UM2380
User manual

STM32 motor control SDK v5.4 tools

Introduction

The STM32 motor control software development kit (MC SDK) is part of the STMicroelectronics motor-control ecosystem. It is referenced as X-CUBE-MCSDK or X-CUBE-MCSDK-FUL according to the software license agreement applied. It includes the:

- ST MC FOC firmware library for permanent-magnet synchronous motor (PMSM) field-oriented control (FOC)
- ST MC Workbench software tool, a graphical user interface for the configuration of the MC FOC firmware library parameters, including the ST Motor Profiler tool (MP)

The STM32 motor control software development kit allows evaluation of the performance of STM32 microcontrollers in applications driving single or dual three-phase permanent-magnet synchronous motors within the STM32 ecosystem.

This user manual details the use of the software tools in STM32 motor control software development kit.

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1 General information

The MC SDK is used for the development of motor-control applications running on STM32 32-bit microcontrollers based on Arm®[a] Cortex® processor(s).

The ST MC workbench software tool provides an easy way to configure motor control application software matching hardware setup. The projects generated from this basis are compatible with the use of STM32CubeMX for further extension or modification of the application.

ST MC Workbench runs on a Windows® 7/10-based PC system equipped with a USB Type- A connector for connecting to the application board.

Refer to the STM32 MC SDK release note for all information about possible use of the ST MC Workbench software tool.

Note: ST MC Workbench provides contextual information tips when the cursor goes over parameters in the GUI window.1

1.1 Definitions

Table 1 lists the acronyms that are relevant for a better understanding of this document.

Table 1. List of acronyms

Acronym	Description
GUI	Graphical user interface
IDE	Integrated development environment
FOC	Field-oriented control
FW	Firmware
MC	Motor control
MC WB	Motor control Workbench (STMicroelectronics software tool)
MP	Motor Profiler (STMicroelectronics software tool)
OCP	Over-current protection
PFC	Power factor correction
PMSM	Permanent-magnet synchronous motor
PWM	Pulse-width modulation
SDK	Software development kit

a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

1.2 Reference documents

Arm® documents

The following documents are available from the http://infocenter.arm.com web page:

- Cortex®-M0 Technical Reference Manual
- Cortex®-M3 Technical Reference Manual
- Cortex®-M4 Technical Reference Manual

STMicroelectronics documents

The following documents are available from the *www.st.com* web page:

- STM32F0 Series product data sheets
- STM32F1 Series product data sheets
- STM32F3 Series product data sheets
- STM32F4 Series product data sheets
- STM32F7 Series product data sheets
- STM32L4 Series product data sheets
- STM32G0 Series product data sheets
- STM32G4 Series product data sheets
- *X-NUCLEO-IHM expansion boards FOR motor control - Selection guide* on-line presentation

2 ST Motor Profiler

The ST Motor Profiler software tool is used to identify the motor's main PMSM characteristics, which are further transferred to the ST MC Workbench.

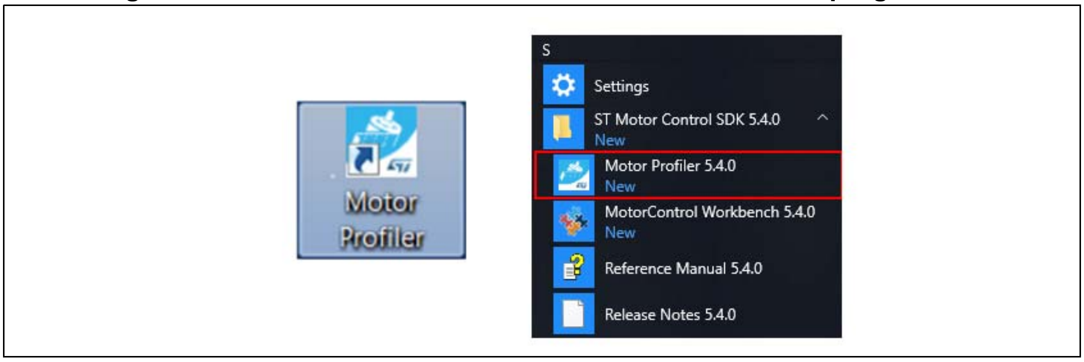
2.1 Launching the ST Motor Profiler

Launch the ST MC Workbench software tool either:

- by clicking on its icon, or
- by running it directly from the installation folder tree

Both ways of launching the ST MC Workbench are illustrated in *Figure 1*.

Figure 1. ST Motor Profiler - Icon and location in the start program list



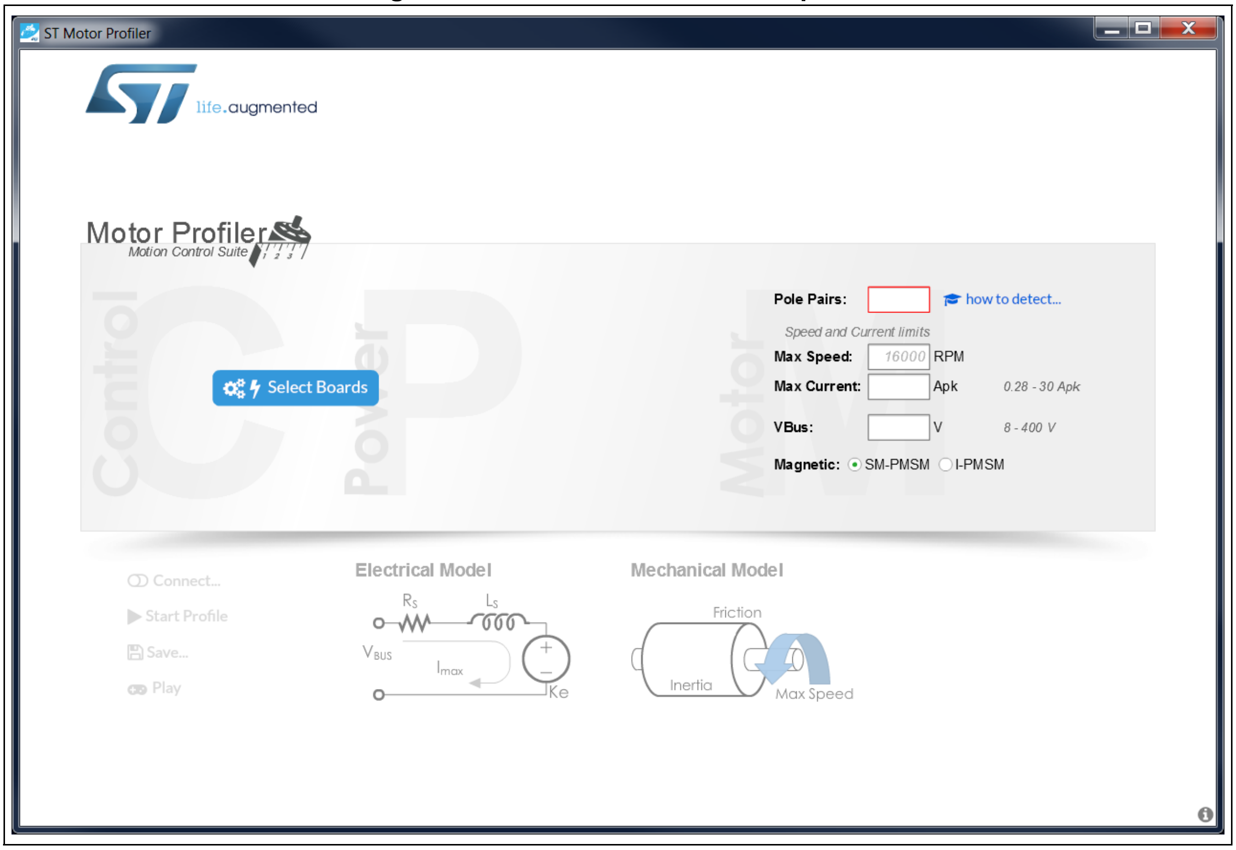
Open the ST Motor Profiler tool either by:

- using its dedicated button in the ST MC Workbench GUI, as illustrated in *Figure 2*, or
- running it directly from the installation folder tree, as illustrated in *Figure 1*.

Figure 2. ST MC Workbench - GUI expanded top view

A GUI window is displayed by the ST Motor Profiler, as shown in *Figure 3*.

Figure 3. ST Motor Profiler - Startup GUI

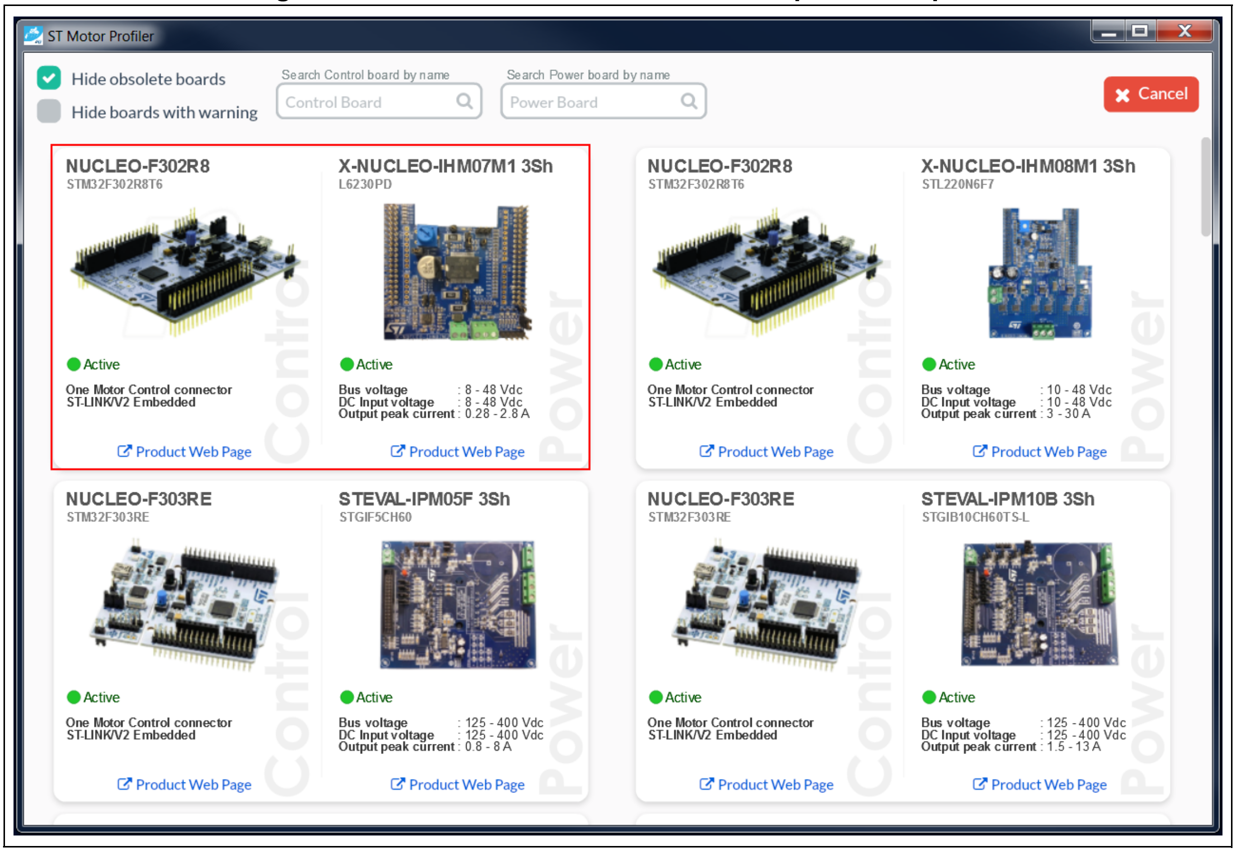


2.2 Hardware setup configuration

Click on the *Select Boards* button (as shown in *Figure 3*) to display the list of supported boards, as illustrated in *Figure 4*. Select the used application board within this list.

Note: *The ST Motor Profiler tool can be used only with ST hardware in the list of supported setups.*

Figure 4. ST Motor Profiler - Hardware setup list examples



Click on the STMicroelectronics hardware setup to select it and configure the ST Motor Profiler tool.

As an example, *Figure 4* shows the selection of the P-NUCLEO-IHM001 motor control Nucleo Pack with NUCLEO-F302R8 and X-NUCLEO-IHM07M1.

After hardware setup selection, fill in the parameter fields with the motor information:

- The number of pole pairs (mandatory field)
- The *Max Speed* (optional field)
  By default, the ST Motor Profiler tool searches for the maximum allowed speed matching the motor and the hardware setup used.
- The *Max Current* allowed by the motor (optional field)
  By default, it is the maximum peak current deliverable by the hardware setup.
- The nominal DC bus voltage used by the hardware setup (optional field)
  By default, it is the power supply stage, either the bus voltage for low voltage applications (DC voltage), or the RMS value for high voltage applications (AC voltage).
- The magnetic built-in type (mandatory field)
  By default, the SM-PMSM is selected.
- The Ld / Lq ratio (mandatory field) only when I-PMSM built-in is selected (as shown in *Figure 6*)

Figure 5 gives example values for the BR2804-1700KV-1 motor provided with the P-NUCLEO-IHM001 hardware setup.

Figure 5. ST Motor Profiler - SM-PMSM parameters example

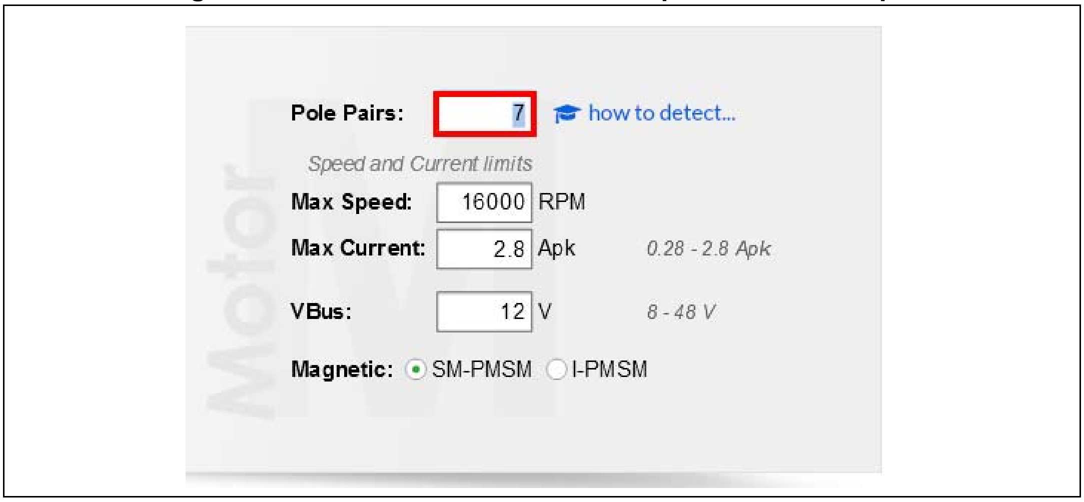
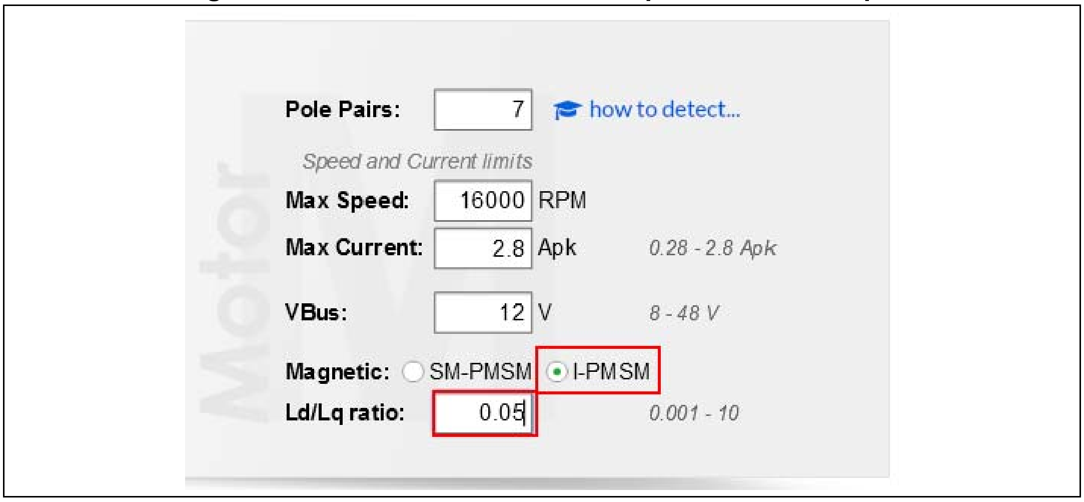


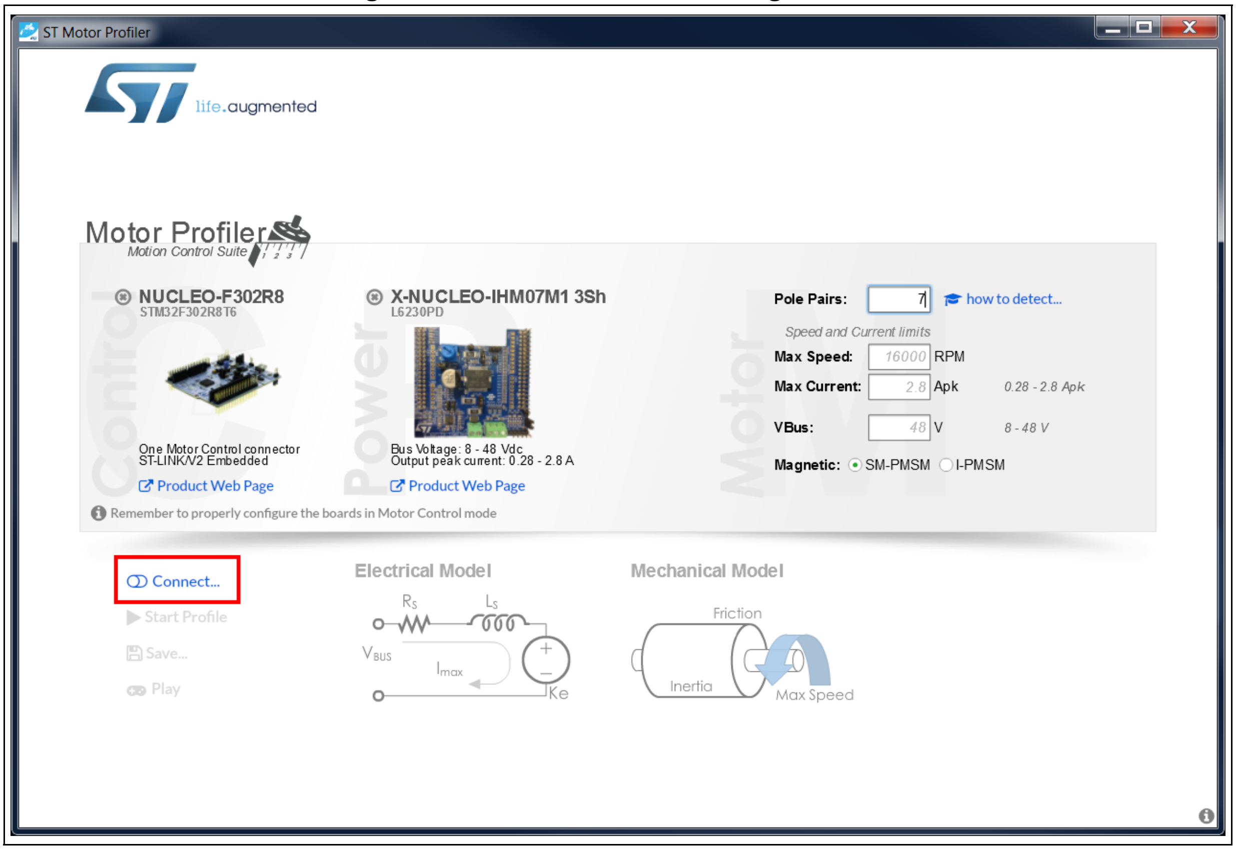
Figure 6. ST Motor Profiler - I-PMSM parameters example



2.3 Hardware setup connection

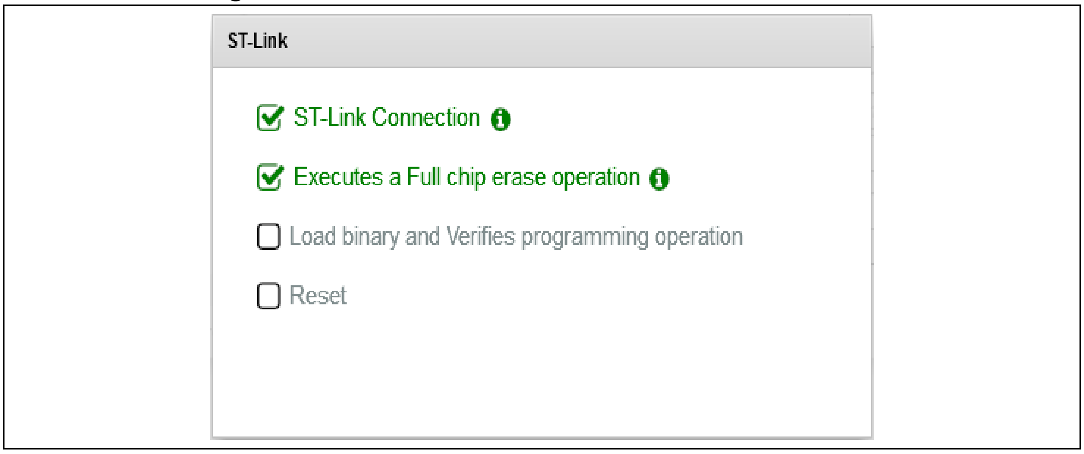
Once the ST Motor Profiler is configured, click on the *Connect* button, as shown in *Figure 7*.

Figure 7. ST Motor Profiler - Configured GUI



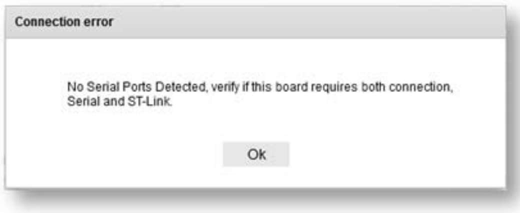
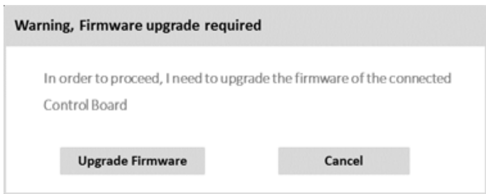
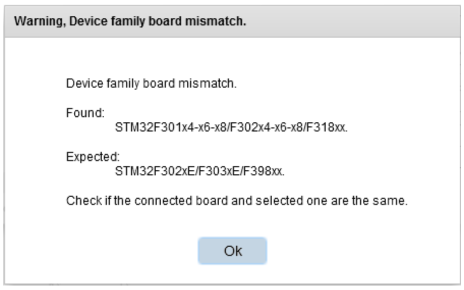
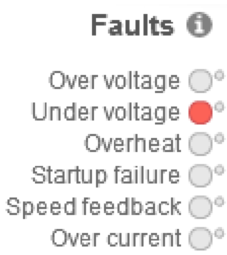
Once the connection is requested, a status widows is displayed, as shown in *Figure 8*. Its content depends on the hardware setup history.

Figure 8. ST Motor Profiler - Download status window



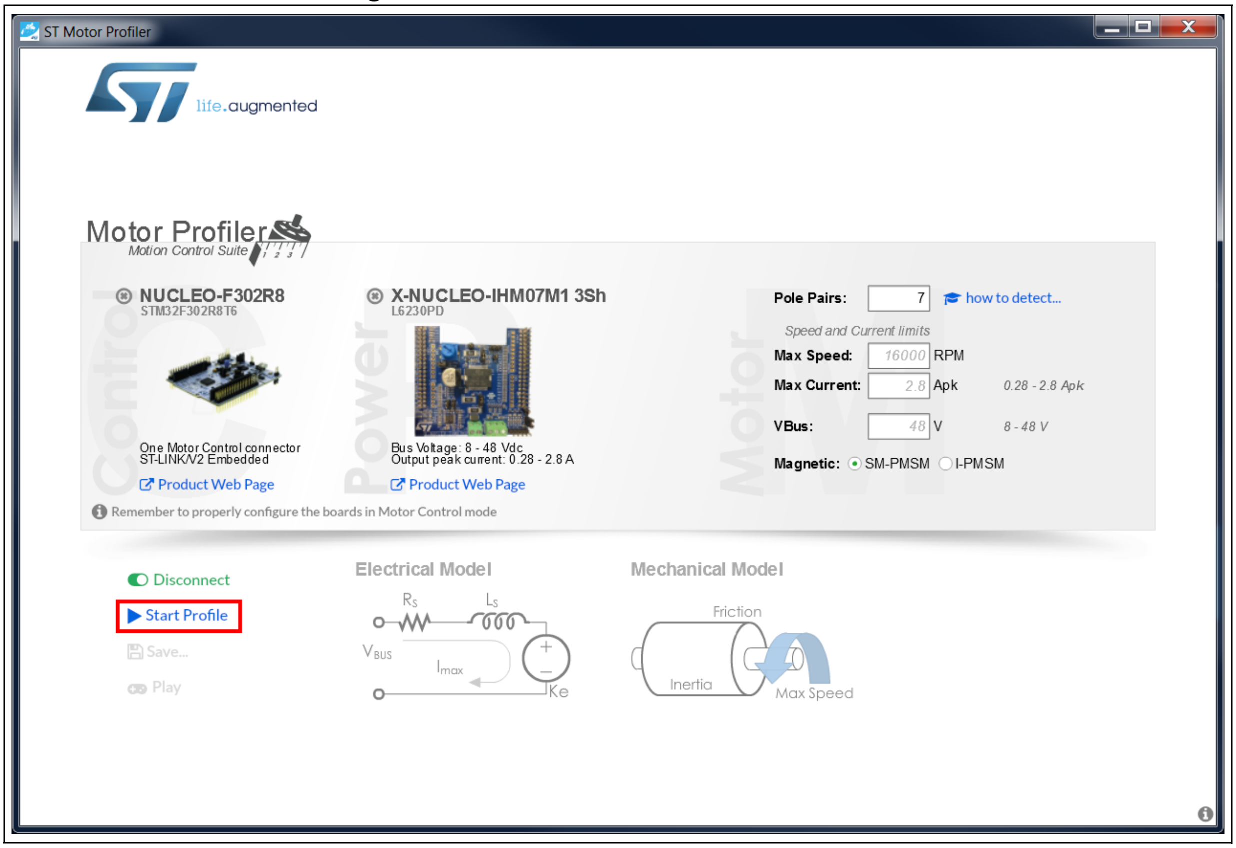
If a problem is encountered, a troubleshoot message window (among those listed in *Table 2*) is displayed to support recovery actions.

Table 2. ST Motor Profiler - Troubleshoot message examples

Message type	Information content	Action needed
Error		Depending on the status window: – If the programming procedure cannot be executed, check the JTAG/SWD programming cable. – If the programming procedure is executed but the Motor Profiler cannot communicate with the board, check the serial communication connections.
Warning		When the board is new or has been erased, the motor profiler FW is automatically loaded into the microcontroller by pressing the *Upgrade Firmware* button to confirm proper FW upload.
Warning		Acknowledge and return to the selection of the boards used in the hardware setup.
Faults		In case of over- or under-voltage detection, correct the bus voltage setting and its proper connection to the power board.

Once the connection is successful, the *Start Profile* button is proposed in the GUI (see *Figure 9*).

Figure 9. ST Motor Profiler - Connected GUI



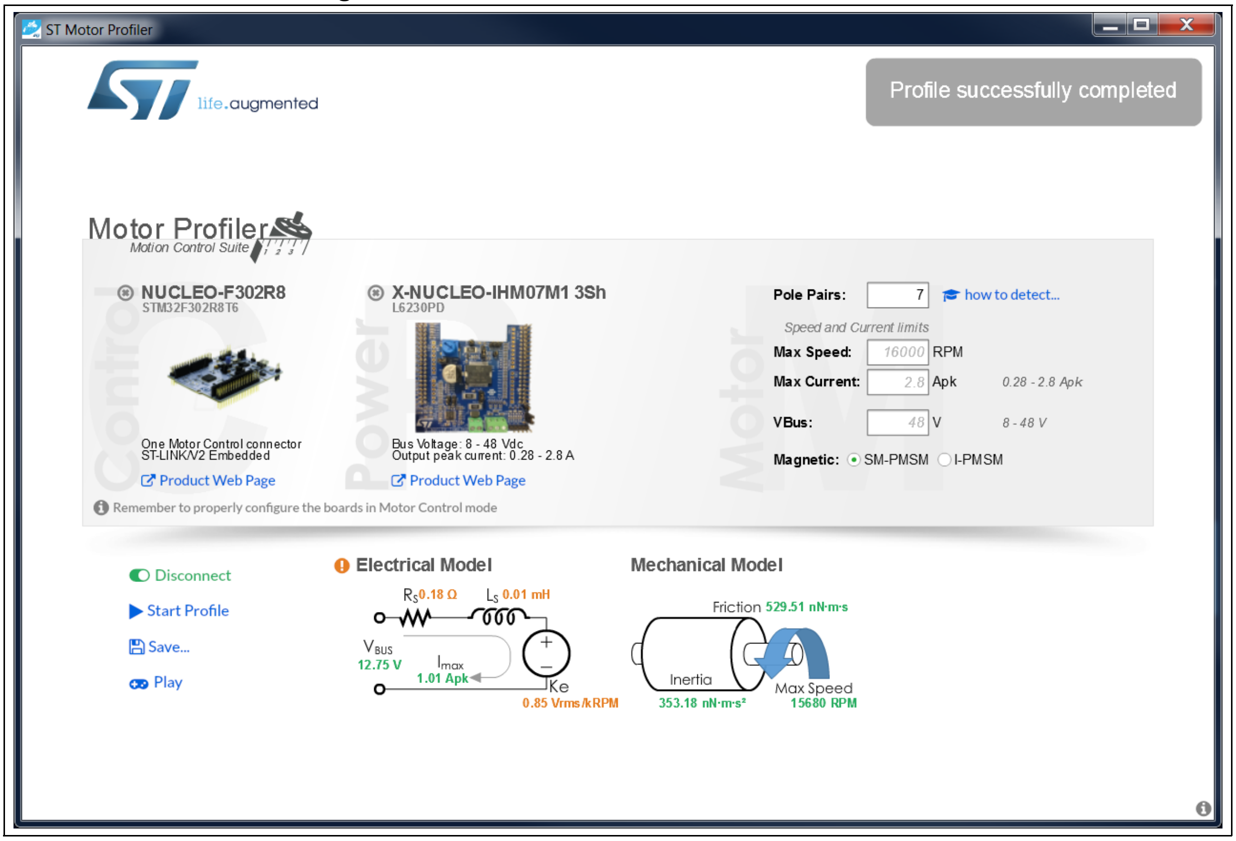
2.4 Motor profiling

Click on the *Start Profile* button proposed in the GUI as indicated in *Figure 9* to start motor profiling.

The profiling first identifies the electrical parameters, and then the mechanical ones. In case of over-current fault detection, the profiling is restarted with a reduced current.

When the profiling is successfully completed, all the motor measurements are shown in green or orange (depending on their relative accuracy), as illustrated in *Figure 10*. When one or more results are displayed in red, check the hardware setup and restart the motor profiling sequence.

Figure 10. ST Motor Profiler - Profiled motor GUI

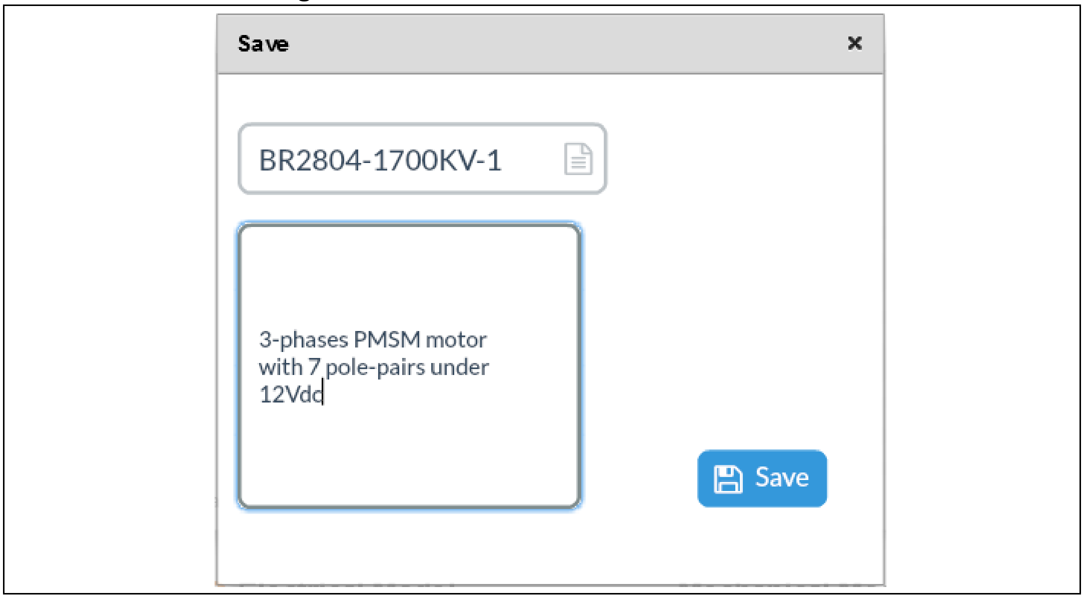


2.5 Profiled motor saving

Click on the *Save* button (refer to *Figure 10*) to store the motor measurements for later use with the ST MC Workbench software tool. *Figure 11* shows the menu displayed in that case:

- Enter the name of the profiled motor, such as *BR2804-1700KV-1*
- Provide details about the profiled motor, such as *3-phase motor with 7 pole-pairs under 12 Vdc*
- Eventually add details on the hardware setup used

Figure 11. ST Motor Profiler - Save window



2.6 Motor spinning

Click on the *Play* button (refer to *Figure 10*) to spin the profiled motor.

Figure 12 shows the sequence of operations to operate the motor through the spin control window:

1. Preset the maximum acceleration
2. Click on the *Start* button to activate motor control
3. Adjust the *Speed [RPM]* slider with the cursor

Figure 12. ST Motor Profiler - Spin control window (Start)

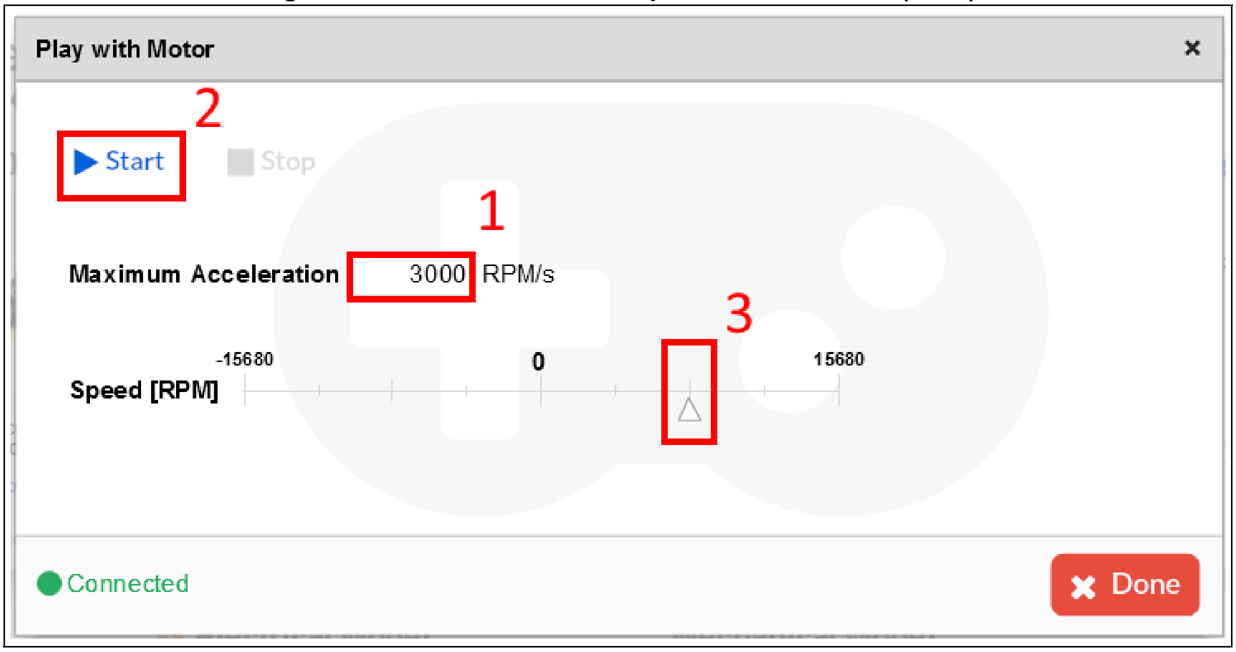
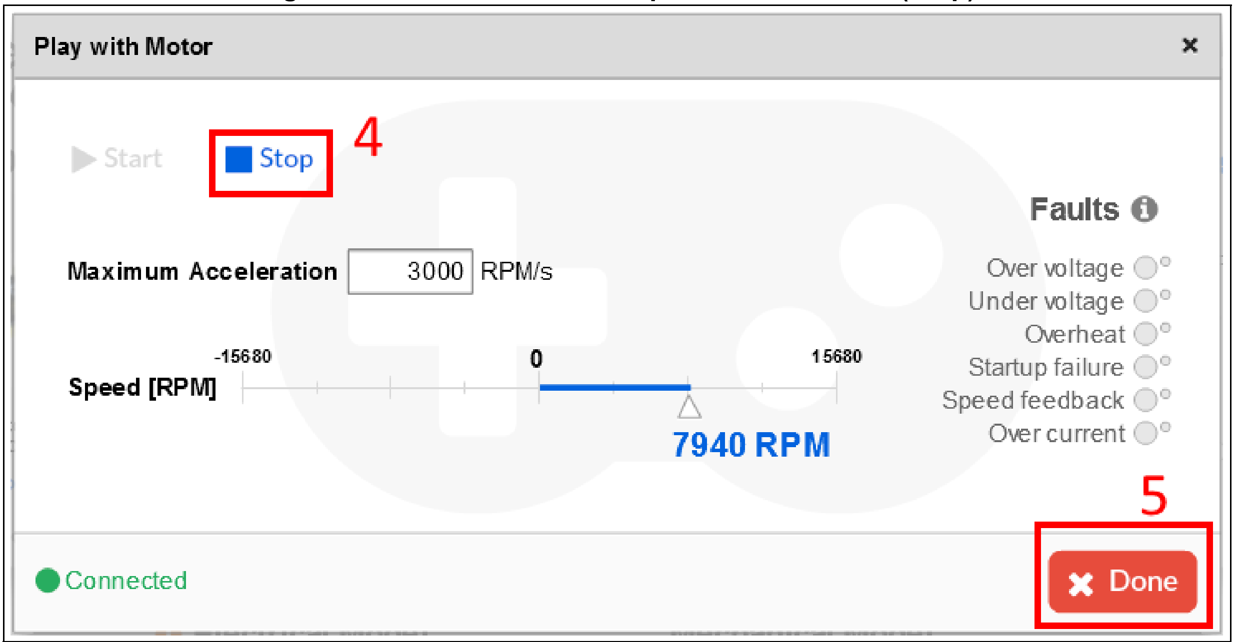


Figure 13 shows the two additional steps to stop the motor properly through the spin control window:

4. Click on the *Stop* button to stop activating motor control
5. Click on the Done button

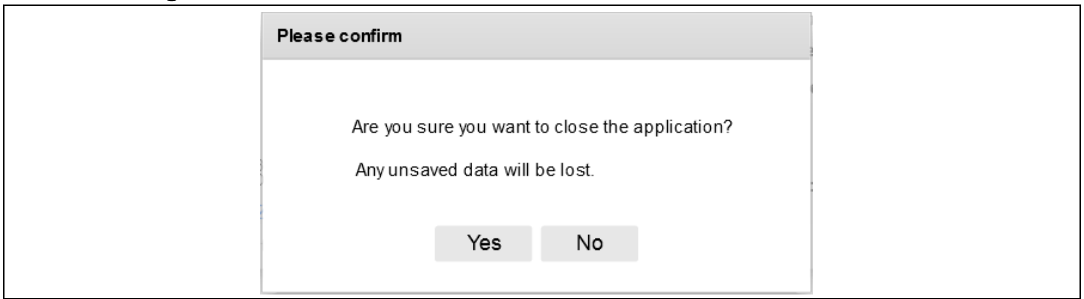
Figure 13. ST Motor Profiler - Spin control window (Stop)



2.7 Closing the ST Motor Profiler

Click on the *Disconnect* button (refer to *Figure 10*) to release the connection properly and close the ST Motor Profiler window by means of its upper-right icon. A confirmation window is displayed (see *Figure 14*).

Figure 14. ST Motor Profiler - Tool closure confirmation window



If the motor parameters have not been saved yet and need to be, proceed as follows:

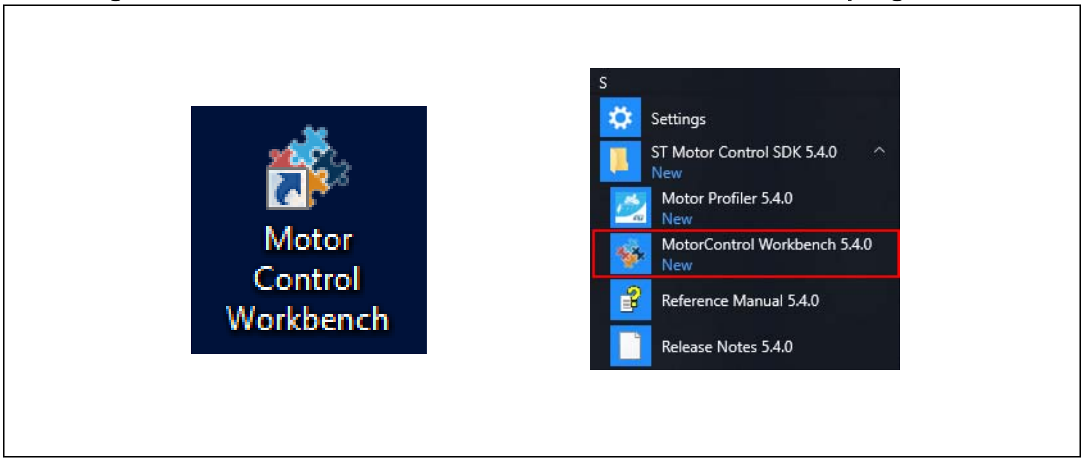
1. Select the *No* button in the confirmation window
2. Click on the *Connect* button, as shown in *Figure 7*
3. Save the motor parameters, as detailed in *Section 2.5*

Clicking on the *Yes* button closes the ST Motor Profiler software tool, unsaved motor parameters being lost.

3 The ST Motor Control Workbench

Launch the ST MC Workbench software tool either by clicking on its icon, or running it directly from the installation folder tree, as shown in *Figure 15*.

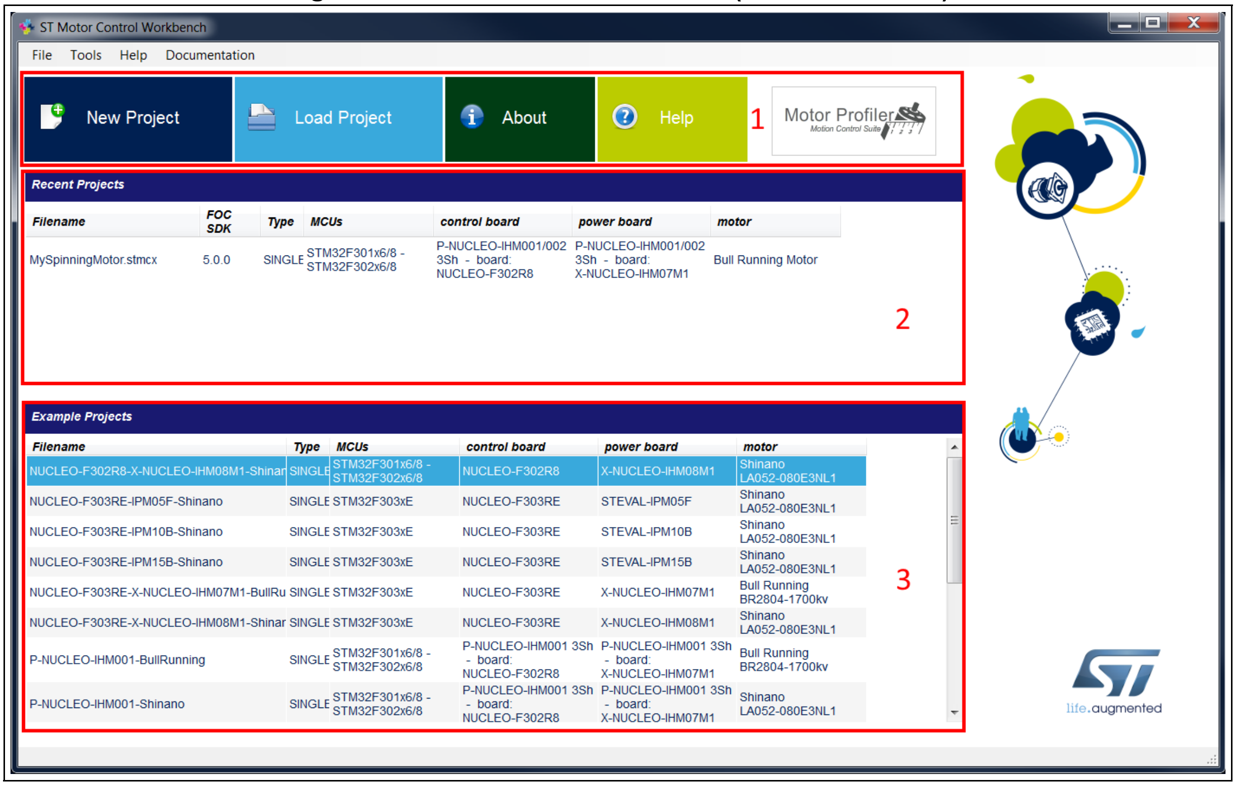
Figure 15. ST MC Workbench - Icon and location in the start program list



The ST MC Workbench GUI features three different areas (numbered boxes in *Figure 16*):

1. User-buttons: used to start a new project, to load a previous one, or to launch the ST Motor Profiler software tool
2. *Recent Project:* used to load a recent project
3. *Example Projects:* used to load a project example

Figure 16. ST MC Workbench - GUI (Launch window)

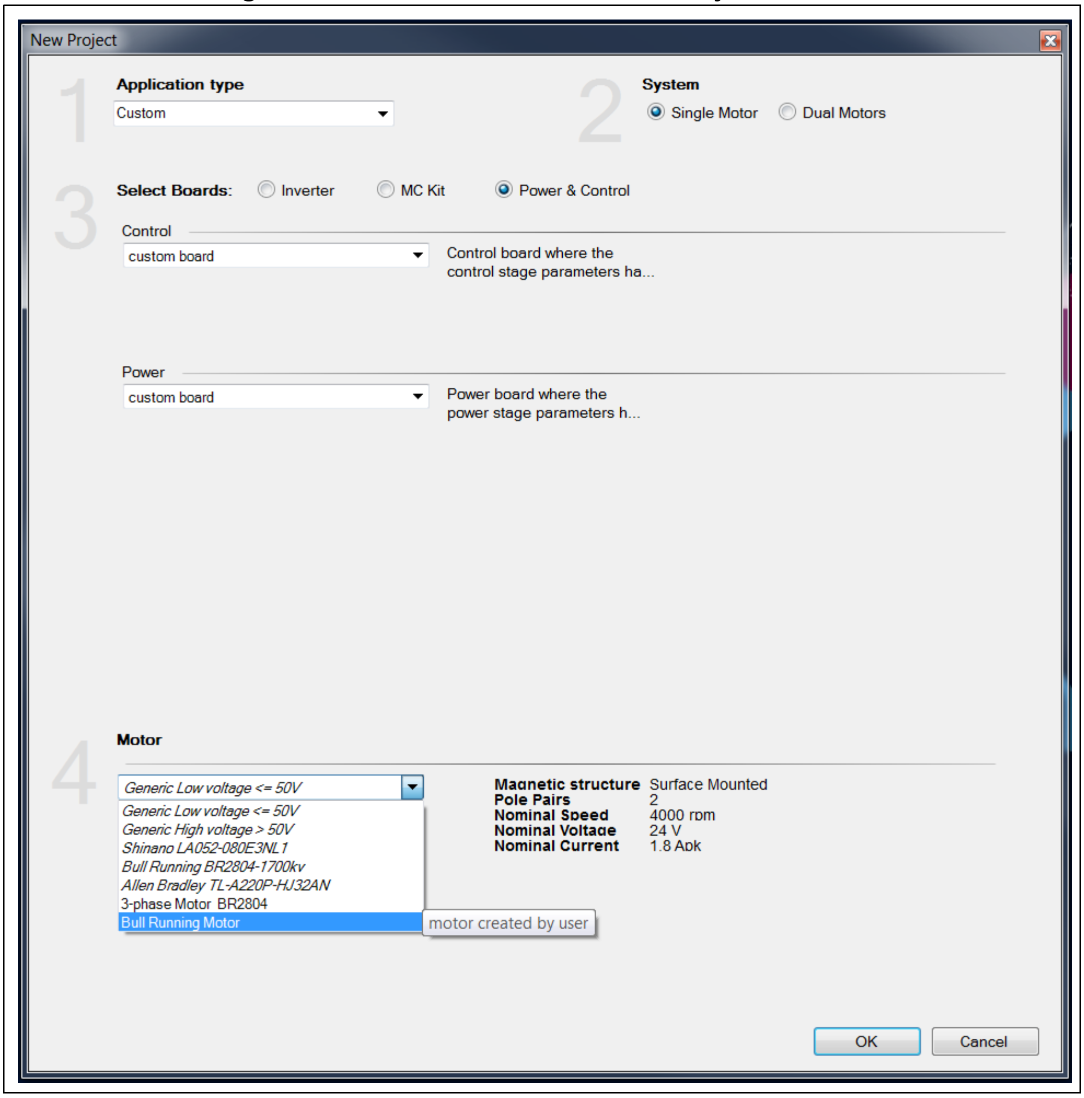


3.1 Creating a new project

Clicking on the *New Project* button (see *Figure 16*) displays the *New Project* window (see *Figure 17*) used for the definition of the hardware setup information through steps *1* to *4*:

1. Select the *Application Type*
2. Check the *Single Motor* or the *Dual Motors* check box
3. Select the ST hardware setup boards:
   – If the ST board is a complete inverter board (single board with both power and control electronics), select the *Inverter* combo box and select the *Inverter* choice from the drop-down list
   – If an ST MC Kit such as P-NUCLEO-IHM001 is used, select the *MC Kit* combo box and select the *Kit* choice from the drop-down list
   – If the system is composed of a control evaluation board associated with a power evaluation board, select the *Power & Control* box and select the C*ontrol board* and the *Power board* from the drop-down lists
4. Select the profiled motor from the drop-down list
5. Click on the *OK* button to import all needed hardware settings

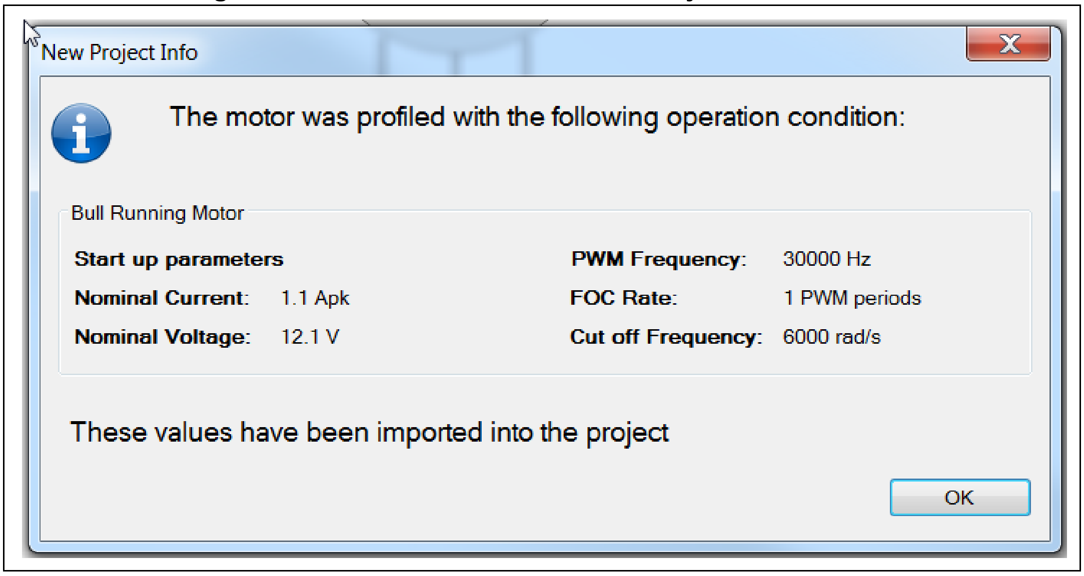
Figure 17. ST MC Workbench - New Project window



The created project imports the hardware settings according to the selected boards and motor profiling results. It also imports other settings like the PWM frequency and the startup acceleration used during motor profiling.

After a few seconds, a *New Project Info* window is displayed where the motor operating conditions can be checked, as shown in *Figure 18*.

Figure 18. ST MC Workbench - New Project Info window



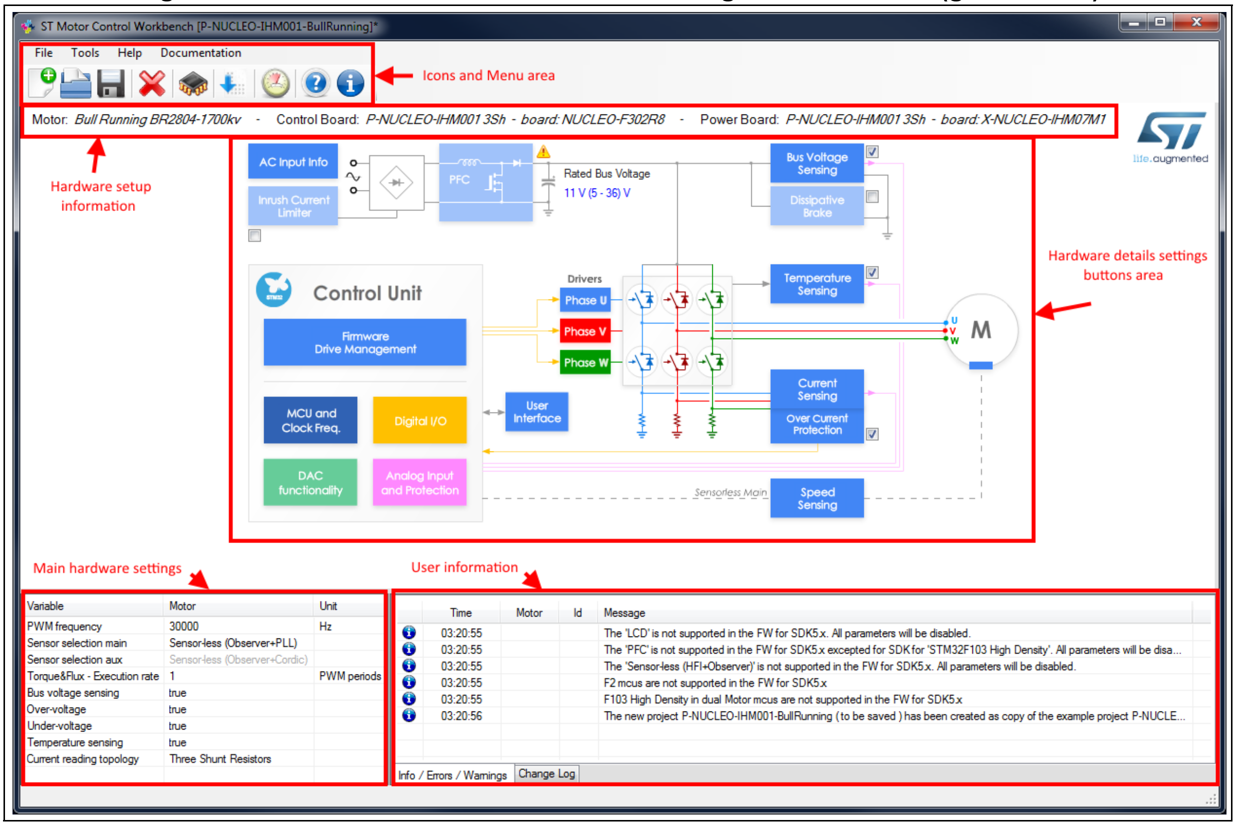
Clicking on the *OK* button opens the same GUI (as if loading an existing project), as detailed in *Section 3.2*.

3.2 Loading an existing project

Clicking on the *Load Project* button (see *Figure 16*) displays the hardware configuration window used for the tuning of hardware setup information, shown in *Figure 19*:

- Icons and Menu: used for the control of all project settings such as project workspace directory, used IDE, and others
- Hardware details setting buttons: used to fine tune the functionalities of the selected hardware, such as motor parameters or sensor use
- Main hardware settings: view of the main parameters at a glance
- User information: feedback about user actions on project settings. As an example, it can inform the user that a new project has been created, but not yet saved
- Hardware setup information: informs the user about overall hardware part settings

Figure 19. ST MC Workbench - Hardware configuration window (global view)



The following sections provide detailed informations about the areas shown in *Figure 19*:

- *Section 3.3: Icons and Menu area*
- *Section 3.4: Configuring a project*
- *Section 3.5: Main hardware settings*
- *Section 3.6: User information*

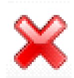
3.3 Icons and Menu area

The Icons and Menu area is used for the control of project settings through several menus, described in this section:

- *File menu on page 26*
- *Tools menu on page 28*
- *Help menu on page 33*
- *Documentation menu on page 34*

Shortcuts exist through usage of icon buttons, as summarized in *Table 3*.

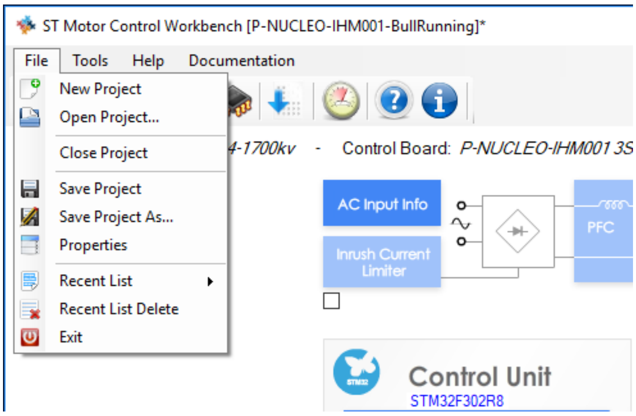
Table 3. ST MC Workbench – Menu icons

Function	Icon	Description
Create a new project		Create a new project, as shown in *Figure 17*
Load an existing project		Load and open an existing project, as shown in *Figure 19*
Save the current project		Save the current project settings
Clear the log		Clear the user information sheet, as shown in *Figure 34*
Pins assignment		Check the pin assignment of the MCU as well as the pins left available, as shown in *Figure 27*
Generate or Update the project		Open the GUI to Generate or to Update the MC application project files for the selected IDE, as shown in *Figure 33*
Open Monitor		Monitor and spin the motor, as shown in *Figure 33*
Help		Open the on-line help file
About		Check the ST MC Workbench software tool version, as shown in *Figure 37*

3.3.1 File menu

Figure 20 shows the *File* menu of the hardware configuration window.

Figure 20. ST MC Workbench - *File* menu



This menu allows the user to:

- Create a new project, as shown in *Figure 17*
- Open an existing project, as shown in *Figure 19*
- Close the current project.
  If the project is not saved yet, a confirmation window is displayed asking for one of three possible answers, as shown in *Figure 21*:
  - *Yes*: the current project is saved
  - *No*: the current project is not saved and its settings are lost
  - *Cancel*: returns to the hardware configuration window shown in *Figure 19*
- Save the current project settings.
  If the project is not saved yet, a file manager window is displayed asking to save the current project settings as a new project, as shown in *Figure 22*
- Save the project settings as a new project.
  A file manager window is displayed asking to save the current project settings as a new project, as shown in *Figure 22*
- View the project properties.
  A window is displayed with some project informations, as shown in *Figure 23*
- Load an existing project from the recent-project list.
  If the current project is not saved yet, a confirmation window is displayed asking to delete it from the recent project list, as shown in *Figure 24*
- Delete the recent project list, after user confirmation, as shown in *Figure 25*
- Exit from the hardware configuration window.
  If the project is not saved yet, a confirmation window is displayed asking for one of three possible answers, as shown in *Figure 21*:
  - *Yes*: the current project is saved
  - *No*: the current project is not saved and its settings are lost
  - *Cancel*: returns to the hardware configuration window shown in *Figure 19*

Figure 21. ST MC Workbench - Project saving confirmation window

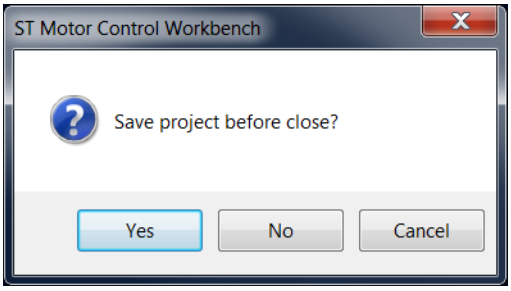


Figure 22. ST MC Workbench - Project *Save As* window

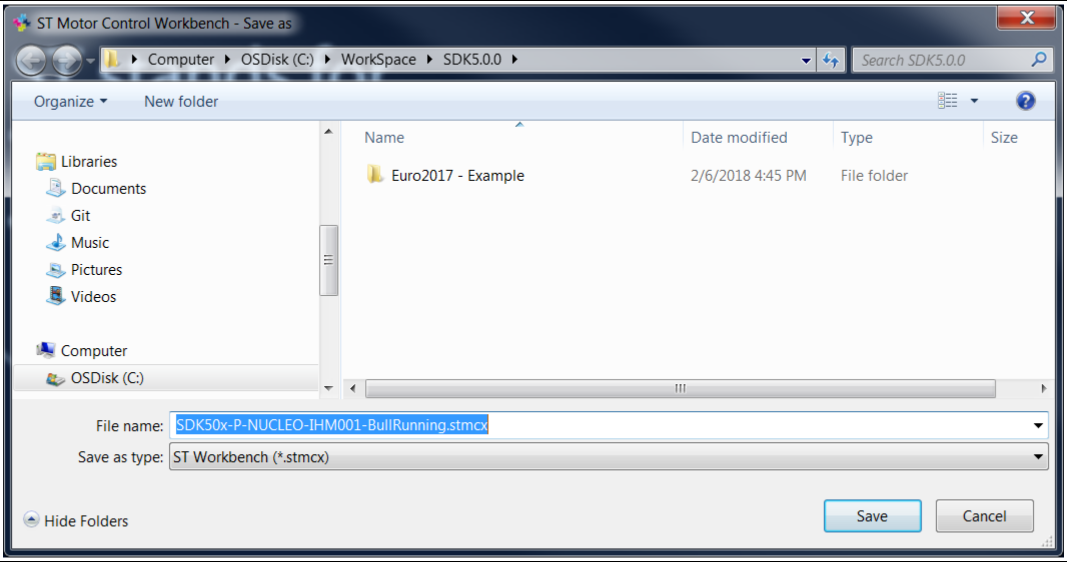


Figure 23. ST MC Workbench - *Project Properties* window

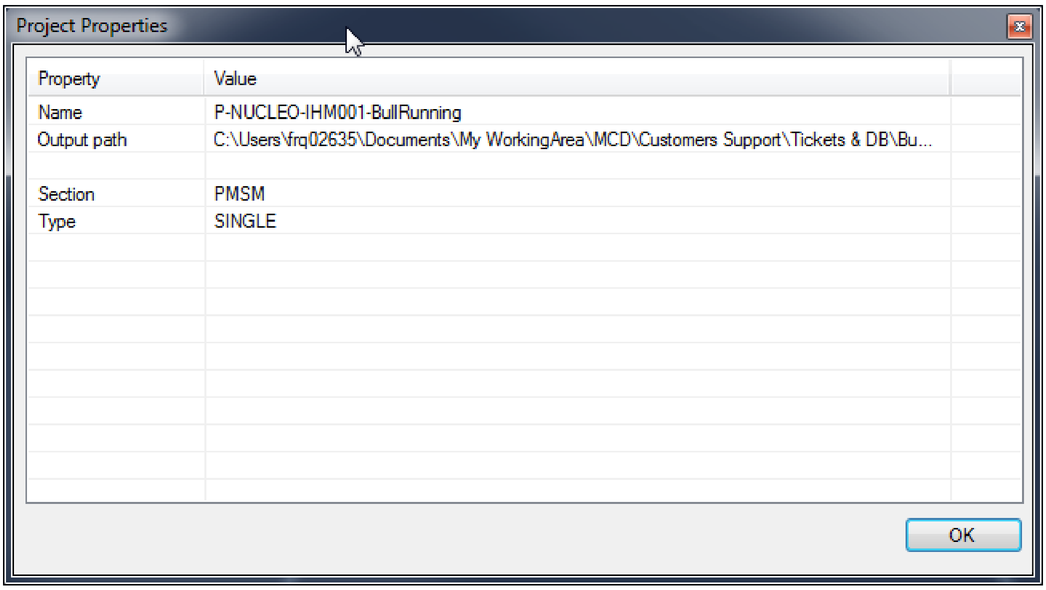


Figure 24. ST MC Workbench - Recent project list confirmation window

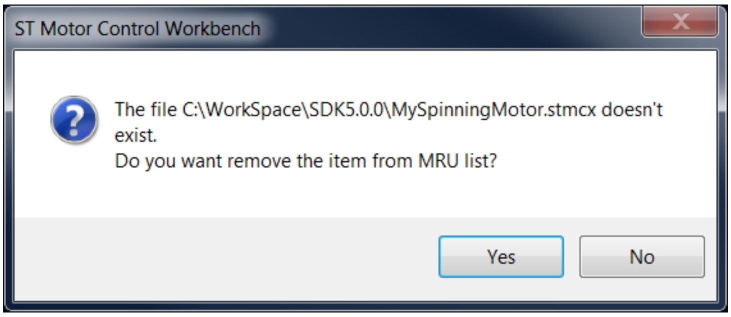
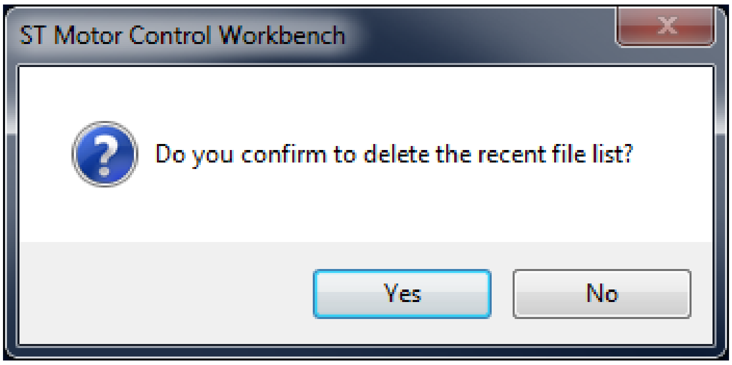


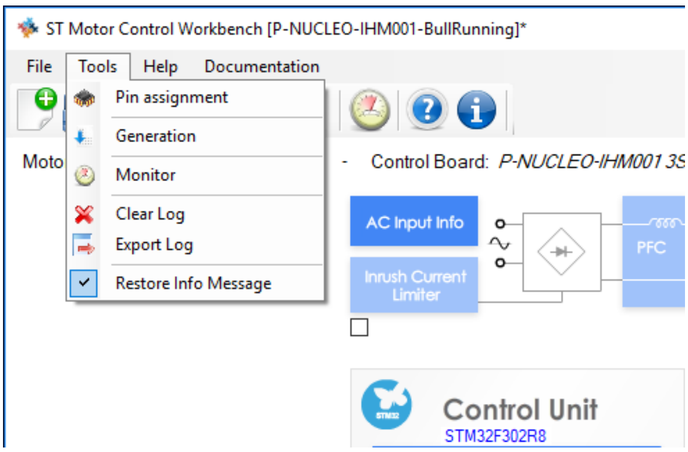
Figure 25. ST MC Workbench - Project deleting confirmation window



3.3.2 Tools menu

Figure 26 shows the *Tools* menu of the hardware configuration window.

Figure 26. ST MC Workbench - *Tools* menu



This menu allows the user to:

- Check the pin assignment of the MCU as well as the pins left available, as shown in *Figure 27*:
  - Click on the *Check* button to control the coherency of the pin assignment. A reporting window is displayed, see *Figure 28*. Use the *OK* button to close it.
  - Click on the *Reset* button to restore the default pin assignment of the STMicroelectronics board. A confirmation window is displayed, see *Figure 29*. Click on the *Yes* or *No* button to confirm or invalidate the action.
  - Close the window (upper-right click) to cancel the pin assignment action.
- Generate the MC application project files for the selected IDE:
  - If the current project is not saved yet, a file manager window is displayed asking to save the current project settings as a new project, as shown in *Figure 22*. Canceling this action, displays an information window indicating that the project needs to be saved before generating any files. Use the *OK* button to close it, as shown in *Figure 30*.
  - If the current project is saved, a project settings window is displayed to select the STM32CubeMx version usage (if several ones are installed) and to select the IDE toolchain (note that HAL/LL driver selection is not used in this current MC Workbench version).
  - Click on the Generate button to create the *.ioc file; or click on the Update button to update only the MC firmware configuration inside an existing *.ioc file (i.e. useful to keep additional modifications from the STM32CubeMX usage). Note that any physical hardware modification linked to motor control (e.g. MC pin assignment) is not taking into account using this Update button, this means that the MC project have to generate again in that case.
  - Then, the Generation tab is activated to inform about the used version configuration, and to show the IDE toolchain generation log (see *Figure 31*) while the user information sheet is updated (see *Figure 32*). When completed, the user has to manually close the progression window.
- Monitor and spin the motor, as shown in *Figure 33*. Refer to *Section 3.7* for details.
- Clear the user information sheet, as shown in *Figure 34*.
- Export the user information sheet in a log file in text format and open it in a text editor, as shown in *Figure 35*.
- Show user information messages when necessary.

Figure 27. ST MC Workbench - *Pin Assignment* window

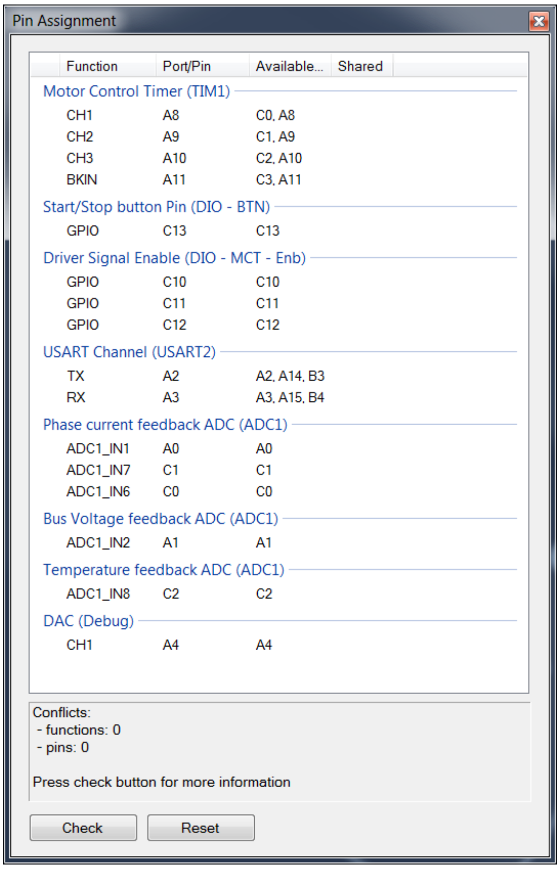


Figure 28. ST MC Workbench - *Pin Assignment* check window

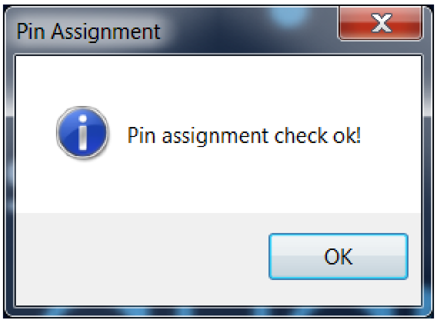


Figure 29. ST MC Workbench - *Pin Assignment* reset window

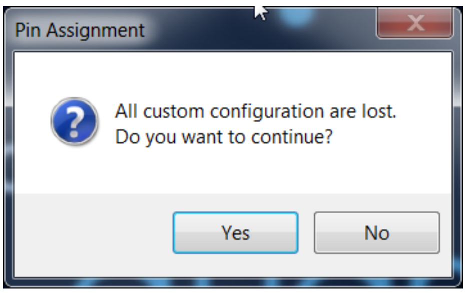


Figure 30. ST MC Workbench - Information window

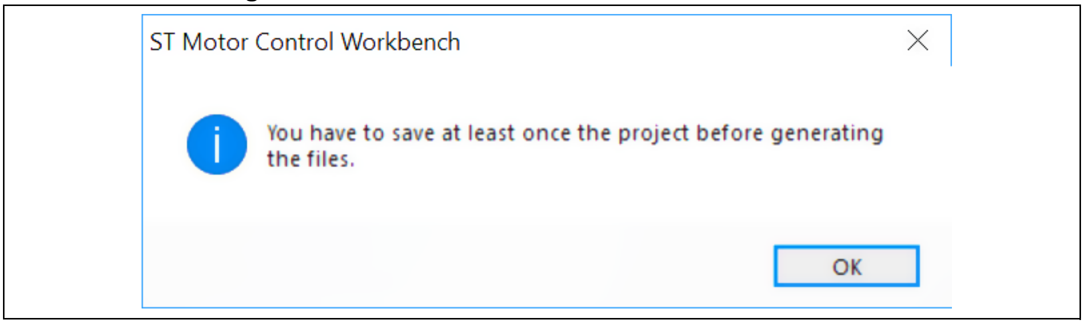


Figure 31. ST MC Workbench - Script progress window

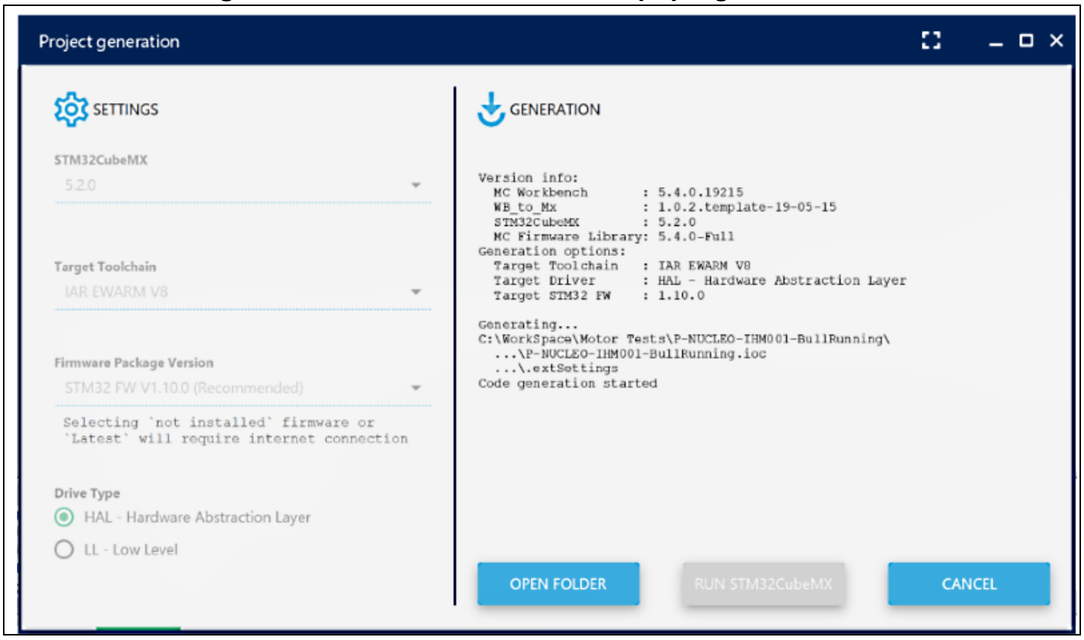


Figure 32. ST MC Workbench - User information sheet example

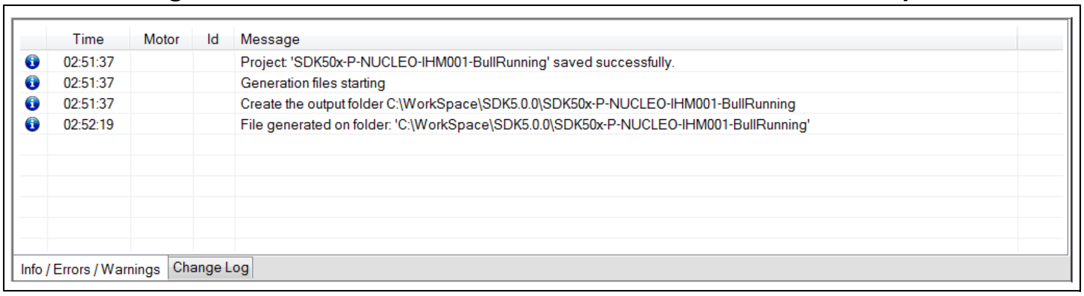


Figure 33. ST MC Workbench - Monitor window

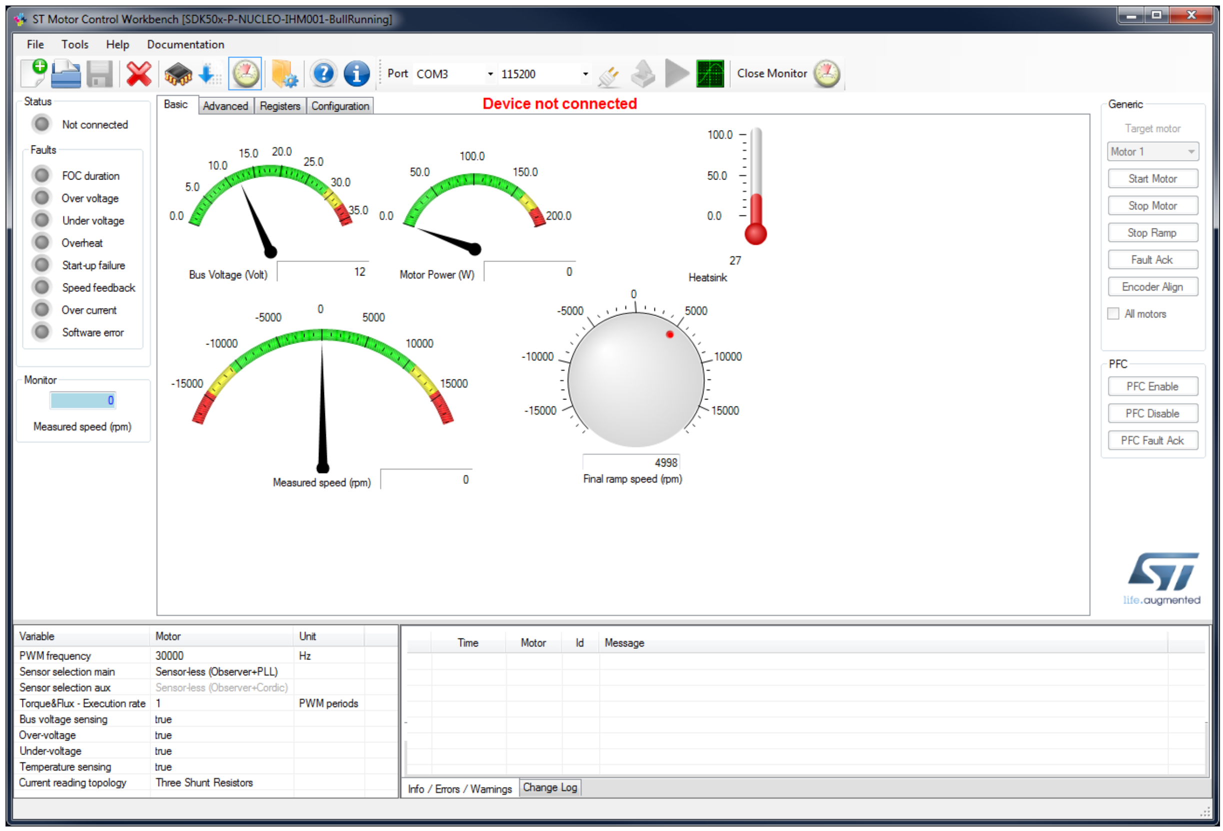


Figure 34. ST MC Workbench - User information sheet cleared

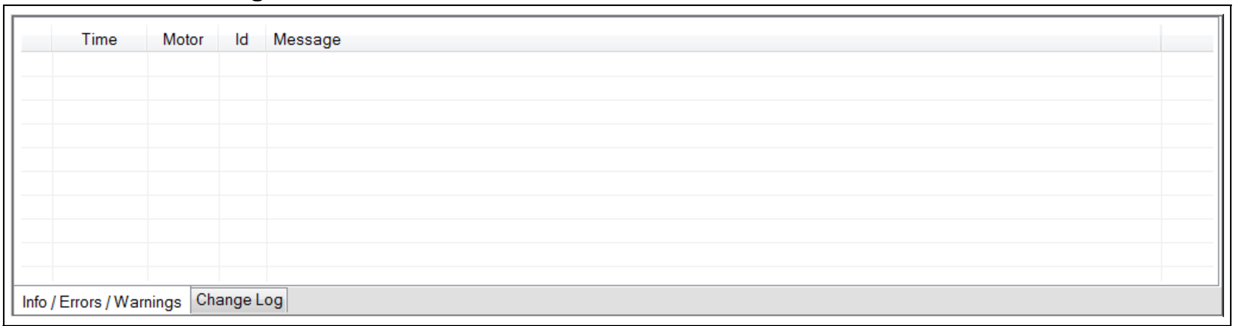
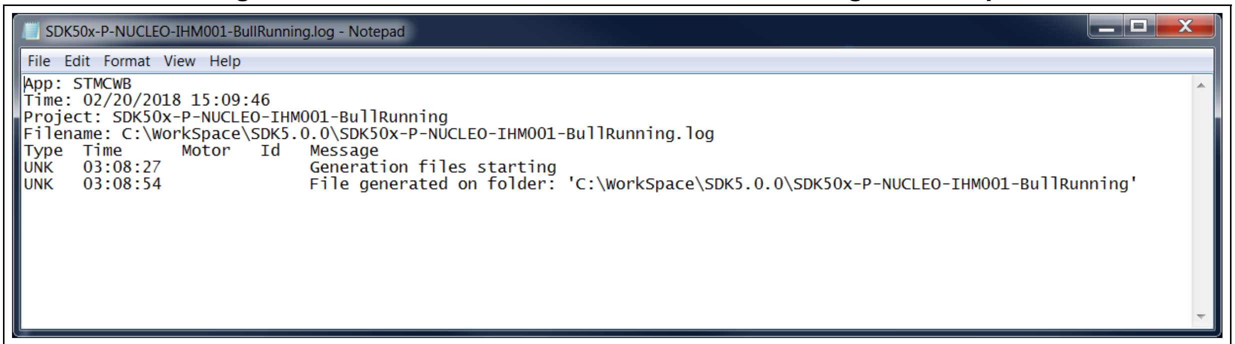


Figure 35. ST MC Workbench - User information log file example

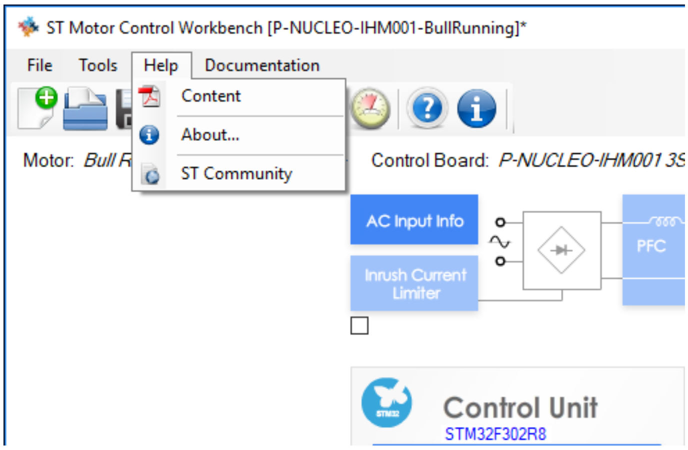



```
App: STMCWB
Time: 02/20/2018 15:09:46
Project: SDK50x-P-NUCLEO-IHM001-BullRunning
Filename: C:\WorkSpace\SDK5.0.0\SDK50x-P-NUCLEO-IHM001-BullRunning.log
Type  Time      Motor    Id    Message
UNK   03:08:27                 Generation files starting
UNK   03:08:54                 File generated on folder: 'C:\WorkSpace\SDK5.0.0\SDK50x-P-NUCLEO-IHM001-BullRunning'
```

3.3.3 Help menu

Figure 36 shows the *Help* menu of the hardware configuration window.

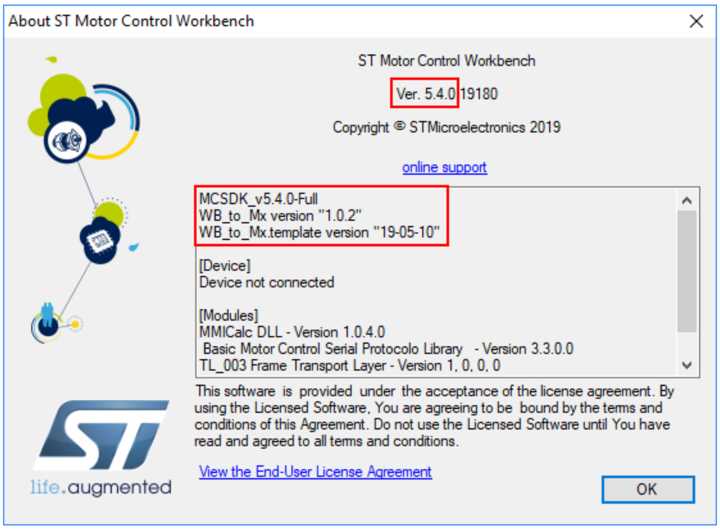
Figure 36. ST MC Workbench - *Help* menu



This menu allows the user to:

- Have easy access to this user manual
- Check the ST MC Workbench software tool version.
  Select the *About…* menu to prompt the software tool version window, and click on the *OK* button to quit this window, as shown in *Figure 37*.
- Gain direct access to the ST community website

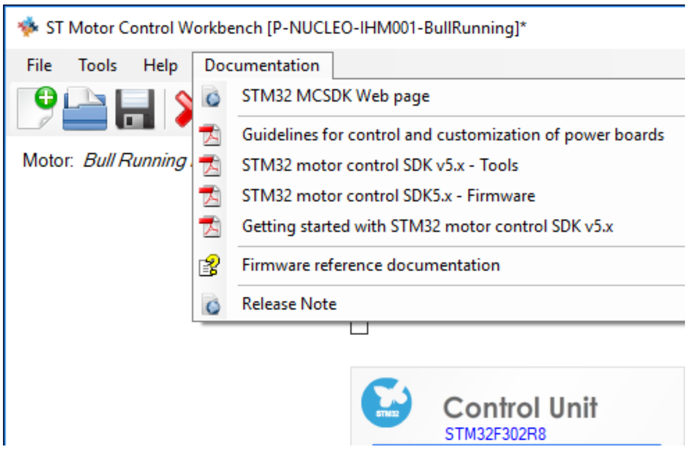
Figure 37. ST MC Workbench - *About* window



3.3.4 Documentation menu

Figure 38 shows the *Documentation* menu of the hardware configuration window.

Figure 38. ST MC Workbench - *Documentation* menu



This menu allows the user to:

- Direct access to the ST MC SDK webpage
- Have access to the STM32 MC SDK documents in pdf format
- Open the on-line STM32 MC Firmware Reference document
- Read the STM32 MC SDK package Release Note

3.4 Configuring a project

Depending on MC application software needs, MC FOC firmware is set according to the hardware part used. The following functionalities are detailed in this section:

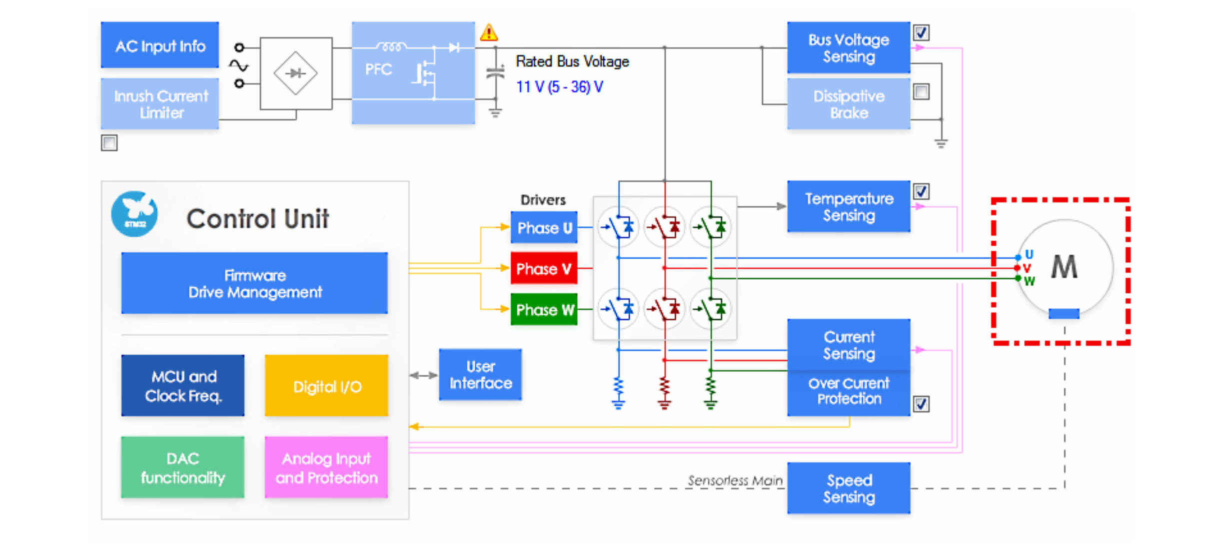
- *Motor on page 34*
- *Power stage on page 39*
- *Drive management on page 50*
- *Control stage on page 63*

3.4.1 Motor

Figure 39 shows the *Motor* window used for motor configuration. The user has to click on the motor or on the sensor to pop-up the GUI for parameter settings:

- the motor parameter GUI is shown in *Figure 40*
- the sensors GUI is shown in *Figure 42*

Figure 39. ST MC Workbench - *Motor* window



The PMSM motor parameters are imported from the ST Motor Profiler tool (refer to *Section 2*) or entered manually, as shown in *Figure 40*.

Figure 40. ST MC Workbench - Motor parameter GUI (Surface Mounted PMSM)

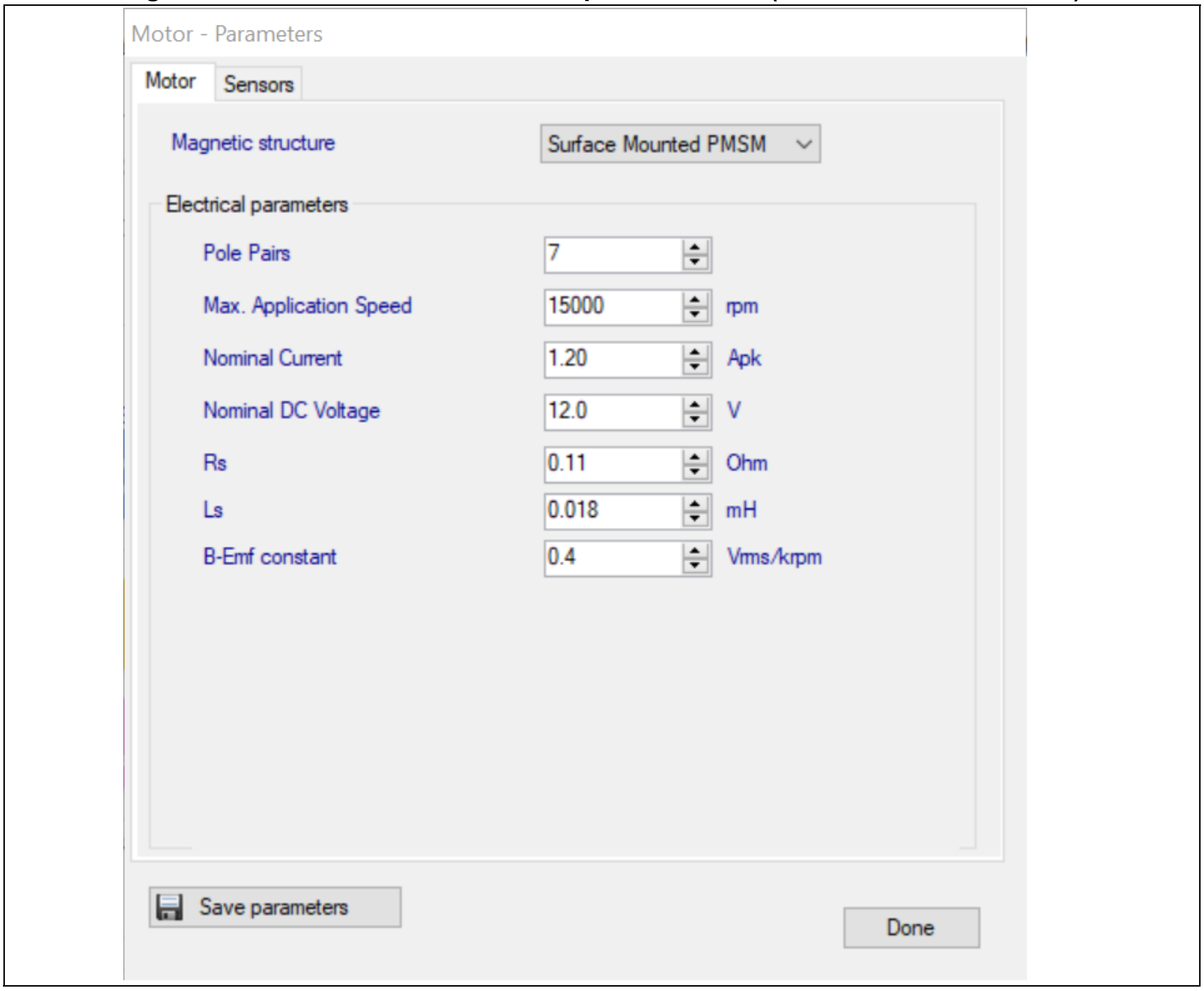
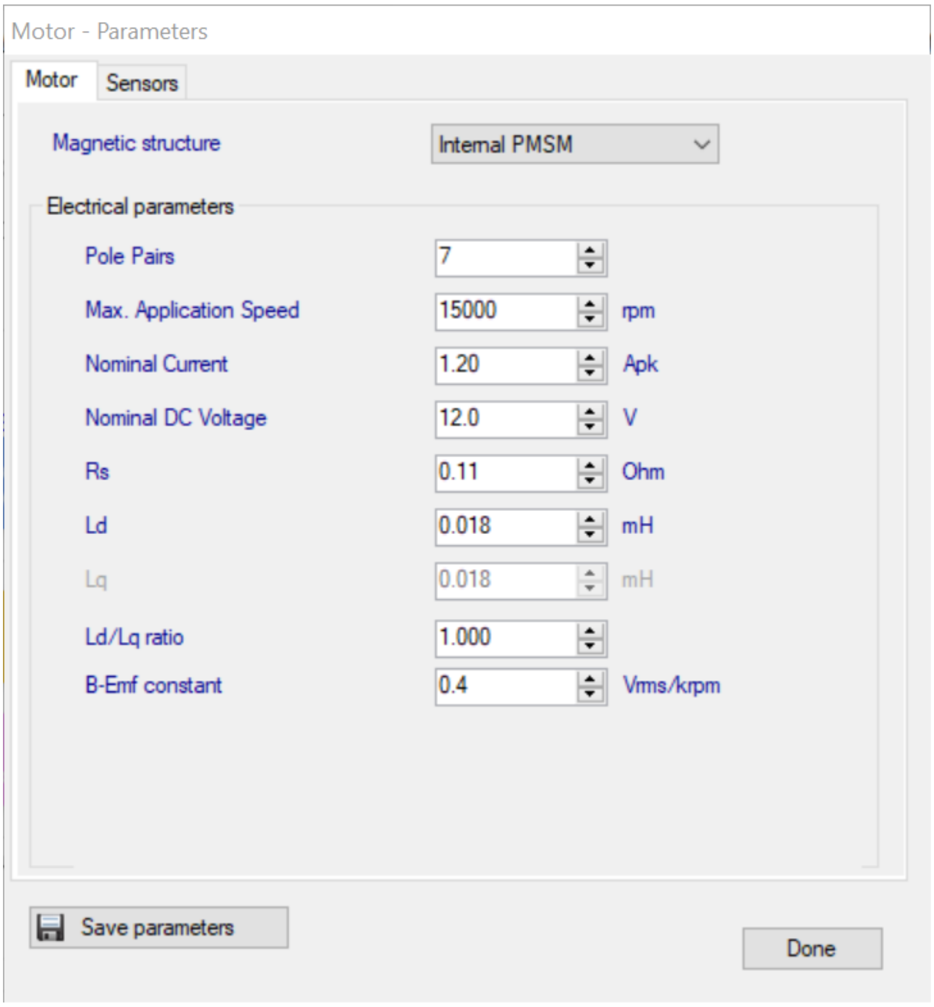
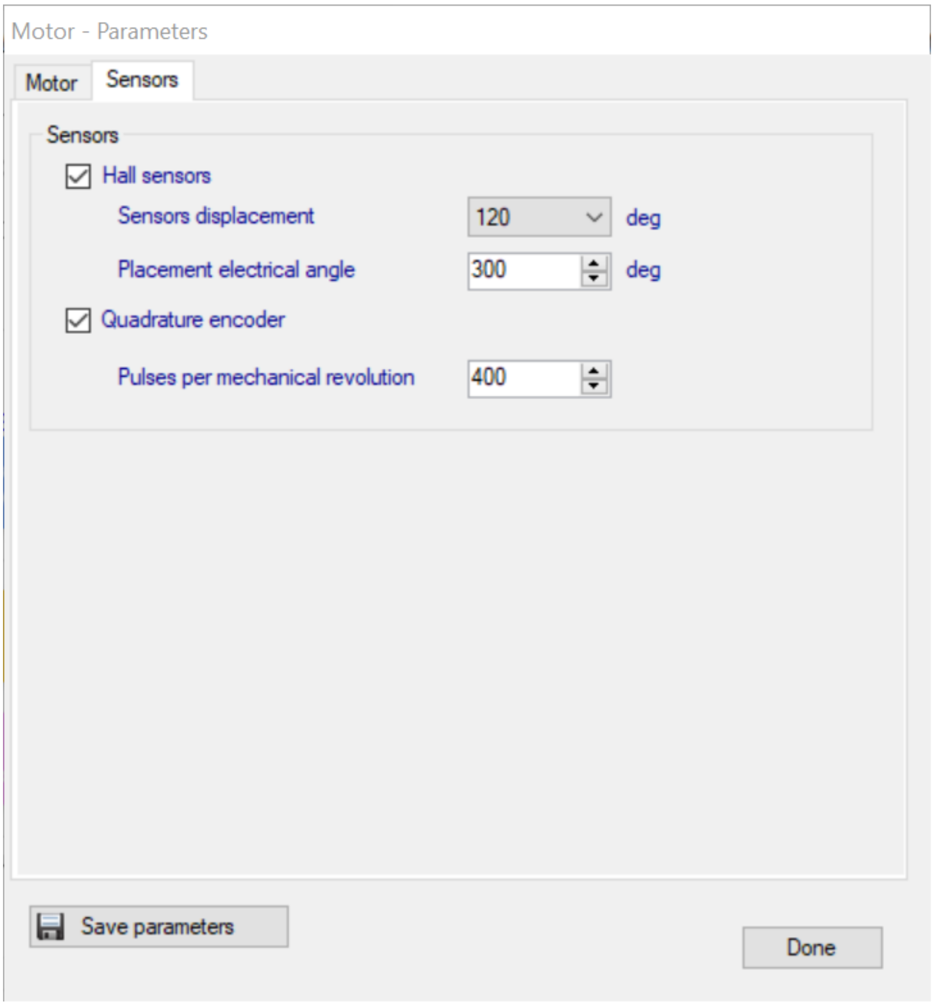


Figure 41. ST MC Workbench - Motor parameter GUI (Internal PMSM)



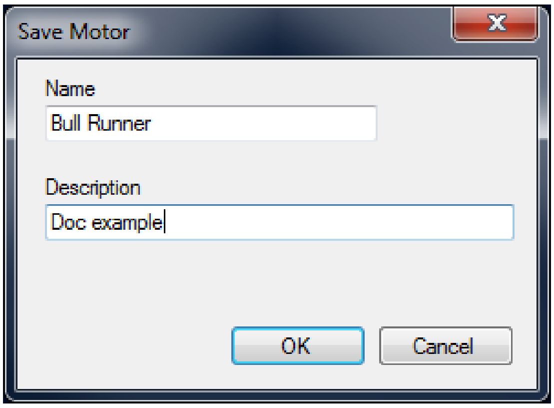
The selection of the sensors used (all selection configuration are allowed) and the setting of sensor parameters is illustrated in *Figure 42*.

Figure 42. ST MC Workbench - Sensor parameter GUI



Click on the *Save parameters* buttons (refer to *Figure 40* and *Figure 42*) to reuse the parameters in a following new project. The save motor parameter window asks for a name and a short description of the set parameter, as shown *Figure 43*.

Figure 43. ST MC Workbench - Save motor parameter window



3.4.2 Power stage

Figure 44 shows the *Power Stage* window used for power stage configuration through several GUIs for parameter settings:

- AC voltage input information (refer to *Figure 45*)
- DC bus voltage input (refer to *Figure 46*), and sensing information (when supported; refer to *Figure 47*)
- Temperature sensing use (when supported; refer to *Figure 48*)
- Current sensing use (refer to *Figure 49* and *Figure 50*)
- Over-current protection setup (when supported; refer to *Figure 51*)
- Power drivers setup (x3; refer to *Figure 52*)
- Power switches setup (x6; refer to *Figure 53*)
- Brake use (when supported; refer to *Figure 54*)
- Inrush Current Limiter feature (when supported; refer to *Figure 55*)
- Power Factor Correction feature (when supported; refer to *Figure 56*)

Figure 44. ST MC Workbench - *Power Stage* window

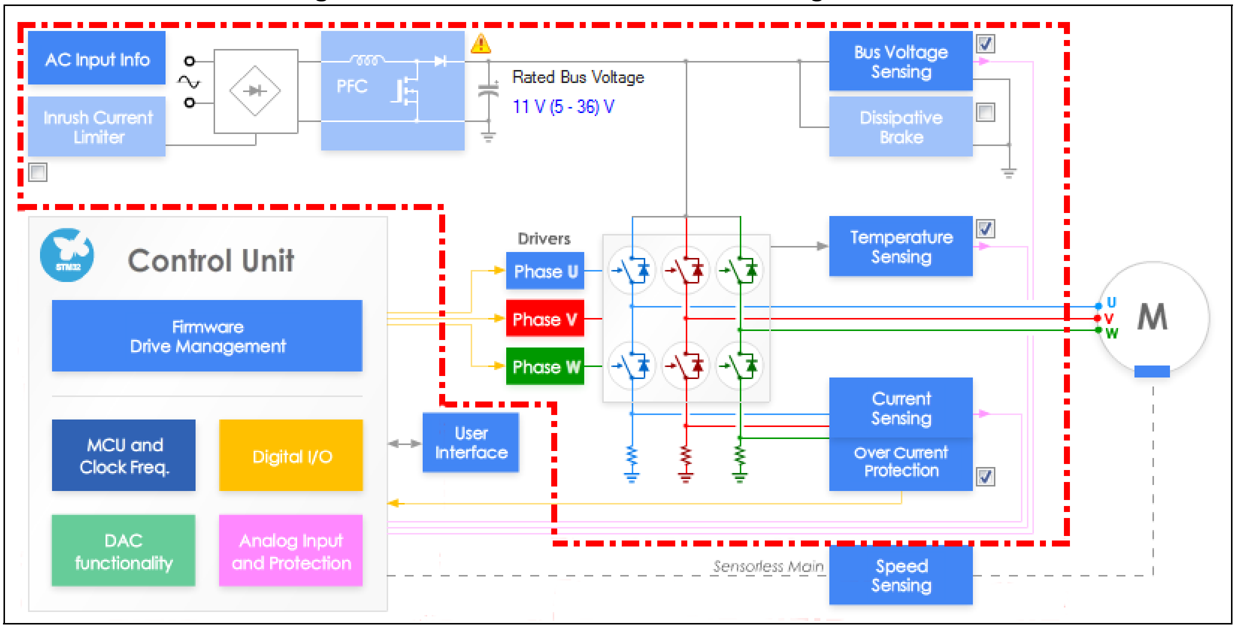


Figure 45 shows the *AC Input Info* GUI where the user applies the pre-defined AC voltage range or customizes it according to the hardware setup. In addition, an input over-voltage protection is set by default to the maximum AC voltage. To modify it, uncheck the box and enter the desired threshold value.

Figure 45. ST MC Workbench - *AC Input Info* GUI

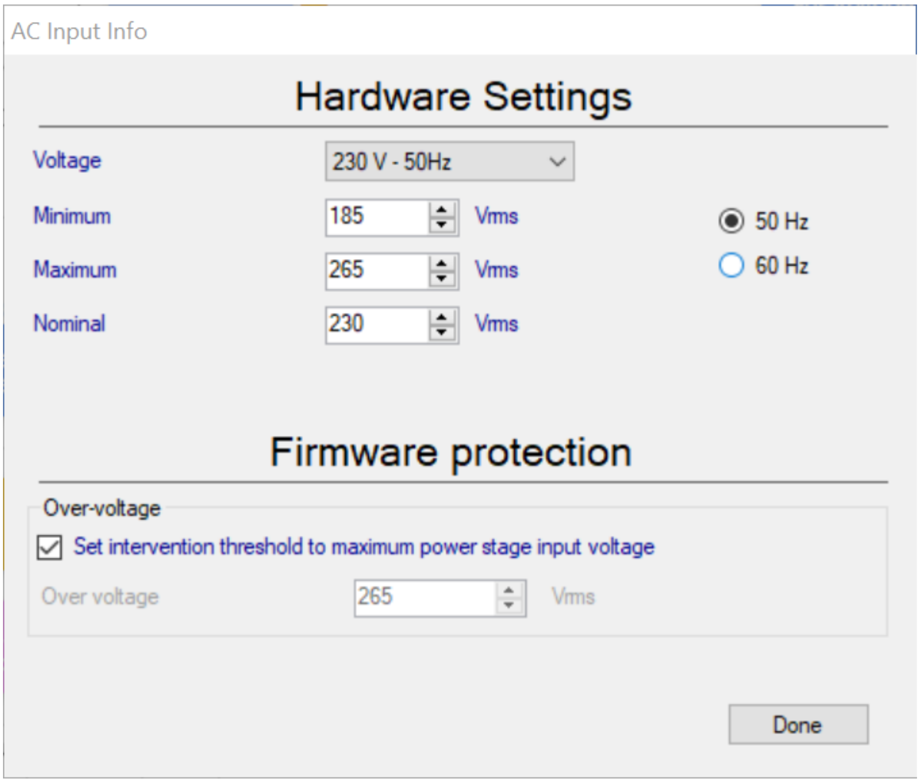
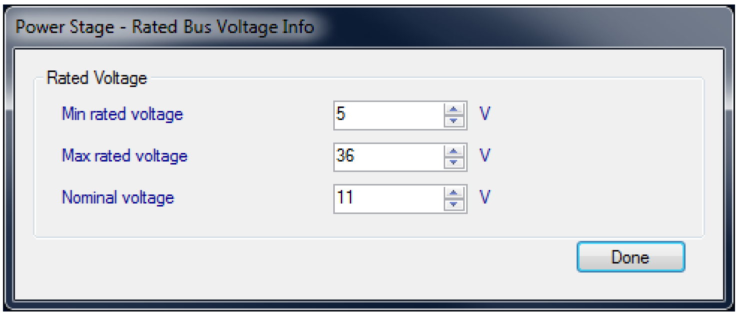


Figure 46 shows the *Rated Bus Voltage Info* GUI where the user configures the DC bus voltage input range (minimum and maximum rated values), as well as the nominal voltage.

Figure 46. ST MC Workbench - *Rated Bus Voltage Info* GUI



The sensing implementation topology and related values can then be defined, as shown in *Figure 47*. The inverse value of the DC bus voltage divider is automatically computed.

Figure 47. ST MC Workbench - *Bus Voltage Sensing* GUI

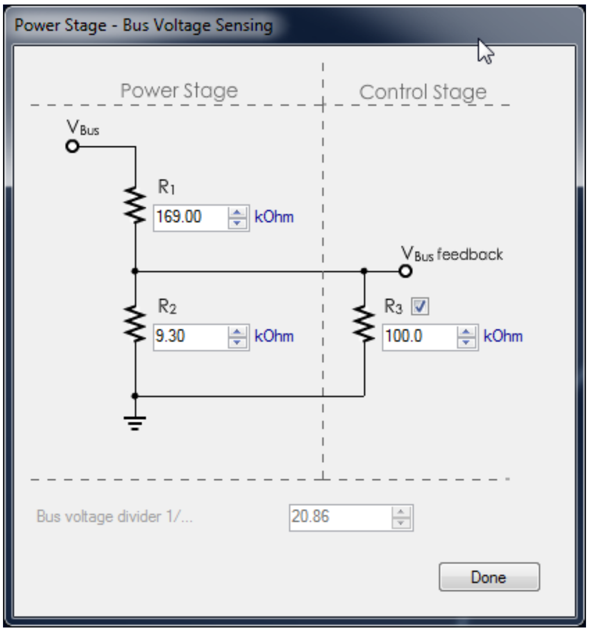


Figure 48 shows the *Temperature Sensing* GUI where the user configures the temperature sensing range as a function of the hardware setup. In addition, an input over-temperature protection is set by default to the maximum working temperature. To modify it, uncheck the box and enter the desired threshold value. The hysteresis value can be updated as well by the user.

Figure 48. ST MC Workbench - *Temperature Sensing* GUI

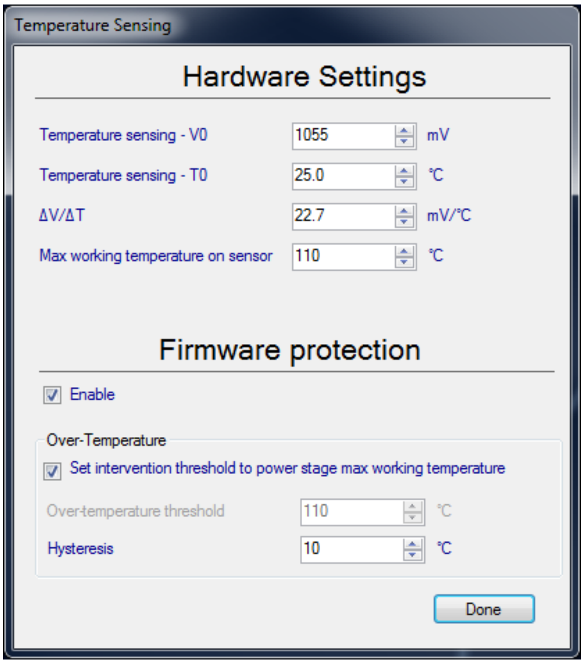


Figure 49 shows the *Current Sensing* GUI where the user selects the current sensing topology, and defines the conditioning method. Clicking on the *Calculate* button displays the *Current Sensing Gain Calculator* GUI, which is useful for setting the amplifying network gain value.

Figure 49. ST MC Workbench - *Current Sensing* GUI

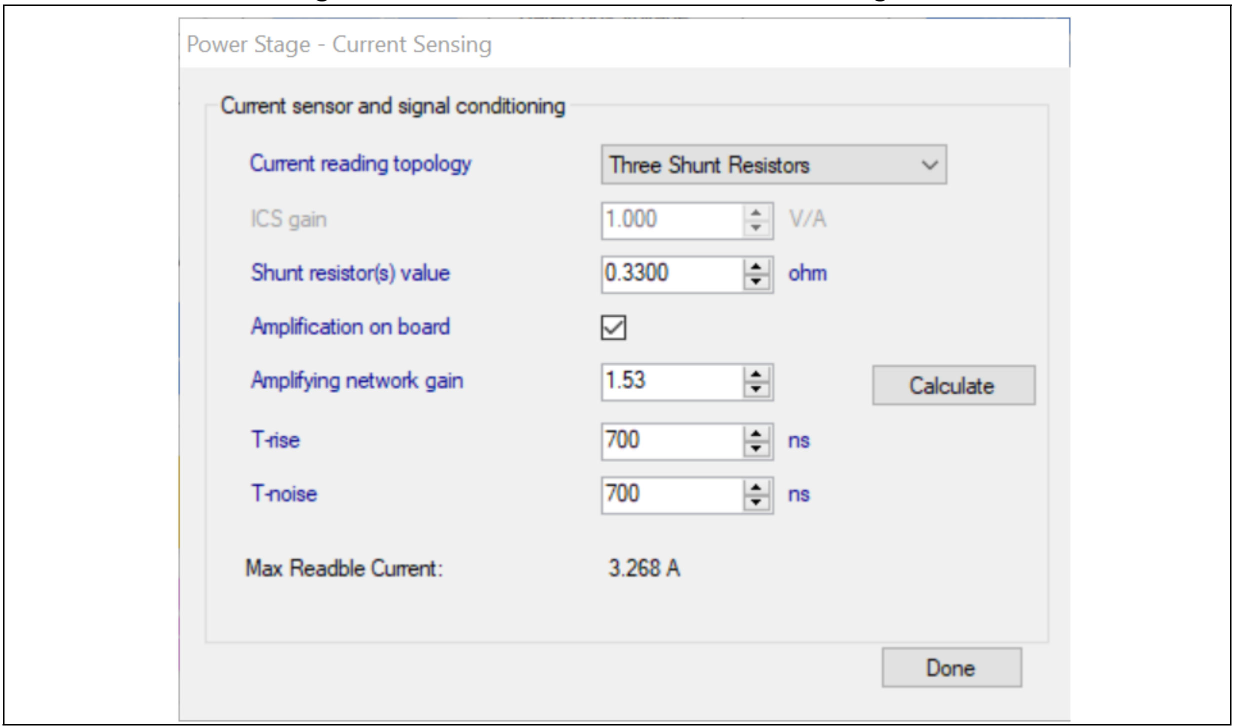
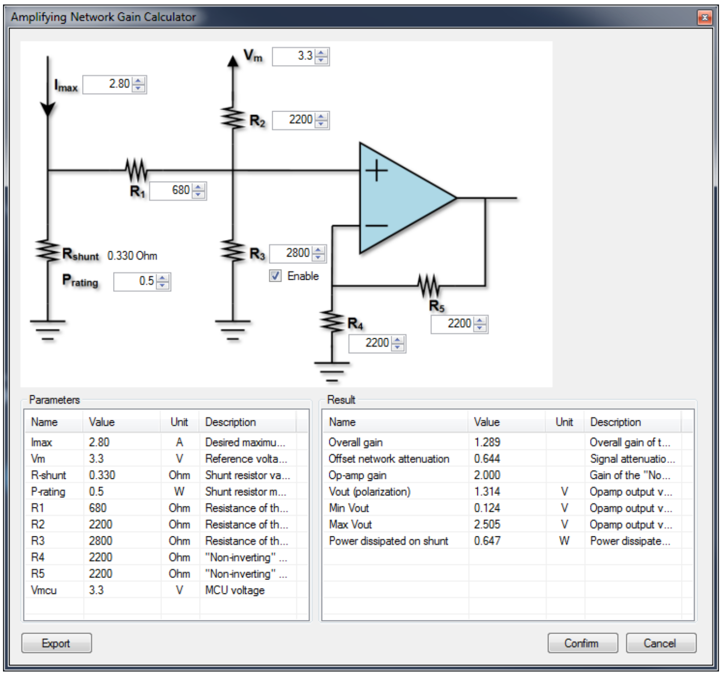


Figure 50 shows the *Amplifying Network Gain Calculator* GUI where the user configures the sensing implementation topology and related values.

Figure 50. ST MC Workbench - *Amplifying Network Gain Calculator* GUI



Note: All the needed firmware values are automatically computed.

Click on the Export button to save the configuration and generate an HTML page with the implementation and the computation reported. Click on the *Confirm* button to save the configuration. Click on the *Cancel* button to invalidate the modification. Both buttons close the window.

Figure 51 shows the *Over Current Protection* GUI, where the user configures the external over-current protection comparator settings. It illustrates the selection of the trigger input signal polarity from the related drop-down box. This value is also known as the over-current feedback signal polarity.

Depending on MC application software needs, the user can decide to use an output pin to disable this external OCP mechanism. In this case, the *Over-current protection disabling network* checkbox must be checked and the active signal polarity set.

If the internal comparator is used, refer to *Control stage*.

Figure 51. ST MC Workbench - *Over Current Protection* GUI

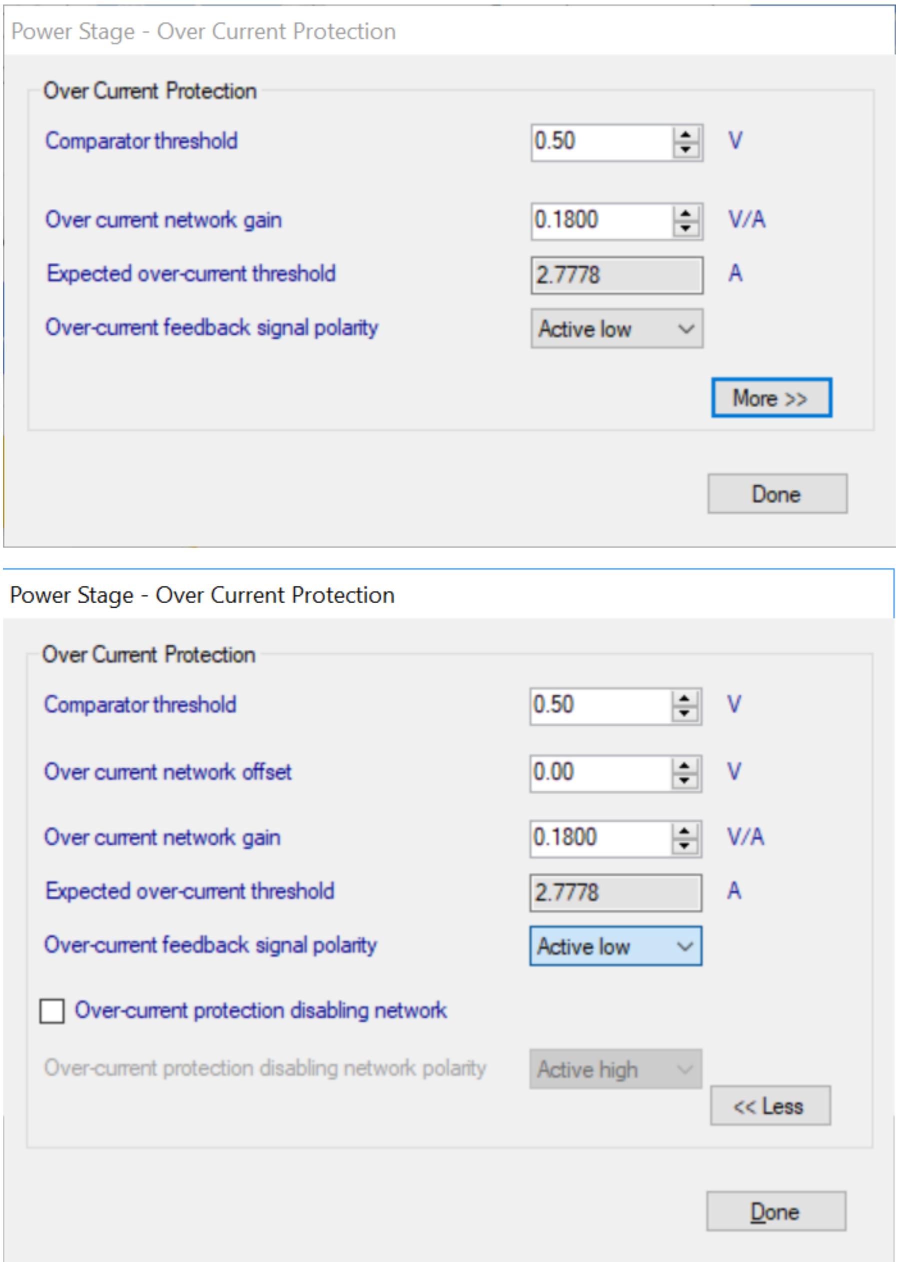
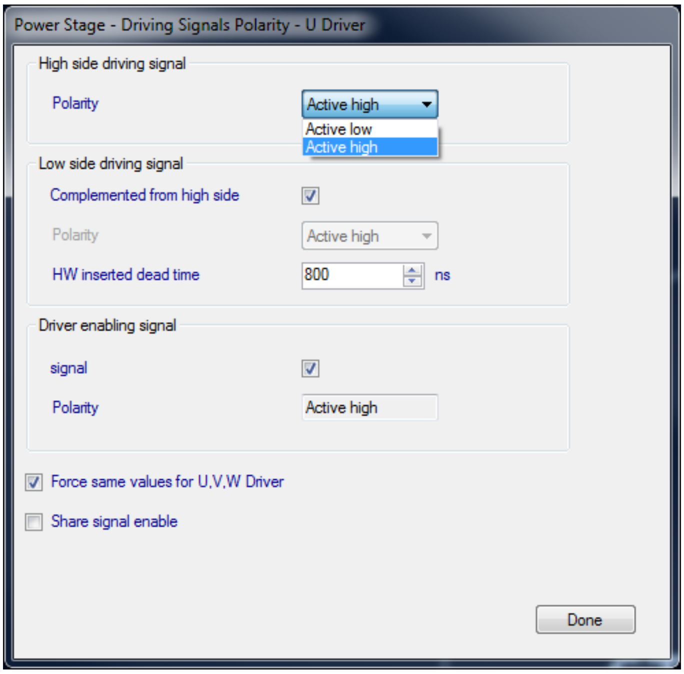


Figure 52 shows the *Power drivers* GUI where the user parameterizes each power driver (one per motor phase) with its high- and low-side values.

Figure 52. ST MC Workbench - Power drivers GUI



Note: The user can easily force the same settings for all three power drivers by ticking the “Force same values for U, V, W Driver” checkbox.

When the low-side driver is not hardware driven and complemented from the high side, the HW inserted dead-time definition is useless. Otherwise, the dead-time must reflect the implemented hardware electrical characteristics.

Select the *Share signal enable* checkbox to save the two other remaining Low side driver enabling pins (refer to *Control stage*).

Figure 53 shows the *Power Switches* GUI where the user configures the six power switches according to their electrical characteristics.

Figure 53. ST MC Workbench - *Power Switches* GUI

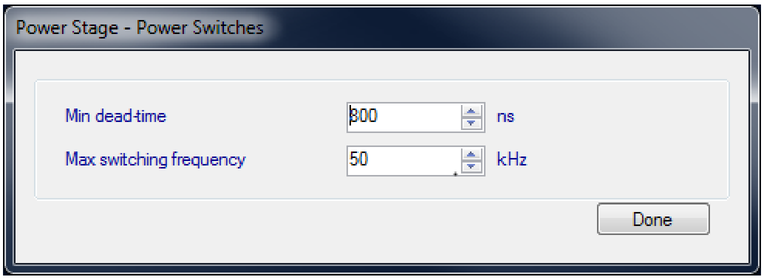


Figure 54 shows the *Dissipative Brake* GUI where the user selects the active signal polarity used for the braking usage.

Figure 54. ST MC Workbench - *Dissipative Brake* GUI

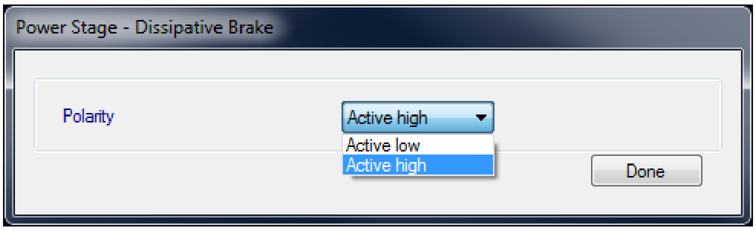


Figure 55 shows the *Inrush Current Limiter* GUI where the user selects the active signal polarity used for the Inrush Current Limiter. This GUI offers the possibility to configure the activation startup if needed.

Figure 55. ST MC Workbench - *Inrush Current Limiter* GUI

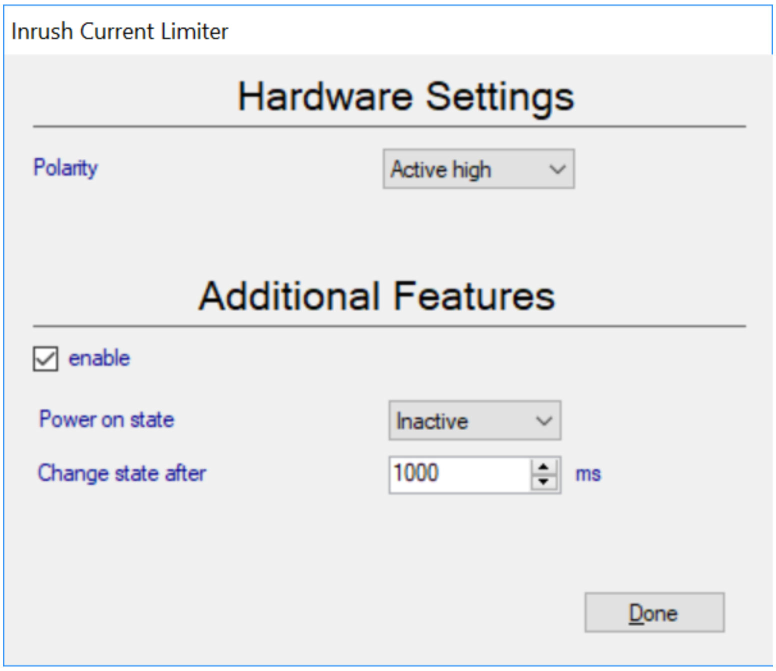


Figure 56 shows the *Power Factor Correction* GUI where the user reflects hardware settings and defines the PFC firmware parameters.

Figure 56. ST MC Workbench - *Power Factor Correction* GUI (Hardware Settings)

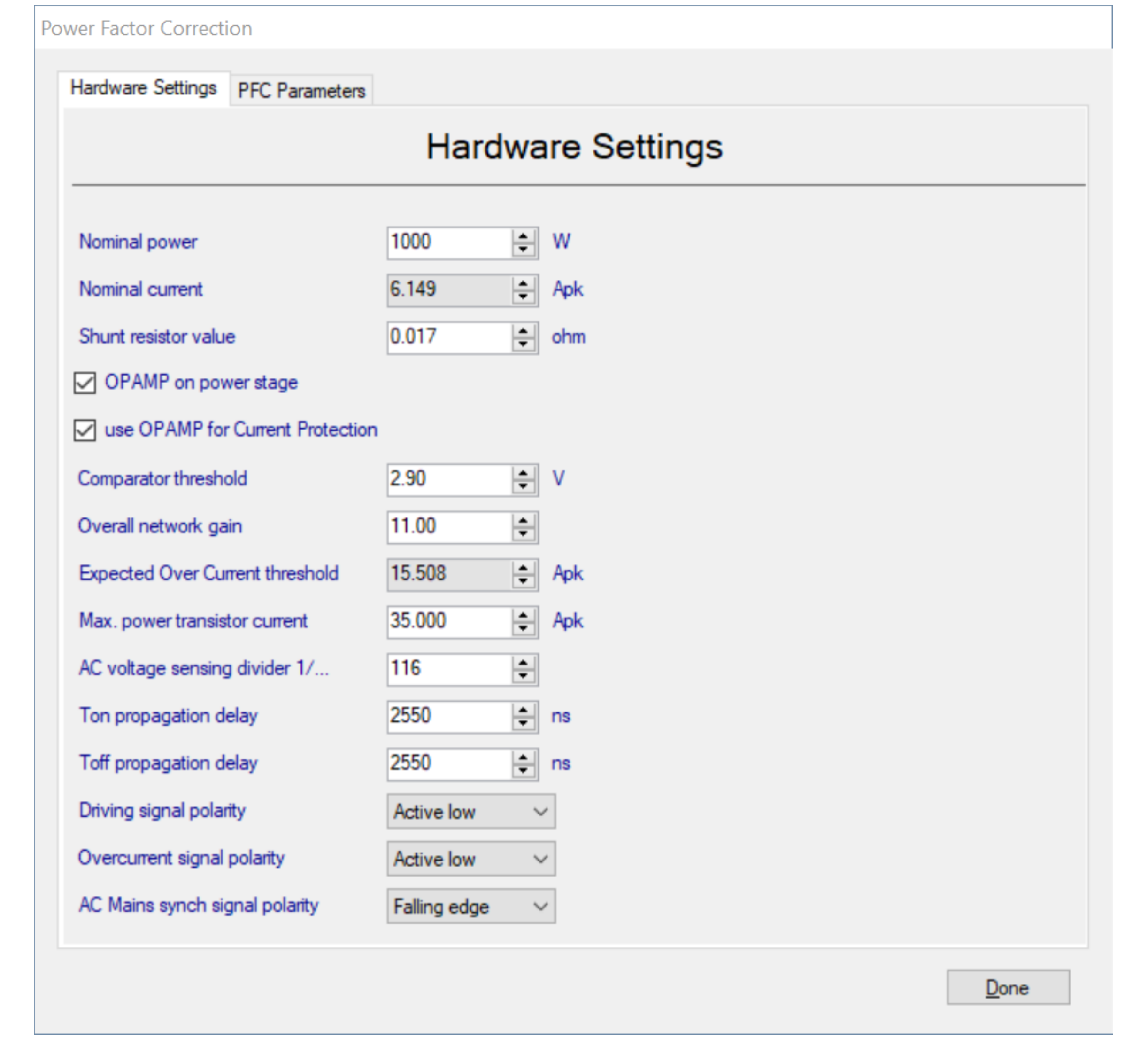
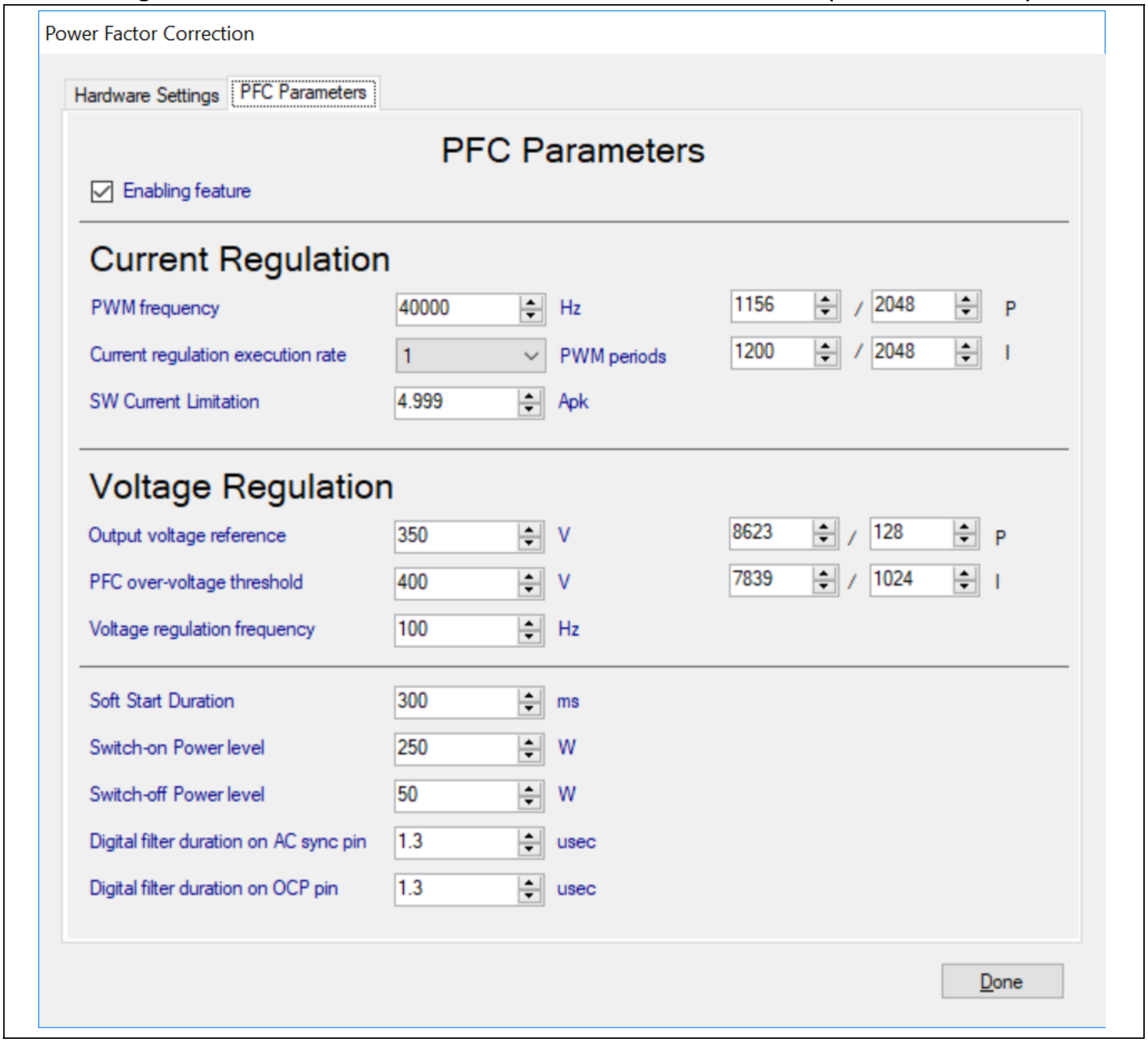


Figure 57. ST MC Workbench - *Power Factor Correction* GUI (PFC Parameters)

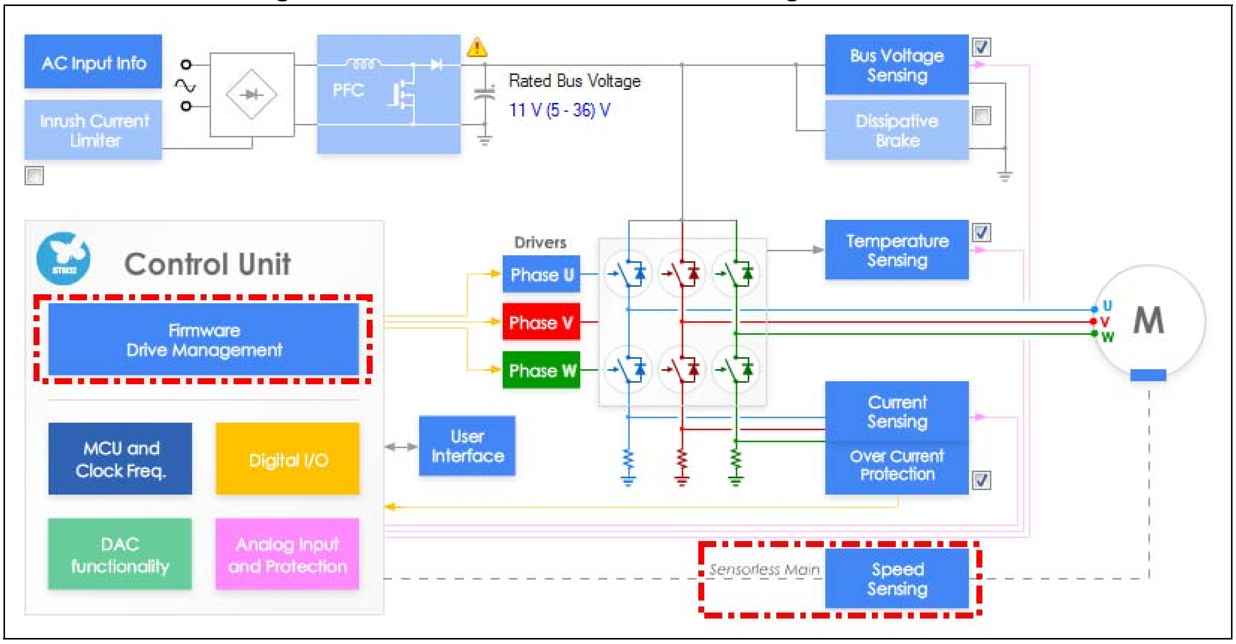


3.4.3 Drive management

Figure 58 shows the *Drive Management areas* used for the configuration. Clicking on the Firmware Drive Management box gives access to the configuration of:

- Speed/Position Feedback Management
- Drive Settings
- Sensing Enabling and Firmware Protections
- Start-up Parameters
- Additional Features and PFC settings
- FreeRTOS usage

Figure 58. ST MC Workbench - *Drive Management* window



The following figures detail the Speed/Position Feedback Management GUI, where the user selects and configures the sensor(-less) as the main one, and eventually the auxiliary as another one, measuring the motor speed or position.

- Through the Sensor-less (Luenberger observer + PLL) selection (*Figure 59*), user configures the sensor-less estimator. User may also customize the Luenberger observer and the PLL PI filters.
- Through the Sensor-less (Luenberger observer + Cordic) selection (*Figure 60*), user configures the sensor-less estimator. User may also customize the Luenberger observer PI filter.
- Through the Quadrature encoder selection (*Figure 61*), user parametrizes the sensor usage. User choses the counter direction.
- Through the Hall sensors selection (*Figure 62*), user parametrizes the sensor usage.
- Through the Auxiliary sensor tab, user selects and configures a second sensor(-less), measuring the motor speed or position. To avoid mistakes, user can select only the supported but remaining sensor(-less) when enabled (*Figure 63*).

Figure 59. ST MC Workbench – Speed/Position Feedback Management GUI (Sensor-less using Luenberger observer + PLL)

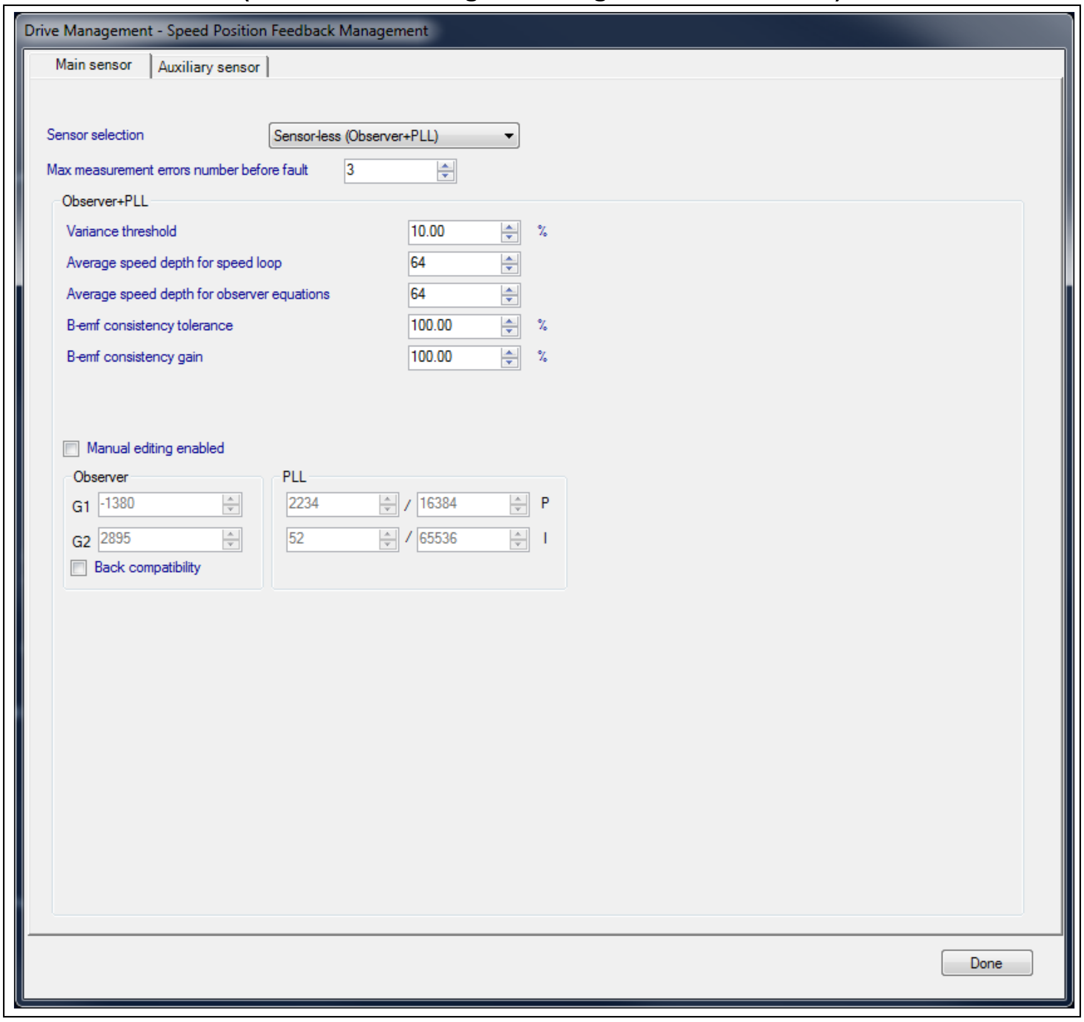


Figure 60. ST MC Workbench – Speed/Position Feedback Management GUI (Sensor-less using Luenberger observer + Cordic)

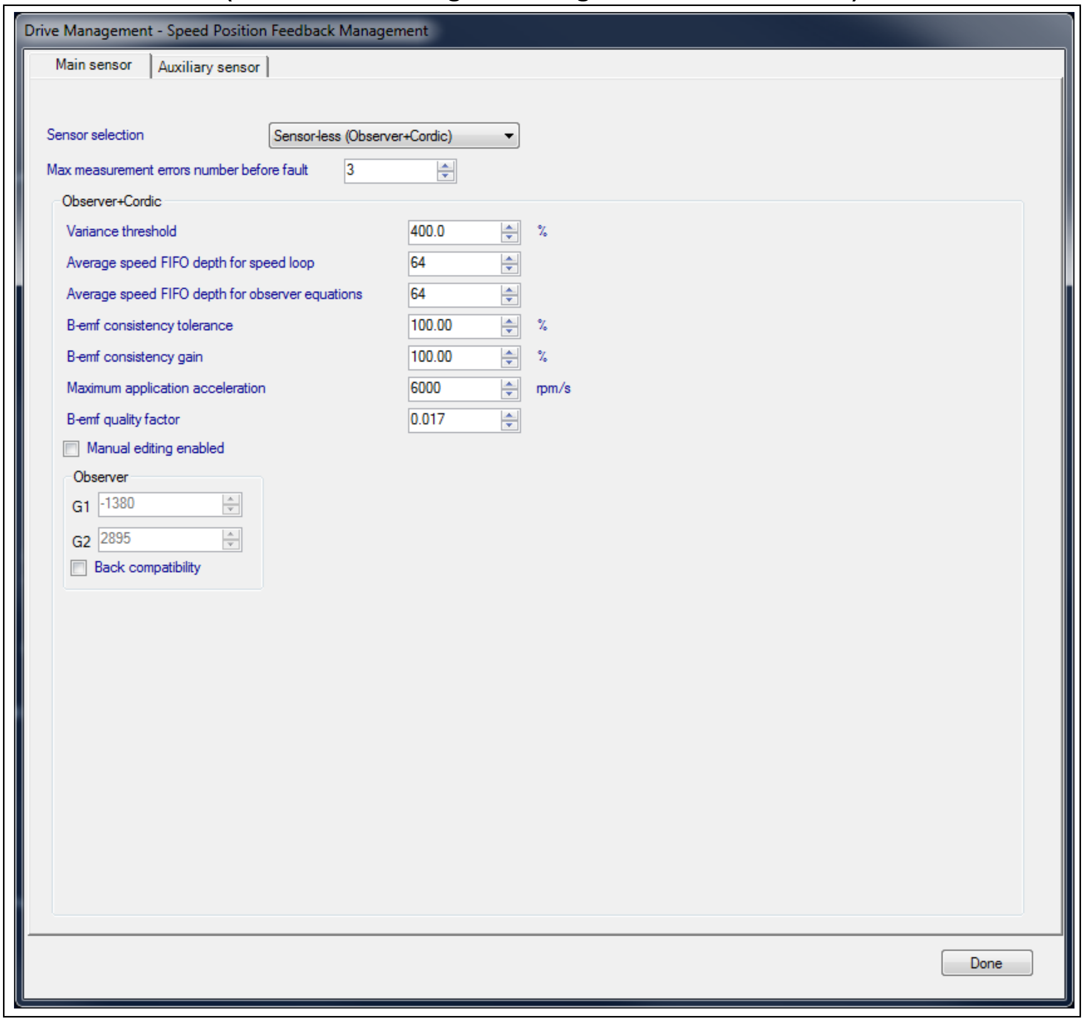


Figure 61. ST MC Workbench – Speed/Position Feedback Management GUI (Quadrature encoder)

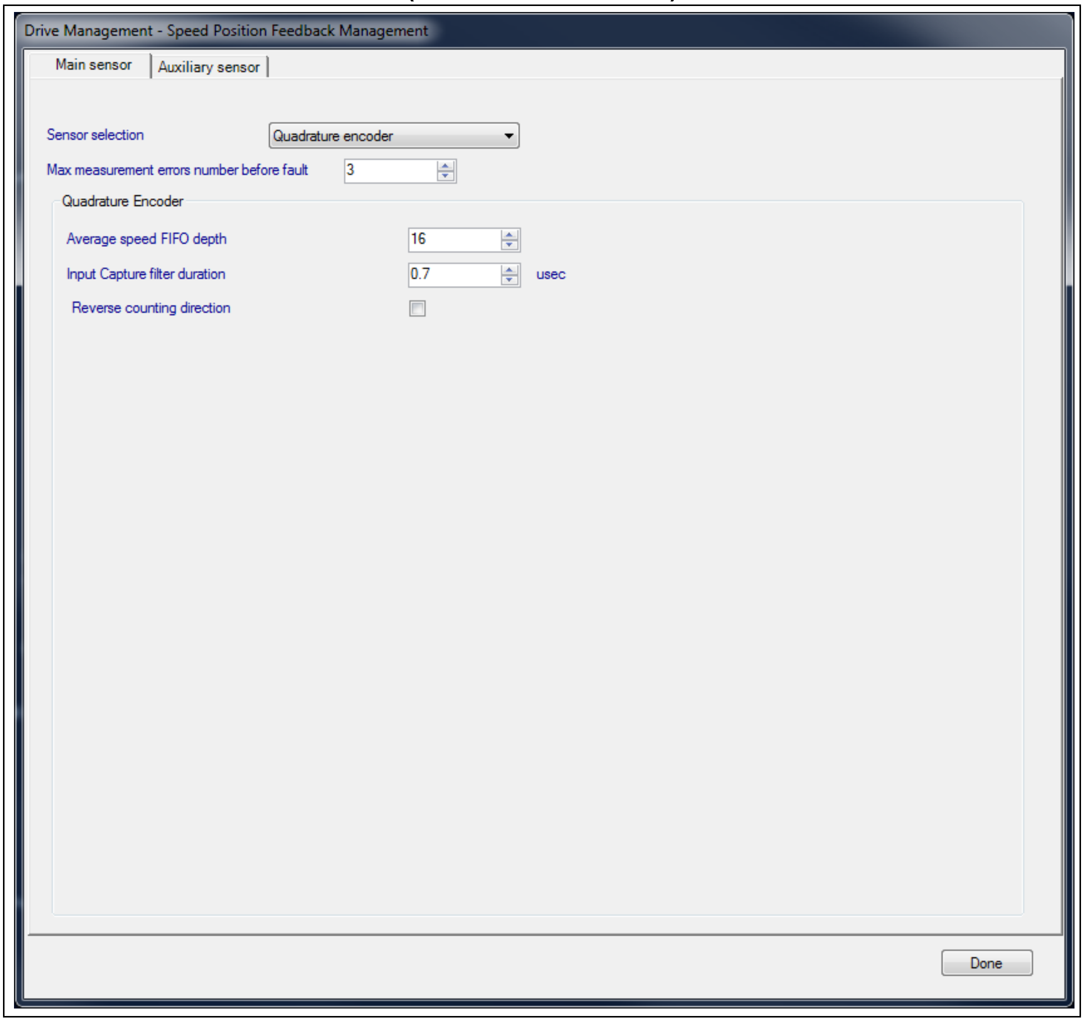


Figure 62. ST MC Workbench – Speed/Position Feedback Management GUI (Hall sensors)

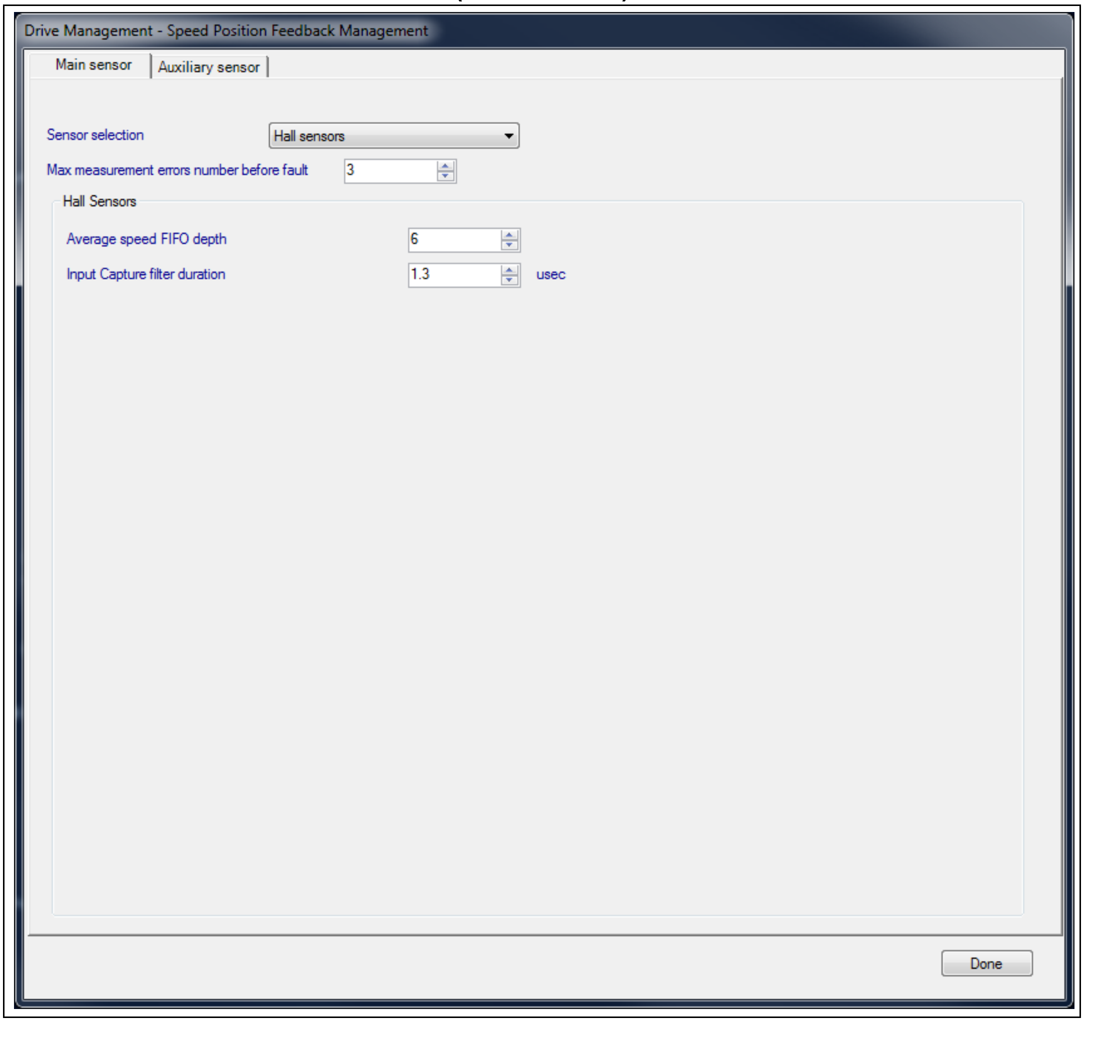


Figure 63. ST MC Workbench – Auxiliary sensor(-less) GUI

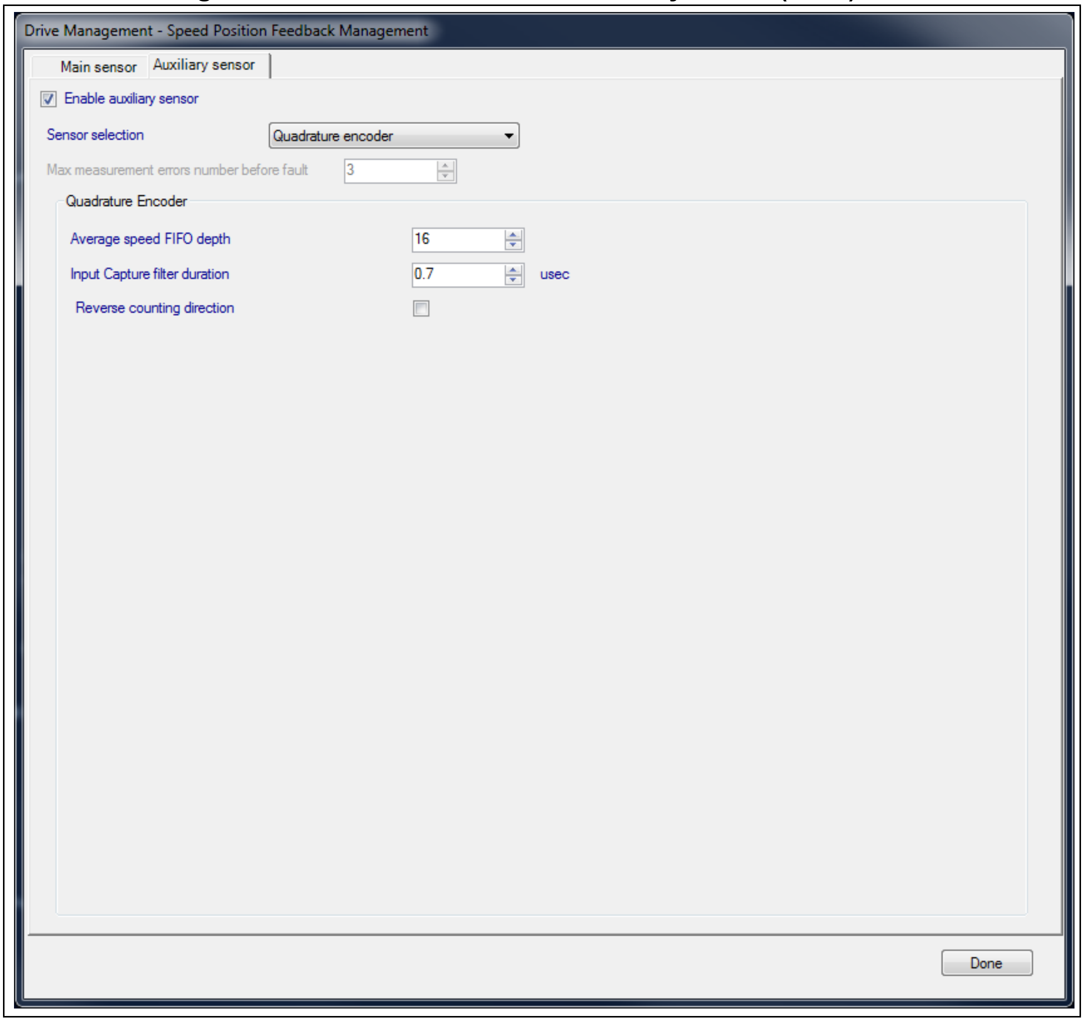
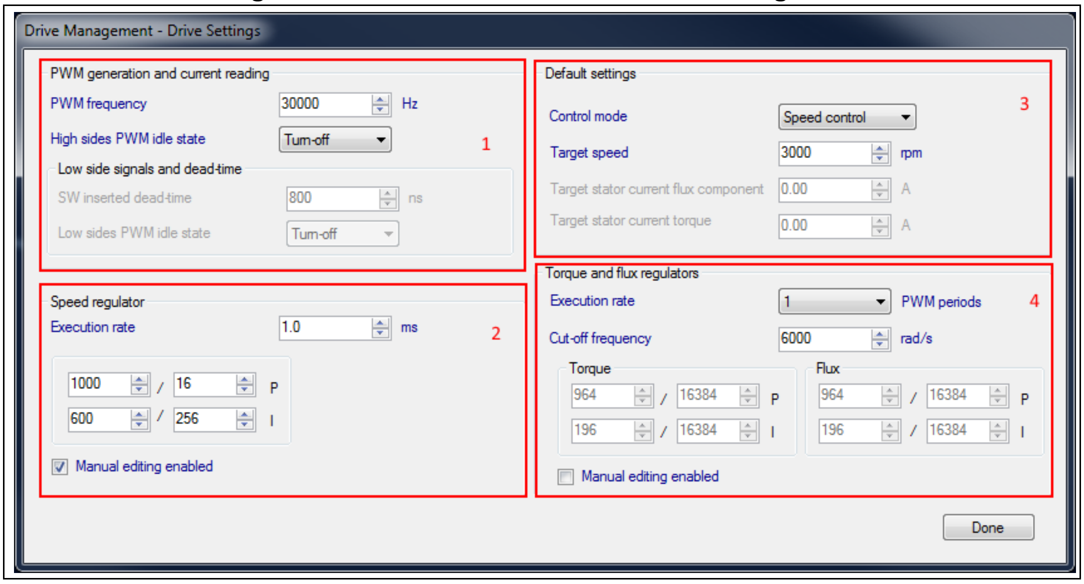


Figure 64 shows the Drive Settings GUI, where the user configures the PWM generation, the Speed or the Torque regulator, the Flux regulator and the default control settings.

Figure 64. ST MC Workbench – Drive Settings GUI



The PWM frequency is used to drive the power switches, while the PWM idle state for High and Low sides are usually Turn-Off (area 1).

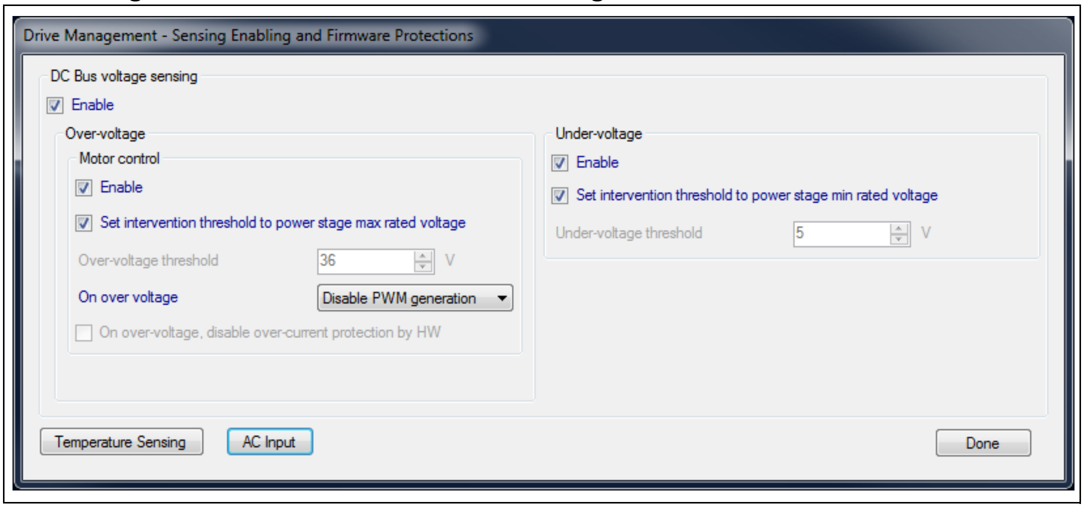
The Speed or the Torque regulator (areas 2 and 4) configures the algorithm execution rate (or Medium Frequency Task) linked with the Systick frequency usage. It is also the place where user may customize the Speed or the Torque PI filters.

User selects the default control mode (Speed or Torque) and its parameters in area 3.

The flux regulator (area 4) configures the motor flux control execution rate (or High Frequency Task) linked with the number of PWM periods. User may also customize this PI filter.

Figure 65 shows the Sensing and Firmware Protection GUI where the user configures the DC Bus voltage protection mechanism. From this interface the user can recall the other protection mechanism GUI, Temperature and AC Input voltage.

Figure 65. ST MC Workbench – Sensing and Firmware Protection GUI



The following figures show the Start-Up Parameters GUI, where the user customizes the motor ramp-up phase during a start-up sequence. User chooses between normal Rev-Up or On-the-Fly start-up, and between Basic or Advanced profiles.

- Through the Basic Rev-Up phase (*Figure 66*), user defines the motor speed ramp and its current consumption during that timeframe. When enabled, he also defines the transition duration between the open-loop and the close-loop.
- Through the Basic On-The-Fly phase (*Figure 67*), user defines the motor speed ramp and its current consumption during that timeframe. Then, he also provides the speed detection duration for the estimator convergence before testing the loop closure.
- Through the Advanced Rev-Up phase (*Figure 68*), user defines up to five ramps for the motor speed and its current consumption during a provided duration. Then, user choses the first ramp to start from. When enabled, he also defines the transition duration between the open-loop and the close-loop.
- Through the Advanced On-The-Fly phase (*Figure 69*), user defines up to three ramps for the motor speed and its current consumption during a provided duration. Then, user also provides the speed detection duration for the estimator convergence before testing the loop closure.

During this ramp-up phase, the loop is tested as a closed one when the estimated speed range is within the provided variance (band tolerance). It is based from a minimum output speed. User defines the number of consecutive passed tests to consider the loop as closed.

Figure 66. ST MC Workbench – Start-Up Parameters GUI (Basic Rev-Up)

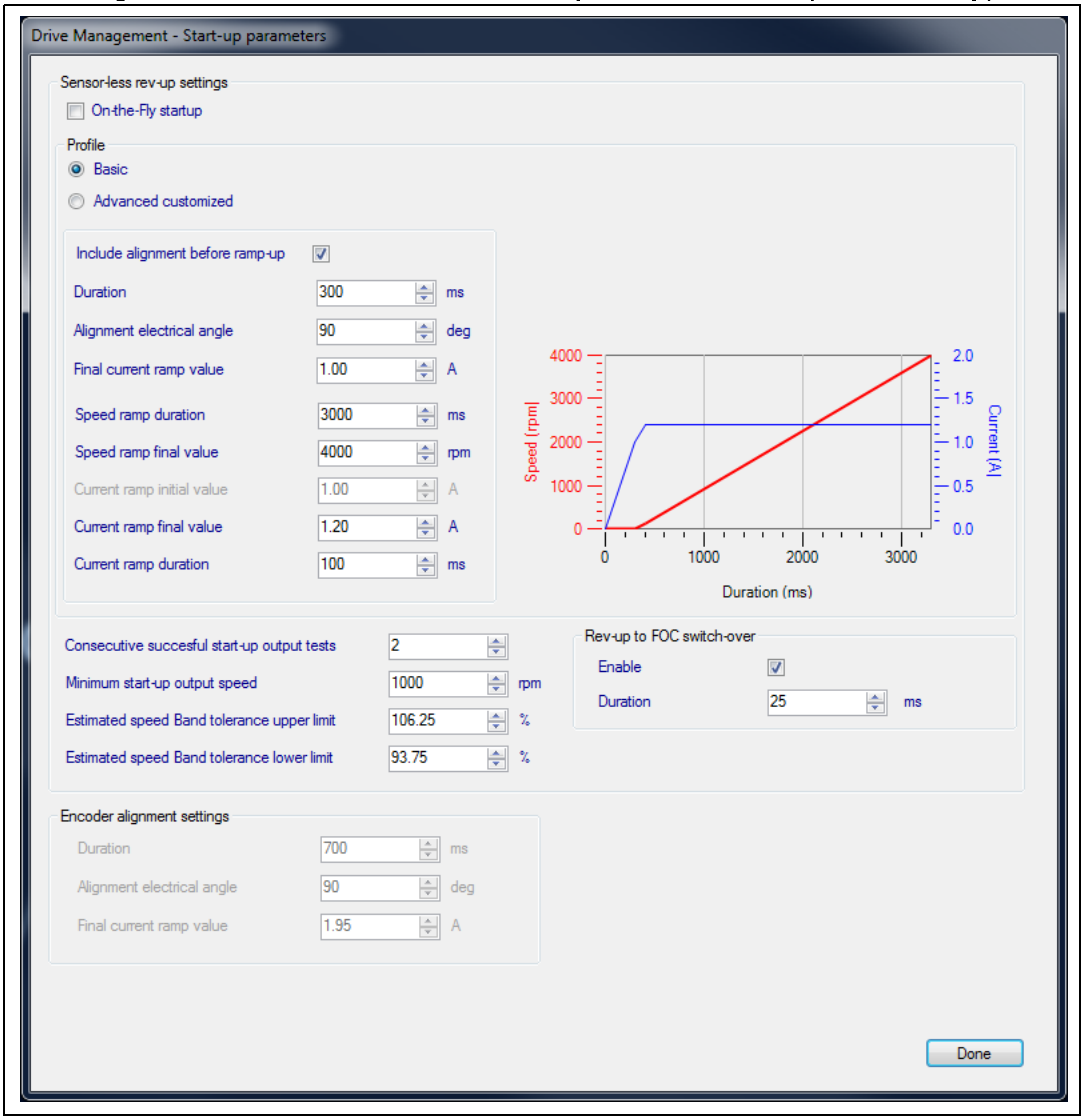


Figure 67. ST MC Workbench – Start-Up Parameters GUI (Basic On-the-Fly)

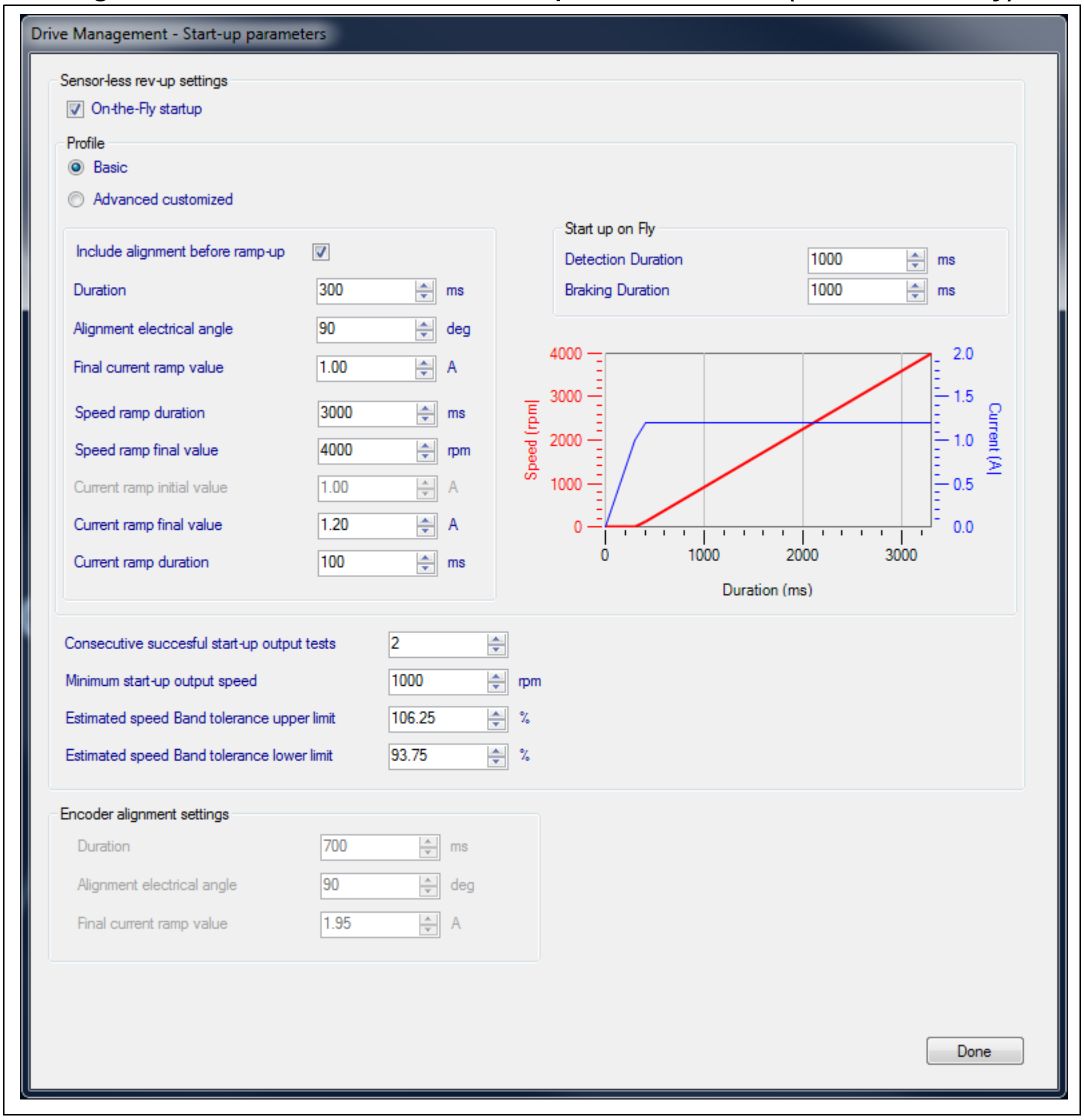


Figure 68. ST MC Workbench – Start-Up Parameters GUI (Advanced Rev-Up)

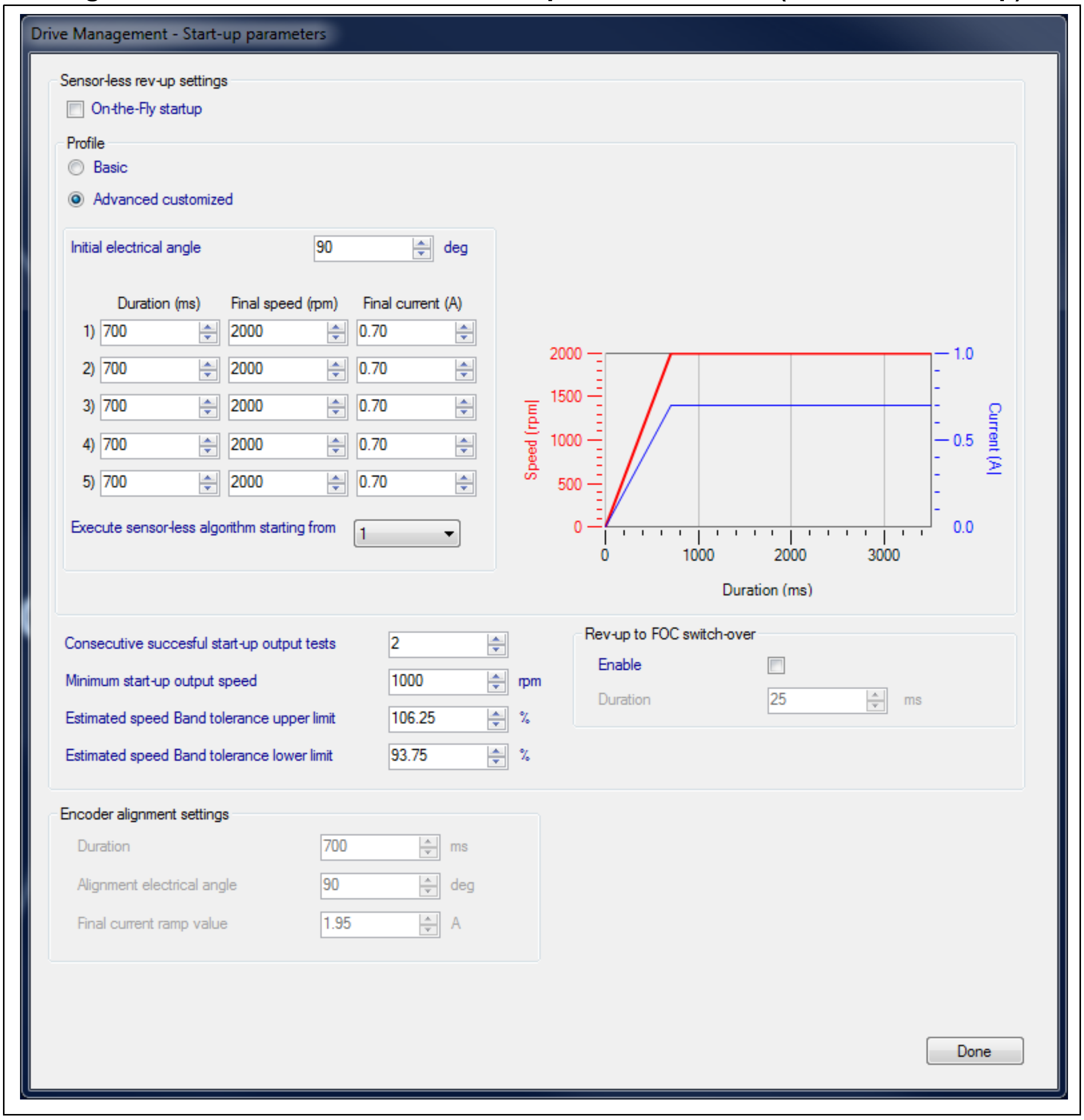


Figure 69. ST MC Workbench – Start-Up Parameters GUI (Advanced On-the-Fly)

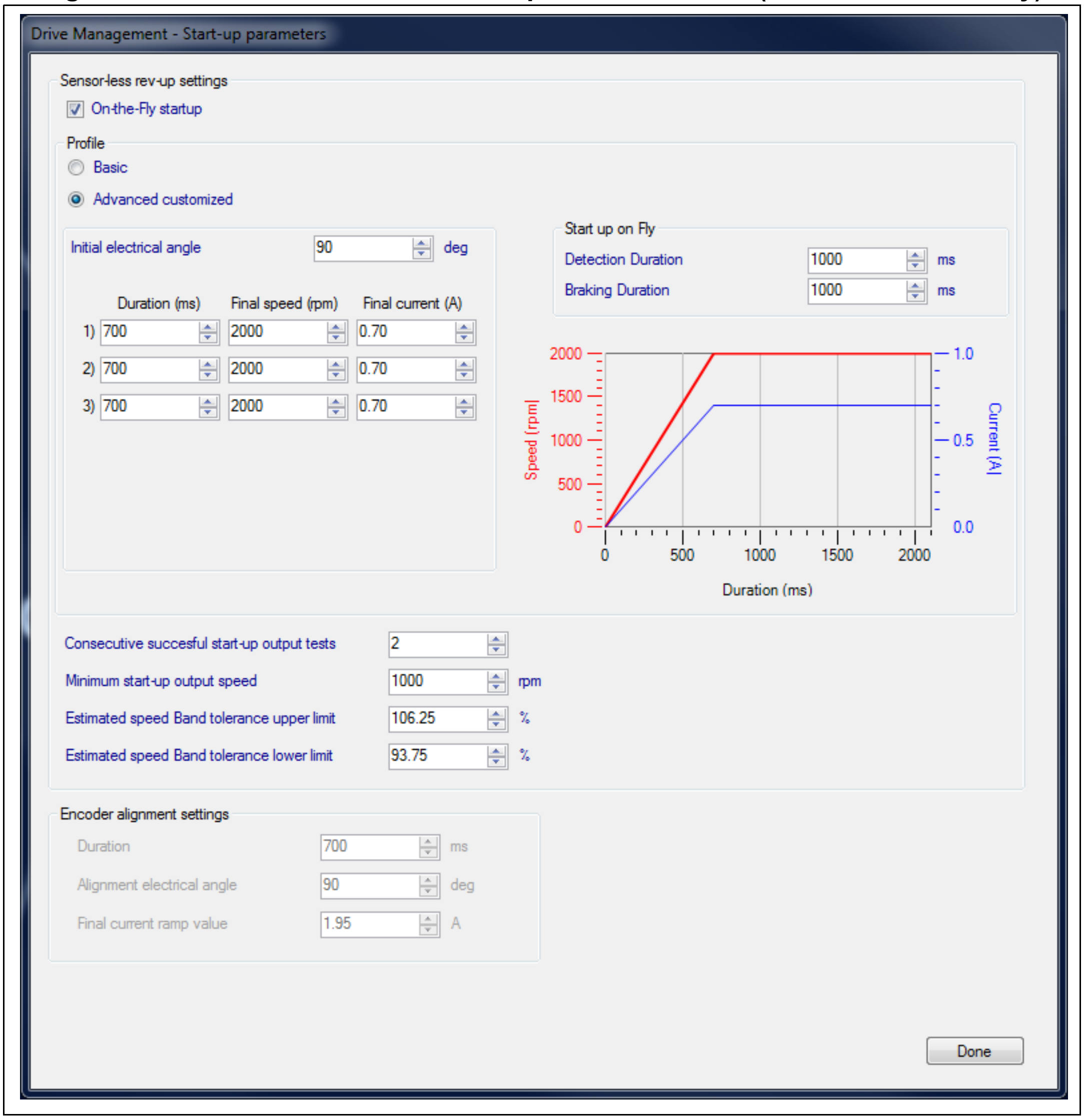


Figure 70 shows the Additional Features and PFC settings GUI, where the user selects the additional features usable for its motor control.

Note that when the Flux Weakening feature is selected, user parametrizes the PI filter, as well as the upper limit of the voltage to apply.

The Inrush Current Limiter button is popping-up the GUI shown in *Figure 55*.

Figure 70. ST MC Workbench – Additional Features and PFC settings GUI

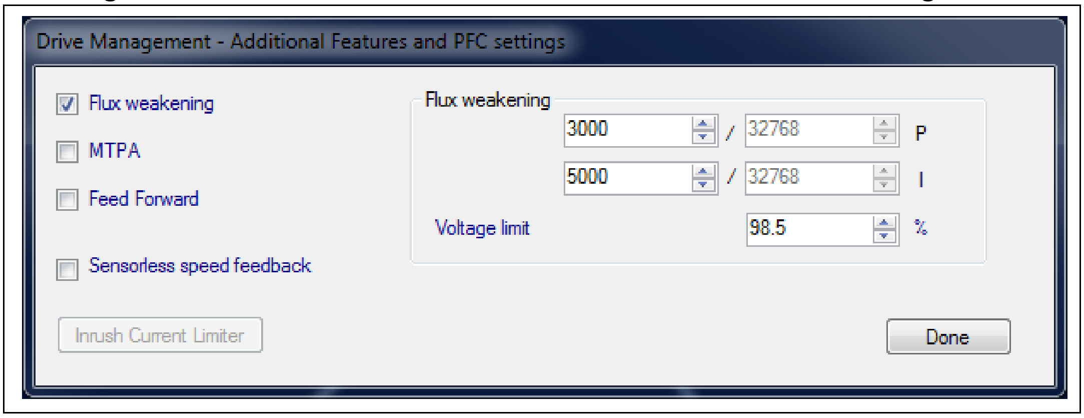
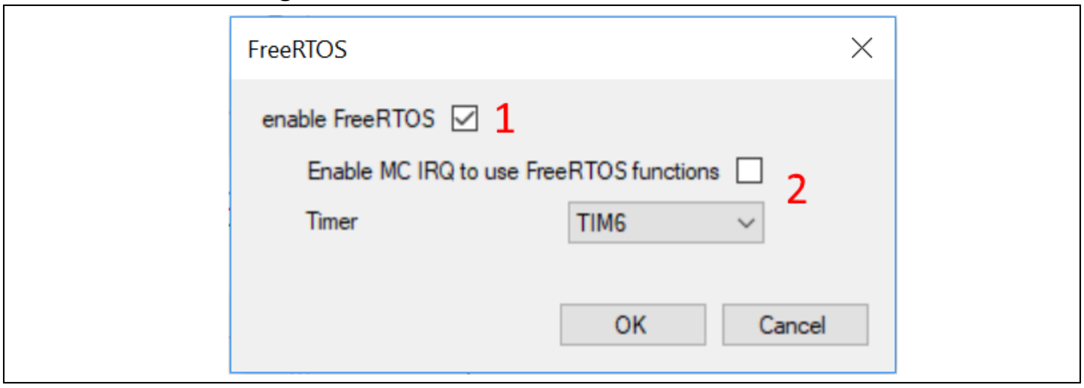


Figure 71 shows the FreeRTOS GUI, where the user enables and configures, Timer and IT usage supporting the OS, for its motor control application.

Figure 71. ST MC Workbench - FreeRTOS GUI



3.4.4 Control stage

Figure 72 shows the *Control Stage* window used for the configuration of:

- MCU and clock frequency
- Analog input and protection
- DAC functionality
- Digital I/O
- User interface

Figure 72. ST MC Workbench - *Control Stage* window

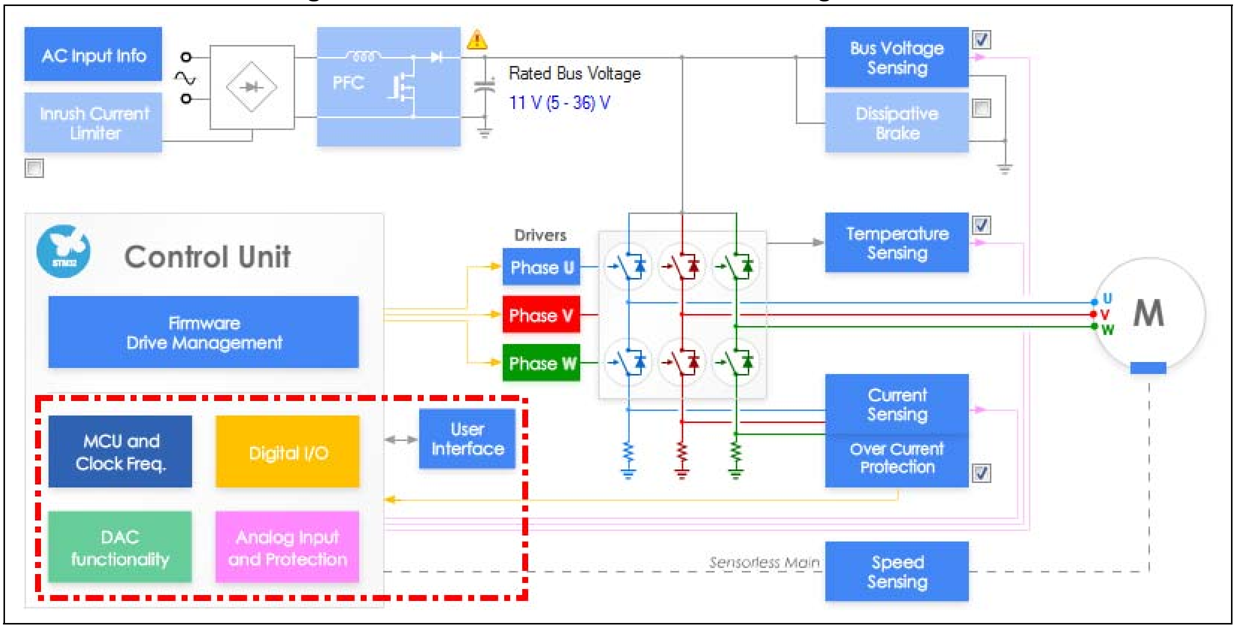


Figure 73 shows the MCU and Clock Frequency GUI, where the user selects the MCU used, as well as its clocking information.

Figure 73. ST MC Workbench – MCU and Clock Frequency GUI

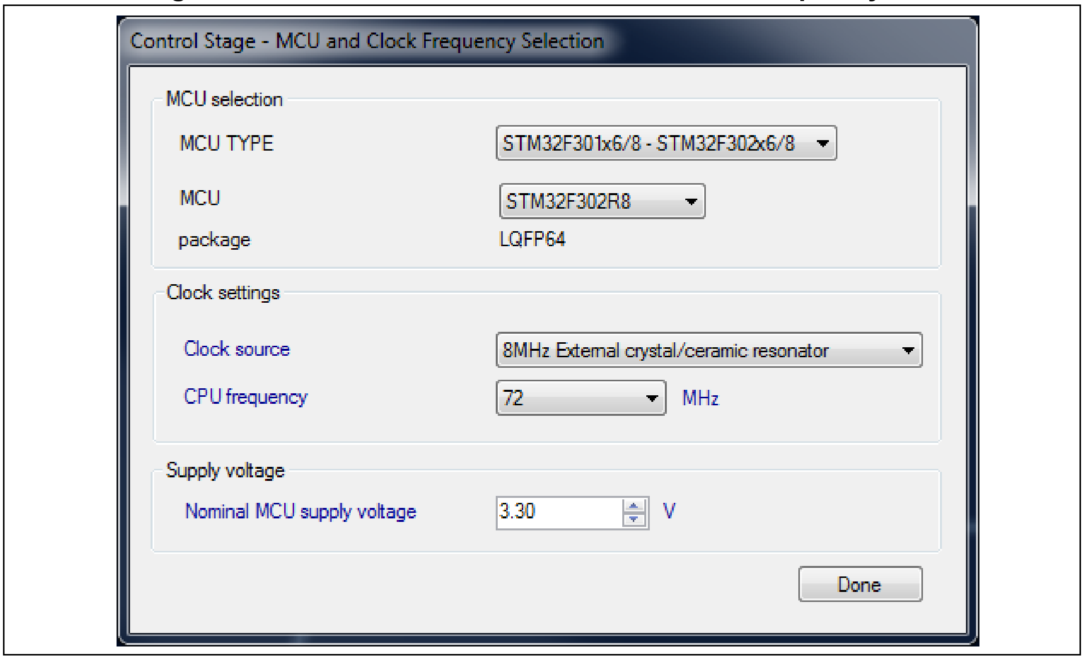
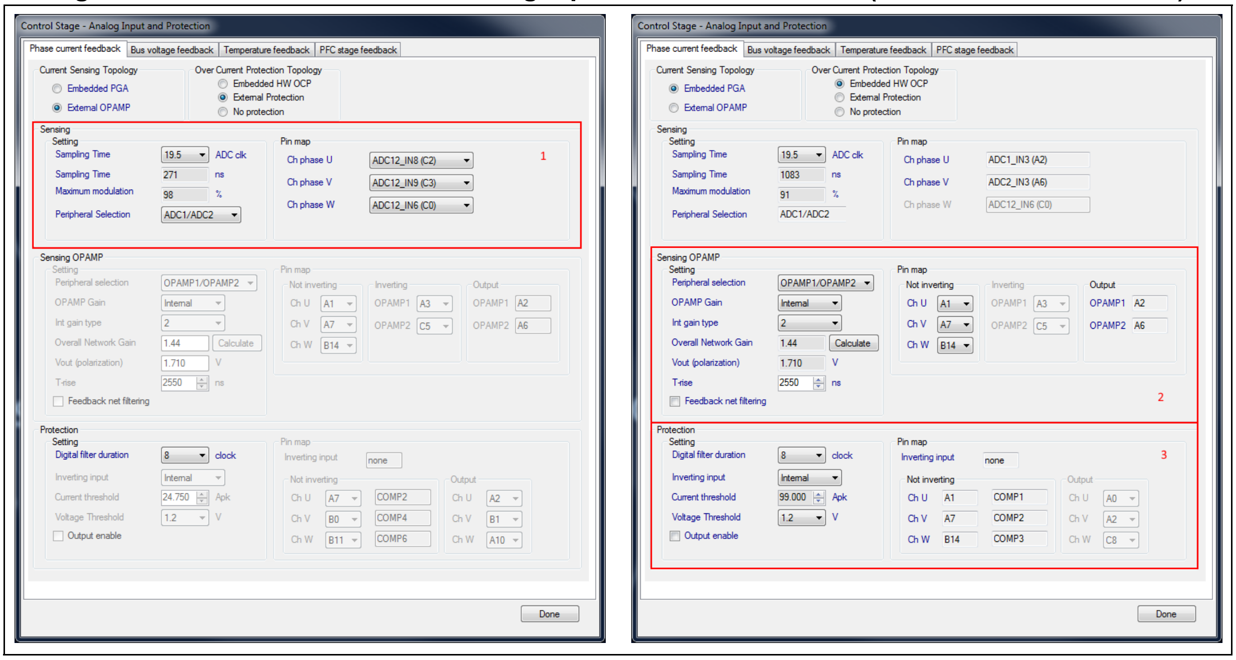


Figure 74 shows the Analog Input and Protection GUI, where the user selects the MCU pin assignments and configures the analog input parameters.

Figure 74. ST MC Workbench – Analog Input and Protection GUI (Phase current feedback)



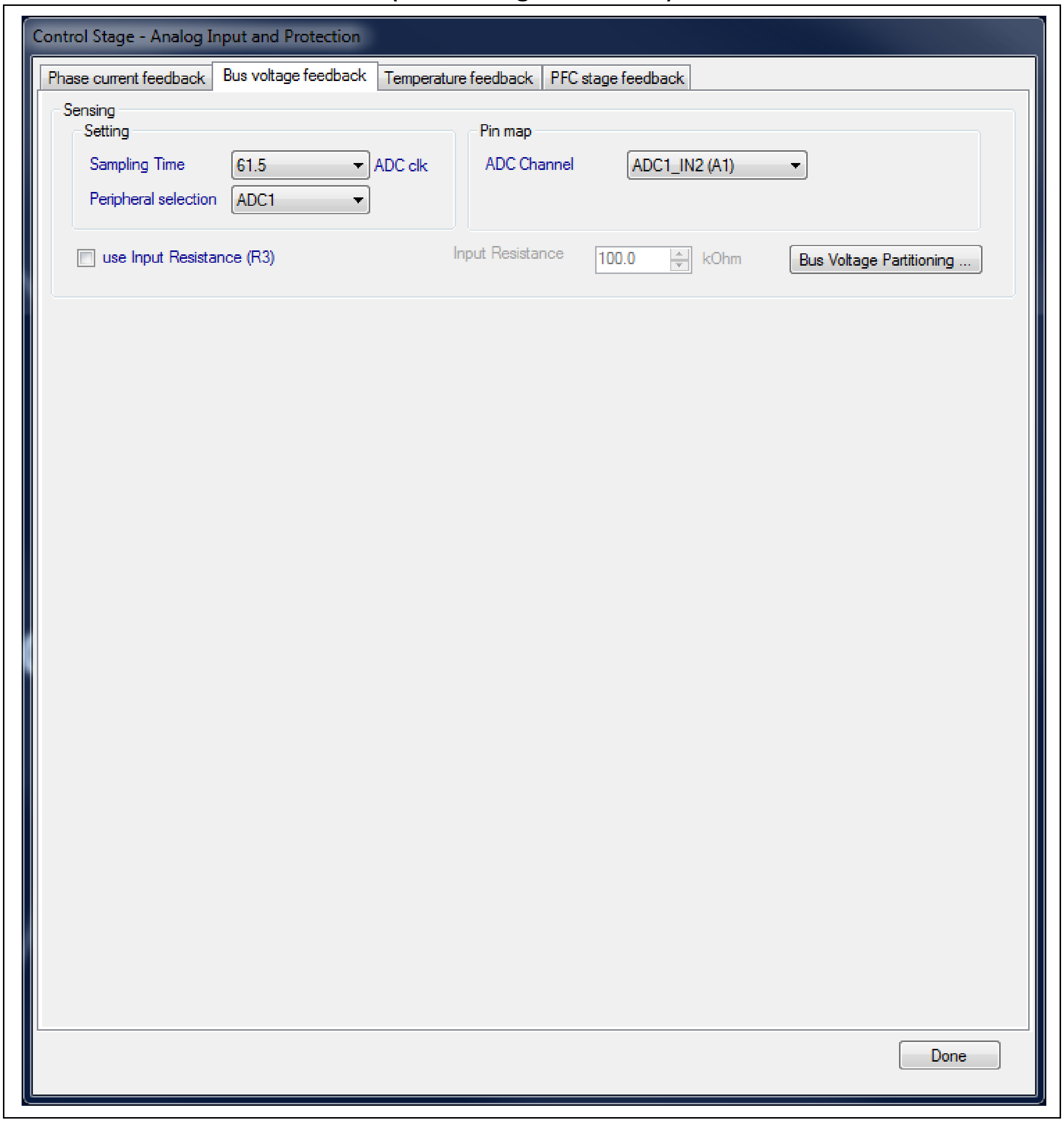
Through the Phase current feedback tab, the user

- Configures and selects the ADC for the motor current acquisition, as well as its pins usage (area 1). Note that the GUI reflects either the 1- or the 3-shunt topology selected.
- Configures the current sensing topology
  - internal (Embedded PGA), area 2: user selects and sets the MCU Op-Amp usage as well as the pin assignments, and defines the overall network gain (thanks to the Calculate button that pops-up the GUI shown in *Figure 50*).
  - external (operational amplifier) to the MCU
- Configures the over-current protection topology:
  - no protection
  - internal (embedded HW OCP), area 3: user sets the MCU comparator usage as well as the pin assignment
  - external to the MCU (only the Digital filter duration is required)

Through the Bus voltage feedback tab (*Figure 75*), user selects and configures the ADC for the DC bus voltage acquisition as well as its input pin usage.

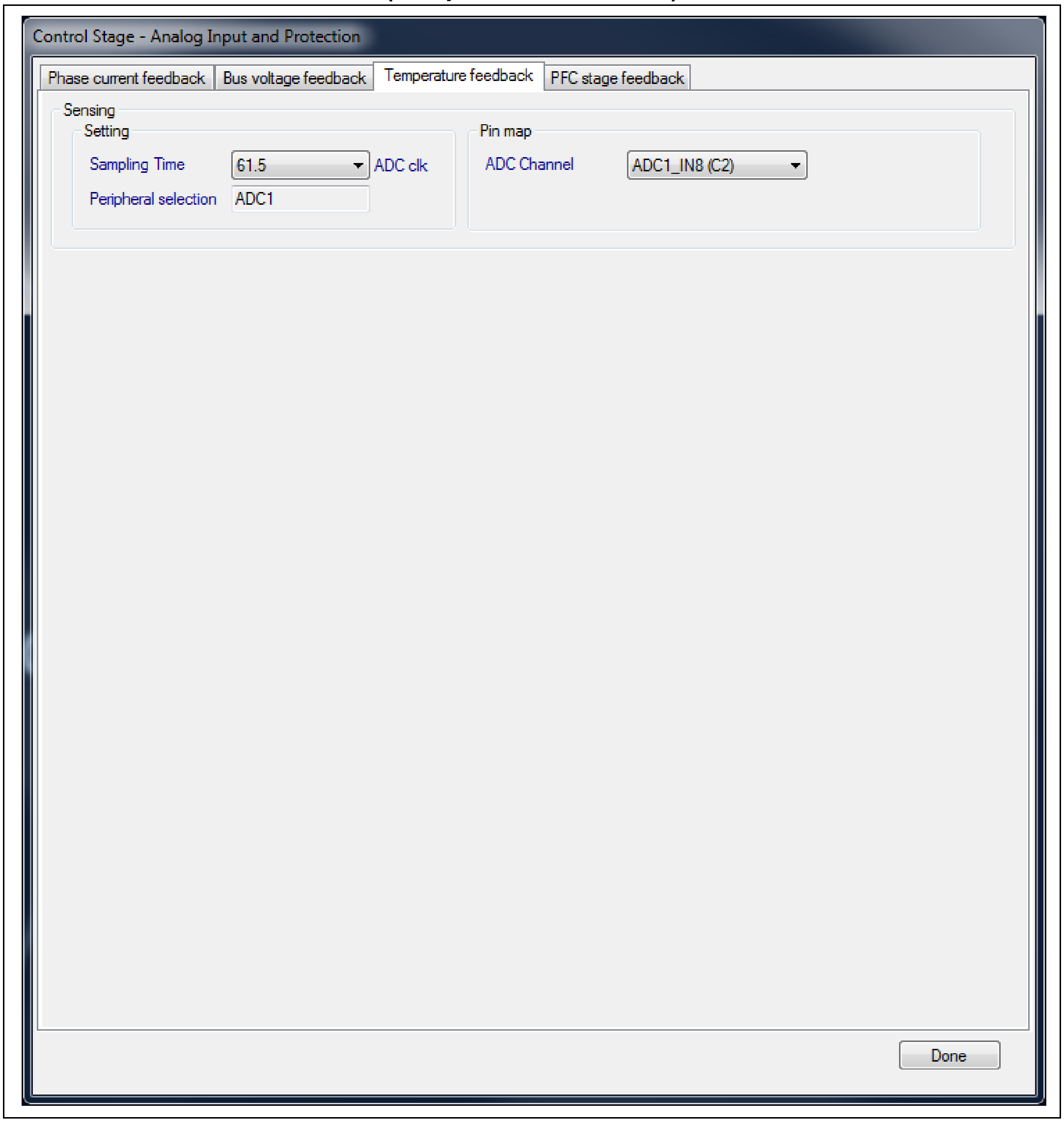
A click on the Bus Voltage Partitioning button pops-up the GUI shown in *Figure 47*.

Figure 75. ST MC Workbench – Analog Input and Protection GUI (Bus voltage feedback)



Through the Temperature feedback tab (*Figure 76*), user selects and configures the ADC for the temperature image acquisition (usually an NTC resistor) as well as its input pin usage.

Figure 76. ST MC Workbench – Analog Input and Protection GUI (Temperature feedback)



Through the PFC stage feedback tab (*Figure 77*), user selects and configures the ADC for the PFC current sensing and the AC voltage sensing, as well as their input pins usage.

Figure 77. ST MC Workbench – Analog Input and Protection GUI (PFC stage feedback)

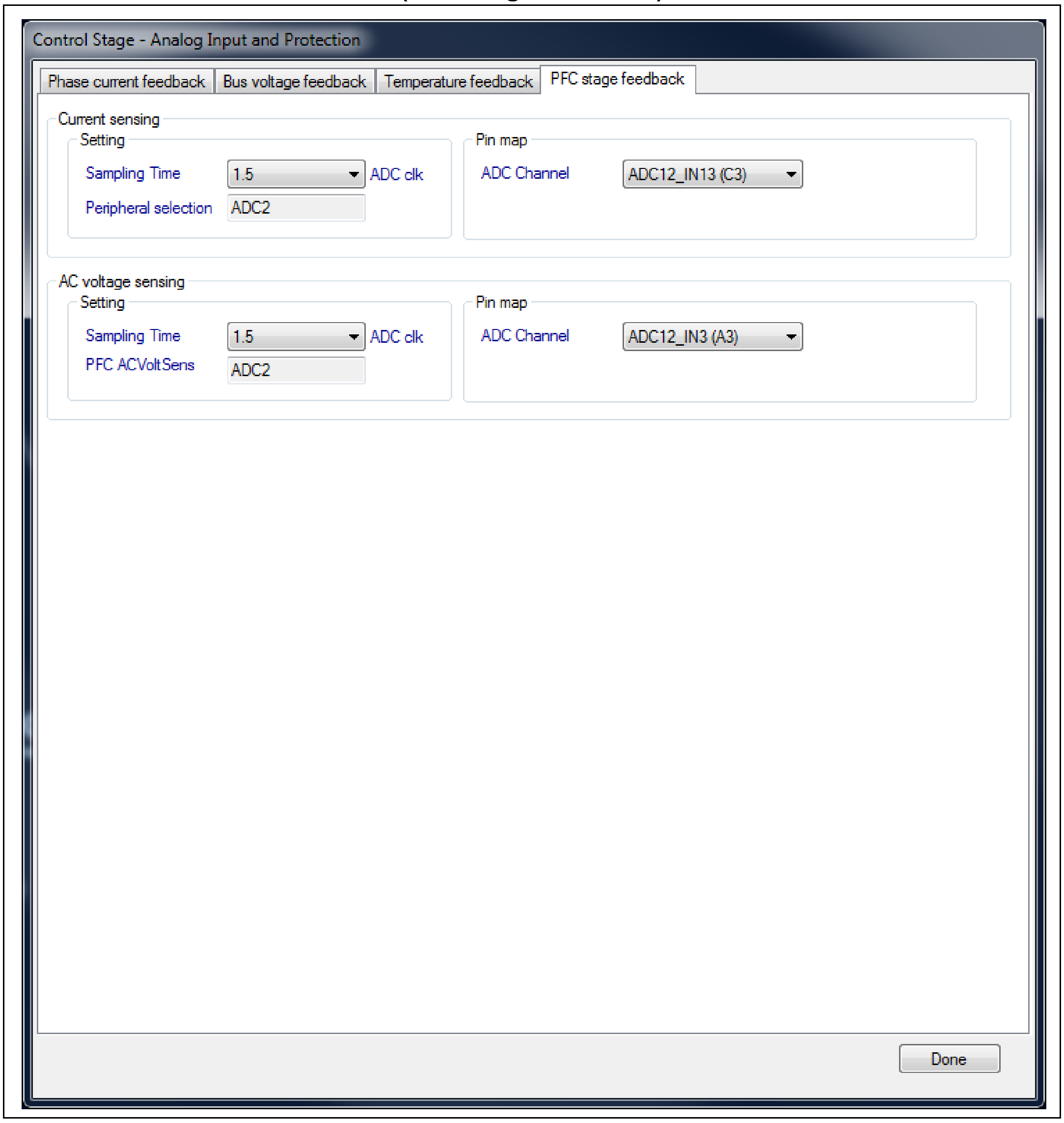


Figure 78 shows the DAC functionality GUI, where the user selects the DAC channel used for debug (if any) and the data to output.

Figure 78. ST MC Workbench – DAC functionality GUI

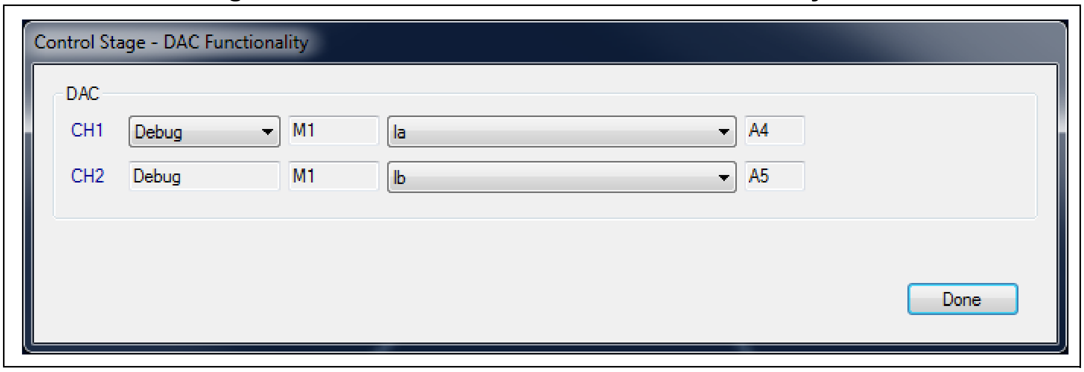


Figure 79 shows the Digital I/O GUI, where the user configures the Timers used to

- control the power switches
- control the PFC driver
- configure the serial communication link for the UART
- interface the Encoder or the Hall sensors for the speed/position acquisition
- configure the Inrush Current Limiter.

Figure 79. ST MC Workbench – Digital I/O GUI

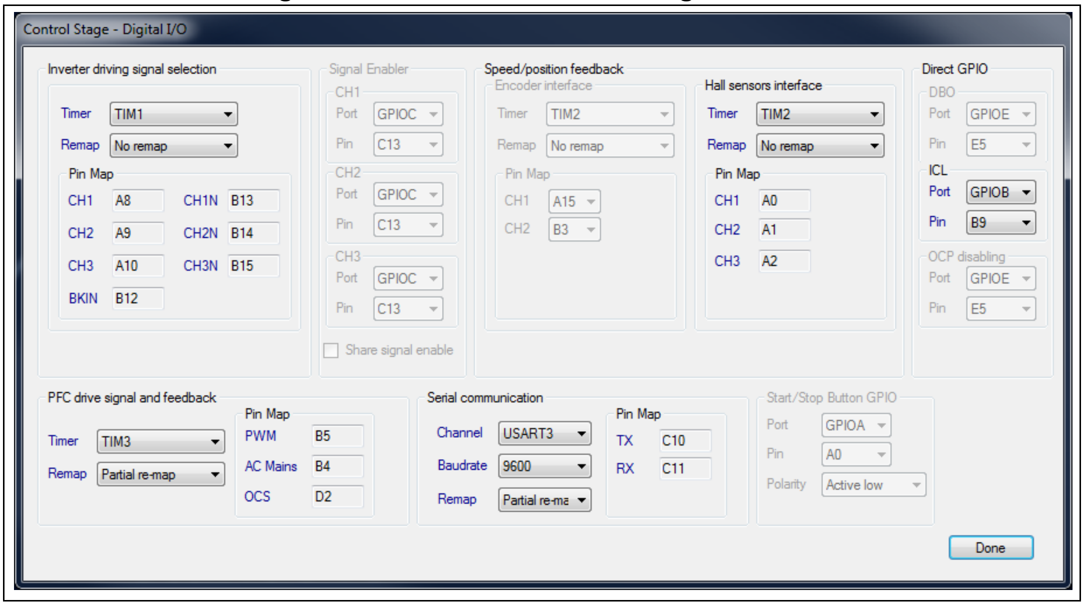
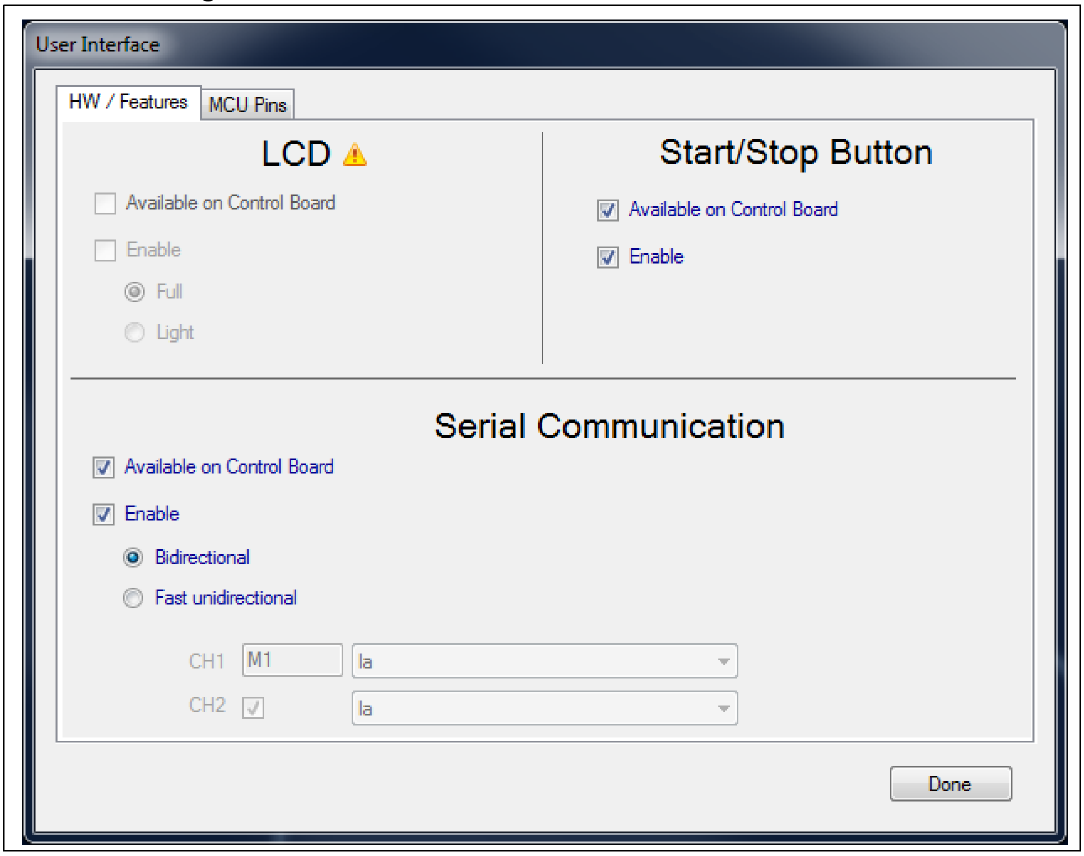


Figure 80 shows the User Interface Add-on GUI, where the user configures the interface for the control board usage: LCD (if supported), a Start/Stop push-button, and/or the serial communication link with software application.

Figure 80. ST MC Workbench – User Interface Add-on GUI



3.5 Main hardware settings

At a first glance, the user can view the main hardware settings reflecting all the main parameters as follows:

- PWM frequency used
- Main sensor usage selected
- Auxiliary sensor usage selected when the hardware setup supports it
- Torque and flux execution rate: it is the number of PWM periods executed during only one complete FOC algorithm execution
- Bus voltage sensing enabled/disabled
- Over-voltage detection enabled/disabled
- Under-voltage detection enabled/disabled
- Temperature sensing enabled/disabled
- Current reading topology selection

The hardware setting area is shown in *Figure 81*.

Figure 81. ST MC Workbench - Main hardware setting area

Variable	Motor	Unit
PWM frequency	30000	Hz
Sensor selection main	Sensor-less (Observer+PLL)	
Sensor selection aux	Sensor-less (Observer+Cordic)	
Torque&Flux - Execution rate	1	PWM periods
Bus voltage sensing	true	
Over-voltage	true	
Under-voltage	true	
Temperature sensing	true	
Current reading topology	Three Shunt Resistors	

Double clicking on any of the parameters in the *Motor* column directly displays the full configuration GUI (refer to *Section 3.4*).

Note: This sheet is not configurable.

3.6 User information

A user information sheet provides feedback about user's action:

- The *Info / Errors / Warnings* tab reflects the project settings or MC controls performed and the resulting outcomes. This tab can only be cleaned
- The *Change Log* tab reflects the hardware setting modifications done

The user information area is shown in *Figure 82*.

Figure 82. ST MC Workbench - User information area

Time	Motor	Id	Message
11:59:02			The 'LCD' is not supported in the FW for SDK5.0. All parameters will be disabled.
11:59:02			The 'PFC' is not supported in the FW for SDK5.0. All parameters will be disabled.
11:59:02			The 'Sensor-less (HFI+Observer)' is not supported in the FW for SDK5.0. All parameters will be disa...
11:59:02			F1 F2 mcu are not supported in the FW for SDK5.0
11:59:02			Working folder is set to C:\WorkSpace\SDK5.0.0

Info / Errors / Warnings | Change Log

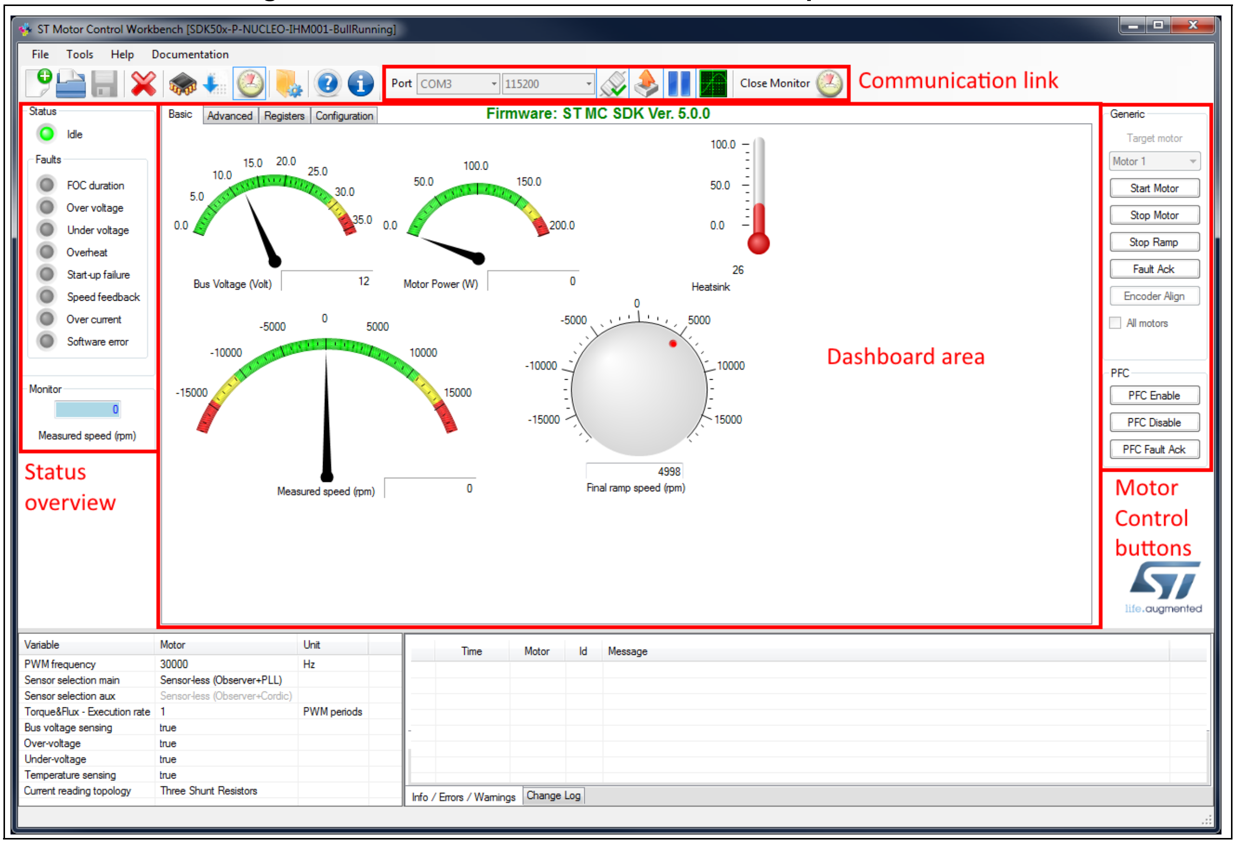
3.7 Motor monitoring and spinning

Caution: By default, ST MC FOC firmware embeds the needed code to dialog with the ST MC Workbench software tool. This section only applies if this code is embedded in the motor control application software.

Figure 83 shows the monitor and spin control GUI, which a user can use to observe and modify some MC parameters and to fine tune its MC application software through several areas:

- Communication link area: used to setup the connection with the board, connect to the board, or disconnect from the board. It is also used for reading, writing or plotting data, as well as for closing the GUI
- Dashboard area: the adaptive dashboard area reflects the user experience in several ways:
  - Basic
  - Advanced
  - Expert (register and configuration tabs)
- Motor Control buttons area: used to command the hardware setup
- Status overview area: used to monitor hardware setup at a glance

Figure 83. ST MC Workbench - Monitor and spin control GUI



3.7.1 Communication link

The communication link area (refer to *Figure 83*) features several functions, listed in *Table 4*.

Table 4. ST MC Workbench - Communication link GUI commands

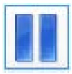
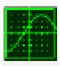
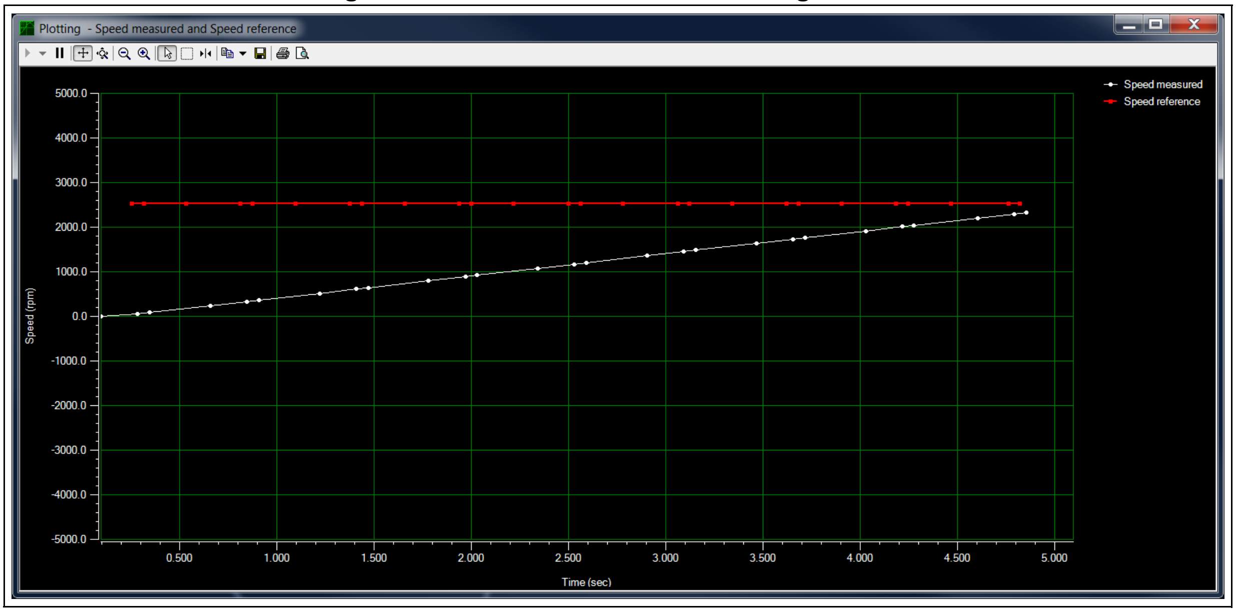
Function	Icon or field	Detail
Configure the communication link	Port COM3	Selects the communication port used from the drop-down box.
	115200	Selects the communication speed from the drop-down box.
Connect or disconnect		Connects to the board.
		Disconnects from the board
Read and/or write data from/to MC application software		Forces the reading of data.
		Suspends the periodic data writing and reading.
		Resumes the periodic data writing and reading.
Plot speed data		Displays the plotting window with the speed measured and the speed reference, as shown in *Figure 84*.
Close the monitor and spin control GUI	Close Monitor	Exits the GUI.

Figure 84 shows the plotting window with an example illustrating the measured speed vs. the reference.

Figure 84. ST MC Workbench - Plotting window



3.7.2 Motor control dashboard

The motor control dashboard provides a set of views that can be selected as a function of the user's experience:

- Basic view (refer to *Figure 85*)
- Advanced view (refer to *Figure 86*)
- Expert views (refer to *Figure 87* and *Figure 90*)

Figure 85 shows the basic dashboard, where the user can:

- monitor the bus voltage, motor speed, and power component heat-sink
- modify the final ramp speed value, which may also be used to control motor speed during spinning

Figure 85. ST MC Workbench - Basic dashboard view

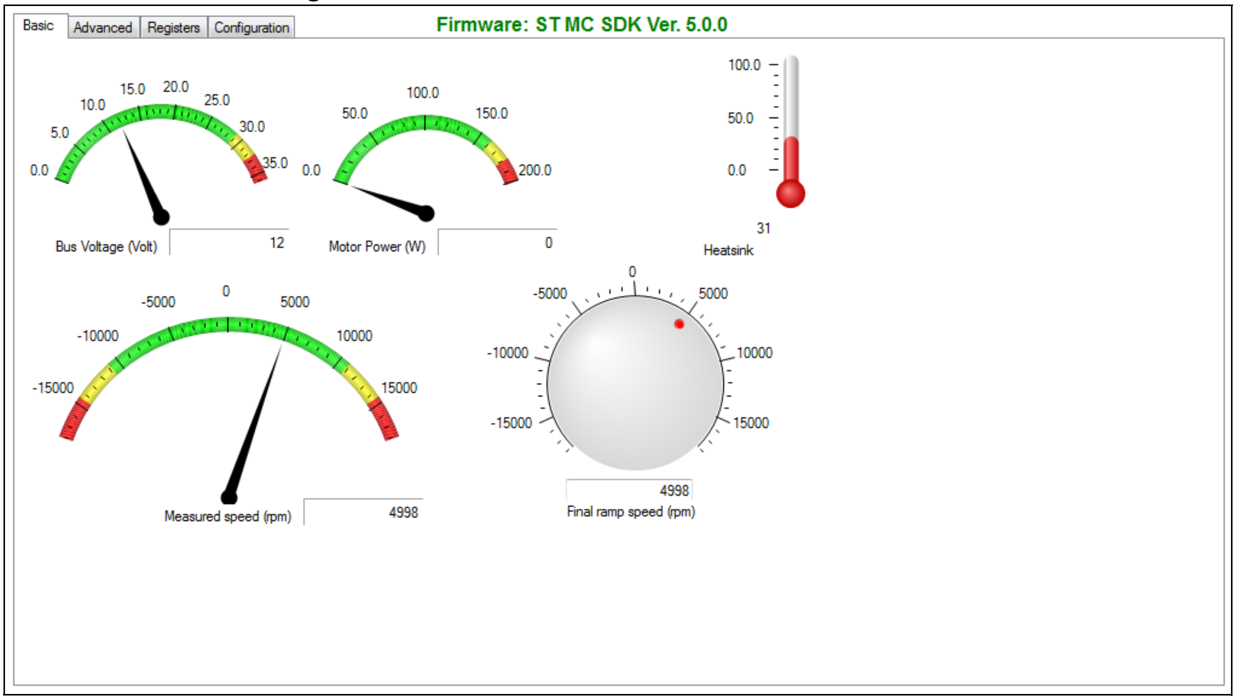


Figure 86 shows the dashboard where the advanced user can:

- Configure (drop-down boxes) control modes an monitor (blue fields) a few firmware variables for debugging purpose using only the DAC
- Monitor (blue fields) and define (white fields) some current controller parameters
- Tune the speed controller (white fields) through variables
- Configure (white fields) the sensor-less observers: PLL and Cordic
- Tune (white fields) and monitor (blue fields) the flux weakening feature

Figure 86. ST MC Workbench - Advanced dashboard view

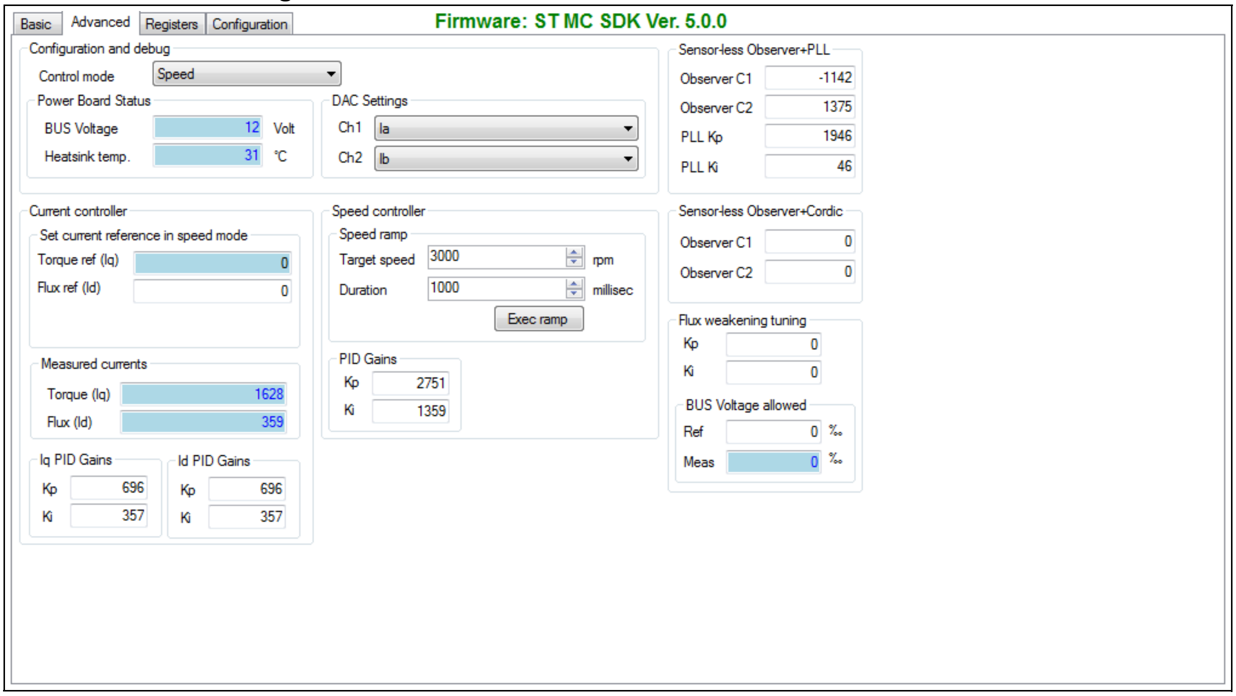
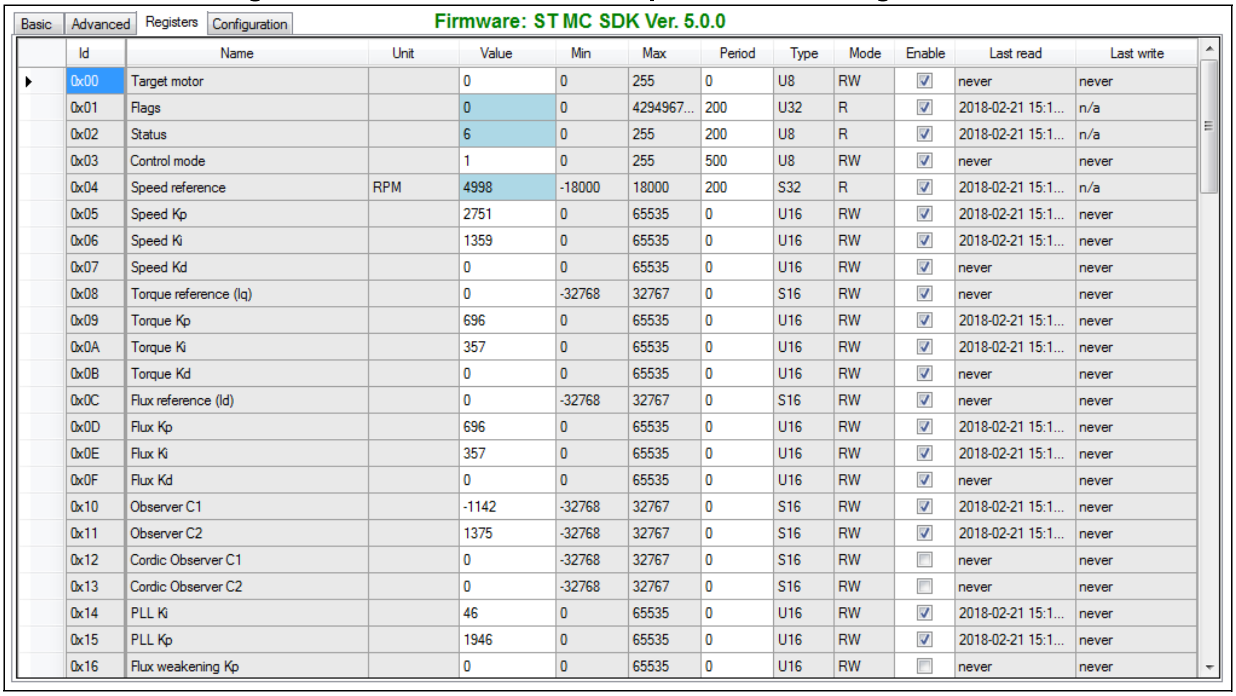


Figure 87 shows the dashboard where the expert user can:

- Read/Write (white field) or read only (blue fields) the content of 102 registers matching corresponding variables in MC FOC firmware

Figure 87. ST MC Workbench - Expert dashboard register view



Id	Name	Unit	Value	Min	Max	Period	Type	Mode	Enable	Last read	Last write
0x00	Target motor		0	0	255	0	U8	RW	☑	never	never
0x01	Flags		0	0	4294967...	200	U32	R	☑	2018-02-21 15:1...	n/a
0x02	Status		6	0	255	200	U8	R	☑	2018-02-21 15:1...	n/a
0x03	Control mode		1	0	255	500	U8	RW	☑	never	never
0x04	Speed reference	RPM	4998	-18000	18000	200	S32	R	☑	2018-02-21 15:1...	n/a
0x05	Speed Kp		2751	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x06	Speed Ki		1359	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x07	Speed Kd		0	0	65535	0	U16	RW	☑	never	never
0x08	Torque reference (Iq)		0	-32768	32767	0	S16	RW	☑	never	never
0x09	Torque Kp		696	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x0A	Torque Ki		357	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x0B	Torque Kd		0	0	65535	0	U16	RW	☑	never	never
0x0C	Flux reference (Id)		0	-32768	32767	0	S16	RW	☑	never	never
0x0D	Flux Kp		696	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x0E	Flux Ki		357	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x0F	Flux Kd		0	0	65535	0	U16	RW	☑	never	never
0x10	Observer C1		-1142	-32768	32767	0	S16	RW	☑	2018-02-21 15:1...	never
0x11	Observer C2		1375	-32768	32767	0	S16	RW	☑	2018-02-21 15:1...	never
0x12	Cordic Observer C1		0	-32768	32767	0	S16	RW	☐	never	never
0x13	Cordic Observer C2		0	-32768	32767	0	S16	RW	☐	never	never
0x14	PLL Ki		46	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x15	PLL Kp		1946	0	65535	0	U16	RW	☑	2018-02-21 15:1...	never
0x16	Flux weakening Kp		0	0	65535	0	U16	RW	☐	never	never

When using the expert dashboard register view, the user has access to the additional icons shown in *Figure 88*:

- The first additional icon is used to import a configuration from another ST MC Workbench project through the import register configuration window shown in *Figure 89*
- The second additional icon is used to set the registers value to default ones

These icons are available only when the periodic write and read of registers has been suspended, or before the connection to the board.

Figure 88. ST MC Workbench - Communication link icons in expert dashboard register view

Note: These buttons do not exist in other dashboard views.

Figure 89. ST MC Workbench - Import registers configuration window

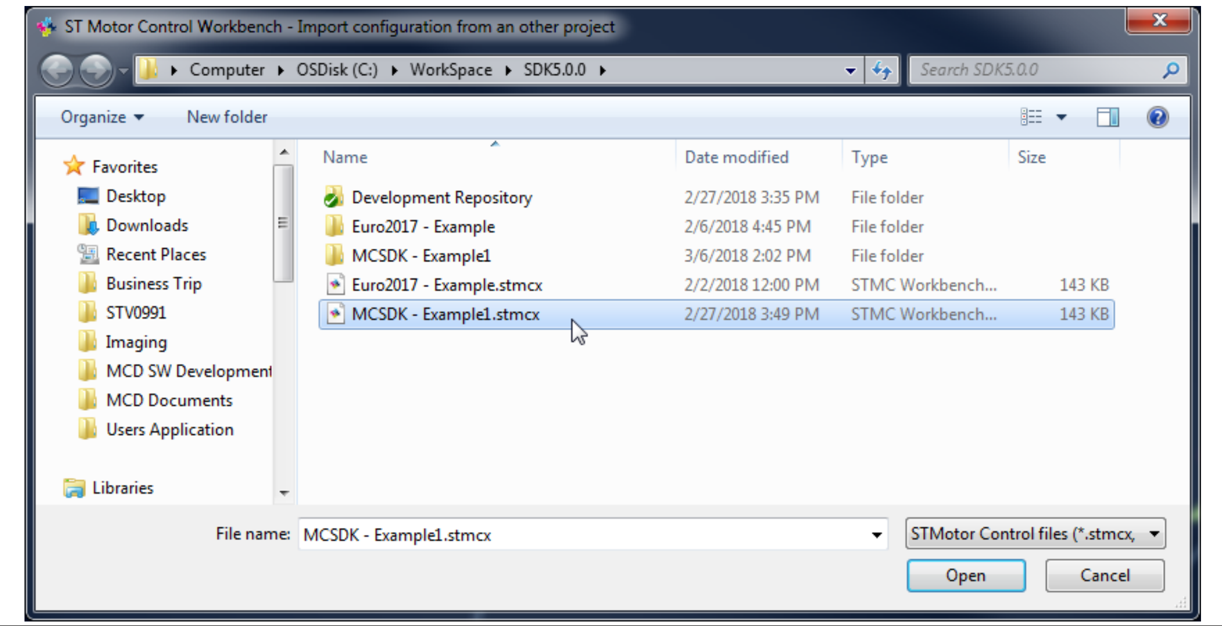
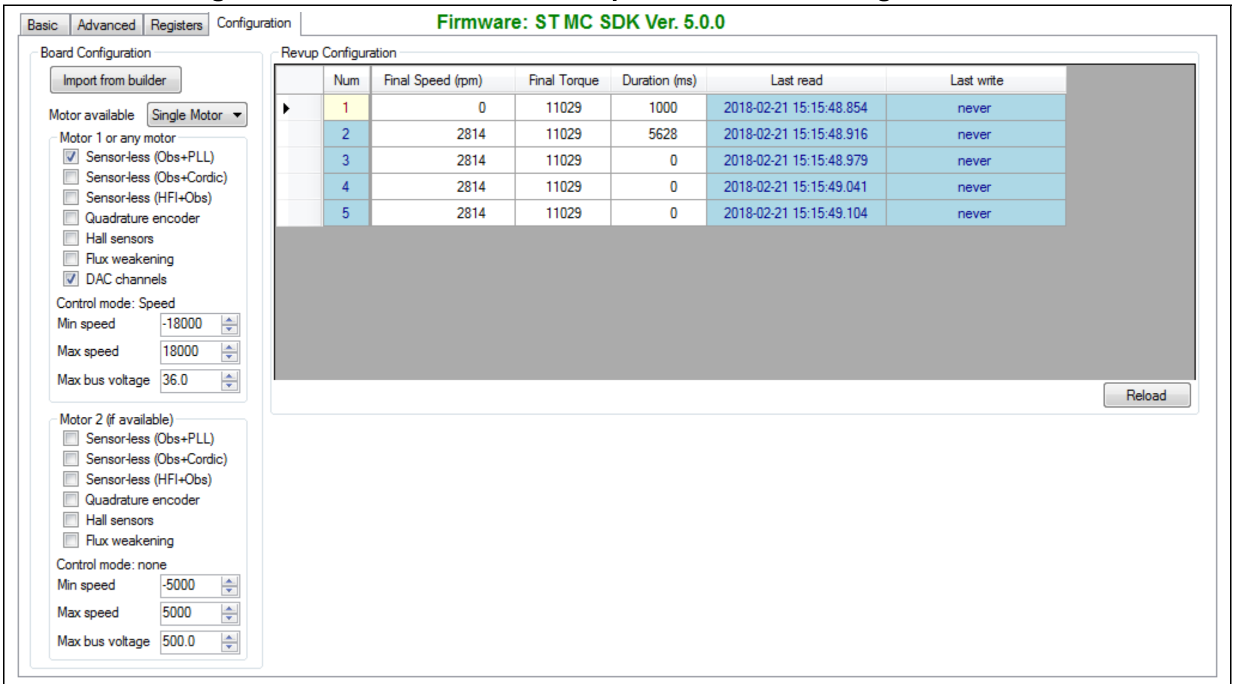


Figure 90 shows the dashboard where the expert user can:

- Import (button) the configuration from the current ST MC Workbench project
- Customize (check boxes and white fields) the monitor view accordingly to the MC application software
- Update (white fields) the startup configuration used with the motor. This is also known as rev-up.

Figure 90. ST MC Workbench - Expert dashboard configuration view

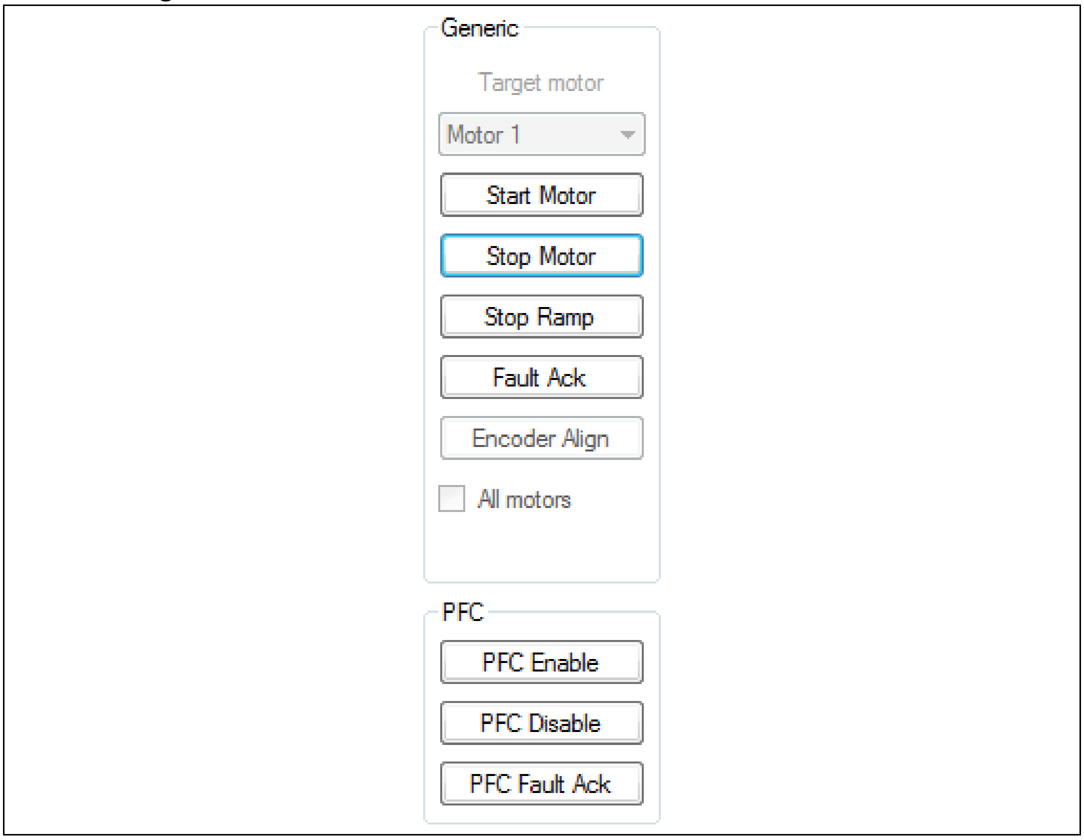


3.7.3 Motor control buttons

The motor control button area is shown in *Figure 91*. It is useful for motor control with remote commands such as:

- Start-up the motor when in idle state.
- Stop the motor when in start or run state.
- Stop a ramp during its execution request.
  It does not stop the motor itself, but the execution of the defined ramp at the current on-going speed or torque value.
- Acknowledge a motor failure.
  May be used only after fault correction to prevent security issues.
- Align with the encoder used.
- Enable or disable PFC usage when the hardware setup supports it.
- Acknowledge a PFC failure when the hardware setup supports it.

Figure 91. ST MC Workbench - Motor remote control button view

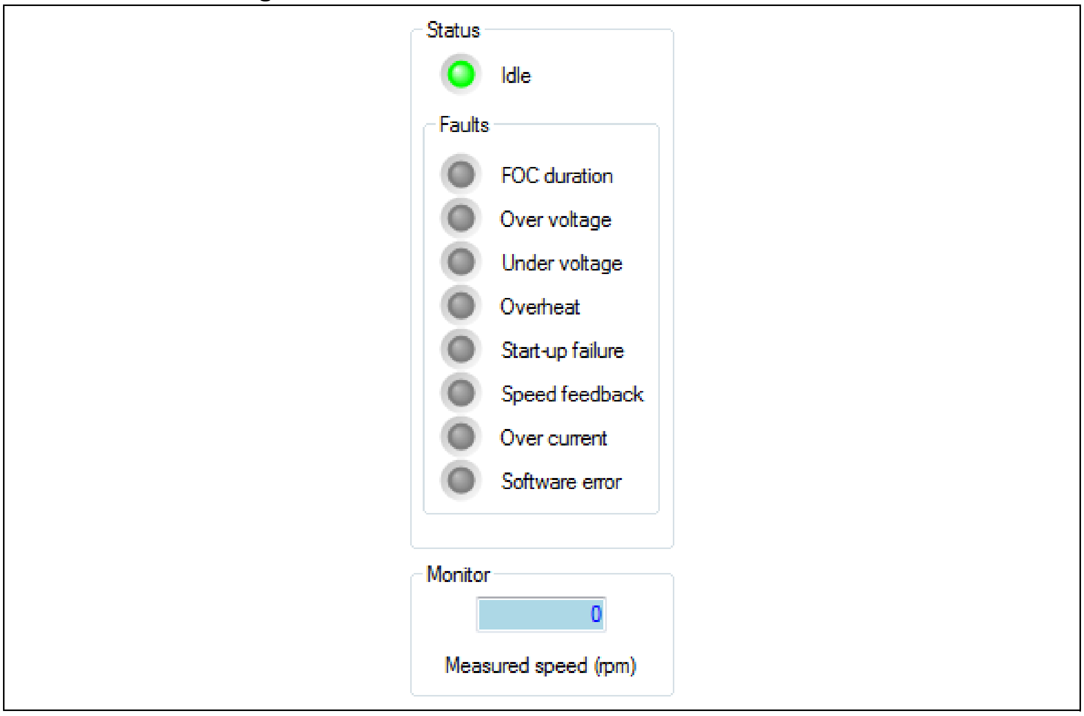


3.7.4 Status overview

The status overview, illustrated in *Figure 92*, provides information on:

- the motor state machine
- the detected motor failure
- the measured motor speed.

Figure 92. ST MC Workbench - Motor status view



4 Precautions of use and restrictions

The motor profiling algorithm is intended for rapid evaluation of the ST MC solution. It can be used to drive any three-phase PMSM without any specific instrument or special skill.

Although the performed measurements are not as precise as with a proper instrumentation, ST Motor Profiler measurements are optimized (green color in *Figure 10*) when:

- the stator resistance is greater than 1 Ω
- the stator inductance is greater than 1 mH

It is important to choose the appropriate HW according to the characteristics of the motor. For instance, the maximum current should match the maximum current of the board as closely as possible.

The ST Motor Profiler can be used only with compatible STMicroelectronics evaluation boards.

Warning: Use the ST Motor Profiler tool to refer to the list of supported systems.

5 Revision history

Table 5. Document revision history

Date	Revision	Changes
20-Mar-2018	1	Initial release.
02-Jul-2018	2	Updated document title to refer to software version 5.1. Updated *Section 3.3: Icons and Menu area*, *Tools menu*, *Documentation menu*, *Power stage*, *Control stage* and *Section 3.4: Configuring a project*. Minor text edits across the whole document. Updated *Figure 15: ST MC Workbench - Icon and location in the start program list*, *Figure 18: ST MC Workbench - New Project Info window*, *Figure 27: ST MC Workbench - Pin Assignment window*, *Figure 31: ST MC Workbench - Script progress window*, *Figure 33: ST MC Workbench - Monitor window*, *Figure 37: ST MC Workbench - About window*, *Figure 38: ST MC Workbench - Documentation menu* and *Figure 44: ST MC Workbench - Power Stage window*. Updated caption of *Figure 1: ST Motor Profiler - Icon and location in the start program list*. Removed former *Figure 32: ST MC Workbench - Update .ioc file error window*.

Table 5. Document revision history

Date	Revision	Changes
31-Aug-2018	3	Updated document title to refer to software version 5.2. Updated *Section 3.2: Loading an existing project*, *Section 3.4.1: Motor*, *Section 3.4.3: Drive management* and *Section 3.4.4: Control stage*. Updated *Figure 15: ST MC Workbench - Icon and location in the start program list*, *Figure 19: ST MC Workbench - Hardware configuration window (global view)*, *Figure 23: ST MC Workbench - Project Properties window*, *Figure 37: ST MC Workbench - About window*, *Figure 44: ST MC Workbench - Power Stage window*, *Figure 58: ST MC Workbench - Drive Management window* and *Figure 72: ST MC Workbench - Control Stage window*.
26-Jun-2019	4	Updated: – SDK version in the title of document, *Section 1: General information*, *STMicroelectronics documents*, *Section 3.3.2: Tools menu*, *Section 3.3.3: Help menu*, *Section 3.3.4: Documentation menu* – *Figure 1: ST Motor Profiler - Icon and location in the start program list*; *Figure 15: ST MC Workbench - Icon and location in the start program list*; *Figure 20: ST MC Workbench - File menu*, *Figure 26: ST MC Workbench - Tools menu*, *Figure 30: ST MC Workbench - Information window*, *Figure 31: ST MC Workbench - Script progress window*, *Figure 36: ST MC Workbench - Help menu*, *Figure 37: ST MC Workbench - About window*, *Figure 38: ST MC Workbench - Documentation menu*, *Figure 40: ST MC Workbench - Motor parameter GUI (Surface Mounted PMSM)*, *Figure 42: ST MC Workbench - Sensor parameter GUI*, *Figure 49: ST MC Workbench - Current Sensing GUI*, *Figure 51: ST MC Workbench - Over Current Protection GUI*, *Figure 54: ST MC Workbench - Dissipative Brake GUI* Added: *Figure 41: ST MC Workbench - Motor parameter GUI (Internal PMSM)* Removed figure33. ST Workbench - Project Settings option window Added *Figure 40: ST MC Workbench - Motor parameter GUI (Surface Mounted PMSM)*, *Figure 57: ST MC Workbench - Power Factor Correction GUI (PFC Parameters)*, *Figure 71: ST MC Workbench - FreeRTOS GUI*