation** for a user-defined application sequence
- **Self-updates** allowing the user to keep STM32CubeMX up-to-date
- Download and update of STM32Cube embedded software required for user application development (see Appendix E for details on the STM32Cube embedded software offer)
- Download of CAD resources (schematic symbols, PCB footprints, and 3D models)

Although STM32CubeMX offers a user interface and generates C code compliant with STM32 MCU design and firmware solutions, users need to refer to the product technical documentation for details on actual implementation of peripherals and firmware. The following documents are available on www.st.com:

- STM32 microcontroller reference manuals and datasheets
- STM32Cube HAL/LL driver user manuals for STM32C0 (UM2985), STM32F0 (UM1785), STM32F1 (UM1850), STM32F2 (UM1940), STM32F3 (UM1786), STM32F4 (UM1725), STM32F7 (UM1905), STM32G0 (UM2303), STM32G4 (UM2570), STM32H7 (UM2217), STM32L0 (UM1749), STM32L1 (UM1816), STM32L4/L4+ (UM1884), STM32L5 (UM2659), STM32MP1 (https://wiki.st.com/stm32mpu), STM32U5 (UM2883), STM32WL (UM2642) and STM32WB (UM2442).
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1 STM32Cube overview

STM32Cube is an STMicroelectronics original initiative to make developers’ lives easier by reducing development effort, time and cost. STM32Cube covers the whole portfolio of STM32 devices, based on 32-bit Arm® Cortex® cores.

STM32Cube includes:

- STM32CubeMX, a graphical software configuration tool that allows the generation of C initialization code using graphical wizards.
- A comprehensive embedded software platform, delivered per series (such as STM32CubeF2 for STM32F2 series and STM32CubeF4 for STM32F4 series)
  - The STM32Cube HAL, STM32 abstraction layer embedded software ensuring maximized portability across the STM32 portfolio.
  - Low-layer APIs (LL) offering a fast light-weight expert-oriented layer, closer to the hardware compared with the HAL. These APIs are available only for a set of peripherals.
  - A consistent set of middleware components such as RTOS, USB, TCP/IP.
  - All embedded software utilities, delivered with a full set of examples.

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a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.
2 Getting started with STM32CubeMX

2.1 Principles

Customers need to quickly identify the MCU that best meets their requirements (core architecture, features, memory size, performance…). While board designers main concerns are to optimize the microcontroller pin configuration for their board layout and to fulfill the application requirements (choice of peripherals operating modes), embedded system developers are more interested in developing new applications for a specific target device, and migrating existing designs to different microcontrollers.

The time taken to migrate to new platforms and update the C code to new firmware drivers adds unnecessary delays to the project. STM32CubeMX was developed within STM32Cube initiative which purpose is to meet customer key requirements to maximize software reuse and minimize the time to create the target system:

- Software reuse and application design portability are achieved through STM32Cube firmware solution proposing a common Hardware Abstraction Layer API across STM32 portfolio.
- Optimized migration time is achieved thanks to STM32CubeMX built-in knowledge of STM32 microcontrollers, peripherals and middleware (LwIP and USB communication protocol stacks, FatFs file system for small embedded systems, FreeRTOS).

STM32CubeMX graphical interface performs the following functions:

- Fast and easy configuration of the MCU pins, clock tree and operating modes for the selected peripherals and middleware
- Generation of pin configuration report for board designers
- Generation of a complete project with all the necessary libraries and initialization C code to set up the device in the user defined operating mode. The project can be directly open in the selected application development environment (for a selection of supported IDEs) to proceed with application development (see Figure 1).

During the configuration process, STM32CubeMX detects conflicts and invalid settings and highlights them through meaningful icons and useful tool tips.
Figure 1. Overview of STM32CubeMX C code generation flow

STM32 Microcontrollers
Reference Manual & Datasheets

STM32CubeF4 Embedded Software Package
- **C projects, Documentation, Utilities**
- **Middleware Libraries** (freeRTOS, LwIP, USB, Graphics, etc.)
- **Drivers**
  - BFP, CMSIS,
  - HAL (Hardware abstraction layer)
  - LL (Low level drivers)

STM32CubeMX generated C project

STM32 Microcontroller configuration using STM32CubeMX
2.2 Key features

STM32CubeMX comes with the following features:

- **Project management**
  STM32CubeMX allows the user to create, save and load previously saved projects:
  - When STM32CubeMX is launched, the user can choose to create a new project or to load a previously saved project.
  - Saving the project saves user settings and configuration performed within the project in an .ioc file to be used when the project will be loaded in STM32CubeMX again.
  STM32CubeMX also allows the user to import previously saved projects in new ones.
  STM32CubeMX projects come in two flavors:
    - MCU configuration only: .ioc file is saved in a dedicated project folder.
    - MCU configuration with C code generation: in this case .ioc files are saved in a dedicated project folder along with the generated source C code. There can be only one .ioc file per project.

- **Easy project creation starting from an MCU, a board or an example**
  The new project window allows the user to create a project by selecting a microcontroller, a board, or an example project from STMicroelectronics STM32 portfolio. Different filtering options are available to ease the MCU and board selection. There is also the possibility to select an MCU through the Cross selector tab by comparing characteristics to those of competitors. Comparison criteria can be adjusted.

- **Easy pinout configuration**
  - From the Pinout view, the user can select the peripherals from a list and configure the peripheral modes required for the application. STM32CubeMX assigns and configures the pins accordingly.
  - For more advanced users, it is also possible to directly map a peripheral function to a physical pin using the Pinout view. The signals can be locked on pins to prevent STM32CubeMX conflict solver from moving the signal to another pin.
  - Pinout configuration can be exported as a .csv file.

- **Complete project generation**
  The project generation includes pinout, firmware and middleware initialization C code for a set of IDEs. It is based on STM32Cube embedded software libraries. The following actions can be performed:
  - Starting from the previously defined pinout, the user can proceed with the configuration of middleware, clock tree, services (RNG, CRC, etc...) and peripheral parameters. STM32CubeMX generates the corresponding initialization C code. The result is a project directory including generated main.c file and C header files for configuration and initialization, plus a copy of the necessary HAL and middleware libraries as well as specific files for the selected IDE.
  - The user can modify the generated source files by adding user-defined C code in user dedicated sections. STM32CubeMX ensures that the user C code is
preserved upon next C code generation (the user C code is commented if it is no longer relevant for the current configuration).

- STM32CubeMX can generate user files by using user-defined freemarker .ftl template files.

- From the **Project settings** menu, the user can select the development toolchain (IDE) for which the C code has to be generated. STM32CubeMX ensures that the IDE relevant project files are added to the project folder so that the project can be directly imported as a new project within STM32Cube or third party IDEs (IAR™ EWARM, Keil™ MDK-ARM).

**Power consumption calculation**

Starting with the selection of a microcontroller part number and a battery type, the user can define a sequence of steps representing the application life cycle and parameters (choice of frequencies, enabled peripherals, step duration). STM32CubeMX Power Consumption Calculator returns the corresponding power consumption and battery life estimates.

**Clock tree configuration**

STM32CubeMX offers a graphic representation of the clock tree as it can be found in the device reference manual. The user can change the default settings (clock sources, prescaler and frequency values). The clock tree is then updated accordingly. Invalid settings and limitations are highlighted and documented with tool tips. Clock tree configuration conflicts can be solved by using the solver feature. When no exact match is found for a given user configuration, STM32CubeMX proposes the closest solution.

**Automatic updates of STM32CubeMX and STM32Cube MCU packages**

STM32CubeMX comes with an updater mechanism that can be configured for automatic or on-demand check for updates. It supports STM32CubeMX self-updates as well as STM32Cube firmware library package updates. The updater mechanism also allows deleting previously installed packages.

**Report generation**

.pdf and .csv reports can be generated to document the user configuration work.

**Support of embedded software packages in CMSIS-Pack format (Software Packs)**

STM32CubeMX allows getting and downloading updates of embedded software packages delivered in CMSIS-Pack format. Selected software components belonging to these new releases can then be added to the current project.

**Generating Software Packs with STM32PackCreator**

STM32PackCreator is a graphical tool installed with STM32CubeMX in the Utilities folder. It allows the user to create Software Packs and STM32Cube Expansion
packages enhanced for STM32CubeMX. It can be launched from the ST Tools tab found in STM32CubeMX Tools view.

- **Contextual help**
  Contextual help windows can be displayed by hovering the mouse over Cores, Series, Peripherals and Middleware. They provide a short description and links to the relevant documentation corresponding to the selected item.

- **Access to ST tools**
  From STM32CubeMX project, the Tools tab allows the user to launch Tools directly or to access tools download pages on [www.st.com](http://www.st.com).

- **Video tutorials**
  STM32CubeMX allows the user to browse and play video tutorials. The video tutorial browser is accessible from the Help menu.

### 2.3 Rules and limitations

- C code generation covers only peripheral and middleware initialization. It is based on STM32Cube HAL firmware libraries.
- STM32CubeMX C code generation covers only initialization code for peripherals and middleware components that use the drivers included in STM32Cube embedded software packages. The code generation of some peripherals and middleware components is not yet supported.
- Refer to Appendix A for a description of pin assignment rules.
- Refer to Appendix B for a description of STM32CubeMX C code generation design choices and limitations.
3 Installing and running STM32CubeMX

3.1 System requirements

3.1.1 Supported operating systems and architectures

- Windows® 8.1: 64-bit (x64)
- Windows® 10: 64-bit (x64)
- Windows® 11: 64-bit (x64)
- Linux®: 64-bit (x64) (tested on Ubuntu LTS and Fedora)
- macOS®: 64-bit (x64) (tested on macOS Catalina and later)

For macOS the full disk access is required to load project files or install other packages from the file system. To enable full disk access for STM32CubeMX:
1. Go to “System preferences” and click to open “Security & Privacy” window (Figure 2)
2. Select “Privacy” tab
3. Select “Full Disk Access” from the left panel
4. Click the checkbox to enable full disk access to STM32CubeMX

Figure 2. Full disk access for macOS
3.1.2 Memory prerequisites

- Recommended minimum RAM: 2 Gbytes.

3.1.3 Software requirements

Administrator rights are required to download STM32CubeMX self-update packages, and at next STM32CubeMX launch, to complete the update process.

Java™ Runtime Environment

Starting with version V6.2.0, STM32CubeMX embeds the Java Runtime Environment (JRE™(a)) required for its execution and no longer uses the one installed on the user machine.

- For STM32CubeMX 6.3 the bundled JRE is AdoptOpenJDK-11.0.10+9 and JavaFX-11.0.2
- For STM32CubeMX 6.2 the bundled JRE is Liberica 1.8.0_265 of BellSoft

Versions earlier than STM32CubeMX V6.2.0 require a JRE to be installed. The JRE version constraints are:

- 64-bit version mandatory, 32-bit version not supported
- the STM32PackCreator companion tool requires JRE supporting JavaFX
- minimum JRE version is 1.8_45 (known limitation with 1.8_251)
- version 11 is supported, versions 7, 9, 10, 12 and upper are not supported

STMicroelectronics promotes the use of the following JREs:

- Oracle(a), subject to license fee
- Amazon Corretto™(b), no-cost solution based on OpenJDK, JDK installer recommended.

STM32CubeMX operation is not guaranteed with other JREs.

macOS software requirements

- Xcode must be installed on macOS computers
- Both Xcode and Rosetta must be installed on macOS computers embedding Apple® M1 processor.

3.2 Installing/uninstalling STM32CubeMX standalone version

3.2.1 Installing STM32CubeMX standalone version

To install STM32CubeMX, make sure you have administrator rights and then:

1. From an Internet browser, open the page www.st.com/stm32cubemx
2. Click “Get Software” to go to the software download section

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b. All other trademarks are the properties of their respective owners.
On Windows
   a) On STM32CubeMX-Win line, click “Get software” to download the package
   b) Extract (unzip) the downloaded package
   c) Make sure you have administrator rights
   d) Double-click on SetupSTM32CubeMX-VERSION-Win.exe to launch the installation wizard

Note: Upon successful installation on Windows, STM32CubeMX icon is displayed on your desktop and STM32CubeMX application is available from the Program menu. STM32CubeMX .ioc files are displayed with a cube icon, double-clicking on it opens the project in STM32CubeMX. When working on Windows, only the latest installation of STM32CubeMX is enabled in the Program menu. Previous versions can be kept on your PC (not recommended) when different installation folders have been specified. Otherwise, the new installation overwrites the previous one(s).

On Linux:
   a) On STM32CubeMX-Lin line, Click “Get software” to download the package
   b) Extract (unzip) the downloaded package.
   c) Make sure you have administrator rights to access the target installation directory. You can run the installation as root (or sudo) to install STM32CubeMX in shared directories.
   d) Do chmod 777 SetupSTM32CubeMX-VERSION to change the properties, so that the file is executable.
   e) Double-click on the SetupSTM32CubeMX-VERSION file, or launch it from the console window.

On macOS:
   a) On STM32CubeMX-Mac line, Click “Get software” to download the package
   b) Extract (unzip) the downloaded package.
   c) Make sure you have administrator rights.
   d) Double-click SetupSTM32CubeMX-VERSION.app application file to launch the installation wizard.

In case of error, try to fix it: - $sudo xattr -cr <Folder where the zip was extracted>
3.2.2 Installing STM32CubeMX from command line

There are two ways to launch an installation from a console window: either in console interactive mode or via a script.

Interactive mode

To perform interactive installation, proceed as follows:
1. extract (unzip) to folder the auto-extract installation file (SetupSTM32CubeMX-VERSION-Win.exe)
2. open a console window with administrator rights
3. go to the extracted folder (cd <folder path>)
4. run the command `jre\bin\java -jar SetupSTM32CubeMX-<VERSION>.exe -console`

At each installation step, an answer is requested (see Figure 3).

Figure 3. Example of STM32CubeMX installation in interactive mode
Auto-install mode

At end of an installation, performed either using STM32CubeMX graphical wizard or console mode, it is possible to generate an auto-installation script containing user preferences (see Figure 4).

You can then launch the installation by typing, from a console window with administrator rights, the following command:

```
SetupSTM32CubeMX-VERSION-Win.exe ABSOLUTE_PATH_TO_AUTO_INSTALL.xml
```

### 3.2.3 Uninstalling STM32CubeMX standalone version

**Uninstalling STM32CubeMX on macOS®**

There are two different ways to uninstall STM32CubeMX on Mac:

1. Move STM32CubeMX.VERSION.app to the trash
2. Use the following command line:
   a) For STM32CubeMX 6.2.x and later versions only:
      ```
cd SetupSTM32CubeMX-VERSION.app/Contents/Resources/Uninstaller
./uninstall.sh
```
   b) For STM32CubeMX 6.1.x and older versions only:
      ```
java -jar SetupSTM32CubeMX-VERSION.app/Contents/Resources/Uninstaller/uninstaller.jar.
```
Uninstalling STM32CubeMX on Linux®

There are two different ways to uninstall STM32CubeMX on Linux:

1. From a shell prompt by launching the uninstall script
   a) For STM32CubeMX 6.2.x and later versions:
      cd <STM32CubeMX installation path>/Uninstaller
      uninstall.sh
   b) For STM32CubeMX 6.1.x and older versions:
      java -jar <STM32CubeMX installation path>/Uninstaller/uninstaller.jar.

2. From a file explorer
   a) Go to <STM32CubeMX installation path>/Uninstaller
   b) For STM32CubeMX 6.2.x and later versions:
      Double-click the uninstall.sh script
   c) For STM32CubeMX 6.1.x and older versions:
      Double-click the start uninstall desktop shortcut.

Uninstalling STM32CubeMX on Windows®

There are three different ways to uninstall STM32CubeMX on Windows:

1. Through the Windows Control Panel:
   a) Select Programs and Features from the Windows Control Panel to display the list of programs installed on your computer.
   b) Right-click STM32CubeMX and select uninstall.

2. From a shell prompt with administrator rights, by using the following commands
   a) For STM32CubeMX 6.2.x and later versions:
      cd <STM32CubeMX installation path>/Uninstaller
      uninstall.bat
   b) For STM32CubeMX 6.1.x and older versions:
      java -jar <STM32CubeMX installation path>/Uninstaller/uninstaller.jar

3. Through a Windows File Explorer window:
   a) For STM32CubeMX 6.2.x and later versions:
      Go to the Uninstaller folder in STM32CubeMX installation directory.
      Right-click the uninstall.bat and “run as administrator”
   b) For STM32CubeMX 6.1.x and older versions only:
      Go to the Uninstaller folder in STM32CubeMX installation directory.
      Double-click startuninstall.exe, or double-click the uninstall shortcut on the desktop.
### 3.3 Launching STM32CubeMX

When running STM32CubeMX behind a proxy, see [Section 3.4.1](#).

#### 3.3.1 Running STM32CubeMX as a standalone application

To run STM32CubeMX as a standalone application on Windows select STM32CubeMX from Program Files > ST Microelectronics > STM32CubeMX or double-click STM32CubeMX icon on your desktop.

To run STM32CubeMX as a standalone application on Linux, launch the STM32CubeMX executable from STM32CubeMX installation directory.

To run STM32CubeMX as a standalone application on macOS, launch the STM32CubeMX application from the launchpad.

*Note:* There is no STM32CubeMX desktop icon on macOS.

#### 3.3.2 Running STM32CubeMX in command-line mode

To facilitate its integration with other tools, STM32CubeMX provides command-line modes. Thanks to the commands listed in [Table 1](#), it is possible to:

- load an MCU
- load an existing configuration
- save a current configuration
- set project parameters and generate corresponding code
- generate user code from templates
- load a board identified through its part number
- refresh the list of embedded software packages (packs and STM32Cube MCU packages) and install/remove a package
- select additional software (packs) components to add to the project.

Three command-line modes are available:

- To run STM32CubeMX in interactive command-line mode, use the following command lines:
  - On Windows:
    ```
    cd <STM32CubeMX installation path>
    jre\bin\java -jar STM32CubeMX.exe -i
    ```
  - On Linux:
    ```
    cd <STM32CubeMX installation path>
    ./STM32CubeMX -i
    ```
  - On macOS:
    ```
    cd <STM32CubeMX installation path> cd Contents/MacOs
    ./STM32CubeMX -i
    ```
  The “MX>” prompt is displayed, to indicate that the application is ready to accept commands.

- To run STM32CubeMX in command-line mode, getting commands from a script, use the following command lines:
  - On Windows:
    ```
    cd <STM32CubeMX installation path>
    jre\bin\java -jar STM32CubeMX.exe -i
    ```

---

*STM*
cd <STM32CubeMX installation path>
`jre\bin\java -jar STM32CubeMX.exe -s <script filename>`

- On Linux and macOS:
  `. /STM32CubeMX -s <script filename>`

All the commands to be executed must be listed in the script file. An example of script file content is shown below:

```plaintext
load STM32F417VETx
project name MyFirstMXGeneratedProject
project toolchain "MDK-ARM v4"
project path C:\STM32CubeProjects\STM32F417VETx
project generate
exit
```

- To run STM32CubeMX in command-line mode getting commands from a script and without UI, use the following command lines:
  - On Windows:
    cd <STM32CubeMX installation path>
    `jre\bin\java -jar STM32CubeMX.exe -q <script filename>`
  - On Linux and macOS:
    `. /STM32CubeMX -q <script filename>`

Here again, the user can enter commands when the MX prompt is displayed.

### Table 1. Command line summary

<table>
<thead>
<tr>
<th>Command line</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>help</td>
<td>Displays the list of available commands.</td>
<td>help</td>
</tr>
<tr>
<td>swmgr refresh</td>
<td>Refreshes the list of embedded software package versions available for download.</td>
<td>swmgr refresh</td>
</tr>
<tr>
<td>swmgr install stm32cube_&lt;series&gt;_&lt;version&gt; ask</td>
<td>Installs the specified STM32Cube MCU package version.</td>
<td>swmgr install stm32cube_f1_1.8.0 ask</td>
</tr>
<tr>
<td>swmgr remove stm32cube_&lt;series&gt;_&lt;version&gt;</td>
<td>Removes the specified STM32Cube MCU package version.</td>
<td>swmgr remove stm32cube_f1_1.8.0</td>
</tr>
<tr>
<td>swmgr install &lt;packVendor&gt;.&lt;packName&gt;.&lt;packVersion&gt; ask</td>
<td>Installs the specified pack version.</td>
<td>swmgr install STMicroelectronics. X-CUBE-NFC4.1.4.1 ask</td>
</tr>
<tr>
<td>swmgr remove &lt;packVendor&gt;.&lt;packName&gt;.&lt;packVersion&gt;</td>
<td>Removes the specified pack version.</td>
<td>swmgr remove STMicroelectronics. X-CUBE-BLE1.4.2.0</td>
</tr>
</tbody>
</table>
Table 1. Command line summary (continued)

<table>
<thead>
<tr>
<th>Command line</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>pack enable &lt;vendor&gt; &lt;pack&gt;[/bundle] &lt;version&gt; &lt;class&gt; &lt;group&gt;[/subgroup] [variant]</td>
<td>Selects a software pack component to add in the project. The presence of “/” in the second and/or the fifth parameter(s) indicates, respectively, the explicit mention of a bundle and/or a subgroup (reference: Arm CMSIS pack pdsc format). To find out the pack / bundle / class / group / subgroup names of the component to enable, select the component and click “Hide/Show details” from the Additional Software window.</td>
<td>pack enable STMicroelectronics “X-CUBE-BLE1/BlueNRG-MS” 1.0.0 “Wireless” “Controller”</td>
</tr>
<tr>
<td>pack validate</td>
<td>Applies in the project all pack components enabled since the “pack validate” command was last called.</td>
<td>pack validate</td>
</tr>
</tbody>
</table>
| load <mcu> | Loads the selected MCU. | load STM32F101RCTx  
load STM32F101Z(F-G)Tx |
| load <board part number> <allmodes|nomode> | Loads the selected board with all peripherals configured in their default mode (allmodes) or without any configuration (nomode). | loadboard NUCLEO-F030R8 allmodes  
loadboard NUCLEO-F030R8 nomode |
| config load <filename> | Loads a previously saved configuration. | config load “C:\Cube\ccmram\ccmram.ioc” |
| config save <filename> | Saves the current configuration. | config save “C:\Cube\ccmram\ccmram.ioc” |
| config saveext <filename> | Saves the current configuration with all parameters, including those for which values have been kept to default (unchanged by the user). | config saveext “C:\Cube\ccmram\ccmram.ioc” |
| config saveas <filename> | Saves the current project under a new name. | config saveas “C:\Cube\ccmram2\ccmram2.ioc” |
| csv pinout <filename> | Exports the current pin configuration as a csv file. This file can be (later) imported into a board layout tool. | Csv pinout mypinout.csv |
| script <filename> | Runs all commands in the script file. There must be one command per line. | script myscript.txt |
| project couplefilesbyip <0|1> | This option allows the user to choose between 0 (to generate the peripheral initializations in the main) and 1 (to generate each peripheral initialization in dedicated .c/.h files). | project couplefilesbyip 1 |
### Table 1. Command line summary (continued)

<table>
<thead>
<tr>
<th>Command line</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>setDriver &lt;Peripheral Name&gt; &lt;HAL</td>
<td>LL&gt;</td>
<td>For the supported series, STM32CubeMX can generate peripheral initialization code based on LL or on HAL drivers. This command line allows the user to choose, for each peripheral, between HAL- and LL-based code generation. By default code generation is based on HAL drivers.</td>
</tr>
<tr>
<td>generate code &lt;path&gt;</td>
<td>Generates only &quot;STM32CubeMX generated&quot; code and not a complete project that would include STM32Cube firmware libraries and toolchains project files. To generate a project, use “project generate”.</td>
<td>generate code C:\mypath</td>
</tr>
<tr>
<td>set tpl_path &lt;path&gt;</td>
<td>Sets the path to the source folder containing the .ftl user template files. All the template files stored in this folder are used for code generation.</td>
<td>set tpl_path C:\myTemplates\</td>
</tr>
<tr>
<td>set dest_path &lt;path&gt;</td>
<td>Sets the path to the destination folder that will hold the code generated according to user templates.</td>
<td>set dest_path C:\myMXProject\inc\</td>
</tr>
<tr>
<td>get tpl_path</td>
<td>Retrieves the path name of the user template source folder.</td>
<td>get tpl_path</td>
</tr>
<tr>
<td>get dest_path</td>
<td>Retrieves the path name of the user template destination folder.</td>
<td>get dest_path</td>
</tr>
<tr>
<td>SetStructure &lt;Advanced/Basic&gt;</td>
<td>Selects the project structure to generate.</td>
<td>SetStructure Basic</td>
</tr>
<tr>
<td>SetCopyLibrary &lt;copy all / copy only / copy as reference&gt;</td>
<td>Selects how the reference libraries are copied to the projects.</td>
<td>SetCopyLibrary &quot;copy all&quot;</td>
</tr>
<tr>
<td>project setCustomFWPath &lt;CustomFwLocation&gt;</td>
<td>Specifies a path to STM32Cube MCU software libraries different from STM32Cube repository path (specified under Help &gt; Updater settings).</td>
<td>project SetCustomFwPath &quot;F:\SharedRepository\STM32Cube_FW_F0_V1.11.0&quot;</td>
</tr>
<tr>
<td>project toolchain &lt;toolchain&gt;</td>
<td>Specifies the toolchain to be used for the project. Use the “project generate” command to generate the project for that toolchain.</td>
<td>EWARM “MDK-ARM V4” “MDK-ARM V5” STM32CubeIDE</td>
</tr>
<tr>
<td>project name &lt;name&gt;</td>
<td>Specifies the project name.</td>
<td>project name ccmram</td>
</tr>
<tr>
<td>project path &lt;path&gt;</td>
<td>Specifies the path where to generate the project.</td>
<td>project path C:\Cube\ccmram</td>
</tr>
<tr>
<td>project generate</td>
<td>Generates the full project.</td>
<td>project generate</td>
</tr>
<tr>
<td>exit</td>
<td>Ends STM32CubeMX process.</td>
<td>exit</td>
</tr>
</tbody>
</table>
3.4 Getting updates using STM32CubeMX

STM32CubeMX implements a mechanism to access the Internet and to:

- download embedded software packages: STM32Cube MCU packages (full releases and patches) and third-party packages (.pack) based on the Arm® CMIS pack format
- manage a user-defined list of third-party packs
- check for STM32CubeMX and embedded software packages updates
- perform self-updates of STM32CubeMX
- refresh STM32 MCUs descriptions and documentation offer.

Installation and update related submenus are available under the Help menu and from the home page as well.

Off-line updates can also be performed on computers without Internet access (see Section 3.4.3). This is done by browsing the filesystem and selecting available STM32Cube MCU packages.

If the PC on which STM32CubeMX runs is connected to a computer network using a proxy server, STM32CubeMX needs to connect to that server to access the Internet, get self-updates and download firmware packages. Refer to Section 3.4.2 for a description of this connection configuration.

To view Windows default proxy settings, select Internet options from the Control panel and select LAN settings from the Connections tab (see Figure 5).

Figure 5. Displaying Windows default proxy settings
Several proxy types exist and different computer network configurations are possible:

- Without proxy: the application directly accesses the web (Windows default configuration).
- Proxy without login/password
- Proxy with login/password: when using an Internet browser, a dialog box opens and prompts the user to enter its login/password.
- Web proxies with login/password: when using an Internet browser, a web page opens and prompts the user to enter its login/password.

If needed, contact your IT administrator for proxy information (proxy type, http address, port).

STM32CubeMX does not support web proxies. In this case, the user cannot benefit from the update mechanism and must manually copy the STM32Cube MCU packages from http://www.st.com/stm32cube to the repository. To do it, follow the sequence below:

1. Go to http://www.st.com/stm32cube and download the relevant STM32Cube MCU package from the Associated Software section.
2. Unzip the zip package to your STM32Cube repository. Find out the default repository folder location in the Updater settings tab as shown in Figure 6 (you might need to update it to use a different location or name).

3.4.1 Running STM32CubeMX behind a proxy server

When proxies are implementing full SSL inspection, STM32CubeMX must be configured to use the proxy certificate.

- On Windows:
  Typically, it comes down to using Windows certificate list.
  a) there is no additional configuration necessary to run STM32CubeMX executable (it is already configured to use Windows certificate list)
  b) the command line must be adjusted to run STM32CubeMX from the command line:
     
     cd <STM32CubeMX install path>
     jre\bin\java -Djavax.net.ssl.trustStoreType=WINDOWS-ROOT -jar
     STM32CubeMX.exe

- On Mac/Linux and on Windows systems when the proxy certificate is not in Windows certificate store, the certificate must be manually imported. This is done using keytool from a command prompt, as follows:

  $ cd  <CUBEMX_INSTALL_DIR>/jre
  $ bin/keytool -importcert -alias <your certificate alias name> -keystore lib/security/cacerts -file  <path to you proxy certificate file>.crt

  When prompted, enter the password: changeit
  When prompted, accept to trust the certificate: yes

  Then (Windows only) edit file <CUBEMX_INSTALL_DIR>/STM32CubeMX.I4j.ini and remove the line: -Djavax.net.ssl.trustStoreType=WINDOWS-ROOT
3.4.2 Updater configuration

To perform STM32Cube new library package installation or updates, the tool must be configured as follows:

1. Select Help > Updater Settings to open the Updater Settings window.
2. From the Updater Settings tab (see Figure 6)
   a) Specify the repository destination folder where the downloaded packages will be stored.
   b) Enable/Disable the automatic check for updates.

![Updater Settings window](image)

3. In the Connection Parameters tab, specify the proxy server settings appropriate for your network configuration by selecting a proxy type among the following possibilities (see Figure 7):
   - No Proxy
   - Use System Proxy Parameters
     On Windows, proxy parameters are retrieved from the PC system settings.
     Uncheck “Require Authentication” if a proxy server without login/password configuration is used.
– Manual Configuration of Proxy Server
   Enter the Proxy server http address and port number. Enter login/password information or uncheck “Require Authentication” if a proxy server without login/password configuration is used.

4. Optionally uncheck **Remember my credentials** to prevent STM32CubeMX to save encrypted login/password information in a file. This implies reentering login/password information each time STM32CubeMX is launched.

5. Click the **Check Connection** button to verify if the connection works. A green check mark appears to confirm that the connection operates correctly.

   Figure 7. Connection Parameters tab - Manual Configuration of Proxy Server

6. Select **Help > Install New Libraries** submenu to select among a list of possible packages to install.

7. If the tool is configured for manual checks, select **Help > Check for Updates** to find out about new tool versions or firmware library patches available to install.
3.4.3 Installing STM32 MCU packages

To download new STM32 MCU packages, follow the steps below:

1. Select Help > Manage embedded software packages to open the Embedded Software Packages Manager (see Figure 8), or use Install/Remove button from the Home page.

Expand/collapse buttons expands/collapses the list of packages, respectively.

If the installation was performed using STM32CubeMX, all the packages available for download are displayed along with their version including the version currently installed on the user PC (if any), and the latest version available from www.st.com.

If no Internet access is available at that time, choose “From Local …”, then browse to select the zip file of the desired STM32Cube MCU package that has been previously downloaded. An integrity check is performed on the file to ensure that it is fully supported by STM32CubeMX.

The package is marked in green when the version installed matches the latest version available from www.st.com.

2. Click the checkbox to select a package then “Install Now” to start the download.

See Figure 8 for an example.

Figure 8. Embedded Software Packages Manager window
3.4.4 Installing STM32 MCU package patches

Use the procedure described in Section 3.4.3 to download STM32 MCU package patches. A library patch, such as STM32Cube_FW_F7_1.4.1, can be easily identified by its version number which third digit is non-null (e.g. ‘1’ for the 1.4.1 version).

The patch is not a complete library package but only the set of library files that need to be updated. The patched files go on top of the original package (e.g. STM32Cube_FW_F7_1.4.1 complements STM32Cube_FW_F7_1.4.0 package).

Prior to 4.17 version, STM32CubeMX copies the patches within the original baseline directory (e.g. STM32Cube_FW_F7_V1.4.1 patched files are copied within the directory called STM32Cube_FW_F7_V1.4.0).

Starting with STM32CubeMX 4.17, downloading a patch leads to the creation of a dedicated directory. As an example, downloading STM32Cube_FW_F7_V1.4.1 patch creates the STM32Cube_FW_F7_V1.4.1 directory that contains the original STM32Cube_FW_F7_V1.4.0 baseline plus the patched files contained in STM32Cube_FW_F7_V1.4.1 package.

Users can then choose to go on using the original package (without patches) for some projects and upgrade to a patched version for others projects.

3.4.5 Installing embedded software packs

Starting from the release 4.24, STM32CubeMX offers the possibility to select third-party embedded software packages coming in the Arm® Keil™ CMSIS-Pack format (.pack), whose contents are described thanks to the pack description (.pdsc) file. Reference documentation is available from http://www.keil.com.

1. Select Help > Manage embedded software packages to open the New Libraries Manager window (see Figure 9), or use Install/Remove button from the Home page, or from the project Pinout & Configuration view (select Software Packs > Manage Software Packs).

   Use Expand/collapse buttons to expand/collapse the list of packages, respectively.
2. Click **From Local** ... button to browse the computer filesystem and select an embedded software package. STM32Cube MCU packages come as zip archives and embedded software packs come as .pack archives. This action is required in the following cases:
   - No Internet access is possible but the embedded software package is available locally on the computer.
   - The embedded software package is not public and hence not available on Internet. For such packages, STM32CubeMX cannot detect and propose updates.

3. Click **From URL**... button to specify the download location from Internet for either one of the pack .pdsc file or the vendor pack index (.pidx). Proceed as follow:
   a) Choose **From URL** ... and click **New** (see Figure 10).
   b) Specify the .pdsc file url. As an example, the url of Oryx-Embedded middleware pack is https://www.oryx-embedded.com/download/pack/Oryx-Embedded.Middleware.pdsc (see Figure 11).
c) Click the **Check** button to verify that the provided url is valid (see *Figure 11*).

*Figure 11. Checking the validity of vendor pack.pdsc file url*
d) Click OK. The pack pdsc information is now available in the user defined pack list (see Figure 12).

To delete a url from the list, select the url checkbox and click Remove.

Figure 12. User-defined list of software packs

![User Defined Packs Manager](image)

e) Click OK to close the window and start retrieving psdc information. Upon successful completion, the available pack versions are shown in the list of libraries that can be installed. Use the corresponding checkbox to select a given release.

Figure 13. Selecting an embedded software pack release

![Embedded Software Packages Manager](image)
Installing and running STM32CubeMX UM1718

f) Click **Install Now** to start downloading the software pack. A progress bar opens to indicate the installation progress. If the pack comes with a license agreement, a window pops up to ask for user’s acceptance (see **Figure 14**). When the installation is successful, the check box turns green (see **Figure 15**). The user can then add software components from this pack to its projects.

**Figure 14. License agreement acceptance**

![License agreement acceptance](image)
3.4.6 Removing already installed embedded software packages

Proceed as follows (see figures 16 to 18) to clean up the repository from old library versions, thus saving disk space:

1. Select Help > Manage embedded software packages to open the Embedded Software Packages Manager, or use Install/Remove button from the Home page.
2. Click a green checkbox to select a package available in stm32cube repository.
3. Click the Remove Now button and confirm. A progress window then opens to show the deletion status.
Installing and running STM32CubeMX

Figure 16. Removing libraries

Figure 17. Removing library confirmation message

Figure 18. Library deletion progress window
3.4.7 Checking for updates

STM32CubeMX can check if updates are available for STM32CubeMX currently installed version or for the embedded software packages installed in the repository folder (Figure 19).

When the updater is configured for automatic checks, it regularly verifies if updates are available.

When automatic checks have been disabled in the updater settings window, the user can manually check if updates are available:

1. Click the icon to open the Update Manager window or Select Help > Check for Updates. All the updates available for the user current installation are listed.
2. Click the check box to select a package, and then Install Now to download the update.

---

**Warning:** When performing STM32CubeMX self-updates, administrator rights are required when downloading the self-update package and during the STM32CubeMX launch that completes the update process:

1. Launch STM32CubeMX with administrator account
2. Go to Help > Check for updates menu, select MX update package and click "Install now" to start the download.
3. Re-launch STM32CubeMX with the administrator account to finish the update process

---

Figure 19. Help menu: checking for updates
4 STM32CubeMX user interface

STM32CubeMX user interface comes with three main views the user can navigate through using convenient breadcrumbs:
1. the Home page
2. the New project window
3. the project page

They come with panels, buttons and menus allowing users to take actions and make configuration choices with a single click.

The user interface is detailed in the following sections.

For C code generation, although the user can switch back and forth between the different configuration views, it is recommended to follow the sequence below:
1. From the Project Manager view, configure the project settings.
2. From the Mode panel in the Pinout & Configuration view, configure the RCC peripheral by enabling the external clocks, master output clocks, audio input clocks (when relevant for your application). This automatically displays more options on the Clock configuration view (see Figure 97). Then, select the features (peripherals, middlewares) and their operating modes relevant to the application.
3. If necessary, adjust the clock tree configuration from the clock configuration view.
4. From the Configuration panel in the Pinout & Configuration view configure the parameters required to initialize the peripherals and middleware operating modes.
5. Generate the initialization C code by clicking GENERATE CODE.
4.1 Home page

The Home page is the first window that opens up when launching STM32CubeMX (see Figure 20). Closing it closes down the application. It offers shortcuts for some top level menus, an image carousel displaying STM32 latest news, as well as links to social network sites and external tools. Top-level menus and social network links remain accessible from the subsequent project page and are detailed in the following sections.

Figure 20. STM32CubeMX Home page
4.1.1 File menu

Refer to Table 2 for a description of the File menu and shortcuts.

Table 2. Home page shortcuts

<table>
<thead>
<tr>
<th>Name</th>
<th>Keyboard shortcut</th>
<th>Description</th>
<th>Home page shortcut</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Project...</td>
<td>Ctrl-N</td>
<td>Opens a new project window showing all supported MCUs and a set of STMicroelectronics boards to choose from(1).</td>
<td>To create a new project starting from a board click</td>
</tr>
<tr>
<td></td>
<td></td>
<td>To create a new project starting from an MCU click</td>
<td>ACCESS TO BOARD SELECTOR</td>
</tr>
<tr>
<td>Load Project...</td>
<td>Ctrl-L</td>
<td>Loads an existing STM32CubeMX project configuration by selecting an STM32CubeMX configuration .ioc file (see Caution:).</td>
<td>Under Other project, click browse icon</td>
</tr>
<tr>
<td>Import Project...</td>
<td>Ctrl-I</td>
<td>Opens a new window to select the configuration file to be imported as well as the import settings. The import is possible only if you start from an empty MCU configuration. Otherwise, the menu is disabled(2).</td>
<td>None</td>
</tr>
<tr>
<td>Save Project</td>
<td>Ctrl-S</td>
<td>Saves current project configuration (pinout, clock tree, peripherals, middlewares, Power Consumption Calculator) as a new project. This action creates a project folder including an .ioc file, according to user defined project settings.</td>
<td>None</td>
</tr>
<tr>
<td>Save Project as...</td>
<td>Ctrl-A</td>
<td>Saves the current project.</td>
<td>None</td>
</tr>
<tr>
<td>Close Project</td>
<td>Ctrl-C</td>
<td>Closes the current project and switches back to the welcome page.</td>
<td>None</td>
</tr>
<tr>
<td>Recent Projects</td>
<td>none</td>
<td>Displays the list of the five most recently saved projects.</td>
<td>Under Recent Project, click icon next to the project name.</td>
</tr>
<tr>
<td>Generate Report</td>
<td>Ctrl-R</td>
<td>Saves the project current configuration as two documents (pdf and text formats).</td>
<td>None</td>
</tr>
<tr>
<td>Exit</td>
<td>Ctrl-X</td>
<td>Proposes to save the project (if needed), then closes the application.</td>
<td>To close the window and the application click on .</td>
</tr>
</tbody>
</table>

1. On New project: to avoid any popup error messages at this stage, make sure an Internet connection is available (Connection Parameters tab under Help > Updater settings menu) or that Data Auto-refresh settings are set to No Auto-Refresh at application start (Updater Settings tab under Help > Updater Settings menu).

2. On Import, a status window displays the warnings or errors detected when checking for import conflicts. The user can then decide to cancel the import.
Caution: On project load: STM32CubeMX detects if the project was created with an older version of the tool and if this is the case, it proposes the user to either migrate to use the latest STM32CubeMX database and STM32Cube firmware version, or to continue. Prior to STM32CubeMX 4.17, clicking Continue still upgrades to the latest database “compatible” with the SMT32Cube firmware version used by the project. Starting from STM32CubeMX 4.17, clicking Continue keeps the database used to create the project untouched. If the required database version is not available on the computer, it is automatically downloaded.

When upgrading to a new version of STM32CubeMX, make sure to always backup your projects before loading the new project (especially when the project includes user code).

4.1.2 Window menu and Outputs tabs

The Window menu allows the user to access the Outputs function.

Table 3. Window menu

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs</td>
<td>Selecting/deselecting Outputs from the Window menu hides/shows the following Outputs tabs at the bottom of STM32CubeMX project page (see Figure 21)</td>
</tr>
<tr>
<td></td>
<td>– MCUs selection tab that lists the MCUs of a given family matching the user criteria (series, peripherals, package,...) when an MCU was selected last(1).</td>
</tr>
<tr>
<td></td>
<td>– Outputs tab that displays a non-exhaustive list of the actions performed, raised errors and warnings (see Figure 22) found upon user actions.</td>
</tr>
<tr>
<td>Font size</td>
<td>Makes possible to change STM32CubeMX font size settings. STM32CubeMX must be re-launched for changes to take effect.</td>
</tr>
</tbody>
</table>

1. Selecting a different MCU from the list resets the current project configuration and switches to the new MCU. The user is then prompted to confirm this action before proceeding.
Figure 21. Window menu

Figure 22. Output view
4.1.3 Help menu

Refer to Table 4 for a description of the Help menu and shortcuts.

<table>
<thead>
<tr>
<th>Name</th>
<th>Keyboard shortcut</th>
<th>Description</th>
<th>Home page shortcut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Help</td>
<td>F1</td>
<td>Opens the STM32CubeMX user manual.</td>
<td>None</td>
</tr>
<tr>
<td>About</td>
<td>Alt-A</td>
<td>Shows version information.</td>
<td>None</td>
</tr>
<tr>
<td>Docs &amp; Resources</td>
<td>Alt-D</td>
<td>Displays the official documentation available for the MCU used in the current project.</td>
<td>None</td>
</tr>
<tr>
<td>Video Tutorials</td>
<td>Alt-V</td>
<td>Opens the Video Tutorial browser that proposes a list of videos and allows the user to launch a video in one click.</td>
<td>None</td>
</tr>
<tr>
<td>Refresh Data</td>
<td>Alt-R</td>
<td>Opens a dialog window that proposes to refresh STM32CubeMX database with STM32 MCU latest information (description and list of official documents), and allows the user to download all official documentation in one shot.</td>
<td>None</td>
</tr>
<tr>
<td>Check for Updates</td>
<td>Alt-C</td>
<td>Shows the software and firmware release updates available for download.</td>
<td>Click [CHECK FOR UPDATES]</td>
</tr>
<tr>
<td>Manage embedded software packages</td>
<td>Alt-U</td>
<td>Shows all the embedded software packages available for installation. A green check box indicates that the package is already installed in the user repository folder (the repository folder location is specified under Help &gt; Updater Settings menu).</td>
<td>Click [INSTALL/REMOVE]</td>
</tr>
<tr>
<td>Updater Settings...</td>
<td>Alt-S</td>
<td>Opens the updater settings window to configure manual versus automatic updates, proxy settings for Internet connections, repository folder where the downloaded software and firmware releases will be stored.</td>
<td>None</td>
</tr>
<tr>
<td>User Preferences</td>
<td></td>
<td>Opens the user preference window to enable or disable collect of features usage statistics.</td>
<td>None</td>
</tr>
</tbody>
</table>

4.1.4 Social links

Developer communities on popular social platforms such as Facebook™, Twitter™, STM32 YouTube™ channel, as well as ST Community can be accessed from the STM32CubeMX toolbar (see Figure 23).

Figure 23. Link to social platforms
4.2 New Project window

The New Project window is accessible through the File Menu or directly through shortcuts from the Home page (see Figure 24).

Figure 24. New Project window shortcuts

The main purpose here is to select from the STM32 portfolio a microcontroller or board part number that best fits the user application needs, or simply to get started using an example project.

This window shows three tabs to choose from:

- an **MCU selector** tab (offering a list of target processors)
- a **Board selector** tab (showing a list of STMicroelectronics boards)
- an **Example selector** tab (allows the user to browse and open an example project)

The new project window also features a **Cross selector** tab (allows the user to find, for a given MCU/MPU part number and for a set of criteria, the best replacement within the STM32 portfolio)

For STM32L5 series the security features of the Arm Cortex-M33 processor and its Arm® TrustZone® for Armv8-M are combined with ST security implementation. Selecting an
STM32L5 MCU or board requires to choose whether to activate Arm® TrustZone® (hardware security) or not (see Figure 25). The project is adjusted accordingly:

- if Arm® TrustZone® is not activated, the solution is the same as for other STM32Lx series
- if Arm® TrustZone® is activated, the project configuration and the generated project shows specificities related to the security features (refer to dedicated sections in this manual).

![Figure 25. Enabling Arm® TrustZone® for STM32L5 series](image)

The selectors result view can be adjusted (see Figure 26):

- Left click the column to sort
- Right click to add/remove columns.

![Figure 26. Adjusting selector results](image)

### 4.2.1 MCU selector

**MCU selection**

The MCU selector enables filtering on a combination of criteria: series, lines, packages, peripherals, or additional characteristics such as price, memory size or number of I/Os (see Figure 27), and on their graphics capabilities as well.
Export to Excel feature

By clicking on the 🔄 Export icon, the user can save the MCU table information to an Excel file.

Show favorite MCUs feature

Clicking the ★ icon for an MCU from the list marks it as favorite, see Figure 28.
MCU close selector feature

When the number of MCUs found is lower than 50, the selector offers to list the MCUs with close features (see Figure 29). Clicking the Display similar items button displays them (see Figure 30): by default, MCUs are sorted first by matching ratio, then by part number. For close MCUs (those with a matching ratio lower than 100%) rows are shown in gray, and non matching cells are highlighted in dark gray.

Figure 29. New Project window - MCU list with close function
Figure 30. New Project window - List showing close MCUs

Note: A matching percentage is computed for each user selected criteria, for example:
- When requesting four instances of the CAN peripheral, the MCUs with only three instances reach a 75% match on the CAN criteria.
- If the maximum price criteria is selected, the matching ratio for a given MCU is the maximum requested price divided by the actual MCU price. In the case of a minimum price criteria, the matching ratio is the MCU price divided by the minimum requested price. Finally, all criteria ratios are averaged to give the Match column percentage value.
4.2.2 Board selector

The Board selector enables filtering on STM32 board types, series and peripherals (see Figure 31). Only the default board configuration is proposed. Alternative board configurations obtained by reconfiguring jumpers or by using solder bridges are not supported.

When a board is selected, the Pinout view is initialized with the relevant MCU part number along with the pin assignments for the LCD, buttons, communication interfaces, LEDs, and other functions. Optionally, the user can choose to initialize it with the default peripheral modes.

When a board configuration is selected, the signals change to 'pinned', i.e. they cannot be moved automatically by STM32CubeMX constraint solver (user action on the peripheral tree, such as the selection of a peripheral mode, does not move the signals). This ensures that the user configuration remains compatible with the board.

Figure 31. New Project window - Board selector
4.2.3 Example selector

The Example selector allows the user to browse a large set of examples and to start a new project from a selected example.

Note: An example is always for a specific board and consequently for the MCU available with that board.

Thanks to the filter panel it is possible to filter down the example list for a specific board type, series, peripheral or middleware as well as other characteristics (see Figure 32).

![Figure 32. New project window - Example selector](image)

Selecting an example and clicking "Start project" allows STM32CubeMX to copy the example as a new project (the user can change the default location at this stage).

**Warning:** For some examples the "Start Project" button is shown with an "Under Development" warning icon. Projects created from these examples may be not functional (they do not compile). Fixes are in development.

Several options are available to open the newly created project (see Figure 33):
- with STM32CubeMX (available only for examples listed with a CubeMX version set)
- with a File explorer
- with one of the supported toolchains (provided the toolchain is already installed on your computer)
Note: If the STM32Cube MCU package necessary for the example is missing from the repository STM32CubeMX automatically starts the download process.

4.2.4 Cross selector

Part number selection

The Cross selector allows users to find products of the STM32 portfolio that best replace the MCU or MPU they are currently using (from ST or other silicon vendors).

To access this functionality, STM32CubeMX data must be up to date. This is ensured using Refresh Data from the Help menu (see Figure 34).
Clicking “ACCESS TO CROSS SELECTOR” under the “Start my project from Cross Selector” section of the main page opens the New Project window on the Cross selector tab.

Two drop downs menus allow the user to select the vendor and the part number of the product to be compared to (see Figure 35). A part number can also be entered partially: STM32CubeMX proposes a list of matching products (see Figure 36).

**Figure 35. Cross selector - Part number selection per vendor**

![Cross selector - Part number selection per vendor](image1)

**Figure 36. Cross selector - Partial part number selection completion**

![Cross selector - Partial part number selection completion](image2)

**Compare cart**

Once a part number is selected, a list of matching ST part number candidates is displayed along with their matching ratio in the Matching ST candidates panel.

By default, the three closest matches are selected and added to the compare cart along with the part number to be compared to (see Figure 37).
This selection can be changed anytime in the Matching ST candidates panel.

The comparison can be customized: the features to be used for comparison can be unselected when considered as irrelevant and their level of importance can be adjusted. These choices affect the computed matching ratio.

The comparison is disabled for features that are not supported on the part number to be compared with, or when the feature information is unavailable.

Buttons are available to manipulate and save a copy of the compare cart view:
- to hide criteria that are not used for the comparison or show all criteria.
- to come back to default STM32CubeMX comparison settings
- to copy and paste the current cart view in a document or email.

**MCU/MPU selection for a new project**

Clicking an STM32 part number from the compare cart selects it in the MCU/MPU Selector tab, and clicking on creates a new project for that part number (see Figure 38).
4.3 Project page

Once an STM32 part number or a board has been selected or a previously saved project has been loaded, the project page opens, showing the following set of views (refer to dedicated sections for their detailed description):

- Pinout & Configuration
- Clock Configuration
- Project Manager
- Tools

Users can move across the different views without impacting their project configuration.

A **GENERATE CODE** button is always accessible for the user to click and allows to generate the code corresponding to the current project configuration.

Moreover, thanks to convenient navigation breadcrumbs (see Figure 39), the user can detect what its current location is in STM32CubeMX user interface, and can move to other locations:

- to the home page by clicking the Home breadcrumb
- to the new project window by clicking the part number
- back to the project page by clicking the project name (or Untitled if the project does not have a name yet).
Figure 39. STM32CubeMX Main window upon MCU selection
Selecting a board, then answering No in the dialog window requesting to initialize all peripherals to their default mode, automatically sets the pinout for this board. However, only the pins set as GPIOs are marked as configured, i.e. highlighted in green, while no peripheral mode is set. The user can then manually select from the peripheral tree the peripheral modes required for its application (see Figure 40).

Figure 40. STM32CubeMX Main window upon board selection (peripherals not initialized)
Selecting a board and accepting to initialize all peripherals to their default mode automatically sets both the pinout and the default modes for the peripherals available on the board. This means that STM32CubeMX generates the C initialization code for all the peripherals available on the board and not only for those relevant to the user application (see Figure 41).

Figure 41. STM32CubeMX Main window upon board selection (peripherals initialized with default configuration)

4.4 Pinout & Configuration view

The Pinout & Configuration view comes with the following main panels, function and menu:

- A **Component list** that can be visualized in alphabetical order and per categories. By default, it consists of the list of peripheral and middleware that the selected MCU supports. Selecting a component from that list opens two additional panels (Mode and Configuration) that allow the user to set its functional mode and configure the initialization parameters that will be included in the generated code.
- A **Pinout view** that shows a graphic representation of the pinout for the selected package (e.g. BGA, QFP) where each pin is represented with its name (e.g. PC4) and its current alternate function assignment, if any.
- A **System view** that gives an overview of all the software configurable components: GPIOs, peripherals, middleware and additional software components. Clickable
buttons allow opening the configuration options for the given component (Mode and Configuration panels). The button icon color reflects the status of the configuration status.

- **A Software Packs** menu with two sub-menus:
  - **Select Components** to select, for the current project, software components not available by default. This selection updates the **Pinout & Configuration** view accordingly
  - **Manage Software Packs** to install/uninstall software packs.
- **An Additional Software** function that allows to select, for the current project, software components that are not available by default. Selecting an additional software component updates the **Pinout & Configuration** view accordingly.
- **A Pinout** menu that allows the user to perform pinout related actions such as clear pinout configuration or export pinout configuration as csv file.

**Tips**

- You can resize the different panels at will: hovering the mouse over a panel border displays a two-ended arrow: right-click and pull in a direction to either extend or reduce the panel.
- You can show/hide the Configuration, Mode, Pinout and System views using the open and close arrows.

### 4.4.1 Component list

The component list shows all the components available for the project. Selecting a component from the component list, opens the Mode and Configuration panels.

**Contextual help**

The **Contextual Help** window is displayed when hovering the mouse over a peripheral or a middleware short name.

By default, the window displays the extended name and source of configuration conflicts if any (see **Figure 42**).

![Figure 42. Contextual Help window (default)](image)

Clicking the *details and documentation* link (or CTRL+d) provides additional information such as summary and reference documentation links (see **Figure 43**). For a given...
peripheral, clicking *Datasheet or Reference manual* opens the corresponding document, stored in STM32CubeMX repository folder, at the relevant chapter. Since microcontrollers datasheets and reference manuals are downloaded to STM32CubeMX repository only upon user request, a functional Internet connection is required:

- To check your Internet connection, open the **Connection** tab from the **Help > Updater Settings** menu.
- To request the download of reference documentation for the currently selected microcontroller, click **Refresh** from the **Help > Refresh Data** menu window.

**Figure 43. Contextual Help detailed information**

<table>
<thead>
<tr>
<th>Icons and color schemes</th>
</tr>
</thead>
</table>

*Table 5* shows the icons and color scheme used in the component list view and the corresponding color scheme in the Mode panel.

**Table 5. Component list, mode icons and color schemes**

<table>
<thead>
<tr>
<th>Display</th>
<th>Component status</th>
<th>Corresponding Mode view / Tooltips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain black text</td>
<td><strong>Example:</strong> UART5 The peripheral is not configured (no mode is set) and all modes are available.</td>
<td><img src="image" alt="Mode view" /></td>
</tr>
<tr>
<td>Gray italic text</td>
<td><strong>Example:</strong> LWIP Peripheral is not available because some constraints are not solved. See tooltip.</td>
<td><img src="image" alt="Mode view" /></td>
</tr>
</tbody>
</table>
4.4.2 Component Mode panel

Select a component from the component list on the left panel to open the **Mode** panel.

The **Mode** panel helps the user configuring the MCU pins based on a selection of peripherals and of their operating modes. Since STM32 MCUs allow a same pin to be used by different peripherals and for several functions (alternate functions), the tool searches for the pinout configuration that best fits the set of peripherals selected by the user.

STM32CubeMX highlights the conflicts that cannot be solved automatically (see Table 5).

The **Mode** panel also allows to enable middleware and other software components for the project.

**Note:** For some middleware (USB, FATS, LwIP), a peripheral mode must be enabled before activating the middleware mode. Tooltips guide the user through the configuration. For FatFs, a user-defined mode has been introduced. This allows STM32CubeMX to generate

---

### Table 5. Component list, mode icons and color schemes (continued)

<table>
<thead>
<tr>
<th>Display</th>
<th>Component status</th>
<th>Corresponding Mode view / Tooltips</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️</td>
<td>The peripheral is configured (at least one mode is set) and all other modes are available. The green check mark indicates that all parameters are properly configured, a cross indicates they are not.</td>
<td></td>
</tr>
<tr>
<td>😶</td>
<td>The peripheral is not configured (no mode is set) and at least one of its modes is unavailable.</td>
<td></td>
</tr>
<tr>
<td>😤</td>
<td>The peripheral is configured (one mode is set) and at least one of its other modes is unavailable.</td>
<td></td>
</tr>
<tr>
<td>📝</td>
<td>The peripheral is not configured (no mode is set) and no mode is available. Move the mouse over the peripheral name to display the tooltip describing the conflict.</td>
<td></td>
</tr>
<tr>
<td>🌟</td>
<td>Peripheral is not available because of constraints.</td>
<td></td>
</tr>
</tbody>
</table>

---

Example:

- ** ETH**
- ** USB_OTG_HS**
- ** I2C2**
- ** IRTIM**
FatFs code without a predefined peripheral mode. Then, it is up to the user to connect the middleware with a user-defined peripheral by updating the generated user_diskio.c/.h driver files with the necessary code.

4.4.3 Pinout view

Select __Pinout view__ to show for the selected part number, a graphic representation of the pinout for the selected package (e.g. BGA, QFP...) where each pin is represented with its name (e.g. PC4), its configuration state and its current alternate function assignment if any (e.g. ETH_MII_RXD0), see Figure 44 for an example.

![Figure 44. Pinout view](image)

The Pinout view is automatically refreshed to match the user’s component configuration performed in the Mode panel.

Assigning pins directly through the Pinout view instead of the Mode panel requires a good knowledge of the MCU since each individual pin can be assigned to a specific function.
Tips and tricks

See Table 2: Home page shortcuts for list of menus and shortcuts.

- Use the mouse wheel to zoom in and out.
- Click and drag the chip diagram to move it.
- Click best fit to reset it to best suited position and size.
- Use Pinout > Export pinout menus to export the pinout configuration as .csv text format.
- Some basic controls, such as insuring blocks of pins consistency, are built-in. See Appendix A: STM32CubeMX pin assignment rules for details.

4.4.4 Pinout menu and shortcuts

<table>
<thead>
<tr>
<th>Name or Icon</th>
<th>Shortcut</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep Current Signals Placement</td>
<td>Ctrl-K</td>
<td>Prevents moving pin assignments to match a new peripheral operating mode. It is recommended to use the new pinning feature that can block each pin assignment individually and leave this checkbox unchecked.</td>
</tr>
<tr>
<td>Show User Label</td>
<td>None</td>
<td>Displays user defined labels in the Pinout view.</td>
</tr>
<tr>
<td>Undo Mode and pinout</td>
<td>Ctrl-Z</td>
<td>Undoes last configuration steps (one by one).</td>
</tr>
<tr>
<td>Redo Mode and pinout</td>
<td>Ctrl-Y</td>
<td>Redoes steps that have been undone (one by one). Warning (limitation): configurations in the platform settings tabs are not restored.</td>
</tr>
<tr>
<td>Disable All Modes</td>
<td>Ctrl-D</td>
<td>Resets to &quot;Disabled&quot; all peripherals and middleware modes that have been enabled. The pins configured in these modes (green color) are consequently reset to &quot;Unused&quot; (gray color). Peripheral and middleware labels change from green to black (when unused) or gray (when not available).</td>
</tr>
<tr>
<td>Clear Pinouts</td>
<td>Ctrl-P</td>
<td>Clears user pinout configuration in the Pinout view. Note that this action puts all configured pins back to their reset state and disables all the peripheral and middleware modes previously enabled (whether they were using signals on pins or not).</td>
</tr>
<tr>
<td>Pins/Signals Option</td>
<td>Ctrl-O</td>
<td>Opens a window showing the list of all the configured pins together with the name of the signal on the pin and a Label field allowing the user to specify a label name for each pin of the list. For this menu to be active, at least one pin must have been configured. Click the pin icon to pin/unpin signals individually. Select multiple rows then right click to open contextual menu and select action to pin or unpin all selected signals at once. Click column header names to sort alphabetically by name or according to placement on MCU.</td>
</tr>
<tr>
<td>Clear Single Mapped Signals</td>
<td>Ctrl-M</td>
<td>Clears signal assignments to pins for signals that have no associated mode (highlighted in orange and not pinned).</td>
</tr>
</tbody>
</table>
Table 6. Pinout menu and shortcuts (continued)

<table>
<thead>
<tr>
<th>Name or Icon</th>
<th>Shortcut</th>
<th>Description</th>
</tr>
</thead>
</table>
| List Pinout Compatible MCUs | Alt-L | Provides a list of MCUs that best match the pin configuration of the current project. The matching can be:  
- An exact match  
- A partial match with hardware compatibility: pin locations are the same, pin names may have been changed  
- A partial match without hardware compatibility: all signals can be mapped but not all at the same pin location  
Refer to Section 15: Tutorial 5: Exporting current project configuration to a compatible MCU. |
| Export pinout with Alternate functions | - | Generates pin configuration as a .csv text file including alternate functions information. |
| Export pinout without Alternate functions | Ctrl-U | Generates pin configuration as a .csv text file excluding alternate functions information. |
| Reset used GPIOs | Alt-G | Opens a window to specify the number of GPIOs to be freed among the total number of GPIO pins that are configured. |
| Set unused GPIOs | Ctrl-G | Opens a window to specify the number of GPIOs to be configured among the total number of GPIO pins that are not used yet. Specify their mode: Input, Output or Analog (recommended configuration to optimize power consumption).  
**Caution:** Before using this menu, make sure that debug pins (available under SYS peripheral) are set to access microcontroller debug facilities. |
| Layout reset | - | - |
| | - | Zooms-in the pinout view. |
| | - | Adjusts the chip pinout diagram to the best fit size. |
| | - | Zooms-out the pinout view. |
| | - | Rotates 90 degrees clock wise. |
| | - | Rotate 90 degrees counter-clock wise. |
| | - | Flips horizontally between bottom view and top view. |
| | - | Flips vertically between bottom view and top view. |
| | - | This Search field allows the user to search the Pinout view for a pin name, a signal name, a signal label or an alternate pin name. When it is found, the pin or set of pins matching the search criteria blinks on the Pinout view. Click the Pinout view to stop blinking. |
4.4.5 Pinout view advanced actions

Manually modifying pin assignments

To manually modify a pin assignment, follow the sequence below:

1. Click the pin in the Pinout view to display the list of all other possible alternate functions together with the current assignment highlighted in blue (see Figure 45).
2. Click to select the new function to assign to the pin.

![Figure 45. Modifying pin assignments from the Pinout view](image)

Manually remapping a function to another pin

To manually remap a function to another pin, follow the sequence below:

1. From the Pinout view, hold down the CTRL key then left-click on the pin and hold: if any pins are possible for relocation, they are highlighted in blue and blinking.
2. Drag the function to the target pin.

Caution: A pin assignment performed from the Pinout view overwrites any previous assignment.

Manual remapping with destination pin ambiguity

For MCUs with block of pins consistency (STM32F100x / F101x / F102x / F103x and STM32F105x / F107x), the destination pin can be ambiguous, e.g. there can be more than one destination block including the destination pin. To display all the possible alternative remapping blocks, move the mouse over the target pin.

Note: A “block of pins” is a group of pins that must be assigned together to achieve a given peripheral mode. As shown in Figure 46, two blocks of pins are available on a STM32F107xx MCU to configure the Ethernet peripheral in RMII synchronous mode: \{PC1, PA1, PA2, PA7, PC4, PC5, PB11, PB12, PB13, PB5\} and \{PC1, PA1, PA2, PD10, PD9, PD8, PB11, PB12, PB13, PB5\}. 
Resolving pin conflicts

To resolve the pin conflicts that may occur when some peripheral modes use the same pins, STM32CubeMX attempts to reassign the peripheral mode functions to other pins. The peripherals for which pin conflicts cannot be solved are highlighted in fuchsia with a tooltip describing the conflict.

If the conflict cannot be solved by remapping the modes, the user can try the following:

- If the Keep Current Signals Placement box is checked, try to select the peripherals in a different sequence.
- Uncheck the Keep Current Signals Placement box and let STM32CubeMX try all the remap combinations to find a solution.
- Manually remap a mode of a peripheral when you cannot use it because there is no pin available for one of the signals of that mode.

4.4.6 Keep Current Signals Placement

This checkbox is available from the Pinout menu. It can be selected or deselected at any time during the configuration. It is unselected by default.

It is recommended to keep the checkbox unchecked for an optimized placement of the peripherals (maximum number of peripherals concurrently used).

The Keep Current Signals Placement checkbox should be selected when the objective is to match a board design.

Keep Current Signals Placement is unchecked

This allows STM32CubeMX to remap previously mapped blocks to other pins in order to serve a new request (selection of a new peripheral mode or a new peripheral mode function) which conflicts with the current pinout configuration.
Keep Current Signals Placement is checked

This ensures that all the functions corresponding to a given peripheral mode remain allocated (mapped) to a given pin. Once the allocation is done, STM32CubeMX cannot move a peripheral mode function from one pin to another. New configuration requests are served if feasible within current pin configuration.

This functionality is useful to:

- lock all the pins corresponding to peripherals that have been configured using the Peripherals panel
- maintain a function mapped to a pin while doing manual remapping from the Pinout view.

Tip

If a mode becomes unavailable (highlighted in fuchsia), try to find another pin remapping configuration for this mode by following the steps below:

1. From the Pinout view, deselect the assigned functions one by one until the mode becomes available again.
2. Then, select the mode again and continue the pinout configuration with the new sequence (see Appendix A: STM32CubeMX pin assignment rules for a remapping example). This operation being time consuming, it is recommended to deselect the Keep Current Signals Placement checkbox.

Note: Even if Keep Current Signals Placement is unchecked, GPIO_ functions (excepted GPIO_EXTI functions) are not moved by STM32CubeMX.

4.4.7 Pinning and labeling signals on pins

STM32CubeMX comes with a feature allowing the user to selectively lock (or pin) signals to pins. This prevents STM32CubeMX from automatically moving pinned signals to other pins when resolving conflicts. Labels, that are used for code generation, can also be assigned to the signals (see Section 6.1 for details).

There are several ways to pin, unpin and label the signals:

1. From the Pinout view, right-click a pin with a signal assignment. This opens a contextual menu:
   a) For unpinned signals, select Signal Pinning to pin the signal. A pin icon is then displayed on the relevant pin. The signal can no longer be moved automatically (for example when resolving pin assignment conflicts).
   b) For pinned signals, select Signal Unpinning to unpin the signal. The pin icon is removed. From now on, to resolve a conflict (such as peripheral mode conflict), this signal can be moved to another pin, provided the Keep user placement option is unchecked.
   c) Select Enter User Label to specify a user defined label for this signal. The new label replaces the default signal name in the Pinout view.
2. From the **Pinout** menu, select **Pins/Signals Options**
   The Pins/Signals Options window (see **Figure 47**) lists all configured pins.

![Figure 47. Pins/Signals Options window](image)

   a) Click the first column to individually pin/unpin signals.
   b) Select multiple rows and right-click to open the contextual menu and select **Signal(s) Pinning** or **Unpinning**.
   c) Select the User Label field to edit the field and enter a user-defined label.
   d) Order list alphabetically by Pin or Signal name by clicking the column header. Click once more to go back to default i.e. to list ordered according to pin placement on MCU.

**Note:** Even if a signal is pinned, it is still possible however to manually change the pin signal assignment from the **Pinout** view: click the pin to display other possible signals for this pin and select the relevant one.

### 4.4.8 Pinout for multi-bonding packages

Multi-bonding has been introduced for packages with low pin counts (less than 20 pins) such as SO8N, TSSOP20 and WLCSP18 packages. It consists of having several MCU pads share a same pin on the package.

Multi-bonding has been introduced on the STM32G0 series for the STM32G031/G041 MCUs.

STM32CubeMX pinout view allows to displays all signals arriving on the pin and allows to select only one per pin, except for analog signals that can be combined with other analog GPIOs.
STM32CubeMX offers also an extended mode selected by right-clicking the pin: it allows to select more than one signal per pin. This mode is meant for test purposes such as loopback tests. It is to be used with caution as it can lead to electrical conflicts or increased power consumption that can damage the device.
4.4.9 System view

Select **System view** to show all the software configurable components: GPIOs, peripherals and middleware. Clickable buttons allow the user to open the mode and configuration options of the component. The button icon reflects the component configuration status (see Table 7 for configuration states and Figure System view).

When the user changes the component configuration from the Configuration panel, the system view is automatically refreshed with the new configuration state.

If the user disables the component from the Mode panel, the system view is automatically refreshed and there is no longer a button showing for that component.

![Figure 50. System view](image)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Configuration is complete and correct.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Configuration is correct but some parts remain to be configured (may be optional).</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Configuration is invalid and needs to be fixed for the generated C project to be functional.</td>
</tr>
</tbody>
</table>
GPIO, DMA and NVIC settings can be accessed either via a dedicated button (like other peripherals, or via a tab in the Configuration panel (see Figure 51).

Figure 51. Configuration window tabs (GPIO, DMA and NVIC settings for STM32F4 series)

4.4.10 Component configuration panel

This panel appears when clicking on a component name in the left panel. It allows the user to configure the functional parameters required to initialize the peripheral or the middleware in the selected operating mode (see Figure 52). STM32CubeMX uses these settings to generate the corresponding initialization C code.
The configuration window includes several tabs:

- **Parameter settings** to configure library dedicated parameters for the selected peripheral or middleware,
- **NVIC, GPIO and DMA settings** to set the parameters for the selected peripheral (see Section 4.4.14, Section 4.4.12 and Section 4.4.13 for configuration details).
- **User constants** to create one or several user defined constants, common to the whole project (see Section 4.4.11 for user constants details).

Invalid settings are detected and are:

- reset to minimum / maximum valid value if user choice is, respectively, smaller / larger than minimum / maximum threshold
- reset to previous valid value if the previous value is neither a maximum nor a minimum threshold value
- highlighted in fuchsia.
Table 8 describes peripheral and middleware configuration buttons and messages.

### Table 8. Peripheral and Middleware configuration window buttons and tooltips

<table>
<thead>
<tr>
<th>Buttons and messages</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shows / hides the description panel.</strong></td>
<td></td>
</tr>
</tbody>
</table>
| **Guides the user through the settings of parameters with valid min-max range.**  
  To display it, move the mouse over a parameter value from a list of possible values. |
| **Clicking on the gear icon allows to select whether to display hexadecimal or decimal values, or any value unchecked (No check option).** |
| **Search**  
  
  Resets the component back to its default configuration (initial settings from STM32CubeMX). |

#### No check option

By default, STM32CubeMX checks that the parameter values entered by the user are valid. You can bypass this check by selecting the option No Check for a given parameter. This allows entering you any value (such as a constant) that might not be known by STM32CubeMX configuration.

The validity check can be bypassed only on parameters whose values are of integer type (either hexadecimal or decimal). It cannot be bypassed on parameters coming from a predefined list of possible values or on those which are of non-integer or text type.

To go back to the default mode (decimal or hexadecimal values with validity check enabled), enter a decimal or hexadecimal value and check the relevant option (hexadecimal or decimal check).

**Caution:** When a parameter depends upon another parameter that is set to No Check:

- Case of a parameter depending on another parameter for the evaluation of its minimum or maximum possible value: If the other parameter is set to No Check, the minimum or maximum value is no longer evaluated and checked.

- Case of a parameter depending on another parameter for the evaluation of its current value: If the other parameter is set to No Check, the value is no longer automatically derived. Instead, it is replaced with the formula text showing as variable the string of the parameter set to No check (see Figure 53).
4.4.11 User Constants configuration window

An **User Constants** tab is available to define user constants (see **Figure 54**). Constants are automatically generated in the STM32CubeMX user project within the main.h file (see **Figure 55**). Once defined, they can be used to configure peripheral and middleware parameters (see **Figure 56**).
STM32CubeMX user interface

Figure 55. Extract of the generated main.h file

```c
/* Includes -------------------------------------------------------------*/

/* USER CODE BEGIN Includes */

/* USER CODE END Includes */

/* Private define --------------------------------------------------------*/
#define CONSTANT_1 10
#define CONSTANT_2 0xff
#define CONSTANT_3 CONSTANT_1
#define CONSTANT_4 (CONSTANT_3+CONSTANT_1)*100/CONSTANT_1
#define CONSTANT_5 (CONSTANT_2 - CONSTANT_1)

/* USER CODE BEGIN Private defines */

/* USER CODE END Private defines */
```

Figure 56. Using constants for peripheral parameter settings
Creating/editing user constants

Click the **Add** button to open the **User Constants** tab and create a new user-defined constant (see Figure 57).

A constant consists of:

- **A name** that must comply with the following rules:
  - It must be unique.
  - It shall not be a C/C++ keyword.
  - It shall not contain a space.
  - It shall not start with digits.

- A **value**
  
  The constant value can be (see Figure 54 for examples):
  - a simple decimal or hexadecimal value
  - a previously defined constant
  - a formula using arithmetic operators (subtraction, addition, division, multiplication, and remainder) and numeric value or user-defined numeric constants as operands
  - a character string: the string value must be between double quotes (example: “constant_for_usart”).

Once a constant is defined, its name and/or its value can still be changed: double-click the row that specifies the user constant to be modified. This opens the **User Constants** tab for edition. The change of constant name is applied wherever the constant is used. This does not affect the peripheral or middleware configuration state. However changing the constant value impacts the parameters that use it and might result in invalid settings (e.g. exceeding a maximum threshold). Invalid parameter settings are highlighted in fuchsia.

**Figure 57. Specifying user constant value and name**
Deleting user constants

Click the **Remove** button to delete an existing user-defined constant.

The user constant is then automatically removed except in the following cases:

- When the constant is used for the definition of another constant. In this case, a popup window displays an explanatory message (see **Figure 58**).

**Figure 58. Deleting an user constant is not allowed when the constant is already used for another constant definition**

- When the constant is used for the configuration of a peripheral or middleware library parameter. In this case, the user is requested to confirm the deletion since the constant removal results in a invalid peripheral or middleware configuration (see **Figure 59**).

**Figure 59. Confirmation request to delete a constant for parameter configuration**

Clicking **Yes** leads to an invalid peripheral configuration (see **Figure 60**).

**Figure 60. Consequence when deleting a user constant for peripheral configuration**
Searching for user constants

The **Search Constants** field makes it possible the search of a constant name or value in the complete list of user constants (see *Figure 61* and *Figure 62*).

*Figure 61. Searching for a name in a user constant list*

*Figure 62. Searching for a value in a user constant list*
4.4.12 GPIO configuration window

Click GPIO in the System view panel to open the GPIO configuration window to configure the GPIO pin settings (see Figure 63). The configuration is populated with default values that might not be adequate for some peripheral configurations. In particular, check if the GPIO speed is sufficient for the peripheral communication speed and select the internal pull-up whenever needed.

Note: GPIO settings can be accessed for a specific peripheral instance via the dedicated window in the peripheral instance configuration window. In addition, GPIOs can be configured in output mode (default output level). The generated code is updated accordingly.

Figure 63. GPIO configuration window - GPIO selection

Click on a row or select a set of rows to display the corresponding GPIO parameters:

- **GPIO PIN state**
  It changes the default value of the GPIO Output level. It is set to low by default and can be changed to high.

- **GPIO mode** (analog, input, output, alternate function)
  Selecting a peripheral mode in the Pinout view automatically configures the pins with the relevant alternate function and GPIO mode.

- **GPIO pull-up/pull-down**
  It is set to a default value and can be configured when other choices are possible.

- **GPIO maximum output speed** (for communication peripherals only)
  It is set to Low by default for power consumption optimization and can be changed to a higher frequency to fit application requirements.

- **User Label**
  It changes the default name (e.g. GPIO_input) into a user defined name. The Pinout view is updated accordingly. The GPIO can be found under this new name via the Find menu.
The **Group by Peripherals** checkbox allows the user to group all instances of a peripheral under the same window (see *Figure 64*).

![Figure 64. GPIO configuration grouped by peripheral](Image)

As shown in *Figure 65*, row multi-selection can be performed to change a set of pins to a given configuration at the same time.

![Figure 65. Multiple pins configuration](Image)
4.4.13 DMA configuration window

Click DMA in the System view to open the DMA configuration window.

This window is used to configure the generic DMA controllers available on the MCU. The DMA interfaces allow to perform data transfers between memories and peripherals while the CPU is running, and memory to memory transfers (if supported).

Note: Some peripherals (such as USB or Ethernet) have their own DMA controller, which is enabled by default or via the Peripheral Configuration window.

Clicking Add in the DMA configuration window adds a new line at the end of the DMA configuration window with a combo box proposing to choose between possible DMA requests to be mapped to peripherals signals (see Figure 66).

Figure 66. Adding a new DMA request

![DMA configuration window](image)

Selecting a DMA request automatically assigns a stream among all the streams available, a direction and a priority. When the DMA channel is configured, it is up to the application code to fully describe the DMA transfer run-time parameters such as the start address.

The DMA request (called channel for STM32F4 MCUs) is used to reserve a stream to transfer data between peripherals and memories (see Figure 67). The stream priority is used to decide which stream to select for the next DMA transfer.

DMA controllers support a dual priority system using the software priority first, and in case of equal software priorities, a hardware priority that is given by the stream number.
Additional DMA configuration settings can be done through the **DMA configuration** window:

- **Mode**: regular mode, circular mode, or peripheral flow controller mode (only available for the SDIO peripheral).
- **Increment Add**: the type of peripheral address and memory address increment (fixed or postincremented, in which case the address is incremented after each transfer). Click the checkbox to enable the post-incremented mode.
- **Peripheral data width**: 8, 16, or 32 bits
- Switching from the default direct mode to the **FIFO mode** with programmable **threshold**:
  a) Click the **Use FIFO** checkbox.
  b) Configure the peripheral and memory data width (8, 16, or 32 bits).
  c) Select between **single transfer** and **burst transfer**. If you select burst transfer, choose a burst size (1, 4, 8, or 16).

In case of memory-to-memory transfer (MemToMem), the DMA configuration applies to a source memory and to a destination memory.
4.4.14 **NVIC configuration window**

Click **NVIC** in the **System** view to open the Nested Vector interrupt controller configuration window (see Figure 69).

Interrupt unmasking and interrupt handlers are managed within two tabs:
- **NVIC**, to enable peripheral interrupts in the NVIC controller and to set their priorities
- **Code generation**, to select options for interrupt related code generation

**Enabling interruptions using the NVIC tab view**

The **NVIC** view (see Figure 69) does not show all possible interrupts, but only the ones available for the peripherals selected in the **Pinout & Configuration** panels. System interrupts are displayed but can never be disabled.

Check/uncheck the **Show only enabled interrupts** box to filter or not enabled interrupts.

When DMA channels are configured in the project, check/uncheck “Force DMA channels interrupts” to automatically enable/disable DMA channels interrupts in the generated code.

Use the **search field** to filter out the interrupt vector table according to a string value. As an example, after enabling UART peripherals from the **Pinout** panel, type UART in the NVIC search field and click the green arrow close to it: all UART interrupts are displayed.

Enabling a **peripheral interrupt** generates NVIC function calls **HAL_NVIC_SetPriority** and **HAL_NVIC_EnableIRQ** for this peripheral.
When FreeRTOS is enabled, an additional column is shown (see Figure 70).

In this case, all the interrupt service routines (ISRs) that are calling the interrupt safe
FreeRTOS APIs must have a priority lower than the priority defined in the
LIBRARY_MAX_SYSCALL_INTERRUPT_PRIORITY parameter (the highest the value, the
lowest the priority). The check in the corresponding checkbox guarantees that the restriction
is applied.

If an ISR does not use such functions, the checkbox can be unchecked and any priority level
can be set. It is possible to check/uncheck multiple rows (see rows highlighted in blue in
Figure 70).
Peripheral dedicated interrupts can also be accessed through the NVIC window in the configuration window (see Figure 71).

Figure 70. NVIC configuration tab - FreeRTOS enabled

Figure 71. I2C NVIC configuration window
STM32CubeMX NVIC configuration consists in selecting a priority group, enabling/disabling interrupts and configuring interrupts priority levels (preemption and sub-priority levels):

1. Select a **priority group**
   Several bits allow to define NVIC priority levels. These bits are divided in two priority groups corresponding to two priority types: preemption priority and sub-priority. For example, in the case of STM32F4 MCUs, the NVIC priority group 0 corresponds to 0-bit preemption and 4-bit sub-priority.

2. In the interrupt table, click one or more rows to select one or more interrupt vectors. Use the widgets below the interrupt table to configure the vectors one by one or several at a time:
   - **Enable checkbox**: check/uncheck to enable/disable the interrupt.
   - **Preemption priority**: select a priority level. The preemption priority defines the ability of one interrupt to interrupt another.
   - **Sub-priority**: select a priority level. The sub-priority defines the interrupt priority level.

**Code generation options for interrupt handling**

The **Code Generation** view allows customizing the code generated for interrupt initialization and interrupt handlers:

- **Selection/Deselection of all interrupts for sequence ordering and IRQ handler code generation**
  Use the checkboxes in front of the column names to configure all interrupts at a time (see **Figure 72**). Note that system interrupts are not eligible for init sequence reordering as the software solution does not control it.
Default initialization sequence of interrupts

By default, the interrupts are enabled as part of the peripheral MSP initialization function, after the configuration of the GPIOs and the enabling of the peripheral clock. This is shown in the CAN example below, where `HAL_NVIC_SetPriority` and `HAL_NVIC_EnableIRQ` functions are called within `stm32xxx_hal_msp.c` file inside the peripheral `msp_init` function.

Interrupt enabling code is shown in bold:

```c
void HAL_CAN_MspInit(CAN_HandleTypeDef* hcan) {
    GPIO_InitTypeDef GPIO_InitStruct;
    if(hcan->Instance==CAN1) {
        /* Peripheral clock enable */
        __CAN1_CLK_ENABLE();
        /**CAN1 GPIO Configuration
        PD0     ------> CAN1_RX
        PD1     ------> CAN1_TX
        */
        GPIO_InitStruct.Pin = GPIO_PIN_0|GPIO_PIN_1;
        GPIO_InitStruct.Mode = GPIO_MODE_AF_PP;
```

Figure 72. NVIC Code generation – All interrupts enabled
GPIO_InitStruct.Pull = GPIO_NOPULL;
GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_VERY_HIGH;
GPIO_InitStruct.Alternate = GPIO_AF9_CAN1;
HAL_GPIO_Init(GPIOD, &GPIO_InitStruct);
/* Peripheral interrupt init */
HAL_NVIC_SetPriority(CAN1_TX_IRQn, 2, 2);
HAL_NVIC_EnableIRQ(CAN1_TX_IRQn);

For EXTI GPIOs only, interrupts are enabled within the MX_GPIO_Init function:

/** EXTI interrupt init*/
GPIO_InitStruct.Pin = MEMS_INT2_Pin;
GPIO_InitStruct.Mode = GPIO_MODE_EVT_RISING;
GPIO_InitStruct.Pull = GPIO_NOPULL;
HAL_GPIO_Init(MEMS_INT2_GPIO_Port, &GPIO_InitStruct);

/* EXTI interrupt init*/
HAL_NVIC_SetPriority(EXTI15_10_IRQn, 0, 0);
HAL_NVIC_EnableIRQ(EXTI15_10_IRQn);

For some peripherals, the application still needs to call another function to actually activate the interruptions. Taking the timer peripheral as an example, the HAL_TIM_IC_Start_IT function needs to be called to start the Timer input capture (IC) measurement in interrupt mode.

- **Configuration of interrupts initialization sequence**

  Checking **Select for Init sequence ordering** for a set of peripherals moves the HAL_NVIC function calls for each peripheral to a same dedicated function, named MX_NVIC_Init, defined in the main.c. Moreover, the HAL_NVIC functions for each peripheral are called in the order specified in the Code generation view bottom part (see Figure 73).

  As an example, the configuration shown in Figure 73 generates the following code:

  ```c
  /** NVIC Configuration */
  void MX_NVIC_Init(void)
  {
  /* CAN1_TX_IRQn interrupt configuration */
  HAL_NVIC_SetPriority(CAN1_TX_IRQn, 2, 2);
  HAL_NVIC_EnableIRQ(CAN1_TX_IRQn);
  /* PVD_IRQn interrupt configuration */
  HAL_NVIC_SetPriority(PVD_IRQn, 0, 0);
  HAL_NVIC_EnableIRQ(PVD_IRQn);
  /* FLASH_IRQn interrupt configuration */
  HAL_NVIC_SetPriority(FLASH_IRQn, 0, 0);
  HAL_NVIC_EnableIRQ(FLASH_IRQn);
  /* RCC_IRQn interrupt configuration */
  ```
HAL_NVIC_SetPriority(RCC_IRQn, 0, 0);
HAL_NVIC_EnableIRQ(CAN1_IRQn);

/* ADC_IRQn interrupt configuration */
HAL_NVIC_SetPriority(ADC_IRQn, 0, 0);
HAL_NVIC_EnableIRQ(ADC_IRQn);
}

- **Interrupts handler code generation**

By default, STM32CubeMX generates interrupt handlers within the stm32xxx_it.c file. As an example:

```c
void NMI_Handler(void)
{
    HAL_RCC_NMI_IRQHandler();
}

void CAN1_TX_IRQHandler(void)
{
    HAL_CAN_IRQHandler(&hcan1);
}
```

The column **Generate IRQ Handler** allows the user to control whether the interrupt handler function call can be generated or not. Deselecting CAN1_TX and NMI interrupts from the **Generate IRQ Handler** column as shown in [Figure 73](#) removes the code mentioned earlier from the stm32xxx_it.c file.

**Figure 73. NVIC Code generation – IRQ Handler generation**
4.4.15 FreeRTOS configuration panel

Through STM32CubeMX FreeRTOS configuration window, the user can configure all the resources required for a real-time OS application, and reserve the corresponding heap. FreeRTOS elements are defined and created in the generated code using CMSIS-RTOS API functions. Follow the sequence below:

1. In the Pinout & Configuration tab, click FreeRTOS to reveal the Mode and Configuration panels (see Figure 74).
2. Enable freeRTOS in the Mode panel.
3. Go to the configuration panel to proceed with configuring FreeRTOS native parameters and objects, such as tasks, timers, queues, and semaphores. In the Config tab, configure Kernel and Software settings. In the Include parameters tab, select the API functions required by the application and this way, optimize the code size. Both Config and Include parameters are part of the FreeRTOSConfig.h file.

Figure 74. FreeRTOS configuration view
Tasks and Queues Tab

As any RTOS, FreeRTOS allows structuring a real-time application into a set of independent tasks, with only one task being executed at a given time. Queues are meant for inter-task communications: they allow to exchange messages between tasks or between interrupts and tasks.

In STM32CubeMX, the FreeRTOS Tasks and Queues tab enables the creation and configuration of such tasks and queues (see Figure 75). The corresponding initialization code is generated within main.c or freeRTOS.c if the option “generate code as pair of .c/.h files per peripherals and middleware” is set in the Project Settings menu.

The corresponding initialization code is generated within main.c by default or within freeRTOS.c if the option “generate code as pair of .c/.h files per peripherals and middleware” is set in the Project Manager menu.

Figure 75. FreeRTOS: configuring tasks and queues

- Tasks

Under the Tasks section, click the Add button to open the New Task window where task name, priority, stack size and entry function can be configured (see Figure 76). These settings can be updated at any time: double-clicking a task row opens again the new task window for editing.

The entry function can be generated as weak or external:
- When the task is generated as weak, the user can propose a definition different from the one generated by default.
- When the task is extern, it is up to the user to provide its function definition. By default, the function definition is generated including user sections to allow customization.

- Queues

Under the Queues section, click the Add button to open the New Queue window where the queue name, size and item size can be configured (see Figure 76). The queue size corresponds to the maximum number of items that the queue can hold at a
time, while the item size is the size of each data item stored in the queue. The item size can be expressed either in number of bytes or as a data type:

- 1 byte for `uint8_t`, `int8_t`, `char` and `portCHAR` types
- 2 bytes for `uint16_t`, `int16_t`, `short` and `portSHORT` types
- 4 bytes for `uint32_t`, `int32_t`, `int`, `long` and `float`
- 8 bytes for `uint64_t`, `int64_t` and `double`

By default, the FreeRTOS heap usage calculator uses four bytes when the item size cannot be automatically derived from user input. These settings can be updated at any time: double-clicking a queue row opens again the new queue window for editing.

Figure 76. FreeRTOS: creating a new task
The following code snippet shows the generated code corresponding to Figure 75.

```c
/* Create the thread(s) */
/* definition and creation of defaultTask */
osThreadDef(defaultTask, StartDefaultTask, osPriorityNormal, 0, 128);
defaultTaskHandle = osThreadCreate(osThread(defaultTask), NULL);

/* definition and creation of Task_A */
osThreadDef(Task_A, StartTask_A, osPriorityHigh, 0, 128);
Task_AHandle = osThreadCreate(osThread(Task_A), NULL);

/* definition and creation of Task_B */
osThreadDef(Task_B, StartTask_B, osPriorityLow, 0, 256);
Task_BHandle = osThreadCreate(osThread(Task_B), NULL);

/* Create the queue(s) */
/* definition and creation of myQueue_1 */
osMessageQDef(myQueue_1, 16, 4);
myQueue_1Handle = osMessageCreate(osMessageQ(myQueue_1), NULL);

/* definition and creation of myQueue_2 */
osMessageQDef(myQueue_2, 32, 2);
myQueue_2Handle = osMessageCreate(osMessageQ(myQueue_2), NULL);
```

Timers, Mutexes and Semaphores

FreeRTOS timers, mutexes and semaphores can be created via the FreeRTOS Timers and Semaphores tab. They first need to be enabled from the Config tab (see Figure 77).

![Figure 77. FreeRTOS - Configuring timers, mutexes and semaphores](image)
Under each object dedicated section, clicking the Add button to open the corresponding New <object> window where the object specific parameters can be specified. Object settings can be modified at any time: double-clicking the relevant row opens again the New <object> window for edition.

Note: Expand the window if the newly created objects are not visible.

- **Timers**

  Prior to creating timers, their usage (USE_TIMERS definition) must be enabled in the software timer definitions section of the Configuration parameters tab. In the same section, timer task priority, queue length and stack depth can be also configured.

  The timer can be created to be one-shot (run once) or auto-reload (periodic). The timer name and the corresponding callback function name must be specified. It is up to the user to fill the callback function code and to specify the timer period (time between the timer being started and its callback function being executed) when calling the CMSIS-RTOS osTimerStart function.

- **Mutexes / Semaphores**

  Prior to creating mutexes, recursive mutexes and counting semaphores, their usage (USE_MUTEXES, USE_RECURSIVE_MUTEXES, USE_COUNTING_SEMAPHORES definitions) must be enabled within the Kernel settings section of the Configuration parameters tab.

  The following code snippet shows the generated code corresponding to Figure 77.

```c
/* Create the semaphores(s) */

/* definition and creation of myBinarySem01 */
osSemaphoreDef(myBinarySem01);
myBinarySem01Handle = osSemaphoreCreate(osSemaphore(myBinarySem01), 1);

/* definition and creation of myCountingSem01 */
osSemaphoreDef(myCountingSem01);
myCountingSem01Handle = osSemaphoreCreate(osSemaphore(myCountingSem01), 7);

/* Create the timer(s) */

/* definition and creation of myTimer01 */
osTimerDef(myTimer01, Callback01);
myTimer01Handle = osTimerCreate(osTimer(myTimer01), osTimerPeriodic, NULL);

/* definition and creation of myTimer02 */
osTimerDef(myTimer02, Callback02);
myTimer02Handle = osTimerCreate(osTimer(myTimer02), osTimerOnce, NULL);

/* Create the mutex(es) */

/* definition and creation of myMutex01 */
osMutexDef(myMutex01);
myMutex01Handle = osMutexCreate(osMutex(myMutex01));
```

/* Create the recursive mutex(es) */
/* definition and creation of myRecursiveMutex01 */

osMutexDef(myRecursiveMutex01);

myRecursiveMutex01Handle =
osRecursiveMutexCreate(osMutex(myRecursiveMutex01));

FreeRTOS heap usage

The FreeRTOS Heap usage tab displays the heap currently used and compares it to the TOTAL_HEAP_SIZE parameter set in the Config Parameters tab. When the total heap used crosses the TOTAL_HEAP_SIZE maximum threshold, it is shown in fuchsia and a cross of the same color appears on the tab (see Figure 78).

Figure 78. FreeRTOS Heap usage

4.4.16 Setting HAL timebase source

By default, the STM32Cube HAL is built around a unique timebase source, the Arm® Cortex® system timer (SysTick).

However, HAL-timebase related functions are defined as weak so that they can be overloaded to use another hardware timebase source. This is strongly recommended when the application uses an RTOS, since this middleware has full control on the SysTick configuration (tick and priority) and most RTOSs force the SysTick priority to be the lowest.

Using the SysTick remains acceptable if the application respects the HAL programming model, that is, does not perform any call to HAL timebase services within an Interrupt Service Request context (no dead lock issue).

To change the HAL timebase source, go to the SYS peripheral in the Component list panel and select a clock among the available sources: SysTick, TIM1, TIM2,... (see Figure 79).
When used as timebase source, a given peripheral is grayed and can no longer be selected (see Figure 80).

Figure 80. TIM1 selected as HAL timebase source
As illustrated in the following examples, the selection of the HAL timebase source and the use of FreeRTOS influence the generated code.

**Example of configuration using SysTick without FreeRTOS**

As illustrated in *Figure 81*, the SysTick priority is set to 0 (High) when using the SysTick without FreeRTOS.

*Figure 81. NVIC settings when using SysTick as HAL timebase, no FreeRTOS*

Interrupt priorities (in main.c) and handler code (in stm32f4xx_it.c) are generated accordingly:

- **main.c file**

  /* SysTick_IRQn interrupt configuration */
  
  HAL_NVIC_SetPriority(SysTick_IRQn, 0, 0);

- **stm32f4xx_it.c file**

  /**
   * @brief This function handles System tick timer.
   */
  
  void SysTick_Handler(void)
  {
   /* USER CODE BEGIN SysTick_IRQn 0 */
   /* USER CODE END SysTick_IRQn 0 */
   HAL_IncTick();
   HAL_SYSTICK_IRQHandler();
   /* USER CODE BEGIN SysTick_IRQn 1 */
   /* USER CODE END SysTick_IRQn 1 */
  }

```c
/* USER CODE BEGIN SysTick_IRQn 0 */
/* USER CODE END SysTick_IRQn 0 */
HAL_IncTick();
HAL_SYSTICK_IRQHandler();
/* USER CODE BEGIN SysTick_IRQn 1 */

/* USER CODE END SysTick_IRQn 1 */
```
Example of configuration using SysTick and FreeRTOS

As illustrated in Figure 82, the SysTick priority is set to 15 (Low) when using the SysTick with FreeRTOS.

**Figure 82. NVIC settings when using FreeRTOS and SysTick as HAL timebase**

As shown in the code snippets below, the SysTick interrupt handler is updated to use CMSIS-os osSystickHandler function.

- main.c file
  ```c
  /* SysTick_IRQn interrupt configuration */
  HAL_NVIC_SetPriority(SysTick_IRQn, 15, 0);
  ```

- stm32f4xx_it.c file
  ```c
  /**
   * @brief This function handles System tick timer.
   */
  void SysTick_Handler(void)
  {
    /* USER CODE BEGIN SysTick_IRQn 0 */

    /* USER CODE END SysTick_IRQn 0 */
    HAL_IncTick();
    osSystickHandler();
    /* USER CODE BEGIN SysTick_IRQn 1 */

    /* USER CODE END SysTick_IRQn 1 */
  }
  ```
Example of configuration using TIM2 as HAL timebase source

When TIM2 is used as HAL timebase source, a new stm32f4xx_hal_timebase_TIM.c file is generated to overload the HAL timebase related functions, including the `HAL_InitTick` function that configures the TIM2 as the HAL time-base source.

The priority of TIM2 timebase interrupts is set to 0 (High). The SysTick priority is set to 15 (Low) if FreeRTOS is used, otherwise is set to 0 (High).

![Figure 83. NVIC settings when using FreeRTOS and TIM2 as HAL timebase](image)

The stm32f4xx_it.c file is generated accordingly:
- `SysTick_Handler` calls `osSystickHandler` when FreeRTOS is used, otherwise it calls `HAL_SYSTICK_IRQHandler`.
- `TIM2_IRQHandler` is generated to handle TIM2 global interrupt.

4.5 Pinout & Configuration view for STM32MP1 series

For the STM32MP1 series the Pinout & Configuration view allows the user to:
- assign components to one or several run time contexts
- configure peripherals as boot devices
- select the peripherals to be managed by boot loaders
- assign GPIOs to one runtime (see Figure 85).

These possibilities are offered in two different panels (see Figure 84)
1. from the component tree panel, that lists all supported peripherals and middleware (the “Show contexts” option must be enabled)
2. from each component mode panel, opened by clicking the component name.
4.5.1 Run time configuration

The STM32MP1 devices are multi-core (Arm® Cortex®-A7 dual-core and Cortex®-M4) and multi-firmware, each firmware executing on one of the cores. The association between firmware and core defines a runtime context where the firmware executes its code.

Three runtime contexts are available:
1. Cortex-A7 Non Secure running the Linux kernel
2. Cortex-A7 Secure running the SP_min
3. Cortex-M4 running the STM32Cube firmware.
Assigning a component to a runtime context means specifying which context(s) will control the component at runtime. Assignments to a Cortex-A7 context are reflected in the device tree code generation, while assignments to the Cortex-M4 context are reflected in STM32Cube based C code generation (refer to code generation sections for more details). The component assignment to a context is done in the context dedicated column.

4.5.2 Boot stages configuration

Boot ROM peripherals selection

Several execution stages are needed by the microprocessor to be up and running. The binary code embedded in the ROM is the first to be executed. It uses a default configuration to initialize the clock tree and all peripherals involved in the boot detection. The peripherals managed by the boot ROM program can be selected as boot devices. This choice is done in the Boot ROM column (see Figure 86).

![Figure 86. Select peripherals as boot devices](image)

When a peripheral is set as boot device, it imposes a specific pinout: some signals have to be mapped exclusively on pins visible by the boot ROM and only these signals/pins are taken into account by the boot ROM program.

When a functional mode of a ROM-bootable peripheral is set, the pinout linked to this mode is the same of that for a runtime context except for the signals imposed on specific pins by the boot ROM code.

During the boot step (boot ROM code execution), the peripheral is running only with the sub-set of bootable signals and pins. After boot, during runtime, the peripheral runs with all signals necessary to the selected functional mode.

Boot loader (A7 FSBL) peripherals selection

When the board starts, the launching of each of the Cortex-A7 runtime contexts (Secure and Non Secure) on which a firmware executes (for example Linux kernel for Cortex-A7 Non Secure) preceded by an early boot execution stage, that is before U-Boot relocation in DDR.
The Boot loader (A7 FSBL) column is used to define which devices can be managed during this Boot loader stage.

This assignment are reflected in the different Device-Trees generated (refer to code generation sections for more details).

4.6 Pinout & Configuration view for STM32H7 dual-core product lines

Some STM32H7 product lines come with an Arm Cortex-M7 core, an Arm Cortex-M4 core and three power domains.

For such products, the Pinout & Configuration view allows the user to:

- For each peripheral and middleware: assign it to one core context or both, whenever possible. In case both contexts are selected, assign an “initializer” core to indicate on which core the peripheral or middleware initialization function shall be called.
- For each peripheral: view the power domain it belongs to.
- For GPIOs: assign it to a core or leave it free for other components that may require it. In this last case the GPIO initialization are performed on the same core as the component reserving it (code is generated accordingly).

For peripherals and middleware, these possibilities are offered in two different panels
1. from the component tree panel, which lists all supported peripherals and middleware (clicking the gear icon enables the “Show contexts” option), see Figure 87
2. from each component mode panel, opened by clicking the component name.

Figure 87. STM32H7 dual-core: peripheral and middleware context assignment

For GPIOs (see Figure 88), assignment is done through the Pinout view directly or later and automatically through its selection in the platform settings panel of a middleware.
4.7 Enabling security in Pinout & Configuration view (STM32L5 and STM32U5 series only)

The STM32L5 MCU series harnesses the security features of the Arm Cortex-M33 processor and its TrustZone® for Armv8-M combined with ST security implementation.

STM32L5 MCUs support

- two levels of privilege
  - unprivileged: software has limited access to system resources
  - privileged: software has full access to system resources, subject to security restrictions

- two security states, Secure and Non-secure: TrustZone® security is activated when the TZEN option bit is set in the FLASH.OPTR register. Security states are orthogonal to mode and privilege, therefore, each security state supports execution in both modes and both levels of privilege.

In STM32CubeMX the choice to activate TrustZone® is made at project creation (see Section 4.2: New Project window). When TrustZone® is enabled, STM32CubeMX Pinout & Configuration view is adjusted accordingly with a split between secure (M33S) and non-secure context (M33NS), and more security-related configuration options (see Figure 89).
4.7.1 Privilege access for peripherals, GPIO EXTIs and DMA requests

Independently of TrustZone®, STM32CubeMX enables privilege access:

- for each peripheral: in the GTZC configuration panel (see Section 4.7.5), as shown in Figure 90
- for each GPIO EXTI: in the GPIO configuration panel, as shown in Figure 91
- for each DMA channel: in the DMA configuration panel (see Section 4.7.4), as shown in Figure 92.

Note: When TrustZone® is active, either all or none of the RCC registers can be put in privilege mode. In STM32CubeMX, this is done by selecting “Privileged-only attribute” check box from RCC mode panel (see Figure 93). In privilege mode, all RCC registers configuration are reserved for the privilege application through the PWR_CR_PRIVEN bit, which is secured when Trustzone® is activated.
Figure 90. Setting privileges for peripherals
Figure 91. Setting privileges for GPIO EXTIs
Figure 92. Configuring security and privilege of DMA requests

Figure 93. RCC privilege mode
4.7.2 Secure/non-secure context assignment for GPIO/Peripherals/Middleware

STM32CubeMX allows the user

- to assign each peripheral and middleware to one of the contexts
- to assign a GPIO input or output to one of the context or to leave it free for other components that may require it. In this last case the GPIO assignment is in the same context as the component reserving it. By default all IOs are secured.

The assignment is done in different panels:

- For peripherals and middleware only: from the component tree panel when “Show contexts” option is enabled (clicking the gear icon) or from the mode panel.
- For peripherals only: from the GTZC configuration panel (peripherals only).
- For GPIOs only: from the configuration panel or from the Pinout view, through a right-click on the GPIO pin and by selecting “Pin Reservation”.
- For DMA requests: from the DMA configuration panel.

Note: RCC resources can be secured through the Clock configuration view (see Section 4.8.2).

Note: For middleware requiring a peripheral the middleware can only be assigned to the context the peripheral is already assigned to.

4.7.3 NVIC and context assignment for peripherals interrupts

When TrustZone® is enabled, the interrupt controller is split into NVIC_NS for the non-secure context and NVIC_S for the secure context. Two SysTick instances are available as well, one for each context: they are visible, respectively, under SYS_NS and SYS_S.

By default, all interrupts are secured.

Peripherals interrupts are automatically assigned to the interrupt controller relevant to the context:

- For peripherals assigned to the non-secure context, interrupts are enabled on NVIC_NS.
- For peripherals assigned to the secure context, interrupts are enabled on NVIC_S.

4.7.4 DMA (context assignment and privilege access settings)

STM32CubeMX allows the user to set as privileged the DMA channel and in some cases, to secure the DMA channel, source and destination see Figure 94.
The DMA channel is set to non-privileged by default. The choice to set it as privileged is always available.

The choice to secure the DMA channel, source, and destination depends on the request characteristics.

There are four cases:

- The request is either a memory to memory transfer request or a DMA generator request: the channel is not secure by default but can be secured. The source and destination can be secured only when the channel is secure.

- The request is for a peripheral assigned to the non-secure context: channel, source and destination cannot be secured (checkboxes are disabled) and so they are forced to the non-secure context.

- The request is a peripheral to memory request for a peripheral assigned to the secure context: channel and source are automatically secured (checkboxes enabled, cannot be disabled), while there is a choice to secure or not the destination.

- The request is a memory to peripheral request for a peripheral assigned to the secure context: channel and destination are automatically secured (checkboxes enabled, cannot be disabled), while there is a choice to secure or not the source.
4.7.5 GTZC

To configure TrustZone® system security, STM32L5 series come with a Global TrustZone® security controller (GTZC). Refer to reference manual RM0438 for more details.

In STM32CubeMX, for projects with TrustZone® activated, GTZC is enabled by default and cannot be disabled. For projects without Trustzone® active, GTZC can be enabled and gives only the possibility to set privileges.

GTZC is made up of three blocks that can be configured through CubeMX using dedicated tabs in GTZC configuration panel:

- **TZSC (TrustZone® security controller)**
  - Defines which peripherals are secured and/or privileged, and controls the non-secure area size for the watermark memory peripheral controller (MPCWM).
  - The TZSC block informs some peripherals (such as RCC or GPIOs) about the secure status of each securable peripheral, by sharing with RCC and I/O logic.
  - The privileges are set in the TrustZone® Security Controller – Privilegeable Peripherals tab.
  - The secure states are set in TrustZone® Security Controller – Securable Peripherals tab (they match the assignment to context (M33S or M33NS) done on the Tree view or in the Mode panel).
  - The MPCWM configuration is done through the TrustZone® Security Controller – Memory Protection Controller Watermark tab.

- **MPCBB (block-based memory protection controller)**
  - Controls secure states of all blocks (256-byte pages) of the associated SRAM. It is configured through the Block-based Memory Protection Controller tab.

- **TZIC (TrustZone® illegal access controller)**
  - Gathers all illegal access events in the system and generates a secure interrupt towards NVIC. It is configured through the TrustZone® Illegal Access Controller tab.
4.7.6 **OTFDEC**

On-the-fly decryption engine (OTFDEC) allows the user to decrypt on-the-fly AHB traffic based on the read request address information. When security is enabled in the product OTFDEC can be programmed only by a secure host.

*Figure 96. OTFDEC secured when TrustZone® is active*
4.8 Clock Configuration view

STM32CubeMX Clock Configuration window (see Figure 97) provides a schematic overview of the clock paths, clock sources, dividers, and multipliers. Drop-down menus and buttons can be used to modify the actual clock tree configuration, to meet the application requirements.

Figure 97. STM32F469NIHx clock tree configuration view

Actual clock speeds are displayed and active. The use clock signals are highlighted in blue.
Out-of-range configured values are highlighted as shown in Figure 98 to flag potential issues. A solver feature is proposed to automatically resolve such configuration issues.

**Figure 98. Clock tree configuration view with errors**

Reverse path is supported: just enter the required clock speed in the blue field and STM32CubeMX attempts to reconfigure multipliers and dividers to provide the requested value. The resulting clock value can then be locked by right clicking the field to prevent modifications.

STM32CubeMX generates the corresponding initialization code:
- main.c with relevant HAL_RCC structure initializations and function calls
- stm32xxxx_hal_conf.h for oscillator frequencies and VDD values.

### 4.8.1 Clock tree configuration functions

**External clock sources**

When external clock sources are used, the user must previously enable them from the Pinout view available under the RCC peripheral.
Peripheral clock configuration options

Other paths, corresponding to clock peripherals, are grayed out. To become active, the peripheral must be properly configured in the Pinout view (e.g. USB). This view allows the user to:

- **Enter a frequency value for the CPU Clock (HCLK), buses or peripheral clocks**
  STM32CubeMX tries to propose a clock tree configuration that reaches the desired frequency while adjusting prescalers and dividers and taking into account other peripheral constraints (such as USB clock minimum value). If no solution can be found, STM32CubeMX proposes to switch to a different clock source or can even conclude that no solution matches the desired frequency.

- **Lock the frequency fields for which the current value should be preserved**
  Right click a frequency field and select Lock to preserve the value currently assigned when STM32CubeMX searches for a new clock configuration solution. The user can unlock the locked frequency fields when the preservation is no longer necessary.

- **Select the clock source that will drive the system clock (SYSCLK)**
  - External oscillator clock (HSE) for a user defined frequency.
  - Internal oscillator clock (HSI) for the defined fixed frequency.
  - Main PLL clock

- **Select secondary sources (as available for the product)**
  - Low-speed internal (LSI) or external (LSE) clock
  - I2S input clock
  - Other sources

- **Select prescalers, dividers and multipliers values**

- **Enable the Clock Security system (CSS) on HSE when it is supported by the MCU**
  This feature is available only when the HSE clock is used as the system clock source directly or indirectly through the PLL. It allows detecting HSE failure and inform the software about it, thus allowing the MCU to perform rescue operations.

- **Enable the CSS on LSE when it is supported by the MCU**
  This feature is available only when the LSE and LSI are enabled and after the RTC or LCD clock sources have been selected to be either LSE or LSI.

- **Reset the Clock tree default settings by using the toolbar Reset button**
  This feature reloads STM32CubeMX default clock tree configuration.

- **Undo/Redo user configuration steps by using the toolbar Undo/Redo buttons**

- **Detect and resolve configuration issues**
  Erroneous clock tree configurations are detected prior to code generation. Errors are highlighted in fuchsia and the Clock Configuration view is marked with a fuchsia cross (see Figure 98).
  Issues can be resolved manually or automatically by clicking the Resolve Clock Issue button that is enabled only if issues have been detected.
  The underlying resolution process follows a specific sequence:
  a) Setting HSE frequency to its maximum value (optional).
  b) Setting HCLK frequency then peripheral frequencies to a maximum or minimum value (optional).
  c) Changing multiplexers inputs (optional).
d) Finally, iterating through multiplier/dividers values to fix the issue. The clock tree is cleared from fuchsia highlights if a solution is found, otherwise an error message is displayed.

**Note:** To be available from the clock tree, external clocks, I2S input clock, and master clocks must be enabled in RCC configuration in the **Pinout** view. This information is also available as tooltips.

The tool automatically performs the following operations:

- Adjust bus frequencies, timers, peripherals and master output clocks according to user selection of clock sources, clock frequencies and prescalers/multipliers/dividers values.
- Check the validity of user settings.
- Highlight invalid settings in fuchsia and provide tooltips to guide the user to achieve a valid configuration.

The **Clock Configuration** view is adjusted according to the RCC settings (configured in RCC **Pinout & Configuration** views) and vice versa:

- If in RCC **Pinout** view, the external and output clocks are enabled, they become configurable in the **Clock Configuration** view.
- If in RCC Configuration view, the Timer prescaler is enabled, the choice of Timer clocks multipliers is adjusted.

Conversely, the clock tree configuration may affect some RCC parameters in the configuration view:

- Flash latency: number of wait states automatically derived from $V_{DD}$ voltage, HCLK frequency, and power over-drive state.
- Power regulator voltage scale: automatically derived from HCLK frequency.
- Power over-drive is enabled automatically according to HCLK frequency. When the power drive is enabled, the maximum possible frequency values for AHB and APB domains are increased. They are displayed in the **Clock Configuration** view.

The default optimal system settings that is used at startup are defined in the `system_stm32f4xx.c` file. This file is copied by STM32CubeMX from the STM32CubeF4 MCU package. The switch to user defined clock settings is done afterwards in the main function.
Figure 97 gives an example of Clock tree configuration for an STM32F429x MCU, and Table 9 describes the widgets that can be used to configure each clock.

<table>
<thead>
<tr>
<th>Format</th>
<th>Configuration status of the Peripheral Instance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSI RC</td>
<td>Active clock sources</td>
</tr>
<tr>
<td>Audio Clock Input</td>
<td>Unavailable settings are blurred or grayed out (clock sources, dividers,...)</td>
</tr>
<tr>
<td>AHB Prescaler</td>
<td>Gray drop down lists for prescalers, dividers, multipliers selection.</td>
</tr>
<tr>
<td>X1</td>
<td>Multiplier selection</td>
</tr>
<tr>
<td>HSE OSC</td>
<td>User defined frequency values</td>
</tr>
<tr>
<td>HCLK (MHz)</td>
<td>Automatically derived frequency values</td>
</tr>
<tr>
<td>16</td>
<td>User-modifiable frequency field</td>
</tr>
<tr>
<td>Right click blue border rectangles to lock/unlock a frequency field. Lock to preserve the frequency value during clock tree configuration updates.</td>
<td></td>
</tr>
</tbody>
</table>

4.8.2 Securing clock resources (STM32L5 series only)

When the TrustZone® security is activated, the RCC is able, through the security configuration register, to prevent non-secure access to system clock resources.

Accordingly, STM32CubeMX allows the user to configure as secure:

- system clock sources with a fixed frequency: HSI, LSI, and RC48
- system clock sources with a configurable frequency: HSE (+CSS), MSI and LSE (+CSS)
- two multiplexers: CLK48 clock multiplexer, System Clock (+MCO source) multiplexer
- other system configurations: PLLSYS, PLLSAI1, PLLSAI2 phase-locked loops and AHB/APB1/APB2 bus pre-scalers
In the Clock Configuration view, these securable resources are highlighted with a key icon. Security is enabled using the Secure checkbox accessed through a right-click on the resource. Once the resource is secure, it is highlighted with a green square.

Configurable resources can be locked to prevent further configuration changes: this is done by selecting the Lock checkbox accessed through a right-click on the resource.

There is also a shortcut button to lock/unlock in one click all resources that are both securable and configurable.

When a peripheral is configured as secure, its related clock, reset, clock source and clock enable are also secure. In STM32CubeMX the peripheral is configured as secure in the Pinout & Configuration view and its clock source is automatically highlighted as secure using a green square in the Clock configuration view.

### Table 10. Clock Configuration security settings

<table>
<thead>
<tr>
<th>View</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Non-configurable system clock resource" /></td>
<td>Example of non-configurable system clock resource that is secured.</td>
</tr>
<tr>
<td><img src="image" alt="System clock HSE clock source" /></td>
<td>Example of the system clock HSE clock source that is secured and remains open for editing: the frequency value can be changed.</td>
</tr>
<tr>
<td><img src="image" alt="System clock HSE clock source" /></td>
<td>Example of the system clock HSE clock source that is secured and has been locked for editing: the frequency value cannot be modified.</td>
</tr>
<tr>
<td><img src="image" alt="System clock multiplexer" /></td>
<td>Example of the System clock multiplexer that is secured and unlocked: the clock source can be changed.</td>
</tr>
<tr>
<td><img src="image" alt="Main PLL multiplexer" /></td>
<td>Example of the main PLL multiplexer that is secured and locked. The clock source is HSE and cannot be changed. PLLxxM, PLLxxN, PLLxxP, PLLxxQ and PLLxxR are secured and locked for editing as well.</td>
</tr>
</tbody>
</table>
Example of the UART4 clock source multiplexer: the clock source is secured because the UART4 peripheral is configured as secure in the Pinout & Configuration view. It is set to PCLK1 and can be changed as the Lock checkbox is unchecked.

Example of the UART4 clock source multiplexer: the clock source is secured because the UART4 peripheral is configured as secure in the Pinout & Configuration view. It is set to PCLK1 and can no longer be changed as Lock is on.

Example of securing and locking the access to AHB prescaler. APB1 and APB2 prescalers are locked as well.

Example of LSI highlighted as a securable resource using the key icon.

Lock/Unlock All button (only active for securable resources).

<table>
<thead>
<tr>
<th>View</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UART4 Clock Mux</td>
<td>Example of the UART4 clock source multiplexer: the clock source is secured because the UART4 peripheral is configured as secure in the Pinout &amp; Configuration view. It is set to PCLK1 and can be changed as the Lock checkbox is unchecked.</td>
</tr>
<tr>
<td>UART4 Clock Mux</td>
<td>Example of the UART4 clock source multiplexer: the clock source is secured because the UART4 peripheral is configured as secure in the Pinout &amp; Configuration view. It is set to PCLK1 and can no longer be changed as Lock is on.</td>
</tr>
<tr>
<td>AHB Prescaler</td>
<td>Example of securing and locking the access to AHB prescaler. APB1 and APB2 prescalers are locked as well.</td>
</tr>
<tr>
<td>LSI RC</td>
<td>Example of LSI highlighted as a securable resource using the key icon.</td>
</tr>
<tr>
<td>Clock Configuration</td>
<td>Lock/Unlock All button (only active for securable resources).</td>
</tr>
</tbody>
</table>
4.8.3 Recommendations

The Clock Configuration view is not the only entry for clock configuration, RCC and RTC peripherals can also be configured.

1. From the Pinout & Configuration view, go to the RCC mode panel to enable the clocks as needed: external clocks, master output clocks and Audio I2S input clock when available. Then go to the RCC configuration panel, and adjust the default settings if needed. Changes are reflected in the Clock Configuration view. The defined settings may change the settings in the RCC configuration as well (see Figure 99).

Figure 99. Clock tree configuration: enabling RTC, RCC clock source and outputs from Pinout view
2. Go to the **RCC configuration** in the **Pinout & Configuration** view. The settings defined there for advanced configurations are reflected in the **Clock configuration** view. The defined settings may change the settings in the RCC configuration.

![Clock configuration: RCC peripheral advanced parameters](image)

**Figure 100. Clock tree configuration: RCC peripheral advanced parameters**

### 4.8.4 STM32F43x/42x power-over drive feature

STM32F42x/43x MCUs implement a power over-drive feature that allows them to work at the maximum AHB/APB bus frequencies (e.g., 180 MHz for HCLK) when a sufficient \(V_{DD}\) supply voltage is applied (e.g. \(V_{DD} > 2.1\) V).

*Table 11* lists the different parameters linked to the power over-drive feature and their availability in STM32CubeMX user interface.
Table 11. Voltage scaling versus power over-drive and HCLK frequency

<table>
<thead>
<tr>
<th>Parameter</th>
<th>STM32CubeMX panel</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$ voltage</td>
<td></td>
<td>User-defined within a predefined range. Impacts power over-drive.</td>
</tr>
<tr>
<td>Power regulator voltage scaling</td>
<td></td>
<td>Automatically derived from HCLK frequency and power over-drive (see Table 12).</td>
</tr>
<tr>
<td>Power over-drive</td>
<td>Configuration (RCC)</td>
<td>This value is conditioned by HCLK and $V_{DD}$ values (see Table 12). It can be enabled only if $V_{DD} \geq 2.2$ V. When $V_{DD} \geq 2.2$ V it is either automatically derived from HCLK or it can be configured by the user if multiple choices are possible (e.g. HCLK = 130 MHz)</td>
</tr>
<tr>
<td>HCLK/AHB clock maximum frequency value</td>
<td>Clock Configuration</td>
<td>Displayed in blue to indicate the maximum possible value. For example: maximum value is 168 MHz for HCLK when power over-drive cannot be activated (when $V_{DD} \leq 2.1$ V), otherwise it is 180 MHz.</td>
</tr>
<tr>
<td>APB1/APB2 clock maximum frequency value</td>
<td></td>
<td>Displayed in blue to indicate the maximum possible value.</td>
</tr>
</tbody>
</table>

Table 12 gives the relations between power-over drive mode and HCLK frequency.

Table 12. Relations between power over-drive and HCLK frequency

<table>
<thead>
<tr>
<th>HCLK frequency range: $V_{DD} &gt; 2.1$ V required to enable power over-drive (POD)</th>
<th>Corresponding voltage scaling and power over-drive (POD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 120$ MHz</td>
<td>Scale 3</td>
</tr>
<tr>
<td></td>
<td>POD is disabled</td>
</tr>
<tr>
<td>120 to 144 MHz</td>
<td>Scale 2</td>
</tr>
<tr>
<td></td>
<td>POD can be either disabled or enabled</td>
</tr>
<tr>
<td>144 to 168 MHz</td>
<td>Scale 1 when POD is disabled</td>
</tr>
<tr>
<td></td>
<td>Scale 2 when POD is enabled</td>
</tr>
<tr>
<td>168 to 180 MHz</td>
<td>POD must be enabled</td>
</tr>
<tr>
<td></td>
<td>Scale 1 (otherwise frequency range not supported)</td>
</tr>
</tbody>
</table>

4.8.5 Clock tree glossary

Table 13. Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSI</td>
<td>High speed Internal oscillator: enabled after reset, lower accuracy than HSE</td>
</tr>
<tr>
<td>HSE</td>
<td>High speed external oscillator: requires an external clock circuit</td>
</tr>
<tr>
<td>PLL</td>
<td>Phase locked loop: used to multiply above clock sources</td>
</tr>
<tr>
<td>LSI</td>
<td>Low speed Internal clock: low power clocks usually used for watchdog timers</td>
</tr>
</tbody>
</table>
4.9 Project Manager view

This view (see Figure 101) comes with three tabs:

- General project setting: to specify the project name, location, toolchain, and firmware version.
- Code generation: to set code generation options such as the location of peripheral initialization code, library copy/link options, and to select templates for customized code.
- Advanced settings: dedicated to ordering STM32CubeMX initialization function calls.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSE</td>
<td>Low speed external clock: powered by an external clock</td>
</tr>
<tr>
<td>SYSCLK</td>
<td>System clock</td>
</tr>
<tr>
<td>HCLK</td>
<td>Internal AHB clock frequency</td>
</tr>
<tr>
<td>FCLK</td>
<td>Cortex free running clock</td>
</tr>
<tr>
<td>AHB</td>
<td>Advanced high performance bus</td>
</tr>
<tr>
<td>APB1</td>
<td>Low speed advanced peripheral bus</td>
</tr>
<tr>
<td>APB2</td>
<td>High speed advanced peripheral bus</td>
</tr>
</tbody>
</table>

The code is generated in the project folder tree shown in Figure 102.
4.9.1 Project tab

The Project tab of the Project Settings window allows configuring the following options (see Figure 101):

- Project settings:
  - Project name: name used to create the project folder and the .ioc file name at a given project location
  - Project location: directory where the project folder is stored.
  - Application structure: select between Basic and Advanced options.
    - Basic structure: recommended for projects using one or no middleware. This structure consists in placing the IDE configuration folder at the same level as the sources, organized in sources and includes subfolders (see Figure 103)
    - Advanced structure: recommended when several middleware components are used in the project, makes the integration of middleware applications easier (see Figure 104)
  - Toolchain folder location: by default, it is located in the project folder at the same level as the .ioc file.
  - Toolchain/IDE: selected toolchain
  - For the STM32MP1 series only, OpenSTLinux settings: location of generated device tree and manifest version and contents for current project (see Figure 105). These information enable the synchronization of the right SW components versions with STM32CubeMP1 for Cortex® M and Linux, tf-a, u-boot for Cortex® A. It is important to take them into account especially to ensure one Cube firmware version is aligned with SW components for Cortex® A around OpenAMP / RPM link and resource management API.

Selecting Makefile under Toolchain/IDE leads to the generation of a generic gcc-based makefile.
- Additional project settings for STM32CubeIDE toolchain:
  Select the optional **Generate under root** checkbox to generate the toolchain project files in STM32CubeMX user project root folder or deselect it to generate them under a dedicated toolchain folder.
  STM32CubeMX project generation under the root folder allows the user to benefit from the following Eclipse features:
  - Optional copy of the project into the Eclipse workspace when importing a project.
  - Use of source control systems such as GIT or SVN from the Eclipse workspace.
  Choosing to copy the project into workspace prevents any further synchronization between changes done in Eclipse and changes done in STM32CubeMX, as there will be two different copies of the project.
- Linker settings: value of minimum heap and stack sizes to be allocated for the application. The default values proposed are 0x200 and 0x400 for heap and stack sizes, respectively. These values may need to be increased when the application uses middleware stacks.
- Firmware package selection when more than one version is available (this is the case when successive versions implement the same API and support the same MCUs). By default, the latest available version is used.
- Firmware location selection option
  The default location is the location specified under the **Help > updater settings** menu. Deselecting the **Use Default Firmware Location** checkbox allows the user to specify a different path for the firmware that will be used for the project (see **Figure 106**).
Figure 103. Selecting a basic application structure
Figure 104. Selecting an advanced application structure

Figure 105. OpenSTLinux settings (STM32MP1 series only)
The new location must contain at least a *Drivers* directory containing the HAL and CMSIS drivers from the relevant STM32Cube MCU package. An error message pops up if the folders cannot be found (see *Figure 107*).

To reuse the same *Drivers* folder across all projects that use the same firmware location, select the *Add the library files as reference* from the *Code generator* tab allows (see *Figure 108*).
Caution: STM32CubeMX manages firmware updates solely for this default location. Choosing another location prevents the user from benefiting from automatic updates. The user must manually copy new driver versions to its project folder.

4.9.2 Code Generator tab

The Code Generator tab allows specifying the following code generation options (see Figure 109):
- STM32Cube Firmware Library Package option
- Generated files options
- HAL settings options
- Custom code template options

STM32Cube Firmware Library Package option

The following actions are possible:
- Copy all used libraries into the project folder
  STM32CubeMX copies to the user project folder the drivers libraries (HAL, CMSIS) and the middleware libraries relevant to the user configuration (e.g. FatFs, USB).
- Copy only the necessary library files:
  STM32CubeMX copies to the user project folder only the library files relevant to the user configuration (e.g., SDIO HAL driver from the HAL library).
- Add the required library as referenced in the toolchain project configuration file
  By default, the required library files are copyed to the user project. Select this option for the configuration file to point to files in STM32CubeMX repository instead: the user project folder will not hold a copy of the library files but only a reference to the files in STM32CubeMX repository.

Generated files options

This area allows the user to define the following options:
- Generate peripheral initialization as a pair of .c/.h files or keep all peripheral initializations in the main.c file.
- Backup previously generated files in a backup directory
  The .bak extension is added to previously generated .c/.h files.
  Keep user code when regenerating the C code.
  This option applies only to user sections within STM32CubeMX generated files. It does not apply to the user files that might have been added manually or generated via ftl templates.
- Delete previously generated files when these files are no longer needed by the current configuration. For example, uart.c/.h file are deleted if the UART peripheral, that was enabled in previous code generation, is now disabled in current configuration.

HAL settings options

This area allows selection one HAL settings options among the following:
- Set all free pins as analog to optimize power consumption
- Enable/disable Use the Full Assert function: the Define statement in the stm32xx_hal_conf.h configuration file is commented or uncommented, respectively.
Custom code template options

To generate custom code, click the Settings button under Template Settings, to open the Template Settings window (see Figure 110).

The user is then prompted to choose a source directory to select the code templates from, and a destination directory where the corresponding code will be generated.

The default source directory points to the extra_template directory, within the installation folder, to use for storing all user defined templates. The default destination folder is located in the user project folder.

STM32CubeMX then uses the selected templates to generate user custom code (see Section 6.3: Custom code generation).

Figure 111 shows the result of the template configuration shown on Figure 110: a sample.h file is generated according to sample_.h.ftl template definition.

Figure 109. Project Settings code generator
Figure 110. Template Settings window
4.9.3 Advanced Settings tab

This tab comes with three panels (see Figure 112):

- The **Driver selector** panel, to select the driver (HAL or LL) to be used when generating the initialization code of a peripheral instance.
- The **Generated Function Calls** panel, to choose whether the function calls must be generated or not, generated as static or not and in which order.
- The **Register callback** panel, to select the peripherals for which the register callback define must be generated as part of the stm32xxxx_hal_conf.h file.

As an example, when ADC is enabled in the register callback panel, STM32CubeMX generates

```c
#define USE_HAL_ADC_REGISTER_CALLBACKS 1U
```

**Choosing not to generate code for some peripherals or middlewares**

By default, STM32CubeMX generates initialization code. This automatic generation can be disabled per peripheral or middleware in the Generate code column.
Ordering initialization function calls
By default, the generated code calls the peripheral/middleware initialization functions in the order in which peripherals and middleware have been enabled in STM32CubeMX. The user can then choose to re-order them by modifying the Rank number, using the up and down arrow buttons.

The reset button allows the user to switch back to alphabetical order.

Disabling calls to initialization functions
If the "Not to be generated" checkbox is checked, STM32CubeMX does not generate the call to the corresponding peripheral initialization function. It is up to the user code to do it.

Choosing between HAL and LL based code generation for a given peripheral instance
Starting from STM32CubeMX 4.17 and STM32L4 series, STM32CubeMX offers the possibility for some peripherals to generate initialization code based on Low Layer (LL) drivers instead of HAL drivers: the user can choose between LL and HAL driver in the Driver Selector section. The code is generated accordingly (see Section 6.2: STM32Cube code generation using Low Layer drivers).

Figure 112. Advanced Settings window
Unselecting the Visibility (Static) option, as shown for MX_I2C1_init function in Figure 112, allows the generation of the function definition without the static keyword, and hence extends its visibility outside the current file (see Figure 113).

Figure 113. Generated init functions without C language “static” keyword

```
/* Private function prototypes ------
void SystemClock_Config(void);
static void MX_GPIO_Init(void);
static void MX_LPTIM1_Init(void);
static void MX_LPTIM2_Init(void);
** void MX_I2C1_Init(void)**;
static void MX_I2C2_Init(void);
static void MX_SPI1_Init(void);
static void MX_SPI2_Init(void);
static void MX_USART1_UART_Init(void);
static void MX_USART2_Init(void);
```

Caution: For the STM32MP1 series only
By default the SystemClock_Config function is called in STM32Cube Cube firmware main() function, as the ‘Not generate Function call’ box in Project Manager/Advanced Settings panel is not activated by default (see Figure 112). This configuration is valid for running STM32Cube firmware in engineering mode (Cortex-M4 stand-alone mode).
This configuration is not valid for running STM32Cube firmware in production mode: the ‘Not generate Function call’ box must be checked under Project Manager/Advanced Settings panel, so that there is no call to SystemClock_Config() in the main() function.

4.10 Import Project window

The Import Project menu eases the porting of a previously-saved configuration to another MCU. By default the following settings are imported:

- **Pinout** tab: MCU pins and corresponding peripheral modes. The import fails if the same peripheral instances are not available in the target MCU.
- **Clock configuration** tab: clock tree parameters.
- **Configuration** tab: peripherals and middleware libraries initialization parameters.
- **Project settings**: choice of toolchain and code generation options.

To import a project, proceed as follows:

1. Select the Import project icon ![Import project icon](image) that appears under the File menu after starting a New Project and once an MCU has been selected.
   The menu remains active as long as no user configuration settings are defined for the new project, that is just after the MCU selection. It is disabled as soon as a user action is performed on the project configuration.
2. Select File > Import Project for the dedicated Import project window to open. This window allows to specify the following options:
   - The STM32CubeMX configuration file (.ioc) pathname of the project to import on top of current empty project.
- Whether to import the configuration defined in the **Power Consumption Calculator** tab or not.
- Whether to import the project settings defined through the **Project > Settings** menu: IDE selection, code generation options and advanced settings.
- Whether to import the project settings defined through the **Project > Settings** menu: IDE selection and code generation options.
- Whether to attempt to import the whole configuration (automatic import) or only a subset (manual import).
  a) Automatic project import (see Figure 114)

**Figure 114. Automatic project import**
b) Manual project import

In this case, checkboxes allow the user to select manually the set of peripherals (see Figure 115).

Select the Try Import option to attempt importing.

Figure 115. Manual project import
The Peripheral List indicates:

- The peripheral instances configured in the project to be imported
- The peripheral instances, if any exists for the MCU currently selected, to which the configuration has to be imported. If several peripheral instances are candidate for the import, the user needs to choose one.

Conflicts can occur when importing a smaller package with less pins or a lower-end MCU with less peripheral options.

Click the Try Import button to check for such conflicts: the Import Status window and the Peripheral list get refreshed to indicate errors (see Figure 116), warnings and whether the import has been successful or not:

- Warning icons indicate that the user has selected a peripheral instance more than once, and that one of the import requests will not be performed.
- A cross sign indicates that there is a pinout conflict, and that the configuration cannot be imported as such.

The manual import can be used to refine import choices and resolve the issues raised by the import trial. Figure 117 gives an example of successful import trial, obtained by deselecting the import request for some peripherals.

The Show View function allows switching between the different configuration tabs (pinout, clock tree, peripheral configuration) for checking influence of the “Try Import” action before actual deployment on current project (see Figure 117).
Figure 116. Import Project menu - Try Import with errors

Import Analysis: C:\STM32CubeMX \Import IOC\IOC to import\f4_demo.icol project
The NUI (STM32F427IGKH) found in the Project being imported is not the same as the NUI in
Import error: ETH peripheral doesn’t exist in STM32F722ICRx

Import Try:
- import ADC2 partly failed
- error: External-Trigger-for-Injected-conversion: Set mode doesn’t exist in STM32F722
- import ADC3 partly failed
- error: External-Trigger-for-Injected-conversion: Set mode doesn’t exist in STM32F722
- Some parameters can’t be imported for RCC
  - Can’t import parameter: Instruction Cache, it doesn’t exist in STM32F722ICRx
  - Can’t import parameter: Prefetch Buffer, it doesn’t exist in STM32F722ICRx
  - Can’t import parameter: Data Cache, it doesn’t exist in STM32F722ICRx

Importing project completed
3. Choose **OK** to import with the current status or **Cancel** to go back to the empty project without importing.

Upon import, the Import icon gets grayed since the MCU is now configured and it is no more possible to import a non-empty configuration.
4.11 Set unused / Reset used GPIOs windows

These windows are used to configure several pins at the same time in the same GPIO mode.

To open them:

- Select Pinout > Set unused GPIOs from the STM32CubeMX menu bar.

**Note:** The user selects the number of GPIOs and lets STM32CubeMX choose the actual pins to be configured or reset, among the available ones.

![Figure 118. Set unused pins window](image1)

- Select Pinout > Reset used GPIOs from the STM32CubeMX menu bar.

Depending whether the Keep Current Signals Placement option is checked or not on the toolbar, STM32CubeMX conflict solver will be able to move or not the GPIO signals to other unused GPIOs:

- When Keep Current Signals Placement is off (unchecked), STM32CubeMX conflict solver can move the GPIO signals to unused pins in order to fit in another peripheral mode.
- When Keep Current Signals Placement is on (checked), GPIO signals is not moved and the number of possible peripheral modes is limited.

Refer to **Figure 120** and **Figure 121** and check the limitation(s) in available peripheral modes.

![Figure 119. Reset used pins window](image2)
Figure 120. Set unused GPIO pins with Keep Current Signals Placement checked
4.12 Update Manager windows

Three windows can be accessed through the Help menu available from STM32CubeMX menu bar:

1. Select **Help > Check for updates** to open the **Check Update Manager** window and find out about the latest software versions available for download.

2. Select **Help > Manage embedded software packages** to open the **Embedded Software Package Manager** window and find out about the embedded software packages available for download. It also allows checking for package updates and removing previously installed software packages.

3. Select **Help > Updater settings** to open the **Updater settings** window and configure update mechanism settings (proxy settings, manual versus automatic updates, repository folder where embedded software packages are stored).

Refer to **Section 3.4: Getting updates using STM32CubeMX** for a detailed description of these windows.
4.13 Additional software component selection window

The Additional Software Component selection window can be opened by clicking \textbf{Additional Software} from the \textbf{Pinout & Configuration} tab, at any time when working on the project. It allows the user to select additional software components for the current project. This feature is currently not supported for multi-core products.

It comes as four panels, as shown in \textit{Figure 122}:

- **Filters** panel
  Can be hidden using the “Show/hide filters” button. It is located on the left side of the window and provides a set of criteria to filter the pack component list.

- **Packs** panel
  It is the main panel, as it displays the list of software components per pack that can be selected for the project.

- **Component dependencies** panel
  Can be hidden using the “Show/hide dependencies” button. It displays dependencies, if any, for the component selected in the packs panel. It proposes solutions when any is found.
  Dependencies that are not solved are highlighted with fuchsia icons.
  Once the dependency is solved (by selecting a component among the solution candidates) it is highlighted with green icons.

- **Details and warnings** panel
  Can be hidden using the “Show/hide details” button. It is located on the right hand side.
  It provide informations for the element selected in the Pack panel.
  This element can be a pack, a bundle or a component. It offers the possibility to install a version of the pack available but not yet installed, and allows the user to migrate the current project to a newer version of the pack, raising incompatibilities that cannot be automatically resolved.
Figure 122. Additional Software window

See Section 10: Support of additional software components using CMSIS-Pack standard for more details on how to handle additional software components through STM32CubeMX CMSIS-Pack integration.

4.13.1 Introduction on software components

Arm® Keil™ CMSIS-Pack standard defines the pack (*.pdsc) format for software components to be distributed as Software Packs. A Software pack is a zip file containing a *.pdsc description file.

STM32CubeMX parses the pack .pdsc file to extract the list of software components. This list is presented in the Packs panel.

Arm® Keil™ CMSIS-Pack standard defines a software component as a list of files. The component or each of the corresponding individual files can optionally refer to a condition that must resolve to true, otherwise the component or file is not applicable in the given context. These conditions are listed in the Component dependencies panel.

There are no component names. Instead, each component is uniquely identified for a given vendor pack by the combination of class name, group name and a version. Additional categories, such as sub-group and variant can be assigned. These details are listed in the Details & Warnings panel.
4.13.2 Filter panel

Click on ☰️ to open the Filter panel.

To filter the software component list, choose pack vendor names and software component classes or enter a text string in the search field.

The resulting software component table is collapsed. Click the left arrow to expand it and display all the components that match the filtering criteria.

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show only favorite packs.</td>
<td>A pack is set as favorite in the Details and Warnings panel by clicking ★ Add to favorites</td>
</tr>
<tr>
<td>Show only selected components.</td>
<td>Components are selected in the Packs panel through checkboxes or variant selection when several implementation choices are available for the same component.</td>
</tr>
<tr>
<td>Show only installed packs.</td>
<td>Enables to show or hide not yet installed packs. Not yet installed packs are distinguished with the icon ↓</td>
</tr>
<tr>
<td>Show only packs compatible with this version of STM32CubeMX.</td>
<td>Packs not compatible with this version are distinguished with the icon ✗</td>
</tr>
<tr>
<td>Show only packs compatible with the MCU used for the current project.</td>
<td></td>
</tr>
<tr>
<td>Reset all filters</td>
<td></td>
</tr>
</tbody>
</table>

4.13.3 Packs panel

By default, the Packs panel shows a collapsed view: all known packs are displayed with their name and for one given version (latest version is the default). Icons are used only to highlight the status of a pack version or of a component (see Table Packs panel icons). Details and warnings and Component dependencies panels are used to provide detailed information.

The default view can be expanded by clicking the left arrows, revealing the next level, which can be a Bundle or a top component. The lowest level is the component level.

From this panel, clicking an icon highlighting a limitation or an action opens the relevant secondary panel (Details & Warnings or Component Dependency resolution).

Note: Some packs can have conditions on Arm® cores or STM32 series or STM32 MCUs, they are visible only when the selected MCU meets the criteria. For example, a pack stating the "<accept Dcore="Cortex-M4"/>" condition will show up, but will be grayed out for MCUs not coming with an Arm® Cortex®-M4 core.

Note: A pack may promote an API and be shown under the “exposed APIs” entry. Clicking the API name allows to display additional information in the Details & warnings panel. Selecting the component implementing the API selects the API itself. STM32CubeMX generates the project with both the API .h definition file and the API implementation .c file.
Table 15. Additional Software window – Packs panel columns

<table>
<thead>
<tr>
<th>Column name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack/Bundle/Component</td>
<td>At pack level, shows the &lt;name of the Software pack&gt;</td>
</tr>
<tr>
<td></td>
<td>At bundle level, shows the &lt;Name of the Class&gt;_.&lt;Bundle name, if any&gt;</td>
</tr>
<tr>
<td></td>
<td>At component level, shows the &lt;Group name&gt;/&lt;Subgroup name, if any&gt;.</td>
</tr>
<tr>
<td></td>
<td>Class names are standardized by the Arm CMSIS standard(^{(1)})</td>
</tr>
<tr>
<td>Version</td>
<td>Shows the version that has been selected from a list of one or more</td>
</tr>
<tr>
<td></td>
<td>available versions of a pack.</td>
</tr>
<tr>
<td></td>
<td>Bundle and components can either inherit the version of the pack or have</td>
</tr>
<tr>
<td></td>
<td>their own specific version. The version is shown in the Details and Warning</td>
</tr>
<tr>
<td>Selection</td>
<td>Selects a component through a checkbox when only one implementation is</td>
</tr>
<tr>
<td></td>
<td>available, or from a list if variants exist.</td>
</tr>
</tbody>
</table>

\(^{(1)}\) The Arm\(^{\circledR}\) Keil\(^{\text{TM}}\) CMIS-Pack website, http://www.keil.com, lists the following classes:
- Data Exchange: Software components for data exchange
- File System: File drive support and file system
- Graphics: Graphic libraries for user interfaces
- Network: Network stack using Internet protocols
- RTOS: Real-time operating systems
- Safety: Components for testing application software against safety standards
- Security: Encryption for secure communication or storage
- USB: Universal serial bus stack
- Wireless: Communication stacks such as Bluetooth\(^{\circledR}\), WiFi\(^{\circledR}\), and ZigBee\(^{\circledR}\).

Table 16. Additional Software window – Packs panel icons

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>🌟</td>
<td>The pack has been added to the user favorite list of packs. Use the Details and Warnings panel to add/remove packs from list of favorites.</td>
</tr>
<tr>
<td>✗</td>
<td>The pack version is not compatible with this STM32CubeMX version. Solution: select a compatible version.</td>
</tr>
<tr>
<td>⬇️</td>
<td>The pack version is not yet installed. Solution: go to the Details and Warnings panel to download the pack version to use it for a project.</td>
</tr>
<tr>
<td>☹️</td>
<td>The component is not available for selection. Solution: download the pack this component belongs to.</td>
</tr>
<tr>
<td>⚠️</td>
<td>A component is selected and at least one condition remains to be solved. Select the line of the component with such icon to refresh the Component dependencies panel with the list of dependencies, status and solutions if any found.</td>
</tr>
<tr>
<td>✔️</td>
<td>At least one component is selected and all conditions, if any, are met.</td>
</tr>
<tr>
<td>🔄</td>
<td>Other pack versions are available to switch to. Solution: use the Details and Warnings panel to proceed with a change.</td>
</tr>
</tbody>
</table>
4.13.4 Component dependencies panel

The conditions are dependency rules applying to a given software component. When a component is selected, it shows with a green icon if there is no dependency to resolve, with a warning icon otherwise. Click [icon] to open the dependency panel (see Figure 123).

Table 16. Additional Software window – Packs panel icons (continued)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Icon]</td>
<td>Highlights the components natively available in STM32CubeMX for the currently selected MCU. They correspond to peripheral drivers and middleware stacks. For such components, the dependencies cannot be automatically resolved: go to the STM32CubeMX pinout view and enable the relevant peripheral instance or middleware in the mode panel. They will appear as selected (green checkbox) in the Component Selector.</td>
</tr>
</tbody>
</table>

Figure 123. Component dependency resolution
The panel is refreshed when selecting a component, providing details on the dependencies to solve and the available solutions, if found (see Table 17):

- click the Show button to show the component solving the dependency
- click the Select button to select the component solving the dependency
- when available, click Resolve button to automatically resolve the dependencies.

<table>
<thead>
<tr>
<th>Component dependencies</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No dependency to solve.</td>
<td>No dependency to solve.</td>
</tr>
<tr>
<td>Dependency to solve but issue encountered (no solution found or conflict).</td>
<td>Dependency to solve but issue encountered (no solution found or conflict).</td>
</tr>
<tr>
<td>Dependency to solve and at least one solution found.</td>
<td>Dependency to solve and at least one solution found.</td>
</tr>
</tbody>
</table>

### 4.13.5 Details and Warnings panel

Click on ![info](image) to show the panel (see Figure 124).

This panel is refreshed upon selecting a line from the Packs panel.

The following actions are possible from this panel:

- Add/remove the pack from the list of favorite packs
- Install the pack
- Access the pack documentation through links
- Migrate the project to a new pack version

To migrate a project to a new software pack version:

1. Open the project
2. Migrate to the new pack version
3. Generate the code

Known issue: performing step 2 after step 3 (migrating after code generation) leads to errors (wrong file path generation and project compilation failure). To fix such issue, the project must be saved as new, and the code must be generated again. Actions are possible in this panel, namely adding/removing the pack to/from the list of favorite packs, installing a pack, accessing pack documentation through links.
4.13.6 Updating the tree view for additional software components

Once the selection of the software components required for the application is complete (see Figure 125), click OK to refresh STM32CubeMX window: the selected component appears in the tree view under Additional Software (Figure 126).

The current selection of additional software components appears in the tree view (see Figure 126). The software components must be enabled in the Mode panel and may be configured further if any parameter is proposed in the configuration panel. Hovering the mouse over the component name reveals contextual help with links to documentation.
4.14 LPBAM Scenario & Configuration view

Starting with STM32CubeMX 6.5.0, for projects without TrustZone activated and on the STM32U575/585 product line, users can optionally create LPBAM applications using the LPBAM Scenario & Configuration view (see Figure 127).

Starting with STM32CubeMX 6.6.0, users can create LPBAM applications for projects with TrustZone activated on the STM32U575/585 product lines.
Thanks to this view it is possible to:

- add/remove LPBAM applications
- for each LPBAM application, create queues
- for each queue, create functional nodes using the LPBAM firmware API available for peripherals on the Smart Run Domain
- for each LPBAM application, configure the pinout, the clock tree, and HAL-related configurations for the peripherals on the Smart Run Domain.

For details on how to work with this view, refer to **Section 18: Creating LPBAM projects**.

**Figure 127. LPBAM window**

4.15 **CAD Resources view section**

STM32CubeMX CAD Resources view allows the user to quickly access and download schematic symbols, PCB footprints and 3D CAD models for one or more design toolchains. It requires STM32CubeMX to be connected to the Internet.

To configure and check the Internet connection select **Help > Updater settings** to open STM32CubeMX updater settings window.

CAD Resources can be accessed from the MCU Selector window and from STM32CubeMX project view.
Access from MCU selector

- Open the MCU selector from STM32CubeMX homepage
- Select an MCU commercial part number (Marketing status must not be “Coming soon”)
- Select the CAD Resources tab to see the CAD resources (see Figure 128).
- Use the slider to go down the panel and access the different resource views (Symbols, Footprint, and 3D models).

**Note:** For MCU commercial part numbers in “Coming Soon” Marketing status, there are no CAD resources available (see Figure 129).

To select the resources for download (see Figure 130)

- Select the design toolchain
- Select the CAD formats
- Accept terms and conditions
- Click to download
- Specify the download location

**Figure 128. CAD Resources view**
Access from STM32CubeMX project view

- Open an STM32CubeMX project (the MCU must not be in “Coming Soon” Marketing status)
- Select the CAD tab from the Tools panel to access CAD Resources (see Figure 131).
The Symbol view reflects the STM32CubeMX project pinout configuration and, optionally, the labeling (see Figure 132). The downloaded CAD files are aligned with the pinout configuration and optionally, with the labels as well.
4.16 Boot path

STM32CubeMX-6.8.0 introduces the possibility to configure the boot path for the STM32H5 series.

Figure 133. Boot path configuration ecosystem

![Boo Figure 133. Boot path configuration ecosystemth path configuration ecosystem](image)

Note: STM32H56x and STM32H503 do not support cryptographic hardware accelerator (a feature needed for the ST-iROT and ST-uROT), therefore the full spectrum of boot paths is not available for these MCUs. STM32H503 does not support any boot path in the current implementation.

For details about boot path and its usage, read the wiki page available on www.st.com, and the guide located under the Utilities folder of the STM32Cube firmware package.

This section details, through examples, how to configure a boot path and generate the associated code. It includes compilation, encryption, and provisioning.

4.16.1 Available boot paths

The following tables give an overview of the different boot paths supported by STM32CubeMX, depending upon the device.

<table>
<thead>
<tr>
<th>MCU</th>
<th>Application</th>
<th>OEM-iRoT → Application</th>
<th>OEM-iRoT → uRoT → Application</th>
<th>ST-iRoT → Application</th>
<th>ST-iRoT → uRoT → Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>STM32H56x</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>STM32H57x</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>STM32H503x</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
The following figures indicate the boot paths that STM32CubeMX-6.8.0 can configure, and the entry points after reset.

The related user option bytes are configured automatically (through Trusted Package Creator installed with CubeMX), and programmed during the provisioning stage.

**Table 19. Boot paths with TrustZone (TZEN = 1)(1)**

<table>
<thead>
<tr>
<th>MCU</th>
<th>S/NS application</th>
<th>OEM-iRoT → S/NS application</th>
<th>OEM-iRoT → uRoT application</th>
<th>ST-iRoT → S application</th>
<th>ST-iRoT → ST-uRoT → Secure manager → NS application</th>
</tr>
</thead>
<tbody>
<tr>
<td>STM32H56x</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>STM32H57x</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>


**Figure 134. Boot paths for STM32H57x devices**

![Diagram of boot paths for STM32H57x devices]

**Figure 135. Boot paths for STM32H56x devices**

![Diagram of boot paths for STM32H56x devices]
4.16.2 Creating a boot path project: an example

Prerequisites
- Hardware: Discovery board STM32H573I-DK-REVC
- Tools
  - STM32CubeMX-6.8.0 or later
  - Trusted Package Creator (embedded in STM32CubeMX installation folder)
  - The boot path setting does not work correctly if CubeFW is not installed through CubeMX
  - IAR Embedded Workbench® rev 9.20.4 or later
4.16.3 How to configure an OEM-iRoT boot path

The following instructions describe how to generate an OEM immutable Root of Trust (OEM-iRoT) boot path. The procedure to generate other boot paths is similar, but the data required for the configuration can be different.

Step 1: Selecting the MCU

Figure 138. Select the device or board

Click here to access the list of supported boards, or use the MCU selector for a custom product

Figure 139. Select the STM32H5 device

Click to open the MCU/MPU selector

Select STM32H5
If you click yes, there will be an error during the secure code compilation. By default, all peripherals are set as secure, and the memory allocation for the secure code (defined through the OEM-iRoT_boot application) is too small.

Step 2: Project creation with OEM-iRoT boot path
For this example, enable TrustZone (TZ = 1).

Step 3: Device and peripherals configuration
At this point, the device and its peripherals can be configured. For this example, the default configuration is kept.
Figure 143. Device and peripherals configuration

Select the Project Manager tab to save the project, and to set and configure the boot path.
Step 4: Overall configuration

Configure your application, then save the project.

**Figure 144. Configuring the project**

Choose project name and location (the project directory is created automatically)

S- and NS-application code selected by default

IDE selection (only IAR is currently supported)

The needed files are copied from the selected firmware. Current firmware package version information

Firmware repository, keep it for STM32CubeMX

**Figure 145. Saving the project**

Directory and file created in the Cube firmware folder
Step 5: Boot path selection
The possible first stages are proposed according to selected device and project structure.

**Figure 146. Boot path selection**

- Select OEM-iRoT for this example

**Figure 147. Select OEM-iRoT**
• All possible boot paths for the second stage are proposed according to the selected device and project structure.
• Select “Secure Application”, it generates secure and non-secure codes.
• Click on FINISH to generate the binary, RoT folder, and sub-folders.

**Figure 150. Last boot path stage**

Note: If a selected boot path is not supported, a warning message is displayed, and the “FINISH” button is grayed out.

**Figure 151. Project provisioning**

These default files are copied from Cube firmware (installed with STM32CubeMX)
Step 6: Authentication and encryption keys regeneration, option byte file generation

Customization of OEMiROT configuration file (OEMiROT_Config.obk):

- The default configuration file of CubeFW can be used, but the default keys must be regenerated or replaced.
- To customize the configuration file, proceed as follow:
  a) Launch Trusted Package Creator and select H5 (click edit in Project Manager as indicated in Figure 151)
  b) Open OBkey tab
  c) Select the OEMiROT_Config.xml file in the folder created during Step 5: Boot path selection
  d) The default keys can be regenerated
  e) The OEMiROT_Config.obk file is generated. The modified parameters are saved in OEMiROT_Config
• The H5-Image Gen1 and Gen2 tabs indicate the location of the image configuration files and the path of the binary input and output files. Keep the default settings.

Figure 154. Secure image configuration
Step 7: Code generation

Figure 155. Non-secure image configuration

Figure 156. Generate the code

Click here to generate the code and the IDE environment

Figure 157. Code is generated

Additional directories, including the IDE environment, are created.
The S and NS applications can be developed using the generated code skeletons.

**Step 8: Code compilation and encrypted binaries generation**

If the “Sign Binary(ies)” option has been ticked at **Step 7: Code generation**, the application binaries are encrypted. Select Project → Option → Build Actions. The link to the Trusted Package executable and to the secure and non-secure application xml files are filled automatically.

The secure code must be generated before the non-secure code. Compile each code separately (right click on Project → Rebuild all). The secure and non-secure signed and encrypted binaries are generated during the post build phase.
Step 9: Provisioning of the board

The program cannot be flashed using an IDE. Use provisioning scripts found in the user environment, and double click on the provisioning.bat file (Figure 161). During provisioning, log files are generated to inform the user about the activity. Follow the on-screen instructions (Figure 162).

Figure 160. Trusted Package Creator output directory

Figure 161. Board provisioning
In the user environment, CubeMX has generated an env.bat file, containing the information required for provisioning. Do not change this file.

A pop-up (see Figure 163) shows up when you forget to compile the project OEMiRoT_Boot in the CubeFW.
4.16.4 How to configure an ST-iRoT boot path

The configuration for an ST immutable Root of Trust (ST-iRoT) boot path. The requirements are the same of the previous example.

Step 1: Generating the code

- Select an STM32H57x MCU
- Create a project with TrustZone activated (TZEN = 1)
- In Project Manager, choose “Secure Project”
- Save the project
- Go to “BootPath Settings” tab, and press the Select button
- Choose ST immutable Root of Trust (ST-iRoT)
• Select Secure Application

Figure 165. Select ST-iRoT

• Click “FINISH”, the boot path configuration panel is displayed (see Figure 167), use it to configure the application, then press the GENERATE CODE button to generate the code for IAR

Figure 166. Final boot path stage
For this boot path, only the secure project is generated.
Additional directories, including the IDE environment are created.

Secure applications can be developed using the generated code skeletons.

The Post build command creates a secure compiled encrypted code for the provisioning

**Step 2: Code compilation and encrypted binaries generation**

If the “Sign Binary(ies)” option is ticked during boot path settings configuration, the generated application binaries are encrypted.

- Open the project in IAR
- Select: Project → Option → Build Actions
- The links to the Trusted Package executable and to the secure application xml are filled automatically
- Compile secure (right click on Project → Rebuild all)
- After the Post build command the secure signed and encrypted binaries are generated
Figure 171. IDE post build commands

Post build command added

STM32 Trusted Package Creator v2.13.0-B01

Image generated successfully
Total number of errors: 0
Total number of warnings: 0
Build succeeded

Trusted Package Creator generates an encrypted binary
ST-iRoT board provisioning

The program cannot be flashed using an IDE, use the provisioning scripts found in the user environment.

- Double click on the provisioning.bat file (Figure 172)

Figure 172. Board provisioning

- During provisioning log files are generated to inform the user about the activity
- Follow the on-screen instructions (Figure 173)

Figure 173. On-screen instructions
In the user environment STM32CubeMX has generated an env.bat file containing the required data for provisioning, do not change it.

**Figure 174. Environment configuration file**

```
\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{environment_configuration_file.png}
\caption{Environment configuration file}
\end{figure}
```

### 4.16.5 How to configure an ST-iRoT with a Secure manager NS application boot path

The boot path configuration described below is the ST-iRoT → Secure manager, also known as SMAK.

**Prerequisites:**
- Hardware: Discovery board STM32H573I-DK-REVC or later
- Required tools
  - Secure manager package, to be downloaded and installed from [www.st.com](http://www.st.com)
  - STM32CubeMX-6.8.0 or later
  - STM32 Trusted Package Creator (embedded in STM32CubeMX installation folder)
  - IAR Embedded Workbench rev 9.20.4 or later, and the patch found in the STM32CubeH5 firmware (EWARM/EWARMv8_STM32H5xx_V0.21.zip)
Step 1: SMAK code generation

- Select an STM32H57x MCU
- Create a project with TrustZone activated (TZEN = 1)
- In Project Manager, choose “Non-secure Project”
- Save the project
- Go to “BootPath Settings” tab and press the Select button
- Only ST immutable Root of Trust (ST-iRoT) is proposed
• Updatable Root of Trust (uRoT) option is set by default and cannot be modified

Figure 176. First boot path stage

• Secure Manager Non-Secure application button is checked by default and cannot be modified

Figure 177. Second boot path stage
Click “FINISH”, the panel of boot path configuration is displayed (Figure 179), use it to configure the boot path in the “Boot Path Setting” tab.

Press the “GENERATE CODE” button to generate the configuration code for IAR
Figure 180. Select the project structure

Additional directories including the IDE environment are created
The non-secure application can be developed using the generated code skeletons.

**SMAK code compilation and encrypted binaries generation**

If the “Sign Binary(ies)” option is ticked during boot path settings configuration, the generated application binaries are encrypted.

- Open the project in IAR
- Select: Project → Option → Build Actions
- The link to the STM32 Trusted Package executable and the link to the secure application xml are filled automatically
- Compile secure (right click on Project → Rebuild all)
- After the post build phase, the secure signed and encrypted binaries are generated
Secure manager API

When SMAK boot path is set, the middleware “Secure Manager API” can be configured (see Figure 183).

Figure 183. IDE post build commands

Figure 184. Secure manager API configuration
Depending upon the configuration, the code is generated, and the "Secure Manager API" is added. Additional services can be added with the middleware, such as cryptography or initial attestation.

4.17 About window

This window displays STM32CubeMX version information.

To open it, select Help > About from the STM32CubeMX menu bar.

Figure 185. About window
5 STM32CubeMX tools

5.1 External Tools

This panel is accessible from the home page. It provides an overview of the tools relevant for the STM32 product portfolio (see Figure 186):

- click 🤖 to open the tool information note
- click 🌐 to open the tool webpage on www.st.com
- click ⏯️ to launch the tool.

Figure 186. ST Tools
5.2 Power Consumption Calculator view

For an ever-growing number of embedded systems applications power consumption is a major concern. To help minimizing it, STM32CubeMX offers the **Power Consumption Calculator** tab (see *Figure 187*), which, given a microcontroller, a battery model and a user-defined power sequence, provides the following results:

- Average current consumption
  Power consumption values can either be taken from the datasheet or interpolated from a user specified bus or core frequency.
- Battery life
- Average DMIPs
  DMIPs values are directly taken from the MCU datasheet and are neither interpolated nor extrapolated.
- Maximum ambient temperature ($T_{\text{AMAX}}$)
  According to the chip internal power consumption, the package type and a maximum junction temperature of 105 °C, the tool computes the maximum ambient temperature to ensure good operating conditions.
  Current $T_{\text{AMAX}}$ implementation does not account for I/O consumption. For an accurate estimate, I/O consumption must be specified using the Additional Consumption field. The formula for I/O dynamic current consumption is specified in the microcontroller datasheet.

The **Power Consumption Calculator** view allows developers to visualize an estimate of the embedded application consumption and lower it further at each power sequence step:

- make use of low power modes when available
- adjust clock sources and frequencies based on the step requirements
- enable only the peripherals necessary for each phase.

For each step the user can choose $V_{\text{BUS}}$ as possible power source instead of the battery, impact battery life. If power consumption measurements are available at different voltage levels, STM32CubeMX also proposes a choice of voltage values (see *Figure 190*).

An additional option, the transition checker, is available for STM32L0, STM32L1, STM32L4, STM32L4+, STM32G0, STM32G4, STM32H7 and STM32WB series. When enabled, the transition checker detects invalid transitions within the currently configured sequence. It ensures that only possible transitions are proposed to the user when a new step is added.
5.2.1 Building a power consumption sequence

The default starting view is shown in Figure 187.

![Figure 187. Power Consumption Calculator default view](image)

Selecting a V\textsubscript{DD} value

From this view and when multiple choices are available, the user must select a V\textsubscript{DD} value.
Selecting a battery model (optional)

Optionally, the user can select a battery model. This can also be done once the power consumption sequence is configured.

The user can select a predefined battery or choose to specify a new battery that best matches its application (see Figure 188).

Figure 188. Battery selection

Power sequence default view

The user can now proceed and build a power sequence.

Managing sequence steps

Steps can be reorganized within a sequence (Add new, Delete a step, Duplicate a step, move Up or Down in the sequence) using the set of Step buttons (see Figure 189).

The user can undo or redo the last configuration actions by clicking the Undo button in the Power Consumption Calculator view or the Undo icon from the main toolbar.

Figure 189. Step management functions
Adding a step

There are two ways to add a new step:

- Click Add in the Power Consumption panel. The New Step window opens with empty step settings.
- Or, select a step from the sequence table and click Duplicate. A New Step window opens duplicating the step settings (see Figure 190).

Figure 190. Power consumption sequence: New Step default view

Once a step is configured, resulting current consumption and $T_{\text{AMAX}}$ values are provided in the window.
Editing a step
To edit a step, double-click it in the sequence table, this opens the Edit Step window.

Moving a step
By default, a new step is added at the end of a sequence. Click the step in the sequence table to select it and use the Up and Down buttons to move it elsewhere in the sequence.

Deleting a step
Select the step to be deleted and click the Delete button.

Using the transition checker
Not all transitions between power modes are possible. The Power Consumption Calculator power menu proposes a transition checker to detect invalid transitions or restrict the sequence configuration to only valid transitions.

Enabling the transition checker option prior to sequence configuration ensures that the user will be able to select only valid transition steps.

Enabling the transition checker option on an already configured sequence will highlight the sequence with a green frame if all transitions are valid (see Figure 191), or in fuchsia if at least one transition is invalid (fuchsia frame with description of invalid step highlighted in fuchsia, see Figure 192). In the latter case, the user can click the Show log button to find out how to solve the transition issue (see Figure 193).

Figure 191. Enabling the transition checker option on an already configured sequence - All transitions valid

Figure 192. Enabling the transition checker option on an already configured sequence - At least one transition invalid
Figure 193. Transition checker option - Show log

Log for current sequence

Transition allowed!

Check transition between step 6 (RUN, Range1-High) and step 7 (STOP, NoRange)
Possible next step(s): RUN [Range1-High, Range2-Medium, Range3-Low]
Possible next step(s): LOWPOWER_RUN [Range3-Low]
Possible next step(s): SLEEP [Range1-High, Range2-Medium, Range3-Low]
Possible next step(s): LOWPOWER_SLEEP [Range3-Low]
Possible next step(s): STOP [NoRange]

Transition allowed!

Check transition between step 7 (STOP, NoRange) and step 8 (SLEEP, Range1-High)
Possible next step(s): WU_FROM_STOP [NoRange]

Transition not possible!
5.2.2 Configuring a step in the power sequence

The step configuration is performed from the Edit Step and New Step windows. The graphical interface guides the user by forcing a predefined order for setting parameters.

Their naming may differ according to the selected MCU series. For details on each parameter, refer to glossary in Section 5.2.4 and to Appendix D: STM32 microcontrollers power consumption parameters, or to the electrical characteristics section of the datasheet.

The parameters are set automatically by the tool when there is only one possible value (in this case, the parameter cannot be modified and is grayed out). The tool proposes only the configuration choices relevant to the selected MCU.

To configure a new step:

1. Click Add or Duplicate to open the New step window or double-click a step from the sequence table to open the Edit step window.

2. Within the open step window, select in the following order:
   - The Power Mode
     Changing the Power Mode resets the whole step configuration.
   - The Peripherals
     Peripherals can be selected/deselected at any time after the Power Mode is configured.
   - The Power scale
     The power scale corresponds to the power consumption range (STM32L1) or the power scale (STM32F4).
     Changing the Power Mode or the Power Consumption Range discards all subsequent configurations.
   - The Memory Fetch Type
   - The VDD value if multiple choices available
   - The voltage source (battery or VBUS)
   - A Clock Configuration
     Changing the Clock Configuration resets the frequency choices further down.
     When multiple choices are available, the CPU Frequency (STM32F4) and the AHB Bus Frequency/CPU Frequency (STM32L1) or, for active modes, a user specified frequency. In this case, the consumption value will be interpolated (see Using interpolation).

3. Optionally set
   - A step duration (1 ms is the default value)
   - An additional consumption value (expressed in mA) to reflect, for example, external components used by the application (external regulator, external pull-up, LEDs or other displays). This value added to the microcontroller power consumption will impact the step overall power consumption.

4. Once the configuration is complete, the Add button becomes active. Click it to create the step and add it to the sequence table.
Using interpolation

For steps configured for active modes (Run, Sleep), frequency interpolation is supported by selecting CPU frequency as User Defined and entering a frequency in Hz (see Figure 194).

Figure 194. Interpolated power consumption
Importing pinout

*Figure 195* illustrates the example of the ADC configuration in the **Pinout** view: clicking **Enable IPs from Pinout** in the Power Consumption Calculator view selects the ADC peripheral and GPIO A (*Figure 196*).

The **Enable IPs from Pinout** button allows the user to automatically select the peripherals that have been configured in the **Pinout** view.

---

**Figure 195. ADC selected in Pinout view**

<table>
<thead>
<tr>
<th>Pinout &amp; Configuration</th>
<th>Clock Configuration</th>
<th>Additional Softwares</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Options</strong></td>
<td><strong>ADC Mode and Configuration</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Categories</strong></td>
<td>Mode</td>
<td></td>
</tr>
<tr>
<td>ADC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMP1</td>
<td>IN0</td>
<td></td>
</tr>
<tr>
<td>COMP2</td>
<td>IN1</td>
<td></td>
</tr>
<tr>
<td>CRC</td>
<td>IN2</td>
<td></td>
</tr>
<tr>
<td>DAC</td>
<td>IN3</td>
<td></td>
</tr>
<tr>
<td>DMA</td>
<td>IN4</td>
<td></td>
</tr>
<tr>
<td>FATFS</td>
<td>IN5</td>
<td></td>
</tr>
<tr>
<td>FREERTOS</td>
<td>IN6</td>
<td></td>
</tr>
<tr>
<td>GPIO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I2C1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I2C2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Selecting/deselecting all peripherals

Clicking **Enable All IPs** allows the user to select all peripherals at once.

Clicking **Disable All IPs** removes them as contributors to the consumption.

**Figure 196. Power Consumption Calculator Step configuration window:**
ADC enabled using import pinout

5.2.3 Managing user-defined power sequence and reviewing results

The configuration of a power sequence leads to an update of the Power Consumption Calculator view (see **Figure 197**):

- The sequence table shows all steps and step parameters values. A category column indicates whether the consumption values are taken from the datasheet or are interpolated.
- The sequence chart area shows different views of the power sequence according to a display type (e.g. plot all steps, plot low power versus run modes)
- The results summary provides the total sequence time, the maximum ambient temperature (T\text{MAX}), plus an estimate of the average power consumption, DMIPS, and battery lifetime provided a valid battery configuration has been selected.
Managing the whole sequence (load, save and compare)

From the power menu (see Figure 198), the current sequence can be saved, deleted or compared to a previously saved sequence that will be displayed in a dedicated popup window.
Managing the results charts and display options

In the Display area, select the type of chart to display (e.g. sequence steps, pie charts, consumption per peripherals). You can also click External Display to open the charts in dedicated windows (see Figure 199).

Right-click on the chart to access the contextual menus: Properties, Copy, Save as png picture file, Print, Zoom menus, and Auto Range to reset to the original view before zoom operations. Zooming can also be achieved by mouse selecting from left to right a zone in the chart and Zoom reset by clicking the chart and dragging the mouse to the left.

Figure 199. Power Consumption: Peripherals consumption chart

Overview of the Results summary area

This area provides the following information (see Figure 200):

- Total sequence time, as the sum of the sequence steps durations.
- Average consumption, as the sum of each step consumption weighed by the step duration.
- The average DMIPS (Dhrystone million instructions per second) based on Dhrystone benchmark, highlighting the CPU performance for the defined sequence.
- Battery life estimation for the selected battery model, based on the average power consumption and the battery self-discharge.
- \( T_{\text{AMAX}} \): highest maximum ambient temperature value found during the sequence.

Figure 200. Description of the Results area
5.2.4 Power sequence step parameters glossary

The parameters that characterize power sequence steps are the following (refer to Appendix D: STM32 microcontrollers power consumption parameters for more details):

- **Power modes**
  To save energy, it is recommended to switch the microcontroller operating mode from running mode, where a maximum power is required, to a low-power mode requiring limited resources.

- **$V_{\text{CORE}}$ range (STM32L1) or Power scale (STM32F4)**
  These parameters are set by software to control the power supply range for digital peripherals.

- **Memory Fetch Type**
  This field proposes the possible memory locations for application C code execution. It can be either RAM, FLASH or FLASH with ART ON or OFF (only for families that feature a proprietary Adaptive real-time (ART) memory accelerator which increases the program execution speed when executing from flash memory).
  The performance achieved thanks to the ART accelerator is equivalent to 0 wait state program execution from flash memory. In terms of power consumption, it is equivalent to program execution from RAM. In addition, STM32CubeMX uses the same selection choice to cover both settings, RAM and flash memory with ART ON.

- **Clock Configuration**
  This operation sets the AHB bus frequency or the CPU frequency that will be used for computing the microcontroller power consumption. When there is only one possible choice, the frequencies are automatically configured.
  The clock configuration drop-down list allows to configure the application clocks:
  - the internal or external oscillator sources: MSI, HSI, LSI, HSE or LSE
  - the oscillator frequency
  - other determining parameters, among them PLL ON, LSE Bypass, AHB prescaler value, LCD with duty

- **Peripherals**
  The peripheral list shows the peripherals available for the selected power mode. The power consumption is given assuming that peripherals are only clocked (e.g. not in use by a running program). Each peripheral can be enabled or disabled. Peripherals individual power consumptions are displayed in a tooltip. An overall consumption due to peripheral analog and digital parts is provided in the step Results area (see Figure 201).
The user can select the peripherals relevant for the application:

- none (Disable All)
- some (using peripheral dedicated checkbox)
- all (Activate All)
- or all from the previously defined pinout configuration (Import Pinout).

Only the selected and enabled peripherals are taken into account when computing the power consumption.

- **Step duration**
  The user can change the default step duration value. When building a sequence, the user can either create steps according to the application actual power sequence or define them as a percentage spent in each mode. For example, if an application
spends 30% in Run mode, 20% in Sleep and 50% in Stop, the user must configure a 3-step sequence consisting in 30 ms in Run, 20 ms in Sleep and 50 ms in Stop.

- **Additional Consumption**
  This field allows entering an additional consumption resulting from specific user configuration (e.g. MCU providing power supply to other connected devices).

### 5.2.5 Battery glossary

- **Capacity (mAh)**
  Amount of energy that can be delivered in a single battery discharge.

- **Self-discharge (% / month)**
  This percentage, over a specified period, represents the loss of battery capacity when the battery is not used (open-circuit conditions), as a result of internal leakage.

- **Nominal voltage (V)**
  Voltage supplied by a fully charged battery.

- **Max. continuous current (mA)**
  This current corresponds to the maximum current that can be delivered during the battery lifetime period without damaging the battery.

- **Max. pulse current (mA)**
  This is the maximum pulse current that can be delivered exceptionally, for instance when the application is switched on during the starting phase.

### 5.2.6 SMPS feature

Some microcontrollers (e.g. STM32L496xxxxP) allow the user to connect an external switched mode power supply (SMPS) to further reduce power consumption.

For such microcontrollers, the Power Consumption Calculator tool offers the following features:

- **Selection of SMPS for the current project**
  From the left panel, check the **Use SMPS** box to use SMPS (see **Figure 202**). By default, ST SMPS model is used.

- **Selection of another SMPS model by clicking the **Change** button**
  This opens the SMPS database management window in which the user can add a new SMPS model (see **Figure 203**). The user can then select a different SMPS model for the current sequence (see **Figure 204**, **Figure 205** and **Figure 206**).

- **Check for invalid SMPS transitions in the current sequence by enabling the SMPS checker**
  To do this, select the checkbox to enable the checker and click the **Help** button to open the reference state diagram (see **Figure 207**).

- **Configuration of SMPS mode for each step (see **Figure 208**)**
  If the SMPS checker is enabled, only the SMPS modes valid for the current step are proposed.
Figure 202. Selecting SMPS for the current project
Figure 203. SMPS database - Adding new SMPS models

Figure 204. SMPS database - Selecting a different SMPS model
Figure 205. Current project configuration updated with new SMPS model

![Image of current project configuration updated with new SMPS model]

Figure 206. SMPS database management window with new model selected

![Image of SMPS database management window with new model selected]
Figure 207. SMPS transition checker and state diagram helper window
Figure 208. Configuring the SMPS mode for each step
5.2.7 BLE and ZigBee support (STM32WB series only)

The Power Consumption tool allows the user to take into account the consumption related to the RF peripheral and corresponding BLE functional mode, combined with the usage of the SMPS feature.

Figure 209. RF related consumption (STM32WB series only)

The BLE mode can be selected from the left panel and configured to reflect the user’s application relevant settings. For each new step enabling BLE, the peripheral consumption part is updated accordingly (see Figure 210). A similar approach is used for ZigBee (see Figure 211).
Figure 210. RF BLE mode configuration (STM32WB series only)

Figure 211. ZigBee configuration (STM32WB series only)
5.2.8 Sub-Ghz support (STM32WL series only)

Sub-GHz usage can be enabled from the left panel and configured to reflect the user’s application relevant settings. For each new step enabling ZigBee, the peripheral consumption part is updated accordingly (see Figure 212).

![Figure 212. RF sub-Ghz configuration]

5.2.9 Example feature (STM32MP1 and STM32H7 dual-core only)

Under the section “Sequence Examples”, the PCC tool allows to access examples: each example come with an explanatory slide-set and a ready-made sequence to be loaded in PCC (see Figure 213).
Clicking “Load Example N” loads the sequence corresponding to the example N (see Figure 214).

Clicking “Example N Presentation” displays the explanations for that example.
The example can be changed anytime: the new sequence can be either added to the current sequence, or replace it (see Figure 215).

Figure 215. Power Consumption Calculator – Example sequence new selection

Note: The examples are provided for a given part number and may require adjustments when used for a different part number. Also, after loading, it is recommended to edit each step and check settings.

5.3 DDR Suite (for STM32MP1 series only)

DDR SDRAMs are complex high speed devices that need careful PCB design.

The STM32MP15 devices support the following DDR types:
- LPDDR2
- LPDDR3
- DDR3 / DDR3L

They are specified by the JEDEC standard (standardization of interfaces, commands, timings, packages and ballout).

STM32CubeMX has been extended to provide an exhaustive tool suite for the STM32MP1 DDR subsystem. It proposes the following key features.
- **Configuration of DDR** controller and PHY registers is managed automatically based on reduced set of editable parameters.
- **DDR testing** is offered based on a rich tests list. Tests go from basic to stress tests. User can also develop its own tests.

**DDR configuration** is accessible like the other peripherals in the Pinout & Configuration view: clicking the DDR from the component panel, opens the mode and configuration panels.
**DDR Test suite testing and tuning** features are available from the Tools view.

The DDR suite relies on two important concepts:
- the **DDR timings** as key inputs for the configuration of the DDR Controller and PHY
- the tuning of DDR signals to compensate board design imperfections.

## 5.3.1 DDR configuration

STM32CubeMX allows to set DDR system parameters and JEDEC core timings. The timing parameters are available in the DDR datasheet.

### DDR type, width and density

The DDR type, width and density parameter settings are required to proceed with the DDR configuration step. This can be done in the mode panel after selecting the DDR in the Pinout & Configuration view.

See Figure 216 for an example of LPDDR2 settings.

![Figure 216. DDR pinout and configuration settings](image)

Another example: for a configuration with two “DDR3 16 bits 2 Gb” chips, settings are “DDR3/DDR3L”, “32 bits” and 4 Gb”.

**Note:** Contexts for DDR IP cannot be changed, DDR is tied to “Cortex-A7 Non-Secure” identified as “Cortex-A7 NS” in the tool.
**DDR configuration**

Clicking on a parameter will show additional details in the DDR configuration footer.

- The DDR frequency is taken from the ‘Clock configuration’ tab, it cannot be changed in the DDR configuration.
- The ‘Relaxed Timing’ mode is used during bring-up phase for trying relaxed key DDR timings value (one t\textsubscript{CK} added to t\textsubscript{RC}, t\textsubscript{RCD} and t\textsubscript{RP} timings)
- Other parameters must be retrieved from the user DDR datasheet.
- Some parameters are read-only: they are for information only and depend on the DDR type.

Clicking “generate code” automatically computes the DDR node of the device tree (DDR Controller and DDR PHY registers values) based on these parameters.

**DDR3 configuration**

For DDR3, the configuration is made easier with the selection of a **Speed Bin / Grade** combination, instead of manually editing timing parameters.
The Speed Bin / Grade combination must match the selected DDR. If the exact combination is not in the pick-list, “1066E / 6-6-6” must be selected for faster DDR Speed bin / Grade, whereas “1066G / 8-8-8” can be used as a relaxed configuration.
Timing edition is then optional, and reserved for advanced users: select Show Advanced parameters to display the list.

5.3.2 Connection to the target and DDR register loading

To manage DDR tests and tuning, STM32CubeMX must establish a connection with the target and more specifically with U-Boot SPL using the DDR interactive protocol:

- the DDR interactive protocol is only available in the Basic boot scheme U-Boot SPL binary and supported over the UART4 peripheral instance
- when U-Boot SPL detects a connection to STM32CubeMX on UART4, it stops its initialization process and accepts commands from STM32CubeMX.

There are two connection options:
1. the U-Boot SPL binary is available in flash memory
2. the U-Boot SPL needs to be loaded in SYSRAM because the DDR has not yet been tested nor tuned (and, consequently, is not fully functional yet).

Prerequisites

- Installation of ST-Link USB driver to perform firmware upgrades: for Windows, latest version of STSW-LINK009 must be used. For Linux, the STSW-LINK007 driver must be used. Both can be downloaded from www.st.com.

Connection to the target

The COM port must be selected to connect to the target, as indicated in Figure 218.

Figure 218. DDR Suite - Connection to target
If U-Boot SPL loading in SysRAM is required, it can be performed through UART or USB using the STM32CubeProgrammer tool. If not automatically detected by STM32CubeMX, the STM32CubeProgrammer tool location must be specified in the Connection settings window: click to open it. U-Boot SPL file must be manually selected in the build image folder.

Once up, the connection gives the various services and target information (see Figure 219).

Figure 219. DDR Suite - Target connected

Output/Log messages

STM32CubeMX outputs DDR suite related activity logs (see Figure 220) and interactive protocol communication logs (see Figure 221). They are displayed by enabling outputs from the Window menu.

Figure 220. DDR activity logs
DDR register loading (optional)

Once connected in DDR interactive mode, user can load the current DDR configuration in SYSRAM.

This step is optional if the used U-Boot SPL already contains the required DDR configuration. It trigs the DDR Controller and PHY initialization with those registers, and allows the user to quickly test a configuration without generating the device tree and dedicated U-Boot SPL binary file.
5.3.3 DDR testing

Prerequisites
To proceed with DDR testing:
- The DDR suite must be in connected state
- The DDR configuration must be available in memory, either with the U-Boot SPL (with DDR register file in Device Tree) or in the DDR registers (see Section 5.3.2).

DDR test list
DDR tests are part of the U-Boot SPL (see Figure 223).

New tests can be added by modifying the U-boot SPL.
Most of the tests come with parameters to be set prior to execution, such as:
- Address: the memory address where the test is executed. All writes and reads are performed on this address. The given address has to be located in the DDR memory region [DDR base address, DDR base address + DDR size].
- On STM32MP15, DDR base address is 0xC0000000 (as an example, DDR size for 4 Gbits is 0x20000000).
- Loop: number of test iterations before verdict. Same test is repeated [Loop] times. Verdict OK if all tests are OK, KO otherwise.
- Size: the byte size of the region to test. Size must be a multiple of 4 (read/writes are performed on 32-bit unsigned integers) with minimal value equal to 4. Size can be up to DDR size.
- Pattern: the 32-bit pattern to be used for read / write operations.

The DDR Suite embeds an auto-correction feature preventing users to specify wrong values.

All tests are performed with Data cache disabled and Instruction cache enabled.
DDR test results

The test verdict is reported by the U-Boot SPL: the parameters used for the tests are recalled, along with Pass/Fail status and results details (see Figure 224). The test history is available in the output and Logs panels (see Figure 225).

Figure 224. DDR test suite results

<table>
<thead>
<tr>
<th>Parameter(s)</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Loop</td>
<td>1</td>
</tr>
</tbody>
</table>

Verdict

<table>
<thead>
<tr>
<th>Item(s)</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Loop(s)</td>
<td>1</td>
</tr>
<tr>
<td>Result</td>
<td>Pass</td>
</tr>
<tr>
<td>Result details</td>
<td>no error for 1 loops</td>
</tr>
</tbody>
</table>

Figure 225. DDR tests history

<table>
<thead>
<tr>
<th>MCU Selection</th>
<th>Output</th>
<th>DDR Interactive logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>step to 1:DDR_READY</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>1:DDR_CTRL_INIT_DONE</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>2:DDR_PHY_INIT_DONE</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>3:DDR_READY</td>
</tr>
<tr>
<td>Host &gt; Target</td>
<td>test 1</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>execute 2:DataBusWalking0</td>
</tr>
<tr>
<td>Host &gt; Target</td>
<td>test 3</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>Result: Pass [no error for 1 loops]</td>
</tr>
<tr>
<td>Host &gt; Target</td>
<td>test 3</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>execute 3:DataBusWalking1</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>running 1 loops at 0xC0000000</td>
</tr>
<tr>
<td>Host &gt; Target</td>
<td>test 4</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>Result: Pass [no error for 1 loops]</td>
</tr>
<tr>
<td>Host &gt; Target</td>
<td>test 4</td>
<td>0xC0000000</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>execute 4:AddressBus</td>
</tr>
<tr>
<td>Target &gt; Host</td>
<td>Host</td>
<td>Result: Pass [address 0xC0000000, size 0x4]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MCU Selection</th>
<th>Output</th>
<th>DDR Interactive logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target board configuration name: DDR5-1048/888 bin G 2x32b 400.0.0.0.0MHz v1.48</td>
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<td></td>
</tr>
<tr>
<td>Target board DDR size: 8 GBits</td>
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<tr>
<td>Target board DDR frequency: 400.0MHz</td>
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<tr>
<td>Current configuration DDR registers loaded to the target board</td>
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<tr>
<td>DDR test #2 (DataBusWalking0) triggered with parameters: [loop] 1 [addr] 0xC0000000</td>
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<td></td>
</tr>
<tr>
<td>DDR test #3 (DataBusWalking1) triggered with parameters: [loop] 1 [addr] 0xC0000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDR test #4 (AddressBus) triggered with parameters: [size] 4 [addr] 0xC0000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6 STM32CubeMX C Code generation overview

6.1 STM32Cube code generation using only HAL drivers (default mode)

During the C code generation process, STM32CubeMX performs the following actions:

1. If it is missing, it downloads the relevant STM32Cube MCU package from the user repository. STM32CubeMX repository folder is specified in the Help > Updater settings menu.

2. It copies from the firmware package, the relevant files in Drivers/CMSIS and Drivers/STM32F4_HAL_Driver folders and in the Middleware folder if a middleware was selected.

3. It generates the initialization C code (.c/.h files) corresponding to the user MCU configuration and stores it in the Inc and Src folders. By default, the following files are included:
   - `stm32f4xx_hal_conf.h` file: this file defines the enabled HAL modules and sets some parameters (e.g. External High Speed oscillator frequency) to predefined default values or according to user configuration (clock tree).
   - `stm32f4xx_hal_msp.c` (MSP = MCU Support package): this file defines all initialization functions to configure the peripheral instances according to the user configuration (pin allocation, enabling of clock, use of DMA and Interrupts).
   - `main.c` is in charge of:
     - Resetting the MCU to a known state by calling the `HAL_init()` function that resets all peripherals, initializes the flash memory interface and the SysTick.
     - Configuring and initializing the system clock.
   - Configuring and initializing the GPIOs that are not used by peripherals.
   - Defining and calling, for each configured peripheral, a peripheral initialization function that defines a handle structure that will be passed to the corresponding peripheral HAL init function which in turn will call the peripheral HAL MSP initialization function. Note that when LwIP (respectively USB) middleware is used, the initialization C code for the underlying Ethernet (respectively USB peripheral) is moved from main.c to LwIP (respectively USB) initialization C code itself.
   - `main.h` file:
     - This file contains the define statements corresponding to the pin labels set from the Pinout tab, as well as the user project constants added from the Configuration tab (refer to Figure 226 and Figure 227 for examples):

```c
#define MyTimeOut 10
#define LD4_Pin GPIO_PIN_12
#define LD4_GPIO_Port GPIOD
#define LD3_Pin GPIO_PIN_13
#define LD3_GPIO_Port GPIOD
#define LD5_Pin GPIO_PIN_14
#define LD5_GPIO_Port GPIOD
#define LD6_Pin GPIO_PIN_15
#define LD6_GPIO_Port GPIOD
```
In case of duplicate labels, a unique suffix, consisting of the pin port letter and the pin index number, is added and used for the generation of the associated define statements.

In the example of a duplicate I2C1 labels shown in Figure 228, the code generation produces the following code, keeping the I2C1 label on the original port B pin 6 define statements and adding B7 suffix on pin 7 define statements:

```c
#define I2C1_Pin GPIO_PIN_6
#define I2C1_GPIO_Port GPIOB
#define I2C1B7_Pin GPIO_PIN_7
#define I2C1B7_GPIO_Port GPIOB
```
In order for the generated project to compile, define statements shall follow strict naming conventions. They shall start with a letter or an underscore as well as the corresponding label. In addition, they shall not include any special character such as minus sign, parenthesis or brackets. Any special character within the label will be automatically replaced by an underscore in the define name.

If the label contains character strings between "[]" or "()", only the first string listed is used for the define name. As an example, the label "LD6 [Blue Led]" corresponds the following define statements:

```c
#define LD6_Pin   GPIO_PIN_15
#define LD6_GPIO_Port   GPIOD
```

The define statements are used to configure the GPIOs in the generated initialization code. In the following example, the initialization of the pins labeled Audio_RST_Pin and LD4_Pin is done using the corresponding define statements:

```c
/*Configure GPIO pins : LD4_Pin Audio_RST_Pin */
GPIO_InitStruct.Pin = LD4_Pin | Audio_RST_Pin;
GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;
GPIO_InitStruct.Pull = GPIO_NOPULL;
GPIO_InitStruct.Speed = GPIO_SPEED_LOW;
HAL_GPIO_Init(GPIOD, &GPIO_InitStruct);
```

4. Finally it generates a Projects folder that contains the toolchain specific files that match the user project settings. Double-clicking the IDE specific project file launches the IDE and loads the project ready to be edited, built and debugged.

### 6.2 STM32Cube code generation using Low Layer drivers

For all STM32 series except STM32H7 and STM32P1, STM32CubeMX allows the user to generate peripheral initialization code based either on the peripheral HAL driver or on the peripheral Low Layer (LL) driver.

The choice is made through the Project Manager view (see Section 4.9.3: Advanced Settings tab).

The LL drivers are available only for the peripherals which require an optimized access and do not have a complex software configuration. The LL services allow performing atomic operations by changing the relevant peripheral registers content:

- Examples of supported peripherals: RCC, ADC, GPIO, I2C, SPI, TIM, USART,…
- Examples of peripherals not supported by LL drivers: USB, SDMMC, FSMC.
The LL drivers are available within the STM32CubeL4 package:

- They are located next to the HAL drivers (\texttt{stm32l4_hal_<peripheral_name>}) within the \texttt{Inc} and \texttt{Src} directory of the \texttt{STM32Cube_FW_L4_V1.6\Drivers\STM32L4xx_HAL_Driver} folder.
- They can be easily recognizable by their naming convention: \texttt{stm32l4_ll_<peripheral_name>}

For more details on HAL and LL drivers refer to the \textit{STM32L4 HAL and Low-layer drivers} user manual (UM1884).

As the decision to use LL or HAL drivers is made on a peripheral basis, the user can mix both HAL and LL drivers within the same project.

The following tables show the main differences between the three possible STM32CubeMX project generation options: HAL-only, LL-only, and mix of HAL and LL code.

**Table 20. LL versus HAL code generation: drivers included in STM32CubeMX projects**

<table>
<thead>
<tr>
<th>Project configuration and drivers to be included</th>
<th>HAL only</th>
<th>LL only</th>
<th>Mix of HAL and LL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSIS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>STM32xxx_HAL_Driver</td>
<td>Only HAL driver files</td>
<td>Only LL driver files</td>
<td>Mix of HAL and LL driver files</td>
<td>Only the driver files required for a given configuration (selection of peripherals) are copied when the project settings option is set to “Copy only the necessary files”. Otherwise (“all used libraries” option) the complete set of driver files is copied.</td>
</tr>
</tbody>
</table>

**Table 21. LL versus HAL code generation: STM32CubeMX generated header files**

<table>
<thead>
<tr>
<th>Generated header files</th>
<th>HAL only</th>
<th>LL only</th>
<th>Mix of HAL and LL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>main.h</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>This file contains the include statements and the generated define statements for user constants (GPIO labels and user constants).</td>
</tr>
<tr>
<td>stm32xxx_hal_conf.h</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>This file enables the HAL modules necessary to the project.</td>
</tr>
<tr>
<td>stm32xxx_it.h</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Header file for interrupt handlers</td>
</tr>
<tr>
<td>stm32xx_assert.h</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>This file contains the assert macros and the functions used for checking function parameters.</td>
</tr>
</tbody>
</table>
### Table 22. LL versus HAL: STM32CubeMX generated source files

<table>
<thead>
<tr>
<th>Generated source files</th>
<th>HAL only</th>
<th>LL only</th>
<th>Mix of HAL and LL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>main.c</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>This file contains the main functions and optionally STM32CubeMX generated functions.</td>
</tr>
</tbody>
</table>
| stm32xxx_hal_msp.c     | Yes      | No      | Yes               | This file contains the following functions:  
|                        |          |         |                   | – HAL_MspInit  
|                        |          |         |                   | – for peripherals using HAL drivers:  
|                        |          |         |                   | HAL_<Peripheral>_MspInit,  
|                        |          |         |                   | HAL_<Peripheral>_MspDelInit,  
|                        |          |         |                   | These functions are available only for the peripherals that use HAL drivers. |
| stm32xxx_it.c          | Yes      | Yes     | Yes               | Source file for interrupt handlers |

### Table 23. LL versus HAL: STM32CubeMX generated functions and function calls

<table>
<thead>
<tr>
<th>Generated source files</th>
<th>HAL only</th>
<th>LL only</th>
<th>Mix of HAL and LL</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Hal_init()             | Called in main.c | Not used | Called in main.c | This file performs the following functions:  
|                        |          |         |                   | – Configuration of flash memory prefetch and instruction and data caches  
|                        |          |         |                   | – Selection of the SysTick timer as timebase source  
|                        |          |         |                   | – Setting of NVIC group priority  
|                        |          |         |                   | – MCU low-level initialization. |
| Hal_msp_init()         | Generated in stm32xxx_hal_msp.c and called by HAL_init() | Not used | Generated in stm32xxx_hal_msp.c And called by HAL_init() | This function performs the peripheral resources configuration\(^1\). |
| MX_<Peripheral>._Init()| [1]: Peripheral configuration and call to HAL_<Peripheral>._Init() | [2]: Peripheral and peripheral resource configuration\(^1\) using LL functions Call to LL_Peripheral_Init() | – When HAL driver is selected for the <Peripheral>, function generation and calls are done following \([1]\): Peripheral configuration and call to HAL_<Peripheral>._Init()  
|                        |          |         |                   | – When LL driver selected for the <Peripheral>, function generation and calls are done following \([2]\): Peripheral and peripheral resource configuration using LL functions |

\(^1\) Peripheral and peripheral resource configuration using LL functions.
### Table 23. LL versus HAL: STM32CubeMX generated functions and function calls (continued)

<table>
<thead>
<tr>
<th>Generated source files</th>
<th>HAL only</th>
<th>LL only</th>
<th>Mix of HAL and LL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAL_&lt;Peripheral&gt;_MspInit()</td>
<td>[3]: Generated in stm32xxx_hal_msp.c when HAL driver selected for the &lt;Peripheral&gt;</td>
<td>Not used</td>
<td>Only HAL driver can be selected for the &lt;Peripheral&gt;: function generation and calls are done following [3]: Generated in stm32xxx_hal_msp.c when HAL driver selected for the &lt;Peripheral&gt;</td>
<td>Peripheral resources configuration(1)</td>
</tr>
<tr>
<td>HAL_&lt;Peripheral&gt;_MspDeInit()</td>
<td>[4]: Generated in stm32xxx_hal_msp.c when HAL driver selected for the &lt;Peripheral&gt;</td>
<td>Not used</td>
<td>Only HAL driver can be selected for the &lt;Peripheral&gt;: function generation and calls are done following [4]: Generated in stm32xxx_hal_msp.c when HAL driver selected for the &lt;Peripheral&gt;</td>
<td>This function can be used to free peripheral resources.</td>
</tr>
</tbody>
</table>

1. Peripheral resources include:
   - peripheral clock
   - pinout configuration (GPIOs)
   - peripheral DMA requests
   - peripheral interrupt requests and priorities.
Figure 229. HAL-based peripheral initialization: usart.c code snippet

```c
void MX_USART1_UART_Init(void)
{
    huart1.Instance = USART1;
    huart1.Init.BaudRate = 115200;
    huart1.Init.WordLength = UART_WORLDENGTH_7B;
    huart1.Init.StopBits = UART_STOPBITS_1;
    ...
    if (HAL_UART_Init(&huart1) != HAL_OK)
    {
        Error_Handler();
    }
}

void HAL_UART_MspInit(UART_HandleTypeDef *uartHandle)
{
    GPIO_InitTypeDef GPIO_InitStruct;
    if(uartHandle->Instance==USART1)
    {
        /* Peripheral clock enable */
        __HAL_RCC_USART1_CLK_ENABLE();
        /* USART1 GPIO Configuration */
        GPIO_InitStruct.Pin = GPIO_PIN_10;
        GPIO_InitStruct.Mode = GPIO_MODE_AF_PP;
        GPIO_InitStruct.Pull = GPIO_PULLUP;
        ...
        HAL_GPIO_Init(GPIOB, &GPIO_InitStruct);
    }
}

void HAL_UART_MspDeInit(UART_HandleTypeDef *uartHandle)
{
    if(uartHandle->Instance==USART1)
    {
        /* Peripheral clock disable */
        __HAL_RCC_USART1_CLK_DISABLE();
        /* USART1 GPIO Configuration */
        HAL_GPIO_DeInit(GPIOA, GPIO_PIN_10);
        HAL_GPIO_DeInit(GPIOB, GPIO_PIN_6);
    }
}
```
Figure 230. LL-based peripheral initialization: \texttt{usart.c} code snippet

```c
void MX_USART1_UART_Init(void)
{
    LL_USART_InitTypeDef USART_InitStruct;
    LL_GPIO_InitTypeDef GPIO_InitStruct;
    /* Peripheral clock enable */
    LL_APB2_GRP1_EnableClock(LL_APB2_GRP1_PERIPH_USART1);

    /* USART1 GPIO Configuration */
    PA10        --> USAR1_RX
    PB6         --> USAR1_TX
    
    GPIO_InitTypeDef-pin = LL_GPIO_PIN_10;
    GPIO_InitTypeDef-mode = LL_GPIO_MODE_ALTERNATE;
    GPIO_InitTypeDef-speed = LL_GPIO_SPEED_FREQ_VERY_HIGH;
    GPIO_InitTypeDef.pull = LL_GPIO_PULL_UP;
    GPIO_InitTypeDef.alternate = LL_GPIO_AF_7;
    LL_GPIO_Init(GPIOB, &GPIO_InitStruct);

    GPIO_InitTypeDef-pin = LL_GPIO_PIN_6;
    GPIO_InitTypeDef-mode = LL_GPIO_MODE_ALTERNATE;
    GPIO_InitTypeDef-speed = LL_GPIO_SPEED_FREQ_VERY_HIGH;
    GPIO_InitTypeDef.pull = LL_GPIO_PULL_UP;
    GPIO_InitTypeDef.alternate = LL_GPIO_AF_7;
    LL_GPIO_Init(GPIOB, &GPIO_InitStruct);

    USART_InitTypeDef.baudrate = 115200;
    USART_InitTypeDef.datawidth = LL_USART_DATAWIDTH_7B;
    USART_InitTypeDef.stopbits = LL_USART_STOPBITS_1;
    USART_InitTypeDef.parity = LL_USART_PARITY_NONE;
    USART_InitTypeDef.transferdirection = LL_USART_DIRECTION_TX_RX;
    USART_InitTypeDef.hardwarflowcontrol = LL_USART_HWCONTROL_NONE;
    USART_InitTypeDef.oversampling = LL_USART_OVERSAMPLING_16;

    LL_USART_Init(USART1, &USART_InitStruct);
    LL_USART_ConfigAsyncMode(USART1);
}
```

Figure 231. HAL versus LL: \texttt{main.c} code snippet
6.3 Custom code generation

STM32CubeMX supports custom code generation by means of a FreeMarker template engine (see http://www.freemarker.org).

6.3.1 STM32CubeMX data model for FreeMarker user templates

STM32CubeMX can generate a custom code based on a FreeMarker template file (.ftl extension) for any of the following MCU configuration information:

- List of MCU peripherals used by the user configuration
- List of parameters values for those peripherals
- List of resources used by these peripherals: GPIO, DMA requests and interrupts.

The user template file must be compatible with STM32CubeMX data model. This means that the template must start with the following lines:

```
[#ftl]
[#list configs as dt]
[#assign data = dt]
[#assign peripheralParams = dt.peripheralParams]
[#assign peripheralGPIOParams = dt.peripheralGPIOParams]
[#assign usedIPs = dt.usedIPs]
[/#list]
```

A sample template file is provided for guidance (see Figure 232).

STM32CubeMX will also generate user-specific code if any is available within the template. As shown in the below example, when the sample template is used, the ftl commands are provided as comments next to the data they have generated:

```
FreeMarker command in template:
${peripheralParams.get("RCC").get("LSI_VALUE")}

Resulting generated code:
LSI_VALUE : 32000       [peripheralParams.get("RCC").get("LSI_VALUE")]
```

Figure 232. extra_templates folder - Default content
6.3.2 Saving and selecting user templates

The user can either place the FreeMarker template files under STM32CubeMX installation path within the db/extra_templates folder or in any other folder.

Then for a given project, the user will select the template files relevant for its project via the Template Settings window accessible from the Code Generator Tab in the Project Manager view menu (see Section 4.9).

6.3.3 Custom code generation

To generate custom code, the user must place the FreeMarker template file under STM32CubeMX installation path within the db/extra_templates folder (see Figure 233).

The template filename must follow the naming convention <user filename>_<file extension>.ftl in order to generate the corresponding custom file as <user filename>_<file extension>.

By default, the custom file is generated in the user project root folder, next to the .ioc file (see Figure 234).

To generate the custom code in a different folder, the user shall match the destination folder tree structure in the extra_template folder (see Figure 235).

Figure 233. extra_templates folder with user templates
Figure 234. Project root folder with corresponding custom generated files

Figure 235. User custom folder for templates
6.4 Additional settings for C project generation

STM32CubeMX allows specifying additional project settings through the .extSettings file. This file must be placed in the same project folder and at the same level as the .ioc file.

As an example, additional settings can be used when external tools call STM32CubeMX to generate the project and require specific project settings.

Possible entries and syntax

All entries are optional. They are organized under the followings three categories: ProjectFiles, Groups or Others.

- **[ProjectFiles]**: section where to specify additional include directories
  
  **Syntax**
  
  \[HeaderPath = \langle include directory 1 path\rangle;\langle include directory 2 path \rangle\]
  
  **Example**
  
  \[HeaderPath=../IIR_Filter_int32/Inc ;\]

- **[Groups]**: section where to create new groups of files and/or add files to a group

  **Syntax**
  
  \[<Group name> = \langle file pathname1\rangle;\langle file pathname2\rangle\]
  
  **Example**
  
  \[Doc=$ \_PROJ\_DIR$\..eadme.txt\]
  \[Lib=C:\libraries\mylib1.lib; C:\libraries\mylib2.lib;\]
  \[Drivers/BSP/MyRefBoard = C:\MyRefBoard\BSP\board_init.c; C:\MyRefBoard\BSP\board_init.h;\]

- **[Others]** section where to enable HAL modules and/or specify preprocessor define statements

  - Enabling pre-processor define statements
    
    Preprocessor define statements can be specified using the following syntax after the [Others] line:
    
    **Syntax**
    
    \[Define = \langle define1_name\rangle;\langle define2_name\rangle\]
    
    **Example**
    
    \[\]
Define = USE_STM32F429I_DISCO

- Enabling HAL modules in generated stm32f4xx_hal_conf.h

HAL modules can be enabled using the following syntax after the [Others] line:

**Syntax**

```
HALModule = <ModuleName1>; <ModuleName1>
```

**Example**

```plaintext
HALModule = I2S; I2C
```

### .extSettings file example and generated outcomes

For the purpose of the example, a new project is created by selecting the STM32F429I-DISCO board from STM32CubeMX board selector. The EWARM toolchain is selected in the Project tab of the **Project Manager** view. The project is saved as **MyF429IDiscoProject**. In the project folder, next to the generated .ioc file, a .extSettings text file is placed with the following contents:

**[Groups]**

```plaintext
[Groups]

Drivers/BSP/STM32F429IDISCO=C:\Users\frq09031\STM32Cube\Repository\STM32Cube_FW_F4_V1.14.0\Drivers\BSP\STM32F429I-Discovery\stm32f429i_discovery.c; 
C:\Users\frq09031\STM32Cube\Repository\STM32Cube_FW_F4_V1.14.0\Drivers\BSP\STM32F429I-Discovery\stm32f429i_discovery.h 
Lib=C:\Users\frq09031\STM32Cube\Repository\STM32Cube_FW_F4_V1.14.0\Middlewares\Third_Party\FreeRTOS\Source\portable\IAR\ARM_CM4F\portasm.s 
Doc=$PROJ_DIR$\..\..\readme.txt
```

**[Others]**

```plaintext
[Others]

Define = USE_STM32F429I_DISCO
HALModule = UART; SPI
```

Upon project generation, the presence of this .extSettings file triggers the update of:
- the project **MyF429IDiscoProject.ewp** file in EWARM folder (see **Figure 237**)
- the **stm32f4xx_hal_conf.h** file in the project Inc folder (see **Figure 238**)
- the project view within EWARM user interface as shown in **Figure 239** and **Figure 240**.
Figure 237. Update of the project .ewp file (EWARM IDE) for preprocessor define statements

```xml
<settings>
  <name>IOCCARM</name>
  <archiveVersion>2</archiveVersion>
  <data>
    <version>28</version>
    <wantNonLocal>1</wantNonLocal>
    <debug>1</debug>
    <option>
      <name>CCDefines</name>
      <state>USE_HAL_DRIVER</state>
      <state>USE_STM32F429I_DISCO</state>
    </option>
  </data>
</settings>
```

Figure 238. Update of stm32f4xx_hal_conf.h file to enable selected modules

```c
/*
 * define HAL_RTC_MODULE_ENABLED */
/* define HAL_RTC_MODULE_ENABLED */
/* define HAL_SD_MODULE_ENABLED */
/* define HAL_SD_MODULE_ENABLED */
#define HAL_SPI_MODULE_ENABLED
/* define HAL_TIM_MODULE_ENABLED */
#define HAL_UART_MODULE_ENABLED
/* define HAL_USART_MODULE_ENABLED */
/* define HAL_USART_MODULE_ENABLED */
/* define HAL_USART_MODULE_ENABLED */
/* define HAL_SD_MODULE_ENABLED */
/* define HAL_PWM_MODULE_ENABLED */
/* define HAL_HDC_MODULE_ENABLED */
```

Figure 239. New groups and new files added to groups in EWARM IDE
Figure 240. Preprocessor define statements in EWARM IDE
7 Code generation for dual-core MCUs (STM32H7 dual-core product lines only)

For working with Arm Cortex-M dual-core products, STM32CubeMX generates code for both cores automatically according to the context assignment and initializer choices made in the user interface (see Section 4.6: Pinout & Configuration view for STM32H7 dual-core product lines for details).

Figure 241. Code generation for STM32H7 dual-core devices

Generated initialization code

The code is generated in CM4, CM7 and Common folders. The Common folder holds the system_stm32h7xx.c, that contains the clock tree settings.

When a peripheral or middleware is assigned to both contexts, the function MX_<name>_init will be generated for both contexts but will be called only from the initializer side.
Generated startup and linker files

Each configuration (_M4 or _M7) of the project shall come with a startup file and a linker file, each suffixed with _M4 or _M7 respectively.

Figure 242. Startup and linker files for STM32H7 dual-core devices

Generated boot mode code

STM32CubeMX supports only one mode of boot for now, where both ARM Cortex-M cores boot at once.

The other boot modes will be introduced later as a project option in the project manager view:

- Arm Cortex-M7 core booting, Arm Cortex-M4 gated
- Arm Cortex-M4 core booting, Arm Cortex-M7 gated
- A first core booting executing from flash, loads the second core code to the SRAM then enables the second core to boot.

STM32CubeMX uses template files delivered with STM32CubeH7 MCU packages as reference.
## Code generation with TrustZone® enabled (STM32L5 series only)

In STM32CubeMX project manager view, all project generation options remain available. However, the choice of toolchains is limited to the IDEs/compilers supporting the Cortex®-M33 core:
- EWARM v8.32 or higher
- MDK-ARM v5.27 or higher (ARM compiler 6)
- STM32CubeIDE (GCC v4.2 or higher)

Upon product selection, STM32CubeMX requires to choose between enabling TrustZone® or not.
- When TrustZone® is enabled, STM32CubeMX generates two C projects: one secured and one non-secured. After compilation, two images are available for download, one for each context.
- When TrustZone® is disabled, STM32CubeMX generates a non-secured C project, as for other products not supporting it.

### Specificities

When TrustZone® is enabled, the project generation must be adjusted to ensure that secure and non-secure images can be built.

**Figure 243. Building secure and non-secure images with ARMv8-M TrustZone®**
When TrustZone® is enabled for the project, STM32CubeMX generates three folders:

- NonSecure for non-secure code
- Secure for secure code
- Secure_nsclib for non-secure callable region

See Figure 244 (use TZ_BasicStructure_project_inCubeIDE.png) and Figure 245 (use STM32L5_STM32CubeMX_Project_settings_inCubeIDE.png).

Figure 244. Project explorer view for STM32L5 TrustZone® enabled projects
Figure 245. Project settings for STM32CubeIDE toolchain

STM32CubeMX also generates specific files, detailed in Table 24.

<table>
<thead>
<tr>
<th>File</th>
<th>Folder</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>The product core secure/non-secure partitioning .h &quot;template&quot; file&lt;br&gt;Example: partition_stm32l552xx.h</td>
<td>Secure</td>
<td>Initial setup for secure / non-secure zones for ARMCM33 based on CMSIS CORE V5.3.1 partition_ARMCM33.h Template. It initializes Security attribution unit (SAU) CTRL register, setup behavior of Sleep and Exception Handling, Floating Point Unit and Interrupt Target.</td>
</tr>
<tr>
<td>secure_nsc.h file</td>
<td>Secure_nsc</td>
<td>Must be filled by the user with the list of non-secure callable APIs. Templates are available as reference in STM32L5Cube embedded software package in Templates\TrustZone®\Secure_nsc folders.</td>
</tr>
<tr>
<td>System_stm32l5xx_s.c</td>
<td>Secure</td>
<td>CMSIS Cortex-M33 device peripheral access layer system source file to be used in secure application when the system implements security.</td>
</tr>
</tbody>
</table>
### Table 24. Files generated when TrustZone® is enabled (continued)

<table>
<thead>
<tr>
<th>File</th>
<th>Folder</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>System_stm32l5xx_ns.c</td>
<td>NonSecure</td>
<td>CMSIS Cortex-M33 device peripheral access layer system source file to be used in non-secure application when the system implements security.</td>
</tr>
</tbody>
</table>
| STM32L562CETX_FLASH or STM32L552CETX_FLASH | Secure, NonSecure | Linker files for the secure and non-secure memory layouts. File extensions and naming conventions:  
- `.icf` (EWARM)  
- `.sct` (MDK-ARM), or  
- `.ld` (GCC compiler toolchains) |
9 Device tree generation (STM32MP1 series only)

The Device tree in Linux is used to provide a way to describe non-discoverable hardware. STMicroelectronics is widely using the device tree for all the platform configuration data, including DDR configuration.

Linux developers can manually edit device tree source files (dts), but as an alternative STM32CubeMX offers a partial device-tree generation service to reduce effort and to ease new comers. STM32CubeMX intends to generate partially device trees corresponding to board level configuration. Partial means that the entire (board level) device-trees are not generated, but only main sections that usually imply huge efforts and can cause compilation errors and dysfunction:

- folders structure and files to folders distribution
- dtsi and headers inclusions
- pinCtrl and clocks generation
- System-On-Chip device nodes positioning
- multi-core related configurations (Etzpc binding, resources manager binding, peripherals assignment)

9.1 Device tree overview

To run properly, any piece of software needs to get the hardware description of the platform on which it is executed, including the kind of CPU, the memory size and the pin configuration. OpenSTLinux firmware has put such non-discoverable hardware description in a separate binary, the device tree blob (dtb). The device tree blob is compiled from the device tree source files (dts) using the dtc compiler provided with the OpenSTLinux distribution.

The device tree structure consist of a board level file (.dts) that includes two device tree source include files (.dti): a soc level file and a –pinctrl file, that lists the pin muxing configurations.

The device tree structure is very close to C language multiple level structures with the "root" (/) being the highest level then "peripherals" being sub-nodes described further in the hierarchy (see figures 246, 247 and 248).

STM32CubeMX generation uses widely overloading mechanisms to complete or change some SOC devices definitions when user configurations require it.
Figure 246. STM32CubeMX generated DTS – Extract 1

```
model = "STMMicroelectronics custom STM32CubeMX board";
compatible = "st,stm32mp157c-project2-mm", "st,stm32mp157";

/* USER CODE BEGIN root */
/* USER CODE END root */

clocks {
  clk_esi: clk-esi {
    #clock-cells = <0>
    ;
    compatible = "fixed-clock";
    clock-frequency = <32000>;
    u-boot, dal-pre-reset;
  };
  ...
}; /* root*/

&pinctrl {
  /* Pin control configuration, including GPIO configuration */
  u-boot, dal-pre-reset;
  tim1_pins_max: tim1_mx-0 {
    pins {
      pinmax = <STM32_PINMUX('A', S, API)>, /* TIM1_CH1 */
      <STM32_PINMUX('A', 9, API)>, /* TIM1_CH2 */
      bias-disable;
      drive-push-pull;
      slew-rate = <0>;
    }
  }
};
```

---

Figure 247. STM32CubeMX generated DTS – Extract 2

```
&m4_rproc{
  /* Multi-core management */
  m4_system_resources{
    status = "okay";
    /* USER CODE BEGIN m4_system_resources */
    /* USER CODE END m4_system_resources */
  };
  status = "okay";
  /* USER CODE BEGIN m4_rproc */
  /* USER CODE END m4_rproc */
};

&m4_timers1{
  /* Peripheral assignment to Cortex-M4 run time context */
  pinctrl-names = "rproc_default", "rproc_sleep";
  pinctrl-0 = <sttimel_pins_max>;
  pinctrl-1 = <sttimel_sleep_pins_max>;
  status = "okay";
  /* USER CODE BEGIN m4_timers1 */
  /* USER CODE END m4_timers1 */
};
```
9.2 **STM32CubeMX Device tree generation**

For STM32MP1 series, STM32CubeMX code generation feature has been extended to generate Device trees (DT) configuring the firmware.

DTS generation is accessible through the same **GENERATE CODE** button.
The DT generation path can be configured from the Project Manager view, in the Advanced Settings tab, under OpenSTLinux Settings (see Figure 249). For each Device tree STM32CubeMX generates Device tree source (DTS) files.

Figure 249. Project settings for configuring Device tree path

The Device tree structure consists of:
- a complete clock-tree
- a complete pin control
- a complete multi-cores references definition
- a set of device nodes and sub-nodes
- user sections that can be filled to have complete and bootable Device trees (contents are not lost at next generation).

The generated DTS files reflect the user configuration, such as the assignment of peripherals to runtime contexts and boot loaders, or clock tree settings.

STM32CubeMX DT generation ensures the coherency between the different DTs. Additionally, it generates the DDR configuration file as part of the boot loader Device trees. These files, along with the files they include, are compiled to create the device tree blob for the targeted firmware.

The STM32CubeMX Device tree structure depends upon the targeted firmware and, in a few cases, upon the OpenSTLinux manifest version and/or the MPU family. The structures are detailed in https://wiki.st.com/stm32mpu/wiki/Category:Platform_configuration.

The device tree nodes generated by STM32CubeMX can be completed by filling the user sections following the device tree bindings of the different firmware.
10 Support of additional software components using CMSIS-Pack standard

The CMSIS-Pack standard describes a delivery mechanism for software components, device parameters, and evaluation board support.

The XML-based package description (pdsc) file describes the content of a software pack (file collection). It includes source code, header files, software libraries, documentation and source code templates. A software pack consists of the complete file collection along with the pdsc file, shipped in ZIP-format. After installing a software pack, all the included software components are available to the development tools.

A software component is a collection of source modules, header and configuration files as well as libraries. Packs containing software components can also include example projects and user code templates.

Refer to http://www.keil.com website for more details.

STM32CubeMX supports third-party and other STMicroelectronics embedded software solutions, delivered as software packs. STM32CubeMX enables to:

1. Install software packs and check for updates (see Section 3.4.5).
2. Select software components for the current project (see Section 4.13). Once this is done, the selected components appear in the tree view (see Figure 250).
3. Enable the software component from the tree view (see Figure 251). Use contextual help to get more details on the selection.
4. Configure software components (see Figure 251). This function is possible only for components coming with files in STM32CubeMX proprietary format.
5. Generate the C project for selected toolchains (see Figure 252).
   a) Software components files are automatically copied to the project.
   b) Software component configuration and initialization code are automatically generated. This function is possible only for components coming with files in STM32CubeMX proprietary format.
Support of additional software components using CMSIS-Pack standard

Figure 250. Selecting a CMSIS-Pack software component

Figure 251. Enabling and configuring a CMSIS-Pack software component
Figure 252. Project generated with CMSIS-Pack software component
11 Tutorial 1: From pinout to project C code generation using an MCU of the STM32F4 series

This section describes the configuration and C code generation process. It takes as an example a simple LED toggling application running on the STM32F4DISCOVERY board.

11.1 Creating a new STM32CubeMX Project

1. Select **File > New project** from the main menu bar or **New project** from the Home page.
2. Select the **MCU Selector** tab and filter down the STM32 portfolio by selecting STM32F4 as ‘Series’, STM32F407 as ‘Lines’, and LQFP100 as ‘Package’ (see Figure 253).
3. Select the STM32F407VGTx from the MCU list and click **OK**.

**Figure 253. MCU selection**

STM32CubeMX views are then populated with the selected MCU database (**Figure 254**). Optionally, remove the MCUs Selection bottom window by deselecting **Window> Outputs** submenu (see **Figure 255**).
Tutorial 1: From pinout to project C code generation using an MCU of the STM32F4 series

Figure 254. Pinout view with MCUs selection

Figure 255. Pinout view without MCUs selection window
11.2 Configuring the MCU pinout

For a detailed description of menus, advanced actions and conflict resolutions, refer to Section 4 and Appendix A.

1. By default, STM32CubeMX shows the Pinout view.

2. By default, Keep Current Signals Placement is unchecked allowing STM32CubeMX to move the peripheral functions around and to find the optimal pin allocation, that is the one that accommodates the maximum number of peripheral modes. Since the MCU pin configurations must match the STM32F4DISCOVERY board, enable Keep Current Signals Placement for STM32CubeMX to maintain the peripheral function allocation (mapping) to a given pin. This setting is saved as a user preference in order to be restored when reopening the tool or when loading another project.

3. Select the required peripherals and peripheral modes:
   a) Configure the GPIO to output the signal on the STM32F4DISCOVERY green LED by right-clicking PD12 from the Pinout view, then select GPIO_output:

   Figure 256. GPIO pin configuration
b) Enable a timer to be used as timebase for toggling the LED. This is done by selecting Internal Clock as TIM3 clock source from the peripheral tree (see Figure 257).

Figure 257. Timer configuration
c) You can also configure the RCC to use an external oscillator as potential clock source (see Figure 258).

Figure 258. Simple pinout configuration

![Simple pinout configuration](image)

This completes the pinout configuration for this example.

*Note:* Starting with STM32CubeMX 4.2, the user can skip the pinout configuration by directly loading ST Discovery board configuration from the **Board selector** tab.
11.3 Saving the project

1. Click to save the project. When saving for the first time, select a destination folder and filename for the project. The .ioc extension is added automatically to indicate this is an STM32CubeMX configuration file.

![Figure 259. Save Project As window](image)

2. Click to save the project under a different name or location.
11.4 Generating the report

Reports can be generated at any time during the configuration:

1. Click to generate .pdf and .txt reports.

   If a project file has not been created yet, a warning prompts the user to save the project first and requests a project name and a destination folder (see Figure 260). An .ioc file is then generated for the project along with a .pdf and .txt reports with the same name.

   **Figure 260. Generate Project Report - New project creation**

   Answering No will require to provide a name and location for the report only.

   As shown in Figure 261, a confirmation message is displayed when the operation is successful.

   **Figure 261. Generate Project Report - Project successfully created**

2. Open the .pdf report using Adobe Reader or the .txt report using your favorite text editor. The reports summarize all the settings and MCU configuration performed for the project.

11.5 Configuring the MCU clock tree

The following sequence describes how to configure the clocks required by the application based on an STM32F4 MCU.

STM32CubeMX automatically generates the system, CPU and AHB/APB bus frequencies from the clock sources and prescalers selected by the user. Wrong settings are detected
and highlighted in fuchsia through a dynamic validation of minimum and maximum conditions. Useful tooltips provide a detailed description of the actions to undertake when the settings are unavailable or wrong. User frequency selection can influence some peripheral parameters (e.g. UART baud rate limitation).

STM32CubeMX uses the clock settings defined in the Clock tree view to generate the initialization C code for each peripheral clock. Clock settings are performed in the generated C code as part of RCC initialization within the project main.c and in stm32f4xx_hal_conf.h (HSE, HSI and external clock values expressed in Hertz).

Follow the sequence below to configure the MCU clock tree:

1. Click the **Clock Configuration** tab to display the clock tree (see Figure 262).

   The internal (HSI, LSI), system (SYSCLK) and peripheral clock frequency fields cannot be edited. The system and peripheral clocks can be adjusted by selecting a clock source, and optionally by using the PLL, prescalers and multipliers.

---

**Figure 262. Clock tree view**

![Clock tree view](image-url)
2. First select the clock source (HSE, HSI or PLLCLK) that will drive the system clock of the microcontroller.
   In the example taken for the tutorial, select HSI to use the internal 16 MHz clock (see Figure 263).

**Figure 263. HSI clock enabled**

![Figure 263. HSI clock enabled](image)

To use an external clock source (HSE or LSE), the RCC peripheral shall be configured in the **Pinout** view since pins will be used to connect the external clock crystals (see Figure 264).

**Figure 264. HSE clock source disabled**

![Figure 264. HSE clock source disabled](image)

Other clock configuration options for the STM32F4DISCOVERY board:
- Select the external HSE source and enter 8 in the HSE input frequency box since an 8 MHz crystal is connected on the discovery board:

**Figure 265. HSE clock source enabled**

![Figure 265. HSE clock source enabled](image)

- Select the external PLL clock source and the HSI or HSE as the PLL input clock source.

**Figure 266. External PLL clock source enabled**

![Figure 266. External PLL clock source enabled](image)
3. Keep the core and peripheral clocks to 16 MHz using HSI, no PLL and no prescaling.

**Note:** Optionally, further adjust the system and peripheral clocks using PLL, prescalers and multipliers:

Other clock sources independent from the system clock can be configured as follows:

- USB OTG FS, Random Number Generator and SDIO clocks are driven by an independent output of the PLL.
- I²S peripherals come with their own internal clock (PLL_I²S), alternatively derived by an independent external clock source.
- USB OTG HS and Ethernet Clocks are derived from an external source.

4. Optionally, configure the prescaler for the Microcontroller Clock Output (MCO) pins that allow to output two clocks to the external circuit.

5. Click to save the project.

6. Go to the **Configuration** tab to proceed with the project configuration.

### 11.6 Configuring the MCU initialization parameters

**Caution:** The C code generated by STM32CubeMX covers the initialization of the MCU peripherals and middlewares using the STM32Cube firmware libraries.

#### 11.6.1 Initial conditions

From the **Pinout & Configuration** tab, select and configure (one by one) every component (peripheral, middleware, additional software) required by the application using the **Mode** and **Configuration** panels (see Figure 267).

Tooltips and warning messages are displayed when peripherals are not properly configured (see Section 4: STM32CubeMX user interface for details).

**Note:** The **RCC** peripheral initialization will use the parameter configuration done in this view as well as the configuration done in the **Clock tree** view (clock source, frequencies, prescaler values, etc…).
11.6.2 Configuring the peripherals

Each peripheral instance corresponds to a dedicated button in the main panel. Some peripheral modes have no configurable parameters, as illustrated below.

![Case of Peripheral and Middleware without configuration parameters](image)
Follow the steps below to proceed with peripheral configuration:

1. Click the peripheral button to open the corresponding configuration window. 
   In our example
   a) click TIM3 to open the timer configuration window.

   **Figure 269. Timer 3 configuration window**

   ![Timer 3 configuration window](image)

   b) with a 16 MHz APB clock (Clock tree view), set the prescaler to 16000 and the counter period to 1000 to make the LED blink every millisecond.

   **Figure 270. Timer 3 configuration**

   ![Timer 3 configuration](image)
2. Optionally, and when available, select:
   – The **NVIC Settings** tab to display the NVIC configuration and enable interruptions for this peripheral.
   – The **DMA Settings** tab to display the DMA configuration and to configure DMA transfers for this peripheral.
   
   In the tutorial example, the DMA is not used and the GPIO settings remain unchanged. The interrupt is enabled, as shown in **Figure 271**.
   – The **GPIO Settings** tab to display the GPIO configuration and to configure the GPIOs for this peripheral.
   – Insert an item:
     – The **User Constants** tab to specify constants to be used in the project.

**Figure 271. Enabling Timer 3 interrupt**

### 11.6.3 Configuring the GPIOs

The user can adjust all pin configurations from this window. A small icon along with a tooltip indicates the configuration status.

**Figure 272. GPIO configuration color scheme and tooltip**
Follow the sequence below to configure the GPIOs:

1. Click the **GPIO button** in the Configuration view to open the **Pin Configuration** window below.

2. The first tab shows the pins that have been assigned a GPIO mode but not for a dedicated peripheral and middleware. Select a Pin Name to open the configuration for that pin.

   In the tutorial example, select PD12 and configure it in output push-pull mode to drive the STM32F4DISCOVERY LED (see Figure 273).

   **Figure 273. GPIO mode configuration**
11.6.4 Configuring the DMAs

This is not required for this example. It is recommended to use DMA transfers to offload the CPU. The DMA Configuration window provides a fast and easy way to configure the DMAs (see Figure 274):

1. add a new DMA request and select among a list of possible configurations.
2. select among the available streams.
3. select the Direction: Memory to Peripheral or Peripheral to Memory.
4. select a Priority.
5. enable the FIFO.

Note: Configuring the DMA for a given peripheral and middleware can also be performed using the Peripheral and Middleware configuration window.

Figure 274. DMA parameters configuration window
11.6.5 Configuring the middleware

This is not required for the example taken for the tutorial. If a peripheral is required for a middleware mode, the peripheral must be configured in the Pinout view for the middleware mode to become available. A tooltip can guide the user as shown below.

Figure 275. Middleware tooltip

1. Configure the USB peripheral from the Pinout view.

Figure 276. USB Host configuration

2. Select MSC_FS class from USB Host middleware.
3. Select the checkbox to enable FatFs USB mode in the tree panel.
Figure 277. FatFs over USB mode enabled
4. Select the **Configuration** view. FatFs and USB buttons are then displayed.

**Figure 278. System view with FatFs and USB enabled**
5. FatFs and USB using default settings are already marked as configured. Click FatFs and USB buttons to display default configuration settings. You can also change them by following the guidelines provided at the bottom of the window.

Figure 279. FatFs define statements
11.7 Generating a complete C project

11.7.1 Setting project options

Default project settings can be adjusted prior to C code generation as shown in Figure 280.

1. Select the Project Manager view to update project settings and generation options.
2. Select the Project Tab and choose a Project name, location, a toolchain and a toolchain version to generate the project (see Figure 280).

Figure 280. Project Settings and toolchain selection

3. Select the Code Generator tab to choose various C code generation options:
   - The library files copied to Projects folder.
   - C code regeneration (e.g. what is kept or backed up during C code regeneration).
   - HAL specific action (e.g. set all free pins as analog I/Os to reduce MCU power consumption).

In the tutorial example, select the settings as displayed in Figure 281 and click OK.
11.7.2 Downloading firmware package and generating the C code

1. Click **GENERATE CODE** to generate the C code.

   During C code generation, STM32CubeMX copies files from the relevant STM32Cube MCU package into the project folder so that the project can be compiled. When generating a project for the first time, the firmware package is not available on the user PC and a warning message is displayed:

   ![Missing firmware package warning message](image)

2. STM32CubeMX offers to download the relevant firmware package or to go on. Click **Download** to obtain a complete project, that is a project ready to be used in the selected IDE.

   By clicking **Continue**, only **Inc** and **Src** folders will be created, holding STM32CubeMX generated initialization files. The necessary firmware and middleware libraries will have to be copied manually to obtain a complete project.
If the download fails, an error message is displayed.

**Figure 283. Error during download**

To solve this issue, execute the next two steps. Skip them otherwise.

3. Select **Help > Updater settings menu** and adjust the connection parameters to match your network configuration.

**Figure 284. Updater settings for download**

4. Click **Check connection**. The check mark turns green once the connection is established.
5. Once the connection is functional, click **GENERATE CODE** to generate the C code. The C code generation process starts and progress is displayed (see next figures).

Figure 285. Updater settings with connection

Figure 286. Downloading the firmware package
6. Finally, a confirmation message is displayed to indicate that the C code generation has been successful.
7. Click **Open Folder** to display the generated project contents or click **Open Project** to open the project directly in your IDE. Then proceed with **Section 11.8**.

**Figure 289. C code generation output folder**

The generated project contains:
- The STM32CubeMX .ioc project file located in the root folder. It contains the project user configuration and settings generated through STM32CubeMX user interface.
- The **Drivers** and **Middlewares** folders hold copies of the firmware package files relevant for the user configuration.
- The **Projects** folder contains IDE specific folders with all the files required for the project development and debug within the IDE.
- The **Inc** and **Src** folders contain STM32CubeMX generated files for middleware, peripheral and GPIO initialization, including the main.c file. The STM32CubeMX generated files contain user-dedicated sections allowing to insert user-defined C code.

**Caution:** C code written within the user sections is preserved at next C code generation, while C code written outside these sections is overwritten.

User C code will be lost if user sections are moved or if user sections delimiters are renamed.
11.8 Building and updating the C code project

This example explains how to use the generated initialization C code and complete the project, within IAR™ EWARM toolchain, to have the LED blink according to the TIM3 frequency.

A folder is available for the toolchains selected for C code generation: the project can be generated for more than one toolchain by choosing a different toolchain from the Project Manager menu and clicking Generate code once again.

1. Open the project directly in the IDE toolchain by clicking Open Project from the dialog window or by double-clicking the relevant IDE file available in the toolchain folder under STM32CubeMX generated project directory (see Figure 288).

![Figure 290. C code generation output: Projects folder](image-url)
2. As an example, select .eww file to load the project in the IAR™ EWARM IDE.

Figure 291. C code generation for EWARM
3. Select the main.c file to open in editor.

Figure 292. STM32CubeMX generated project open in IAR™ IDE

The htim3 structure handler, system clock, GPIO and TIM3 initialization functions are defined. The initialization functions are called in the main.c. For now the user C code sections are empty.
4. In the IAR™ IDE, right-click the project name and select **Options**.

   **Figure 293. IAR™ options**

   ![IAR™ options](image)

5. Click the ST-LINK category and make sure SWD is selected to communicate with the STM32F4DISCOVERY board. Click **OK**.

   **Figure 294. SWD connection**

   ![SWD connection](image)

6. Select **Project > Rebuild all**. Check if the project building has succeeded.

   **Figure 295. Project building log**

   ![Project building log](image)
7. Add user C code in the dedicated user sections only.

*Note:* The main while(1) loop is placed in a user section.

For example:

a) Edit the main.c file.

b) To start timer 3, update User Section 2 with the following C code:

```
HAL_Init();
/* Configure the system clock */
SystemClock_Config();
/* Initialize all configured peripherals */
MX_GPIO_Init();
MX_TIM_Init();

/* USER CODE BEGIN 2 */
HAL_TIM_Base_Start_IT(stm32f4xx_hal_tim.h);
/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
}
```

This C code implements the weak callback function defined in the HAL timer driver (stm32f4xx_hal_tim.h) to toggle the GPIO pin driving the green LED when the timer counter period has elapsed.

c) Then, add the following C code in User Section 4:

```
/* USER CODE BEGIN 4 */

void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim)
{
    if (htim->Instance == htim3.Instance)
    {
        HAL_GPIO_TogglePin(GPIOD, GPIO_PIN_12);
    }
}
/* USER CODE END 4 */
```

8. Rebuild and program your board using 📦. Make sure the SWD ST-LINK option is checked as a Project options otherwise board programming will fail.

9. Launch the program using 🟢. The green LED on the STM32F4DISCOVERY board will blink every second.

10. To change the MCU configuration, go back to STM32CubeMX user interface, implement the changes and regenerate the C code. The project will be updated, preserving the C code in the user sections if ☐ Keep User Code when re-generating option in Project Manager’s Code Generator tab is enabled.
11.9 Switching to another MCU

STM32CubeMX allows loading a project configuration on an MCU of the same series. Proceed as follows:

1. Select **File > New Project**.
2. Select an MCU belonging to the same series. As an example, you can select the STM32F429ZITx that is the core MCU of the 32F429IDISCOVERY board.
3. Select **File > Import project**. In the **Import project** window, browse to the .ioc file to load. A message warns you that the currently selected MCU (STM32F429ZITx) differs from the one specified in the .ioc file (STM32F407VGTx). Several import options are proposed (see **Figure 298**).
4. Click the **Try Import** button and check the import status to verify if the import has been successful.
5. Click **OK** to really import the project. An output tab is then displayed to report the import results.
6. The green LED on 32F429IDISCOVERY board is connected to PG13: CTRL+ right click **PD12** and drag and drop it on PG13.
7. From **Project Manager** project tab configure the new project name and folder location. Click **Generate icon** to save the project and generate the code.
8. Select **Open the project** from the dialog window, update the user sections with the user code, making sure to update the GPIO settings for PG13. Build the project and flash the board. Launch the program and check that LED blinks once per second.

**Figure 298. Import Project menu**
The tutorial consists in creating and writing to a file on the STM32429I-EVAL1 SD card using the FatFs file system middleware.

To generate a project and run tutorial 2, follow the sequence below:
1. Launch STM32CubeMX.
3. Click the Board Selector Tab to display the list of ST boards.
4. Select EvalBoard as type of Board and STM32F4 as Series to filter down the list.
5. Answer Yes to Initialize all peripherals with their default mode so that the code is generated only for the peripherals used by the application.
6. Select the STM32429I-EVAL board and click OK. Answer No in the dialog box asking to initialize all peripherals to their default modes (see Figure 299). The Pinout view is loaded, matching the MCU pinout configuration on the evaluation board (see Figure 300).

Figure 299. Board peripheral initialization dialog box
7. From the Peripheral tree on the left, expand the SDIO peripheral and select “SD 4 bits wide bus” (see Figure 301). In the configuration panel, from the DMA settings tab, add SDIO_RX and SDIO_TX DMA requests.

8. Finally, go back to the peripheral tree panel, select NVIC and enable the SDIO global interrupt from the configuration panel.

Figure 301. SDIO peripheral configuration
9. Under the Middlewares category, check SD card as FatFs mode (see Figure 302).

**Figure 302. FatFs mode configuration**

From the Pinout view on the right, enable, as GPIO input, a pin to be used for the SDIO detection.

In the configuration panel below the mode panel, go to the platform settings tab and configure the SD_detection using the pin previously enabled.

Finally, go to FatFs "Advanced settings tab" and enable "Use DMA template".

10. Configure the clocks as follows:

a) Select the RCC peripheral from the Pinout view (see Figure 303).

**Figure 303. RCC peripheral configuration**
b) Configure the clock tree from the clock tab (see Figure 304).

![Figure 304. Clock tree view](image)

11. In the **Project** tab, specify the project name and destination folder. Then, select the EWARM IDE toolchain.
   
   Note that project heap and stack size can be adjusted to the minimum required for the FATFS application.

![Figure 305. FATFS tutorial - Project settings](image)

12. Click **Ok**. Then, on the toolbar menu, click **GENERATE CODE** to generate the project.
13. Upon code generation completion, click **Open Project** in the **Code Generation** dialog window (see Figure 306). This opens the project directly in the IDE.
14. In the IDE, check that heap and stack sizes are sufficient: right-click the project name and select **Options**, then select **Linker**. Check **Override default** to use the icf file from STM32CubeMX generated project folder. If not already done through CubeMX User interface (under Linker Settings from Project Manager's project tab), adjust the heap and stack sizes (see **Figure 307**).

**Figure 307. IDE workspace**

---

**Note:** When using the MDK-Arm toolchain, go to the Application/MDK-ARM folder and double-click the **startup_xx.s** file to edit and adjust the heap and stack sizes there.
15. Go to the Application/User folder. Double-click the main.c file and edit it.

16. The tutorial consists in creating and writing to a file on the evaluation board SD card using the FatFs file system middleware:
   a) At startup all LEDs are OFF.
   b) The red LED is turned ON to indicate that an error occurred (e.g. FatFs initialization, file read/write access errors).
   c) The orange LED is turned ON to indicate that the FatFs link has been successfully mounted on the SD driver.
   d) The blue LED is turned ON to indicate that the file has been successfully written to the SD card.
   e) The green LED is turned ON to indicate that the file has been successfully read from file the SD card.

17. For use case implementation, update main.c with the following code:
   a) Insert main.c private variables in a dedicated user code section:

   ```c
   /* USER CODE BEGIN PV */
   /* Private variables ------------------------------------------*/
   FATFS SDFatFs;        /* File system object for SD card logical drive */
   FIL MyFile;           /* File object */
   const char wtext[] = "Hello World!";
   static uint8_t buffer[_MAX_SS]; /* a work buffer for the f_mkfs() */
   /* USER CODE END PV */
   
   b) Insert main functional local variables:

   int main(void)
   {

   /* USER CODE BEGIN 1 */
   FRESULT res;                /* FatFs function common result code */
   uint32_t byteswritten, bytesread; /* File write/read counts */
   char rtext[256];            /* File read buffer */
   /* USER CODE END 1 */

   /* MCU Configuration----------------------------------------*/
   /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
   HAL_Init();

   c) Insert user code in the main function, after initialization calls and before the while loop, to perform actual read/write from/to the SD card:

   int main(void)
   {
   ...
   MX_FATFS_Init();

   /* USER CODE BEGIN 2 */
   /****-0- Turn all LEDs off(red, green, orange and blue) */
   HAL_GPIO_WritePin(GPIOG, (GPIO_PIN_10 | GPIO_PIN_6 | GPIO_PIN_7 | GPIO_PIN_12), GPIO_PIN_SET);
   /****-1- FatFs: Link the SD disk I/O driver #######*/
if(retSD == 0){
    /* success: set the orange LED on */
    HAL_GPIO_WritePin(GPIOG, GPIO_PIN_7, GPIO_PIN_RESET);
}

/**-2- Register the file system object to the FatFs module */
if(f_mount(&SDFatFs, (TCHAR const*)SDPath, 0) != FR_OK){
    /* FatFs Initialization Error : set the red LED on */
    HAL_GPIO_WritePin(GPIOG, GPIO_PIN_10, GPIO_PIN_RESET);
    while(1);
} else {
/**-3- Create a FAT file system (format) on the logical drive */
    /* WARNING: Formatting the uSD card will delete all content on the device */
    if(f_mkfs((TCHAR const*)SDPath, FM_ANY, 0, buffer, sizeof(buffer)) != FR_OK){
        /* FatFs Format Error : set the red LED on */
        HAL_GPIO_WritePin(GPIOG, GPIO_PIN_10, GPIO_PIN_RESET);
        while(1);
    } else {
/**-4- Create & Open a new text file object with write access */
        /*##-5- Write data to the text file */
        res = f_write(&MyFile, wtext, sizeof(wtext), (void *)&byteswritten);
        if((byteswritten == 0) || (res != FR_OK)){
            /* 'Hello.txt' file Write or EOF Error : set the red LED on */
            HAL_GPIO_WritePin(GPIOG, GPIO_PIN_10, GPIO_PIN_RESET);
            while(1);
        } else {
/**-6- Successful open/write : set the blue LED on */
            HAL_GPIO_WritePin(GPIOG, GPIO_PIN_12, GPIO_PIN_RESET);
            f_close(&MyFile);
/**-7- Open the text file object with read access */
        if(f_open(&MyFile, "Hello.txt", FA_READ) != FR_OK){
            /* 'Hello.txt' file Open for read Error : set the red LED on */
            HAL_GPIO_WritePin(GPIOG, GPIO_PIN_10, GPIO_PIN_RESET);
            while(1);
        } else {
/**-8- Read data from the text file */
            res = f_read(&MyFile, rtext, sizeof(wtext), &bytesread);
            if((byteswritten == 0) || (res != FR_OK)){
                /* 'Hello.txt' file Read or EOF Error : set the red LED on */
                HAL_GPIO_WritePin(GPIOG, GPIO_PIN_10, GPIO_PIN_RESET);
                while(1);
            } else {
                /* Successful read : set the green LED On */
                HAL_GPIO_WritePin(GPIOG, GPIO_PIN_6, GPIO_PIN_RESET);
/*##-9- Close the open text file ################*/
    f_close(&MyFile);
}}}}}}
/*##-10- Unlink the micro SD disk I/O driver #########
    FATFS_UnLinkDriver(SDPath);

/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
13 Tutorial 3 - Using the Power Consumption Calculator to optimize the embedded application consumption and more

13.1 Tutorial overview

This tutorial focuses on STM32CubeMX Power Consumption Calculator (Power Consumption Calculator) feature and its benefits to evaluate the impacts of power-saving techniques on a given application sequence.

The key considerations to reduce a given application power consumption are:

- Reducing the operating voltage
- Reducing the time spent in energy consuming modes
  - It is up to the developer to select a configuration that gives the best compromise between low-power consumption and performance.
- Maximizing the time spent in non-active and low-power modes
- Using the optimal clock configuration
  - The core should always operate at relatively good speed, since reducing the operating frequency can increase energy consumption if the microcontroller has to remain for a long time in an active operating mode to perform a given operation.
- Enabling only the peripherals relevant for the current application state and clock-gating the others
- When relevant, using the peripherals with low-power features (e.g. waking up the microcontroller with the I2C)
- Minimizing the number of state transitions
- Optimizing memory accesses during code execution
  - Prefer code execution from RAM to flash memory
  - When relevant, consider aligning CPU frequency with flash memory operating frequency for zero wait states.

The following tutorial shows how the STM32CubeMX Power Consumption Calculator feature can help to tune an application to minimize its power consumption and extend the battery life.

*Note:* The Power Consumption Calculator does not account for I/O dynamic current consumption and external board components that can also affect current consumption. For this purpose, an “additional consumption” field is provided for the user to specify such consumption value.
13.2 Application example description

The application is designed using the NUCLEO-L476RG board based on a
STM32L476RGTx device and supplied by a 2.4 V battery.

The main purpose of this application is to perform ADC measurements and transfer the
conversion results over UART. It uses:

- Multiple low-power modes: Low-power run, Low-power sleep, Sleep, Stop and Standby
- Multiple peripherals: USART, DMA, Timer, COMP, DAC and RTC
  - The RTC is used to run a calendar and to wake up the CPU from Standby when a
    specified time has elapsed.
  - The DMA transfers ADC measurements from ADC to memory
  - The USART is used in conjunction with the DMA to send/receive data via the
    virtual COM port and to wake up the CPU from Stop mode.

The process to optimize such complex application is to start describing first a functional only
sequence then to introduce, on a step by step basis, the low-power features provided by the
STM32L476RG microcontroller.

13.3 Using the Power Consumption Calculator

13.3.1 Creating a power sequence

Follow the steps below to create the sequence (see Figure 308):
1. Launch STM32CubeMX.
2. Click new project and select the Nucleo-L476RG board from the Board tab.
3. Click the Power Consumption Calculator tab to select the Power Consumption
   Calculator view. A first sequence is then created as a reference.
4. Adapt it to minimize the overall current consumption. To do this:
   a) Select 2.4 V VDD power supply. This value can be adjusted on a step by step basis
      (see Figure 309).
   b) Select the Li-MnO2 (CR2032) battery. This step is optional. The battery type can
      be changed later on (see Figure 309).
Tutorial 3 - Using the Power Consumption Calculator to optimize the embedded application con-

Figure 308. Power Consumption Calculation example

Figure 309. V_{DD} and battery selection menu
5. Enable the **Transition checker** to ensure the sequence is valid (see Figure 309). This option allows verifying that the sequence respects the allowed transitions implemented within the STM32L476RG.

6. Click the **Add** button to add steps that match the sequence described in Figure 309.
   - By default the steps last 1 ms each, except for the wake-up transitions preset using the transition times specified in the product datasheet (see Figure 310).
   - Some peripherals for which consumption is unavailable or negligible are highlighted with '*' (see Figure 310).

   **Figure 310. Sequence table**

<table>
<thead>
<tr>
<th>Step</th>
<th>Mode</th>
<th>Vdd</th>
<th>Range/Scale</th>
<th>CPU/Enea Freq</th>
<th>Clock Config</th>
<th>Peripherals</th>
<th>Step Current</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RUN</td>
<td>2.4</td>
<td>Range-4 High</td>
<td>HSE</td>
<td>ADC1 접_5</td>
<td>5.9 mA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>STANDBY</td>
<td>2.4</td>
<td>NoRange</td>
<td>4 MHz</td>
<td>MNI FAST</td>
<td>1.7 mA</td>
<td>20.1 µs</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>RUN</td>
<td>2.4</td>
<td>Range-4 High</td>
<td>HSE</td>
<td>ADC1 접_5</td>
<td>2.16 mA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>RUN</td>
<td>2.4</td>
<td>Range-4 Med</td>
<td>HSE</td>
<td>ADC1 접_5</td>
<td>4.47 mA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SLEEP</td>
<td>2.4</td>
<td>Range-4 Med</td>
<td>HSE</td>
<td>ADC1 접_5</td>
<td>589 µA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>RUN</td>
<td>2.4</td>
<td>Range-4 Med</td>
<td>HSE</td>
<td>ADC1 접_5</td>
<td>4.47 mA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>STOP 1</td>
<td>2.4</td>
<td>NoRange</td>
<td>0 Hz</td>
<td>ALL CLOCK...</td>
<td>6.65 µA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>WIU_FROM...</td>
<td>2.4</td>
<td>NoRange</td>
<td>16 MHz</td>
<td>HSH15</td>
<td>1.02 mA</td>
<td>63 µs</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>RUN</td>
<td>2.4</td>
<td>Range-4 Med</td>
<td>HSE</td>
<td>RTC USART1</td>
<td>1.89 mA</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>STANDBY</td>
<td>2.4</td>
<td>NoRange</td>
<td>0 Hz</td>
<td>LSI RTC</td>
<td>1464 µA</td>
<td>1 ms</td>
<td></td>
</tr>
</tbody>
</table>

7. Click the **Save** button to save the sequence as SequenceOne.

The application consumption profile is generated. It shows that the overall sequence consumes an average of 2.01 mA for 9 ms, and that the battery lifetime is only four days (see Figure 311).

**Figure 311. sequence results before optimization**

### 13.3.2 Optimizing application power consumption

Let us now take actions to optimize the overall consumption and the battery lifetime. These actions are performed on steps 1, 4, 5, 6, 7, 8 and 10.

The next figures show on the left the original step, and on the right the step updated with optimization actions.
Step 1 (Run)

- **Findings**
  All peripherals are enabled although the application requires only the RTC.

- **Actions**
  - Lower the operating frequency
  - Enable only the RTC peripheral
  - To reduce the average current consumption, reduce the time spent in this mode

- **Results**
  The current is reduced from 9.05 to 2.16 mA (see Figure 312).

Figure 312. Step 1 optimization

Step 4 (Run, RTC)

- **Action**
  Reduce the time spent in this mode to 0.1 ms
Step 5 (Run, ADC, DMA, RTC)

- Actions
  - Change to Low-power run mode
  - Lower the operating frequency
- Results
  The current consumption is reduced from 6.17 mA to 271 µA (see Figure 313).

Figure 313. Step 5 optimization
Step 6 (Sleep, DMA, ADC, RTC)

- **Actions**
  - Switch to Lower-power sleep mode (BAM mode)
  - Reduce the operating frequency to 2 MHz

- **Results**
  
The current consumption is reduced from 703 µA to 93 µA (see Figure 314).

**Figure 314. Step 6 optimization**
Step 7 (Run, DMA, RTC, USART)

- **Actions**
  - Switch to Low-power run mode
  - Use the power efficient LPUART peripheral
  - Reduce the operating frequency to 1 MHz using the interpolation feature

- **Results**
  The current consumption is reduced from 1.92 mA to 42 µA (see Figure 315).

**Figure 315. Step 7 optimization**
Step 8 (Stop 0, USART)

- **Actions**
  - Switch to Stop1 low-power mode
  - Use the power-efficient LPUART peripheral

- **Results**
  The current consumption is reduced (see [Figure 316](#)).

[Figure 316. Step 8 optimization]
Step 10 (RTC, USART)

- **Actions**
  - Use the power-efficient LPUART peripheral
  - Reduce the operating frequency to 1 MHz

- **Results**
  The current consumption is reduced from 1.89 mA to 234 µA (see Figure 317).
  The example given in Figure 318 shows an average current consumption reduction of 155 µA.

  

Figure 317. Step 10 optimization

See Figure 318 for the overall results: 7 ms duration, about two months battery life, and an average current consumption of 165.25 µA.

Use the compare button to compare the current results to the original ones saved as SequenceOne.pcs.

Figure 318. Power sequence results after optimizations
14 Tutorial 4 - Example of UART communications with an STM32L053xx Nucleo board

This tutorial aims at demonstrating how to use STM32CubeMX to create a UART serial communication application for a NUCLEO-L053R8 board.

A Windows PC is required for the example. The ST-Link USB connector is used both for serial data communications, and firmware downloading and debugging on the MCU. A Type-A to mini-B USB cable must be connected between the board and the computer. The USART2 peripheral uses PA2 and PA3 pins, which are wired to the ST-Link connector. In addition, USART2 is selected to communicate with the PC via the ST-Link Virtual COM Port. A serial communication client, such as Tera Term, needs to be installed on the PC to display the messages received from the board over the virtual communication Port.

14.1 Tutorial overview

Tutorial 4 will take you through the following steps:

1. Selection of the NUCLEO-L053R8 board from the New Project menu.
2. Selection of the required features (debug, USART, timer) from the Pinout view: peripheral operating modes as well as assignment of relevant signals on pins.
3. Configuration of the MCU clock tree from the Clock Configuration view.
4. Configuration of the peripheral parameters from the Configuration view.
5. Configuration of the project settings in the Project Manager menu and generation of the project (initialization code only).
6. Project update with the user application code corresponding to the UART communication example.
7. Compilation, and execution of the project on the board.
8. Configuration of Tera Term software as serial communication client on the PC.
9. The results are displayed on the PC.

14.2 Creating a new STM32CubeMX project and selecting the Nucleo board

To do this, follow the sequence below:

1. Select File > New project from the main menu bar. This opens the New Project window.
2. Go to the Board selector tab and filter on STM32L0 series.
3. Select NUCLEO-L053R8 and click OK to load the board within the STM32CubeMX user interface (see Figure 319).
Figure 319. Selecting NUCLEO_L053R8 board
14.3 Selecting the features from the Pinout view

1. Select Debug Serial Wire under SYS (see Figure 320).

![Figure 320. Selecting debug pins](image)

2. Select Internal Clock as clock source under TIM2 peripheral (see Figure 321).

![Figure 321. Selecting TIM2 clock source](image)
3. Select the Asynchronous mode for the USART2 peripheral (see Figure 322).

![Figure 322. Selecting asynchronous mode for USART2](image)

4. Check that the signals are properly assigned on pins (see Figure 323):
   - SYS_SWDIO on PA13
   - TCK on PA14
   - USART_TX on PA2
   - USART_RX on PA3

![Figure 323. Checking pin assignment](image)
14.4 Configuring the MCU clock tree from the Clock Configuration view

1. Go to the Clock Configuration tab and leave the configuration untouched, in order to use the MSI as input clock and an HCLK of 2.097 MHz (see Figure 324).

Figure 324. Configuring the MCU clock tree
14.5 Configuring the peripheral parameters from the Configuration view

1. From the Configuration tab, click USART2 to open the peripheral Parameter Settings window and set the baud rate to 9600. Make sure the Data direction is set to “Receive and Transmit” (see Figure 325).
2. Click OK to apply the changes and close the window.

Figure 325. Configuring USART2 parameters
3. Click **TIM2** and change the prescaler to 16000, the Word Length to 8 bits and the Counter Period to 1000 (see *Figure 326*).

*Figure 326. Configuring TIM2 parameters*
4. Enable TIM2 global interrupt from the **NVIC Settings** tab (see *Figure 327*).

*Figure 327. Enabling TIM2 interrupt*
14.6 Configuring the project settings and generating the project

1. In the Project Settings menu, specify the project name, destination folder, and select the EWARM IDE toolchain (see Figure 328).

Figure 328. Project Settings menu

If the firmware package version is not already available on the user PC, a progress window opens to show the firmware package download progress.
2. In the **Code Generator** tab, configure the code to be generated as shown in *Figure 329*, and click **OK** to generate the code.

![Figure 329. Generating the code](image)

### 14.7 Updating the project with the user application code

Add the user code as follows:

```c
/* USER CODE BEGIN 0 */
#include "stdio.h"
#include "string.h"
/* Buffer used for transmission and number of transmissions */
char aTxBuffer[1024];
int nbtime=1;
/* USER CODE END 0 */

Within the main function, start the timer event generation function as follows:

```c
/* USER CODE BEGIN 2 */
```
/* Start Timer event generation */
HAL_TIM_Base_Start_IT(&htim2);
/* USER CODE END 2 */

/* USER CODE BEGIN 4 */
void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim){
sprintf(aTxBuffer,"STM32CubeMX rocks %d times \t", ++nbtime);
HAL_UART_Transmit(&huart2,(uint8_t *) aTxBuffer, strlen(aTxBuffer), 5000);
}
/* USER CODE END 4 */

14.8 Compiling and running the project
1. Compile the project within your favorite IDE.
2. Download it to the board.
3. Run the program.

14.9 Configuring Tera Term software as serial communication client on the PC
1. On the computer, check the virtual communication port used by ST Microelectronics from the Device Manager window (see Figure 330).

Figure 330. Checking the communication port
2. To configure Tera Term to listen to the relevant virtual communication port, adjust the parameters to match the USART2 parameter configuration on the MCU (see Figure 331).

Figure 331. Setting Tera Term port parameters

3. The Tera Term window displays a message coming from the board at a period of a few seconds (see Figure 332).

Figure 332. Setting Tera Term port parameters
15 Tutorial 5: Exporting current project configuration to a compatible MCU

When List pinout compatible MCUs is selected from the Pinout menu, STM32CubeMX retrieves the list of the MCUs which are compatible with the current project configuration, and offers to export the current configuration to the newly selected compatible MCU.

This tutorial shows how to display the list of compatible MCUs and export your current project configuration to a compatible MCU:

1. Load an existing project, or create and save a new project:

2. Go to the Pinout menu and select List Pinout Compatible MCUs. The Pinout compatible window pops up (see Figure 334 and Figure 335).

   If needed, modify the search criteria and the filter options and restart the search process by clicking the Search button.

   The color shading and the Comments column indicate the level of matching:
   - Exact match: the MCU is fully compatible with the current project (see Figure 335 for an example).
   - Partial match with hardware compatibility: the hardware compatibility can be ensured but some pin names could not be preserved. Hover the mouse over the desired MCU to display an explanatory tooltip (see Figure 334 for an example).
Partial match without hardware compatibility: not all signals can be assigned to the exact same pin location and a remapping will be required. Hover the mouse over the desired MCU to display an explanatory tooltip (see Figure 335 for an example).

Figure 334. List of pinout compatible MCUs - Partial match with hardware compatibility

Figure 335. List of Pinout compatible MCUs - Exact and partial match
3. Then, select an MCU to import the current configuration to, and click **OK, Import**:

**Figure 336. Selecting a compatible MCU and importing the configuration**

The configuration is now available for the selected MCU:

**Figure 337. Configuration imported to the selected compatible MCU**
4. To see the list of compatible MCUs at any time, select **Outputs** under the **Window** menu.
   To load the current configuration to another compatible MCU, double-click the list of compatible MCUs.

5. To remove some constraints on the search criteria, several solutions are possible:
   – Select the **Ignore Pinning Status** checkbox to ignore pin status (locked pins).
   – Select the **Ignore Power Pins** checkbox not to take into account the power pins.
   – Select the **Ignore System Pins** not take into account the system pins. Hover the mouse over the checkbox to display a tooltip that lists the system pins available on the current MCU.
16 Tutorial 6 – Adding embedded software packs to user projects

In this tutorial, the Oryx-Embedded.Middleware.1.7.8. pack is taken as an example to demonstrate how to add pack software components to STM32CubeMX projects. The use of this package shall not be understood as an STMicroelectronics recommendation.

To add embedded software packs to your project, proceed as follows:

1. Install Oryx-Embedded.Middleware.1.7.8.pack using the .pdesc file available from http://www.oryx-embedded.com (see Section 3.4.5: Installing embedded software packs).

2. Select New project.

3. Select STM32F01CCFx from the MCU selector.

4. Select Additional Software from the Pinout & Configuration view to open the additional software component window and choose the following software components: Compiler Support, RTOS Port/None and Date Time Helper Routines from the CycloneCommon bundle (see Section 4.13: Additional software component selection window).

5. Click OK to display the selected components on the tree view and click the checkbox to enable the software components for the current project (see Figure 338).

Figure 338. Additional software components enabled for the current project

The pack name highlighted in green indicates that all conditions for the selected software components resolve to true. If at least one condition is not resolved, the pack name is highlighted in orange.
6. Check that no parameters can be configured in the Configuration tab (see Figure 339).

**Figure 339. Pack software components - no configurable parameters**

7. Select the Project manager project tab to specify project parameters (see Figure 340), and choose IAR™ EWARM as IDE.

**Figure 340. Pack tutorial - project settings**
8. Generate your project by clicking [GENERATE CODE]. Accept to download the STM32CubeF4 MCU package if it is not present in STM32Cube repository.

9. Click **Open project**. The Oryx software components are displayed in the generated project (see **Figure 341**).

![Figure 341. Generated project with third party pack components](image)
Tutorial 7 – Using the X-Cube-BLE1 software pack

This tutorial demonstrates how to achieve a functional project using the X-Cube-BLE1 software pack.

Below the prerequisites to run this tutorial:

- **Hardware**: NUCLEO-L053R8, X-NUCLEO-IDB05A1 and mini-USB cable (see Figure 342)
- **Tools**: STM32CubeMX, IDE (Atollic® or any other toolchain supported by STM32CubeMX)
- **Embedded software package**: STM32CubeL0 (version 1.10.0 or higher), X-Cube-BLE1 1.1.0 (see Figure 343).
- **Mobile application** (see Figure 344): STMicroelectronics BlueNRG application for iOS® or Android™

![Figure 342. Hardware prerequisites](image)
**Figure 343. Embedded software packages**

![Image of Embedded Software Packages Manager]

**Figure 344. Mobile application**

![Image of Mobile Application]
Proceed as follows to install and run the tutorial:

1. Check STM32CubeMX Internet connection:
   a) Select the Help > Updater settings menu to open the updater window.
   b) Verify in the Connection tab that the Internet connection is configured and up.

2. Install the required embedded software packages (see Figure 345):
   a) Select the Help > Manage Embedded software packages menu to open the embedded software package manager window.
   b) Click the Refresh button to refresh the list with the latest available package versions.
   c) Select the STM32Cube MCU Package tab and check that the STM32CubeL0 firmware package version 1.10.0 or higher is installed (the checkbox must be green). Otherwise select the checkbox and click Install now.
   d) Select the STMicroelectronics tab and check that the X-Cube-BLE1 software pack version 1.0.0 is installed (checkbox must be green). Otherwise, select the checkbox and click Install now.

Figure 345. Installing Embedded software packages

![Figure 345. Installing Embedded software packages](image)

3. Start a new project:
   a) Select New Project to open the new project window.
   b) Select the Board selector tab.
   c) Select Nucleo64 as board type and STM32L0 as MCU Series.
   d) Select the NUCLEO-L053R8 from the resulting board list (see Figure 346).
   e) Answer No when prompted to initialize all peripherals in their default mode (see Figure 347).
4. Add X-Cube-BLE1 components to the project:
   a) Click **Additional Software** from **Pinout & Configuration** view to open the **Additional Software component Selection** window.
   b) Select the relevant components (see **Figure 348**)

   The Application group comes with a list of applications: the C files implement the application loop, that is the `Process()` function. From the Application group, select the **SensorDemo** application.

   Select the **Controller** and **Utils** components

   Select the **Basic** variant for the **HCI_TL** component. The Basic variant provides the STMicroelectronics implementation of the HCI_TL API while the template option requires users to implement their own code.

   Select the **UserBoard** variant as **HCI_TL_INTERFACE** component. Using the UserBoard option generates the `<boardname>_bus.c` file, that is `nucleo_l053r8_bus.c` for this tutorial, while the template option generates the `custom_bus.c` file and requires users to provide their own implementation.

   Refer to the X-Cube-BLE1 pack documentation for more details on software components.
c) Click OK to apply the selection to the project and close the window. The left panel Additional Software section is updated accordingly.

Figure 348. Selecting X-Cube-BLE1 components

5. Enable peripherals and GPIOs from the Pinout tab (see Figure 349):
   a) Configure USART2 in Asynchronous mode.
   b) Configure SPI1 in Full-duplex master mode.
   c) Left-click the following pins and configure them for the required GPIO settings:
      - PA0: GPIO_EXTI0
      - PA1: GPIO_Output
      - PA8: GPIO_Output
   d) Enable Debug Serial Wire under SYS peripheral.
6. Configure the peripherals from the Configuration tab:
   a) Click the NVIC button under the System section to open the NVIC configuration window. Enable EXTI line 0 and line 1 interrupts and click OK (see Figure 350).
   b) Click the SPI button under the Connectivity section to open the SPI configuration window. Check that the data size is set to 8 bits and the prescaler value to 16 so that HCLK divided by the prescaler value is less or equal to 8 MHz.
   c) Click USART2 under the Connectivity section to open the Configuration window and check the following parameter settings:
      Under Parameter Settings:
      Baud rate: 115200 bits/s
      Word length: 8 bits (including parity)
      Parity: none
      Stop bits: 1
      Under GPIO Settings:
      User labels: USART_TX and USART_RX
7. Enable and configure X-Cube-BLE1 pack components from the **Pinout & Configuration** view:
   a) Click the pack items from the left panel to show the mode and configuration tabs.
   b) Click the check boxes from the Mode panel to enable X-Cube-BLE1, the configuration panel appears showing the parameters to configure. An orange triangle indicates that some parameters are not configured. It turns into a green check mark once all parameters are correctly configured (see **Figure 351**).
   c) Leave the Parameter Settings Tab unchanged.
   d) Go the Platform settings tab, configure the connection with the hardware resources as indicated in **Figure 351** and **Table 25**.

Table 25. Connection with hardware resources

<table>
<thead>
<tr>
<th>Name</th>
<th>IPs or components</th>
<th>Found solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUS IO driver</td>
<td>SPI in Full-duplex master mode</td>
<td>SPI1</td>
</tr>
<tr>
<td>EXTI Line</td>
<td>GPIO:EXTI</td>
<td>PA0</td>
</tr>
<tr>
<td>CS Line</td>
<td>GPIO:output</td>
<td>PA1</td>
</tr>
<tr>
<td>reset Line</td>
<td>GPIO:output</td>
<td>PA8</td>
</tr>
<tr>
<td>BSP LED</td>
<td>GPIO:output</td>
<td>PA5</td>
</tr>
<tr>
<td>BSP Button</td>
<td>GPIO:EXTI</td>
<td>PC13</td>
</tr>
<tr>
<td>BSP USART</td>
<td>USART in Asynchronous mode</td>
<td>USART2</td>
</tr>
</tbody>
</table>

Check that the icon turns to ![green check mark]. Click **OK** to close the **Configuration** window.
8. Generate the SensorDemo project:
   a) Click to generate the code. The Project settings window opens if the project has not yet been saved.
   b) Click to generate the code once the project settings have been properly configured (see Figure 352). When the generation is complete, a dialog window requests to open the project folder (Open Folder) or to open the project in IDE toolchain (Open Project). Select Open Project (see Figure 353).
Figure 352. Configuring the SensorDemo project

Figure 353. Open SensorDemo project in the IDE toolchain
18 Creating LPBAM projects

18.1 LPBAM overview

Disclaimer: to learn about the LPBAM mode and its usage, it is recommended to read the LPBAM application note available on www.st.com, and the LPBAM utility getting started guide located under the Utilities folder of the SMT32Cube firmware package.

18.1.1 LPBAM operating mode

LPBAM stands for low power background autonomous mode. It is an operating mode that allows peripherals to be functional and autonomous independently from power modes and without any software running. It is performed thanks to a hardware subsystem embedded in STM32 products. Thanks to DMA transfers in Linked-list mode, the LPBAM subsystem can chain different actions to build a useful functionality (peripheral configurations and transfers). Optionally, it can generate asynchronous events and interrupts. It operates without any CPU intervention. Consequently, the two major benefits from using the LPBAM subsystem mechanisms are an optimized power consumption, and an offloaded CPU.

18.1.2 LPBAM firmware

The LPBAM firmware has been designed to help users create LPBAM applications: the LPBAM utility is a set of modular drivers located under the Utilities folder of the STM32Cube firmware package. Each module comes as a pair of C file that provides the APIs needed to build an application scenario. Each module manages the configurability and the data transfers for a given peripheral. The LPBAM utility is designed to be compatible with any STM32 devices supporting LPBAM subsystem mechanisms through a configuration module: it requires a configuration file stm32_lpbam_conf.h aligned with the application needs. The LPBAM utility has a single application entry point, the stm32_lpbam.h, that must be included in the project.

18.1.3 Supported series

The LPBAM firmware supports STM32U575/585, STM32U595/5A5 and STM32U599/5A9 products, for projects with or without Trustzone activated.

STM32CubeMX 6.5.0 introduces LPBAM for projects without Trustzone activated on the STM32U575/585 product line: users can create LPBAM applications for their project using STM32CubeMX LPBAM Scenario & Configuration view and generate the corresponding code. The generated C project embeds the LPBAM firmware.

STM32CubeMX 6.6.0 adds LPBAM support for projects with Trustzone activated.
18.1.4 LPBAM design

It is recommended to use LPBAM to save power and offload the CPU.

- The LPBAM mechanism supports the following set of peripherals on the Smart Run Domain: ADC4, COMP1/2, DAC1, I2C3, LPDMA1, LPGPIO, LPTIM1/2/3, LPUART1, OPAMP1/2, SPI3, VREFBUF.
- According to the LPDMA implementation in the Smart Run domain, the LPBAM has access only to SRAM4.
- The LPBAM mechanism implementation can run autonomously until Stop2 mode.
- To reach the lowest power consumption, the system power usage, the system clock and the autonomous peripheral kernel clock can be configured.

18.1.5 LPBAM project support in STM32CubeMX

An LPBAM project is composed of a main project, and of one or more LPBAM applications.

Figure 354. LPBAM project

The “Main project” contains the “SoC and IPs configuration” at initialization time and a runtime description of the main application. STM32CubeMX allows to describe the “SOC and IPs Configuration” part.

Each LPBAM application contains a “SoC and IPs configuration” and a runtime description. STM32CubeMX allows to describe both.

STM32CubeMX generated code for “SoC and IPs configurations” uses the STM32Cube HAL and/or LL APIs, for both the main project and the LPBAM application. The code generated for the LPBAM application runtime uses the LPBAM firmware API.

Figure 355 is an example of what can be executed at runtime for a simple LPBAM project composed of the main application and of one LPBAM application.
18.2 Creating an LPBAM project

18.2.1 LPBAM feature availability

When a project with LPBAM feature capability is opened, a dedicated entry is shown in the user interface (see Figure 356). The feature is optional and when it is not used, it has no impact on the generated project.

18.2.2 Describing an LPBAM project

Describing an LPBAM project in STM32CubeMX consists in describing the main project using STM32CubeMX main project page, and one or more LPBAM applications using the dedicated LPBAM Scenario & Configuration page.
Starting with STM32CubeMX 6.5:

- Create a project by selecting an MCU or board part number from the STM32U575/585 product line.
- Do not activate Trustzone for the project.
- Click “LPBAM Scenario & Configuration” ribbon to view LPBAM dedicated page.

The LPBAM context is highlighted with a pink border. You can switch back and forth between the main project configuration and the LPBAM Scenario & Configuration by clicking the corresponding ribbon.

**Figure 357. LPBAM scenario & configuration view**

### 18.2.3 Managing LPBAM applications in a project

When entering the LPBAM Scenario & Configuration view, you must first add an LPBAM application.

Adding, removing, renaming, and switching between LPBAM applications is done from the left panel under the LPBAM manager section.

To add the first LPBAM application, click “Add Application”:

- If the default name is kept, the application “LpbamApp1” is created.
- The first Queue “Queue1” of LpbamApp1 is created.
- The configuration views (LPBAM scenario, pinout & ip, clock) necessary to describe Lpbam App1 are available.

To add more queues, click “Add Queue”

To delete an application (or a queue), right-click the application (or the queue) name and select “Delete”.
To rename an application (or a queue), right-click the application (or the queue) name and select “Rename”. Note that the application name is used in the generated project.

To switch between LPBAM applications, click the application name, this loads the LPBAM panel for the selected application.

To switch between queues in an LPBAM application, click the queue name: the middle and right panels are refreshed to display the selected queue and its configuration.

**Figure 358. Adding an application**

### 18.3 Describing an LPBAM application

#### 18.3.1 Overview (SoC & IPs configuration, runtime scenario)

Describing an LPBAM application consists in configuring the SoC and IPs, as it is done for a standard STM32CubeMX project, as well as describing the runtime part of the application.

**SoC and IPs configuration**

To configure IP and SOC in the context of an LPBAM application, use the Pinout & Configuration and Clock configuration provided with the LPBAM application.
Runtime description (scenario)

With standard STM32CubeMX projects, the user must add the code to manage the runtime behavior of the main application based on STM32Cube HAL or LL driver APIs, such as HAL_COMP_Start, HAL_TIM_Start, HAL_TIM_Stop.

For LPBAM applications, STM32CubeMX provides the LPBAM Scenario & Configuration panel to create the runtime description (scenario). As shown in Figure 360, this panel is divided in three parts.

Note: LPBAM applications use the LPBAM firmware APIs and consist of chained DMA transfers.
In the context of an LPBAM application, the first panel is used for:

- Managing queues for the application.
- Browsing and adding nodes to the queue currently selected in STM32CubeMX user interface.
- Application specific settings. These settings cannot be changed nor disabled when using LPBAM on STM32U5 series.

The second panel displays the diagram of the queue currently selected for one selected queue of the LPBAM application.

The third panel lets the user to configure either the queue (if the queue name is clicked), or a node (if the node is selected on the diagram).

### 18.3.2 SoC & IPs: configuring the clock

The LPBAM subsystem is functional down to STOP2 mode and supports only IPs on the Smart run domain. Consequently, in the LPBAM context, only a subset of the clock tree can be configured. Refer to Section 4.8 for details on how to configure a clock tree in STM32CubeMX.

**Figure 361. Clock tree configuration**

### 18.3.3 SoC & IPs: configuring the IPs

Only IPs of the Smart run domain are available in the LPBAM context.

In the LPBAM context, most IPs show the same configuration possibilities as the main project. However, for some IPs, some additional configuration is needed. For example, when an IP internal interrupt can be used in the LPBAM context, a dedicated configuration Tab is shown.
All IPs used at runtime by the LPBAM must be configured in the Pinout & Configuration view. Their configuration must be coherent with the LPBAM scenario.

Clicking “Check LPBAM Design” on the upper right corner of the user interface returns, for each IP used but not configured in an LPBAM application, a warning in the LPBAM output window.
**Warning:** “Check LPBAM Design” checks only that the IPs are configured in the “Pinout & Configuration”, it does not check whether the HAL configuration is coherent with the LPBAM APIs used in the scenario.

### 18.3.4 SoC & IPs: configuring Low Power settings

Starting with STM32CubeMX6.5, users can configure low power settings for their project. These settings (to be found under the PWR IP) are very important to minimize the power consumption of an LPBAM application.

![Figure 364. LPBAM low power settings](image)

### 18.3.5 LPBAM scenario: managing queues

An LPBAM scenario consists of one or more queues, each with one or more nodes. The center panel describes the scenario of the LPBAM application: click the queue name to display its diagram in the center panel and its configuration in the right panel. The name of the selected queue is underlined in blue.

To add more queues, click the “+” button in that panel, or click “Add queues” from the LPBAM management section in the left panel:

- The maximum number of queues is four on STM32U5 series, limited by the number of LPDMA1 channels.
- Adding an LPBAM application to the project automatically creates one empty queue for that application.

**Warning:** For LPBAM applications with multiple queues, STM32CubeMX does not manage the runtime synchronization between queues. It is the user's
responsibility when assembling its final application to “start” the different queues at runtime.

The “LPBAM Management” section allows to remove and rename queues:

- To delete a queue, right-click the queue name and select “Delete”.
- To rename a queue, right-click the queue name and select “Rename”.
- To switch between queues in an LPBAM application, click the queue name: the middle and right panels are refreshed to display the selected queue and its configuration.

### 18.3.6 Queue description: managing nodes

A queue description consists of a sequence of functional nodes on a timeline: the sequence is displayed as a diagram in the central panel and the queue configuration in the right panel.

To add nodes to a queue:

- Click the name of the queue to be updated.
- Use the “LPBAM function Toolbox”, in the left panel to browse the list of IPs and functions (LPBAM firmware APIs) that can be used to create nodes.
- Click the IP name to expand and see the list of available functions.
- Click the “+” sign next to the function name to add the function as a node in the queue: the queue diagram in the center panel is updated accordingly.
- Example: on Queue1 of LpbamAp1, COMP1 is started, then data transfer on COMP1 Output is performed (see Figure 365).

To remove nodes from the diagram, click the cross on the node right-end-upper corner.

**Figure 365. Adding nodes to a queue**
18.3.7 Queue description: configuring the queue in circular mode

STM32CubeMX offers the possibility to design circular queues:

- Select the queue to be configured by clicking the queue name in the center panel: the queue configuration is displayed in the right panel.
- Click the Circular mode checkbox to configure the queue in circular mode: by default, the queue loops back to the first node (see Figure 366).
- To loop back to a different node, click the end of the arrow and drag it to the node of choice.
- To remove the loop, uncheck Circular mode.

**Figure 366. Queue in circular mode**

Some functions first configure the IP, then manage the data transfer. In case of circular mode, the loop can be plugged on the configuration (“Conf”) or on the data part (“Data”) of the function.

An example is provided in Figure 367: when the queue is executed, the two first nodes and the configuration of the third node are executed once, whereas the data transfer is repeated as part of the loop.
18.3.8 Queue description: configuring the DMA channel hosting the queue

The execution of an LPBAM queue consists of LPDMA chained transfers. The DMA hosting the queue execution must be configured as needed by the application (see Figure 368).

**Figure 368. LPBAM queue: DMA configuration**

*Basic configuration*

Select the queue to be configured by clicking the queue name on the center panel, the configuration of the DMA channel hosting that queue is shown in the right panel.
Note that some settings usually available for configuring a DMA channel are not provided in the user interface, as they are directly managed either by STM32CubeMX or by the LPBAM driver.

**DMA channel NVIC configuration**

NVIC settings are available only if one DMA channel interrupt is enabled (see right panel in Figure 368). The preemption priority and sub priority ranges in the LPBAM context depend on the NVIC priority group set for the whole project (the main project with the LPBAM applications).

---

**Warning:** Always check preemption and sub-priorities in the LPBAM context after changing the NVIC priority group from the main project Pinout& Configuration view.

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### 18.3.9 Node description: accessing contextual help and documentation

STM32CubeMX provides contextual help and link to reference documentation on LPBAM functions to guide the user during the function selection process:

- From the “LPBAM function Toolbox” in the left panel, hover the mouse on an IP name to show the contextual help with links to reference documentation (see Figure 369).

- It is recommended to read carefully the LPBAM global documentation and the IP “Description, Usage and Constraint” to learn how to assemble nodes in a queue, several queues, what can be done and what cannot be done. Some restrictions apply and are due to the LPBAM mechanism. They are not coming from the IP itself or from HAL constraints.

![Figure 369. LPBAM functions contextual help](image-url)
18.3.10 Node description: configuring node parameters

Once a function is chosen from the “LPBAM Function Toolbox” and added to a queue, it can be configured. In the center panel, click on a node to select it: the function is highlighted in pink, and its configuration is shown in the right panel (see Figure 370).

The example shows the “Start” parameters of the LPBAM COMP1_Start function. The HAL driver uses the same parameter names to configure a COMP IP. As mentioned before, the LPBAM firmware is not a HAL driver. However, the IP being unique, the LPBAM driver has been designed so that the IP parameters use, whenever possible, the same naming as found in the HAL driver.

**Figure 370. LPBAM queue node configuration**

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**Warning:** LPBAM IP functions access IP hardware resources, to be properly configured in the “Pinout & Configuration” view.

When a parameter is set to a hardware resource such as a GPIO, the resource must be configured in the Pinout & Configuration view.

In the example shown in Figure 370, the COMP “Input Plus” is set to PC5. If PC5 is not configured in the “Pinout & configuration” view, the generated LPBAM application can get a “null signal” on Input Plus, and will be not functional.

To fix this issue:

- Go to the Pinout&Configuration view
- Search PC5 using the search field
- Right-click the PC5 pin and select COMP_Inp (see Figure 371)
Another example can be made using a timer to generate a PWM signal. The HAL driver requires a timer channel to be configured as output. Same applies when using the LPBAM firmware.

**Note:** All constraints concerning the initial configuration of the IP are mentioned in the LPBAM firmware documentation. Use STM32CubeMX “LPBAM Design check” mechanism (see dedicated section) to detect missing configurations.

### 18.3.11 Node description: configuring a trigger

For all IPs and functions, with the LPBAM firmware it is possible to use a hardware signal to trigger a node. STM32CubeMX allows to configure such trigger from the node configuration panel. By default, the node execution is not triggered. When trigger is enabled, all possible trigger signals are listed.

**Warning:** It is the user responsibility to properly configure the triggers. STM32CubeMX does not check for configuration errors.

Taking the COMP function “Start” as an example (see Figure 372), choose the function execution to be triggered on the rising edge of hardware signal, for the example, then, select the hardware signal among the list of hardware signals proposed.
If a node is a function managing LPTIM1_CH1, it is possible to select LPTIM1_CH1 as the trigger (see Figure 373).

Figure 373. LPBAM node triggered using timer channel

18.3.12 Node description: reconfiguring a DMA for Data transfer

Nodes set to a function managing data transfers (all functions with associated data transfer and with a name not ending with _Config), come with a specific configuration section: “Reconfigure DMA for Data Transfer” (see Figure 374).

Each DMA data transfer is based on a specific configuration, including, among others, data size, buffer address, address increment. The DMA default settings are functional.
DMA settings can be changed, but they depend upon the IP and the function.

For example, for “COMP Output Level”:

- Data transferred are output data and are transferred from the register IP to the memory. The “Source Address” referring to the IP data register is not incremented: STM32CubeMX user interface shows that the “Source address increment after transfer” parameter cannot be enabled.

- Data transferred to memory can be saved at the same memory address, or in a Table: in this case, the “Destination Address increment after transfer” can be disabled or left enabled (see Figure 374).

Figure 375. Reconfiguring DMA for data transfer when destination is memory
18.4 Checking the LPBAM design

STM32CubeMX offers users with the possibility to check their LPBAM design for coherency and completeness, by detecting:

- Incoherences between the IP LPBAM function selected for a node and the corresponding IP configuration.
- Wrong queue designs (the sequence of nodes is invalid).

Click CHECK LPBAM DESIGN to check all LPBAM applications currently available in the project. Results appear in the LPBAM output log window (see Figure 376).

Note: Warnings raised on the LPBAM design do not prevent users to generate the C code for their project.

Figure 376. Design check
18.5 Generating a project with LPBAM applications

Click Generate Code from the main project view. As exemplified in Figure 376, the resulting project shows, in addition to the main project files and folders, the stm32_lpbam_conf.h file, a dedicated folder for the configuration code, and the utilities folder with the LPBAM utility firmware.

STM32CubeMX generates:

- In the Core/Inc folder, the stm32_lpbam_conf.h file that defines all the LPBAM modules enabled for the LPBAM applications, to be used by the LPBAM utility firmware.
- In the LPBAM folder, the code for the LPBAM applications and their scenarios. The lpbam_<application name>.h file provides the prototypes of the functions to call in the main project to initialize the application, build and initialize the scenario, link it with the DMA, start it, stop it, unlink it, and de-initialize it.

As an example, for the LpbamAp1 application, STM32CubeMX generates the following functions:

```c
/* LpbamAp1 application initialization */
void MX_LpbamAp1_Init(void);

/* LpbamAp1 application - scenario initialization */
void MX_LpbamAp1_Scenario_Init(void);

/* LpbamAp1 application - scenario build */
void MX_LpbamAp1_Scenario_Build(void);

/* LpbamAp1 application - scenario link */
void MX_LpbamAp1_Scenario_Link(DMA_HandleTypeDef *hdma);

/* LpbamAp1 application - scenario start */
void MX_LpbamAp1_Scenario_Start(DMA_HandleTypeDef *hdma);
```
18.6 LPBAM application for TrustZone activated projects

Starting with STM32CubeMX 6.6.0, users can create LPBAM applications for projects with Trustzone activated.

1. Access to MCU selector and select an STM32U575/585 device
2. Click Create a new project
3. Choose the option "with TrustZone activated"

STM32CubeMX standard project view

STM32CubeMX standard project view proposes security settings for peripherals (Figure 378) and the clock tree (Figure 379).

STM32CubeMX LPBAM view

In STM32CubeMX LPBAM Application configuration context, the peripherals and the clock tree do not come with dedicated security settings (see Figure 380 and Figure 381). The choice of context, secure or nonsecure, is done at LPBAM application level (Figure 382).

Security settings coherency check

1. Click CHECK LPBAM DESIGN
2. Enable Show Attribute Warning Messages to see details about LPBAM security related configuration issues (see Figure 383)
Figure 378. STM32CubeMX project - Peripheral secure context assignment

Figure 379. STM32CubeMX project - Clock source secure context assignment
Figure 380. LPBAM project - Peripheral no context assignment

Figure 381. LPBAM application - Clock source no context assignment
Figure 382. LPBAM application - Secure context assignment

Figure 383. LPBAM design security coherency check
19 FAQ

19.1 I encountered a network connection error during a download from STM32CubeMX.

If you experienced a network connection issue during a download select Help > Updater settings and verify the connection status.

If the Check connection button shows a green check mark (connection is up), click it. The button should be refreshed to show a fuchsia cross (connection failed). Adjust the parameters to match your network configuration and click the “Check connection” button again. Once the green check mark appears (connection back up), you may proceed with the download.

19.2 Since I changed my login to access the Internet, some software packs appear not available.

The workaround is to delete the .stm32cubemx folder from the user directory and re-launch STM32CubeMX. Note that all software packs installed using the “From URL” button must be re-installed.

Select Help > Updater settings:
• Check your repository path on the Updater Settings tab.
• If a proxy is used, enter your login and password information on the Connection Parameters tab.

19.3 On dual-context products, why some peripherals or middleware are not available for a given context?

Some peripherals and middleware require another peripheral or middleware to be enabled in the same context.

For example, the LwIP middleware requires the ETH peripheral to be enabled in the same context.

19.4 On the Pinout configuration panel, why does STM32CubeMX move some functions when I add a new peripheral mode?

You may have deselected . In this case, the tool performs an automatic remapping to optimize your placement.

19.5 How can I manually force a function remapping?

Use the Manual Remapping feature.
19.6 Why some pins are highlighted in yellow or in light green in the Pinout view? Why I cannot change the function of some pins (when I click some pins, nothing happens)?

These pins are specific pins (such as power supply or BOOT) which are not available as peripheral signals.

19.7 Why does the RTC multiplexer remain inactive on the Clock tree view?

To enable the RTC multiplexer the user must enable the RTC peripheral in the Pinout view as indicated below.

19.8 How can I select LSE and HSE as clock source and change the frequency?

The LSE and HSE clocks become active once the RCC is configured as such in the Pinout view. See Figure 385 for an example. The clock source frequency can then be edited and the external source selected, see Figure 386.
19.9 Why STM32CubeMX does not allow me to configure PC13, PC14, PC15, and PI8 as outputs when one of them is already configured as an output?

STM32CubeMX implements the restriction documented in the reference manuals as a footnote in the table detailing the output voltage characteristics:

“PC13, PC14, PC15 and PI8 are supplied through the power switch. Since the switch only sinks a limited amount of current (3 mA), the use of GPIOs PC13 to PC15 and PI8 in output mode is limited: the speed should not exceed 2 MHz, with a maximum load of 30 pF, and these I/Os must not be used as a current source (e.g. to drive a LED).”

19.10 Ethernet configuration: why cannot I specify DP83848 or LAN8742A in some cases?

For most series, STM32CubeMX adjusts the list of possible PHY component drivers according to the selected Ethernet mode:

- when the Ethernet MII mode is selected the user is able to choose between the DP83848 component driver or a “User Phy”.
- when the Ethernet RMII mode is selected, the user is able to choose between the LAN8742A component driver or a “User Phy”.

When “User Phy” is selected, the user must manually include the component drivers to be used in its project.

Note: For STM32H7 series, the PHY is seen as an external component and is no longer specified under the Ethernet peripheral configuration. The user can select the PHY under LwIP Platform settings tab. However, as the STM32H7 firmware package provides only the driver code for the LAN8742A component available on all STM32H7 evaluation and Nucleo boards, the user interface offers only the choice between “User Phy” and LAN8742.

When LAN8742 is selected, the BSP driver code is copied into the generated project.

19.11 How to fix MX_DMA_Init call rank in STM32CubeMX generated projects?

When DMA is used, the MX_DMA_Init shall always be called before any other HAL_***_Init (where *** is any peripheral with a HW dependency on DMA init code).

STM32CubeMX version 6.3.0 (STM32CubeIDE Version: 1.7.0 ) introduced a regression: initialization function calls were generated in the wrong order.

STM32CubeMX 6.4.0 fixed this issue for newly created projects. However, the calling order being saved in the project .ioc file, STM32CubeMX 6.3.0 generated projects will still show the issue when opened and re-generated with STM32CubeMX 6.4.0.

To fix the issue, open the saved .ioc file (already created with 6.3.0 version) with any text editor installed in your machine and delete the line: ProjectManager.functionlistsort=....

After saving the modification, re-open the .ioc file with CubeMX version 6.4.0 (STM32CubeIDE Version: 1.8.0) or later. Through Project Manager view > Advanced Settings tab, make sure that the initialization functions are correctly ordered and re-generate your project.
19.12 When is the PeriphCommonClock_Config() function generated?

1. When RCC is in LL mode, it is generated to initialize
   a) ckper clock, when used by a peripheral (for series having ckper)
   b) pll2, pll3, pllsai1, pllsai2, when used
2. When RCC is in HAL mode it is generated to initialize
   a) pll2, pll3, pllsai1, pllsai2, when used by more than one peripheral

What are the conditions and reason for having this function? The reason is to do the split, e.g. the system clock in the system_clockConfig() function, and the RCC peripheral initialization in the HAL_mspInit/Mx_.-_Init() function.

There is a difference between the generation when RCC is in HAL or LL mode because:
• in LL: we have the call to initialize the PLLs directly
• in HAL: we should at least initialize one peripheral

When PLL is used by only one peripheral the initialization is done in the HAL_mspInit/Mx_.-_Init(), otherwise in the PeriphCommonClock_Config().

19.13 How to handle thread-safe solution in STM32CubeMX and STM32CubeIDE?

AN5731 “STM32CubeMX and STM32CubeIDE thread-safe solution” (available on www.st.com) contains a detailed description.
Appendix A  STM32CubeMX pin assignment rules

The following pin assignment rules are implemented in STM32CubeMX:

- Rule 1: Block consistency
- Rule 2: Block inter-dependency
- Rule 3: One block = one peripheral mode
- Rule 4: Block remapping (only for STM32F10x)
- Rule 5: Function remapping
- Rule 6: Block shifting (only for STM32F10x)
- Rule 7: Setting or clearing a peripheral mode
- Rule 8: Mapping a function individually (if Keep CurrentPlacement is unchecked)
- Rule 9: GPIO signals mapping

A.1 Block consistency

When setting a pin signal (provided there is no ambiguity about the corresponding peripheral mode), all the pins/signals required for this mode are mapped and pins are shown in green (otherwise the configured pin is shown in orange).

When clearing a pin signal, all the pins/signals required for this mode are unmapped simultaneously and the pins turn back to gray.

Example of block mapping with a STM32F107x MCU

If the user assigns I2C1_SMBA function to PB5, then STM32CubeMX configures pins and modes as follows:

- I2C1_SCL and I2C1_SDA signals are mapped to the PB6 and PB7 pins, respectively (see Figure 387).
- I2C1 peripheral mode is set to SMBus-Alert mode.
Example of block remapping with a STM32F107x MCU

If the user assigns GPIO_Output to PB6, STM32CubeMX automatically disables I2C1 SMBus-Alert peripheral mode from the peripheral tree view and updates the other I2C1 pins (PB5 and PB7) as follows:

- If they are unpinned, the pin configuration is reset (pin grayed out).
- If they are pinned, the peripheral signal assigned to the pins is kept and the pins are highlighted in orange since they no longer match a peripheral mode (see Figure 388).
For STM32CubeMX to find an alternative solution for the I2C peripheral mode, the user will need to unpin I2C1 pins and select the I2C1 mode from the peripheral tree view (see Figure 389 and Figure 390).
Figure 389. Block remapping - Example 1

Figure 390. Block remapping - Example 2
A.2 Block inter-dependency

On the Pinout view, the same signal can appear as an alternate function for multiple pins. However it can be mapped only once.

As a consequence, for STM32F1 MCUs, two blocks of pins cannot be selected simultaneously for the same peripheral mode: when a block/signal from a block is selected, the alternate blocks are cleared.

Example of block remapping of SPI in full-duplex master mode with a STM32F107x MCU

If SPI1 full-duplex master mode is selected from the tree view, by default the corresponding SPI signals are assigned to PB3, PB4 and PB5 pins (see Figure 391).

If the user assigns to PA6 the SPI1_MISO function currently assigned to PB4, STM32CubeMX clears the PB4 pin from the SPI1_MISO function, as well as all the other pins configured for this block, and moves the corresponding SPI1 functions to the relevant pins in the same block as the PB4 pin (see Figure 392).

(by pressing CTRL and clicking PB4 to show PA6 alternate function in blue, then drag and drop the signal to pin PA6)

Figure 391. Block inter-dependency - SPI signals assigned to PB3/4/5
Figure 392. Block inter-dependency - SPI1_MISO function assigned to PA6
A.3  One block = one peripheral mode

When a block of pins is fully configured in the Pinout view (shown in green), the related peripheral mode is automatically set in the Peripherals tree.

Example of STM32F107x MCU

Assigning the I2C1_SMBA function to PB5 automatically configures I2C1 peripheral in SMBus-Alert mode (see Peripheral tree in Figure 393).

Figure 393. One block = one peripheral mode - I2C1_SMBA function assigned to PB5

A.4  Block remapping (STM32F10x only)

To configure a peripheral mode, STM32CubeMX selects a block of pins and assigns each mode signal to a pin in this block. In doing so, it looks for the first free block to which the mode can be mapped.

When setting a peripheral mode, if at least one pin in the default block is already used, STM32CubeMX tries to find an alternate block. If none can be found, it either selects the functions in a different sequence, or unchecks and remaps all the blocks to find a solution.
Example

STM32CubeMX remaps USART3 hardware-flow-control mode to the (PD8-PD9-PD11-PD12) block, because PB14 of USART3 default block is already allocated to the SPI2_MISO function (see Figure 394).

Figure 394. Block remapping - Example 2

A.5 Function remapping

To configure a peripheral mode, STM32CubeMX assigns each signal of the mode to a pin. In doing so, it will look for the first free pin the signal can be mapped to.

Example using STM32F415x

When configuring USART3 for the Synchronous mode, STM32CubeMX discovered that the default PB10 pin for USART3_TX signal was already used by SPI. It thus remapped it to PD8 (see Figure 395).

Figure 395. Function remapping example
A.6 Block shifting (only for STM32F10x and when “Keep Current Signals placement” is unchecked)

If a block cannot be mapped and there are no free alternate solutions, STM32CubeMX tries to free the pins by remapping all the peripheral modes impacted by the shared pin.

Example

With the Keep current signal placement enabled, if USART3 synchronous mode is set first, the Asynchronous default block (PB10-PB11) is mapped and Ethernet becomes unavailable (shown in red) (see Figure 396).

Unchecking allows STM32CubeMX shifting blocks around and freeing a block for the Ethernet MII mode. (see Figure 397).

Figure 396. Block shifting not applied
A.7 Setting and clearing a peripheral mode

The Peripherals panel and the Pinout view are linked: when a peripheral mode is set or cleared, the corresponding pin functions are set or cleared.

A.8 Mapping a function individually

When STM32CubeMX needs a pin that has already been assigned manually to a function (no peripheral mode set), it can move this function to another pin, only if is unchecked and the function is not pinned (no pin icon).

A.9 GPIO signals mapping

I/O signals (GPIO_Input, GPIO_Output, GPIO_Analog) can be assigned to pins either manually through the Pinout view or automatically through the Pinout menu. Such pins can no longer be assigned automatically to another signal: STM32CubeMX signal automatic placement does not take into account this pin anymore since it does not shift I/O signals to other pins.

The pin can still be manually assigned to another signal or to a reset state.
Appendix B  STM32CubeMX C code generation design choices and limitations

B.1  STM32CubeMX generated C code and user sections

The C code generated by STM32CubeMX provides user sections as illustrated below. They allow user C code to be inserted and preserved at next C code generation.

User sections shall neither be moved nor renamed. Only the user sections defined by STM32CubeMX are preserved. User created sections will be ignored and lost at next C code generation.

```c
/* USER CODE BEGIN 0 */

(...) // User code

/* USER CODE END 0 */
```

Note: STM32CubeMX may generate C code in some user sections. It will be up to the user to clean the parts that may become obsolete in this section. For example, the while(1) loop in the main function is placed inside a user section as illustrated below:

```c
/* Infinite loop */

/* USER CODE BEGIN WHILE */
while (1)
{
  /* USER CODE END WHILE */

  /* USER CODE BEGIN 3 */
  }

/* USER CODE END 3 */
```

B.2  STM32CubeMX design choices for peripheral initialization

STM32CubeMX generates peripheral _Init functions that can be easily identified thanks to the MX_ prefix:

```c
static void MX_GPIO_Init(void);
static void MX_<Peripheral Instance Name>_Init(void);
static void MX_I2S2_Init(void);
```

An MX_<peripheral instance name>_Init function exists for each peripheral instance selected by the user (e.g. MX_I2S2_Init). It performs the initialization of the relevant handle structure (e.g. &hi2s2 for I2S second instance) that is required for HAL driver initialization (e.g., HAL_I2S_Init) and the actual call to this function:

```c
void MX_I2S2_Init(void)
{
  hi2s2.Instance = SPI2;
  hi2s2.Init.Mode = I2S_MODE_MASTER_TX;
  hi2s2.Init.Standard = I2S_STANDARD_PHILLIPS;
  hi2s2.Init.DataFormat = I2S_DATAFORMAT_16B;
  hi2s2.Init.MCLKOutput = I2S_MCLKOUTPUT_DISABLE;
```
hi2s2.Init.AudioFreq = I2S_AUDIOFREQ_192K;
hi2s2.Init.CPOL = I2S_CPOL_LOW;
hi2s2.Init.ClockSource = I2S_CLOCK_PLL;
hi2s2.Init.FullDuplexMode = I2S_FULLDUPLEXMODE_ENABLE;
HAL_I2S_Init(&hi2s2);
}

By default, the peripheral initialization is done in main.c. If the peripheral is used by a middleware mode, the peripheral initialization can be done in the middleware corresponding .c file.

Customized HAL_<Peripheral Name>_MspInit() functions are created in the stm32f4xx_hal_msp.c file to configure the low-level hardware (GPIO, CLOCK) for the selected peripherals.

B.3 STM32CubeMX design choices and limitations for middleware initialization

B.3.1 Overview

STM32CubeMX does not support C user code insertion in Middleware stack native files although stacks such as LwIP might require it in some use cases.

STM32CubeMX generates middleware _init functions that can be easily identified thanks to the MX_ prefix:

MX_LWIP_Init(); // defined in lwip.h file
MX_USB_HOST_Init(); // defined in usb_host.h file
MX_FATFS_Init(); // defined in fatfs.h file

Note however the following exceptions:

- No _init function is generated for FreeRTOS unless the user chooses, from the Project settings window, to generate _init functions as pairs of .c/.h files. Instead, a StartDefaultTask function is defined in the main.c file and CMSIS-RTOS native function (osKernelStart) is called in the main function.

- If FreeRTOS is enabled, the _init functions for the other middlewares in use are called from the StartDefaultTask function in the main.c file.

Example:

```c
void StartDefaultTask(void const * argument)
{
    /* init code for FATFS */
    MX_FATFS_Init();
    /* init code for LWIP */
    MX_LWIP_Init();
    /* init code for USB_HOST */
    MX_USB_HOST_Init();
    /* USER CODE BEGIN 5 */
    /* Infinite loop */
    for(;;)
    {
```
B.3.2 USB host

USB peripheral initialization is performed within the middleware initialization C code in the `usbh_conf.c` file, while USB stack initialization is done within the `usb_host.c` file.

When using the USB Host middleware, the user is responsible for implementing the `USBH_UserProcess` callback function in the generated `usb_host.c` file.

From STM32CubeMX user interface, the user can select to register one class or all classes if the application requires switching dynamically between classes.

B.3.3 USB device

USB peripheral initialization is performed within the middleware initialization C code in the `usbd_conf.c` file, while USB stack initialization is done within the `usb_device.c` file.

USB VID, PID and String standard descriptors are configured via STM32CubeMX user interface and available in the `usbd_desc.c` generated file. Other standard descriptors (configuration, interface) are hard-coded in the same file preventing support of USB composite devices.

When using the USB Device middleware, the user is responsible for implementing the functions in the `usbd_<classname>_if.c` class interface file for all device classes (e.g., `usbd_storage_if.c`).

USB MTP and CCID classes are not supported.

B.3.4 FatFs

FatFs is a generic FAT/exFAT file system solution well suited for small embedded systems.

FatFs configuration is available in `ffconf.h` generated file.

The initialization of the SDIO peripheral for the FatFs SD card mode and of the FMC peripheral for the FatFs External SDRAM and External SRAM modes are kept in the `main.c` file.

Some files need to be modified by the user to match user board specificities (BSP in STM32Cube embedded software package can be used as example):

- `bsp_driver_sd.c/.h` generated files when using FatFs SD card mode
- `bsp_driver_sram.c/.h` generated files when using FatFs External SRAM mode
- `bsp_driver_sdram.c/.h` generated files when using FatFs External SDRAM mode.

Multi-drive FatFs is supported, which means that multiple logical drives can be used by the application (External SDRAM, External SRAM, SD card, USB disk, User defined). However support of multiple instances of a given logical drive is not available (e.g. FatFs using two instances of USB hosts or several RAM disks).

NOR and NAND flash memory are not supported. In this case, the user shall select the FatFs user-defined mode and update the `user_diskio.c` driver file generated to implement the interface between the middleware and the selected peripheral.
B.3.5 FreeRTOS

FreeRTOS is a free real-time embedded operating system well suited for microcontrollers. FreeRTOS configuration is available in `FreeRTOSConfig.h` generated file.

When FreeRTOS is enabled, all other selected middleware modes (e.g., LwIP, FatFs, USB) will be initialized within the same FreeRTOS thread in the main.c file.

When `GENERATE_RUN_TIME_STATS`, `CHECK_FOR_STACK_OVERFLOW`, `USE_IDLE_HOOK`, `USE_TICK_HOOK` and `USE_MALLOC_FAILED_HOOK` parameters are activated, STM32CubeMX generates `freertos.c` file with empty functions that the user shall implement. This is highlighted by the tooltip (see Figure 398).

![Figure 398. FreeRTOS HOOK functions to be completed by user](image-url)
B.3.6 LwIP

LwIP is a small independent implementation of the TCP/IP protocol suite: its reduced RAM usage makes it suitable for use in embedded systems with tens of Kbytes of free RAM.

LwIP initialization function is defined in lwip.c, while LwIP configuration is available in lwipopts.h generated file.

STM32CubeMX supports LwIP over Ethernet only. The Ethernet peripheral initialization is done within the middleware initialization C code.

STM32CubeMX does not support user C code insertion in stack native files. However, some LwIP use cases require modifying stack native files (e.g., cc.h, mib2.c): user modifications shall be backed up since they will be lost at next STM32CubeMX generation.

Starting with LwIP release 1.5, STM32CubeMX LwIP supports IPv6 (see Figure 400). DHCP must be disabled, to configure a static IP address.

**Figure 399. LwIP 1.4.1 configuration**
STM32CubeMX generated C code will report compilation errors when specific parameters are enabled (disabled by default). The user must fix the issues with a stack patch (downloaded from Internet) or user C code. The following parameters generate an error:

- **MEM_USE_POOLS**: user C code to be added either in `lwipopts.h` or in `cc.h` (stack file).
- **PPP_SUPPORT, PPPOE_SUPPORT**: user C code required
- **MEMP_SEPARATE_POOLS with MEMP_OVERFLOW_CHECK > 0**: a stack patch required
- **MEM_LIBC_MALLOC & RTOS enabled**: stack patch required
- **LWIP_EVENT_API**: stack patch required

In STM32CubeMX, the user must enable FreeRTOS in order to use LwIP with the netconn and sockets APIs. These APIs require the use of threads and consequently of an operating system. Without FreeRTOS, only the LwIP event-driven raw API can be used.
B.3.7 Libjpeg

Libjpeg is a widely used C-library that allows reading and writing JPEG files. It is delivered within STM32CubeF7, STM32CubeH7, STM32CubeF2 and STM32CubeF4 embedded software packages.

STM32CubeMX generates the following files, whose content can be configured by the user through STM32CubeMX user interface:

- **libjpeg.c/.h**
  The `MX_LIBJPEG_Init()` initialization function is generated within the libjpeg.c file. It is empty. It is up to the user to enter in the user sections the code and the calls to the libjpeg functions required for the application.

- **jdata_conf.c**
  This file is generated only when FatFs is selected as data stream management type.

- **jdata_conf.h**
  The content of this file is adjusted according to the datastream management type selected.

- **jconf.h**
  This file is generated by STM32CubeMX. but cannot be configured.

- **jmorecfg.h**
  Some but not all the define statements contained in this file can be modified through the STM32CubeMX libjpeg configuration menu.
B.3.8 Mbed TLS

Mbed TLS is a C-library that allows including cryptographic capabilities to embedded products. It handles Secure Sockets Layer (SSL) and Transport Layer Security (TLS) protocols, that are used for establishing a secure, encrypted and authenticated link between two parties over an insecure network. Mbed TLS comes with an intuitive API and minimal coding footprint. Visit https://tls.mbed.org/ for more details.

Mbed TLS is delivered within STM32CubeF2, STM32CubeF4, STM32CubeF7 and STM32CubeH7 embedded software packages.

Mbed TLS can work without LwIP stack (see Figure 402: Mbed TLS without LwIP).

If LwIP stack is used, FreeRTOS must be enabled as well (see Figure 403: Mbed TLS with LwIP and FreeRTOS).
STM32CubeMX generates the following files, whose contents can be modified by the user through STM32CubeMX user interface (see Figure 404: Mbed TLS configuration window) and/or using user sections in the code itself:

- `mbedtls_config.h`
- `mbedtls.h`
- `netsockets.c` (generated only if LwIP is enabled)
- `mbedtls.c`

**Figure 402. Mbed TLS without LwIP**
Figure 403. Mbed TLS with LwIP and FreeRTOS
B.3.9 TouchSensing

The STM32 TouchSensing library is a C-library that allows the creation of higher-end human interfaces by replacing conventional electromechanical switches by capacitive sensors with STM32 microcontrollers.

It requires the touch-sensing peripheral to be configured on the microcontroller.

STM32CubeMX generates the following files, whose contents can be modified by the user through STM32CubeMX user interface (see Figure 405: Enabling the TouchSensing peripheral, Figure 406: Touch-sensing sensor selection panel and Figure 407: TouchSensing configuration panel) and/or using user sections in the code itself:

- `touchsensing.c/.h`
- `tsl_user.c/.h`
- `tsl_conf.h`
Figure 405. Enabling the TouchSensing peripheral
Figure 406. Touch-sensing sensor selection panel
B.3.10 PDM2PCM

The PDM2PCM library is a C-library that allows converting a pulse density modulated (PDM) data output into a 16-bit pulse-code modulation (PCM) format. It requires the CRC peripheral to be enabled.

STM32CubeMX generates the following files, whose content can be modified by the user through STM32CubeMX user interface and/or using user sections in the code itself:

- pdm2pcm.h/c
B.3.11 STM32WPAN BLE/Thread (STM32WB series only)

STM32WPAN BLE and Thread middleware are now supported in STM32CubeMX.

Figure 408. BLE and Thread middleware support in STM32CubeMX

They are exclusive in a given project and configuration with FreeRTOS is not yet supported.
Application projects generated with STM32CubeMX can be found in the project folder of the STM32CubeWB MCU package.

**Figure 409. STM32CubeWB Package download**
This package can be installed through STM32CubeMX following the standard procedure described in Section 3.4.3: Installing STM32 MCU packages.

**Figure 410. STM32CubeWB BLE applications folder**

**BLE configuration**

To enable BLE some peripherals (RTC, HSEM, RF) must be activated first.

Then, an application type must be selected, it can be one among Transparent mode, Server profile, Router profile or Client profile.

Finally, the mode and other parameters relevant to this application type must be configured.

*Note:* The BLE Transparent mode and all Thread applications require either the USART or the LPUART peripheral to be configured as well.
Figure 411. BLE Server profile selection

Figure 412. BLE Client profile selection
Thread configuration

To enable Thread some peripherals (RTC, HSEM, RF) must be activated first.
Then, an application type must be selected and the relevant parameters configured.

Figure 413. Thread application selection

B.3.12 OpenAmp and RESMGR_UTILITY
(STM32MP1 series and STM32H7 dual-core product lines)

New software and hardware have been introduced on dual-core products to enable multi-core cooperation.

- For STM32MP1 series only: the inter-processor communication controller (IPCC) used to exchange data between two processor instances relies on the fact that shared memory buffers are allocated in the MCU SRAM and that each processor owns specific register bank and interrupts.
- For STM32MP1 series only: the OpenAMP middleware for intercommunication between Cortex-A and Cortex-M cores implements the RPMsg messaging protocol (see Figure 414).
- The resource manager library (RESMGR_UTILITY) for system resource management: multi-processor devices give the possibility to run independent firmware on several cores (see Figure 415). This implies a core could use some peripherals without knowledge of the usage of these same peripherals: the role of the resource management library is to control the assignment of a peripheral to a dedicated core and to provide a method to configure the system resources used to operate that peripheral (see Figure 416).
Figure 414. Enabling OpenAmp for STM32MP1 devices

Figure 415. Enabling the Resource Manager for STM32MP1 devices
For more details visit STM32MP1 dedicated wiki site at https://wiki.st.com/stm32mpu.
STM32 microcontroller part numbers are codified following the below naming conventions:

- **Device subfamilies**
  - The higher the number, the more features available.
  - For example STM32L0 line includes STM32L051, L052, L053, L061, L062, L063 subfamilies where STM32L06x part numbers come with AES while STM32L05x do not.
  - The last digit indicates the level of features. In the above example:
    - 1 = Access line
    - 2 = with USB
    - 3 = with USB and LCD.

- **Pin counts**
  - F = 20 pins
  - G = 28 pins
  - K = 32 pins
  - T = 36 pins
  - S = 44 pins
  - C = 48 pins
  - R = 64 (or 66) pins
  - M = 80 pins
  - O = 90 pins
  - V = 100 pins
  - Q = 132 pins (e.g. STM32L162QDH6)
  - Z = 144 pins
  - I = 176 (+25) pins
  - B = 208 pins (e.g. STM32F429BIT6)
  - N = 216 pins

- **Flash memory sizes**
  - 4 = 16 Kbytes of flash memory
  - 6 = 32 Kbytes of flash memory
  - 8 = 64 Kbytes of flash memory
  - B = 128 Kbytes of flash memory
  - C = 256 Kbytes of flash memory
  - D = 384 Kbytes of flash memory
  - E = 512 Kbytes of flash memory
  - F = 768 Kbytes of flash memory
  - G = 1024 Kbytes of flash memory
  - I = 2048 Kbytes of flash memory

- **Packages**
  - B = SDIP
  - H = BGA
– M = SO
– P = TSSOP
– T = LQFP
– U = VFQFPN
– Y = WLCSP

*Figure 417* shows an example of STM32 microcontroller part numbering scheme.

*Figure 417. STM32 microcontroller part numbering scheme*

<table>
<thead>
<tr>
<th>Example:</th>
<th>STM32</th>
<th>F</th>
<th>439</th>
<th>V</th>
<th>I</th>
<th>T</th>
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Appendix D  STM32 microcontrollers power consumption parameters

This section provides an overview on how to use STM32CubeMX Power Consumption Calculator.

Microcontroller power consumption depends on chip size, supply voltage, clock frequency and operating mode. Embedded applications can optimize STM32 MCU power consumption by reducing the clock frequency when fast processing is not required and choosing the optimal operating mode and voltage range to run from. A description of STM32 power modes and voltage range is provided below.

D.1  Power modes

STM32 MCUs support different power modes (refer to STM32 MCU datasheets for full details).

D.1.1  STM32L1 series

STM32L1 microcontrollers feature up to 6 power modes, including 5 low-power modes:

• **Run mode**
  This mode offers the highest performance using HSE/HSI clock sources. The CPU runs up to 32 MHz and the voltage regulator is enabled.

• **Sleep mode**
  This mode uses HSE or HSI as system clock sources. The voltage regulator is enabled and the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.

• **Low-power run mode**
  This mode uses the multispeed internal (MSI) RC oscillator set to the minimum clock frequency (131 kHz) and the internal regulator in low-power mode. The clock frequency and the number of enabled peripherals are limited.

• **Low-power sleep mode**
  This mode is achieved by entering Sleep mode. The internal voltage regulator is in low-power mode. The clock frequency and the number of enabled peripherals are limited. A typical example would be a timer running at 32 kHz.

  When the wake-up is triggered by an event or an interrupt, the system returns to the Run mode with the regulator ON.

• **Stop mode**
  This mode achieves the lowest power consumption while retaining RAM and register contents. Clocks are stopped. The real-time clock (RTC) can be backed up by using LSE/LSI at 32 kHz/37 kHz. The number of enabled peripherals is limited. The voltage regulator is in low-power mode.

  The device can be woken up from Stop mode by any of the EXTI lines.

• **Standby mode**
  This mode achieves the lowest power consumption. The internal voltage regulator is switched off so that the entire V\text{CORE} domain is powered off. Clocks are stopped and the real-time clock (RTC) can be preserved up by using LSE/LSI at 32 kHz/37 kHz.
RAM and register contents are lost except for the registers in the Standby circuitry. The number of enabled peripherals is even more limited than in Stop mode.

The device exits Standby mode upon reset, rising edge on one of the three WKUP pins, or if an RTC event occurs (if the RTC is ON).

Note: When exiting Stop or Standby modes to enter the Run mode, STM32L1 MCUs go through a state where the MSI oscillator is used as clock source. This transition can have a significant impact on the global power consumption. For this reason, the Power Consumption Calculator introduces two transition steps: \texttt{WU\_FROM\_STOP} and \texttt{WU\_FROM\_STANDBY}. During these steps, the clock is automatically configured to MSI.

D.1.2 STM32F4 series

STM32F4 microcontrollers feature a total of 5 power modes, including 4 low-power modes:

- **Run mode**
  This is the default mode at power-on or after a system reset. It offers the highest performance using HSE/HSI clock sources. The CPU can run at the maximum frequency depending on the selected power scale.

- **Sleep mode**
  Only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/even occurs. The clock source is the clock that was set before entering Sleep mode.

- **Stop mode**
  This mode achieves a very low power consumption using the RC oscillator as clock source. All clocks in the 1.2 V domain are stopped as well as CPU and peripherals. PLL, HSI RC and HSE crystal oscillators are disabled. The content of registers and internal SRAM are kept.

  The voltage regulator can be put either in normal Main regulator mode (MR) or in Low-power regulator mode (LPR). Selecting the regulator in low-power regulator mode increases the wake-up time.

  The flash memory can be put either in Stop mode to achieve a fast wake-up time. or in Deep power-down to obtain a lower consumption with a slow wake-up time.

  The Stop mode features two sub-modes:

  - **Stop in Normal mode (default mode)**
    In this mode, the 1.2 V domain is preserved in nominal leakage mode and the minimum V12 voltage is 1.08 V.

  - **Stop in Under-drive mode**
    In this mode, the 1.2 V domain is preserved in reduced leakage mode and V12 voltage is less than 1.08 V. The regulator (in Main or Low-power mode) is in under-drive or low-voltage mode. The flash memory must be in Deep-power-down mode. The wake-up time is about 100 µs higher than in normal mode.

- **Standby mode**
  This mode achieves very low power consumption with the RC oscillator as a clock source. The internal voltage regulator is switched off so that the entire 1.2 V domain is powered off: CPU and peripherals are stopped. The PLL, the HSI RC and the HSE crystal oscillators are disabled. SRAM and register contents are lost except for registers in the backup domain and the 4-byte backup SRAM when selected. Only RTC and LSE oscillator blocks are powered. The device exits Standby mode when an
external reset (NRST pin), an IWDG reset, a rising edge on the WKUP pin, or an RTC alarm/wake-up/tamper/time stamp event occurs.

- **V\text{BAT}** operation
  It allows to significantly reduced power consumption compared to the Standby mode. This mode is available when the V\text{BAT} pin powering the Backup domain is connected to an optional standby voltage supplied by a battery or by another source. The V\text{BAT} domain is preserved (RTC registers, RTC backup register and backup SRAM) and RTC and LSE oscillator blocks powered. The main difference compared to the Standby mode is external interrupts and RTC alarm/events do not exit the device from V\text{BAT} operation. Increasing V\text{DD} to reach the minimum threshold does.

D.1.3 **STM32L0 series**

STM32L0 microcontrollers feature up to 8 power modes, including 7 low-power modes to achieve the best compromise between low-power consumption, short startup time and available wake-up sources:

- **Run mode**
  This mode offers the highest performance using HSE/HSI clock sources. The CPU can run up to 32 MHz and the voltage regulator is enabled.

- **Sleep mode**
  This mode uses HSE or HSI as system clock sources. The voltage regulator is enabled and only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.

- **Low-power run mode**
  This mode uses the internal regulator in low-power mode and the multispeed internal (MSI) RC oscillator set to the minimum clock frequency (131 kHz). In Low-power run mode, the clock frequency and the number of enabled peripherals are both limited.

- **Low-power sleep mode**
  This mode is achieved by entering Sleep mode with the internal voltage regulator in low-power mode. Both the clock frequency and the number of enabled peripherals are limited. Event or interrupt can revert the system to Run mode with regulator on.

- **Stop mode with RTC**
  The Stop mode achieves the lowest power consumption with, while retaining the RAM, register contents and real time clock. The voltage regulator is in low-power mode. LSE or LSI is still running. All clocks in the V\text{CORE} domain are stopped, the PLL, MSI RC, HSE crystal and HSI RC oscillators are disabled.
  Some peripherals featuring wake-up capability can enable the HSI RC during Stop mode to detect their wake-up condition. The device can be woken up from Stop mode by any of the EXTI line, in 3.5 µs, and the processor can serve the interrupt or resume the code.

- **Stop mode without RTC**
  This mode is identical to “Stop mode with RTC”, except for the RTC clock which is stopped here.

- **Standby mode with RTC**
  The Standby mode achieves the lowest power consumption with the real time clock running. The internal voltage regulator is switched off so that the entire V\text{CORE} domain
is powered off. The PLL, MSI RC, HSE crystal and HSI RC oscillators are also switched off. The LSE or LSI is still running.

After entering Standby mode, the RAM and register contents are lost except for registers in the Standby circuitry (wake-up logic, IWDG, RTC, LSI, LSE crystal 32 kHz oscillator, RCC_CSR register).

The device exits Standby mode in 60 µs when an external reset (NRST pin), an IWDG reset, a rising edge on one of the three WKUP pins, RTC alarm (Alarm A or Alarm B), RTC tamper event, RTC timestamp event or RTC wake-up event occurs.

- **Standby mode without RTC**
  
  This mode is identical to Standby mode with RTC, except that the RTC, LSE and LSI clocks are stopped.
  
  The device exits Standby mode in 60 µs when an external reset (NRST pin) or a rising edge on one of the three WKUP pin occurs.

**Note:** The RTC, the IWDG, and the corresponding clock sources are not stopped automatically by entering Stop or Standby mode. The LCD is not stopped automatically by entering Stop mode.

### D.2 Power consumption ranges

STM32 MCUs power consumption can be further optimized thanks to the dynamic voltage scaling feature: the main internal regulator output voltage V12 that supplies the logic (CPU, digital peripherals, SRAM and flash memory) can be adjusted by software by selecting a power range (STM32L1 and STM32L0) or power scale (STM32 F4).

Power consumption range definitions are provided below (refer to STM32 MCU datasheets for full details).

#### D.2.1 STM32L1 series features three V\textsubscript{CORE} ranges

- **High performance Range 1** (\(V_{DD}\) range limited to 2.0-3.6 V), with the CPU running at up to 32 MHz
  
  The voltage regulator outputs a 1.8 V voltage (typical) as long as the \(V_{DD}\) input voltage is above 2.0 V. Flash program and erase operations can be performed.

- **Medium performance Range 2** (full \(V_{DD}\) range), with a maximum CPU frequency of 16 MHz
  
  At 1.5 V, the flash memory is still functional but with medium read access time. Program and erase operations are still possible.

- **Low performance Range 3** (full \(V_{DD}\) range), with a maximum CPU frequency limited to 4 MHz (generated only with the multispeed internal RC oscillator clock source)
  
  At 1.2 V, the flash memory is still functional but with slow read access time. Program and erase operations are no longer available.
D.2.2 STM32F4 series features several \( V_{\text{CORE}} \) scales

The scale can be modified only when the PLL is OFF and when HSI or HSE is selected as system clock source.

- **Scale 1** (V12 voltage range limited to 1.26 - 1.40 V), default mode at reset.  
  HCLK frequency range = 144 MHz to 168 MHz (180 MHz with over-drive).  
  This is the default mode at reset.
- **Scale 2** (V12 voltage range limited to 1.20 - 1.32 V).  
  HCLK frequency range is up to 144 MHz (168 MHz with over-drive).
- **Scale 3** (V12 voltage range limited to 1.08 - 1.20 V), default mode when exiting Stop mode.  
  HCLK frequency \( \leq 120 \) MHz.

The voltage scaling is adjusted to \( f_{\text{HCLK}} \) frequency as follows:

- **STM32F429x/39x MCUs**:  
  - Scale 1: up to 168 MHz (up to 180 MHz with over-drive)  
  - Scale 2: from 120 to 144 MHz (up to 168 MHz with over-drive)  
  - Scale 3: up to 120 MHz.
- **STM32F401x MCUs**:  
  No Scale 1  
  - Scale 2: from 60 to 84 MHz  
  - Scale 3: up to 60 MHz.
- **STM32F40x/41x MCUs**:  
  - Scale 1: up to 168 MHz  
  - Scale 2: up to 144 MHz

D.2.3 STM32L0 series features three \( V_{\text{CORE}} \) ranges

- Range 1 (\( V_{\text{DD}} \) range limited to 1.71 to 3.6 V), with CPU running at a frequency up to 32 MHz
- Range 2 (full \( V_{\text{DD}} \) range), with a maximum CPU frequency of 16 MHz
- Range 3 (full \( V_{\text{DD}} \) range), with a maximum CPU frequency limited to 4.2 MHz.
Appendix E  STM32Cube embedded software packages

Along with STM32CubeMX C code generator, embedded software packages are part of STM32Cube initiative (refer to DB2164 databrief): these packages include a low-level hardware abstraction layer (HAL) that covers the microcontroller hardware, together with an extensive set of examples running on STMicroelectronics boards (see Figure 418). This set of components is highly portable across the STM32 series. The packages are fully compatible with STM32CubeMX generated C code.

Figure 418. STM32Cube Embedded Software package

Note: STM32CubeF0, STM32CubeF1, STM32CubeF2, STM32CubeF3, STM32CubeF4, STM32CubeL0 and STM32CubeL1 embedded software packages are available on st.com. They are based on STM32Cube release v1.1 (other series will be introduced progressively) and include the embedded software libraries used by STM32CubeMX for initialization C code generation.

The user should use STM32CubeMX to generate the initialization C code and the examples provided in the package to get started with STM32 application development.
### Revision history

Table 26. Document revision history

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<td>17-Feb-2014</td>
<td>1</td>
<td>4.1</td>
<td>Initial release.</td>
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<tr>
<td>04-Apr-2014</td>
<td>2</td>
<td>4.2</td>
<td>Added support of STM32CubeF2 and STM32F2 Series in cover page, Section 2.2: Key features, Section 5.14.1: Peripherals and Middleware Configuration window, and Appendix E: STM32Cube embedded software packages. Updated Section 11.1: Creating a new STM32CubeMX Project, Section 11.2: Configuring the MCU pinout, Section 11.6: Configuring the MCU initialization parameters. Section &quot;Generating GPIO initialization C code move to Section 8: Tutorial 3- Generating GPIO initialization C code (STM32F1 Series only) and content updated. Added Section 18.6: Why do I get the error &quot;Java 8 update 45&quot; when installing &quot;Java 8 update 45&quot; or a more recent version of the JRE?.</td>
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| 24-Apr-2014| 3        | 4.3                         | Added support of STM32CubeL0 and STM32L0 Series in cover page, Section 2.2: Key features, Section 2.3: Rules and limitations and Section 5.14.1: Peripherals and Middleware Configuration window Added board selection in Table 13: File menu functions, Section 5.7.3: Pinout menu and Section 4.2: New Project window. Updated Table 15: Pinout menu. Updated Figure 187: Power Consumption Calculator default view and added battery selection in Section 5.2.1: Building a power consumption sequence. Updated note in Section 5.2: Power Consumption Calculator view Updated Section 11.1: Creating a new STM32CubeMX Project. Added Section 19.7: Why does the RTC multiplexer remain inactive on the Clock tree view?, Section 19.8: How can I select LSE and HSE as clock source and change the frequency?, and Section 19.9: Why STM32CubeMX does not allow me to configure PC13, PC14, PC15, and PI8 as outputs when one of them is already configured as an output?.
### Table 26. Document revision history (continued)

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<td>19-Jun-2014</td>
<td>4</td>
<td>4.4</td>
<td>Added support of STM32CubeF0, STM32CubeF3, STM32F0 and STM32F3 Series in cover page, Section 2.2: Key features, Section 2.3: Rules and limitations, Added board selection capability and pin locking capability in Section 2.2: Key features, Table 2: Home page shortcuts, Section 4.2: New Project window, Section 5.7: Toolbar and menus, Section 4.11: Set unused / Reset used GPIOs windows, Section 4.9: Project Manager view, and Section 5.15: Pinout view. Added Section 5.15.1: Pinning and labeling signals on pins. Updated Section 5.16: Configuration view and Section 4.8: Clock Configuration view and Section 5.2: Power Consumption Calculator view. Updated Figure 39: STM32CubeMX Main window upon MCU selection, Figure 101: Project Settings window, Figure 185: About window, Figure 140: STM32CubeMX Pinout view, Figure 120: Chip view, Figure 187: Power Consumption Calculator default view, Figure 188: Battery selection, Figure 87: Building a power consumption sequence, Figure 190: Power consumption sequence: New Step default view, Figure 197: Power Consumption Calculator view after sequence building, Figure 198: Sequence table management functions, Figure 88: PCC Edit Step window, Figure 83: Power consumption sequence: new step configured (STM32F4 example), Figure 195: ADC selected in Pinout view, Figure 196: Power Consumption Calculator Step configuration window: ADC enabled using import pinout, Figure 200: Description of the Results area, Figure 100: Peripheral power consumption tooltip, Figure 308: Power Consumption Calculation example, Figure 155: Sequence table and Figure 156: Power Consumption Calculation results. Updated Figure 142: STM32CubeMX Configuration view and Figure 39: STM32CubeMX Configuration view - STM32F1 Series titles. Added STM32L1 in Section 5.2: Power Consumption Calculator view. Removed Figure Add a new step using the PCC panel from Section 8.1.1: Adding a step. Removed Figure Add a new step to the sequence from Section 5.2.2: Configuring a step in the power sequence. Updated Section 8.2: Reviewing results. Updated appendix B.3.4: FatFs and Appendix D: STM32 microcontrollers power consumption parameters. Added Appendix D.1.3: STM32L0 series and D.2.3: STM32L0 series features three VCORE ranges.</td>
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<td>19-Sep-2014</td>
<td>5</td>
<td>4.5</td>
<td>Added support of STM32CubeL1 Series in cover page, <strong>Section 2.2: Key features, Section 2.3: Rules and limitations</strong>, Updated <strong>Section 3.2.3: Uninstalling STM32CubeMX standalone version</strong>. Added off-line updates in <strong>Section 3.4: Getting updates using STM32CubeMX</strong>, modified <strong>Figure 8: Embedded Software Packages Manager window</strong>, and <strong>Section 3.4.3: Installing STM32 MCU packages</strong>. Updated <strong>Section 4: STM32CubeMX user interface</strong> introduction, <strong>Table 2: Home page shortcuts</strong> and <strong>Section 4.2: New Project window</strong>. Added <strong>Figure 31: New Project window - Board selector</strong>. Updated <strong>Figure 109: Project Settings code generator</strong>. Modified step 3 in <strong>Section 4.9: Project Manager view</strong>. Updated <strong>Figure 39: STM32CubeMX Configuration view - STM32F1 Series</strong>. Added STM32L1 in <strong>Section 5.14.1: Peripherals and Middleware Configuration window</strong>. Updated <strong>Figure 63: GPIO configuration window - GPIO selection</strong>, <strong>Section 4.4.12: GPIO configuration window</strong>, and <strong>Figure 68: DMA MemToMem configuration</strong>. Updated introduction of <strong>Section 4.8: Clock Configuration view</strong>. Updated <strong>Section 4.8.1: Clock tree configuration functions and Section 4.8.3: Recommendations, Section 5.2: Power Consumption Calculator view, Figure 190: Power consumption sequence: New Step default view, Figure 197: Power Consumption Calculator view after sequence building, Figure 83: Power consumption sequence: new step configured (STM32F4 example), and Figure 196: Power Consumption Calculator Step configuration window: ADC enabled using import pinout</strong>. Added <strong>Figure 199: Power Consumption: Peripherals consumption chart</strong> and updated <strong>Figure 100: Peripheral power consumption tooltip</strong>. Updated <strong>Section 5.2.4: Power sequence step parameters glossary</strong>. Updated <strong>Section 6: STM32CubeMX C Code generation overview</strong>. Updated <strong>Section 11.1: Creating a new STM32CubeMX Project</strong> and <strong>Section 11.2: Configuring the MCU pinout</strong>. Added <strong>Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429i-EVAL evaluation board</strong> and updated <strong>Section 8: Tutorial 3- Generating GPIO initialization C code (STM32F1 Series only)</strong>. Updated <strong>Section 5.2.2: Configuring a step in the power sequence</strong>.</td>
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<td>19-Jan-2015</td>
<td>6</td>
<td>4.6</td>
<td>Complete project generation, power consumption calculation and clock tree configuration now available on all STM32 Series. Updated Section 2.2: Key features and Section 2.3: Rules and limitations. Updated Eclipse IDEs in Section 3.1.3: Software requirements. Updated Figure 6: Updater Settings window, Figure 8: Embedded Software Packages Manager window and Figure 31: New Project window - Board selector. Updated Section 4.9: Project Manager view and Section 4.12: Update Manager windows. Updated Figure 185: About window. Removed Figure STM32CubeMX Configuration view - STM32F1 Series. Updated Table 17: STM32CubeMX Chip view - Icons and color scheme. Updated Section 5.14.1: Peripherals and Middleware Configuration window. Updated Figure 66: Adding a new DMA request and Figure 68: DMA MemToMem configuration. Updated Section 4.8.1: Clock tree configuration functions. Updated Figure 188: Battery selection, Figure 87: Building a power consumption sequence, Figure 88: PCC Edit Step window. Added Section 6.3: Custom code generation. Updated Figure 262: Clock tree view and Figure 267: Pinout &amp; Configuration view. Updated peripheral configuration sequence and Figure 269: Timer 3 configuration window in Section 11.6.2: Configuring the peripherals. Removed Tutorial 3: Generating GPIO initialization C code (STM32F1 Series only). Updated Figure 273: GPIO mode configuration. Updated Figure 308: Power Consumption Calculation example and Figure 155: Sequence table. Updated Appendix A.1: Block consistency, A.2: Block interdependency and A.3: One block = one peripheral mode. Appendix A.4: Block remapping (STM32F10x only): updated Section : Example. Appendix A.6: Block shifting (only for STM32F10x and when &quot;Keep Current Signals placement&quot; is unchecked): updated Section : Example. Updated Appendix A.8: Mapping a function individually. Updated Appendix B.3.1: Overview. Updated Appendix D.1.3: STM32L0 series.</td>
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<td>19-Mar-2015</td>
<td>7</td>
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<td><strong>Section 2.2: Key features</strong>: removed Pinout initialization C code generation for STM32F1 Series from; updated Complete project generation.</td>
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<td>Updated <strong>Figure 8: Embedded Software Packages Manager window</strong>, <strong>Figure 31: New Project window - Board selector</strong>.</td>
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<td>Updated IDE list in <strong>Section 4.9: Project Manager view</strong> and modified <strong>Figure 101: Project Settings window</strong>.</td>
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<td>Updated <strong>Section 4.8.1: Clock tree configuration functions</strong>. Updated <strong>Figure 97: STM32F469NIHx clock tree configuration view</strong>.</td>
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<td><strong>Section 5.2: Power Consumption Calculator view</strong>: added transition checker option. Updated <strong>Figure 187: Power Consumption Calculator default view</strong>, <strong>Figure 188: Battery selection</strong> and <strong>Figure 87: Building a power consumption sequence</strong>. Added <strong>Figure 191: Enabling the transition checker option on an already configured sequence - All transitions valid</strong>, <strong>Figure 192: Enabling the transition checker option on an already configured sequence - At least one transition invalid</strong> and <strong>Figure 193: Transition checker option - Show log</strong>. Updated <strong>Figure 197: Power Consumption Calculator view after sequence building</strong>, Updated Section: Managing sequence steps, Section: Managing the whole sequence (load, save and compare), Updated <strong>Figure 88: PCC Edit Step window</strong> and <strong>Figure 200: Description of the Results area</strong>. Updated <strong>Figure 308: Power Consumption Calculation example</strong>, <strong>Figure 155: Sequence table</strong>, <strong>Figure 156: Power Consumption Calculation results</strong> and <strong>Figure 158: Power consumption results - IP consumption chart</strong>. Updated Appendix <strong>B.3.1: Overview</strong> and <strong>B.3.5: FreeRTOS</strong>.</td>
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<td>28-May-2015</td>
<td>8</td>
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<td>Added <strong>Section 3.2.2: Installing STM32CubeMX from command line</strong> and <strong>Section 3.3.2: Running STM32CubeMX in command-line mode</strong>.</td>
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<td>09-Jul-2015</td>
<td>9</td>
<td>4.9</td>
<td>Added STLM32F7 and STM32L4 microcontroller Series.</td>
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<td>Added <strong>Import project feature</strong>. Added Import function in <strong>Table 13: File menu functions</strong>. Added <strong>Section 4.10: Import Project window</strong>. Updated <strong>Figure 190: Power consumption sequence: New Step default view</strong>, <strong>Figure 88: PCC Edit Step window</strong>, <strong>Figure 83: Power consumption sequence: new step configured (STM32F4 example)</strong>, <strong>Figure 196: Power Consumption Calculator Step configuration window: ADC enabled using import pinout</strong> and <strong>Figure 87: Peripheral power consumption tooltip</strong>. Updated command line to run STM32CubeMX in <strong>Section 3.3.2: Running STM32CubeMX in command-line mode</strong>. Updated note in <strong>Section 5.16: Configuration view</strong>. Added new clock tree configuration functions in <strong>Section 4.8.1</strong>. Updated <strong>Figure 275: Middleware tooltip</strong>. Modified code example in Appendix <strong>B.1: STM32CubeMX generated C code and user sections</strong>. Updated Appendix <strong>B.3.1: Overview</strong>. Updated generated .h files in Appendix <strong>B.3.4: FatFs</strong>.</td>
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<td>27-Aug-2015</td>
<td>10</td>
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<td>Replace UM1742 by UM1940 in Section : Introduction. Updated command line to run STM32CubeMX in command-line mode in Section 3.3.2: Running STM32CubeMX in command-line mode. Modified Table 1: Command line summary. Updated board selection in Section 4.2: New Project window. Updated Section 5.16: Configuration view overview. Updated Section 5.14.1: Peripherals and Middleware Configuration window, Section 4.4.12: GPIO configuration window and Section 4.4.13: DMA configuration window. Added Section 4.4.11: User Constants configuration window. Updated Section 4.8: Clock Configuration view and added reserve path. Updated Section 11.1: Creating a new STM32CubeMX Project, Section 11.5: Configuring the MCU clock tree, Section 11.6: Configuring the MCU initialization parameters, Section 11.7.2: Downloading firmware package and generating the C code, Section 11.8: Building and updating the C code project. Added Section 11.9: Switching to another MCU. Updated Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board and replaced STM32F429I-EVAL by STM32429I-EVAL.</td>
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<td>16-Oct-2015</td>
<td>11</td>
<td>4.11</td>
<td>Updated Figure 8: Embedded Software Packages Manager window and Section 3.4.7: Checking for updates. Character string constant supported in Section 4.4.11: User Constants configuration window. Updated Section 4.8: Clock Configuration view. Updated Section 5.2: Power Consumption Calculator view. Modified Figure 308: Power Consumption Calculation example. Updated Section 13: Tutorial 3 - Using the Power Consumption Calculator to optimize the embedded application consumption and more. Added Eclipse Mars in Section 3.1.3: Software requirements</td>
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<td>03-Dec-2015</td>
<td>12</td>
<td>4.12</td>
<td>Code generation options now supported by the Project settings menu. Updated Section 3.1.3: Software requirements. Added project settings in Section 4.10: Import Project window. Updated Figure 114: Automatic project import; modified Manual project import step and updated Figure 115: Manual project import and Figure 116: Import Project menu - Try Import with errors; modified third step of the import sequence. Updated Figure 83: Clock Tree configuration view with errors. Added mxconstants.h in Section 6.1: STM32Cube code generation using only HAL drivers (default mode). Updated Figure 308: Power Consumption Calculation example to Figure 317: Step 10 optimization. Updated Figure 318: Power sequence results after optimizations.</td>
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<td>Updated Section 2.2: Key features:</td>
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<td>– Automatic updates of STM32CubeMX and STM32Cube.</td>
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<td>Updated limitation related to STM32CubeMX C code generation in Section 2.3: Rules and limitations.</td>
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<td>Added Linux in Section 3.1.1: Supported operating systems and architectures. Updated Java Run Time Environment release number in Section 3.1.3: Software requirements.</td>
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<td>Updated Section 3.2.1: Installing STM32CubeMX standalone version, Section 3.2.3: Uninstalling STM32CubeMX standalone version and Section 3.3.1: Downloading STM32CubeMX plug-in installation package.</td>
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<td>Updated Section 4.9: Project Manager view and Section 4.12: Update Manager windows.</td>
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<td>Updated Section 5.15.1: Pinning and labeling signals on pins.</td>
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<td>Added Section 4.4.16: Setting HAL timebase source</td>
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<td></td>
<td>Updated Figure 143: Configuration window tabs for GPIO, DMA and NVIC settings (STM32F4 Series).</td>
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<td>Added note related to GPIO configuration in output mode in Section 4.4.12: GPIO configuration window; updated Figure 63: GPIO configuration window - GPIO selection.</td>
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<td>Modified Figure 187: Power Consumption Calculator default view, Figure 86: Building a power consumption sequence, Figure 189: Step management functions, Figure 191: Enabling the transition checker option on an already configured sequence - All transitions valid, Figure 192: Enabling the transition checker option on an already configured sequence - At least one transition invalid.</td>
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<td>Added import pinout button icon in Section : Importing pinout.</td>
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<td>Added Section : Selecting/deselecting all peripherals. Modified Figure 197: Power Consumption Calculator view after sequence building, Updated Section : Managing the whole sequence (load, save and compare). Updated Figure 200: Description of the Results area and Figure 100: Peripheral power consumption tooltip.</td>
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<td>Updated Figure 308: Power Consumption Calculation example and Figure 310: Sequence table.</td>
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<td>Updated Section 6.3: Custom code generation.</td>
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<td>Updated Figure 254: Pinout view with MCUs selection and Figure 255: Pinout view without MCUs selection window in Section 11.1: Creating a new STM32CubeMX Project.</td>
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<td>Updated Section 11.6.2: Configuring the peripherals.</td>
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<td>Updated Figure 280: Project Settings and toolchain selection and Figure 281: Project Manager menu - Code Generator tab in Section 11.7.1: Setting project options, and Figure 282: Missing firmware package warning message in Section 11.7.2: Downloading firmware package and generating the C code.</td>
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<td>Date</td>
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<tr>
<td>15-Mar-2016</td>
<td>14</td>
<td>4.14</td>
<td>Upgraded STM32CubeMX released number to 4.14.0. Added import of previously saved projects and generation of user files from templates. Added MacOS in Section 3.1.1: Supported operating systems and architectures, Section 3.2.1: Installing STM32CubeMX standalone version, Section 3.2.3: Uninstalling STM32CubeMX standalone version and Section 3.4.3: Running STM32CubeMX plug-in from Eclipse IDE. Added command lines allowing the generation of user files from templates in Section 3.3.2: Running STM32CubeMX in command-line mode. Updated new library installation sequence in Section 3.4.2: Updater configuration. Updated Figure 107: Pinout menus (Pinout tab selected) and Figure 108: Pinout menus (Pinout tab not selected) in Section 5.7.3: Pinout menu. Modified Table 16: Window menu. Updated Section 5.7: Output windows. Updated Figure 101: Project Settings window and Section 4.9.1: Project tab. Updated Figure 81: NVIC settings when using SysTick as HAL timebase, no FreeRTOS and Figure 82: NVIC settings when using FreeRTOS and SysTick as HAL timebase in Section 4.4.16: Setting HAL timebase source. Updated Figure 54: User Constants tab and Figure 55: Extract of the generated main.h file in Section 4.4.11: User Constants configuration window. Section 4.4.12: GPIO configuration window: updated Figure 63: GPIO configuration window - GPIO selection, Figure 64: GPIO configuration grouped by peripheral and Figure 65: Multiple pins configuration. Updated Section 4.4.14: NVIC configuration window.</td>
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<tr>
<td>18-May-2016</td>
<td>15</td>
<td>4.15</td>
<td>Import project function is no more limited to MCUs of the same Series (see Section 2.2: Key features, Section 5.7.1: File menu and Section 4.10: Import Project window). Updated command lines in Section 3.3.2: Running STM32CubeMX in command-line mode. Table 1: Command line summary: modified all examples related to config commands as well as set dest_path &lt;path&gt; example. Added caution note for Load Project menu in Table 13: File menu functions. Updated Generate Code menu description in Table 14: Project menu. Updated Set unused GPIOs menu in Table 15: Pinout menu. Added case where FreeRTOS in enabled in Section : Enabling interruptions using the NVIC tab view. Added Section 4.4.15: FreeRTOS configuration panel. Updated Appendix B.3.5: FreeRTOS and B.3.6: LwIP.</td>
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### Table 26. Document revision history (continued)

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<tr>
<td>23-Sep-2016</td>
<td>16</td>
<td>4.17</td>
<td>Replaced <code>mxconstants.h</code> by <code>main.h</code> in the whole document. Updated <em>Introduction, Section 3.1.1: Supported operating systems and architectures</em> and <em>Section 3.1.3: Software requirements</em>. Added <em>Section 3.4.4: Installing STM32 MCU package patches</em>. Updated Load project description in <em>Table 2: Home page shortcuts</em>. Updated Clear Pinouts function in <em>Table 15: Pinout menu</em>. Updated <em>Section 4.9.3: Advanced Settings tab</em> to add Low Layer driver. Added <em>No check</em> and <em>Decimal and hexadecimal check</em> options in <em>Table 17: Peripheral and Middleware Configuration window buttons and tooltips</em>. Updated <em>Section : Tasks and Queues Tab</em> and <em>Figure 78: FreeRTOS Heap usage</em>. Updated <em>Figure 63: GPIO configuration window - GPIO selection</em>. Replaced PCC by Power Consumption Calculator in the whole document. Added <em>Section 6.2: STM32Cube code generation using Low Layer drivers</em>; updated <em>Table 22: LL versus HAL: STM32CubeMX generated source files</em> and <em>Table 23: LL versus HAL: STM32CubeMX generated functions and function calls</em>. Updated <em>Figure 384: Pinout view - Enabling the RTC</em>. Added <em>Section 14: Tutorial 4 - Example of UART communications with an STM32L053xx Nucleo board</em>. Added correspondence between STM32CubeMX release number and document revision.</td>
</tr>
<tr>
<td>21-Nov-2016</td>
<td>17</td>
<td>4.18</td>
<td>Removed Windows XP and added Windows 10 in <em>Section 3.1.3: Software requirements</em>. Updated <em>Section 3.2.3: Uninstalling STM32CubeMX standalone version</em>. Added <code>setDriver</code> command line in <em>Table 1: Command line summary</em>. Added List pinout compatible MCUs feature: – Updated <em>Table 15: Pinout menu</em>. – Added <em>Section 15: Tutorial 5: Exporting current project configuration to a compatible MCU</em> Added Firmware location selection option in <em>Section 4.9.1: Project tab</em> and <em>Figure 101: Project Settings window</em>. Added Restore Default feature: – Updated <em>Table 8: Peripheral and Middleware configuration window buttons and tooltips</em>. – Updated <em>Figure 56: Using constants for peripheral parameter settings</em>.</td>
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### Table 26. Document revision history (continued)

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<th>Date</th>
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<tr>
<td>12-Jan-2017</td>
<td>18</td>
<td>4.19</td>
<td>Project import no more limited to microcontrollers belonging to the same Series: updated Introduction, Figure 114: Automatic project import, Figure 115: Manual project import, Figure 116: Import Project menu - Try Import with errors and Figure 117: Import Project menu - Successful import after adjustments.Modified Appendix B.3.4: FatFs, B.3.5: FreeRTOS and B.3.6: LwIP. Added Appendix B.3.7: Libjpeg.</td>
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<tr>
<td>02-Mar-2017</td>
<td>19</td>
<td>4.20</td>
<td>Table 17: STM32CubeMX Chip view - Icons and color scheme:– Updated list of alternate function example.– Updated example and description corresponding to function mapping on a pin.– Added example and description for analog signals sharing the same pin.Updated Figure 87: Peripheral Configuration window (STM32F4 Series), Figure 54: User Constants tab, Figure 60: Consequence when deleting a user constant for peripheral configuration, Figure 61: Searching for a name in a user constant list and Figure 62: Searching for a value in a user constant list.Added Section 5.2.6: SMPS feature.Added Section 6.4: Additional settings for C project generation.Added STM32CubeF4 to the list of packages that include Libjpeg in Appendix B.3.7: Libjpeg.</td>
</tr>
<tr>
<td>05-May-2017</td>
<td>20</td>
<td>4.21</td>
<td>Minor modifications in Section 1: STM32Cube overview.Updated Figure 27: New Project window - MCU selector and Figure 101: Project Settings window.Updated description of Project settings in Section 4.9.1: Project tab.Updated Figure 112: Advanced Settings window.In Appendix B.3.7: Libjpeg, added STM32CubeF2 and STM32CubeH7 in the list of software packages in which Libjpeg is embedded.Modified Figure 418: STM32Cube Embedded Software package look-and-feel.</td>
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### Table 26. Document revision history (continued)

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<tr>
<td>06-Jul-2017</td>
<td>21</td>
<td>4.22</td>
<td>Added STM32H7 to the list of supported STM32 Series. Added MCU data and documentation refresh capability in Section 3.4: Getting updates using STM32CubeMX and updated Figure 6: Updater Settings window. Added capability to identify close MCUs in Section 4.2: New Project window, updated Figure 27: New Project window - MCU selector, added Figure 29: New Project window - MCU list with close function and Figure 30: New Project window - List showing close MCUs., updated Figure 253: MCU selection. Updated Figure 39: STM32CubeMX Main window upon MCU selection. Added Rotate clockwise/Counter clockwise and Top/Bottom view in Table 15: Pinout menu. Added Section 4.1.4: Social links. Updated Figure 208: Configuring the SMPS mode for each step. Updated Section 6.2: STM32Cube code generation using Low Layer drivers. Updated Figure 280: Project Settings and toolchain selection.</td>
</tr>
<tr>
<td>05-Sep-2017</td>
<td>22</td>
<td>4.22.1</td>
<td>Added STM32L4+ Series in Introduction, Section 5.2: Power Consumption Calculator view and Section 6.2: STM32Cube code generation using Low Layer drivers. Added guidelines to run STM32CubeMX on MacOS in Section 3.3.1: Running STM32CubeMX as a standalone application. Removed MacOS from Section 3.4.3: Running STM32CubeMX plug-in from Eclipse IDE. Added Section 19.10: Ethernet configuration: why cannot I specify DP83848 or LAN8742A in some cases?</td>
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### Table 26. Document revision history (continued)

<table>
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<th>Date</th>
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<th>STM32CubeMX release number</th>
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|             |          |                            | Updated Section 1: STM32Cube overview.  
|             |          |                            | Updated MacOS in Section 3.1.1: Supported operating systems and architectures. Updated Eclipse requirements in Section 3.1.3: Software requirements.  
|             |          |                            | Section 3.4: Getting updates using STM32CubeMX:  
|             |          |                            | – updated section introduction  
|             |          |                            | – updated Figure 13: Connection Parameters tab - No proxy  
|             |          |                            | – Section 3.4.3 renamed into “Installing STM32 MCU packages” and updated.  
|             |          |                            | – renamed Section 3.4.4 into “Installing STM32 MCU package patches”  
|             |          |                            | – added Section 3.4.5: Installing embedded software packs  
|             |          |                            | – updated Section 3.4.7: Checking for updates  
|             |          |                            | Updated Figure 31: New Project window - Board selector.  
|             |          |                            | Updated Figure 40: STM32CubeMX Main window upon board selection (peripherals not initialized) and introductory sentence.  
|             |          |                            | Updated Figure 41: STM32CubeMX Main window upon board selection (peripherals initialized with default configuration) and introductory sentence.  
|             |          |                            | Added “Select additional software components” menu in Table 14: Project menu.  
|             |          |                            | “Install new libraries” menu renamed “Manage embedded software packages” and corresponding description updated in Table 17: Help menu.  
|             |          |                            | Updated Section 3.4.6: Removing already installed embedded software packages.  
|             |          |                            | Updated Section 4.12: Update Manager windows  
|             |          |                            | Added Section 4.13: Additional software component selection window.  
|             |          |                            | Added pin stacking function in Table 17: STM32CubeMX Chip view - Icons and color scheme.  
|             |          |                            | Section 6.2: STM32Cube code generation using Low Layer drivers: added STM32F0, STM32F3, STM32L0 in the list of product Series supporting low-level drivers.  
|             |          |                            | Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board: updated Figure 300: Board selection and modified step 6 of the sequence for generating a project and running tutorial 2.  
|             |          |                            | Section 14: Tutorial 4 - Example of UART communications with an STM32L053xx Nucleo board: updated Figure 319: Selecting NUCLEO_L053R8 board.  
<p>|             |          |                            | Added Section 16: Tutorial 6 – Adding embedded software packs to user projects. |</p>
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<tr>
<td>07-Mar-2018</td>
<td>25</td>
<td>4.25</td>
<td>Updated Introduction, Section 1: STM32Cube overview, Section 2.3: Rules and limitations, Section 3.2.1: Installing STM32CubeMX standalone version, Section 4: STM32CubeMX user interface, Section 4.9.1: Project tab and Section 5.13.1: Peripheral and Middleware tree panel. Minor text edits across the whole document. Updated Table 13: File menu functions and Table 12: Relations between power over-drive and HCLK frequency. Updated Figure 27: New Project window - MCU selector, Figure 27: Enabling graphics choice in MCU selector, Figure 101: Project Settings window, Figure 106: Selecting a different firmware location, Figure 77: Enabling STemWin framework, Figure 116: Configuration view for Graphics, Figure 385: Pinout view - Enabling LSE and HSE clocks and Figure 386: Pinout view - Setting LSE/HSE clock frequency. Added Export to Excel feature, Show favorite MCUs feature and Section 4.4.16: Graphics frameworks and simulator. Added Section 17: Tutorial 8 – Using STemWin Graphics framework, Section 18: Tutorial 9: Using STM32CubeMX Graphics simulator and their subsections. Added Section B.3.11: Graphics.</td>
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</table>
Updated STM32Cube logo on cover page.
Replaced STMCube™ by STM32Cube™ in the whole document.
Updated Section 1: STM32Cube overview.
Updated Figure 1: Overview of STM32CubeMX C code generation flow.
Updated Section 2.2: Key features to add new features: graphic simulator feature, Support of embedded software packages in CMSIS-Pack format and Contextual Help.
Changed Section 3.4 title into “Getting updates using STM32CubeMX”. Suppressed figures Connection Parameters tab - No proxy and Connection Parameters tab - Use System proxy parameters. Updated Figure 9: Managing embedded software packages - Help menu.

In Section 3.4.5: Installing embedded software packs, updated step 3f of the embedded software pack installation sequence and added Figure 14: License agreement acceptance.

Section 4.2: New Project window: updated Figure 27: New Project window - MCU selector, Figure 28: Marking a favorite and Figure 31: New Project window - Board selector.

Section 5.7.1: File menu: added caution note for New Project in Table 13: File menu functions. Updated Figure 107: Pinout menus (Pinout tab selected) and Figure 108: Pinout menus (Pinout tab not selected).

Section 4.9: Project Manager view:
– Added note related to project saving (step 3).
– Updated Figure 101: Project Settings window
– Updated Section 4.9.1: Project tab and Figure 106: Selecting a different firmware location.

Added Section 4.13.4: Component dependencies panel, Contextual help, Section 10: Support of additional software components using CMSIS-Pack standard and Section 17: Tutorial 7 – Using the X-Cube-BLE1 software pack.

Updated Section 3.4.3: Installing STM32 MCU packages, Section 3.4.5: Installing embedded software packs, Section 3.4.6: Removing already installed embedded software packages, Section 3.4.7: Checking for updates and the figures in it.
Updated Section 4: STM32CubeMX user interface, its subsections and the figures and the tables in them.
Updated Section 10: Support of additional software components using CMSIS-Pack standard, sections 11.6.1 to 11.6.5, Section 11.7.1: Setting project options, Section 11.7.2: Downloading firmware package and generating the C code, Section 11.8: Building and updating the C code project, Section 11.9: Switching to another MCU, Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board and the figures in it, Section 15: Tutorial 5: Exporting current project configuration to a compatible MCU and the figures in it, Section 16: Tutorial 6 – Adding embedded software packs to user projects and Section 17: Tutorial 7 – Using the X-Cube-BLE1 software pack.
### Table 26. Document revision history (continued)

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<tr>
<td>12-Nov-2018</td>
<td>27 (cont’d)</td>
<td>5.0</td>
<td>Added Section 19: Tutorial 10: Using ST-TouchGFX framework and its subsections. Updated Table 23: LL versus HAL: STM32CubeMX generated functions and function calls. Removed former Figure 164: Enabling and configuring a CMSIS-Pack software component, Figure 192: FatFs peripheral instances, Figure 213: Project Import status, Figure 254: Saving software component selection as user preferences and Figure 268: Configuring X-Cube-BLE1. Updated Figure 1: Overview of STM32CubeMX C code generation flow, Figure 4: STM32Cube installation wizard, Figure 7: Closing STM32CubeMX perspective, Figure 9: Opening Eclipse plug-in, Figure 10: STM32CubeMX perspective, Figure 201: Overall peripheral consumption, Figure 227: User constant generating define statements, Figure 250: Selecting a CMSIS-Pack software component, Figure 251: Enabling and configuring a CMSIS-Pack software component, Figure 252: Project generated with CMSIS-Pack software component, Figure 253: MCU selection, Figure 254: Pinout view with MCUs selection, Figure 255: Pinout view without MCUs selection window, Figure 257: Timer configuration, Figure 258: Simple pinout configuration, Figure 259: Save Project As window, Figure 260: Generate Project Report - New project creation, Figure 261: Generate Project Report - Project successfully created, Figure 262: Clock tree view, Figure 267: Pinout &amp; Configuration view, Figure 268: Case of Peripheral and Middleware without configuration parameters, Figure 269: Timer 3 configuration window, Figure 270: Timer 3 configuration, Figure 271: Enabling Timer 3 interrupt, Figure 272: GPIO configuration color scheme and tooltip, Figure 273: GPIO mode configuration, Figure 274: DMA parameters configuration window, Figure 275: Middleware tooltip, Figure 276: USB Host configuration, Figure 276: USB Host configuration, Figure 277: FatFs over USB mode enabled, Figure 278: System view with FatFs and USB enabled, Figure 279: FatFs define statements, Figure 280: Project Settings and toolchain selection, Figure 281: Project Manager menu - Code Generator tab, Figure 282: Missing firmware package warning message, Figure 284: Updater settings for download, Figure 285: Updater settings with connection, Figure 286: Downloading the firmware package, Figure 287: Unzipping the firmware package, Figure 288: C code generation completion message, Figure 298: Import Project menu, Figure 328: Project Settings menu, Figure 338: Additional software components enabled for the current project, Figure 339: Pack software components - no configurable parameters, Figure 340: Pack tutorial - project settings, Figure 343: Embedded software packages, Figure 345: Installing Embedded software packages, Figure 346: Starting a new project - selecting the NUCLEO-L053R8 board, Figure 347: Starting a new project - initializing all peripherals, Figure 348: Selecting X-Cube-BLE1 components, Figure 349: Configuring peripherals and GPIOs, Figure 350: Configuring NVIC interrupts, Figure 351: Enabling X-Cube-BLE1, Figure 351: Enabling X-Cube-BLE1, Figure 352: Configuring the SensorDemo project and Figure 312: Graphics simulator user interface.</td>
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| 19-Feb-2019| 28       | 5.0                         | Updated Introduction, Section 1: STM32Cube overview, Section 2.2: Key features, Section 3.1.3: Software requirements, Section 3.4.3: Installing STM32 MCU packages, Section 4: STM32CubeMX user interface, Resolving pin conflicts, Section 4.4.10: Component configuration panel, Section 4.8: Clock Configuration view, Section 4.9: Project Manager view, Section 4.9.1: Project tab, Section 4.9.3: Advanced Settings tab, Using the transition checker, Section 9.2: STM32CubeMX Device tree generation, Section 6.3.2: Saving and selecting user templates, .extSettings file example and generated outcomes and Section 11.6.4: Configuring the DMAs.  
Added Section 4.5: Pinout & Configuration view for STM32MP1 series, Section 4.5.2: Boot stages configuration, Section 5: STM32CubeMX tools, Section 9: Device tree generation (STM32MP1 series only), Section B.3.11: STM32WPAN BLE/Thread (STM32WB series only), Section B.3.12: OpenAmp and RESMGR_UTILITY (STM32MP1 series and STM32H7 dual-core product lines) and their subsections.  
Removed former Section 1: General information.  
Updated Table 2: Home page shortcuts, Table 5: Component list, mode icons and color schemes, Table 6: Pinout menu and shortcuts and title of Table 9: Clock configuration view widgets.  
Updated Figure 101: Project Settings window, Figure 102: Project folder, Figure 106: Selecting a different firmware location, Figure 114: Automatic project import, Figure 115: Manual project import, Figure 116: Import Project menu - Try Import with errors, Figure 117: Import Project menu - Successful import after adjustments, Figure 118: Set unused pins window, Figure 119: Reset used pins window, Figure 185: About window, Figure 248: STM32CubeMX generated DTS – Extract 3, Figure 250: Selecting a CMSIS-Pack software component, Figure 251: Enabling and configuring a CMSIS-Pack software component, Figure 305: FATFS tutorial - Project settings and Figure 306: C code generation completion message. |
Added Section 4.2.1: MCU selector, Section 4.2.2: Board selector, Section 4.2.4: Cross selector, Section 4.6: Pinout & Configuration view for STM32H7 dual-core product lines, Section 5.2.9: Example feature (STM32MP1 and STM32H7 dual-core only) and Section 7: Code generation for dual-core MCUs (STM32H7 dual-core product lines only).  
Removed former Section 3.3: Installing STM32CubeMX plug-in version and its subsections, and former Section 3.4.3: Running STM32CubeMX plug-in from Eclipse IDE. |
### Table 26. Document revision history (continued)

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| 16-Apr-2019 | 29 (cont’d) | 5.1 | Updated Table 3: Window menu.  
Updated figures 27 to 31, Figure 112: Advanced Settings window, figures 187 to 194, 196 to 199 and 201 to 210, Figure 280: Project Settings and toolchain selection and figures 308 to 318,  
Added Figure 24: New Project window shortcuts, Figure 85: STM32MP1 series: assignment options for GPIOs, Figure 416: Resource Manager: peripheral assignment view and Figure 418: STM32Cube Embedded Software package. |
Updated Table 1: Command line summary, Table 6: Pinout menu and shortcuts, Table 16: Additional Software window – Packs panel icons and Table 17: Component dependencies panel contextual help.  
Updated Figure 20: STM32CubeMX Home page, Figure 125: Selection of additional software components, Figure 126: Additional software components - Updated tree view, Figure 250: Selecting a CMSIS-Pack software component and Figure 348: Selecting X-Cube-BLE1 components.  
Added Section 4.4.8: Pinout for multi-bonding packages and Section 4.13.5: Details and Warnings panel.  
Added Table 15: Additional Software window – Packs panel columns |
## Table 26. Document revision history (continued)

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<tr>
<td>13-Dec-2019</td>
<td>31</td>
<td>5.4</td>
<td>Updated Introduction, Section 1: STM32Cube overview, Section 4.2: New Project window, MCU/MPU selection for a new project and Section 11.7.1: Setting project options. Added Section 4.7: Enabling security in Pinout &amp; Configuration view (STM32L5 and STM32U5 series only) with its subsections, Section 4.8.2: Securing clock resources (STM32L5 series only) and Section 8: Code generation with TrustZone® enabled (STM32L5 series only). Removed former Section 4.4.16: Graphics frameworks and simulator, Section 17: Tutorial 8 – Using STemWin Graphics framework, Section 18: Tutorial 9: Using STM32CubeMX Graphics simulator, Section 19: Tutorial 10: Using ST-TouchGFX framework and Section B.3.11: Graphics. Minor text edits across the whole document. Updated Table 1: Command line summary. Updated Figure 48: Pinout view: MCUs with multi-bonding, Figure 49: Pinout view: multi-bonding with extended mode, Figure 85: STM32MP1 series: assignment options for GPIOs, Figure 101: Project Settings window, Figure 218: DDR Suite - Connection to target, Figure 219: DDR Suite - Target connected, Figure 220: DDR activity logs, Figure 221: DDR interactive logs, Figure 222: DDR register loading, Figure 223: DDR test list from U-Boot SPL, Figure 224: DDR test suite results, Figure 225: DDR tests history, Figure 175: DDR tuning pre-requisites, Figure 176: DDR tuning process, Figure 177: Bit deskew, Figure 178: Eye training (centering) panel, Figure 179: DDR Tuning - saving to configuration, Figure 245: Project settings for STM32CubeIDE toolchain and Figure 280: Project Settings and toolchain selection. Added Figure 25: Enabling Arm® TrustZone® for STM32L5 series.</td>
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<td>10-Jul-2020</td>
<td>32</td>
<td>6.0</td>
<td>Updated Section 2.2: Key features, Section 3.1.1: Supported operating systems and architectures, Section 3.1.3: Software requirements, Section 3.2.1: Installing STM32CubeMX standalone version, Section 3.4: Getting updates using STM32CubeMX, Section 3.4.5: Installing embedded software packs, Section 4.2: New Project window, Export to Excel feature, Section 4.4: Pinout &amp; Configuration view, Section 4.9.3: Advanced Settings tab and Section 18.6: Why do I get the error “Java 8 update 45” when installing “Java 8 update 45” or a more recent version of the JRE?. Added Section 4.2.3: Example selector, Section 5.1: External Tools, Section 19.2: Since I changed my login to access the Internet, some software packs appear not available. and Section 19.3: On dual-context products, why some peripherals or middleware are not available for a given context?. Removed former MCU selection based on graphics criteria. Updated Table 4: Help menu shortcuts and Table 14: Additional software window - Filter icons. Updated Figure 20: STM32CubeMX Home page, Figure 24: New Project window shortcuts, Figure 31: New Project window - Board selector, Figure 34: Cross selector - Data refresh prerequisite, Figure 112: Advanced Settings window, Figure 122: Additional Software window, Figure 200: Device tree generation for the Linux kernel, Figure 201: STM32CubeMX Device tree generation for U-boot, Figure 202: STM32CubeMX Device tree generation for TF-A, Figure 348: Selecting X-Cube-BLE1 components and Figure 306: Java Control Panel.</td>
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<tr>
<td>10-Nov-2020</td>
<td>33</td>
<td>6.1</td>
<td>Updated Introduction, Section 3.1.3: Software requirements, Section 3.4.7: Checking for updates, Section 4.13.3: Packs panel, Section 5.1: External Tools, Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board and Section 18.6: Why do I get the error “Java 8 update 45” when installing “Java 8 update 45” or a more recent version of the JRE?. Added Choosing not to generate code for some peripherals or middlewares. Updated Table 1: Command line summary. Updated Figure 19: Help menu: checking for updates, Figure 20: STM32CubeMX Home page, Figure 112: Advanced Settings window, Figure 122: Additional Software window, Figure 186: ST Tools and Figure 301: SDIO peripheral configuration.</td>
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**Table 26. Document revision history (continued)**

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<th>Date</th>
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<th>Changes</th>
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<tr>
<td>12-Feb-2021</td>
<td>34</td>
<td>6.2</td>
<td>Updated Section 3.1.1: Supported operating systems and architectures, Section 3.1.3: Software requirements, Section 3.2.1: Installing STM32CubeMX standalone version, Section 3.2.2: Installing STM32CubeMX from command line, Section 3.2.3: Uninstalling STM32CubeMX standalone version, Section 3.3.2: Running STM32CubeMX in command-line mode, Warning: in Section 3.4.7: Checking for updates, Section 4.1: Home page, Section 4.13: Additional software component selection window, Section 4.13.2: Filter panel, Section 4.13.3: Packs panel, Section 4.13.4: Component dependencies panel, Section 4.13.5: Details and Warnings panel and Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board. Updated Table 6: Pinout menu and shortcuts. Added Figure 2: Full disk access for macOS and Figure 123: Component dependency resolution. Updated Figure 20: STM32CubeMX Home page, Figure 25: Enabling Arm® TrustZone® for STM32L5 series, Figure 122: Additional Software window. Removed former Figure 5: Auto-install command line and former Section 18.6: Why do I get the error “Java 8 update 45” when installing “Java 8 update 45” or a more recent version of the JRE?. Updated Table 6: Pinout menu and shortcuts. Added Figure 2: Full disk access for macOS and Figure 123: Component dependency resolution. Updated Figure 20: STM32CubeMX Home page, Figure 25: Enabling Arm® TrustZone® for STM32L5 series, Figure 122: Additional Software window. Removed former Figure 5: Auto-install command line and former Section 18.6: Why do I get the error “Java 8 update 45” when installing “Java 8 update 45” or a more recent version of the JRE?.</td>
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<tr>
<td>22-Jun-2021</td>
<td>35</td>
<td>6.3</td>
<td>Updated Section 3.1.1: Supported operating systems and architectures, Section 3.1.3: Software requirements, Section 4.2: New Project window, Section 4.3: Project page, Section 4.4.5: Pinout view advanced actions, Section 4.7: Enabling security in Pinout &amp; Configuration view (STM32L5 and STM32U5 series only) and code in Section 12: Tutorial 2 - Example of FatFs on an SD card using STM32429I-EVAL evaluation board. Added Figure 26: Adjusting selector results and Section 19.1: I encountered a network connection error during a download from STM32CubeMX. Updated Table 1: Command line summary, Table 16: Additional Software window – Packs panel icons and Table 17: Component dependencies panel contextual help. Updated Figure 250: Selecting a CMSIS-Pack software component and Figure 348: Selecting X-Cube-BLE1 components.</td>
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<tr>
<td>05-Nov-2021</td>
<td>36</td>
<td>6.4</td>
<td>Updated Section 2.2: Key features, Section 3.3.1: Running STM32CubeMX as a standalone application, Section 3.4: Getting updates using STM32CubeMX, Section 4.2: New Project window, Enabling interruptions using the NVIC tab view, Section 4.7: Enabling security in Pinout &amp; Configuration view (STM32L5 and STM32U5 series only), Section 4.9.1: Project tab and Section 5.2.7: BLE and ZigBee support (STM32WB series only). Added Section 3.4.1: Running STM32CubeMX behind a proxy server and Section 5.2.8: Sub-Ghz support (STM32WL series only). Updated Figure 69: NVIC configuration tab - FreeRTOS disabled.</td>
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### Table 26. Document revision history (continued)

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<tr>
<td>18-Feb-2022</td>
<td>37</td>
<td>6.5</td>
<td>Updated Introduction and Section 3.1.1: Supported operating systems and architectures. Added Section 18: Creating LPBAM projects with its subsections, and Section 19.11: How to fix MX_DMA_Init call rank in STM32CubeMX generated projects?. Minor text edits across the whole document.</td>
</tr>
<tr>
<td>14-Jun-2022</td>
<td>38</td>
<td>6.6</td>
<td>Updated Introduction, Section 2.2: Key features, Section 3.3.2: Running STM32CubeMX in command-line mode, Boot loader (A7 FSBL) peripherals selection, Section 4.9.1: Project tab, Section 4.14: LPBAM Scenario &amp; Configuration view, Section 9.1: Device tree overview, and Section 9.2: STM32CubeMX Device tree generation. Updated Table 1: Command line summary. Updated Figure 185: About window. Added Section 4.15: CAD Resources view section and Section 18.6: LPBAM application for TrustZone activated projects. Removed former Section 9.2.1: Device tree generation for Linux kernel, Section 9.2.2: Device tree generation for U-boot, and Section 9.2.3: Device tree generation for TF-A. Minor text edits across the whole document.</td>
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<tr>
<td>17-Nov-2022</td>
<td>39</td>
<td>6.7</td>
<td>Updated Section 2.2: Key features and Section 17: Tutorial 7 – Using the X-Cube-BLE1 software pack. Added Section 19.12: When is the PeriphCommonClock_Config() function generated? and Section 19.13: How to handle thread-safe solution in STM32CubeMX and STM32CubeIDE?. Updated Figure 27: New Project window - MCU selector, Figure 28: Marking a favorite, Figure 29: New Project window - MCU list with close function, Figure 30: New Project window - List showing close MCUs, and Figure 185: About window. Minor text edits across the whole document.</td>
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<tr>
<td>21-Feb-2023</td>
<td>40</td>
<td>6.8</td>
<td>Updated Section 3.2.1: Installing STM32CubeMX standalone version, Section 3.3.2: Running STM32CubeMX in command-line mode, Section 3.4.1: Running STM32CubeMX behind a proxy server, and Section 4.9.1: Project tab. Added Section 4.16: Boot path and its subsections. Removed former Section 5.3.4: DDR tuning and DDR tuning tab (read-only). Updated Figure 27: New Project window - MCU selector, Figure 101: Project Settings window, and Figure 376: Design check. Minor text edits across the whole document.</td>
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