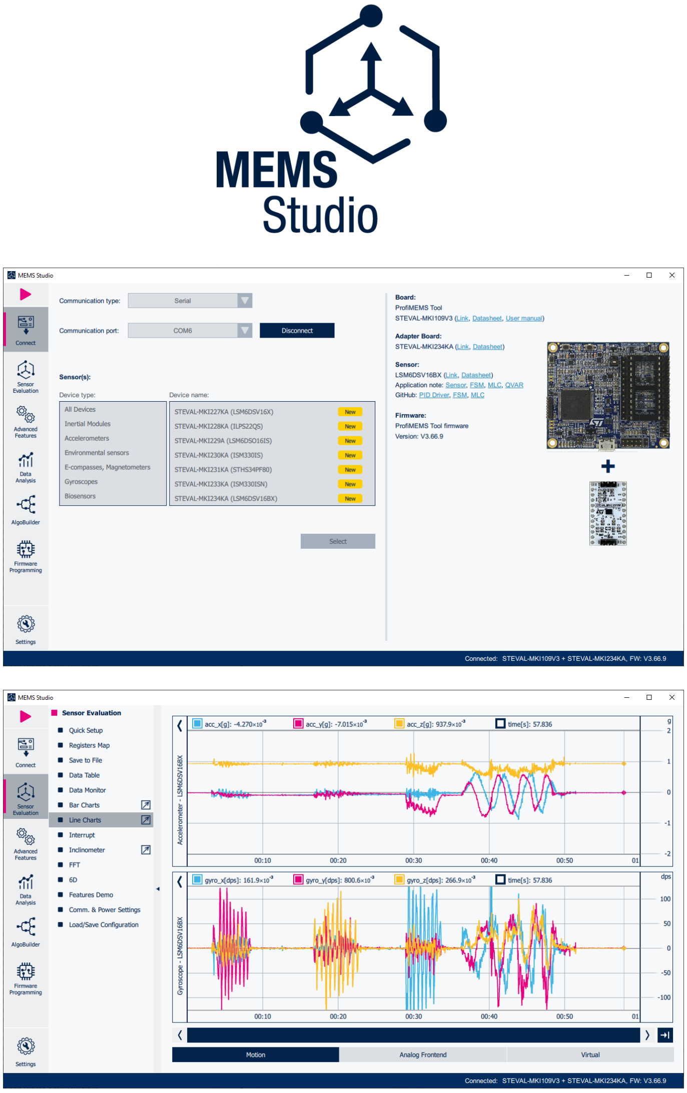
Getting started with MEMS Studio

Introduction

MEMS Studio is a complete desktop software solution designed to develop embedded AI features, evaluate embedded libraries, analyze data, and design no-code algorithms for the entire portfolio of MEMS sensors. This unique software solution offers a versatile development environment, enabling the evaluation and programming of all MEMS sensors, and launches a new generation of solutions to expand the functions of the well-established applications Unico-GUI, Unicleo-GUI, and AlgoBuilder.

MEMS Studio facilitates the process of implementing proof of concept using a graphical interface without writing code for STM32 microcontrollers. This solution allows configuring sensors and embedded AI (machine learning and neural networks), leveraging on a machine learning core (MLC), neural networks for the intelligent sensor processing unit (ISPU), and finite state machines (FSM). It reuses embedded software libraries, combines multiple functionalities in a single project, and visualizes data in real time using plot and display.

Figure 1. **MEMS Studio application**



Communication type: Serial

Communication port: COM6

Disconnect

Sensor(s):

Device type:	Device name:
All Devices	STEVAL-MKI227KA (LSM6DSV16X) New
Inertial Modules	STEVAL-MKI228KA (ILPS22QS) New
Accelerometers	STEVAL-MKI229A (LSM6DSO16IS) New
Environmental sensors	STEVAL-MKI230KA (ISM330IS) New
E-compasses, Magnetometers	STEVAL-MKI231KA (STHS34PF80) New
Gyroscopes	STEVAL-MKI233KA (ISM330ISN) New
Biosensors	STEVAL-MKI234KA (LSM6DSV16BX) New

Select

Board:
ProfiMEMS Tool
STEVAL-MKI109V3 (Link, Datasheet, User manual)

Adapter Board:
STEVAL-MKI234KA (Link, Datasheet)

Sensor:
LSM6DSV16BX (Link, Datasheet)
Application note: Sensor, FSM, MLC, QVAR
GitHub: PID Driver, FSM, MLC

Firmware:
ProfiMEMS Tool firmware
Version: V3.66.9

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.66.9

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.66.9

1 Overview

MEMS Studio offers the following user experience:

- Sensor evaluation for motion, environmental, and infrared sensors in the MEMS portfolio
- Configuration and testing of in-sensor features such as the finite state machine (FSM), machine learning core (MLC), intelligent sensor processing unit (ISPU)
- Runtime and offline data analysis
- No-code graphical design of algorithms

The key features of the application include:

- Sensor configuration
  - Easy sensor configuration and evaluation
  - Access to the full sensor register map
  - Interrupt status monitoring
- Sensor data analysis
  - Runtime sensor data visualization charts (line charts, bar graphs, 3D plots, …)
  - Data logging to .csv file
  - Offline data visualization, data labeling, and editing
  - Fast Fourier transform (FFT) analysis of online and offline data
  - Spectrogram analysis of online and offline data
- Application development
  - Testing of the advanced embedded features (FIFO, pedometer, free fall, …) in the sensor
  - In-sensor AI design and programming for the finite state machine (FSM), machine learning core (MLC), and intelligent sensor processing unit (ISPU)
  - Embedded AutoML tool (automatic filter and feature selection) to simplify the MLC configuration process
  - Visualization and data logging of the output of the embedded software libraries
  - Development of no-code algorithms for data processing in STM32 microcontrollers
  - Analysis of pretrained neural network model, optimization, and conversion to c code
- Support for Windows, macOS, and Linux operating systems
- Network updates with automatic notification of new releases

Note: *Firmware for sensor evaluation using STEVAL-MKI109V3, STEVAL-MKI109D (professional MEMS tool), STEVAL-MKBOXPRO (SensorTile.box PRO) and STEVAL-STWINBX1 (STWIN.box) is distributed within MEMS Studio.*

2 Getting started

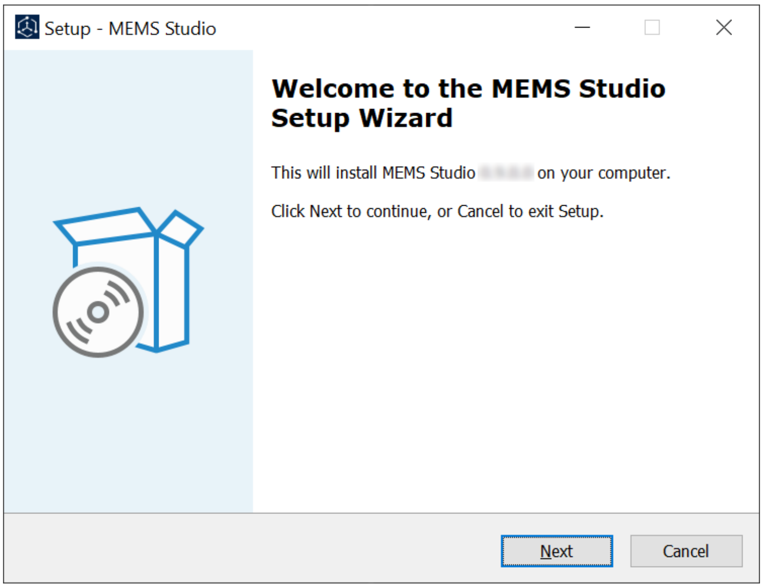
2.1 Installation

The MEMS Studio software has been designed to operate with Microsoft Windows platforms, Linux platforms, and macOS platforms.

Windows platforms

To install MEMS Studio, launch the [**mems-studio.exe**] installation file and follow the instructions that appear on the screen. When the software is installed, you can run it from: [**Start**]>[**STMicroelectronics**]>[**MEMS Studio**]

Figure 2. **MEMS Studio Installer**



Welcome to the MEMS Studio Setup Wizard

This will install MEMS Studio [redacted] on your computer.

Click Next to continue, or Cancel to exit Setup.

Linux platforms

For Linux Debian-based distributions, a .deb package is provided.
On Ubuntu, you can install the .deb package by opening a terminal and writing the following command:

```
sudo dpkg -i mems-studio_VERSION_amd64.deb
```

If the installation fails due to a missing dependent library, it is necessary to install the missing library before proceeding with the MEMS Studio installation:

```
sudo apt-get install <missing_library_name>
```

```
sudo dpkg -i mems-studio_VERSION_amd64.deb
```

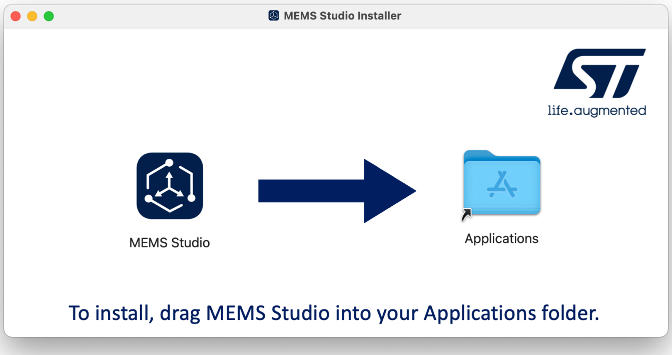
After the installation has been completed, the executable file (“mems-studio”) is stored in the /usr/bin folder. To run the MEMS Studio software, just click on the MEMS Studio icon in the Application launcher menu.

Note: *The current version of MEMS Studio is designed to work on Ubuntu 18.04 LTS, although it should be possible to install and run it on newer versions of Ubuntu or other Debian-based distributions after having installed all the dependencies required.*

macOS platforms

To install MEMS Studio, simply open the DMG package and drag MEMS Studio to your Applications folder.

Figure 3. MEMS Studio Installer for macOS

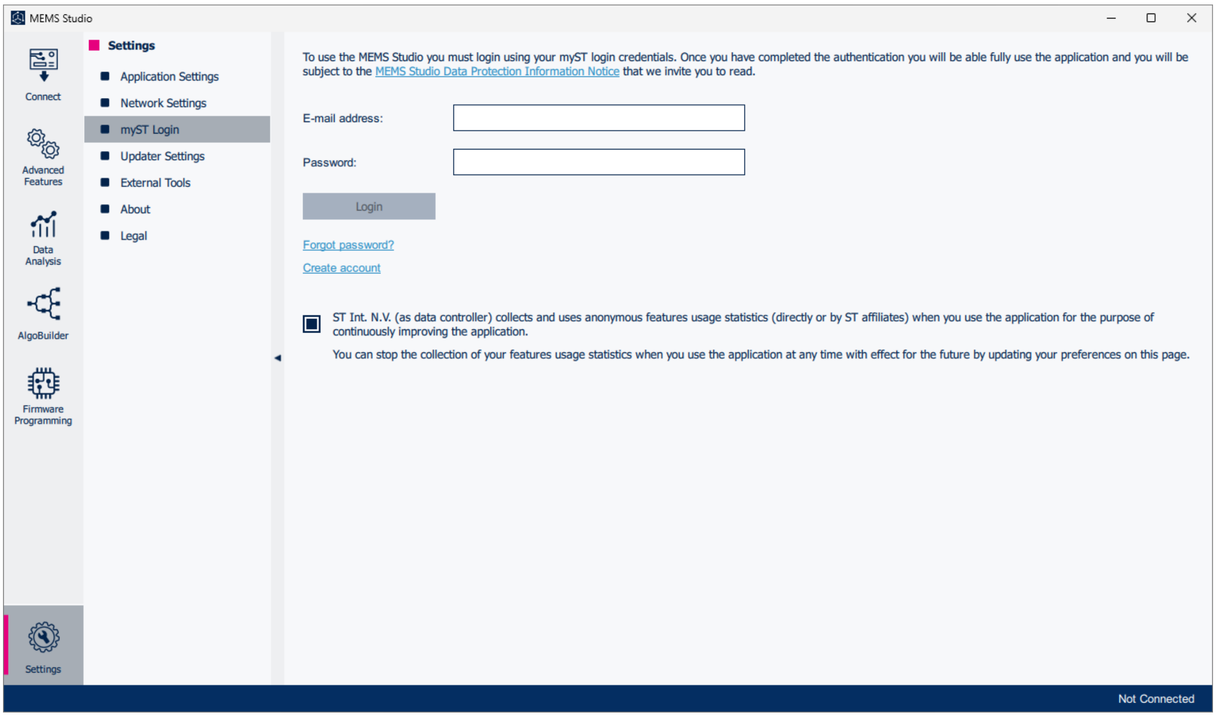


To install, drag MEMS Studio into your Applications folder.

2.2 myST Login

To use MEMS Studio, it is mandatory to enter your myST login credentials. By logging in with your myST credentials, you can fully utilize all the functionalities and services offered by MEMS Studio.

Figure 4. myST Login page



To use the MEMS Studio you must login using your myST login credentials. Once you have completed the authentication you will be able fully use the application and you will be subject to the MEMS Studio Data Protection Information Notice that we invite you to read.

E-mail address:

Password:

☒ ST Int. N.V. (as data controller) collects and uses anonymous features usage statistics (directly or by ST affiliates) when you use the application for the purpose of continuously improving the application.

You can stop the collection of your features usage statistics when you use the application at any time with effect for the future by updating your preferences on this page.

2.3 Application settings

Some application parameters can be adjusted in the [**Applications Settings**] in the [**Settings**] menu.

Application colors can be selected using [**Color theme**]. Available themes are Light, Dark, and Legacy.

[**Font size**] can be adjusted by the user in the application settings for good readability.

[**Plot grid in rolling mode**] can be set to be stationary or moving.

If [**Automatic registers reading**] is enabled, sensor registers are automatically read when entering [**Register map page**].

The user can select the units in the application for acceleration, angular rate, magnetic field, temperature, humidity, and pressure.

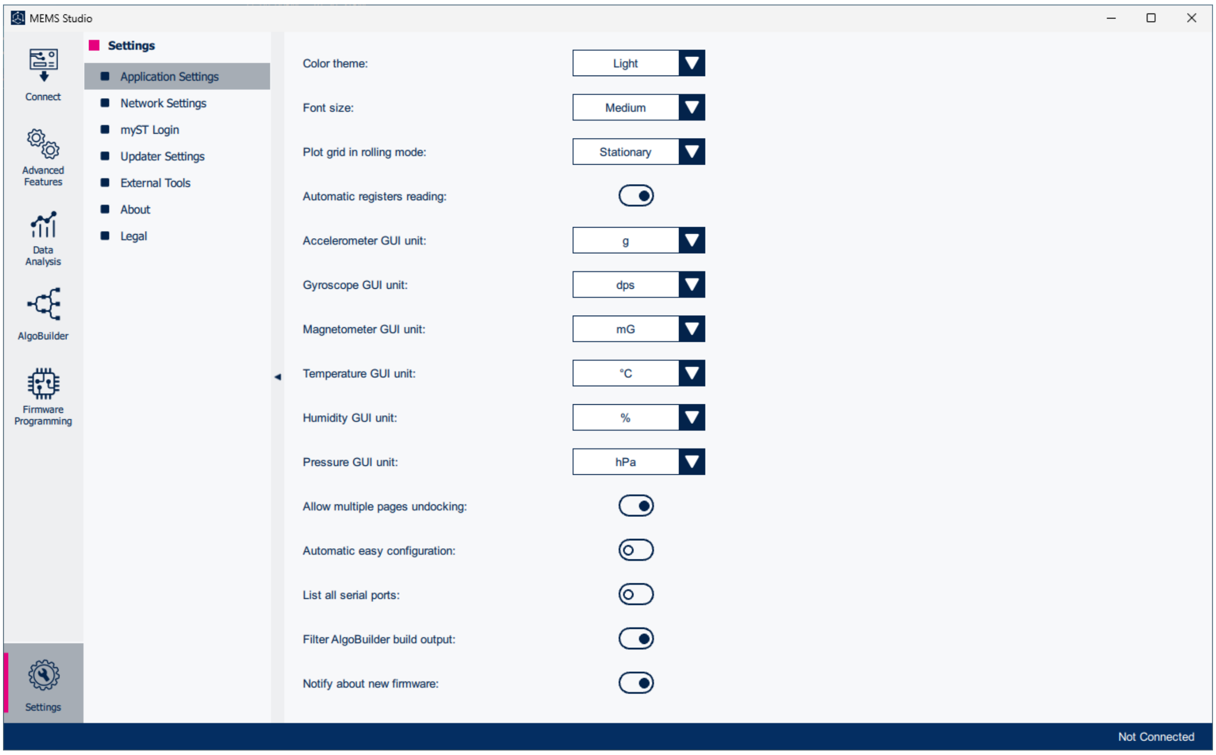
[**Allow multiple page undocking**] enables the possibility to undock more than one page at a time. This option requires more computer resources.

If [**Automatic easy configuration**] is enabled, the sensor is automatically configured after connection (when the sensor is not in power-down mode). This option is valid only for ProfiMEMS firmware.

If [**Filter AlgoBuilder build output**] is enabled, AlgoBuilder automatically filters outputs from the external compiler and makes them more readable in the console.

If [**Notify about new firmware**] is enabled, the application automatically checks if new firmware for the connected board is available and offers a firmware update.

Figure 5. **Application Settings**



Color theme: Light

Font size: Medium

Plot grid in rolling mode: Stationary

Automatic registers reading: ●

Accelerometer GUI unit: g

Gyroscope GUI unit: dps

Magnetometer GUI unit: mG

Temperature GUI unit: °C

Humidity GUI unit: %

Pressure GUI unit: hPa

Allow multiple pages undocking: ●

Automatic easy configuration: ○

List all serial ports: ○

Filter AlgoBuilder build output: ●

Notify about new firmware: ●

2.4 External Tools

MEMS Studio utilizes some external tools. The paths to these tools need to be set in [**External Tools**] in the [**Settings**] menu.

It is necessary to specify the path to at least one compiler in order to compile AlgoBuilder firmware. [**IAR embedded workbench path**], [**Keil uVision path**], or [**STM32CubeIDE path**] can be specified.

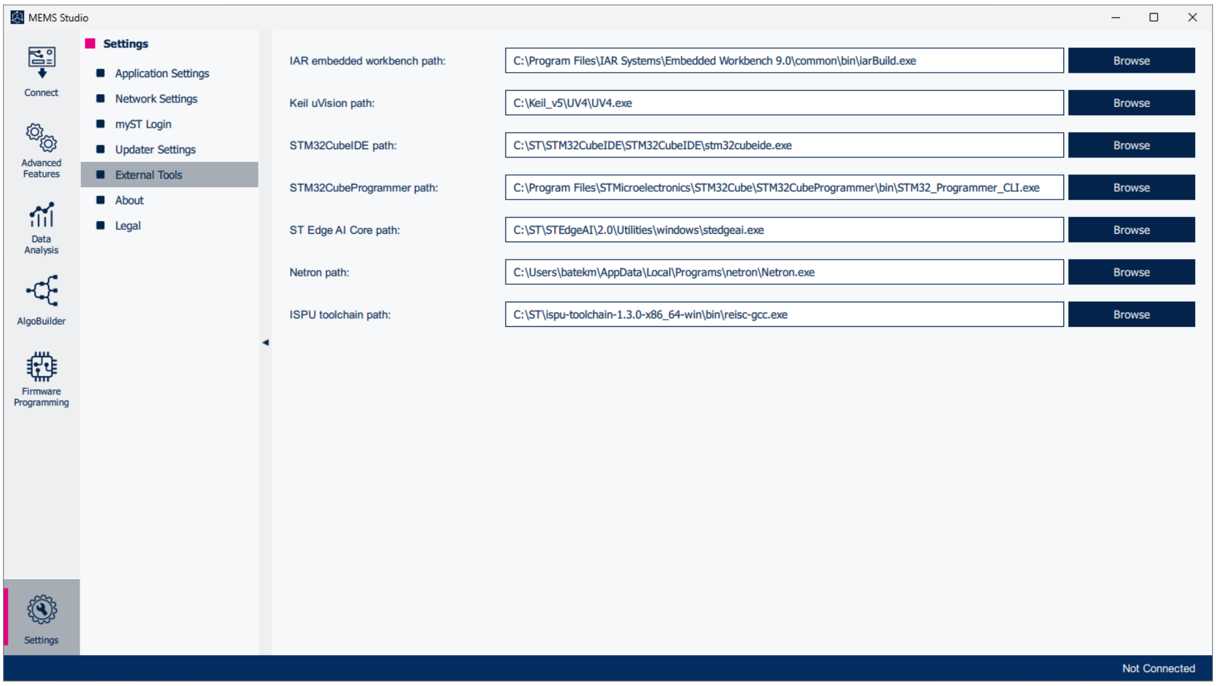
Firmware programing in the standalone page or programming from the AlgoBuilder page utilizes the STM32CubeProgramer CLI tool. [**STM32CubeProgrammer path**] must be specified in order to make the programming available.

[**ISPU Model Converter**] requires that the path to the [**ST Edge AI Core**] tool needs to be specified.

The path to the [**Netron**] tool needs to be specified in order to graphically visualize the neural network.

The path to the [**ISPU toolchain**] needs to be specified in order to invoke ISPU sensor configuration generation directly from MEMS Studio.

Figure 6. **External Tools**



IAR embedded workbench path: C:\Program Files\IAR Systems\Embedded Workbench 9.0\common\bin\iarBuild.exe

Keil uVision path: C:\Keil_v5\UV4\UV4.exe

STM32CubeIDE path: C:\ST\STM32CubeIDE\STM32CubeIDE\stm32cubeide.exe

STM32CubeProgrammer path: C:\Program Files\STMicroelectronics\STM32Cube\STM32CubeProgrammer\bin\STM32_Programmer_CLI.exe

ST Edge AI Core path: C:\ST\STEdgeAI\2.0\Utilities\windows\stedgeai.exe

Netron path: C:\Users\batekm\AppData\Local\Programs\netron\Netron.exe

ISPU toolchain path: C:\ST\ispu-toolchain-1.3.0-x86_64-win\bin\reisc-gcc.exe

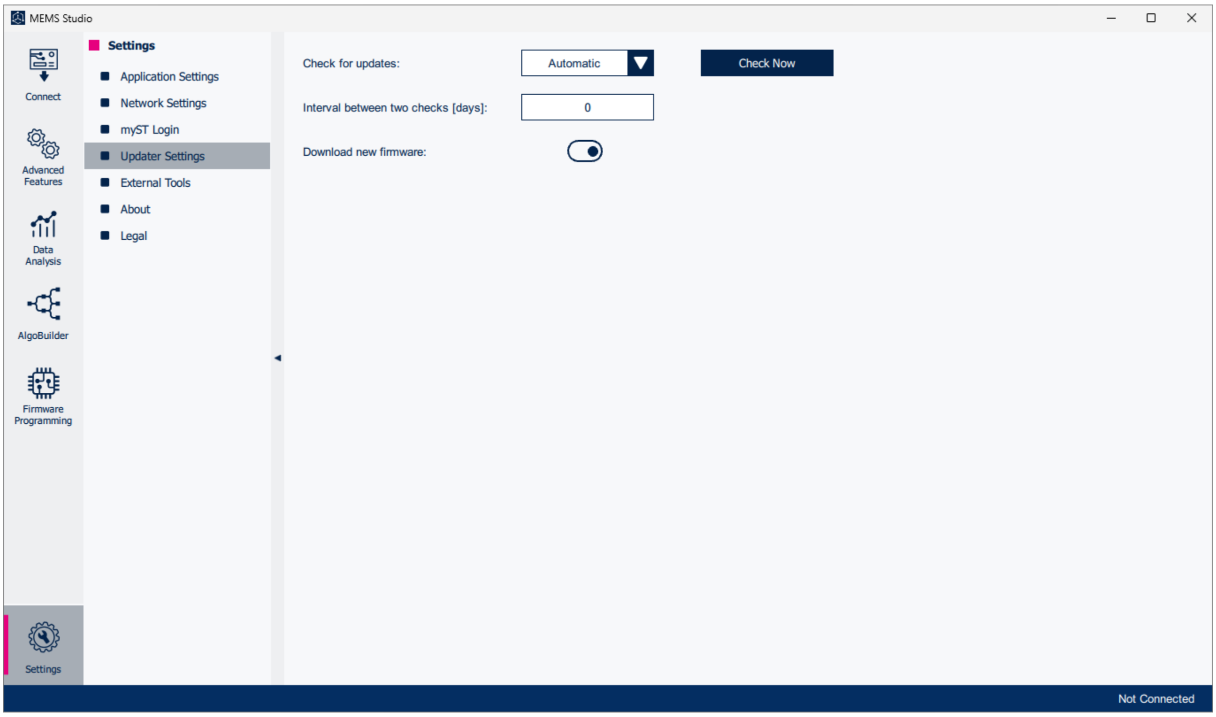
2.5 Updater settings

The MEMS Studio application is able to check and notify if a new version is available. You can then decide whether to download and install the new version or not on the [**Updater Settings**] page. The network parameters have to be properly set in the [**Network Settings**] page. Both pages are in the [**Settings**] menu.

A check for a new version can be done manually by pressing the [**Check Now**] button or automatically during application startup. An interval for the automatic check can be set.

If the [**Download new firmware**] option is enabled, the application will check and download also new firmware for supported evaluation boards. The firmware package is downloaded separately and does not have any impact on the installed MEMS Studio version.

Figure 7. **Updater Settings**



Check for updates: Automatic

Interval between two checks [days]: 0

Download new firmware: ●

2.6 Network Settings

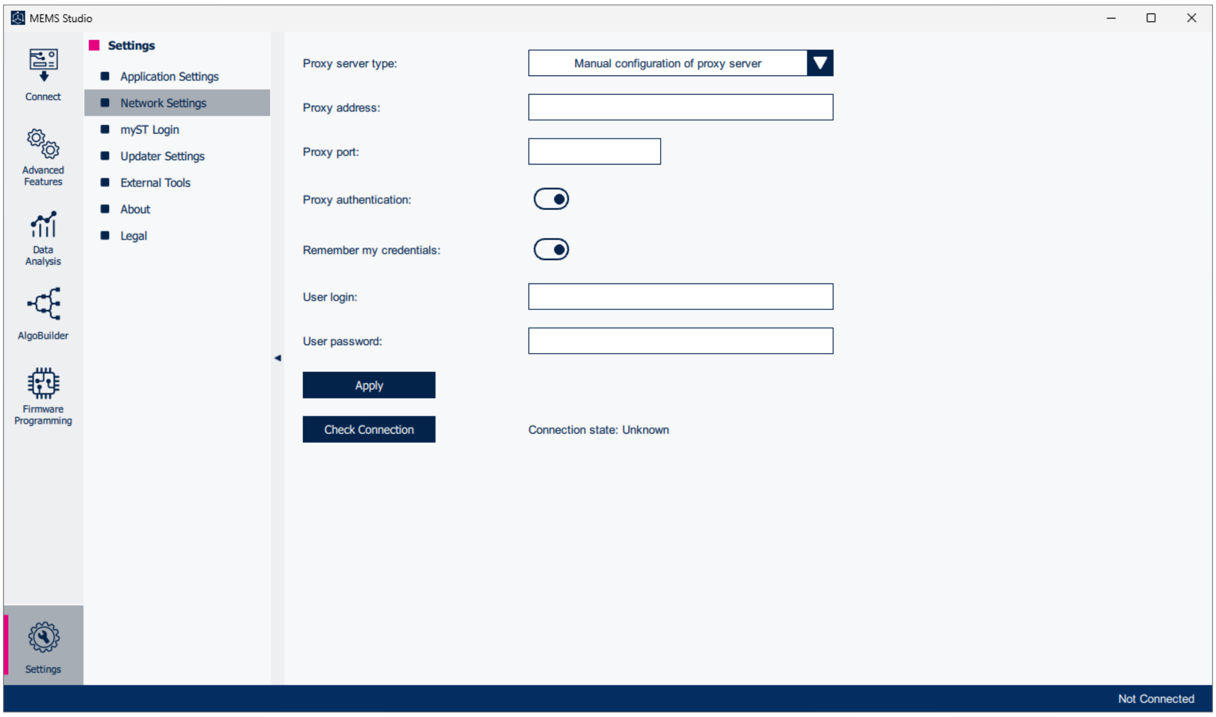
For proper MEMS Studio functionality, network settings must be correctly configured.

If a proxy server is used, corresponding parameters like the HTTP address and port must be set.

If the proxy server requires authentication, user credentials must be entered in the appropriate fields.

The [**Check Connection**] button can be used to check if the settings are done correctly and the server can be reached.

Figure 8. **Network Settings**



Proxy server type: Manual configuration of proxy server

Proxy address:

Proxy port:

Proxy authentication:

Remember my credentials:

User login:

User password:

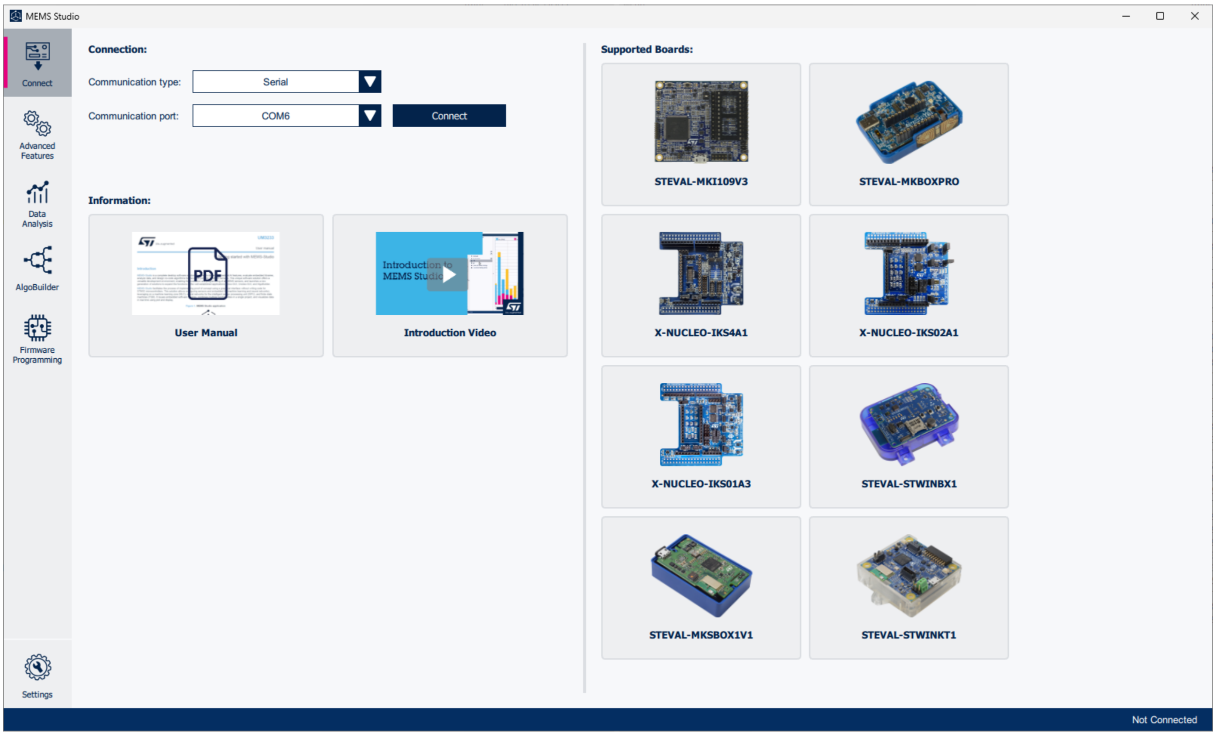
Connection state: Unknown

Not Connected

2.7 Running the application for the first time

After the application startup, the [**Connect**] page is displayed. To evaluate the sensor and libraries, a compatible device with proper firmware must be connected. You can click on a particular board in the [**Supported Boards**] section to see the list of supported sensors and feature on the board or check Section 2.8: Hardware and firmware compatibility. Features that do not require a connected device like data analysis, MLC design, AlgoBuilder, and others are available all the time.

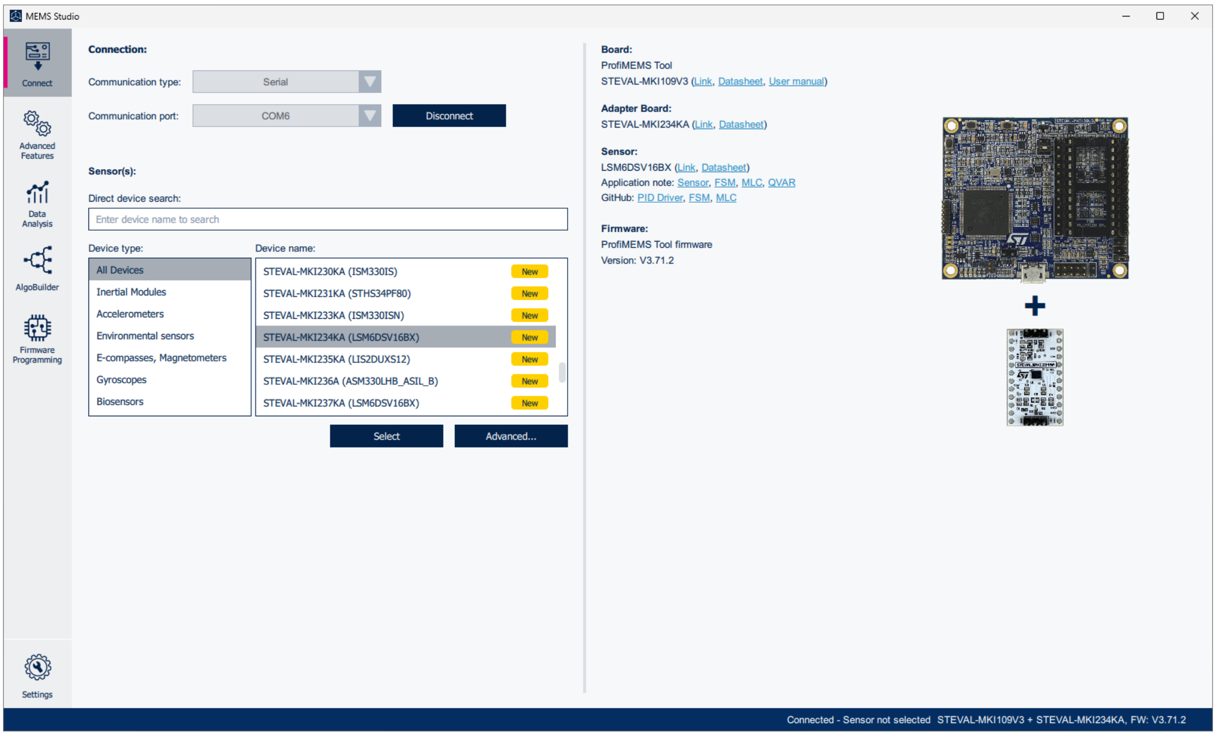
Figure 9. **Connect page**



In order to connect to a board, [**Communication type**] needs to be selected. Serial, USB, and BLE interfaces are supported. The USB is used for data acquisition using High Speed Datalog firmware. The BLE interface is used only for the AlgoBuilder firmware evaluation. According to the selected communication type, [**Communication port**], [**USB device**] or [**BLE device**] can then be selected. Communication with the device is initialized by pressing the [**Connect**] button.

After the connection is established, the firmware for the sensor evaluation allows selecting the sensor. In the case of ProfiMEMS firmware, the reference part number of DIL24 adapters or the sensor name is used for the selection. In the case of DatalogExtended firmware, sensor names are used.

Figure 10. Sensor selection - ProfiMEMS firmware



Connection:

Communication type: Serial

Communication port: COM6

Sensor(s):

Direct device search: Enter device name to search

Device type:

- All Devices
- Inertial Modules
- Accelerometers
- Environmental sensors
- E-compasses, Magnetometers
- Gyroscopes
- Biosensors

Device name:

- STEVAL-MKI230KA (ISM330IS) New
- STEVAL-MKI231KA (STHS34PF80) New
- STEVAL-MKI233KA (ISM330ISN) New
- STEVAL-MKI234KA (LSM6DSV16BX) New
- STEVAL-MKI235KA (LIS2DUXS12) New
- STEVAL-MKI236A (ASM330LHB_ASIL_B) New
- STEVAL-MKI237KA (LSM6DSV16BX) New

Board:
ProfiMEMS Tool
STEVAL-MKI109V3 (Link, Datasheet, User manual)

Adapter Board:
STEVAL-MKI234KA (Link, Datasheet)

Sensor:
LSM6DSV16BX (Link, Datasheet)
Application note: Sensor, FSM, MLC, QVAR
GitHub: PID Driver, FSM, MLC

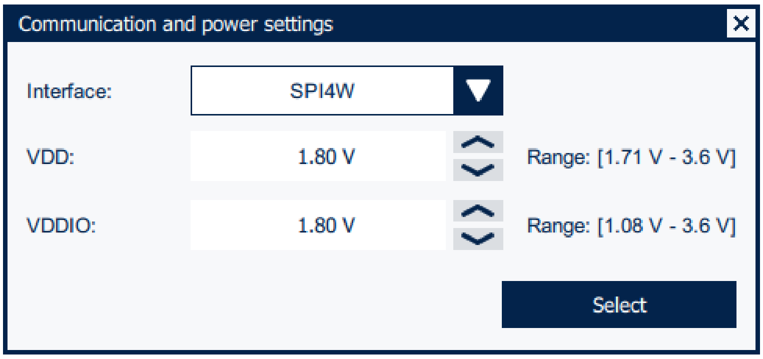
Firmware:
ProfiMEMS Tool firmware
Version: V3.71.2

Connected - Sensor not selected STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.71.2

Note: As soon as the user selects the device, a validation check is performed at firmware level to verify if the selected device is the same as the connected one. The firmware checks the identifier register WHO_AM_I value in order to verify that it matches the expected value. If it does not match, an error is shown to the user.

The communication interface between the microcontroller and the sensor as well as the power supply voltages can be configured before the connection is established by clicking on the [**Advanced...**] button.

Figure 11. Advanced connection parameters

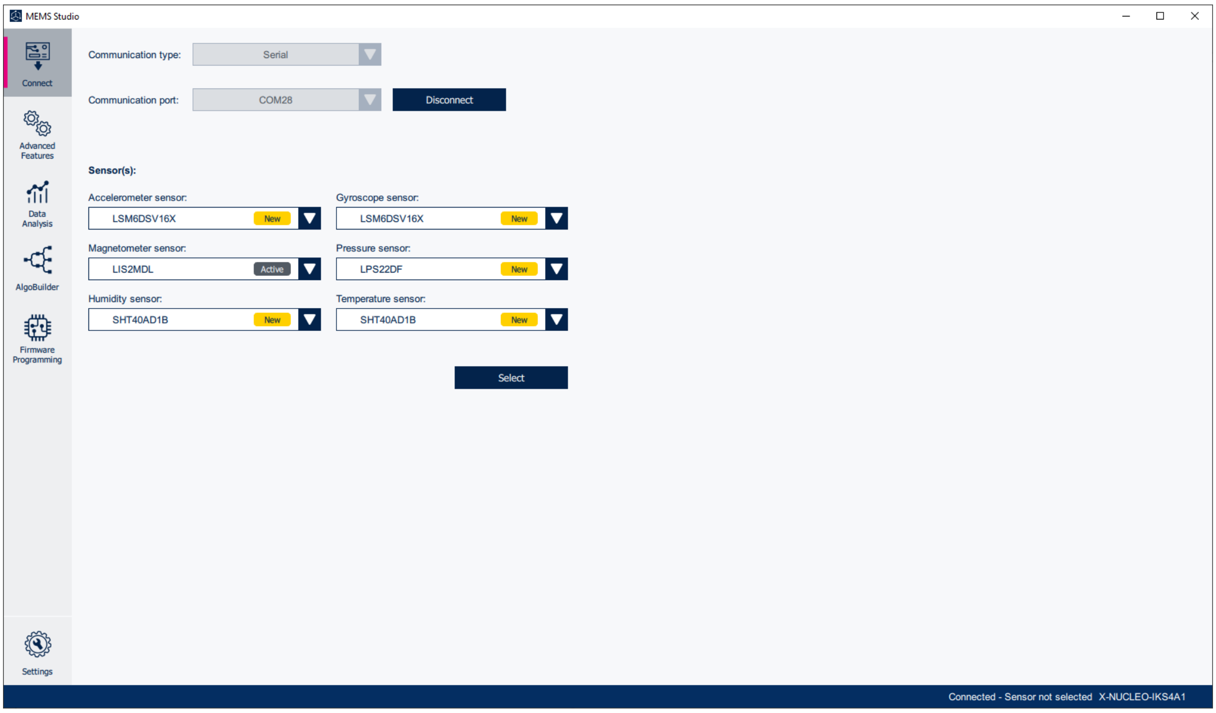


Interface: SPI4W

VDD: 1.80 V Range: [1.71 V - 3.6 V]

VDDIO: 1.80 V Range: [1.08 V - 3.6 V]

Figure 12. Sensor selection - DatalogExtended firmware



Communication type: Serial

Communication port: COM28

Sensor(s):

Accelerometer sensor: LSM6DSV16X New

Gyroscope sensor: LSM6DSV16X New

Magnetometer sensor: LIS2MDL Active

Pressure sensor: LPS22DF New

Humidity sensor: SHT40AD1B New

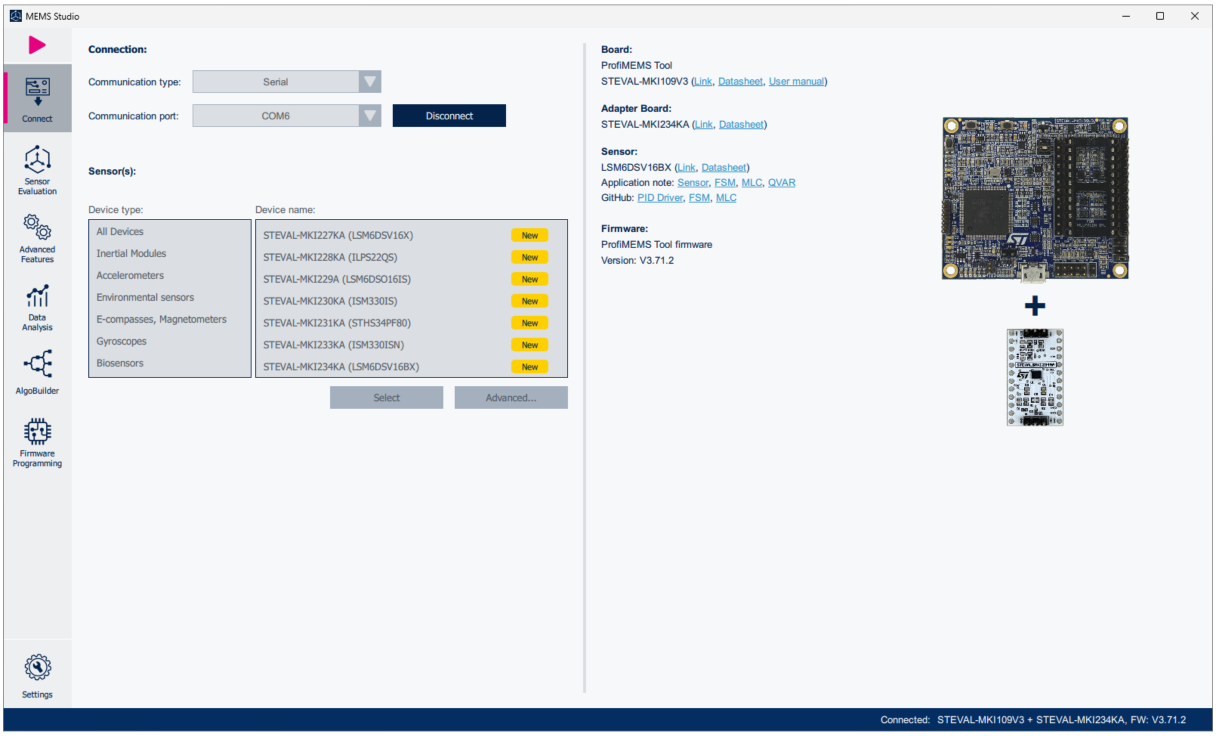
Temperature sensor: SHT40AD1B New

Connected - Sensor not selected X-NUCLEO-IKS4A1

In the case of firmware that does not allow sensor selection (firmware for library evaluation, AlgoBuilder firmware, …), the list of sensors is automatically populated and selected.

Details about connected boards, sensors, and firmware are displayed in the right panel including links to all available resources like datasheets, applications notes, websites, GitHub repositories, and others.

Figure 13. Sensor and board references



Connection:

Communication type: Serial

Communication port: COM6

Sensor(s):

Device type:	Device name:
All Devices	STEVAL-MKI227KA (LSM6DSV16X) New
Inertial Modules	STEVAL-MKI228KA (ILPS22QS) New
Accelerometers	STEVAL-MKI229A (LSM6DSO16IS) New
Environmental sensors	STEVAL-MKI230KA (ISM330IS) New
E-compasses, Magnetometers	STEVAL-MKI231KA (STHS34PF80) New
Gyroscopes	STEVAL-MKI233KA (ISM330ISN) New
Biosensors	STEVAL-MKI234KA (LSM6DSV16BX) New

Board:
ProfiMEMS Tool
STEVAL-MKI109V3 (Link, Datasheet, User manual)

Adapter Board:
STEVAL-MKI234KA (Link, Datasheet)

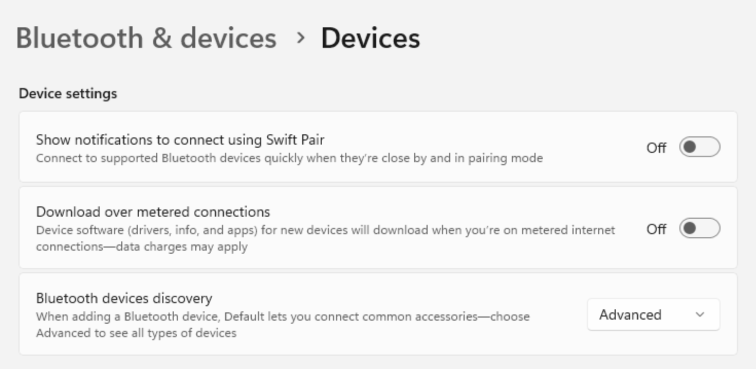
Sensor:
LSM6DSV16BX (Link, Datasheet)
Application note: Sensor, FSM, MLC, QVAR
GitHub: PID Driver, FSM, MLC

Firmware:
ProfiMEMS Tool firmware
Version: V3.71.2

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.71.2

Development boards with appropriate AlgoBuilder firmware can be connected over a Bluetooth interface. In the Windows operating system, the device needs to be paired first. In order to successfully detect the device in Windows 11, the [**Advanced**] Bluetooth device discovery mode needs to be selected in the Bluetooth settings.

Figure 14. **Bluetooth device discovery mode (Windows 11)**



Bluetooth & devices › Devices

Device settings

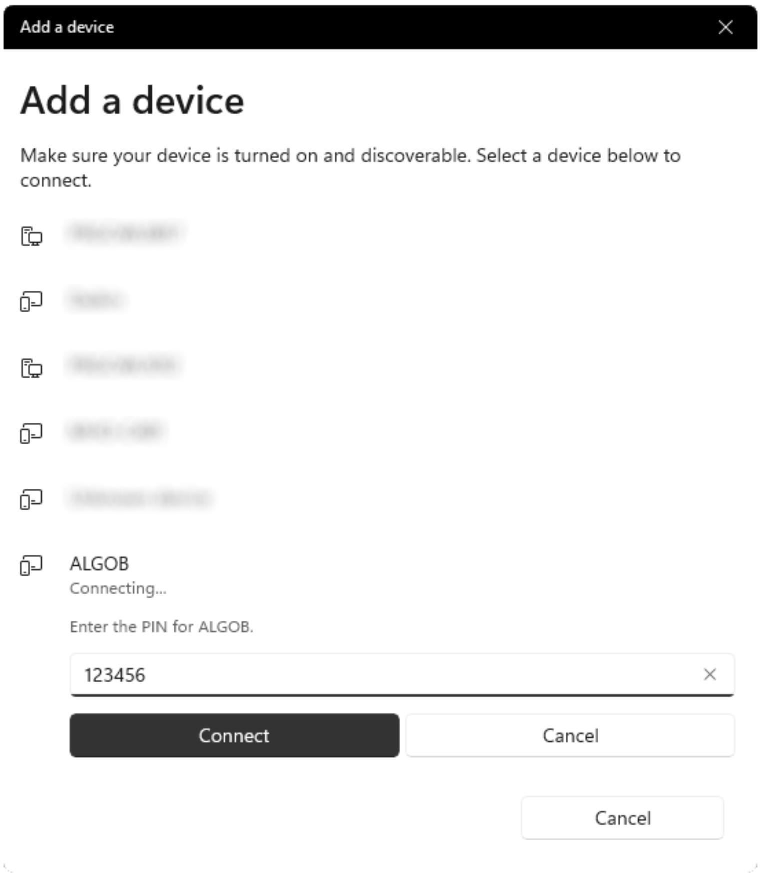
Show notifications to connect using Swift Pair
Connect to supported Bluetooth devices quickly when they're close by and in pairing mode
Off

Download over metered connections
Device software (drivers, info, and apps) for new devices will download when you're on metered internet connections—data charges may apply
Off

Bluetooth devices discovery
When adding a Bluetooth device, Default lets you connect common accessories—choose Advanced to see all types of devices
Advanced

The device with AlgoBuilder firmware appears as **ALGOB**. The pin for pairing is always **123456**.

Figure 15. **Device pairing**



Add a device

Add a device

Make sure your device is turned on and discoverable. Select a device below to connect.

ALGOB
Connecting...

Enter the PIN for ALGOB.

123456

2.8 Hardware and firmware compatibility

The following tables list the combinations of hardware and firmware supported by MEMS Studio for MEMS sensor evaluation as well as those combinations that support library evaluation and the AlgoBuilder functionality.

For a complete evaluation of the sensor, the STEVAL-MKI109D or STEVAL-MKI109V3 (professional MEMS tool) evaluation platform should be used, which supports the adapter boards and sensors indicated in Table 1.

Refer to Table 2 for the X-NUCLEO expansion boards with STM32 ODE (open development environment) used for development and form factor boards dedicated to prototyping. The sensor evaluation firmware on these boards offers configuring and testing some embedded features, such as MLC, FSM, or interrupts.

Refer to Table 3 for supported boards intended for data logging using Datalog2 (High Speed Datalog) firmware.

For library evaluation, refer to Table 4, which indicates the X-NUCLEO expansion board and supported sensor, using the firmware from the X-CUBE-MEMS1 package, however other sensors are supported if the application is generated using STM32CubeMX.

Finally, Table 5 provides the list of hardware platforms and development kits, used in conjunction with AlgoBuilder, that support a limited number of sensors.

Table 1. Supported hardware and firmware for full sensor evaluation

Hardware platform	Firmware	Supported adapter board and sensor
STEVAL-MKI109D STEVAL-MKI109V3 (Professional MEMS tool)	ProfiMEMSToolVx.y.z.bin (from MEMS Studio)	STEVAL-MKI105V1 (LIS3DH) STEVAL-MKI110V1 (AIS328DQ) STEVAL-MKI125V1 (A3G4250D) STEVAL-MKI151V1 (LIS2DH12) STEVAL-MKI153V1 (H3LIS331DL) STEVAL-MKI164V1 (LIS2HH12) STEVAL-MKI165V1 (LPS25HB) STEVAL-MKI166V1 (H3LIS100DL) STEVAL-MKI167V1 (H3LIS200DL) STEVAL-MKI168V1 (IIS2DH) STEVAL-MKI169V1 (I3G4250D) STEVAL-MKI170V1 (IIS328DQ) STEVAL-MKI172V1 (LSM303AGR) STEVAL-MKI174V1 (LIS2DS12) STEVAL-MKI175V1 (LIS2DE12) STEVAL-MKI178V2 (LSM6DSL) STEVAL-MKI179V1 (LIS2DW12) STEVAL-MKI180V1 (LIS3DHH) STEVAL-MKI181V1 (LIS2MDL) STEVAL-MKI182V2 (ISM330DLC) STEVAL-MKI184V1 (ISM303DAC) STEVAL-MKI185V1 (IIS2MDC) STEVAL-MKI186V1 (IIS3DHHC) STEVAL-MKI189V1 (LSM6DSM) STEVAL-MKI190V1 (LIS2DTW12) STEVAL-MKI191V1 (IIS2DLPC) STEVAL-MKI192V1 (LPS22HH) STEVAL-MKI193V1 (ASM330LHH) STEVAL-MKI194V1 (LSM6DSR) STEVAL-MKI195V1 (LSM6DSRX) STEVAL-MKI196V1 (LSM6DSO)

Hardware platform	Firmware	Supported adapter board and sensor
		STEVAL-MKI197V1 (LSM6DSOX)
		STEVAL-MKI200V1K (STTS22H)
		STEVAL-MKI207V1 (ISM330DHCX)
		STEVAL-MKI208V1K (IIS3DWB)
		STEVAL-MKI209V1K (IIS2ICLX)
		STEVAL-MKI210V2K (ISM330DHCX)
		STEVAL-MKI211V1K (LIS25BA)
		STEVAL-MKI212V1 (ASM330LHHX)
		STEVAL-MKI213V1 (LPS27HHW)
		STEVAL-MKI214V1 (LPS33K)
		STEVAL-MKI215V1 (LSM6DSO32)
		STEVAL-MKI216V1K (IIS3DHHC)
		STEVAL-MKI217V1 (LSM6DSOX, LIS2MDL)
		STEVAL-MKI218V1 (AIS2IH)
		STEVAL-MKI220V1 (LPS27HHTW)
		STEVAL-MKI221V1 (LSM6DSO32X)
		STEVAL-MKI222V1 (LIS2DU12)
		STEVAL-MKI223V1 (ILPS28QSW)
		STEVAL-MKI224V1 (LPS22DF)
		STEVAL-MKI225A (LPS28DFW)
		STEVAL-MKI226KA (AIS25BA)
		STEVAL-MKI227KA (LSM6DSV16X)
		STEVAL-MKI228KA (ILPS22QS)
		STEVAL-MKI229A (LSM6DSO16IS)
		STEVAL-MKI230KA (ISM330IS)
		STEVAL-MKI231KA (STHS34PF80)
		STEVAL-MKI233KA (ISM330ISN)
		STEVAL-MKI234KA (LSM6DSV16BX)
		STEVAL-MKI235KA (LIS2DUXS12)
		STEVAL-MKI236A (ASM330LHB ASIL-B)
		STEVAL-MKI237KA (LSM6DSV16BX)
		STEVAL-MKI238A (LIS2DUX12)
		STEVAL-MKI239A (LSM6DSV)
		STEVAL-MKI240KA (LSM6DSV32X)
		STEVAL-MKI241KA (LSM6DSV16B)
		STEVAL-MKI242A (ST1VAFE6AX)
		STEVAL-MKI243A (ASM330LHHXG1)
		STEVAL-MKI244A (ASM330LHBG1)
		STEVAL-MKI245KA (ISM330BX)
		STEVAL-MKI246KA (IIS2DULPX)
		STEVAL-MKI247A (LSM6DSV80X)
		STEVAL-MKI248KA (ISM6HG256X)
		STEVAL-MKI249KA (ST1VAFE6AX)
		STEVAL-MKI250KA (ST1VAFE3BX)
		STEVAL-MKI251A (LSM6DSV320X)

Hardware platform	Firmware	Supported adapter board and sensor
		STEVAL-MKI252KA (IIS3DWG1) STEVAL-MET001V1 (LPS22HB) SENSEVAL-SHT4XV1 (SHT40-AD1B) SENSEVAL-SCB4XV1 (SHT40-AD1B, SGP40-D-R4, LPS22DF)

Table 2. Supported hardware and firmware with reduced sensor evaluation

Hardware platform	Firmware	Supported sensor
X-NUCLEO-IKS02A1	DatalogExtended.bin (from the X-CUBE-MEMS1 package)	ISM330DHCX IIS2MDC IIS2DLPC **In the DIL24 socket:** STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI245KA (ISM330BX) STEVAL-MKI246KA (IIS2DULPX)
X-NUCLEO-IKS01A3	DatalogExtended.bin (from the X-CUBE-MEMS1 package)	LSM6DSO LIS2DW12 LIS2MDL LPS22HH HTS221 **In the DIL24 socket:** STEVAL-MKI125V1 (A3G4250D) STEVAL-MKI151V1 (LIS2DH12) STEVAL-MKI153V1 (H3LIS331DL) STEVAL-MKI185V1 (IIS2MDC) STEVAL-MKI191V1 (IIS2DLPC) STEVAL-MKI193V1 (ASM330LHH) STEVAL-MKI194V1 (LSM6DSR) STEVAL-MKI195V1 (LSM6DSRX) STEVAL-MKI197V1 (LSM6DSOX) STEVAL-MKI207V1 (ISM330DHCX) STEVAL-MKI209V1K (IIS2ICLX) STEVAL-MKI210V2K (ISM330DHCX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI215V1 (LSM6DSO32) STEVAL-MKI218V1 (AIS2IH) STEVAL-MKI221V1 (LSM6DSO32X) STEVAL-MKI222V1 (LIS2DU12) STEVAL-MKI223V1 (ILPS28QSW) STEVAL-MKI224V1 (LPS22DF) STEVAL-MKI225A (LPS28DFW) STEVAL-MKI227KA (LSM6DSV16X) STEVAL-MKI228KA (ILPS22QS) STEVAL-MKI234KA (LSM6DSV16BX) STEVAL-MKI235KA (LIS2DUXS12)

Hardware platform	Firmware	Supported sensor
		STEVAL-MKI238A (LIS2DUX12) STEVAL-MKI239A (LSM6DSV) STEVAL-MKI240KA (LSM6DSV32X) STEVAL-MKI241KA (LSM6DSV16B) STEVAL-MKI247A (LSM6DSV80X) SENSEVAL-SHT4XV1 (SHT40-AD1B)
X-NUCLEO-IKS4A1	DatalogExtended.bin (from the X-CUBE-MEMS1 package)	LSM6DSV16X LSM6DSO16IS LIS2DUXS12 LIS2MDL LPS22DF STTS22H SHT40-AD1B **In the DIL24 socket:** STEVAL-MKI125V1 (A3G4250D) STEVAL-MKI151V1 (LIS2DH12) STEVAL-MKI153V1 (H3LIS331DL) STEVAL-MKI179V1 (LIS2DW12) STEVAL-MKI185V1 (IIS2MDC) STEVAL-MKI191V1 (IIS2DLPC) STEVAL-MKI192V1 (LPS22HH) STEVAL-MKI193V1 (ASM330LHH) STEVAL-MKI194V1 (LSM6DSR) STEVAL-MKI195V1 (LSM6DSRX) STEVAL-MKI196V1 (LSM6DSO) STEVAL-MKI197V1 (LSM6DSOX) STEVAL-MKI207V1 (ISM330DHCX) STEVAL-MKI209V1K (IIS2ICLX) STEVAL-MKI210V2K (ISM330DHCX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI215V1 (LSM6DSO32) STEVAL-MKI218V1 (AIS2IH) STEVAL-MKI221V1 (LSM6DSO32X) STEVAL-MKI222V1 (LIS2DU12) STEVAL-MKI223V1 (ILPS28QSW) STEVAL-MKI225A (LPS28DFW) STEVAL-MKI228KA (ILPS22QS) STEVAL-MKI234KA (LSM6DSV16BX) STEVAL-MKI238A (LIS2DUX12) STEVAL-MKI239A (LSM6DSV) STEVAL-MKI240KA (LSM6DSV32X) STEVAL-MKI241KA (LSM6DSV16B) STEVAL-MKI242A (ST1VAFE6AX) STEVAL-MKI245KA (ISM330BX) STEVAL-MKI247A (LSM6DSV80X)

Hardware platform	Firmware	Supported sensor
		STEVAL-MKI250KA (ST1VAFE3BX) STEVAL-MKI251A (LSM6DSV320X)
X-NUCLEO-IKS5A1	DatalogExtended.bin (from the X-CUBE-MEMS1 package)	ISM6HG256X ISM330IS IIS2DULPX IIS2MDC ILPS22QS **In the DIL24 socket:** STEVAL-MKI191V1 (IIS2DLPC) STEVAL-MKI209V1K (IIS2ICLX) STEVAL-MKI210V2K (ISM330DHCX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI218V1 (AIS2IH) STEVAL-MKI245KA (ISM330BX) SENSEVAL-SHT4XV1 (SHT40-AD1B)
STEVAL-MKBOXPRO (SensorTile.box Pro)	DatalogExtended.bin (from MEMS Studio)	LSM6DSV16X LIS2DU12 LIS2MDL LPS22DF STTS22H **In the DIL24 socket:** STEVAL-MKI110V1 (AIS328DQ) STEVAL-MKI125V1 (A3G4250D) STEVAL-MKI151V1 (LIS2DH12) STEVAL-MKI153V1 (H3LIS331DL) STEVAL-MKI179V1 (LIS2DW12) STEVAL-MKI191V1 (IIS2DLPC) STEVAL-MKI192V1 (LPS22HH) STEVAL-MKI193V1 (ASM330LHH) STEVAL-MKI194V1 (LSM6DSR) STEVAL-MKI195V1 (LSM6DSRX) STEVAL-MKI196V1 (LSM6DSO) STEVAL-MKI197V1 (LSM6DSOX) STEVAL-MKI207V1 (ISM330DHCX) STEVAL-MKI210V2K (ISM330DHCX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI215V1 (LSM6DSO32) STEVAL-MKI218V1 (AIS2IH) STEVAL-MKI220V1 (LPS27HHTW) STEVAL-MKI221V1 (LSM6DSO32X) STEVAL-MKI228KA (ILPS22QS) STEVAL-MKI229A (LSM6DSO16IS) STEVAL-MKI234KA (LSM6DSV16BX) STEVAL-MKI235KA (LIS2DUXS12)

Hardware platform	Firmware	Supported sensor
		STEVAL-MKI238A (LIS2DUX12) STEVAL-MKI239A (LSM6DSV) STEVAL-MKI240KA (LSM6DSV32X) STEVAL-MKI241KA (LSM6DSV16B) STEVAL-MKI242A (ST1VAFE6AX) STEVAL-MKI245KA (ISM330BX) STEVAL-MKI246KA (IIS2DULPX) STEVAL-MKI247A (LSM6DSV80X) STEVAL-MKI250KA (ST1VAFE3BX) STEVAL-MKI251A (LSM6DSV320X)
STEVAL-STWINBX1 (STWIN.box)	DatalogExtended.bin (from MEMS Studio)	ISM330DHCX IIS2MDC ILPS22QS STTS22H IIS2ICLX IIS2DLPC IIS3DWB **In the DIL24 socket:** STEVAL-MKI125V1 (A3G4250D) STEVAL-MKI151V1 (LIS2DH12) STEVAL-MKI179V1 (LIS2DW12) STEVAL-MKI182V2 (ISM330DLC) STEVAL-MKI192V1 (LPS22HH) STEVAL-MKI193V1 (ASM330LHH) STEVAL-MKI194V1 (LSM6DSR) STEVAL-MKI195V1 (LSM6DSRX) STEVAL-MKI196V1 (LSM6DSO) STEVAL-MKI197V1 (LSM6DSOX) STEVAL-MKI212V1 (ASM330LHHX) STEVAL-MKI215V1 (LSM6DSO32) STEVAL-MKI218V1 (AIS2IH) STEVAL-MKI220V1 (LPS27HHTW) STEVAL-MKI221V1 (LSM6DSO32X) STEVAL-MKI227KA (LSM6DSV16X) STEVAL-MKI229A (LSM6DSO16IS) STEVAL-MKI234KA (LSM6DSV16BX) STEVAL-MKI239A (LSM6DSV) STEVAL-MKI240KA (LSM6DSV32X) STEVAL-MKI241KA (LSM6DSV16B) STEVAL-MKI242A (ST1VAFE6AX) STEVAL-MKI245KA (ISM330BX) STEVAL-MKI247A (LSM6DSV80X) STEVAL-MKI251A (LSM6DSV320X)

Note: Reduced sensor evaluation on selected boards, in comparison with the full sensor evaluation on the professional MEMS tool, offers only selected features due to hardware platform and firmware limitations.

Table 3. Supported hardware for datalogging using Datalog2 (High Speed Datalog) firmware

Hardware platform	Firmware	Supported sensor
X-NUCLEO-IKS02A1	DATALOG2_Release.bin (from the FP-SNS-DATALOG2 package)	ISM330DHCX IIS2MDC IIS2DLPC
STEVAL-MKBOXPRO (SensorTile.box Pro)	DATALOG2_Release.bin (from the FP-SNS-DATALOG2 package)	LSM6DSV16X LIS2DU12 LIS2MDL LPS22DF STTS22H **In the DIL24 socket:** STEVAL-MKI153V1 (H3LIS331DL) STEVAL-MKI223V1 (ILPS28QSW) STEVAL-MKI230KA (ISM330IS) STEVAL-MKI234KA (LSM6DSV16BX) STEVAL-MKI240KA (LSM6DSV32X) STEVAL-MKI247A (LSM6DSV80X) STEVAL-MKI251A (LSM6DSV320X)
STEVAL-STWINKT1 (STWIN)	DATALOG2_Release.bin (from the FP-SNS-DATALOG2 package)	ISM330DHCX IIS2MDC LPS22HH HTS221
STEVAL-STWINBX1 (STWIN.box)	DATALOG2_Release.bin (from the FP-SNS-DATALOG2 package)	ISM330DHCX IIS2MDC ILPS22QS STTS22H IIS2ICLX IIS2DLPC IIS3DWB **In the DIL24 socket:** STEVAL-MKI223V1 (ILPS28QSW) STEVAL-MKI230KA (ISM330IS) STEVAL-MKI245KA (ISM330BX) STEVAL-MKI246KA (IIS2DULPX)

Note: Other hardware platforms might be also supported by the Datalog2 firmware for more details check the latest version of the FP-SNS-DATALOG2 package.

Table 4. Supported hardware and firmware for library evaluation

Hardware platform	Firmware	Supported sensor
X-NUCLEO-IKS02A1	see Applications folder (from the X-CUBE-MEMS1 package)	ISM330DHCX IIS2MDC Other components can be used if the application is generated through STM32CubeMX.
X-NUCLEO-IKS01A3	see Applications folder (from the X-CUBE-MEMS1 package)	LSM6DSO LIS2MDL LPS22HH HTS221 Other components can be used if the application is generated through STM32CubeMX.
X-NUCLEO-IKS4A1	see Applications folder (from the X-CUBE-MEMS1 package)	LSM6DSV16X LIS2MDL LPS22DF STTS22H Other components can be used if the application is generated through STM32CubeMX.
X-NUCLEO-IKS5A1	see Applications folder (from the X-CUBE-MEMS1 package)	ISM6HG256X IIS2MDC ILPS22QS Other components can be used if the application is generated through STM32CubeMX.

Table 5. Supported hardware and firmware with AlgoBuilder functionality

Hardware platform	Firmware	Supported sensor
NUCLEO-F401RE or NUCLEO-U575ZI-Q or NUCLEO-U385RG-Q with X-NUCLEO-IKS5A1	generated in AlgoBuilder	ISM6HG256X ISM330IS IIS2MDC ILPS22QS
NUCLEO-F401RE or NUCLEO-U575ZI-Q or NUCLEO-U385RG-Q with X-NUCLEO-IKS4A1		LSM6DSV16X LSM6DSO16IS LIS2MDL LPS22DF SHT40-AD1B
NUCLEO-F401RE NUCLEO-U575ZI-Q with X-NUCLEO-IKS02A1 STEVAL-MKI230KA		STEVAL-MKI230KA (ISM330IS) IIS2MDC
STEVAL-MKSBOX1V1 (SensorTile.box)		LSM6DSOX LIS2MDL LPS22HH HTS221
STEVAL-MKBOXPRO (SensorTile.box Pro)		LSM6DSV16X LIS2MDL LPS22DF STTS22H STEVAL-MKI229KA (LSM6DSO16IS) STEVAL-MKI251A (LSM6DSV320X)
STEVAL-STWINKT1 (STWIN)		ISM330DHCX IIS2MDC LPS22HH HTS221
STEVAL-STWINBX1 (STWIN.box)		ISM330DHCX IIS2MDC ILPS22QS STTS22H STEVAL-MKI230KA (ISM330IS)

3 Sensor evaluation

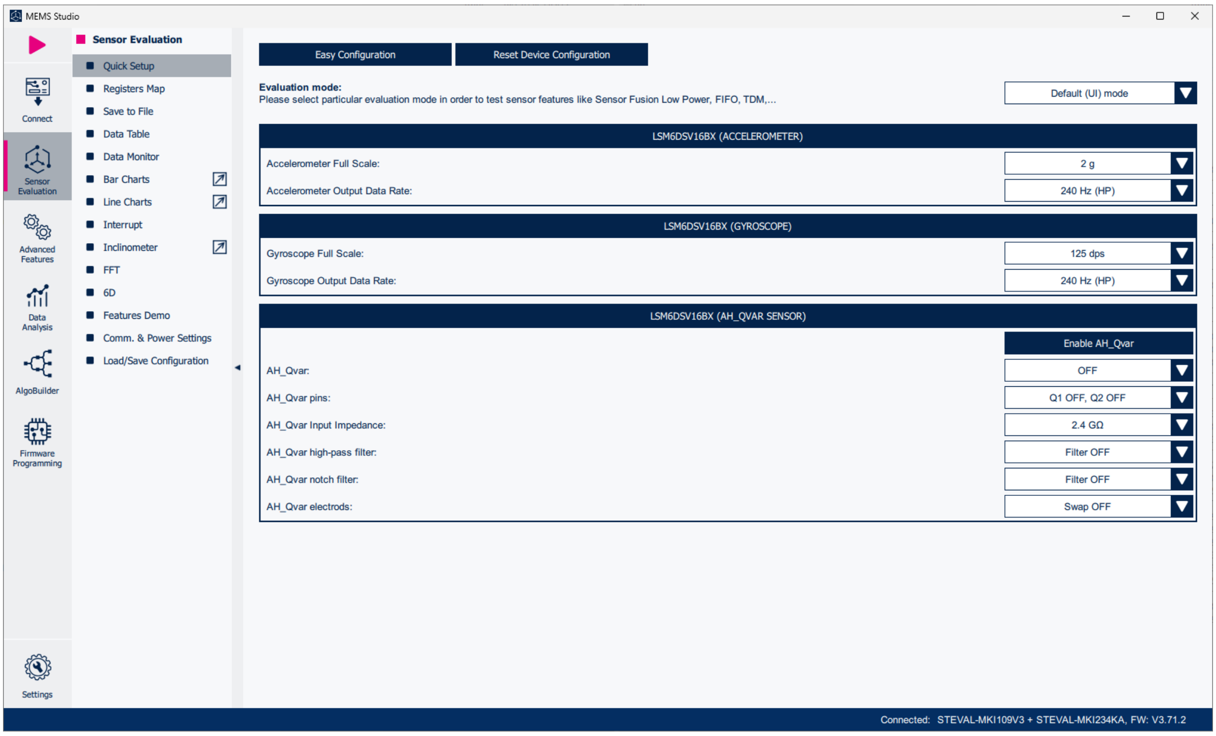
The sensor evaluation features are dynamically adjusted according to the available functionalities of the connected evaluation board, sensor, and firmware.

Quick Setup page

The [**Quick Setup**] page allows the user to configure basic sensor configurations such as the output data rate, full scale, and others according to the device datasheet.

If more evaluation modes are available like sensor fusion low-power, FIFO, TDM, and others, they can be selected on this page. The available sensor evaluation pages are adjusted according to the selected mode. If applicable, the control can align its status to the current register value.

Figure 16. **Quick Setup page**



Evaluation mode:
Please select particular evaluation mode in order to test sensor features like Sensor Fusion Low Power, FIFO, TDM,... Default (UI) mode

LSM6DSV16BX (ACCELEROMETER)

Accelerometer Full Scale: 2 g
Accelerometer Output Data Rate: 240 Hz (HP)

LSM6DSV16BX (GYROSCOPE)

Gyroscope Full Scale: 125 dps
Gyroscope Output Data Rate: 240 Hz (HP)

LSM6DSV16BX (AH_QVAR SENSOR)

AH_Qvar: OFF
AH_Qvar pins: Q1 OFF, Q2 OFF
AH_Qvar Input Impedance: 2.4 GΩ
AH_Qvar high-pass filter: Filter OFF
AH_Qvar notch filter: Filter OFF
AH_Qvar electrodes: Swap OFF

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.71.2

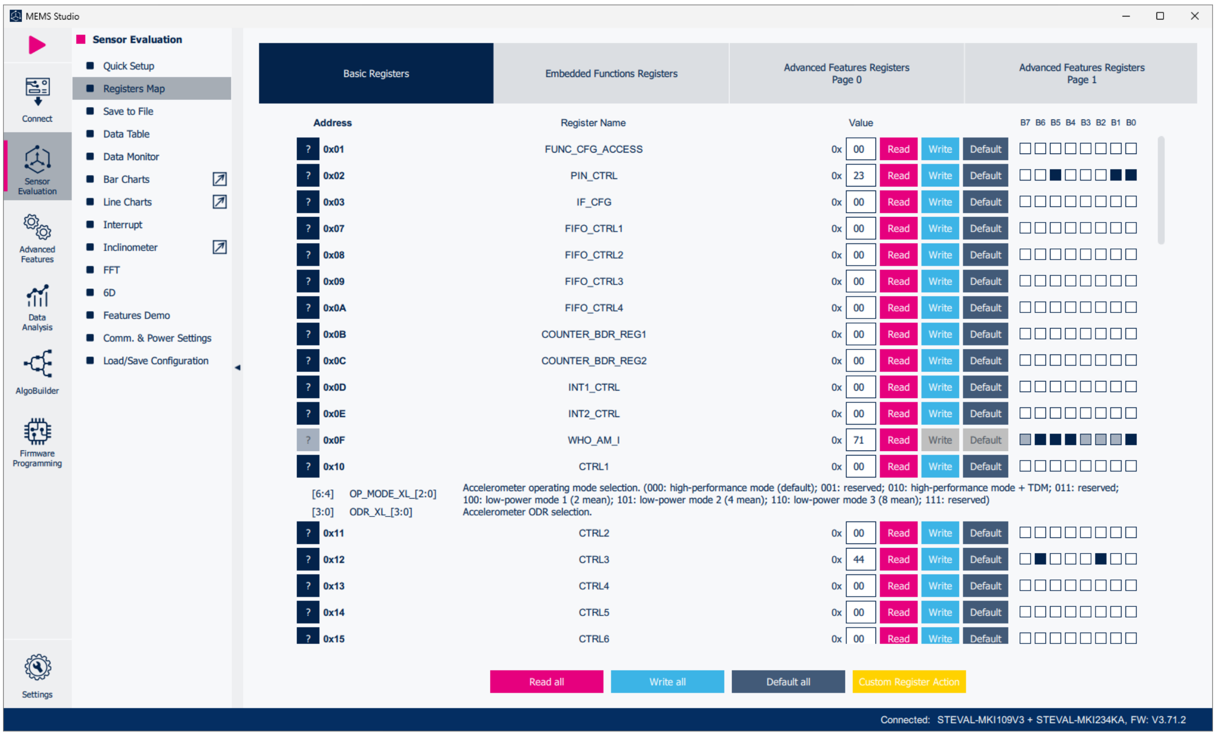
Registers Map page

The [**Registers Map**] displays the list of device registers divided by register pages, if any.

Every register item has a [**Read**], [**Write**], and [**Default**](restore default value) button enabled according to the datasheet and a bit view populated according to the register value.

Using the dedicated button [**?**], any register item can be expanded to explore the register value bit map description.

Figure 17. **Registers Map page**

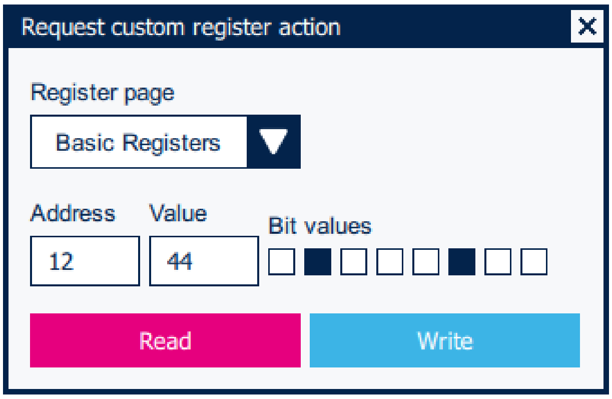


	Address	Register Name	Value				B7 B6 B5 B4 B3 B2 B1 B0
?	0x01	FUNC_CFG_ACCESS	0x 00	Read	Write	Default	□□□□□□□□
?	0x02	PIN_CTRL	0x 23	Read	Write	Default	□□■□□□■■
?	0x03	IF_CFG	0x 00	Read	Write	Default	□□□□□□□□
?	0x07	FIFO_CTRL1	0x 00	Read	Write	Default	□□□□□□□□
?	0x08	FIFO_CTRL2	0x 00	Read	Write	Default	□□□□□□□□
?	0x09	FIFO_CTRL3	0x 00	Read	Write	Default	□□□□□□□□
?	0x0A	FIFO_CTRL4	0x 00	Read	Write	Default	□□□□□□□□
?	0x0B	COUNTER_BDR_REG1	0x 00	Read	Write	Default	□□□□□□□□
?	0x0C	COUNTER_BDR_REG2	0x 00	Read	Write	Default	□□□□□□□□
?	0x0D	INT1_CTRL	0x 00	Read	Write	Default	□□□□□□□□
?	0x0E	INT2_CTRL	0x 00	Read	Write	Default	□□□□□□□□
?	0x0F	WHO_AM_I	0x 71	Read	Write	Default	□■■■□□□■
?	0x10	CTRL1	0x 00	Read	Write	Default	□□□□□□□□
[6:4]	OP_MODE_XL_[2:0]	Accelerometer operating mode selection. (000: high-performance mode (default); 001: reserved; 010: high-performance mode + TDM; 011: reserved; 100: low-power mode 1 (2 mean); 101: low-power mode 2 (4 mean); 110: low-power mode 3 (8 mean); 111: reserved)					
[3:0]	ODR_XL_[3:0]	Accelerometer ODR selection.					
?	0x11	CTRL2	0x 00	Read	Write	Default	□□□□□□□□
?	0x12	CTRL3	0x 44	Read	Write	Default	□■□□□■□□
?	0x13	CTRL4	0x 00	Read	Write	Default	□□□□□□□□
?	0x14	CTRL5	0x 00	Read	Write	Default	□□□□□□□□
?	0x15	CTRL6	0x 00	Read	Write	Default	□□□□□□□□

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.71.2

[**Custom Register Action**] allows direct read and write transactions to a single register by specifying the register address, page and value.

Figure 18. **Custom register action**



Register page: Basic Registers

Address: 12

Value: 44

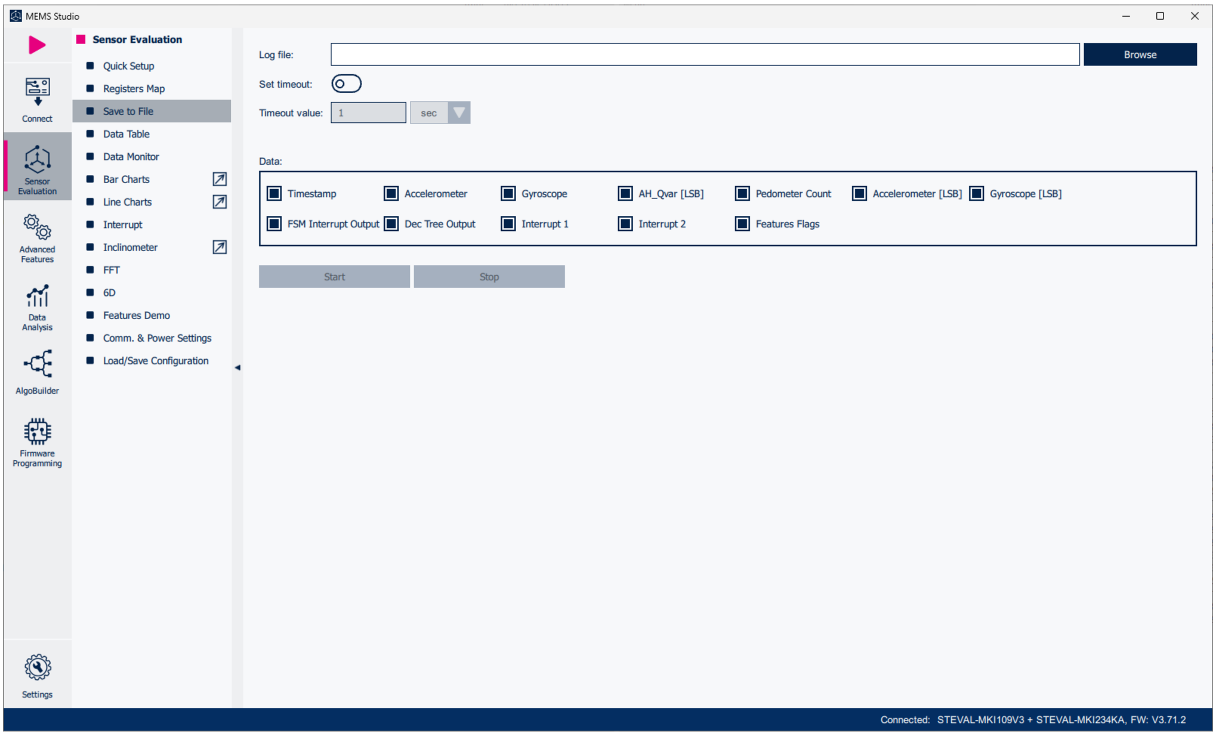
Bit values: □■□□□■□□

Save to File page

The user can use this page to save a stream of sensor output data in a .csv file for postprocessing. This can be done by selecting the data to be stored.

The [**Browse**] button is used to select the folder and insert the file name. The acquisition period can be set to a fixed time in [ms] if desired. Then data to be saved can be selected from the list. The acquisition can be controlled using the [**Start**] and [**Stop**] buttons. If the [**Logging timeout**] option is used, the acquisition is going to run as long as the timeout period.

Figure 19. **Save to File page**



Log file:

Set timeout: ○

Timeout value: 1 sec

Data:

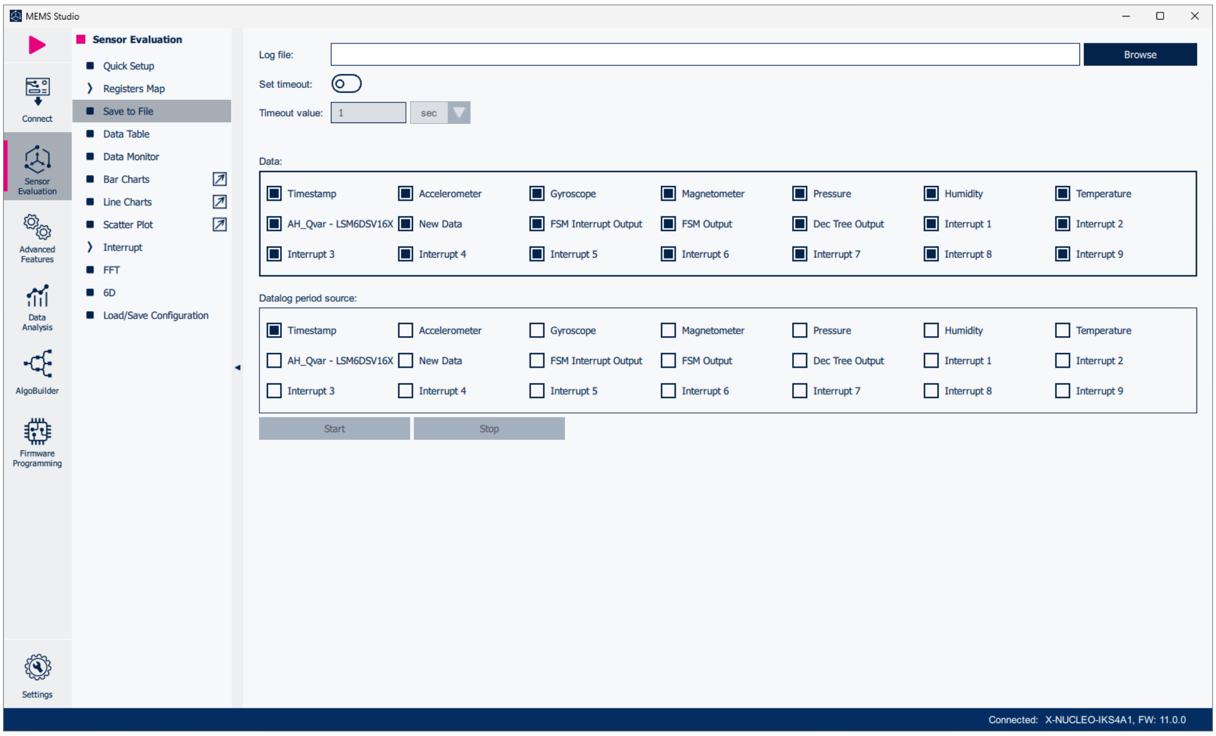
☑ Timestamp ☑ Accelerometer ☑ Gyroscope ☑ AH_Qvar [LSB] ☑ Pedometer Count ☑ Accelerometer [LSB] ☑ Gyroscope [LSB]

☑ FSM Interrupt Output ☑ Dec Tree Output ☑ Interrupt 1 ☑ Interrupt 2 ☑ Features Flags

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.71.2

If the sensors are configured according to different output data rates, the user can select the [**Data log period source**] from among the available data types using a dedicated selection option. Refer to the following figure.

Figure 20. **Data log period source**



Log file:

Set timeout: ○

Timeout value: 1 sec

Data:

☒ Timestamp	☒ Accelerometer	☒ Gyroscope	☒ Magnetometer	☒ Pressure	☒ Humidity	☒ Temperature
☒ AH_Qvar - LSM6DSV16X	☒ New Data	☒ FSM Interrupt Output	☒ FSM Output	☒ Dec Tree Output	☒ Interrupt 1	☒ Interrupt 2
☒ Interrupt 3	☒ Interrupt 4	☒ Interrupt 5	☒ Interrupt 6	☒ Interrupt 7	☒ Interrupt 8	☒ Interrupt 9

Datalog period source:

☒ Timestamp	☐ Accelerometer	☐ Gyroscope	☐ Magnetometer	☐ Pressure	☐ Humidity	☐ Temperature
☐ AH_Qvar - LSM6DSV16X	☐ New Data	☐ FSM Interrupt Output	☐ FSM Output	☐ Dec Tree Output	☐ Interrupt 1	☐ Interrupt 2
☐ Interrupt 3	☐ Interrupt 4	☐ Interrupt 5	☐ Interrupt 6	☐ Interrupt 7	☐ Interrupt 8	☐ Interrupt 9

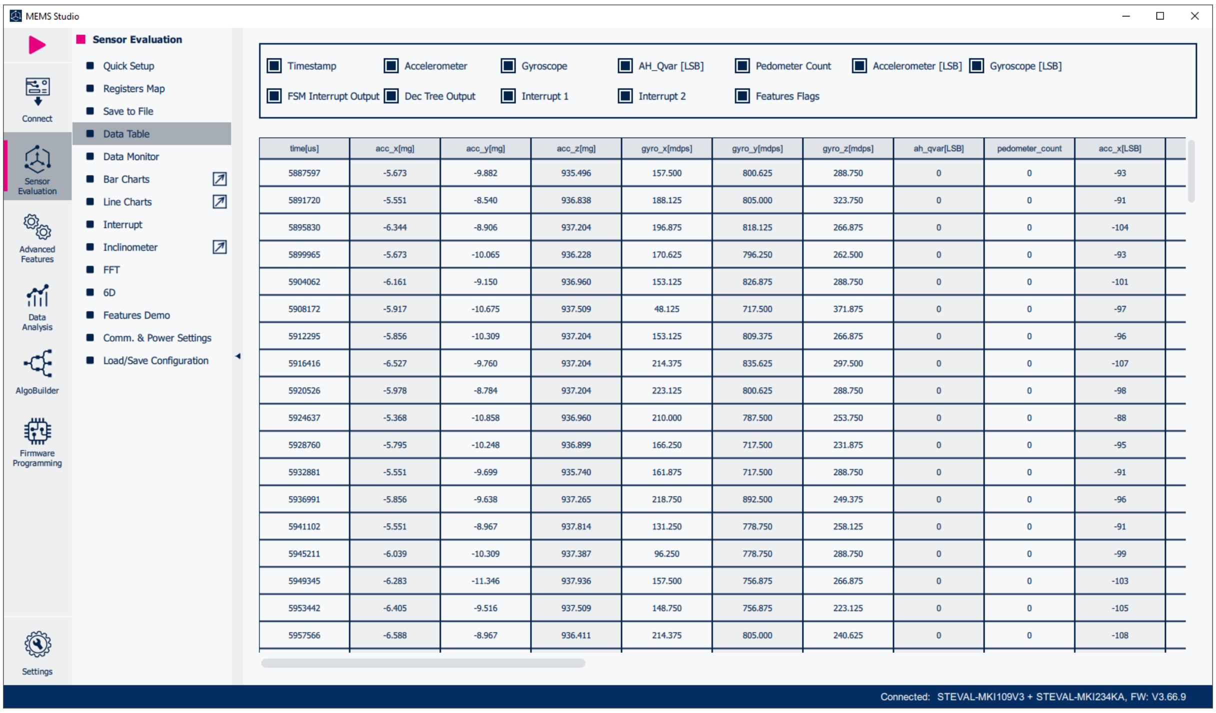
Connected: X-NUCLEO-IKS4A1, FW: 11.0.0

When using Datalog2 (High Speed Datalog) firmware data, are primarily stored in Datalog2 native binary format. Using the [**Convert to CSV**] switch, binary format can be automatically converted to CSV format at the end of the logging session.

Data Table tool

The [**Data Table**] tool displays the output values measured by the sensor connected to the evaluation board. This view provides an overview of all samples received with a table data update rate of 0.5 Hz to reduce overall CPU/ GPU consumption. This functionality is disabled in the case of very high data rates.

Figure 21. Data Table tool



☑ Timestamp ☑ Accelerometer ☑ Gyroscope ☑ AH_Qvar [LSB] ☑ Pedometer Count ☑ Accelerometer [LSB] ☑ Gyroscope [LSB]

☑ FSM Interrupt Output ☑ Dec Tree Output ☑ Interrupt 1 ☑ Interrupt 2 ☑ Features Flags

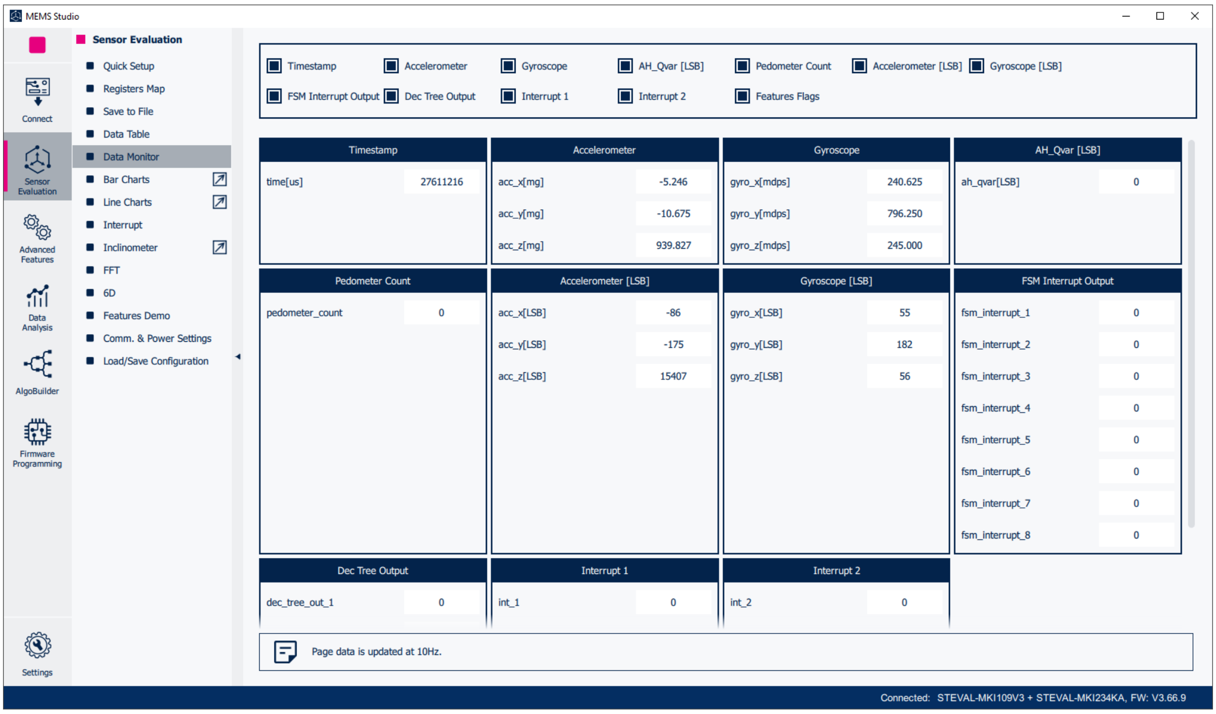
time[us]	acc_x[mg]	acc_y[mg]	acc_z[mg]	gyro_x[mdps]	gyro_y[mdps]	gyro_z[mdps]	ah_qvar[LSB]	pedometer_count	acc_x[LSB]
5887597	-5.673	-9.882	935.496	157.500	800.625	288.750	0	0	-93
5891720	-5.551	-8.540	936.838	188.125	805.000	323.750	0	0	-91
5895830	-6.344	-8.906	937.204	196.875	818.125	266.875	0	0	-104
5899965	-5.673	-10.065	936.228	170.625	796.250	262.500	0	0	-93
5904062	-6.161	-9.150	936.960	153.125	826.875	288.750	0	0	-101
5908172	-5.917	-10.675	937.509	48.125	717.500	371.875	0	0	-97
5912295	-5.856	-10.309	937.204	153.125	809.375	266.875	0	0	-96
5916416	-6.527	-9.760	937.204	214.375	835.625	297.500	0	0	-107
5920526	-5.978	-8.784	937.204	223.125	800.625	288.750	0	0	-98
5924637	-5.368	-10.858	936.960	210.000	787.500	253.750	0	0	-88
5928760	-5.795	-10.248	936.899	166.250	717.500	231.875	0	0	-95
5932881	-5.551	-9.699	935.740	161.875	717.500	288.750	0	0	-91
5936991	-5.856	-9.638	937.265	218.750	892.500	249.375	0	0	-96
5941102	-5.551	-8.967	937.814	131.250	778.750	258.125	0	0	-91
5945211	-6.039	-10.309	937.387	96.250	778.750	288.750	0	0	-99
5949345	-6.283	-11.346	937.936	157.500	756.875	266.875	0	0	-103
5953442	-6.405	-9.516	937.509	148.750	756.875	223.125	0	0	-105
5957566	-6.588	-8.967	936.411	214.375	805.000	240.625	0	0	-108

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.66.9

Data Monitor tool

The [**Data Monitor**] tool displays the latest output values measured by the sensor connected to the evaluation board. This view provides an overview of the last samples received with an update rate of 10 Hz to reduce overall CPU/GPU consumption in the case of high data rates.

Figure 22. Data Monitor tool



☑ Timestamp ☑ Accelerometer ☑ Gyroscope ☑ AH_Qvar [LSB] ☑ Pedometer Count ☑ Accelerometer [LSB] ☑ Gyroscope [LSB]
☑ FSM Interrupt Output ☑ Dec Tree Output ☑ Interrupt 1 ☑ Interrupt 2 ☑ Features Flags

Timestamp		Accelerometer		Gyroscope		AH_Qvar [LSB]	
time[us]	27611216	acc_x[mg]	-5.246	gyro_x[mdps]	240.625	ah_qvar[LSB]	0
		acc_y[mg]	-10.675	gyro_y[mdps]	796.250		
		acc_z[mg]	939.827	gyro_z[mdps]	245.000		

Pedometer Count		Accelerometer [LSB]		Gyroscope [LSB]		FSM Interrupt Output	
pedometer_count	0	acc_x[LSB]	-86	gyro_x[LSB]	55	fsm_interrupt_1	0
		acc_y[LSB]	-175	gyro_y[LSB]	182	fsm_interrupt_2	0
		acc_z[LSB]	15407	gyro_z[LSB]	56	fsm_interrupt_3	0
						fsm_interrupt_4	0
						fsm_interrupt_5	0
						fsm_interrupt_6	0
						fsm_interrupt_7	0
						fsm_interrupt_8	0

Dec Tree Output		Interrupt 1		Interrupt 2	
dec_tree_out_1	0	int_1	0	int_2	0

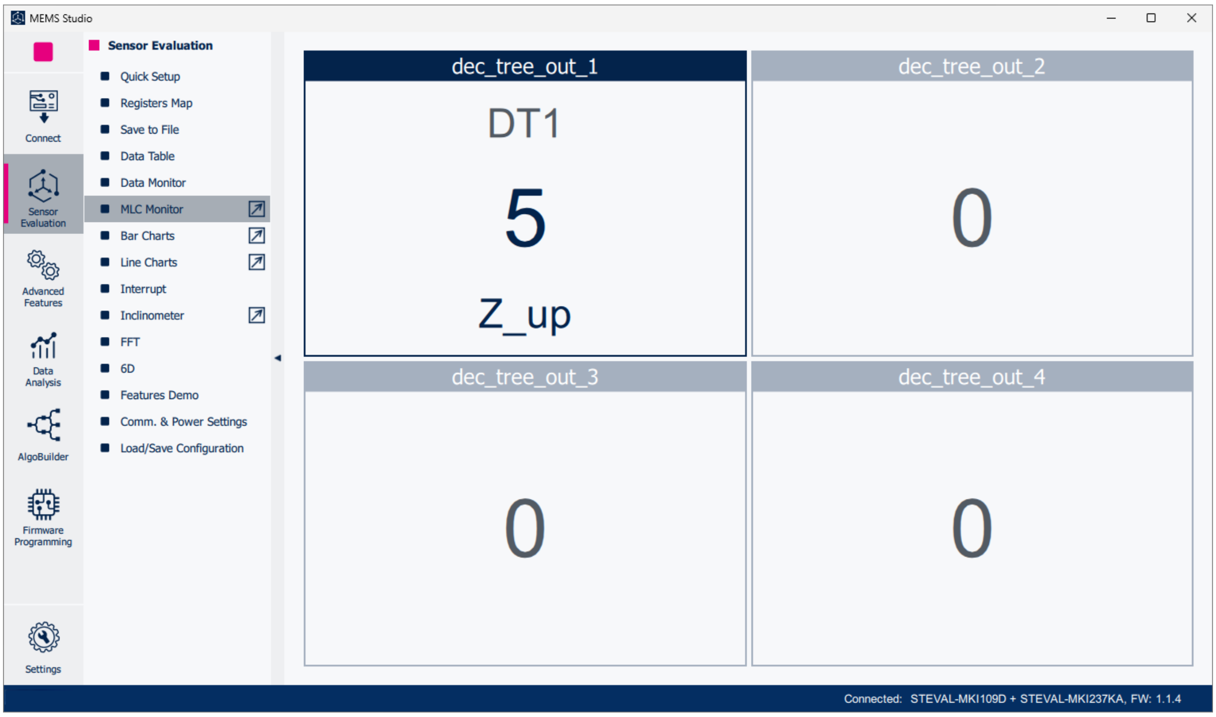
Page data is updated at 10Hz.

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.66.9

MLC Monitor, FSM Monitor

The [**MLC Monitor**] and [**FSM Monitor**] pages can be used to display output from the machine learning core (MLC) or finite state machine (FSM) including the label assigned to each output value. This feature provides a clear and user-friendly overview of the current states and classifications detected by the sensors, making it easier to monitor and interpret the results in real time. The textual values are taken from the JSON file with the sensor configuration, which is loaded from the [**Load/Save Configuration**] page.

Figure 23. **MLC Monitor**

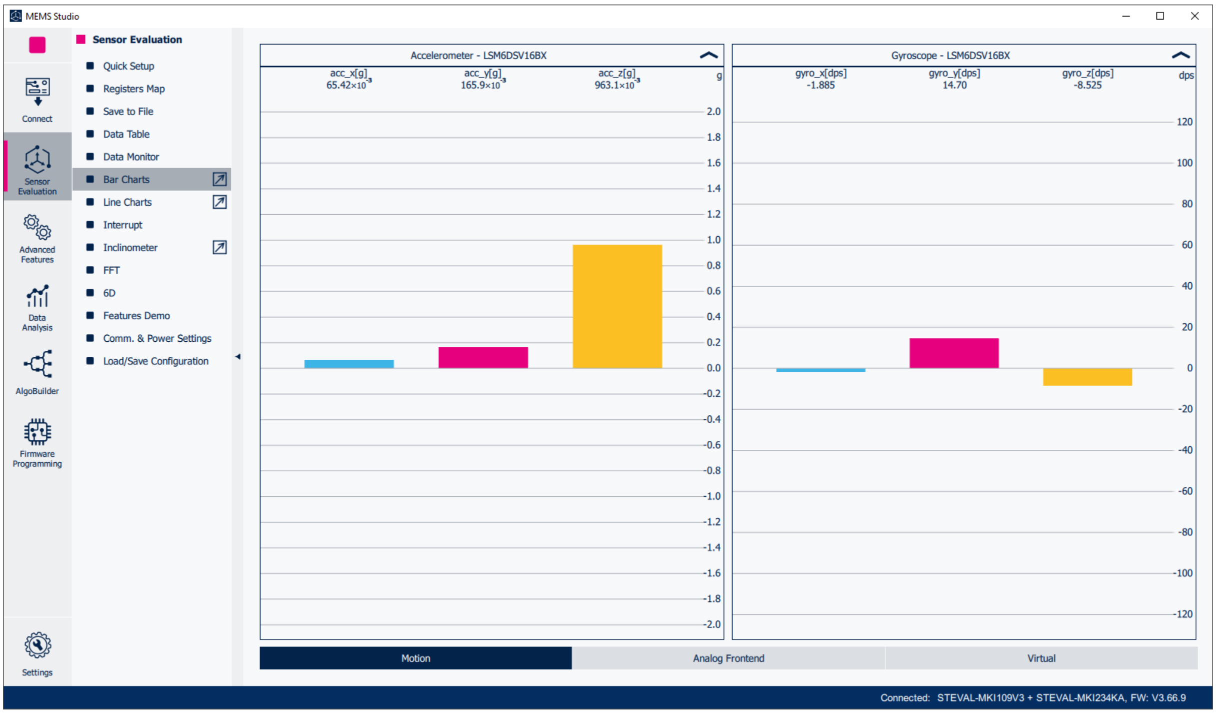


Bar Charts tool

The [**Bar Charts**] tool displays the data measured by the sensor in a bar chart format.

The height of each bar is determined by the amplitude of the signal measured by the sensor along the corresponding axis. The full scale of the graph depends on the configuration and can be changed through either the [**Quick Setup**] or the [**Registers Map**] tab.

Figure 24. **Bar Charts tool**



Line Charts tool

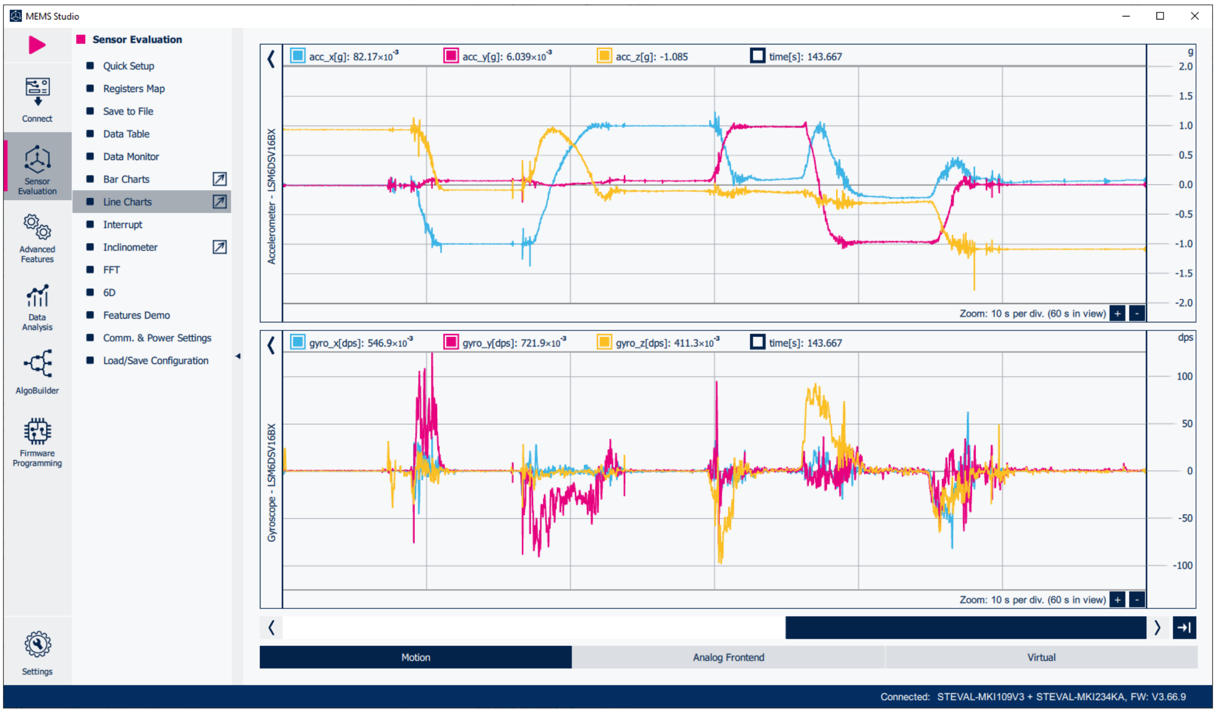
The [**Line Charts**] tool shows the evolution of the output over time. This tool generates a time graph of data samples from the connected sensors.

Each waveform can be shown or hidden by clicking on the corresponding colored box in the top bar of the plot.

The user can click on the minus and plus at the bottom of the graph object to manually scale the plot horizontally. Furthermore, using a dedicated scroll bar at the bottom of the page, the user can display the older samples.

By mousing over the plot area, the top bar labels are updated to display the collected values of the samples.

Figure 25. Line Charts tool

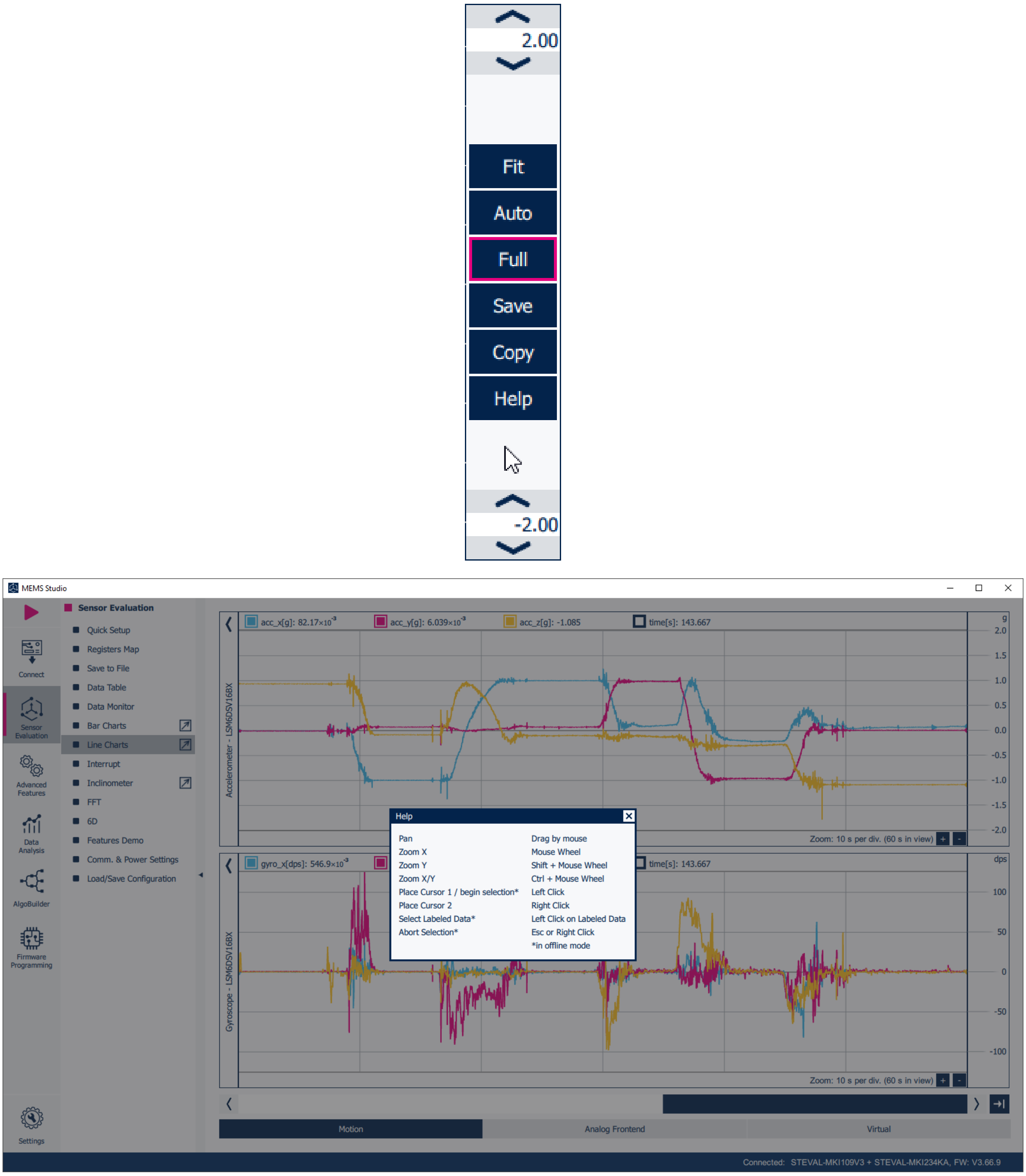


Note: Individual signals can be disabled or enabled in the chart top bar. Using a right mouse click in this area, all channels can be selected or deselected.

Hovering over the right side of a graph object, available options and settings are displayed such as:

- [**Fit**]: updates the Y-axis scale to fit all waveforms
- [**Auto**]: automatic update of the Y-axis scale
- [**Full**]: sets the full-scale value according to the device configuration
- [**Save**]: exports a screenshot of the chart to an image file in .png format
- [**Copy**]: saves the chart as an image in the system clipboard
- [**Help**]: displays the available keyboard shortcuts for navigation in the chart

Figure 26. **Line chart options and help**



Help

Pan	Drag by mouse
Zoom X	Mouse Wheel
Zoom Y	Shift + Mouse Wheel
Zoom X/Y	Ctrl + Mouse Wheel
Place Cursor 1 / begin selection*	Left Click
Place Cursor 2	Right Click
Select Labeled Data*	Left Click on Labeled Data
Abort Selection*	Esc or Right Click
	*in offline mode

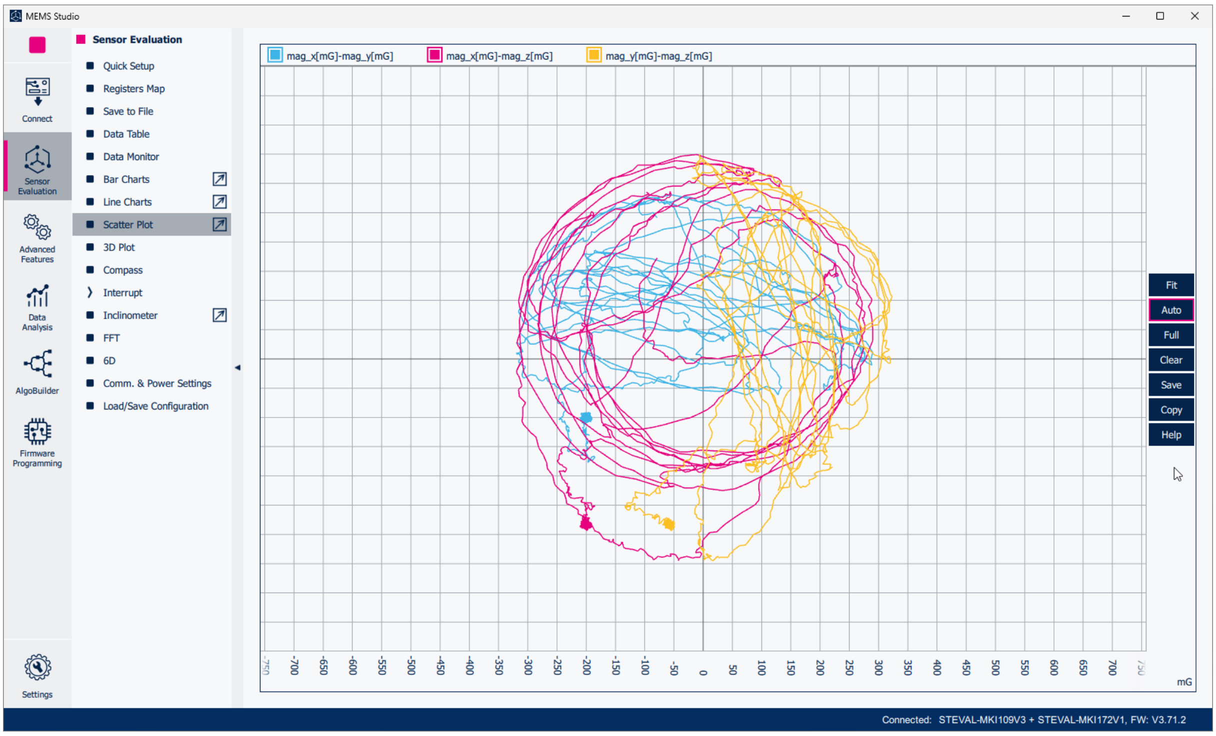
Scatter Plot tool

The [**Scatter Plot**] tool shows the graphical representation of the magnetometer data using Cartesian coordinates. In general, a scatter plot is used to display values for typically two variable sets of data.

The plot shows three lines according to the sensor axes (X-Y, Y-Z, X-Z). The three lines can be enabled and disabled independently by clicking on the corresponding colored box at the top of the graph. By clicking on the [**Clear**] button, the user can reset all data in the plot.

The plot component detects mouse wheel events in order to zoom in or out on data. [**Auto**] allows the user to set the automatic zoom in order to fit all data on the graph.

Figure 27. **Scatter Plot tool**



Connected: STEVAL-MKI109V3 + STEVAL-MKI172V1, FW: V3.71.2

Compass tool

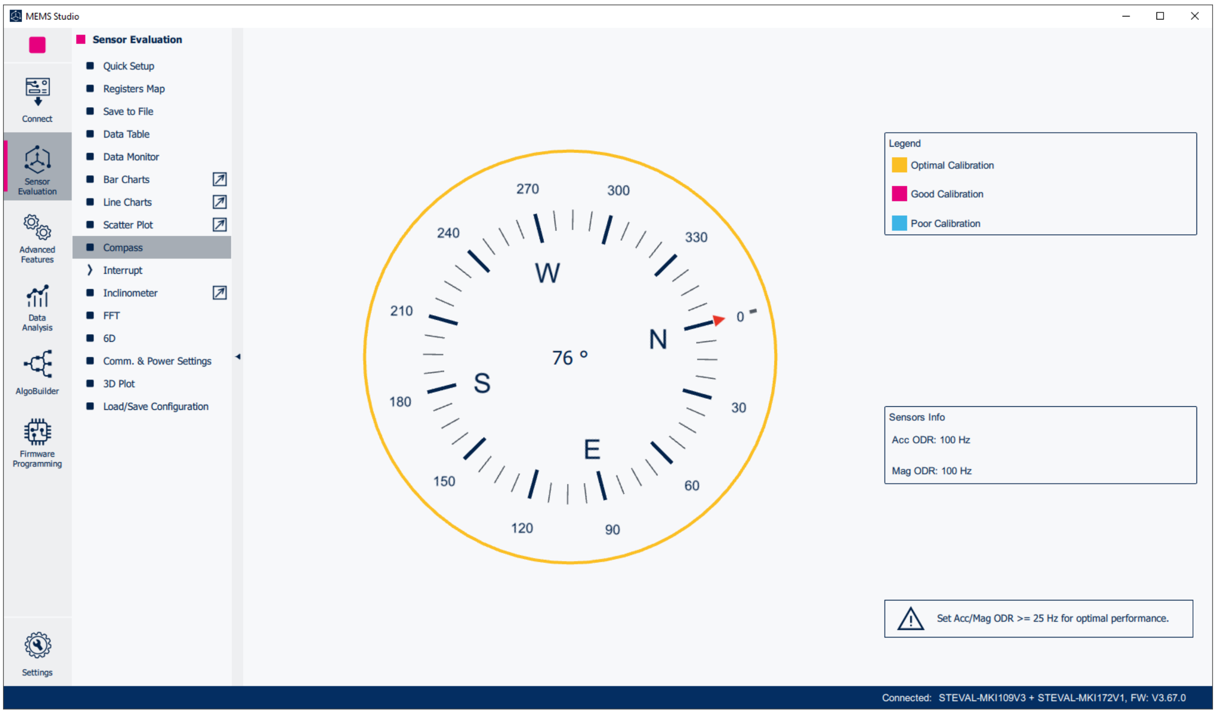
The [**Compass**] tool shows an example of a compass application, which can be implemented using a 6-axis module (3-axis accelerometer and 3-axis magnetometer).

The algorithm uses the magnetometer data to measure the Earth's magnetic field, and the accelerometer data to compensate for the inclination of the board. Rotating the board, the application shows the heading of the compass.

The performance of the compass is related to the configuration used. So, the application shows the current configuration and the recommended configuration (accelerometer and magnetometer ODR).

Before using the compass demo, the system must be calibrated by moving the board randomly for a few seconds; the quality of the calibration step is indicated by the compass object border color according to the legend on the right side.

Figure 28. **Compass tool**



Acc ODR: 100 Hz

Mag ODR: 100 Hz

Set Acc/Mag ODR >= 25 Hz for optimal performance.

Connected: STEVAL-MKI109V3 + STEVAL-MKI172V1, FW: V3.67.0

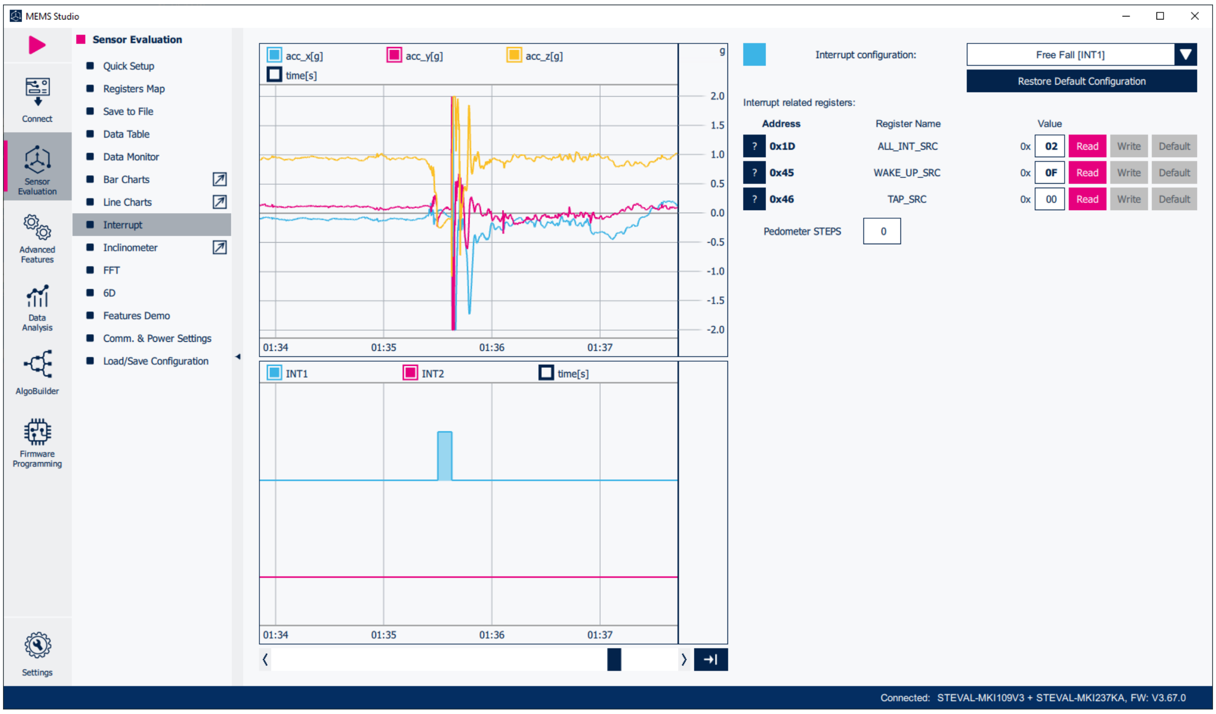
Interrupt tool

The [**Interrupt**] tool allows evaluating the interrupt generation features of the MEMS sensor.

On this page, it is possible to configure the characteristics of the inertial events that must be recognized by the device and to visualize (in real time) the evolution of the interrupt lines.

The application provides access to the interrupt registers, which allow the configuration of the interrupt sources of the device.

The user can configure the interrupts using the dedicated combo box in order to load the recommended configurations in the device.



Interrupt configuration: Free Fall [INT1]

Interrupt related registers:

Address	Register Name	Value			
0x1D	ALL_INT_SRC	0x 02	Read	Write	Default
0x45	WAKE_UP_SRC	0x 0F	Read	Write	Default
0x46	TAP_SRC	0x 00	Read	Write	Default

Pedometer STEPS 0

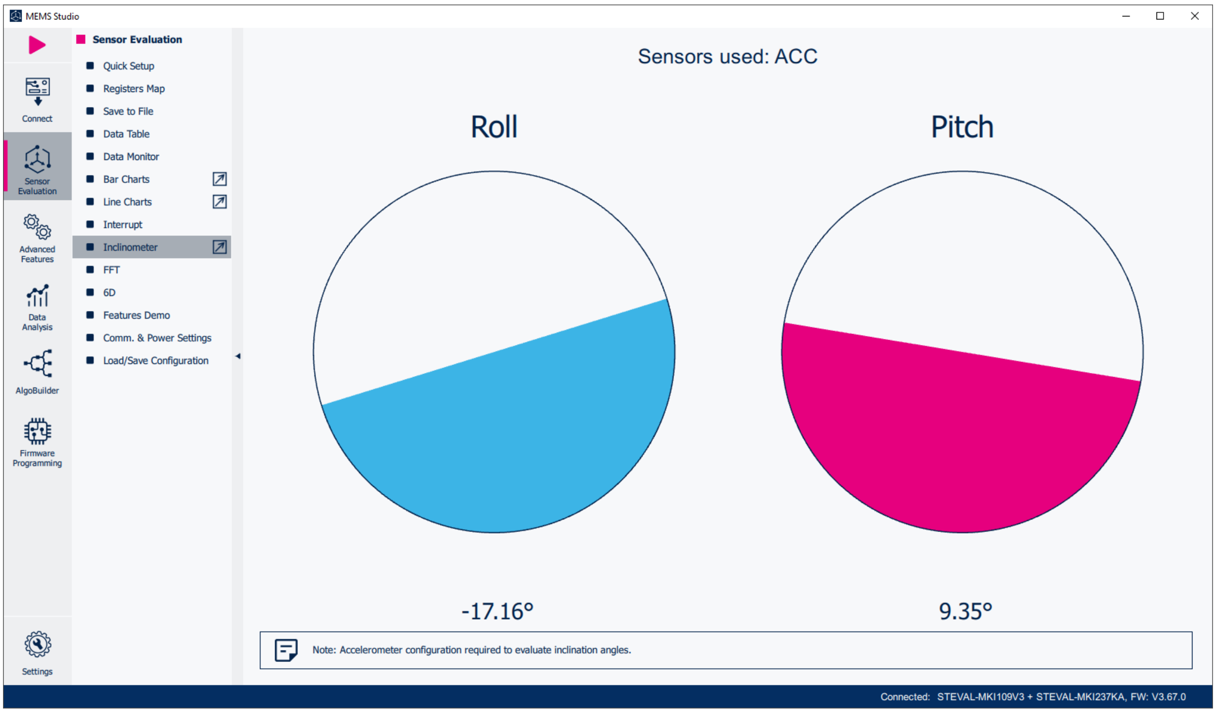
Connected: STEVAL-MKI109V3 + STEVAL-MKI237KA, FW: V3.67.0

Figure 29. **Interrupt tool**

Inclinometer tool

The [**Inclinometer**] tool represents the angle between the accelerometer axis and the horizontal plane. This tool is available if the sensor in use integrates an accelerometer.

Figure 30. **Inclinometer tool**



Note: Accelerometer configuration required to evaluate inclination angles.

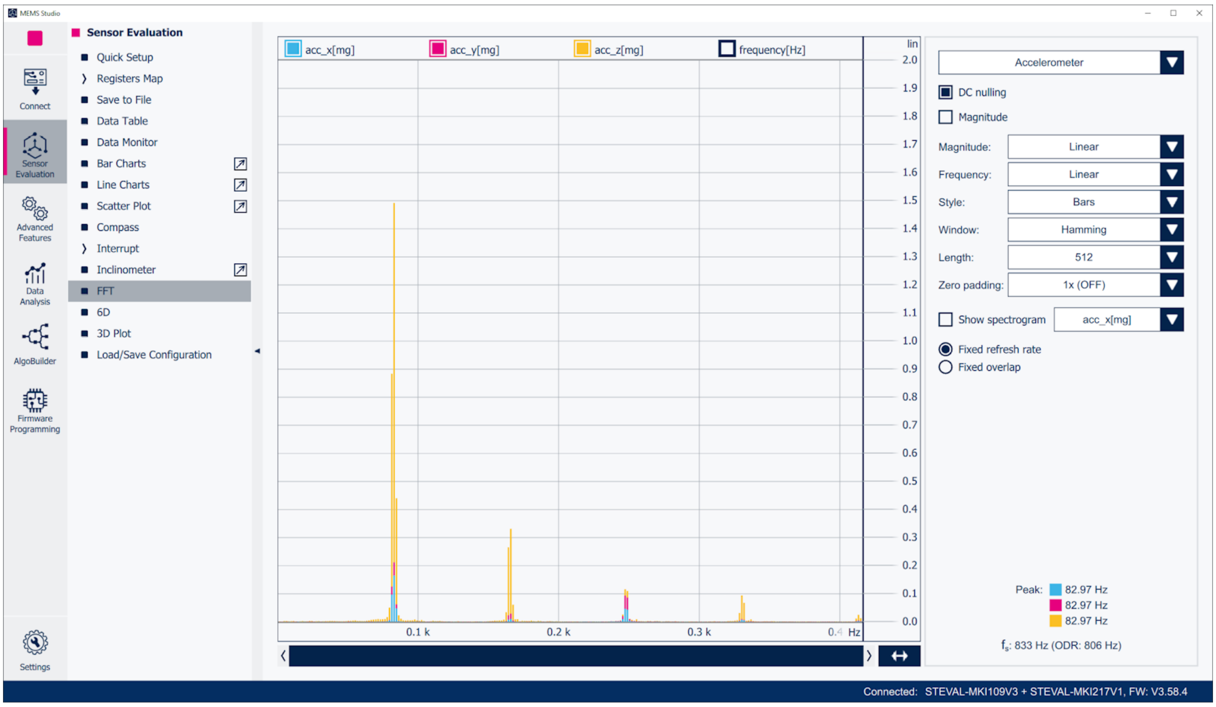
Connected: STEVAL-MKI109V3 + STEVAL-MKI237KA, FW: V3.67.0

FFT tool

The [**FFT**] tool displays the fast Fourier transform of the sensor data. The page shows the frequency-domain plot for each axis of the selected sensor.

The tool provides various options such as:

- [**DC nulling**]: removes the DC component from the signal
- [**Magnitude**]: calculates Euler's formula of the vector composed of the axis components
- [**Magnitude (scale)**]: Y-axis scale
- [**Frequency (scale)**]: X-axis scale
- [**Style**]: style of chart (waveform or bars)
- [**Window**]: window function applied to the signal before FFT evaluation
- [**Length**]: length of the window used to evaluate FFT (number of samples from which FFT is computed)
- [**Zero padding**]: number of zero samples added to the captured signal
- [**Show spectrogram**]: enables or disables spectrogram visualization
- [**Fixed refresh rate**]: updates the FFT chart without overlapping windows
- [**Fixed overlap**]: updates the FFT chart, overlapping windows according to the slider value of the window overlap
- [**Slider value**]: percentage of the samples saved for the next FFT computation



Accelerometer
☑ DC nulling
□ Magnitude
Magnitude: Linear
Frequency: Linear
Style: Bars
Window: Hamming
Length: 512
Zero padding: 1x (OFF)
□ Show spectrogram acc_x[mg]
● Fixed refresh rate
○ Fixed overlap

Peak: 82.97 Hz
82.97 Hz
82.97 Hz

f_s: 833 Hz (ODR: 806 Hz)

Connected: STEVAL-MKI109V3 + STEVAL-MKI217V1, FW: V3.58.4

Figure 31. **FFT tool**

6D tool

The [**6D**] tool provides an example of how to use the [**6D position**] function.

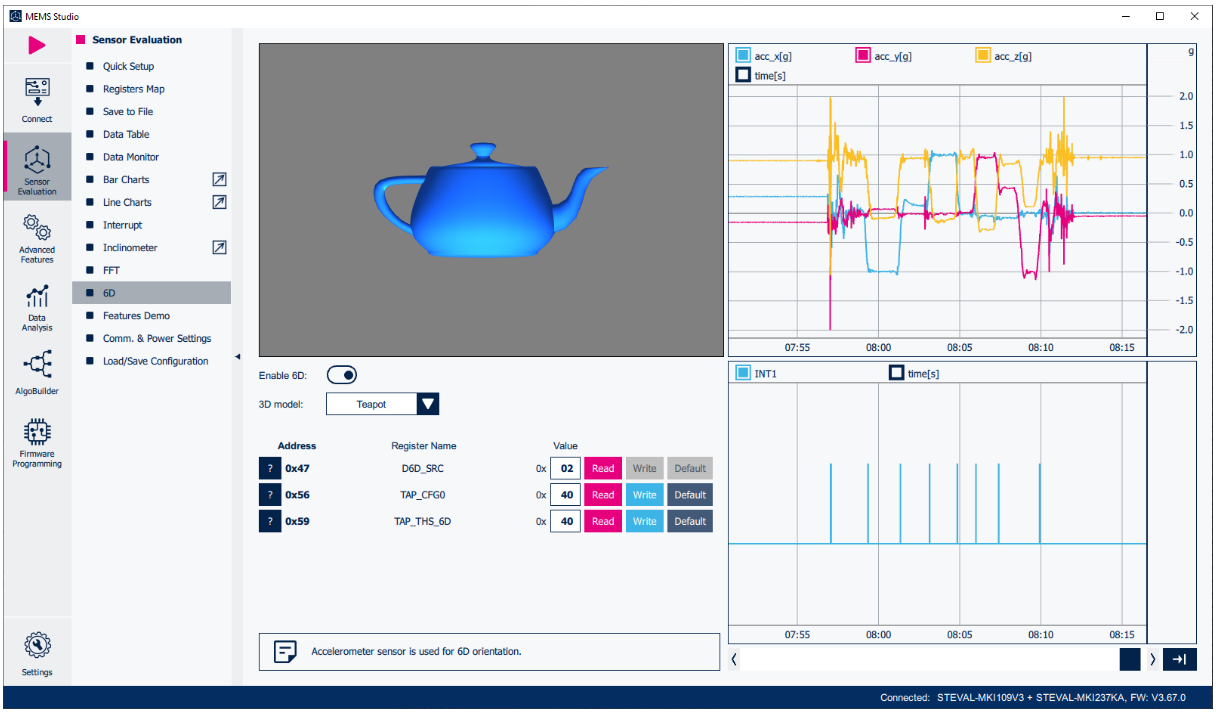
On this page, it is possible to configure the interrupt for 6D recognition by clicking on the [**6D Enabled**] toggle button.

After loading the configuration, the selected 3D model is oriented depending on the 6D position detected.

The window also shows (in real time) the evolution of the interrupt line.

The user can change the register configuration by setting different values in the interrupt registers as shown in the tool.

Figure 32. **6D tool**



Enable 6D: ●

3D model: Teapot

Address	Register Name	Value				
? 0x47	D6D_SRC	0x 02	Read	Write	Default
? 0x56	TAP_CFG0	0x 40	Read	Write	Default
? 0x59	TAP_THS_6D	0x 40	Read	Write	Default

Accelerometer sensor is used for 6D orientation.

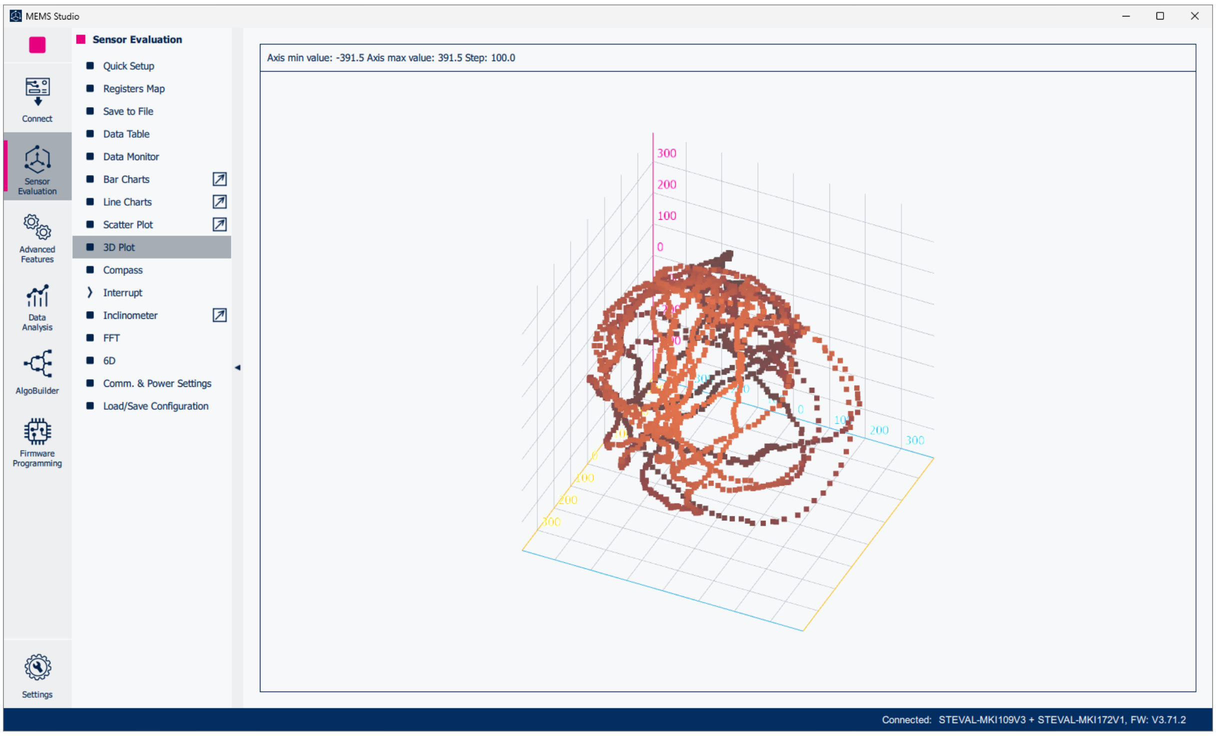
Connected: STEVAL-MKI109V3 + STEVAL-MKI237KA, FW: V3.67.0

3D Plot tool

The [**3D Plot**] tool shows the graphical representation of the magnetometer data in 3D space.

Zooming in and out of the chart is possible using the mouse wheel. Changing the view angle is possible by clicking and panning in the chart.

Figure 33. **3D Plot tool**



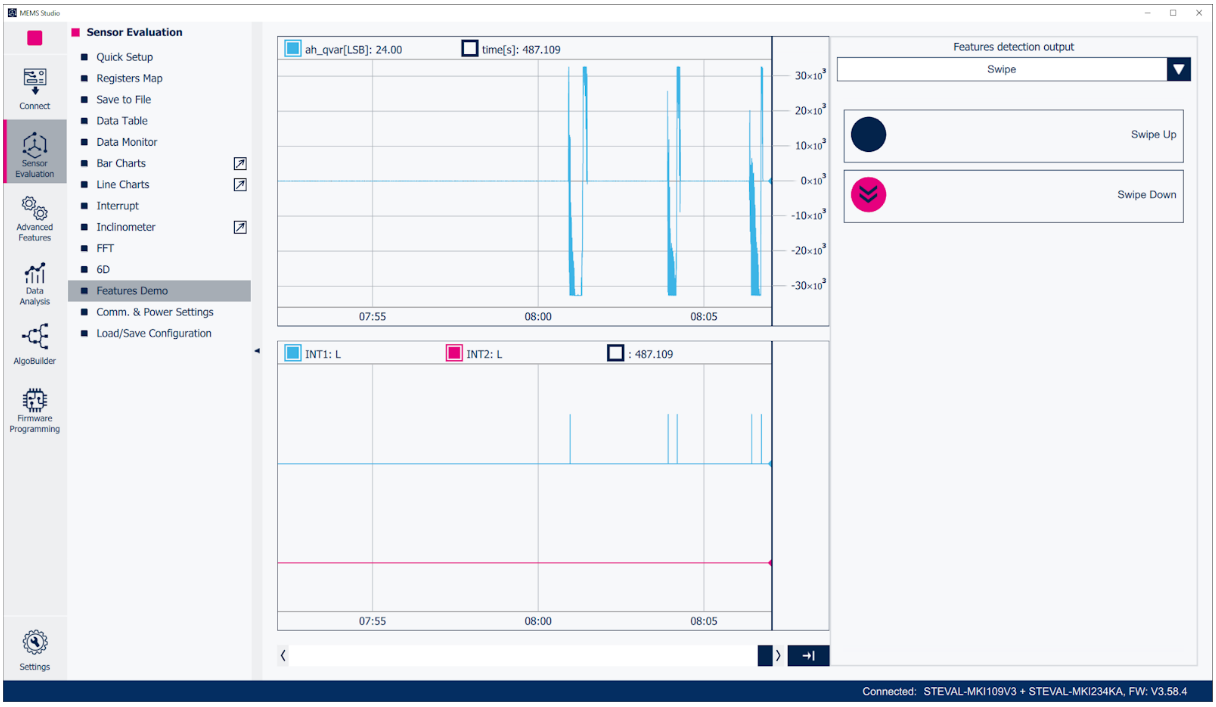
Axis min value: -391.5 Axis max value: 391.5 Step: 100.0

Connected: STEVAL-MKI109V3 + STEVAL-MKI172V1, FW: V3.71.2

Features Demo page

The [**Features Demo**] page allows the user to evaluate demo modes available for a connected sensor when this feature is supported. The side menu on the right displays indicators to notify the user about event detection and set parameters, if applicable.

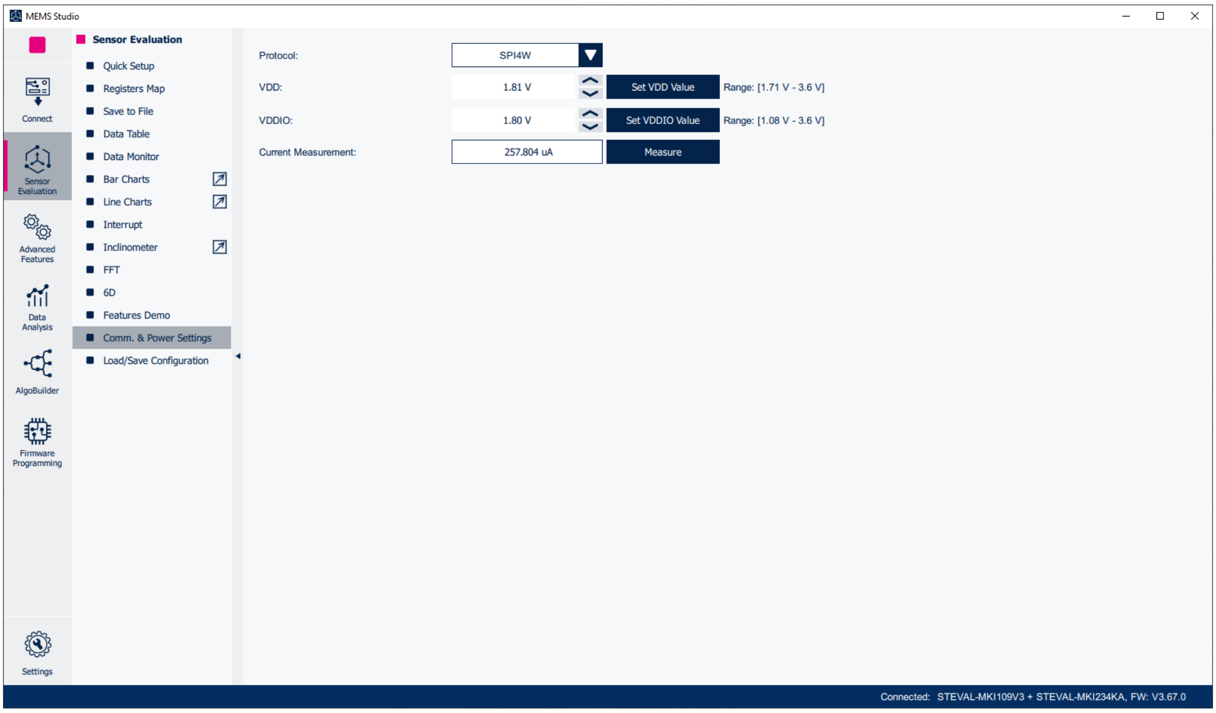
Figure 34. **Features Demo page**



Communication and Power Settings tool

The [**Comm. & Power Settings**] tool allows the user to read the current consumption and update VDD and VDDIO values on the Professional MEMS tool board (STEVAL-MKI109D, STEVAL-MKI109V3).

Figure 35. **Comm. & Power Settings tool**



Protocol: SPI4W

VDD: 1.81 V Range: [1.71 V - 3.6 V]

VDDIO: 1.80 V Range: [1.08 V - 3.6 V]

Current Measurement: 257.804 uA

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.67.0

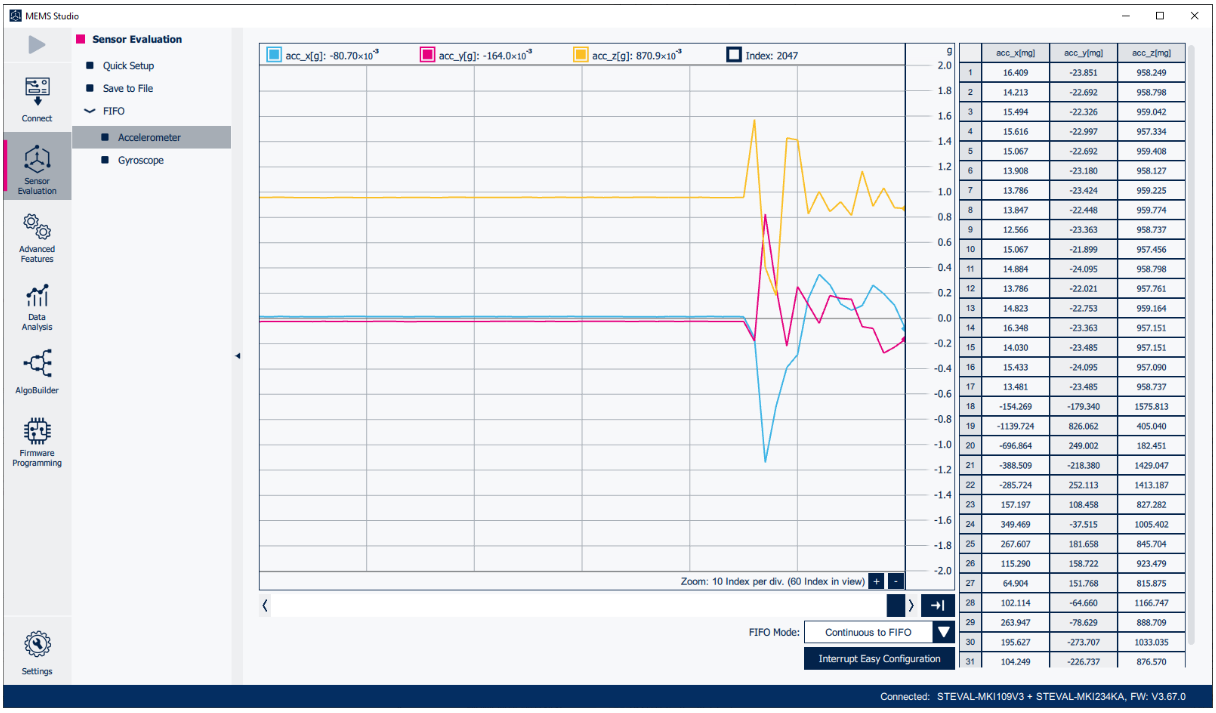
FIFO tool

The [**FIFO**] tool can be used to test the first-in first-out data buffer embedded in the device when this feature is supported by the sensor (see the device datasheet for more details).

By using the combo box available on the page, the FIFO can be configured in all the supported modes (for example, bypass, FIFO, stream, stream-to-FIFO).

The application shows the values of the X, Y, Z data stored in the deep FIFO buffer, indicating both numerical data and the corresponding graph.

Figure 36. **FIFO tool**



FIFO Mode: Continuous to FIFO

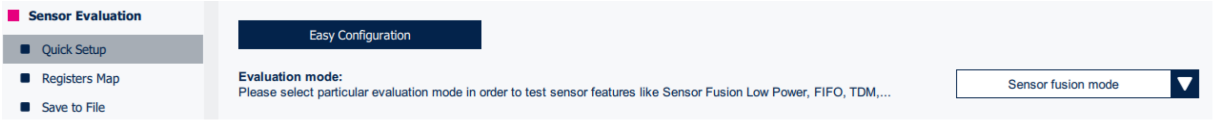
	acc_x[mg]	acc_y[mg]	acc_z[mg]
1	16.409	-23.851	958.249
2	14.213	-22.692	958.798
3	15.494	-22.326	959.042
4	15.616	-22.997	957.334
5	15.067	-22.692	959.408
6	13.908	-23.180	958.127
7	13.786	-23.424	959.225
8	13.847	-22.448	959.774
9	12.566	-23.363	958.737
10	15.067	-21.899	957.456
11	14.884	-24.095	958.798
12	13.786	-22.021	957.761
13	14.823	-22.753	959.164
14	16.348	-23.363	957.151
15	14.030	-23.485	957.151
16	15.433	-24.095	957.090
17	13.481	-23.485	958.737
18	-154.269	-179.340	1575.813
19	-1139.724	826.062	405.040
20	-696.864	249.002	182.451
21	-388.509	-218.380	1429.047
22	-285.724	252.113	1413.187
23	157.197	108.458	827.282
24	349.469	-37.515	1005.402
25	267.607	181.658	845.704
26	115.290	158.722	923.479
27	64.904	151.768	815.875
28	102.114	-64.660	1166.747
29	263.947	-78.629	888.709
30	195.627	-273.707	1033.035
31	104.249	-226.737	876.570

Connected: STEVAL-MKI109V3 + STEVAL-MKI234KA, FW: V3.67.0

Sensor fusion tool

Some sensors can be equipped with the sensor fusion low-power (SFLP) feature for generating game rotation vector, gravity vector, and gyroscope bias data based on the accelerometer and gyroscope data processing. If this feature is available, the evaluation can be activated on the [**Quick Setup**] page.

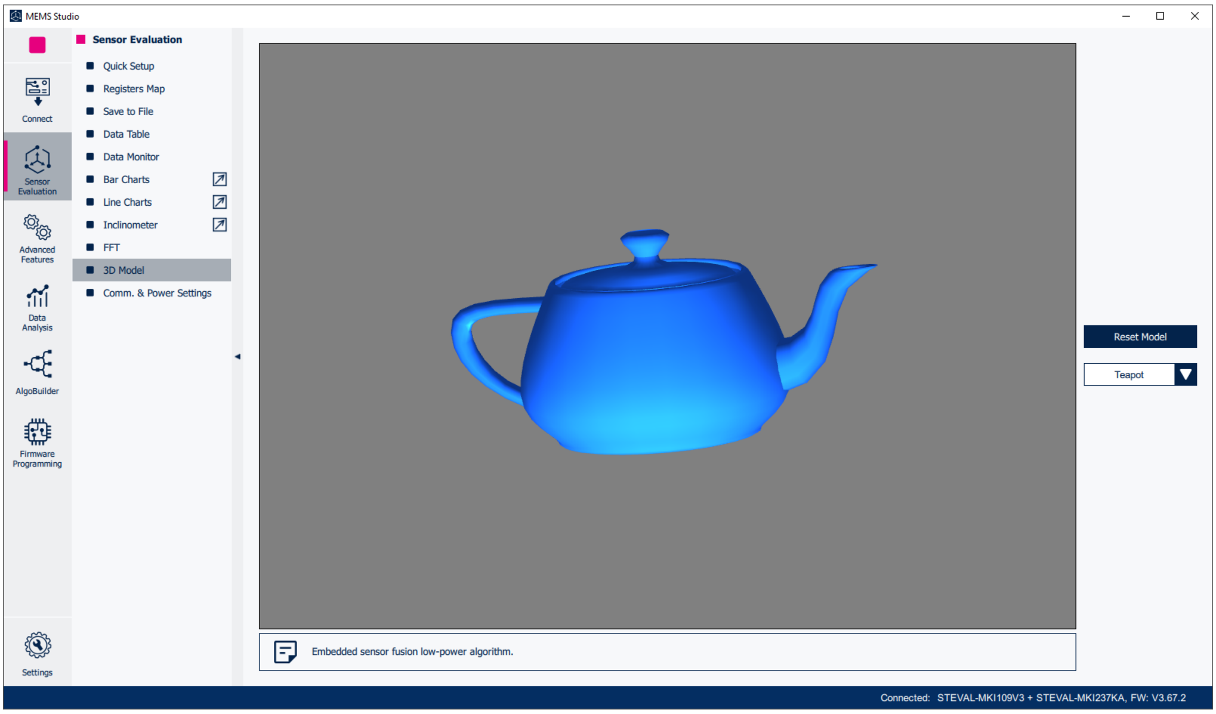
Figure 37. **Evaluation mode selection**



Evaluation mode:
Please select particular evaluation mode in order to test sensor features like Sensor Fusion Low Power, FIFO, TDM,...

If sensor fusion mode is selected, the available sensor evaluation pages are adjusted according to this mode. Game rotation vector, quaternions, gravity vector, and gyroscope bias signals are added in [**Data Table**], [**Data Monitor**], [**Bar Charts**], [**Line Charts**] and [**Save to File**]. The [**3D Model**] page is available in this mode. A 3D model is displayed on this page and the orientation of the model changes based on the game rotation vector data so the model follows the sensor movement. Different 3D models can be selected. The initial position of the model can be set by using the [**Reset Model**] button.

Figure 38. **3D Model page**



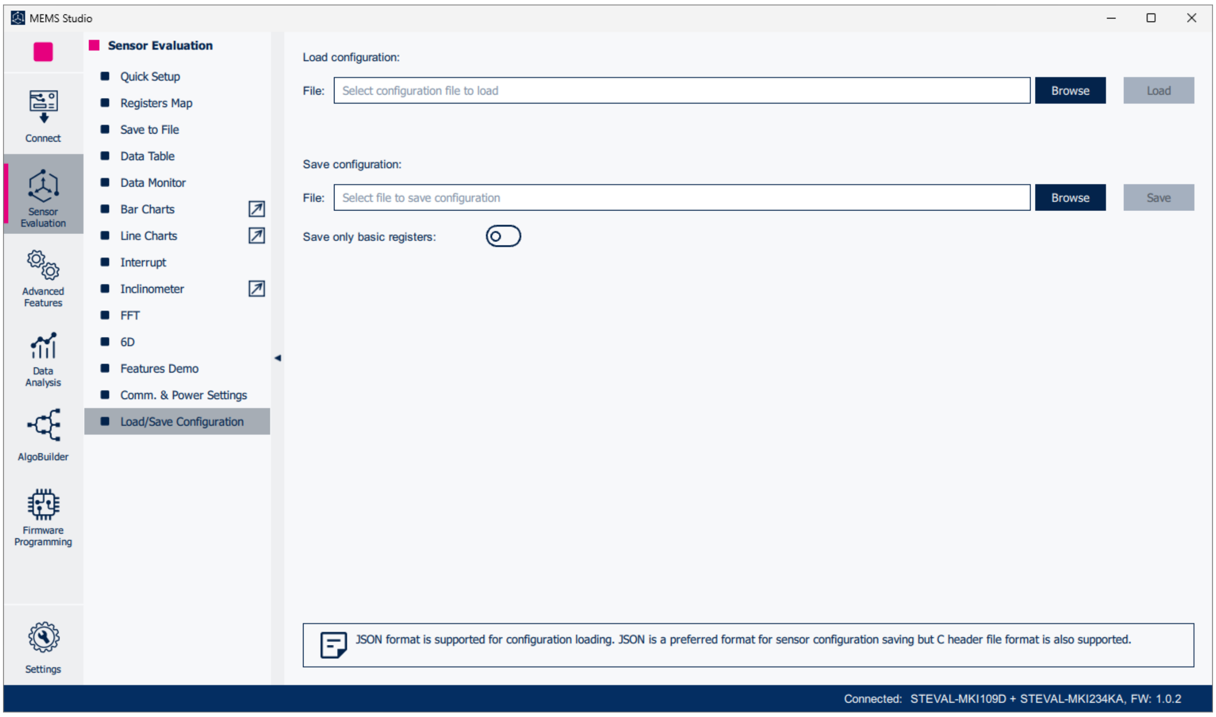
Embedded sensor fusion low-power algorithm.

Connected: STEVAL-MKI109V3 + STEVAL-MKI237KA, FW: V3.67.2

Load/Save Configuration page

The [**Load/Save Configuration**] page allows the user to save and load the current register configuration. Clicking on the [**Save**] button stores the register values in a .json file. The saved configuration can be loaded at any time by clicking on the [**Load**] button.

Figure 39. **Load/Save Configuration page**



Load configuration:

File: Select configuration file to load

Save configuration:

File: Select file to save configuration

Save only basic registers: ○

JSON format is supported for configuration loading. JSON is a preferred format for sensor configuration saving but C header file format is also supported.

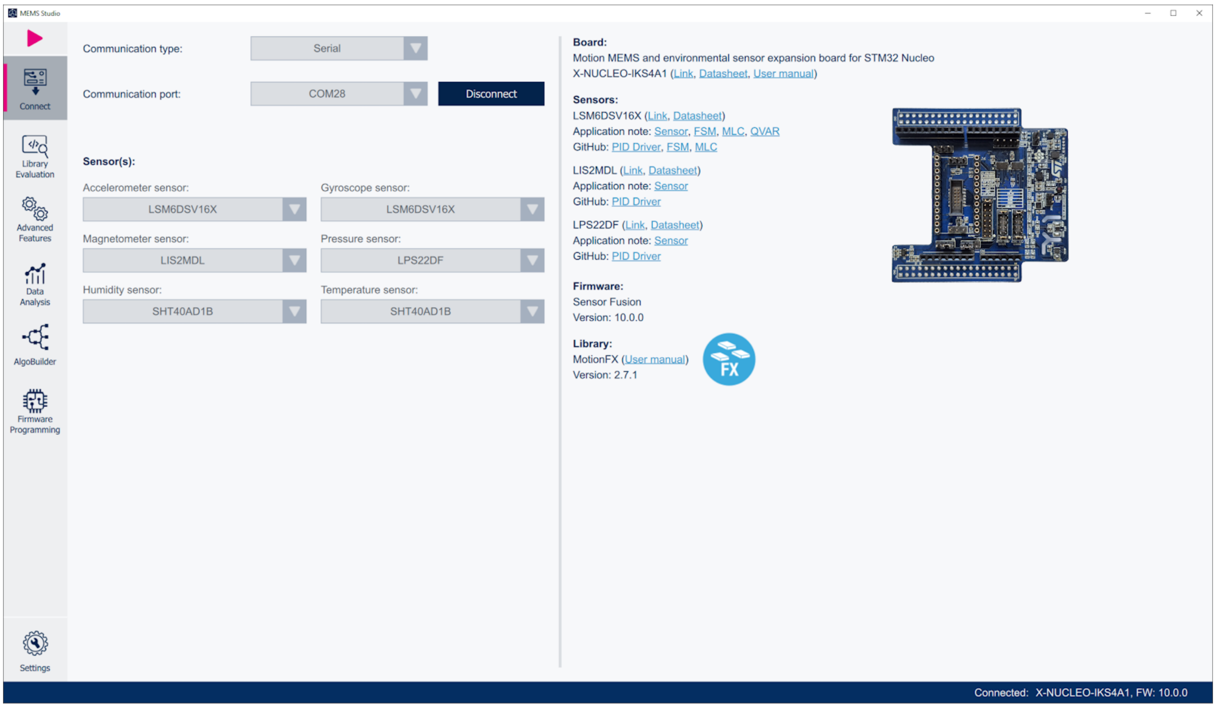
Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.2

4 Library evaluation

Middleware libraries for ST sensors are provided in the X-CUBE-MEMS1 package. This package contains dedicated projects for each library, which can be used for library evaluation. Using MEMS Studio and the firmware for a particular library with the selected development board, a user can evaluate the functionality of the library.

After the development board is programmed with the selected firmware, the connection can be established by selecting [**Communication port**] and pressing the [**Connect**] button. Used sensors are indicated by the firmware, and they are listed on the [**Connect**] page with all details.

Figure 40. **Connect page for library evaluation**



Communication type: Serial

Communication port: COM28

Sensor(s):

Accelerometer sensor: LSM6DSV16X

Gyroscope sensor: LSM6DSV16X

Magnetometer sensor: LIS2MDL

Pressure sensor: LPS22DF

Humidity sensor: SHT40AD1B

Temperature sensor: SHT40AD1B

Board:
Motion MEMS and environmental sensor expansion board for STM32 Nucleo
X-NUCLEO-IKS4A1 (Link, Datasheet, User manual)

Sensors:
LSM6DSV16X (Link, Datasheet)
Application note: Sensor, FSM, MLC, QVAR
GitHub: PID Driver, FSM, MLC

LIS2MDL (Link, Datasheet)
Application note: Sensor
GitHub: PID Driver

LPS22DF (Link, Datasheet)
Application note: Sensor
GitHub: PID Driver

Firmware:
Sensor Fusion
Version: 10.0.0

Library:
MotionFX (User manual)
Version: 2.7.1

Connected: X-NUCLEO-IKS4A1, FW: 10.0.0

After a successful connection, the [**Library Evaluation**] functionality is added in the menu.

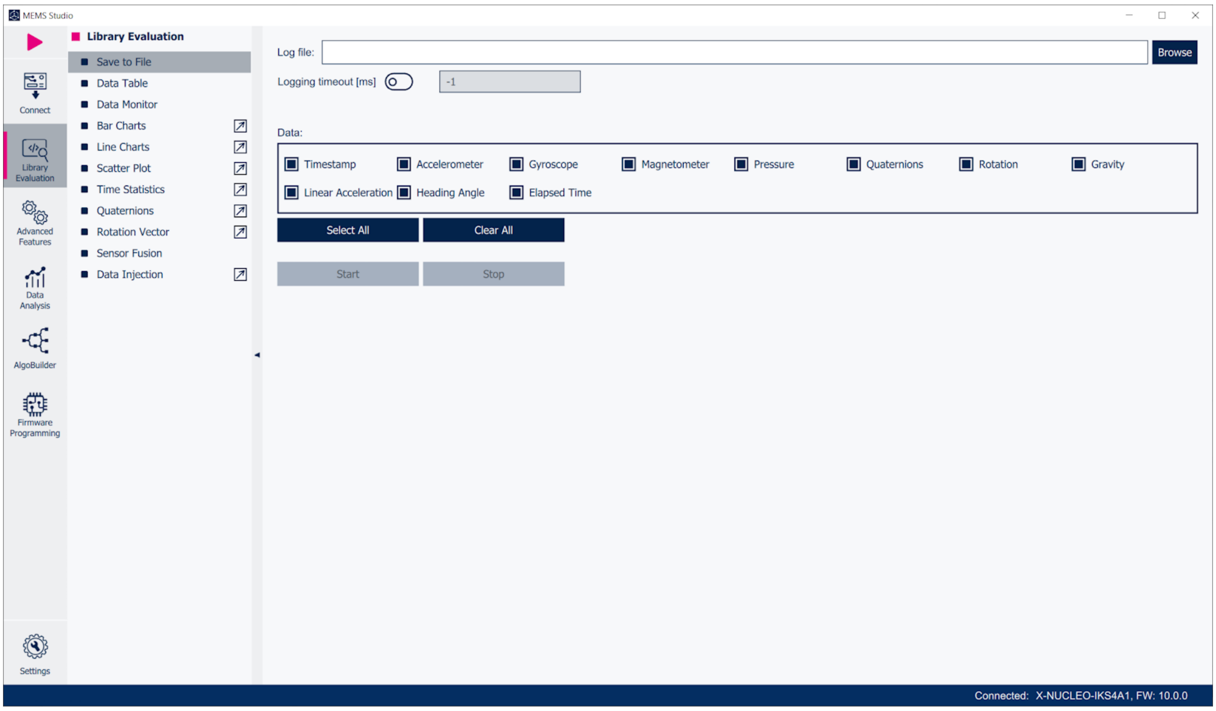
The library evaluation offers:

- Save To File
- Data Table
- Data Monitor
- Data visualization pages
- Time Statistics
- Data Injection

Save To File

The user can use this page to save a stream of sensor and library output data in a .csv file. This can be done by selecting the data to be stored. The [**Browse**] button is used to select the folder and insert the file name, then the [**Start**] and [**Stop**] buttons define the acquisition period. Additionally, the user can define a recording timeout using the dedicated toggle button and text field to interrupt data logging after a defined [ms] interval.

Figure 41. Save To File page



Log file:

Logging timeout [ms] ○ -1

Data:

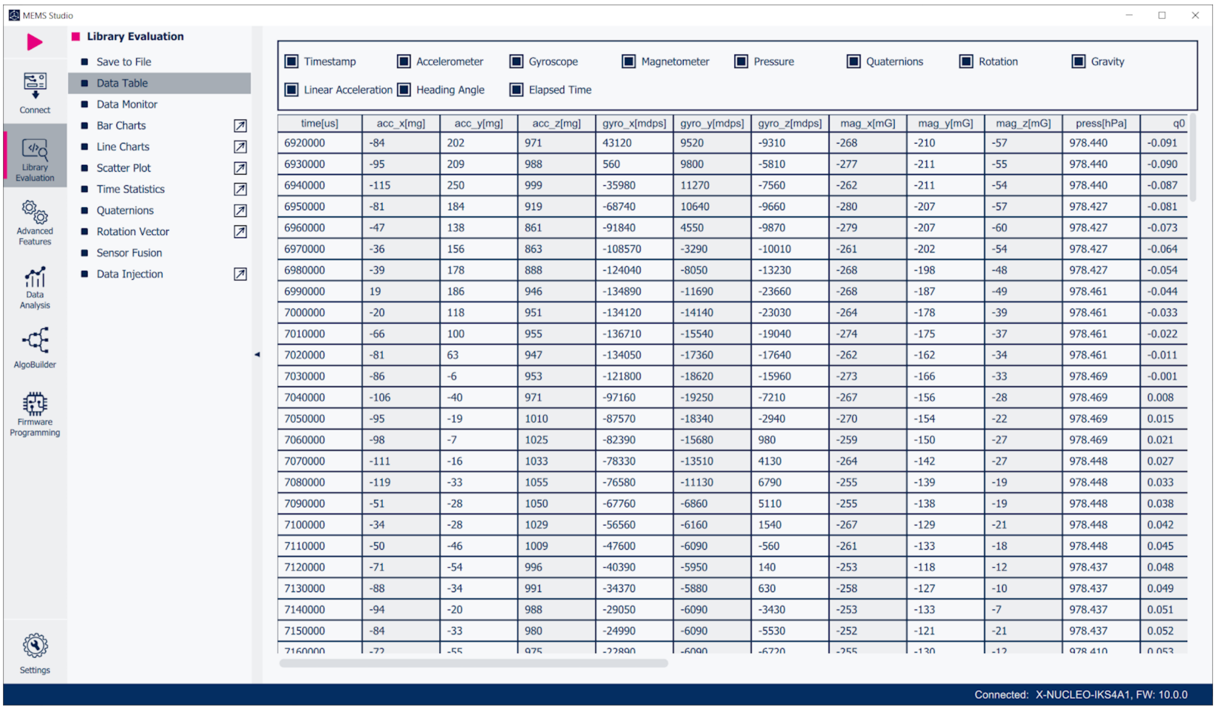
☑ Timestamp ☑ Accelerometer ☑ Gyroscope ☑ Magnetometer ☑ Pressure ☑ Quaternions ☑ Rotation ☑ Gravity
☑ Linear Acceleration ☑ Heading Angle ☑ Elapsed Time

Connected: X-NUCLEO-IKS4A1, FW: 10.0.0

Data Table

The [**Data Table**] tool displays the output values from the sensors and libraries. This view provides an overview of all values received with a table data update rate of 0.5 Hz to reduce overall CPU/GPU consumption.

Figure 42. **Data Table**



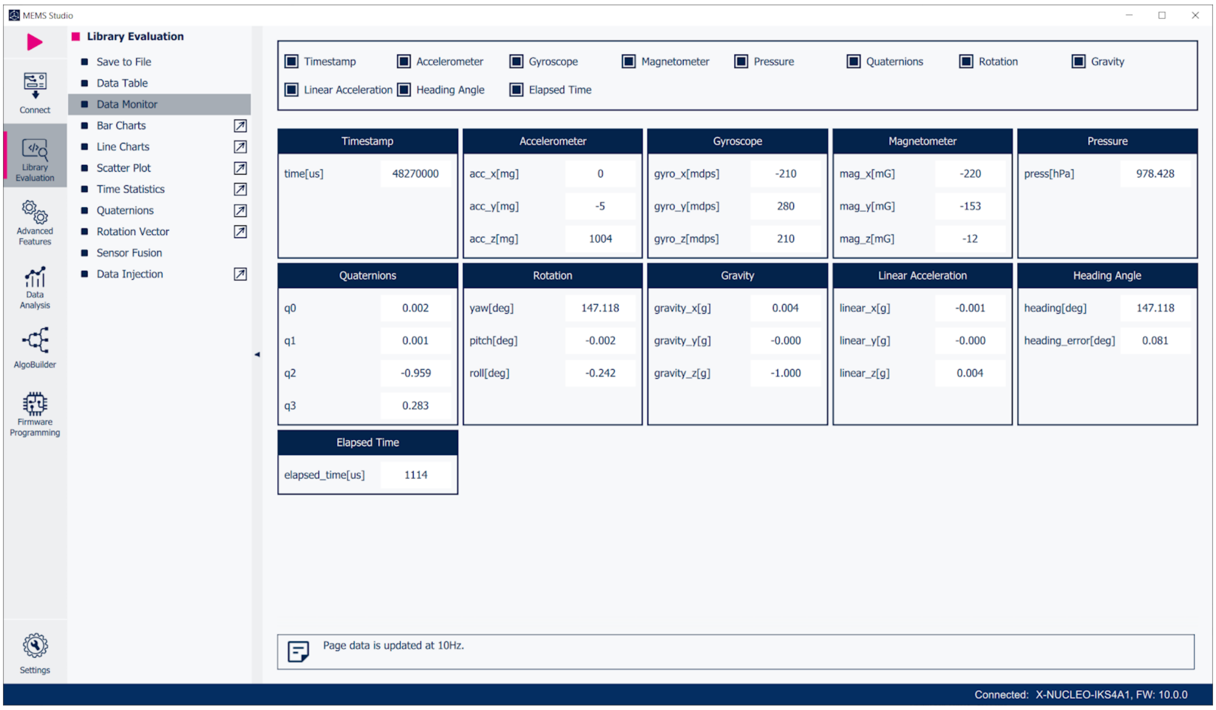
☒ Timestamp ☒ Accelerometer ☒ Gyroscope ☒ Magnetometer ☒ Pressure ☒ Quaternions ☒ Rotation ☒ Gravity
☒ Linear Acceleration ☒ Heading Angle ☒ Elapsed Time

time[us]	acc_x[mg]	acc_y[mg]	acc_z[mg]	gyro_x[mdps]	gyro_y[mdps]	gyro_z[mdps]	mag_x[mG]	mag_y[mG]	mag_z[mG]	press[hPa]	q0
6920000	-84	202	971	43120	9520	-9310	-268	-210	-57	978.440	-0.091
6930000	-95	209	988	560	9800	-5810	-277	-211	-55	978.440	-0.090
6940000	-115	250	999	-35980	11270	-7560	-262	-211	-54	978.440	-0.087
6950000	-81	184	919	-68740	10640	-9660	-280	-207	-57	978.427	-0.081
6960000	-47	138	861	-91840	4550	-9870	-279	-207	-60	978.427	-0.073
6970000	-36	156	863	-108570	-3290	-10010	-261	-202	-54	978.427	-0.064
6980000	-39	178	888	-124040	-8050	-13230	-268	-198	-48	978.427	-0.054
6990000	19	186	946	-134890	-11690	-23660	-268	-187	-49	978.461	-0.044
7000000	-20	118	951	-134120	-14140	-23030	-264	-178	-39	978.461	-0.033
7010000	-66	100	955	-136710	-15540	-19040	-274	-175	-37	978.461	-0.022
7020000	-81	63	947	-134050	-17360	-17640	-262	-162	-34	978.461	-0.011
7030000	-86	-6	953	-121800	-18620	-15960	-273	-166	-33	978.469	-0.001
7040000	-106	-40	971	-97160	-19250	-7210	-267	-156	-28	978.469	0.008
7050000	-95	-19	1010	-87570	-18340	-2940	-270	-154	-22	978.469	0.015
7060000	-98	-7	1025	-82390	-15680	980	-259	-150	-27	978.469	0.021
7070000	-111	-16	1033	-78330	-13510	4130	-264	-142	-27	978.448	0.027
7080000	-119	-33	1055	-76580	-11130	6790	-255	-139	-19	978.448	0.033
7090000	-51	-28	1050	-67760	-6860	5110	-255	-138	-19	978.448	0.038
7100000	-34	-28	1029	-56560	-6160	1540	-267	-129	-21	978.448	0.042
7110000	-50	-46	1009	-47600	-6090	-560	-261	-133	-18	978.448	0.045
7120000	-71	-54	996	-40390	-5950	140	-253	-118	-12	978.437	0.048
7130000	-88	-34	991	-34370	-5880	630	-258	-127	-10	978.437	0.049
7140000	-94	-20	988	-29050	-6090	-3430	-253	-133	-7	978.437	0.051
7150000	-84	-33	980	-24990	-6090	-5530	-252	-121	-21	978.437	0.052
7160000	-72	-55	975	-22890	-6090	-6720	-255	-130	-12	978.410	0.053

Data Monitor

The [**Data Monitor**] tool displays the latest output values from the sensors and libraries. This view provides an overview of the last samples received with an update rate of 10 Hz to reduce overall CPU/ GPU consumption.

Figure 43. **Data Monitor**



☒ Timestamp ☒ Accelerometer ☒ Gyroscope ☒ Magnetometer ☒ Pressure ☒ Quaternions ☒ Rotation ☒ Gravity
☒ Linear Acceleration ☒ Heading Angle ☒ Elapsed Time

Timestamp		Accelerometer		Gyroscope		Magnetometer		Pressure	
time[us]	48270000	acc_x[mg]	0	gyro_x[mdps]	-210	mag_x[mG]	-220	press[hPa]	978.428
		acc_y[mg]	-5	gyro_y[mdps]	280	mag_y[mG]	-153		
		acc_z[mg]	1004	gyro_z[mdps]	210	mag_z[mG]	-12		

Quaternions		Rotation		Gravity		Linear Acceleration		Heading Angle	
q0	0.002	yaw[deg]	147.118	gravity_x[g]	0.004	linear_x[g]	-0.001	heading[deg]	147.118
q1	0.001	pitch[deg]	-0.002	gravity_y[g]	-0.000	linear_y[g]	-0.000	heading_error[deg]	0.081
q2	-0.959	roll[deg]	-0.242	gravity_z[g]	-1.000	linear_z[g]	0.004		
q3	0.283								

Elapsed Time	
elapsed_time[us]	1114

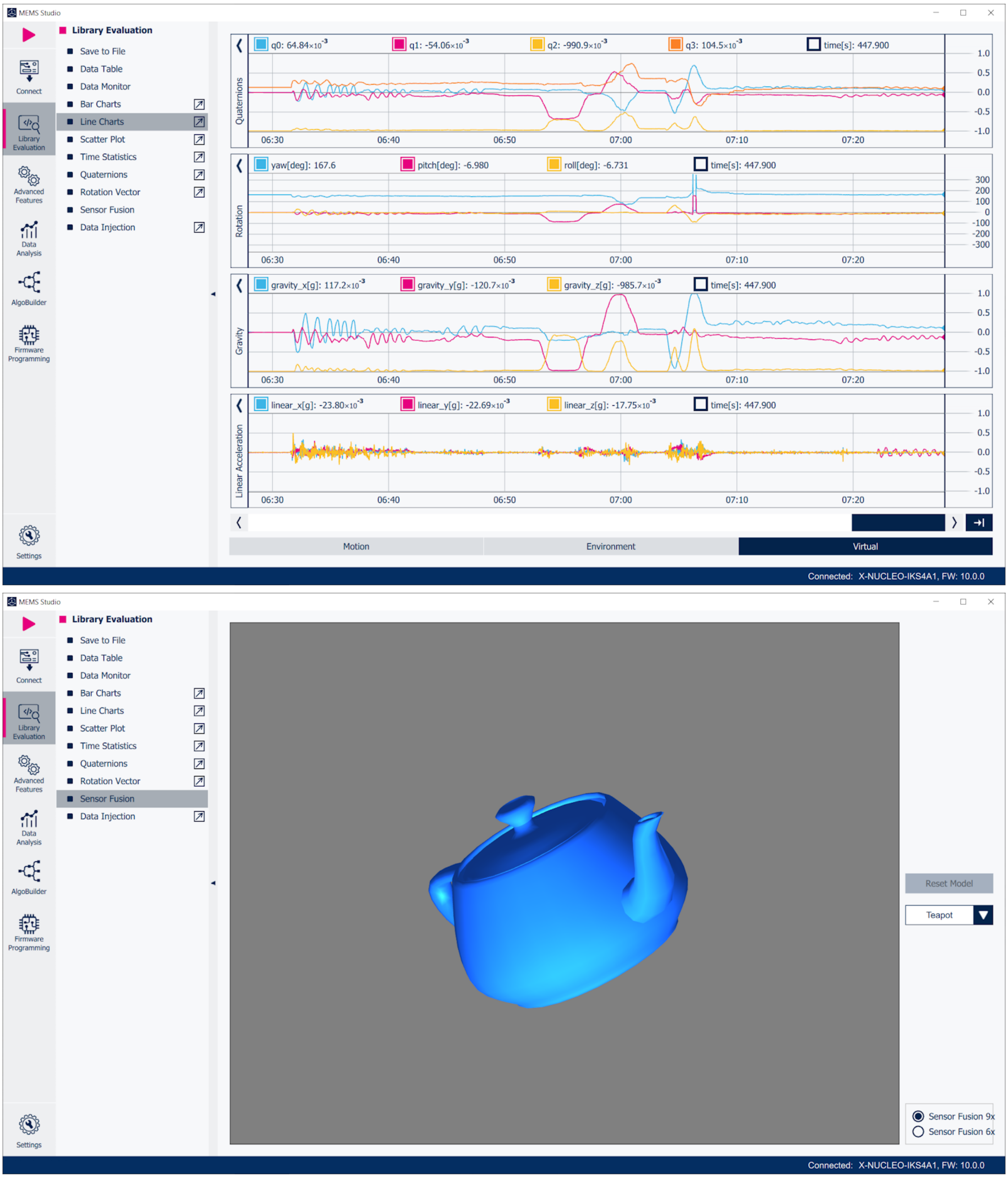
Page data is updated at 10Hz.

Connected: X-NUCLEO-IKS4A1, FW: 10.0.0

Data visualization pages

The available data visualization pages depend on the selected library. Line charts, bar charts, and a scatter plot (for magnetometer data) are always available to visualize sensor data. Additional pages for visualization of library outputs like 3D plot, 3D model, status indicator and table, and others are displayed based on the library functionality.

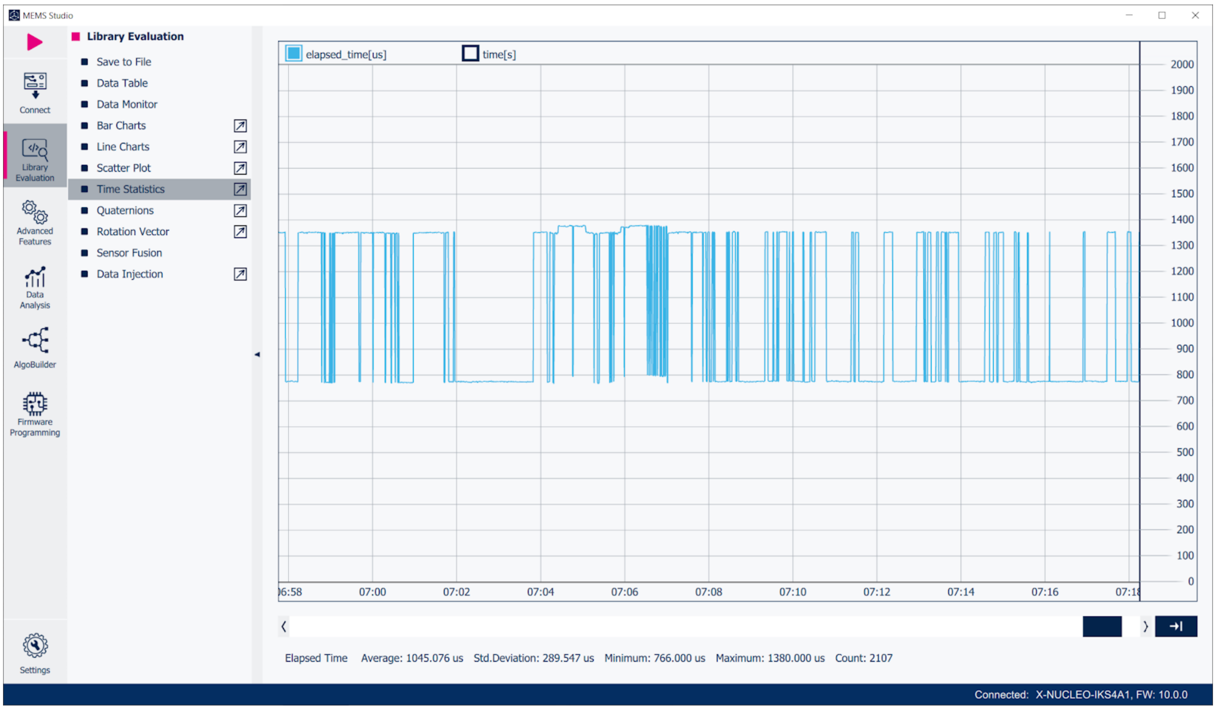
Figure 44. **Example of data visualization pages**



Time Statistics

The [**Time Statistics**] page displays the library elapsed time in line charts and statistical information line average, min, max values.

Figure 45. Time Statistics page



Elapsed Time Average: 1045.076 us Std.Deviation: 289.547 us Minimum: 766.000 us Maximum: 1380.000 us Count: 2107

Connected: X-NUCLEO-IKS4A1, FW: 10.0.0

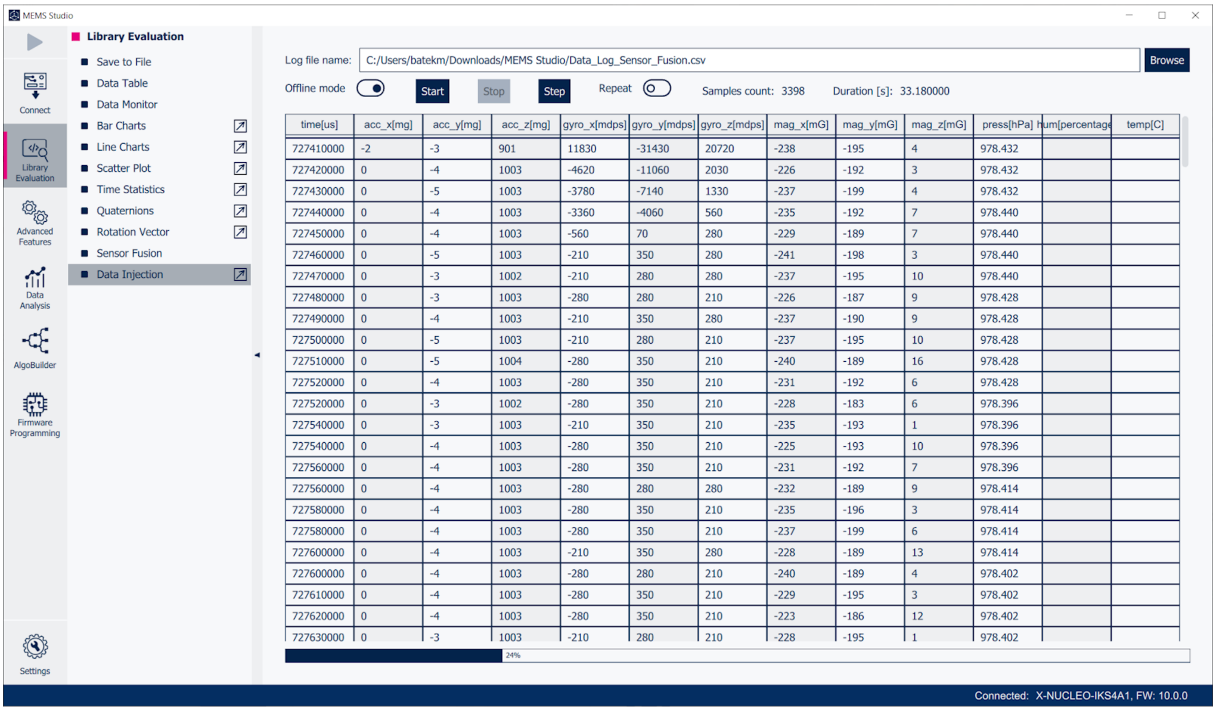
Data Injection

The [**Data Injection**] page allows injecting previously acquired sensor data into the library input instead of real-time sensor data. The library processes the data and sends the results in the same way as working with real-time sensor data. All the other features for the evaluation of the library are available and active.

The data log file with previously acquired data can be opened by clicking on the [**Browse**] button. The data must be acquired with the minimum sampling rate frequency given by the library and the library evaluation firmware. The data log with the higher sampling rate is automatically decimated. Input data are displayed in the table.

Data injection is enabled by switching the firmware to [**Offline mode**]. Data injection is controlled by the [**Start**] and [**Stop**] buttons. Injection line by line can be done using the [**Step**] button. The active line is highlighted in the table. A wraparound to move from the last sample to the first sample can be activated using the [**Repeat**] toggle switch.

Figure 46. **Data injection page**



Log file name: C:/Users/batekm/Downloads/MEMS Studio/Data_Log_Sensor_Fusion.csv

Offline mode ● Repeat ○

Samples count: 3398 Duration [s]: 33.180000

time[us]	acc_x[mg]	acc_y[mg]	acc_z[mg]	gyro_x[mdps]	gyro_y[mdps]	gyro_z[mdps]	mag_x[mG]	mag_y[mG]	mag_z[mG]	press[hPa]	hum[percentage	temp[C]
727410000	-2	-3	901	11830	-31430	20720	-238	-195	4	978.432		
727420000	0	-4	1003	-4620	-11060	2030	-226	-192	3	978.432		
727430000	0	-5	1003	-3780	-7140	1330	-237	-199	4	978.432		
727440000	0	-4	1003	-3360	-4060	560	-235	-192	7	978.440		
727450000	0	-4	1003	-560	70	280	-229	-189	7	978.440		
727460000	0	-5	1003	-210	350	280	-241	-198	3	978.440		
727470000	0	-3	1002	-210	280	280	-237	-195	10	978.440		
727480000	0	-3	1003	-280	280	210	-226	-187	9	978.428		
727490000	0	-4	1003	-210	350	280	-237	-190	9	978.428		
727500000	0	-5	1003	-210	280	210	-237	-195	10	978.428		
727510000	0	-5	1004	-280	350	210	-240	-189	16	978.428		
727520000	0	-4	1003	-280	350	210	-231	-192	6	978.428		
727520000	0	-3	1002	-280	350	210	-228	-183	6	978.396		
727540000	0	-3	1003	-210	350	210	-235	-193	1	978.396		
727540000	0	-4	1003	-280	350	210	-225	-193	10	978.396		
727560000	0	-4	1003	-280	350	210	-231	-192	7	978.396		
727560000	0	-4	1003	-280	280	280	-232	-189	9	978.414		
727580000	0	-4	1003	-280	350	210	-235	-196	3	978.414		
727580000	0	-4	1003	-280	350	210	-237	-199	6	978.414		
727600000	0	-4	1003	-210	350	280	-228	-189	13	978.414		
727600000	0	-4	1003	-280	280	210	-240	-189	4	978.402		
727610000	0	-4	1003	-280	350	210	-229	-195	3	978.402		
727620000	0	-4	1003	-280	350	210	-223	-186	12	978.402		
727630000	0	-3	1003	-210	280	210	-228	-195	1	978.402		

Connected: X-NUCLEO-IKS4A1, FW: 10.0.0

5 Advanced features

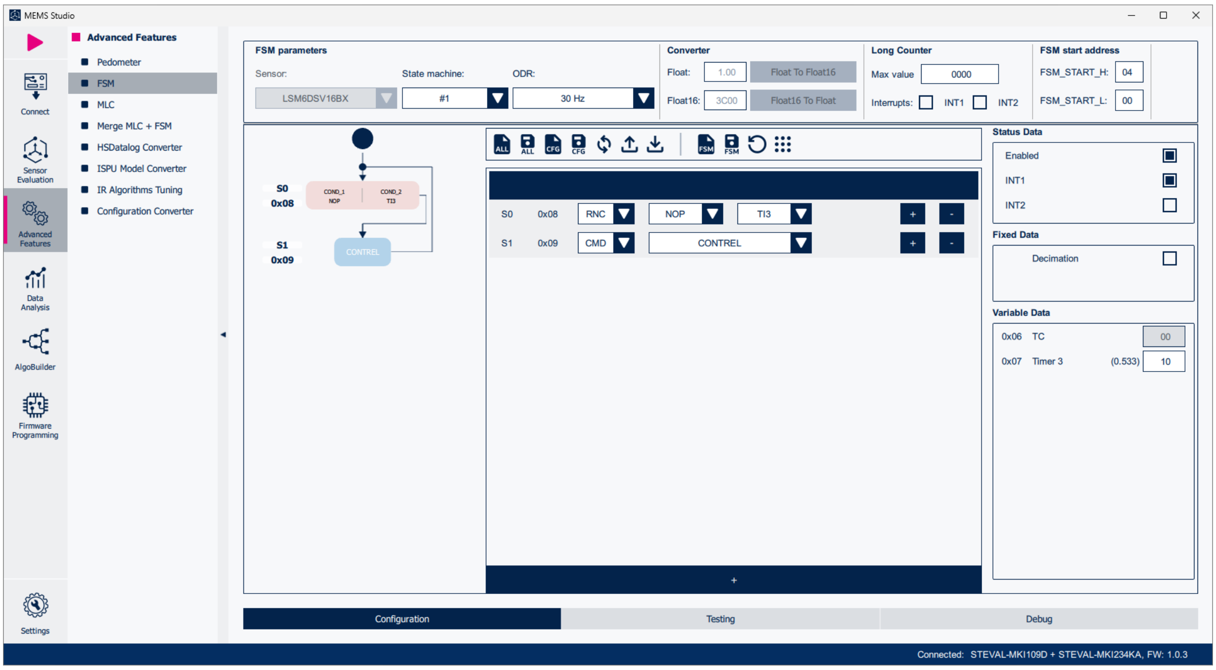
5.1 Finite state machine (FSM) tool

The finite state machine page allows the user to configure the state machines and test their functionality on the connected device in order to detect a sequence of events with specific timing (example: hand or head gesture).

FSM implementation consists of three tools:

- [**Configuration**]: allows configuring the available state machines on the device
- [**Testing**]: shows plots with sensor data, interrupts, and state machine output register information
- [**Debug**]: (available only on the ProfiMEMS board). This page lets the user inject log file samples into the device in order to evaluate the number of interrupts detected and the overall FSM results based on a selected configuration.

Figure 47. **FSM page**



Sensor: LSM6DSV16BX
State machine: #1
ODR: 30 Hz
Float: 1.00
Float16: 3C00
Max value 0000
Interrupts: □ INT1 □ INT2
FSM_START_H: 04
FSM_START_L: 00

S0	0x08	RNC	NOP	TI3
S1	0x09	CMD	CONTREL	

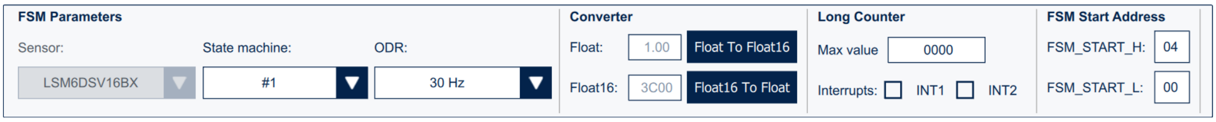
Enabled ☒
INT1 ☒
INT2 □
Decimation □

0x06 TC 00
0x07 Timer 3 (0.533) 10

Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.3

FSM parameters

Figure 48. **Configuration of FSM parameters - menu bar**



FSM Parameters
Sensor: LSM6DSV16BX
State machine: #1
ODR: 30 Hz

Converter
Float: 1.00 Float To Float16
Float16: 3C00 Float16 To Float

Long Counter
Max value 0000
Interrupts: □ INT1 □ INT2

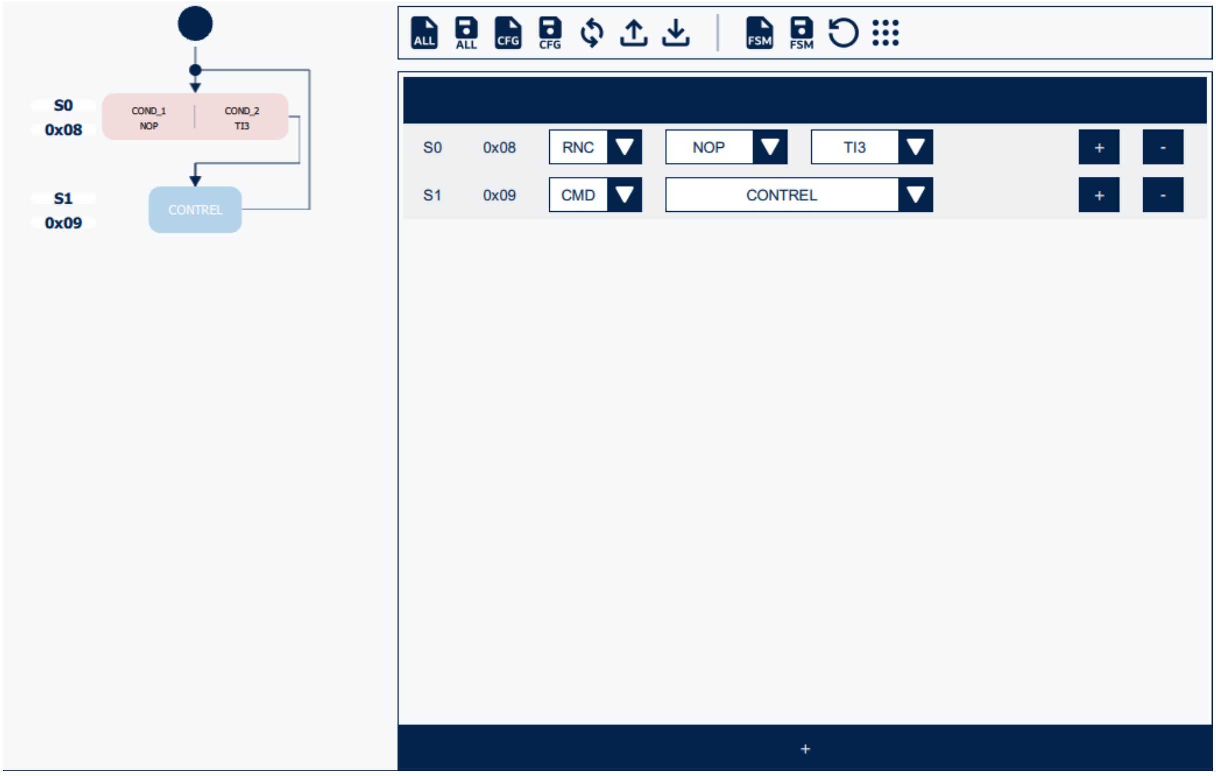
FSM Start Address
FSM_START_H: 04
FSM_START_L: 00

- [**Sensor selector**]: displays the selected device to configure
- [**State machine selector**]: displays the selected state machine to configure. This selection is applied to both the configuration page and debug page if available.
- [**FSM ODR**]: this setting determines the processing / output data rate of the FSM samples.
- [**Converter**]: this tool helps to generate the values to be set in the threshold resources in the [**Variable Data**] section. It converts a float32 value into a float16 format and vice versa.
- [**FSM Start Address**]: determines the first address written in the FSM registers while configuring the state machines

Configuration

This tab lets the user add commands and conditions to the selected state machine and visualize diagrams while editing state parameters. A dedicated tool bar illustrates the actions that can be performed.

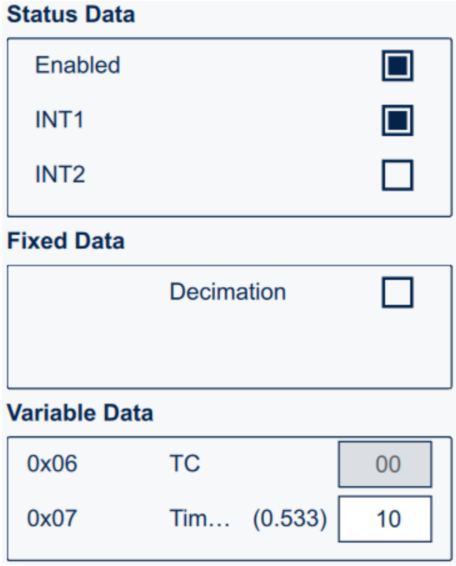
Figure 49. Configuration tab



S0 0x08 RNC NOP TI3

S1 0x09 CMD CONTREL

The right side of the configuration tab shows the active parameters and provides the capability to edit them in order to update the values of the resources used in the [**Variable Data**] section. This section shows the active and enabled resources, depending on the list of instructions that have been set by the user in the FSM state diagram on the left side.



Status Data

Enabled ☒

INT1 ☒

INT2 □

Fixed Data

Decimation □

Variable Data

0x06 TC 00

0x07 Tim… (0.533) 10

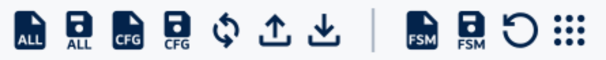


Figure 50. FSM configuration toolbar

The FSM configuration tool bar provides the capability to perform actions on all device state machines or on a single state machine. Some actions are available only if the target device is connected, such as writing or reading data to/from the connected device, while others might work in a different way such as loading an FSM configuration.

Loading an FSM configuration decodes configuration data on a host pc if no target device is connected or writes a configuration on the device and then decodes device data if the target device is connected to the MEMS Studio application in order to allow the user to inspect configuration data, ensuring the best reliability of data shown in the GUI.

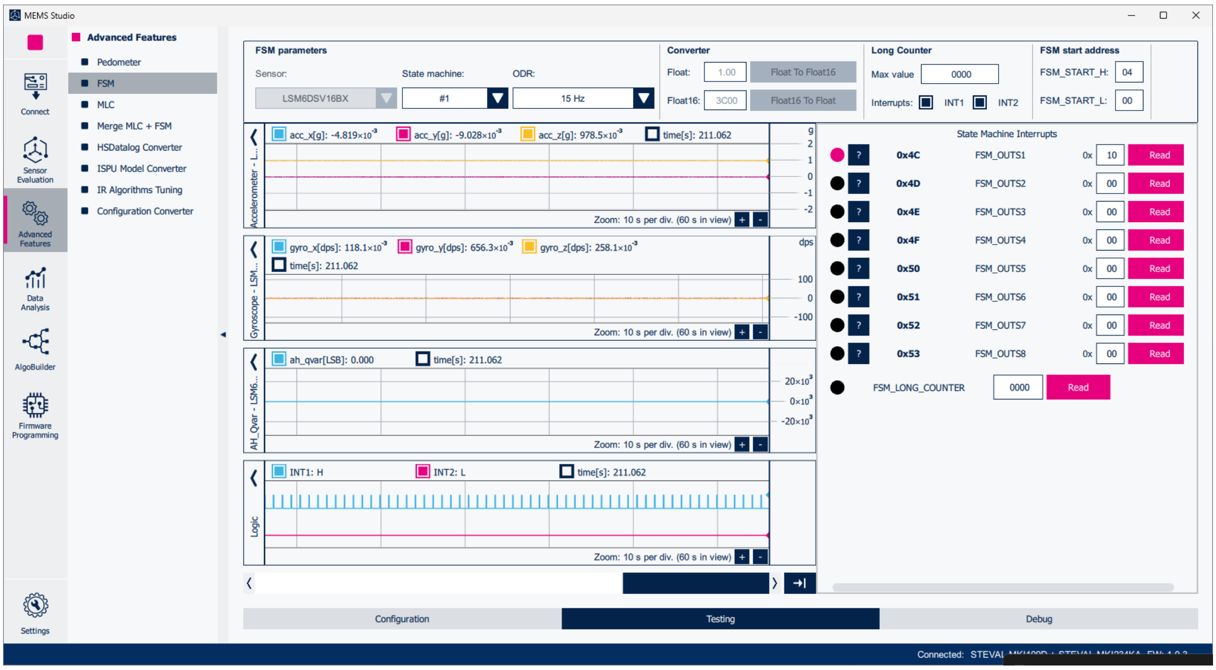
- **Load all state machines from file**: loads multiple state machines from .json file and populates the GUI
- **Save all state machine as**: exports state machines configuration to a dedicated .json file
- **Load device configuration from file**: imports all state machine configurations, writes the configuration to the device, and updates the GUI according to the written instructions
- **Save device configuration as**: exports the instructions of the device configuration for configuring all state machines to a .json file
- **Reset state machine:** clears the selected state machine GUI data without changing the device configuration
- **Read FSM configuration from sensor**: updates all state machine GUI data according to the current FSM device configuration
- **Write FSM configuration to sensor**: writes all current state machine GUI data to the device
- **Load state machine**: loads one state machine from .fsm (legacy) or .json file and populates the GUI
- **Save current FSM**: exports the current state machine configuration to a .json file
- **Reset all state machines**: clears all state machine GUI data
- **Read state machine from examples:** displays the available FSM examples for the selected device with their descriptions and allows the user to load a configuration to the GUI

Testing

This tab shows the available sensor data compatible with the FSM configuration, interrupt data plots, and FSM output register values. A dedicated blinking LED graphic is toggled every time an FSM interrupt is detected during the parsing of the FSM status register data and once it is activated, its state is not changed for ~300 msec.

This page helps the user to check the program functionalities after the FSM configuration is completed.

Figure 51. Testing tab



FSM parameters
Sensor: LSM6DSV16BX
State machine: #1
ODR: 15 Hz

Converter
Float: 1.00
Float16: 3C00

Long Counter
Max value 0000
Interrupts: ■ INT1 ■ INT2

FSM start address
FSM_START_H: 04
FSM_START_L: 00

acc_x[g]: -4.819×10^-3 acc_y[g]: -9.028×10^-3 acc_z[g]: 978.5×10^-3 time[s]: 211.062
Zoom: 10 s per div. (60 s in view)

gyro_x[dps]: 118.1×10^-3 gyro_y[dps]: 656.3×10^-3 gyro_z[dps]: 258.1×10^-3 time[s]: 211.062
Zoom: 10 s per div. (60 s in view)

ah_qvar[LSB]: 0.000 time[s]: 211.062
Zoom: 10 s per div. (60 s in view)

INT1: H INT2: L time[s]: 211.062
Zoom: 10 s per div. (60 s in view)

State Machine Interrupts

●	?	0x4C	FSM_OUTS1	0x	10	Read
●	?	0x4D	FSM_OUTS2	0x	00	Read
●	?	0x4E	FSM_OUTS3	0x	00	Read
●	?	0x4F	FSM_OUTS4	0x	00	Read
●	?	0x50	FSM_OUTS5	0x	00	Read
●	?	0x51	FSM_OUTS6	0x	00	Read
●	?	0x52	FSM_OUTS7	0x	00	Read
●	?	0x53	FSM_OUTS8	0x	00	Read

● FSM_LONG_COUNTER 0000 Read

Connected: STEVAL

Debug

The **Debug** function allows debugging the selected state machine sample by sample after loading an input data pattern.

The main purpose of this tab is to check the state machine functionality in order to validate the program using recorded log files, assuming the device is configured as it was before starting to log data in the file.

During data injection, the [**Program Pointer**] and the [**Reset Pointer**] are updated according to the data that are read from the device.

The [**Program Pointer**] value contains the current address of the program and it is used to highlight the corresponding state in the diagram. The [**Reset Pointer**] value contains the address of the state or condition related to the CONTREL command or return condition of the program.

The tool provides the user with several data injection interactive controls to inject one or multiple samples at a time and write output data to a dedicated table.

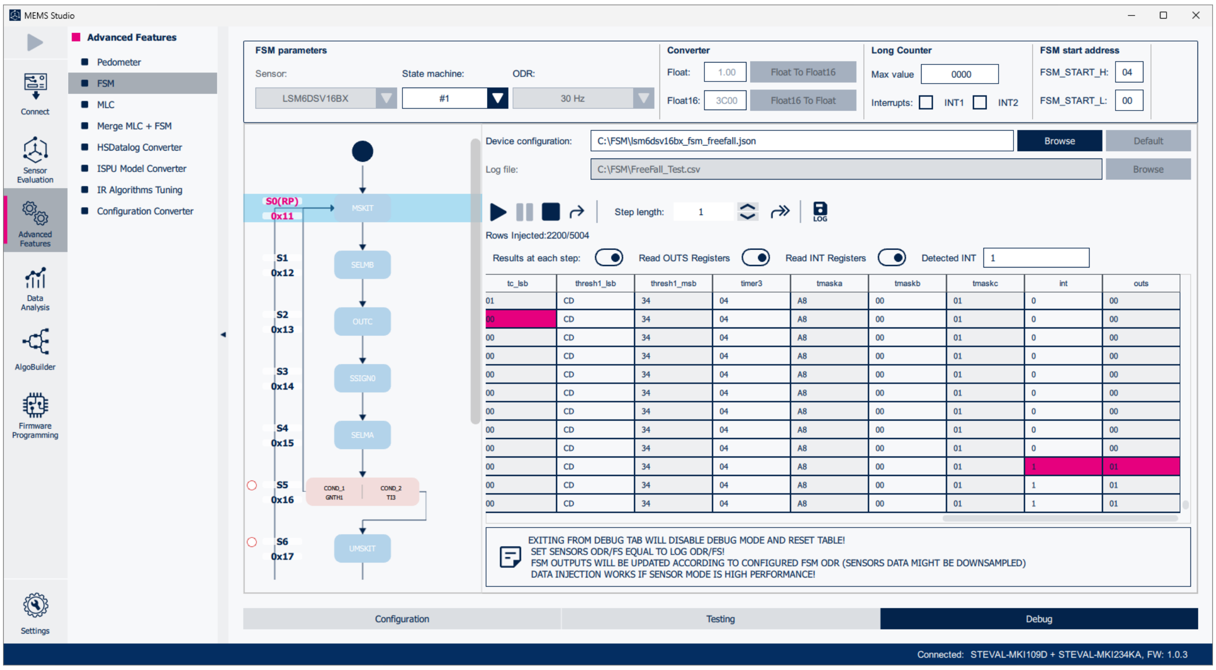
Every command before a condition and every condition has a radio button to configure a break point for pausing the data injection process if the program pointer address is equal to the address of the item with the enabled break point indicator. Whenever a break point is activated, the background color of the current state changes according to the selected color theme of the application.

Data injection controls

- [**Run**]: injects all the next samples
- [**Pause**]: pauses the data injection process
- [**Stop**]: interrupts the data injection process and exits debug mode.
- [**Next**]: injects the next sample and updates the table with output data
- [**Next step**]: injects a defined number of samples according to the [**Step length**]settings
- [**Export log**]: exports the content of the table with the results to a .csv file

The data table is updated at every step if the [**Results at each step**] switch is enabled, otherwise it is updated only when the data injection is paused or stopped. The [**Read OUTS registers**] switch enables or disables reading sensor output registers. The [**Read INT registers**] switch enables or disables reading interrupts status registers. [**Detect INT**] indicates the number of detected interrupts in the processed log file.

Figure 52. **Debug tab**



FSM parameters
Sensor: LSM6DSV16BX
State machine: #1
ODR: 30 Hz

Converter
Float: 1.00
Float16: 3C00

Long Counter
Max value 0000
Interrupts: □ INT1 □ INT2

FSM start address
FSM_START_H: 04
FSM_START_L: 00

Device configuration: C:\FSM\lsm6dsv16bx_fsm_freefall.json
Log file: C:\FSM\FreeFall_Test.csv

Step length: 1

Rows Injected:2200/5004

Results at each step: ● Read OUTS Registers ● Read INT Registers ● Detected INT 1

tc_lsb	thresh1_lsb	thresh1_msb	timer3	tmaska	tmaskb	tmaskc	int	outs
01	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	0	00
00	CD	34	04	A8	00	01	1	01
00	CD	34	04	A8	00	01	1	01
00	CD	34	04	A8	00	01	1	01

EXITING FROM DEBUG TAB WILL DISABLE DEBUG MODE AND RESET TABLE!
SET SENSORS ODR/FS EQUAL TO LOG ODR/FS!
FSM OUTPUTS WILL BE UPDATED ACCORDING TO CONFIGURED FSM ODR (SENSORS DATA MIGHT BE DOWNSAMPLED)
DATA INJECTION WORKS IF SENSOR MODE IS HIGH PERFORMANCE!

Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.3

5.2 Machine learning core (MLC) tool

The machine learning core (MLC) tool allows the user to configure a machine learning core that is embedded in some devices. For more details about the MLC, consult the specific application note for the sensor you would like to use. The configuration procedure is divided into several steps appearing in different tabs:

- [**Data patterns**]: allows managing the data patterns to be used and assigning a label to each data pattern loaded
- [**AFS tool**]: allows processing acquired data and recommends window length, filters, and features that can be used for decision tree generation
- [**ARFF generation**]: allows configuring inputs, filters, and features to generate an .arff file
- [**Decision tree generation**]: allows configuring the decision tree outputs and generating the decision trees
- [**Config generation**]: allows setting the metaclassifier and generating the configuration file
- [**Decision tree output viewer**]: allows live monitoring of MLC outputs in the chart when testing the generated MLC configuration
- [**Debug**]: allows testing the MLC configuration using previously acquired data

To start configuring the machine learning core, the workspace directory must be selected using the [**Browse**] button. After that a device must be selected. If a sensor using the MLC is connected, it is selected automatically. The entire MLC configuration is stored in the mlc_settings.json file inside the workspace directory. The changes are automatically saved to this file. The MLC configuration can be imported into the active workspace using the [**Import**] button.

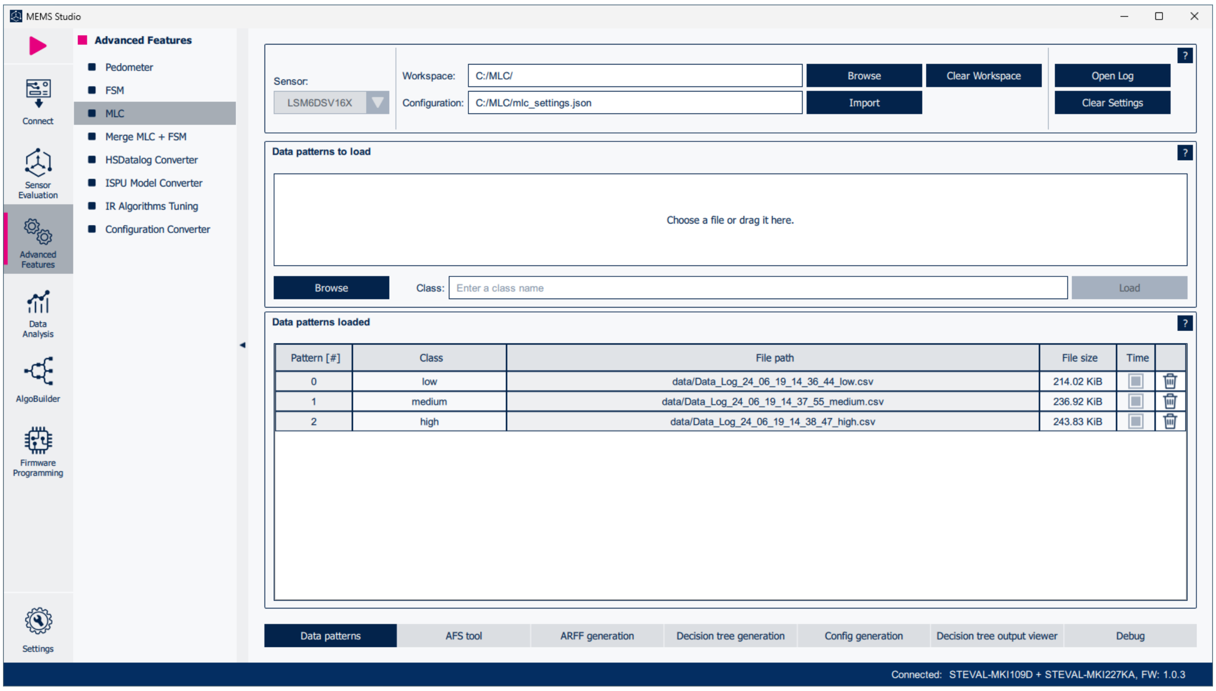
All artifacts generated during the MLC configuration process can be deleted using the [**Clear Workspace**] button, and the mlc_settings.json is not deleted. All the settings can be deleted and restored to the default values using the [**Clear Settings**] button. The history of the performed actions and results are accessible in a dedicated window, which can be displayed using the [**Open Log**] button.

Data patterns

The [**Data patterns**] tab allows managing the data patterns to be used for the machine learning processing. The data patterns that are possible to load must have the same data format as the log files generated by MEMS Studio, Unico-GUI, or Unicleo-GUI.

A data pattern(s) is selected using the [**Browse**] button. Multiple files can be selected. A class label must be assigned to each data pattern, which is then used for machine learning processing. The class label is confirmed by the [**Load**] button. Data patterns can be removed from the list using the [**trash bin**] button in the tables.

Figure 53. Data patterns tab



Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Data patterns to load

Class: Enter a class name

Data patterns loaded

Pattern [#]	Class	File path	File size	Time	
0	low	data/Data_Log_24_06_19_14_36_44_low.csv	214.02 KiB	□	🗑
1	medium	data/Data_Log_24_06_19_14_37_55_medium.csv	236.92 KiB	□	🗑
2	high	data/Data_Log_24_06_19_14_38_47_high.csv	243.83 KiB	□	🗑

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

AFS tool

The AFS tool offers the possibility to estimate suitable window length, filters, and features for classification done by the decision tree.

Automatic window length calculation

The window length is calculated based on the lowest frequency present in the signal across all data classes.

Automatic filter selection

There are two methods that can be used for automatic filter selection. **Basic search** is a peak-based method that identifies the maxima of the signal in the frequency spectrum. This method is less computationally expensive, but it is not accurate on flat signals without significant peaks. **Exhaustive search** is an entropy-based method that searches all combinations of frequency bands (on a logarithmic scale) and selects the frequency of interest that minimizes the entropy against the other classes.

Automatic feature selection

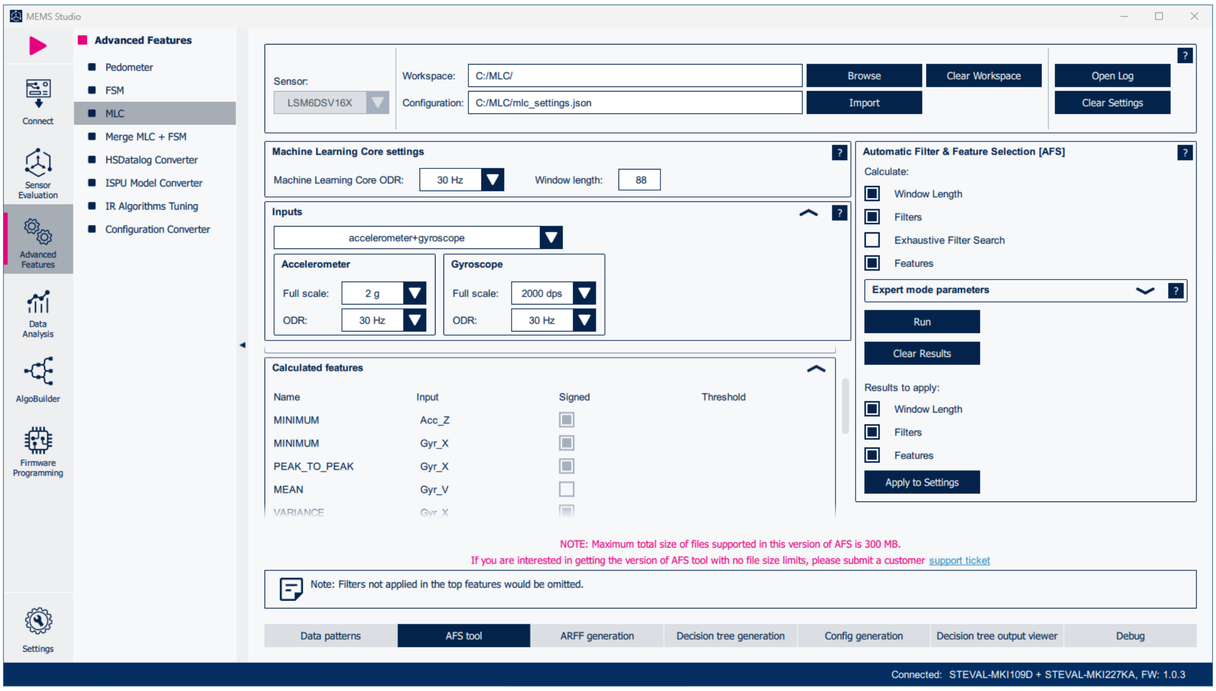
The automatic feature selection algorithm considers filters generated by the automatic filter selection and the features are computed for different filters and raw data. It uses an ensemble method for feature importance and cross correlation to remove highly correlated features. The following statistical features are supported for both single axis and norm: mean, variance, energy, peak to peak, minimum, maximum. The automatic feature selection algorithm selects the top features by computing the rank of each feature according to an ensemble method and averaging across all ensemble methods. There are five different ensemble methods available to determine feature importance: ANOVA, Ada Boost (ADA), Sequential Feature Selection (SFS), Random Forest (RF), Recursive Feature Elimination (RFE). By default, ANOVA, Ada Boost, Random Forest, and Recursive Feature Elimination are used as methods for ranking important features. Including Sequential Feature Selection may improve the overall performance but increases the overall runtime.

Data analysis takes into account the machine learning core ODR and input specification parameters from the [**ARFF generation**] tab. The window length is also taken from this tab in case the window length calculation is not enabled.

After the desired parameter selection, the data analysis is executed using the [**Run**] button.

The generated window length, filter, and features can be transferred to the MLC configuration in the [**ARFF generation**] tab using the [**Apply to Settings**] button.

Figure 54. AFS tool tab



Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Machine Learning Core settings

Machine Learning Core ODR: 30 Hz

Window length: 88

Inputs

accelerometer+gyroscope

Accelerometer

Full scale: 2 g

ODR: 30 Hz

Gyroscope

Full scale: 2000 dps

ODR: 30 Hz

Calculated features

Name	Input	Signed	Threshold
MINIMUM	Acc_Z	☑	
MINIMUM	Gyr_X	☑	
PEAK_TO_PEAK	Gyr_X	☑	
MEAN	Gyr_V	☐	
VARIANCE	Gyr_X	☑	

Automatic Filter & Feature Selection [AFS]

Calculate:

☑ Window Length

☑ Filters

☐ Exhaustive Filter Search

☑ Features

Expert mode parameters

Results to apply:

☑ Window Length

☑ Filters

☑ Features

NOTE: Maximum total size of files supported in this version of AFS is 300 MB.
If you are interested in getting the version of AFS tool with no file size limits, please submit a customer support ticket

Note: Filters not applied in the top features would be omitted.

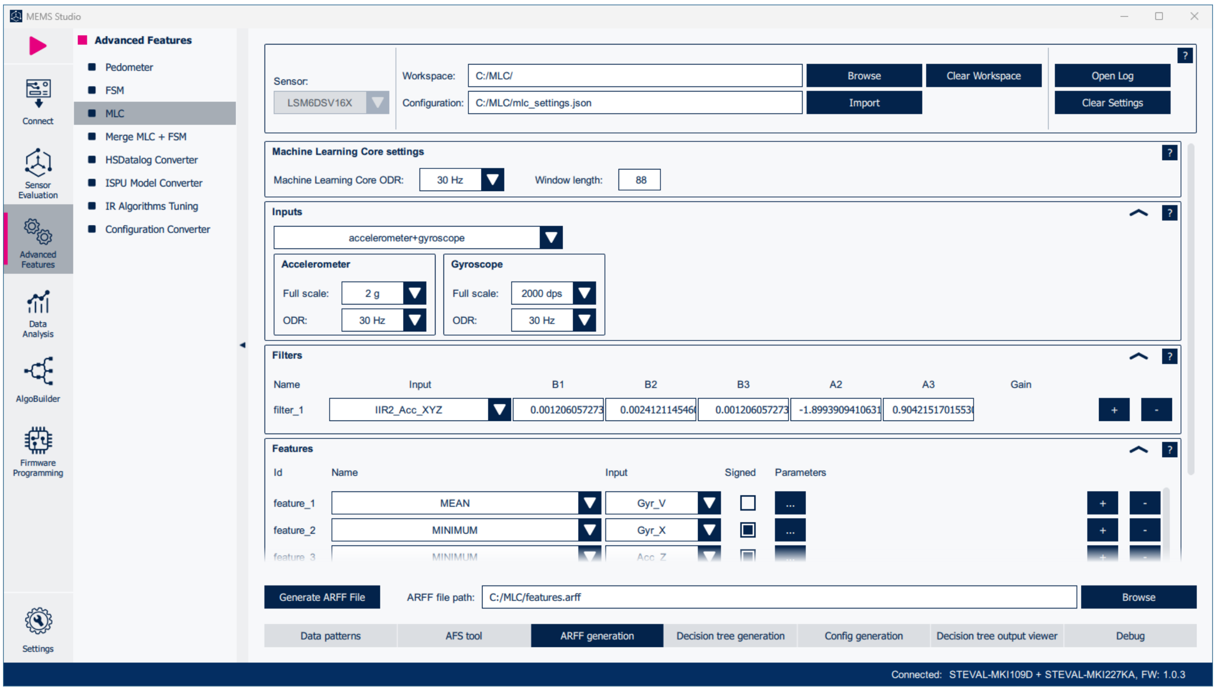
Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

ARFF generation

Attribute-Relation File Format (ARFF) is a file format used for storing data in machine learning applications. It contains a list of instances, where each instance represents a single window processed by the MLC.

The [**ARFF generation**] tab allows configuring sensor and MLC parameters. The MLC processes the data at the [**Machine Learning Core ODR**] rate in consequential data windows. The number of samples in each window can be configured by the [**Window length**] option. The MLC processes the sensor data specified in the [**Inputs**] section. The full scale and output data rate of the selected sensors can be defined. [**Filters**] offer preprocessing on the machine learning core input signals. The [**Features**] section contains a list of features that are calculated from the input data (filtered or not filtered). After setting all the parameters, the ARFF file can be generated using the [**Generate ARFF File**] button. Statistical parameters computed from the inputs are then used for classification in the decision tree.

Figure 55. ARFF generation tab



Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Machine Learning Core settings

Machine Learning Core ODR: 30 Hz

Window length: 88

Inputs

accelerometer+gyroscope

Accelerometer

Full scale: 2 g

ODR: 30 Hz

Gyroscope

Full scale: 2000 dps

ODR: 30 Hz

Filters

Name	Input	B1	B2	B3	A2	A3	Gain
filter_1	IIR2_Acc_XYZ	0.001206057273	0.0024121145460	0.001206057273	-1.8993909410631	0.9042151701553	

Features

Id	Name	Input	Signed	Parameters
feature_1	MEAN	Gyr_V	☐	...
feature_2	MINIMUM	Gyr_X	☒	...
feature_3	MINIMUM	Acc_Z	☐	...

ARFF file path: C:/MLC/features.arff

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

Decision tree generation

The [**Decision tree generation**] tab allows configuring a decision tree using selected classes to process and evaluating decision tree classification performance. The [**Number of decision trees**] can be specified.

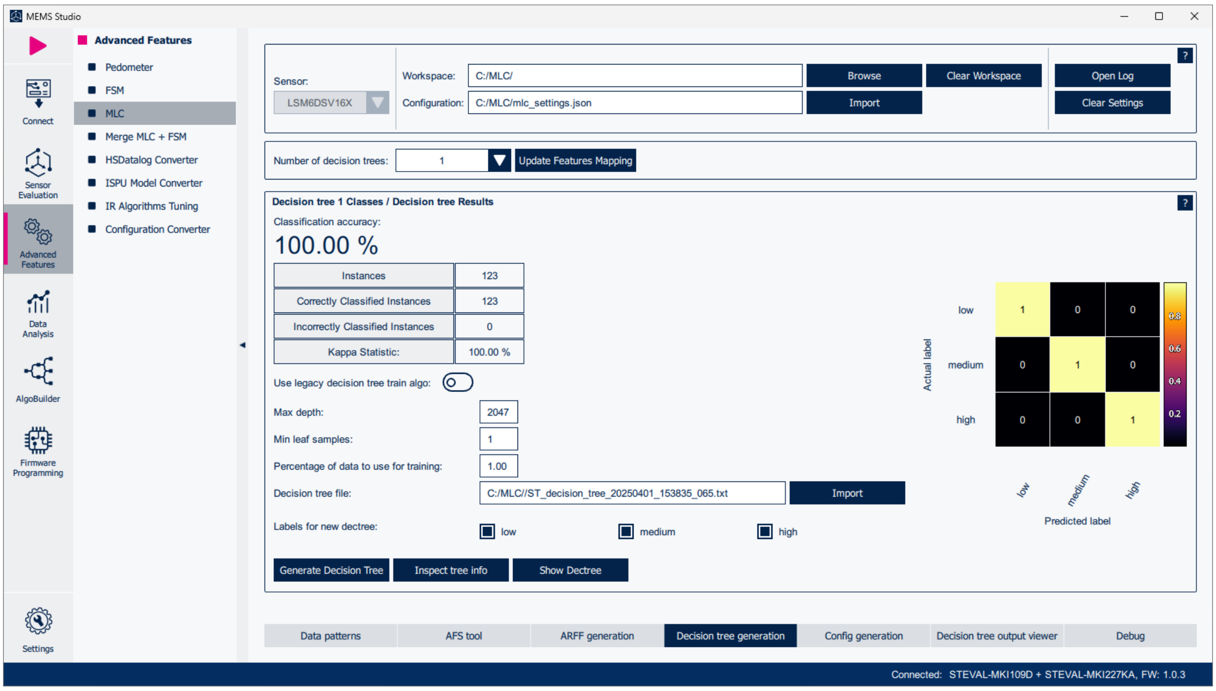
A new decision tree algorithm was introduced in MEMS Studio v2.0.0. The new algorithm has both depth-first and best-first tree building implementations, implements Breiman's cost-complexity pruning, and identifies optimal tree size using cross validation.

The maximum depth of the tree ([**Max depth**]), minimum samples required in a leaf node ([**Min leaf samples**]), and [**Percentage of data to use for training**] can be configured.

The previous algorithm can be enabled using the [**Use legacy decision tree train algo**] switch. In this case, the [**Maximum number of nodes**] and [**Confidence factor**], which control decision tree pruning, can be set.

A decision tree is generated using the [**Generate Decision Tree**] button. A file with an externally generated decision tree definition can be loaded using the [**Import**] button. After decision tree generation or loading, statistical parameters of the decision tree like accuracy, number of instances, confusion matrix, and others are displayed. The resulting decision tree can be analyzed using the [**Inspect tree info**] button for a textual content or using [**Show Decision Tree**] for a graphical representation of the same.

Figure 56. Decision tree generation tab



Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Number of decision trees: 1

Decision tree 1 Classes / Decision tree Results

Classification accuracy:

100.00 %

Instances	123
Correctly Classified Instances	123
Incorrectly Classified Instances	0
Kappa Statistic:	100.00 %

Use legacy decision tree train algo: ○

Max depth: 2047

Min leaf samples: 1

Percentage of data to use for training: 1.00

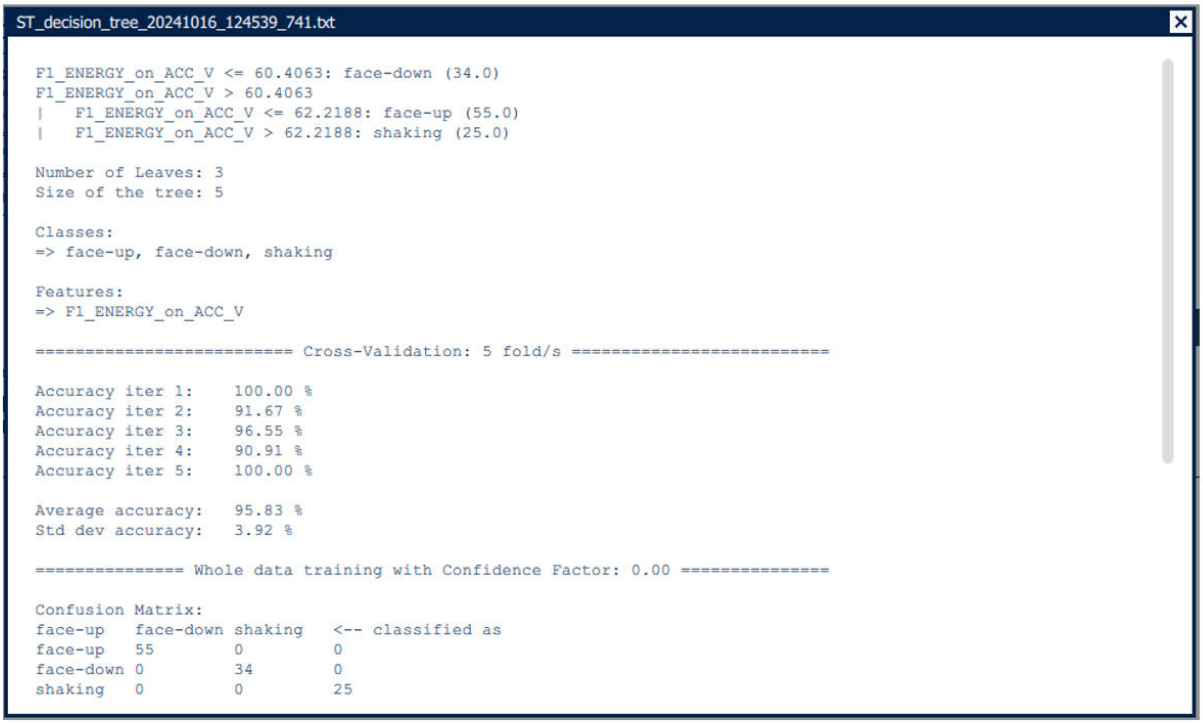
Decision tree file: C:/MLC//ST_decision_tree_20250401_153835_065.txt

Labels for new dectree: ■ low ■ medium ■ high

	low	medium	high
low	1	0	0
medium	0	1	0
high	0	0	1

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

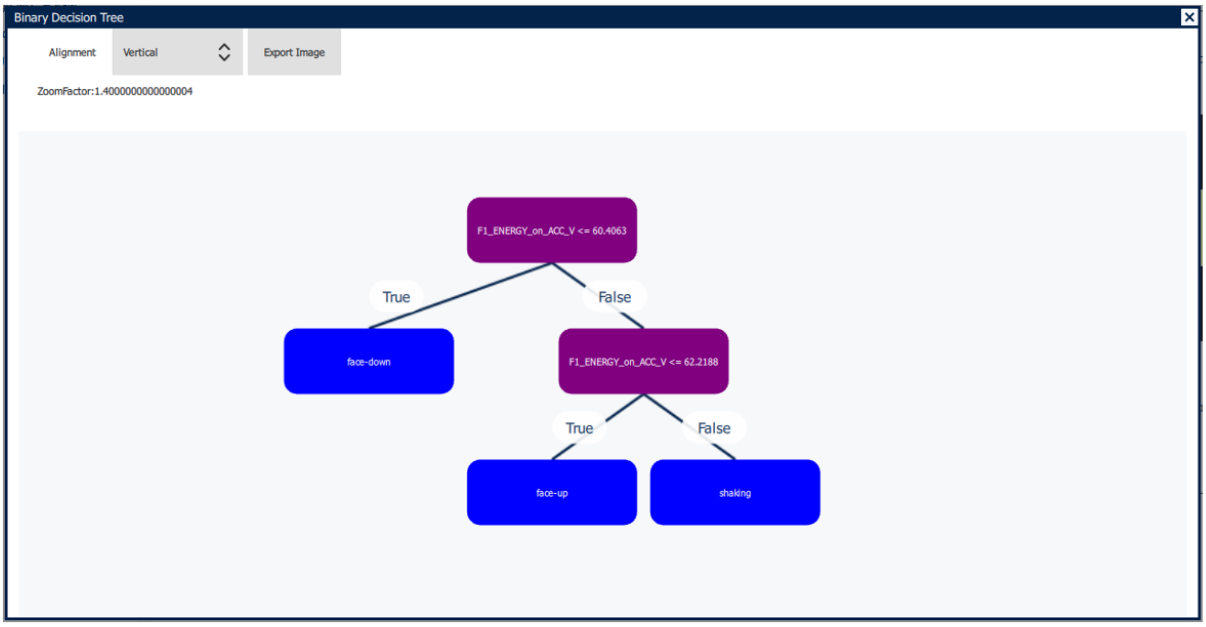
Figure 57. Inspect tree info (textual content)



ST_decision_tree_20241016_124539_741.txt

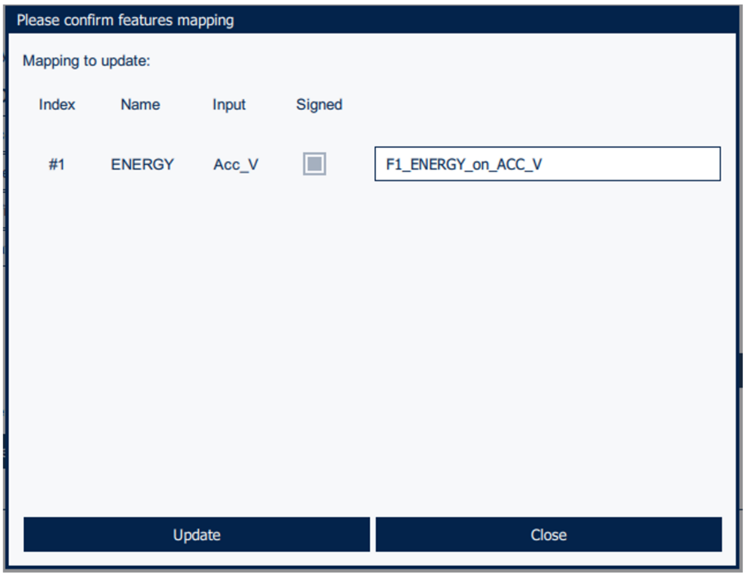
```
F1_ENERGY_on_ACC_V <= 60.4063: face-down (34.0)
F1_ENERGY_on_ACC_V > 60.4063
|   F1_ENERGY_on_ACC_V <= 62.2188: face-up (55.0)
|   F1_ENERGY_on_ACC_V > 62.2188: shaking (25.0)

Number of Leaves: 3
Size of the tree: 5

Classes:
=> face-up, face-down, shaking

Features:
=> F1_ENERGY_on_ACC_V

========================== Cross-Validation: 5 fold/s ==========================

Accuracy iter 1:    100.00 %
Accuracy iter 2:    91.67 %
Accuracy iter 3:    96.55 %
Accuracy iter 4:    90.91 %
Accuracy iter 5:    100.00 %

Average accuracy:   95.83 %
Std dev accuracy:   3.92 %

=============== Whole data training with Confidence Factor: 0.00 ===============

Confusion Matrix:
face-up   face-down shaking   <-- classified as
face-up   55        0         0
face-down 0         34        0
shaking   0         0         25
```

Figure 58. Decision tree (graphical representation)



If the user imports a decision tree, a feature mapping is needed to map every feature selected during arff generation with feature listed into decision tree file every feature selected during arff generation must be mapped, listing each feature in the decision tree file. Note that this mapping is applied for every decision tree imported or generated.

Figure 59. **Confirmation of features mapping**



Please confirm features mapping

Mapping to update:

Index	Name	Input	Signed	
#1	ENERGY	Acc_V	▣	F1_ENERGY_on_ACC_V

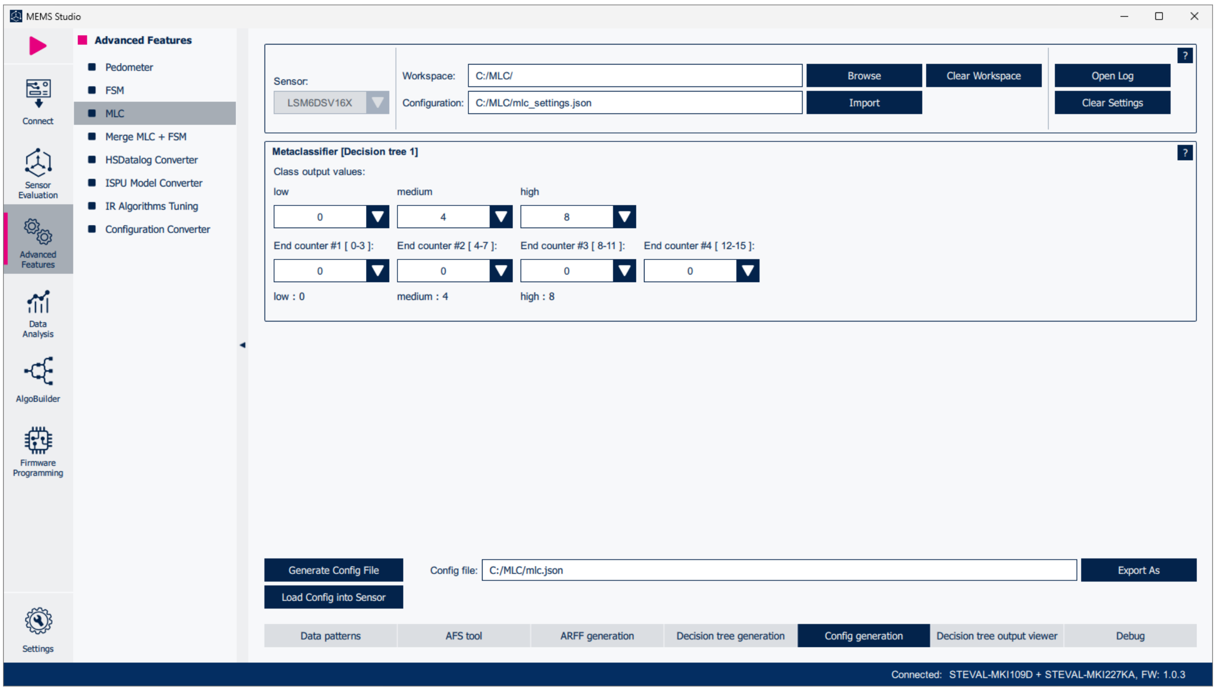
Config generation

The [**Config generation**] tab allows configuring the metaclassifiers and generating the .json file containing the machine learning core configuration.

The generated MLC configuration can be stored also in .h file using the [**Export As**] button.

In the case of a board with a selected sensor connected, the generated configuration can be uploaded to the sensor using the [**Load Config into Sensor**] button.

Figure 60. **Config generation tab**



MEMS Studio

Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Metaclassifier [Decision tree 1]

Class output values:

low: 0
medium: 4
high: 8

End counter #1 [0-3]: 0
End counter #2 [4-7]: 0
End counter #3 [8-11]: 0
End counter #4 [12-15]: 0

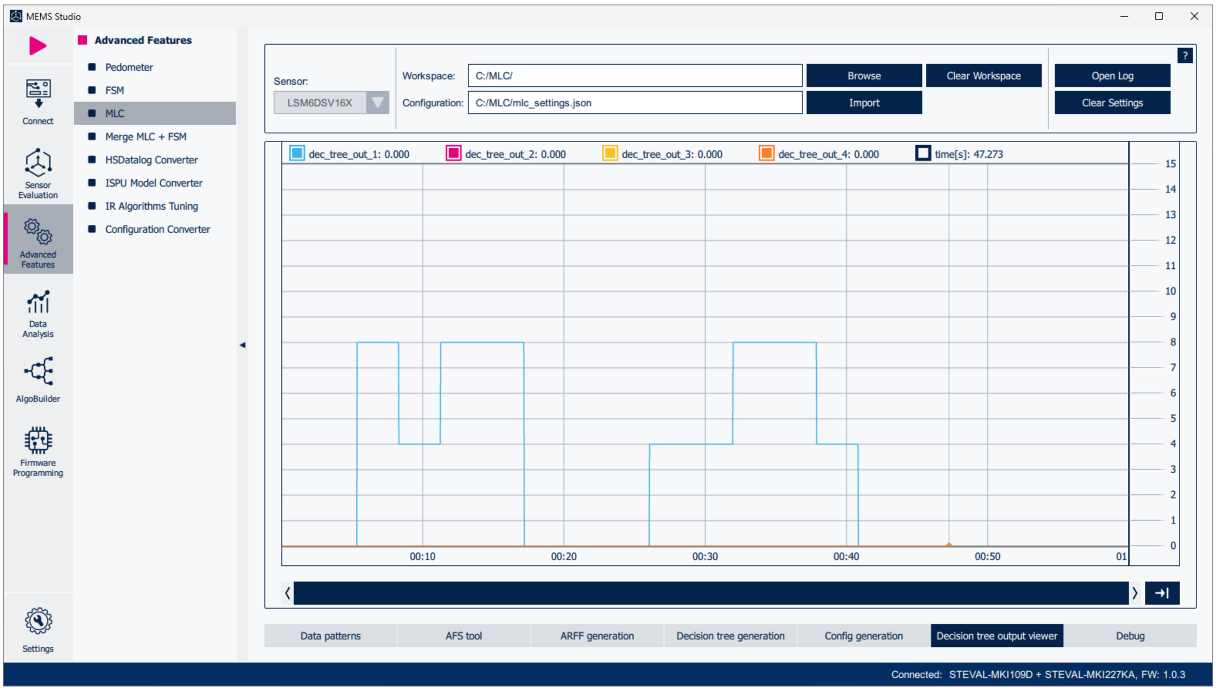
low : 0 medium : 4 high : 8

Config file: C:/MLC/mlc.json

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

Decision tree output viewer

The [**Decision tree output viewer**] tab allows testing the generated MLC configuration by monitoring individual MLC outputs in the chart.



Sensor: LSM6DSV16X
Workspace: C:/MLC/
Configuration: C:/MLC/mlc_settings.json

dec_tree_out_1: 0.000
dec_tree_out_2: 0.000
dec_tree_out_3: 0.000
dec_tree_out_4: 0.000
time[s]: 47.273

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

Figure 61. **Decision tree output viewer tab**

Debug

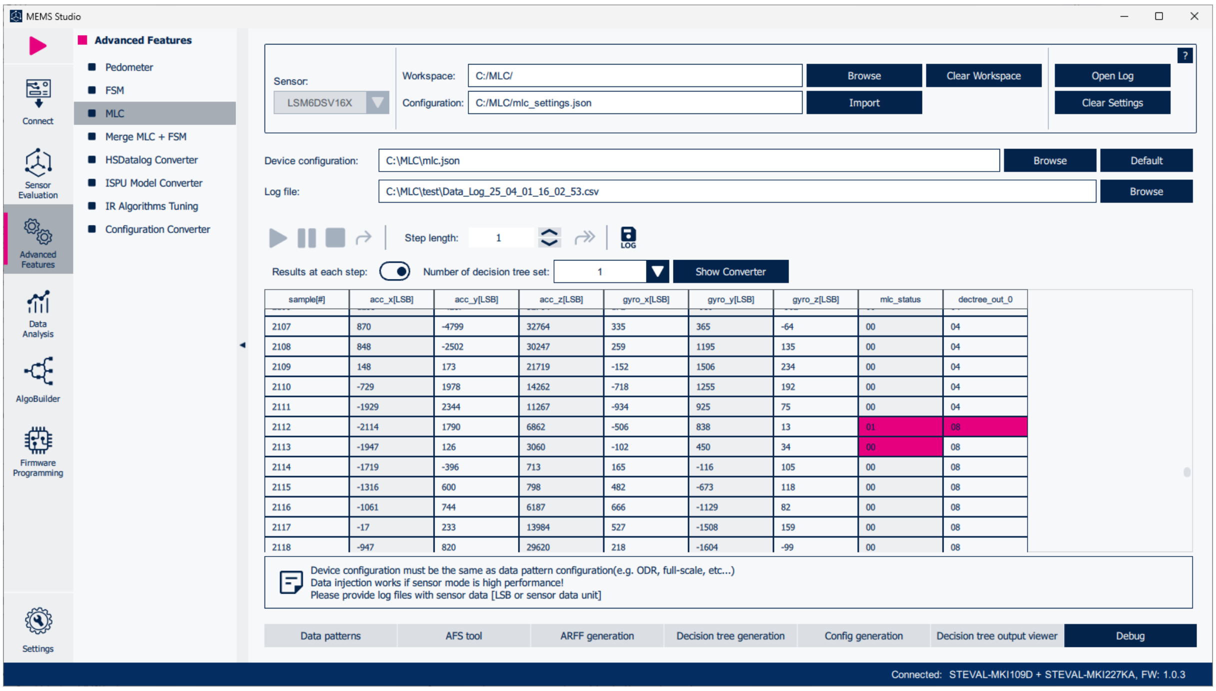
The **Debug** tab allows checking the MLC functionality in order to validate the configuration using previously recorded log files, assuming the device is configured as it was before starting to log data in the file.

Data injection control

- [**Run**]: injects all the next samples
- [**Pause**]: pauses the data injection process with the possibility to resume it
- [**Stop**]: interrupts the data injection process and exits debug mode.
- [**Next**]: injects the next sample and updates the table with output data
- [**Next step**]: injects a defined number of samples according to the [**Step length**]settings
- [**Export log**]: exports the content of the table with the results to a .csv file

The data table is updated at every step if the [**Results at each step**] switch is enabled, otherwise it is updated only when the data injection is paused or stopped. The [**Number of decision tree set**] settings specifies which MLC output registers will be monitored.

Figure 62. Data injection



Sensor: LSM6DSV16X

Workspace: C:/MLC/

Configuration: C:/MLC/mlc_settings.json

Device configuration: C:\MLC\mlc.json

Log file: C:\MLC\test\Data_Log_25_04_01_16_02_53.csv

Step length: 1

Results at each step: ●

Number of decision tree set: 1

sample[#]	acc_x[LSB]	acc_y[LSB]	acc_z[LSB]	gyro_x[LSB]	gyro_y[LSB]	gyro_z[LSB]	mlc_status	dectree_out_0
2107	870	-4799	32764	335	365	-64	00	04
2108	848	-2502	30247	259	1195	135	00	04
2109	148	173	21719	-152	1506	234	00	04
2110	-729	1978	14262	-718	1255	192	00	04
2111	-1929	2344	11267	-934	925	75	00	04
2112	-2114	1790	6862	-506	838	13	01	08
2113	-1947	126	3060	-102	450	34	00	08
2114	-1719	-396	713	165	-116	105	00	08
2115	-1316	600	798	482	-673	118	00	08
2116	-1061	744	6187	666	-1129	82	00	08
2117	-17	233	13984	527	-1508	159	00	08
2118	-947	820	29620	218	-1604	-99	00	08

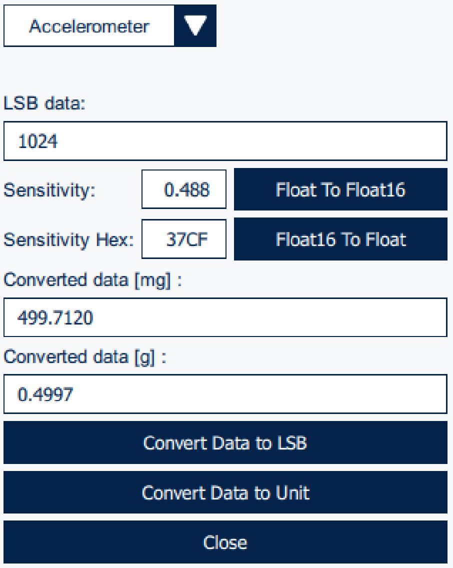
Device configuration must be the same as data pattern configuration(e.g. ODR, full-scale, etc...)
Data injection works if sensor mode is high performance!
Please provide log files with sensor data [LSB or sensor data unit]

Connected: STEVAL-MKI109D + STEVAL-MKI227KA, FW: 1.0.3

The debug page provides the user with a dedicated converter tool to simplify data conversion during log data processing. The tool can be opened using the [**Show Convertor**] button. The debug tool works with raw data in LSB and it converts sensor data internally into LSB using the sensitivity evaluated on the basis of a given configuration file if no LSB data was given.

The MLC in the hardware configures conditions in the units of measurement, which is why users might need a converter tool to easily understand if a certain condition of a decision tree is verified for a certain LSB data. For example if a decision tree condition has a threshold of 0.5 *g*, the corresponding LSB threshold value will be 1024 using a sensitivity of 0.488.

Figure 63. Convertor tool



Accelerometer

LSB data: 1024

Sensitivity: 0.488

Sensitivity Hex: 37CF

Converted data [mg] : 499.7120

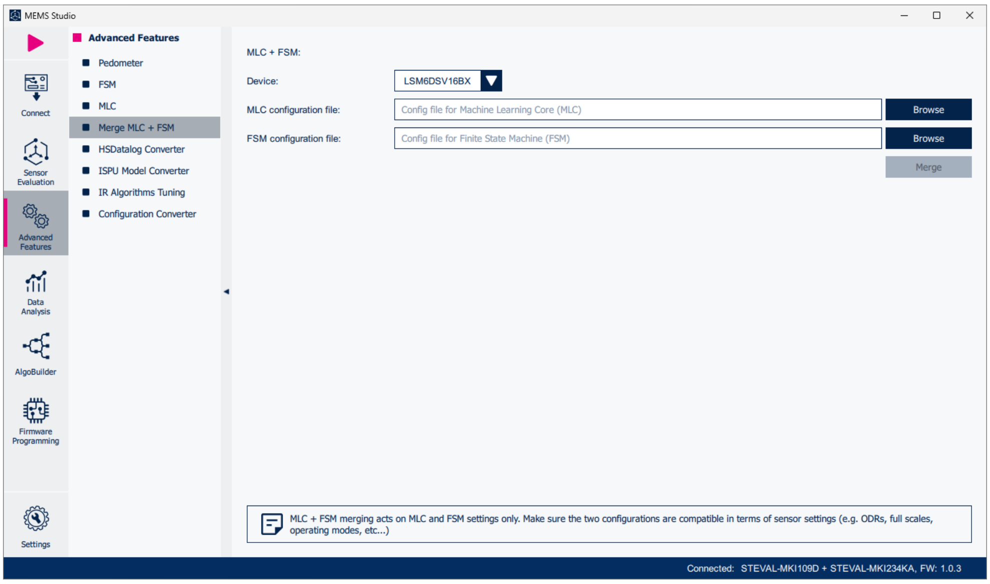
Converted data [g] : 0.4997

5.3 Merge MLC + FSM tool

Merging MLC and FSM configurations requires a special procedure. The [**Merge MLC + FSM**] tool can be used to perform combinations of separate MLC and FSM configuration files into one file.

Note: *The tool acs on the MLC and FSM configuration only. The user must ensure the two configurations are compatible in terms of general sensor configuration like output data rate or full-scale settings.*

Figure 64. Merge MLC + FSM page



MEMS Studio

MLC + FSM:

Device: LSM6DSV16BX

MLC configuration file: Config file for Machine Learning Core (MLC)

FSM configuration file: Config file for Finite State Machine (FSM)

MLC + FSM merging acts on MLC and FSM settings only. Make sure the two configurations are compatible in terms of sensor settings (e.g. ODRs, full scales, operating modes, etc...)

Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.3

5.4 Pedometer

The [**Pedometer**] tool can be used to configure and test the pedometer embedded in the device when this feature is supported by the sensor (see the device datasheet for more details).

There are three different tabs for this tool:

- [**Configuration**] tab: allows fast-configuring the pedometer with its default configuration
- [**Debug**] tab: used to load a data pattern into the device in order to test the pedometer on the pattern loaded
- [**Regression Tool**] tab: allows finding an optimal configuration based on a predefined dataset

*Note: Pedometer [**Configuration**] and [**Debug**] pages are available only on ProfiMEMS board if device with pedometer support is connected.*

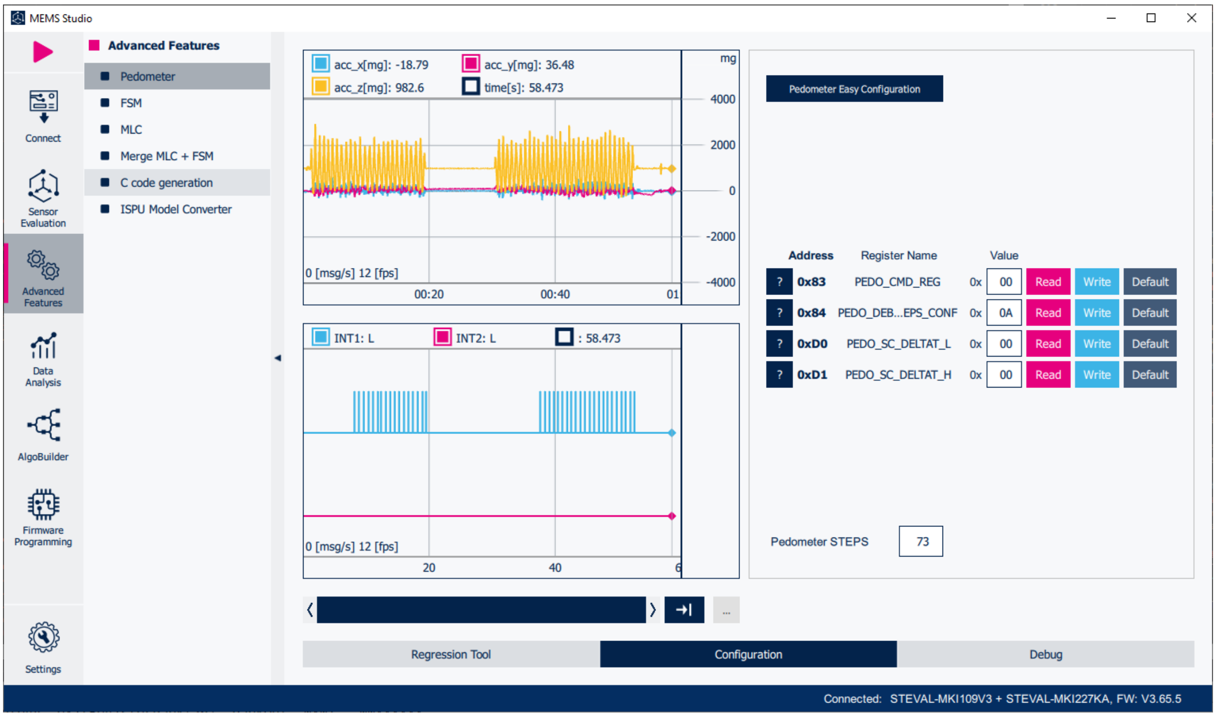
Configuration

The [**Configuration**] tab allows fast-configuring the pedometer. In this window, it is possible to visualize in real time the evolution of both the accelerometer signal and the two interrupt lines and to read the pedometer step count output.

The user can enable and configure the pedometer with its default configuration using a dedicated button.

The GUI also allows directly accessing the pedometer-related registers in order to set a user-defined pedometer configuration.

Figure 65. Configuration tab



	Address	Register Name		Value			
?	0x83	PEDO_CMD_REG	0x	00	Read	Write	Default
?	0x84	PEDO_DEB...EPS_CONF	0x	0A	Read	Write	Default
?	0xD0	PEDO_SC_DELTAT_L	0x	00	Read	Write	Default
?	0xD1	PEDO_SC_DELTAT_H	0x	00	Read	Write	Default

Pedometer STEPS 73

Connected: STEVAL-MKI109V3 + STEVAL-MKI227KA, FW: V3.65.5

Debug

The [**Debug**] tab is used to load a data pattern into the device and run the pedometer logic on the pattern itself (offline postprocessing).

On the right side of the GUI, a three-button toolbar is available for loading a data pattern in the GUI. Pedometer configuration can be loaded from a .ucf or .json file. It is also possible to fast-configure the pedometer in its default configuration by clicking on the [**Pedometer Easy Configuration**] button.

The device enters debug mode right after the data pattern has been loaded.

On the top of the GUI, a toolbar is available to control the data injection, which can be applied with the maximum level of flexibility:

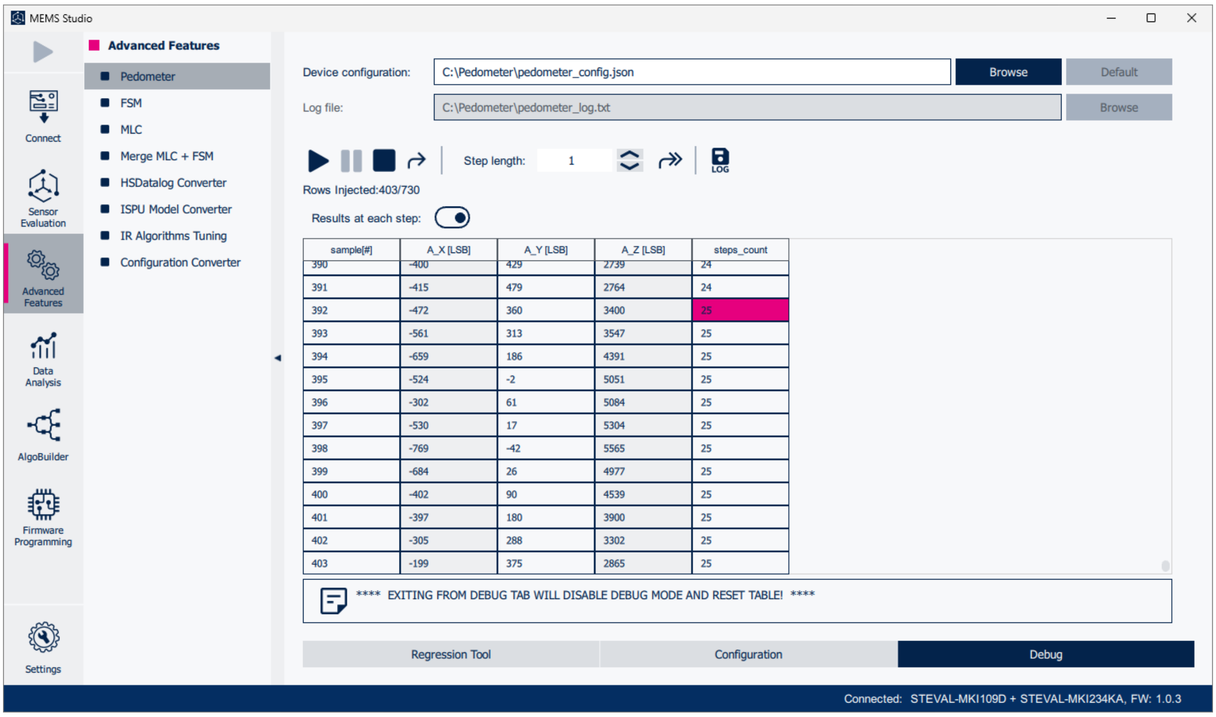
Data injection controls:

- [**Run**]: injects all samples
- [**Pause**]: pauses the data injection process with the possibility to resume it
- [**Stop**]: interrupts the data injection process and exits debug mode
- [**Next**]: injects the next sample and updates the table with the output data
- [**Next step**]: injects a defined number of samples according to the [**Step length**]settings
- [**Export log**]: exports the content of the table with the results to a .csv file

The data table is updated at every step if the [**Results at each step**] switch is enabled, otherwise it is updated only when the data injection is paused or stopped.

Once the debug session is completed, another debug session can be started (the data pattern must be reloaded).

Figure 66. **Debug tab**



Device configuration: C:\Pedometer\pedometer_config.json

Log file: C:\Pedometer\pedometer_log.txt

Step length: 1

Rows Injected:403/730

Results at each step: ●

sample[#]	A_X [LSB]	A_Y [LSB]	A_Z [LSB]	steps_count
390	-400	429	2739	24
391	-415	479	2764	24
392	-472	360	3400	25
393	-561	313	3547	25
394	-659	186	4391	25
395	-524	-2	5051	25
396	-302	61	5084	25
397	-530	17	5304	25
398	-769	-42	5565	25
399	-684	26	4977	25
400	-402	90	4539	25
401	-397	180	3900	25
402	-305	288	3302	25
403	-199	375	2865	25

**** EXITING FROM DEBUG TAB WILL DISABLE DEBUG MODE AND RESET TABLE! ****

Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.3

Regression Tool

The [**Regression Tool**] tab allows finding an optimal configuration on the basis of a predefined dataset (in this context, a dataset is a collection of data patterns with a reference number of steps for each pattern).

On the right side of the GUI, the initialization view contains the two initialization parameters:

- [**Error type**]: the error to be minimized by the tool (that is, mean, mean plus standard deviation, mean plus two times the standard deviation)
- [**Complexity level**]: the level of depth (in terms of iterations) of the regression. The execution time of a low-complexity level regression is lower than a high-complexity level, but the parameter space is less deeply explored.

At the top of the GUI, the run view contains the textbox for the input data path and the output file path.

Using dedicated [**Start**] and [**Stop**] buttons, the user can run the regression. A progress bar is available in order to notify the user about the progress of the regression.

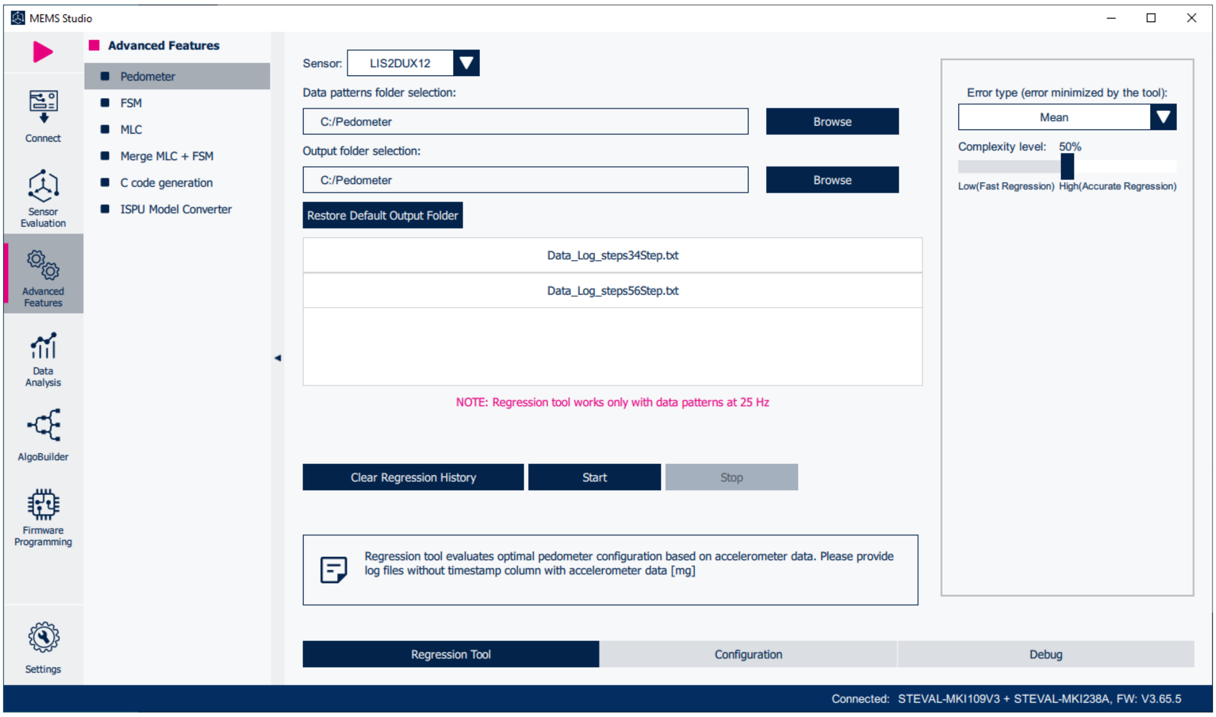
Note: The input data path to be specified in the textbox must be a folder containing only the pedometer data patterns to be applied to the regression session. Each file must contain accelerometer data in a tab or space-separated format in [mg] and collected at the proper output data rate according to the pedometer description in the datasheet. Each filename must contain the 'stepsXXX' string, where XXX is the effective reference number of steps (that is, test001_steps100.txt, data_steps54.txt, pattern_steps1043.txt).

Once the regression has been completed, the tool generates a folder under the output folder, named [data]_[hour]_Pedometer, containing two files:

- pedometer.ucf, containing the optimal pedometer configuration generated by the tool
- regression_tool.config, containing some metainformation used by the [**Regression Tool**] itself and statistical data about the pedometer performance on the input dataset

Under the output folder, another regression_tool.config file is generated. This file is automatically used by the [**Regression Tool**] in order to start a new regression analysis from the optimal configuration found in the latest regression executed. If the user's intention is to run a new regression from scratch (starting from the default pedometer configuration), the user should click on the [**Clear Regression History**] button.

Figure 67. **Regression Tool tab**



Sensor: LIS2DUX12

Data patterns folder selection: C:/Pedometer

Output folder selection: C:/Pedometer

Data_Log_steps34Step.txt
Data_Log_steps56Step.txt

NOTE: Regression tool works only with data patterns at 25 Hz

Regression tool evaluates optimal pedometer configuration based on accelerometer data. Please provide log files without timestamp column with accelerometer data [mg]

Error type (error minimized by the tool): Mean

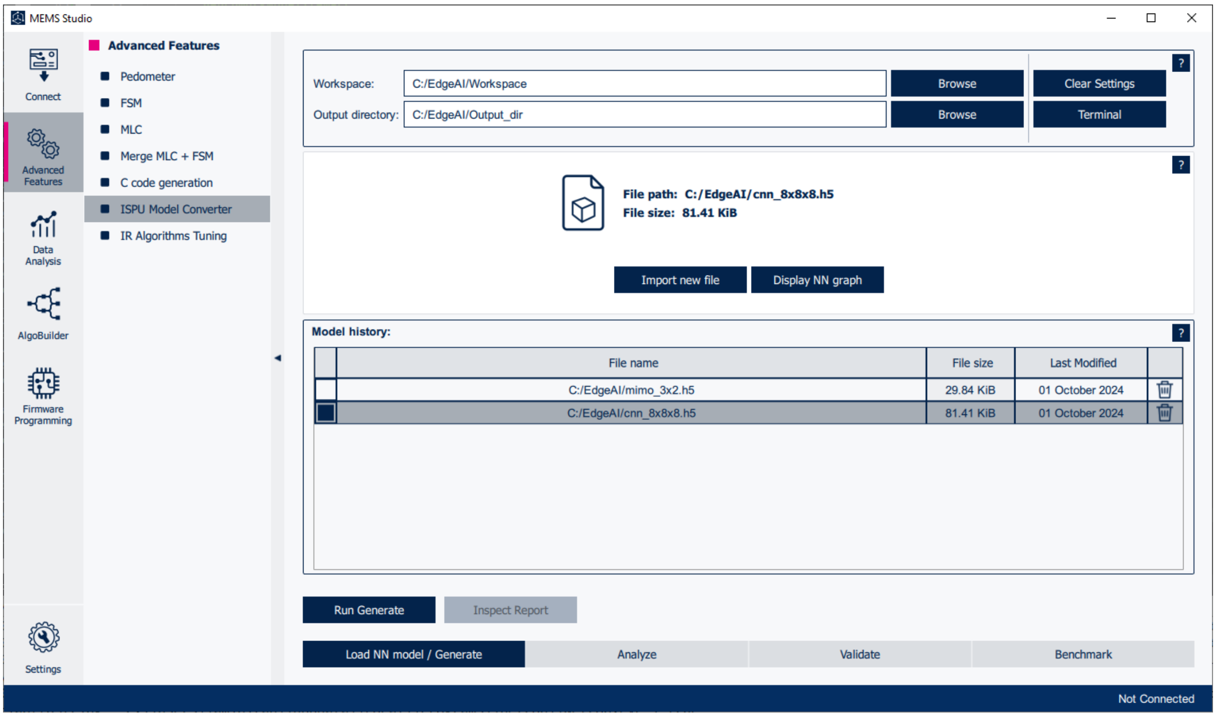
Complexity level: 50%

Connected: STEVAL-MKI109V3 + STEVAL-MKI238A, FW: V3.65.5

5.5 ISPU Model Converter

The [**ISPU Model Converter**] page allows importing pretrained neural network (NN) models from popular ML frameworks. Users can analyze these models in detail, optimize and convert them to .c / .h files, and finally validate the converted model (on the host PC or target using dedicated firmware).

The mentioned .c / .h files might then be included in a custom project (template available in the ISPU GitHub repository in order to build a binary to run the neural network on the ISPU-equipped sensor.



Workspace: C:/EdgeAI/Workspace
Output directory: C:/EdgeAI/Output_dir

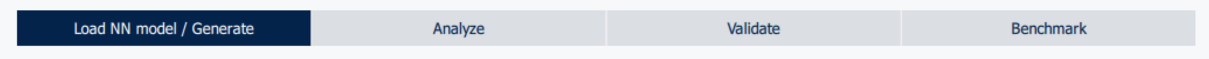
File path: C:/EdgeAI/cnn_8x8x8.h5
File size: 81.41 KiB

Model history:

	File name	File size	Last Modified	
□	C:/EdgeAI/mimo_3x2.h5	29.84 KiB	01 October 2024	🗑
■	C:/EdgeAI/cnn_8x8x8.h5	81.41 KiB	01 October 2024	🗑

Figure 68. **ISPU Model Converter page**

There are four different tabs for this tool:



- [**Load NN Model / Generate**]: loads the pretrained neural network model in the application, generates the .c / .h files and a "Generate" textual report related to the NN model conversion process
- [**Analyze**]: provides information about the NN model architecture, its memory footprint, and computational complexity. It also generates an “Analyze” textual report from the NN model and represents data in table and radar charts.
- [**Validate**]: runs the original and the converted models and compares the results. It also generates a “Validate” textual report from the NN model and represents a summary of data in table, radar chart, and confusion matrix, if applicable.
- [**Benchmark**]: allows the user to compare different model results by numerical parameters and graphical representation using radar charts

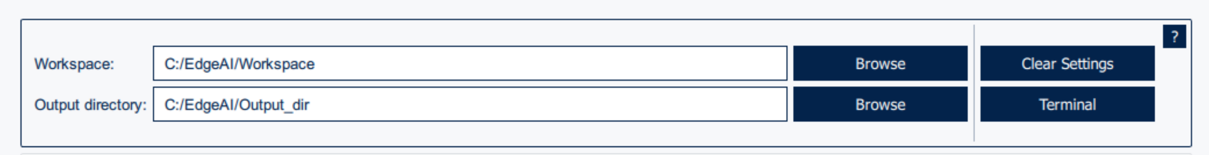
Load NN Model / Generate page

To start configuring the ISPU Model Converter, the Workspace directory and the Output directory must be selected using the corresponding [**Browse**] buttons.

All GUI settings set during neural network processing can be restored to the default values by clicking on the [**Clear Settings**] button.

By clicking on the [**Terminal**] button, accessible from all pages, the user is able to inspect additional information related to the execution of commands requested in the available pages.

Figure 69. **ISPU Model converter configuration bar**

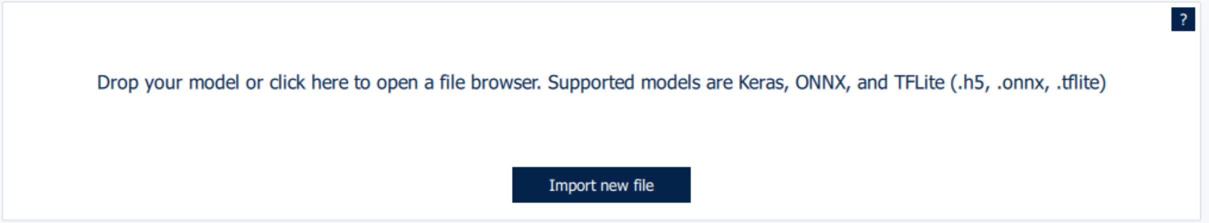


Workspace: C:/EdgeAI/Workspace

Output directory: C:/EdgeAI/Output_dir

A drag and drop box allows importing NN files with supported formats such as Keras, ONNX, and TFLite (.h5, .onnx, .tflite).

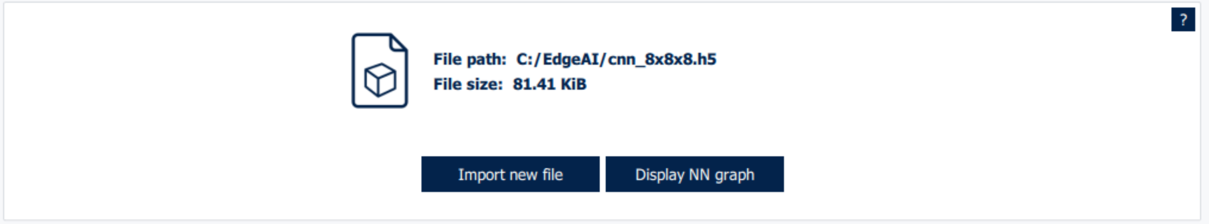
Figure 70. **ISPU Model converter drop area**



Drop your model or click here to open a file browser. Supported models are Keras, ONNX, and TFLite (.h5, .onnx, .tflite)

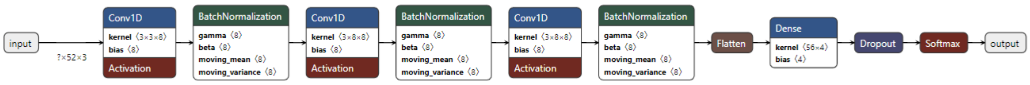
By clicking on the [**Display NN graph**] button, the user is able to see visual graph of the chosen neural network model. To be able to access this function, the user needs to install the Netron application on the device and add it to the MEMS Studio tool path in the “External Tools” page.

Figure 71. **Selected file options view**

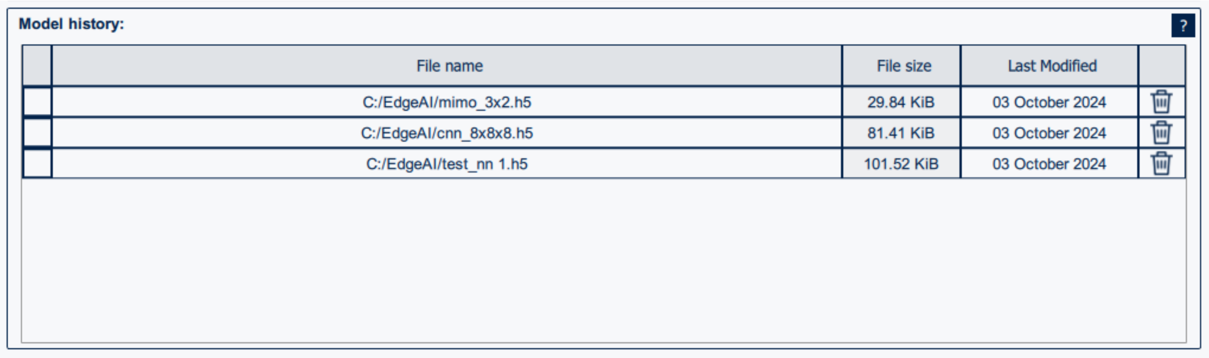


File path: C:/EdgeAI/cnn_8x8x8.h5
File size: 81.41 KiB

Figure 72. **Neural network graph**



The [**Model history**] section stores files previously uploaded by the user, displaying their directory path and the date of upload. Users can reselect files if they still exist in the same directory by clicking the [**Select**] button or delete them from the list by clicking on [**Delete**]. Deleting a file from the history only removes it from the graphical view, not from the container directory.



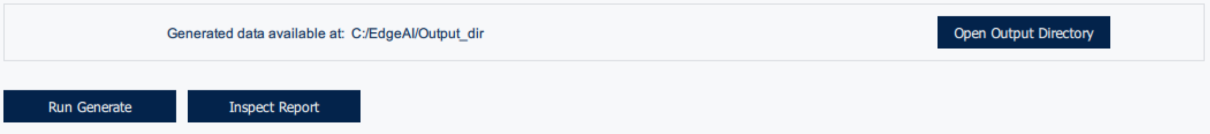
Model history:

	File name	File size	Last Modified	
□	C:/EdgeAI/mimo_3x2.h5	29.84 KiB	03 October 2024	🗑
□	C:/EdgeAI/cnn_8x8x8.h5	81.41 KiB	03 October 2024	🗑
□	C:/EdgeAI/test_nn 1.h5	101.52 KiB	03 October 2024	🗑

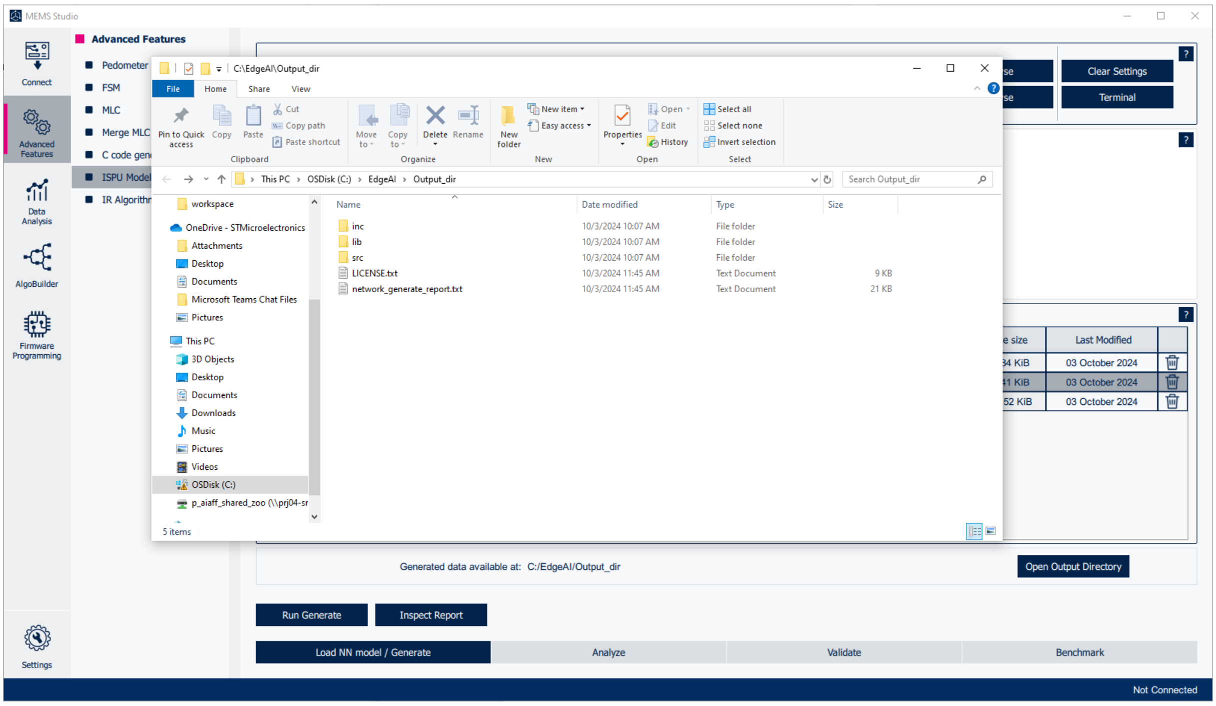
Figure 73. Loaded model history list

Once the workspace directory, output directory, and file to process are set, the [**Run Generate**] button becomes active. Users are able to start the generation of reports, .c and .h files by clicking on this button. Once the process is completed, the [**Inspect Report**] button becomes active, allowing users to view the textual report generated.

An additional button [**Open Output Directory**] is shown to navigate to the output directory.



Generated data available at: C:/EdgeAI/Output_dir



C:\EdgeAI\Output_dir

Name	Date modified	Type	Size
inc	10/3/2024 10:07 AM	File folder	
lib	10/3/2024 10:07 AM	File folder	
src	10/3/2024 10:07 AM	File folder	
LICENSE.txt	10/3/2024 11:45 AM	Text Document	9 KB
network_generate_report.txt	10/3/2024 11:45 AM	Text Document	21 KB

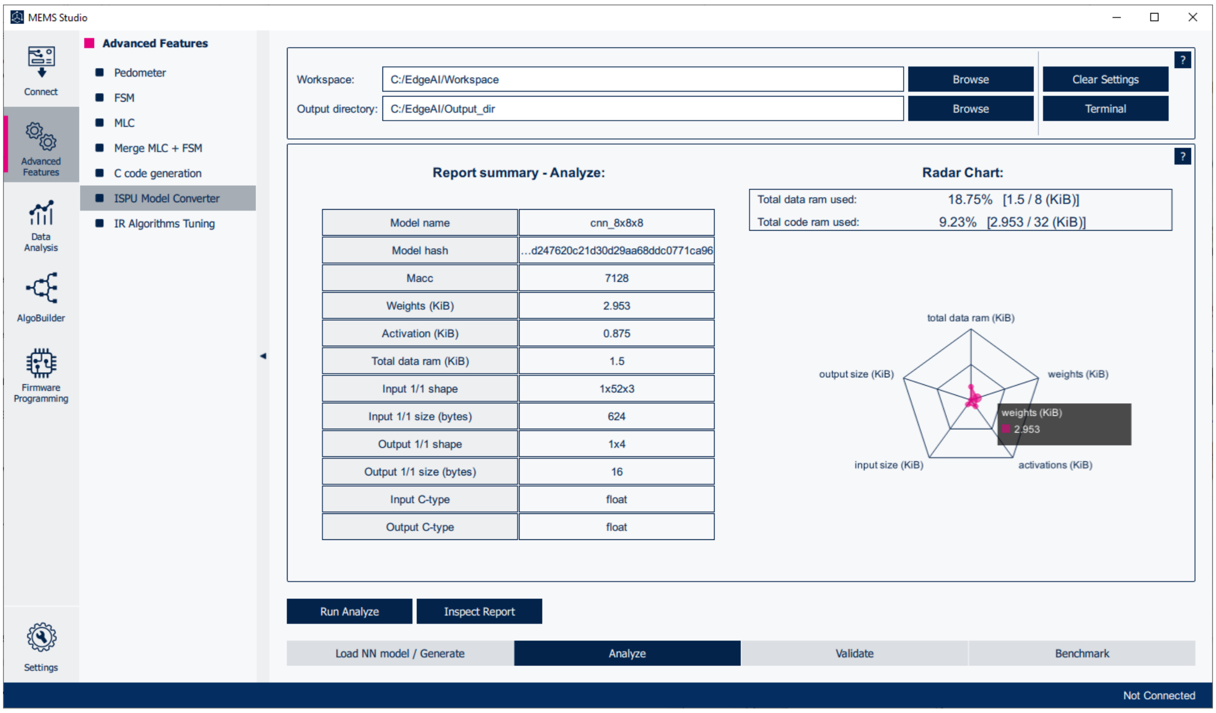
5 items

Generated data available at: C:/EdgeAI/Output_dir

Figure 74. Output directory

Analyze page

Figure 75. Analyze page



Workspace: C:/EdgeAI/Workspace

Output directory: C:/EdgeAI/Output_dir

Report summary - Analyze:

Model name	cnn_8x8x8
Model hash	...d247620c21d30d29aa68ddc0771ca96
Macc	7128
Weights (KiB)	2.953
Activation (KiB)	0.875
Total data ram (KiB)	1.5
Input 1/1 shape	1x52x3
Input 1/1 size (bytes)	624
Output 1/1 shape	1x4
Output 1/1 size (bytes)	16
Input C-type	float
Output C-type	float

Radar Chart:

Total data ram used:	18.75% [1.5 / 8 (KiB)]
Total code ram used:	9.23% [2.953 / 32 (KiB)]

Once the workspace directory, output directory, and file to process are set, the [**Run Analyze**] button becomes active and the user is able to start the analysis of the neural network model. Once the process is completed, the [**Inspect Report**] button becomes active, allowing users to view the textual report generated.

Users can view a summary of the report with the following data representation:

- **Table**: displays structured data extracted from the Analyze report, providing a detailed overview of key information
- **Radar Chart**: shows data metrics in a radar chart format, offering a graphical representation of different parameters.

Note: *All the parameters in the radar chart are normalized in order to present data in a range [0, 1]. They are not in the same scale, so, to be able to show them in a radar chart, they are normalized according to their maximum value.*

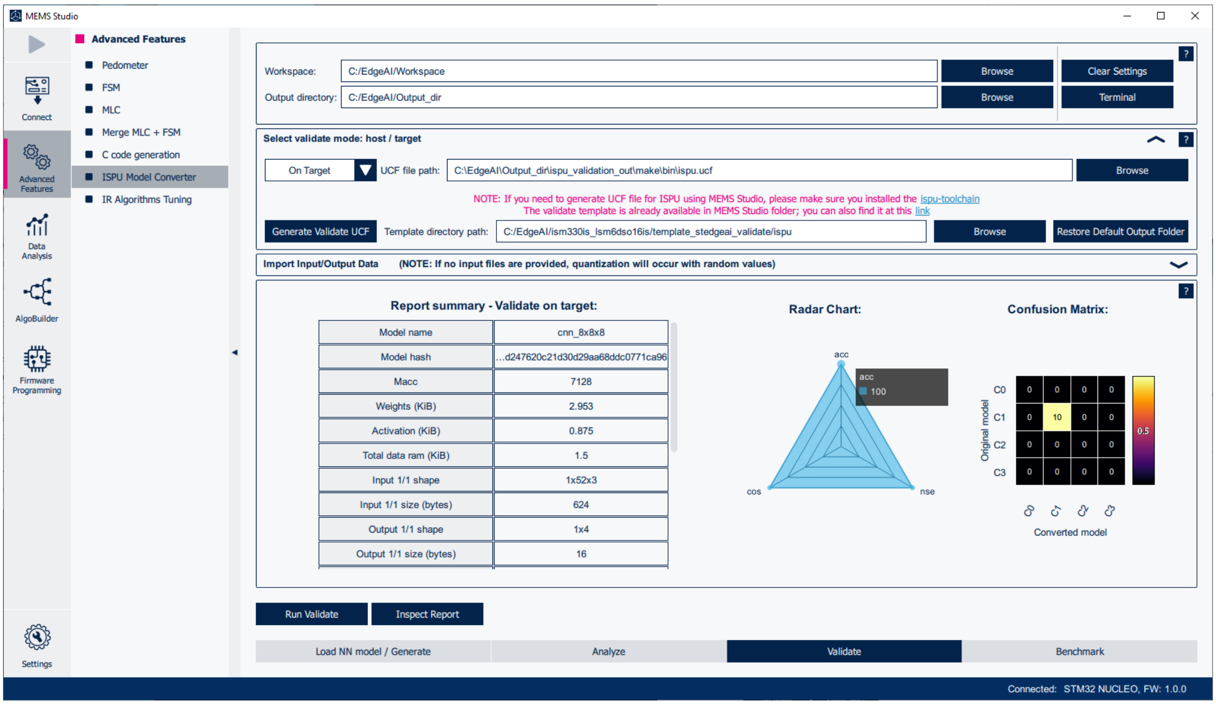
Considering (as an example) the LSM6DSO16IS sensor, the list of maximum values for radar chart parameters is as follows:

- Total data ram: 8 KiB (activation + input + output size)
- Activation: 8 KiB
- Input: 8 KiB
- Output: 8 KiB
- Total code ram: 32 KiB (weight + code)
- Weight: 32 KiB

The percentage of total ram used by the model is divided into two parts: data ram (8 KiB), which is the sum of activation, input and output size, and code ram (32 KiB), which includes code size and weight size.

Validate page

Figure 76. Validate page



Workspace: C:/EdgeAI/Workspace

Output directory: C:/EdgeAI/Output_dir

Select validate mode: host / target

On Target

UCF file path: C:\EdgeAI\Output_dir\ispu_validation_out\make\bin\ispu.ucf

NOTE: If you need to generate UCF file for ISPU using MEMS Studio, please make sure you installed the ispu-toolchain
The validate template is already available in MEMS Studio folder; you can also find it at this link

Template directory path: C:/EdgeAI/ism330is_lsm6dso16is/template_stedgeai_validate/ispu

Import Input/Output Data (NOTE: If no input files are provided, quantization will occur with random values)

Report summary - Validate on target:

Model name	cnn_8x8x8
Model hash	...d247620c21d30d29aa68ddc0771ca96
Macc	7128
Weights (KiB)	2.953
Activation (KiB)	0.875
Total data ram (KiB)	1.5
Input 1/1 shape	1x52x3
Input 1/1 size (bytes)	624
Output 1/1 shape	1x4
Output 1/1 size (bytes)	16

	C0	C1	C2	C3
C0	0	0	0	0
C1	0	10	0	0
C2	0	0	0	0
C3	0	0	0	0

Connected: STM32 NUCLEO, FW: 1.0.0

On the Validate page, the user is able to run the original and converted models and compare the results by clicking on the [**Run Validate**] button. The converted model runs on the host PC and on the Target by connecting the sensor and choosing the mode to run [**On Host/ On Target**]. Once the process is completed, the [**Inspect Report**] button becomes active, allowing users to view the textual report generated. The processed data results are available in three different representations:

- **Table**: displays real values extracted from the Validate report, providing detailed information about various neural network metrics and parameters
- **Radar Chart**: displays normalized values in a radar chart format, offering a graphical representation of the key parameter.

Note: *All the parameters in the radar chart are normalized in order to present data in a range [0, 1]. They are not on the same scale, so, to be able to show them in a radar chart, they are normalized according to their maximum value.*

The maximum scale for each parameter is:

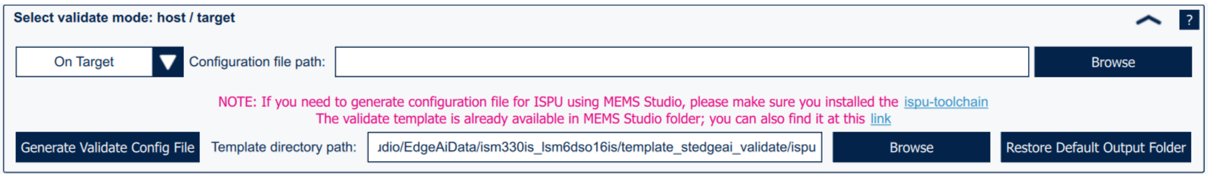
- Classification accuracy: 100 percent
- Cosine: 1
- Nash-Sutcliffe efficiency: 1

Converter models have more similar results to the original model if the parameters are close to the maximum.

- **Confusion Matrix**: if available in the report, displays the performance of a classification model, showing true positive, true negative, false positive, and false negative values, assuming the original model as the reference
- **Select the output**: this combo box appears if the model contains multiple outputs, then the user is able see the result in a table based on the selected output

To be able to "Run Validate" on the Target, after selecting the mode [**On Target**], the user needs to import the UCF file. In order to generate the ISPU UCF file using MEMS Studio, the ISPU-toolchain path should be set in the “External Tools” page and a valid validation template should be selected. MEMS Studio embeds a template and link to download it. Once the [**Generate Validate UCF**] request is completed, a new .ucf file is created in the output directory in the subdirectory *ispu_validation_out /make/bin/ispu.ucf*

Figure 77. **Validate options bar**



Select validate mode: host / target

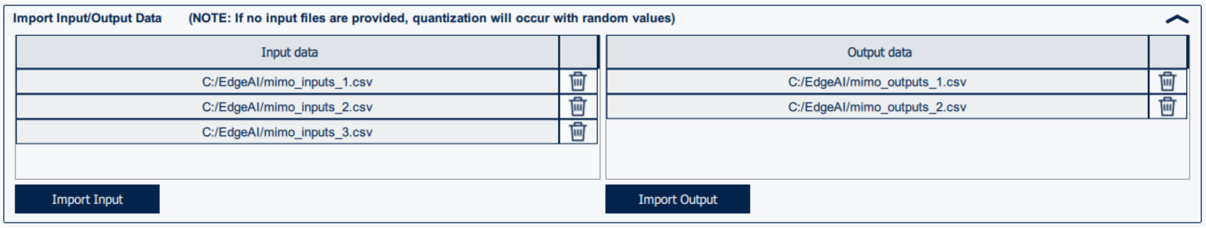
On Target ▼ Configuration file path:

NOTE: If you need to generate configuration file for ISPU using MEMS Studio, please make sure you installed the ispu-toolchain
The validate template is already available in MEMS Studio folder; you can also find it at this link

Template directory path: ıdio/EdgeAiData/ism330is_lsm6dso16is/template_stedgeai_validate/ispu

By default, the validation of the selected neural network is executed using random data. The user can select custom input and output to quantize using custom data.

Figure 78. **Validate input/output selection bar**



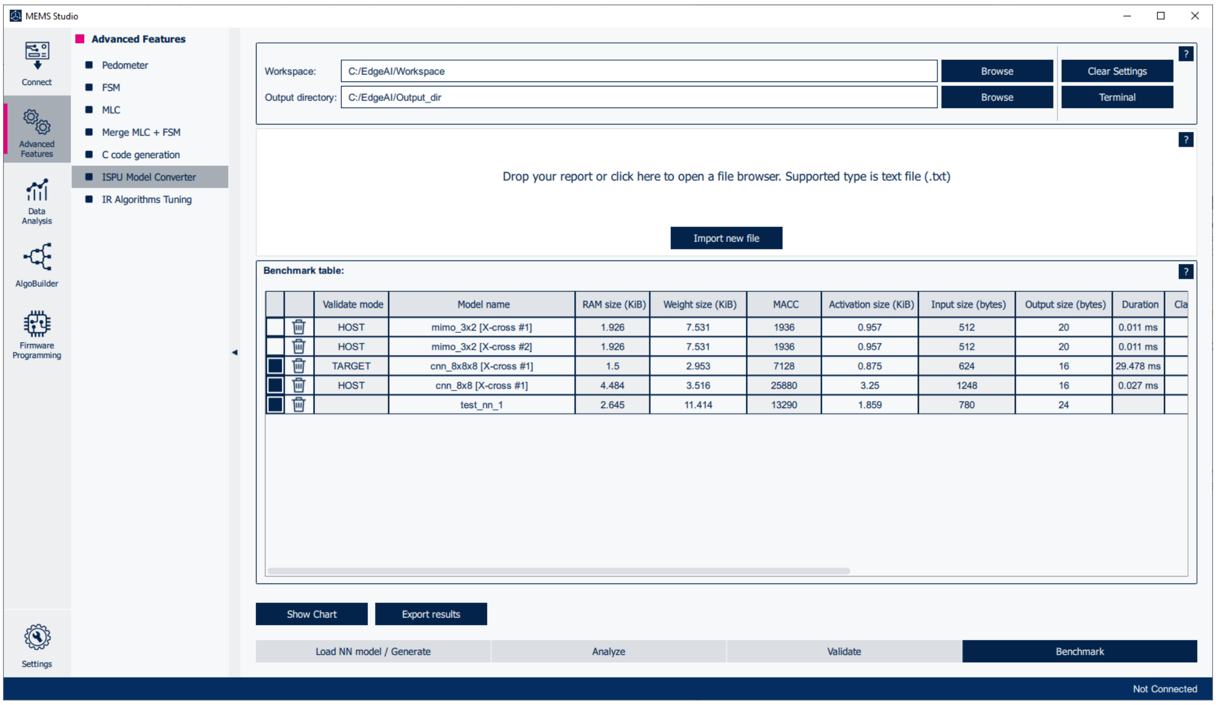
Import Input/Output Data (NOTE: If no input files are provided, quantization will occur with random values)

Input data	
C:/EdgeAI/mimo_inputs_1.csv	🗑
C:/EdgeAI/mimo_inputs_2.csv	🗑
C:/EdgeAI/mimo_inputs_3.csv	🗑

Output data	
C:/EdgeAI/mimo_outputs_1.csv	🗑
C:/EdgeAI/mimo_outputs_2.csv	🗑

Benchmark page

Figure 79. Benchmark page



Workspace: C:/EdgeAI/Workspace

Output directory: C:/EdgeAI/Output_dir

Drop your report or click here to open a file browser. Supported type is text file (.txt)

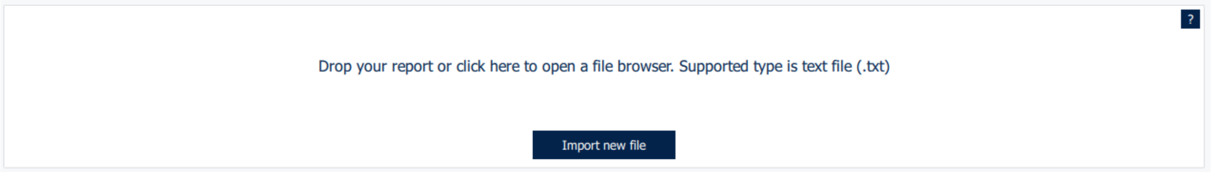
Benchmark table:

		Validate mode	Model name	RAM size (KiB)	Weight size (KiB)	MACC	Activation size (KiB)	Input size (bytes)	Output size (bytes)	Duration	Cla
□	🗑	HOST	mimo_3x2 [X-cross #1]	1.926	7.531	1936	0.957	512	20	0.011 ms	
□	🗑	HOST	mimo_3x2 [X-cross #2]	1.926	7.531	1936	0.957	512	20	0.011 ms	
■	🗑	TARGET	cnn_8x8x8 [X-cross #1]	1.5	2.953	7128	0.875	624	16	29.478 ms	
■	🗑	HOST	cnn_8x8 [X-cross #1]	4.484	3.516	25880	3.25	1248	16	0.027 ms	
■	🗑		test_nn_1	2.645	11.414	13290	1.859	780	24		

On the Benchmark page, the user can compare different neural network models through numerical and visual results. This functionality allows for the comparison of the same model in different validation modes (On Host / On Target).

A drag and drop box allows importing neural network report files with the supported format as text (.txt).

Figure 80. Benchmark drop area

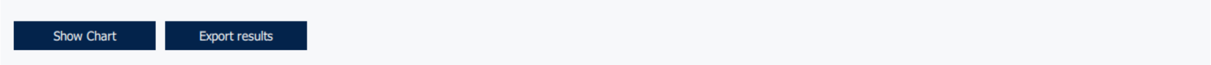


Drop your report or click here to open a file browser. Supported type is text file (.txt)

By clicking on the [**Export results**] button, the user is able to extract the results of the entire benchmark table as a .csv file.

By clicking on the [**Show Chart**] button, the user is able to see multiple layers and compare the parameter visually.

Figure 81. Benchmark result options



The radar chart viewer displays normalized values in a radar chart format, offering a graphical representation of the key parameter in multiple layers of the selected model.

Note: *All the parameters in the radar chart are normalized in order to present data in a range [0, 1]. They are not on the same scale, so, to be able to show them in a radar chart, they are normalized according to their maximum value.*

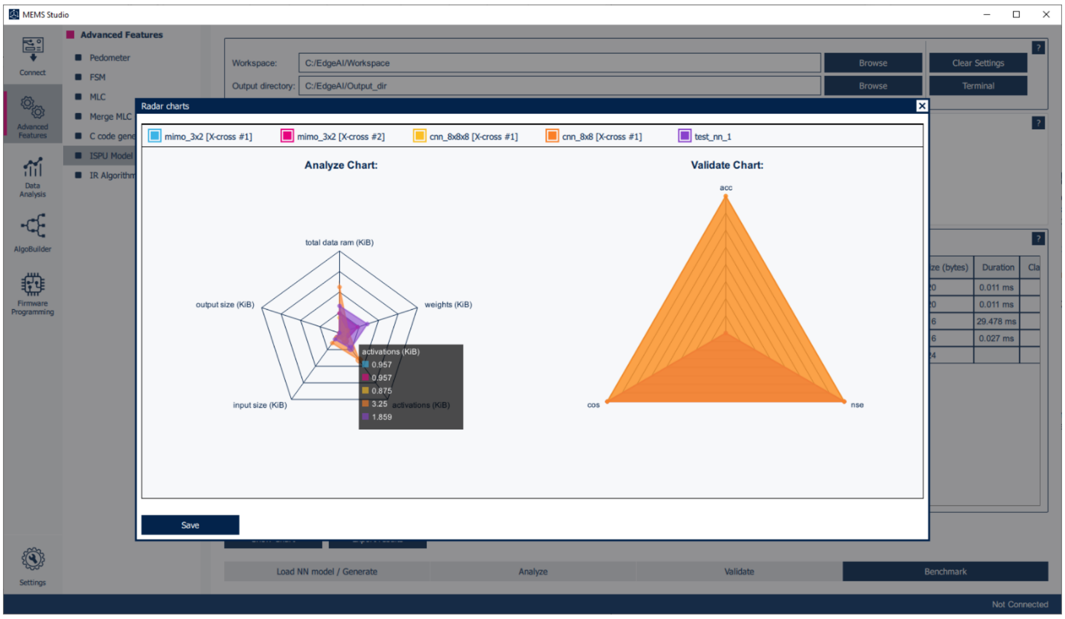
The maximum scale for each parameter is:

- Classification accuracy: 100 percent
- Cosine: 1
- Nash-Sutcliffe efficiency: 1
- Total data ram: 8 KiB (activation + input + output size)
- Activation: 8 KiB
- Input: 8 KiB
- Output: 8 KiB
- Total code ram: 32 KiB (weight + code)
- Weight: 32 KiB

The converter models have more similar results to the original model if the parameters are close to the maximum.

By clicking on the [**Save**] button, the user is able to store the chart viewer results as a .png file.

Figure 82. **Benchmark result charts**



Workspace: C:/EdgeAI/Workspace

Output directory: C:/EdgeAI/Output_dir

5.6 IR Algorithms Tuning

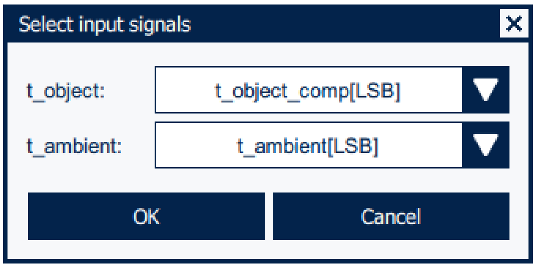
The [**IR Algorithms Tuning**] tool is designed to fine-tune infrared sensor settings to accurately detect presence, motion, and ambient shock.

The tool is divided in four tabs. The first tab is for presence detection, the second for motion detection, the third one for ambient shock detection, and the fourth for sequential processing of multiple files.

To begin using the tool, you need to load previously acquired data. Follow these steps:

1. Click on the [**Browse**] button.
2. Select the file containing the data.
3. Choose the columns corresponding to `t_object` and `t_ambient` data.
4. The data is displayed in charts for further analysis.

Figure 83. **Columns selection**



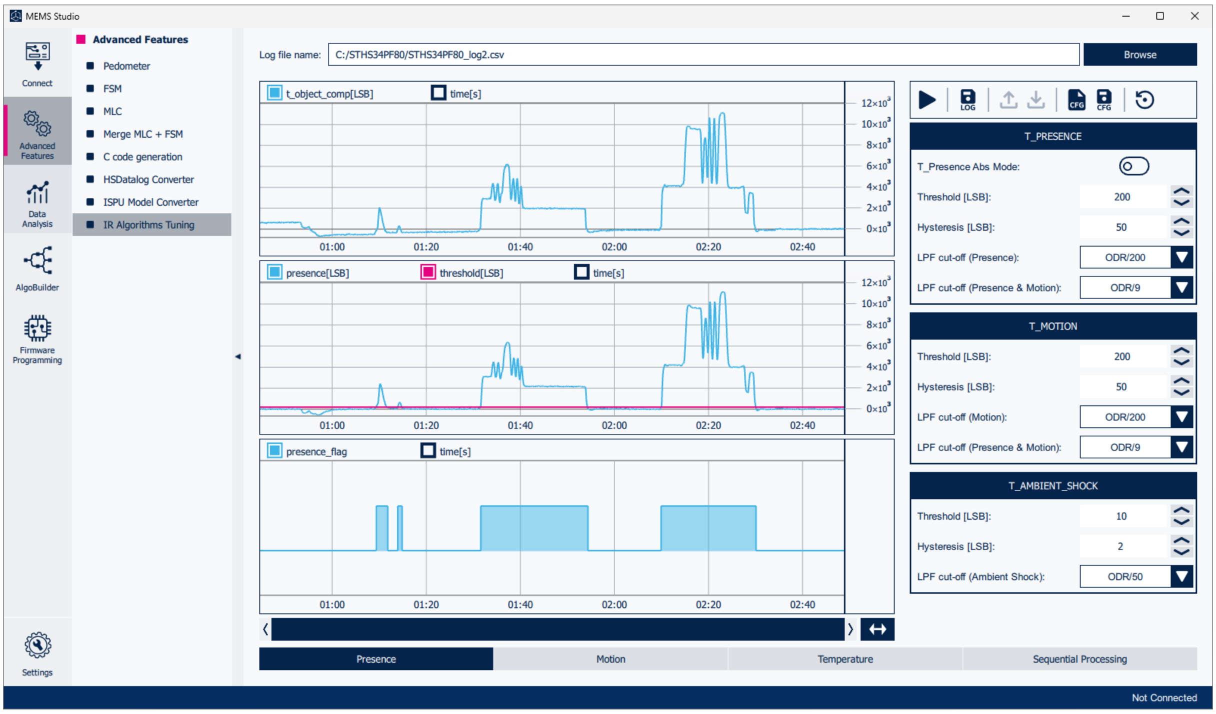
t_object: t_object_comp[LSB]

t_ambient: t_ambient[LSB]

In the Presence Detection section, you can configure the following parameters:

- [**T_Presence Abs Mode**]: enables or disables absolute mode.
- [**Threshold [LBS]**]: sets the threshold value for presence detection.
- [**Hysteresis [LBS]**]: sets the hysteresis value for presence detection.
- [**LPF cut-off (Presence)**]: sets the cutoff frequency for the low-pass filter specific to presence detection.
- [**LPF cut-off (Presence & Motion)**]: sets the cutoff frequency for the low-pass filter that applies to both presence and motion detection.

Figure 84. **Presence detection**



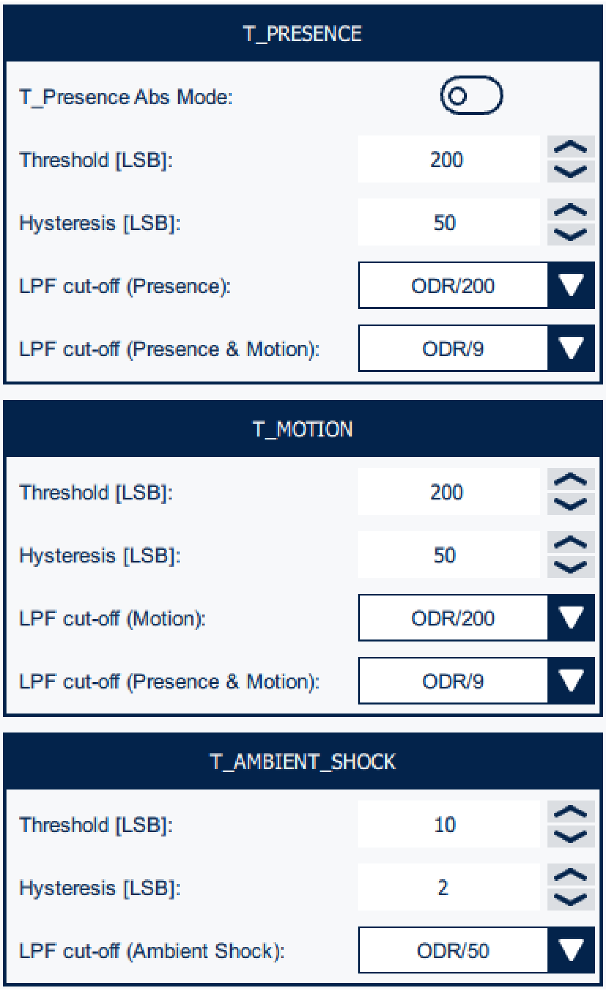
Log file name: C:/STHS34PF80/STHS34PF80_log2.csv

T_PRESENCE
T_Presence Abs Mode: ○
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Presence): ODR/200
LPF cut-off (Presence & Motion): ODR/9

T_MOTION
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Motion): ODR/200
LPF cut-off (Presence & Motion): ODR/9

T_AMBIENT_SHOCK
Threshold [LSB]: 10
Hysteresis [LSB]: 2
LPF cut-off (Ambient Shock): ODR/50

Figure 85. **Sensor parameter settings**



T_PRESENCE

T_Presence Abs Mode: ○

Threshold [LSB]: 200

Hysteresis [LSB]: 50

LPF cut-off (Presence): ODR/200

LPF cut-off (Presence & Motion): ODR/9

T_MOTION

Threshold [LSB]: 200

Hysteresis [LSB]: 50

LPF cut-off (Motion): ODR/200

LPF cut-off (Presence & Motion): ODR/9

T_AMBIENT_SHOCK

Threshold [LSB]: 10

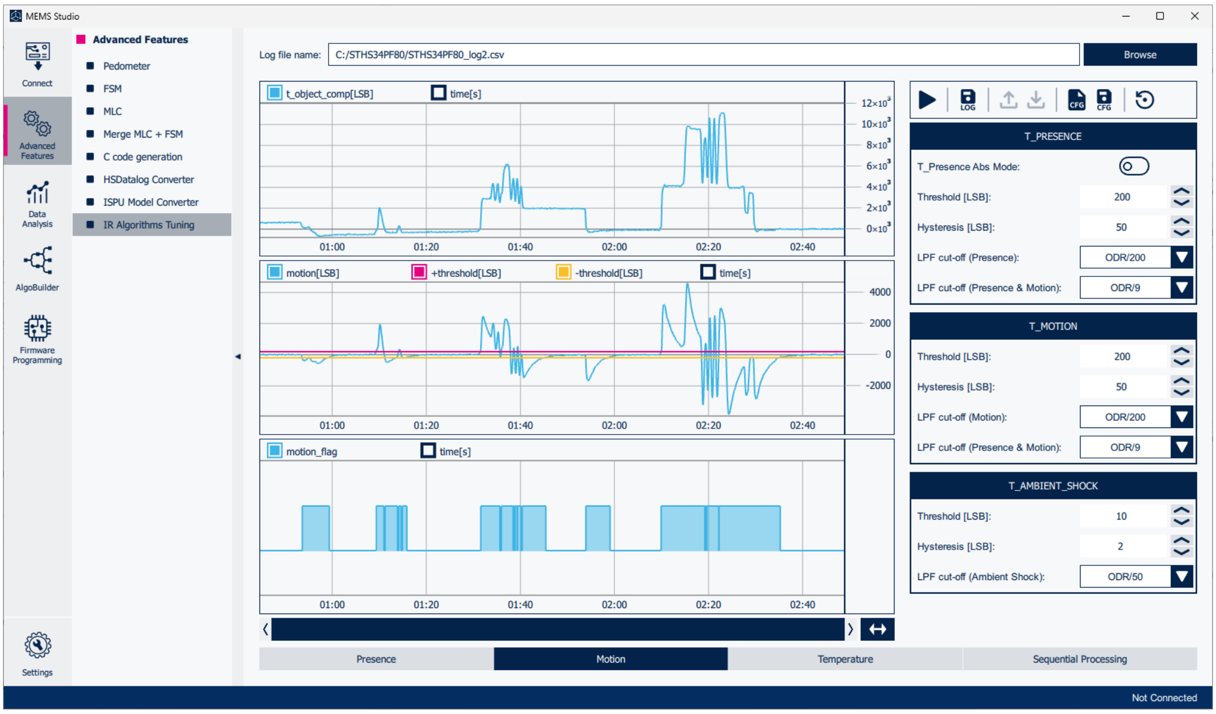
Hysteresis [LSB]: 2

LPF cut-off (Ambient Shock): ODR/50

In the Motion Detection section, you can configure the following parameters:

- [**Threshold [LBS]**]: sets the threshold value for motion detection.
- [**Hysteresis [LBS]**]: sets the hysteresis value for motion detection.
- [**LPF cut-off (Motion)**]: sets the cutoff frequency for the low-pass filter specific to motion detection.
- [**LPF cut-off (Presence & Motion)**]: sets the cutoff frequency for the low-pass filter that applies to both presence and motion detection.

Figure 86. Motion detection



Log file name: C:/STHS34PF80/STHS34PF80_log2.csv

T_PRESENCE
T_Presence Abs Mode: ○
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Presence): ODR/200
LPF cut-off (Presence & Motion): ODR/9

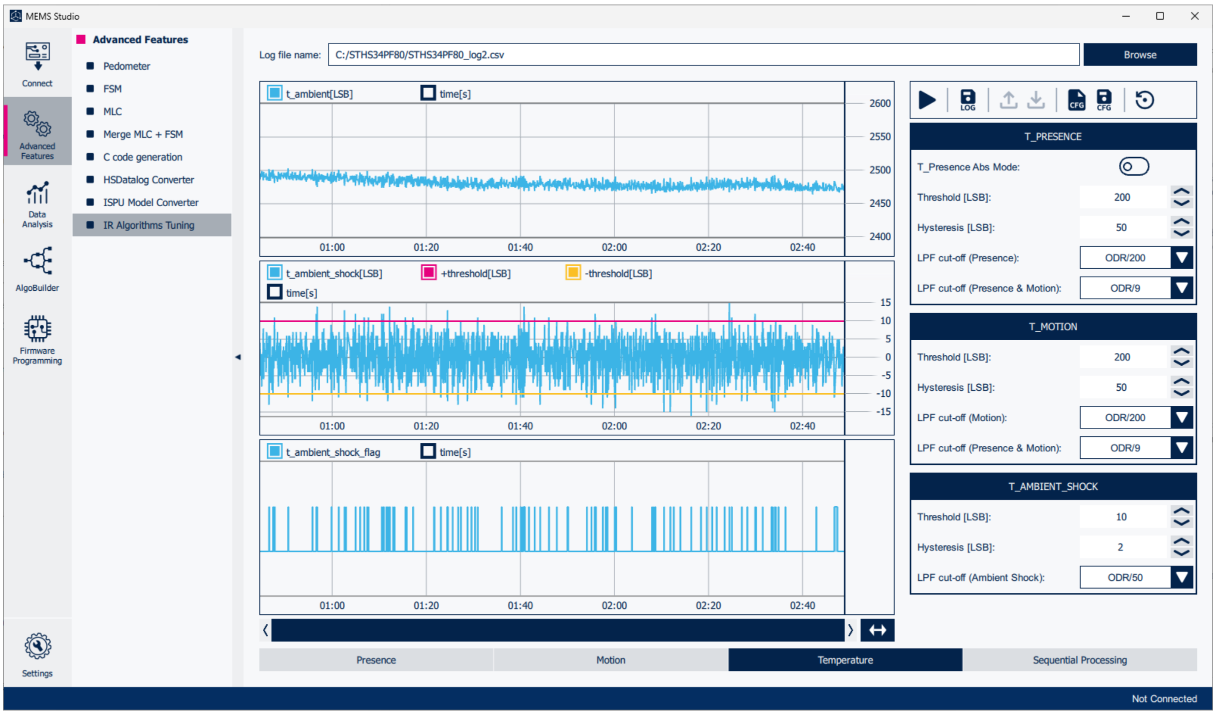
T_MOTION
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Motion): ODR/200
LPF cut-off (Presence & Motion): ODR/9

T_AMBIENT_SHOCK
Threshold [LSB]: 10
Hysteresis [LSB]: 2
LPF cut-off (Ambient Shock): ODR/50

In the Ambient Shock Detection section, you can configure the following parameters:

- [**Threshold [LBS]**]: sets the threshold value for ambient shock detection.
- [**Hysteresis [LBS]**]: sets the hysteresis value to prevent false detections.
- [**LPF cut-off (Motion)**]: sets the cutoff frequency for the low-pass filter specific to motion detection.
- [**LPF cut-off (Ambient Shock)**]: sets the cutoff frequency for the low-pass filter specific to ambient shock detection.

Figure 87. Ambient temperature shock detection



Log file name: C:/STHS34PF80/STHS34PF80_log2.csv

T_PRESENCE
T_Presence Abs Mode: ○
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Presence): ODR/200
LPF cut-off (Presence & Motion): ODR/9

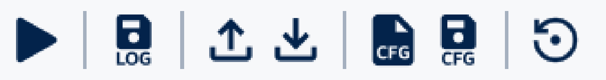
T_MOTION
Threshold [LSB]: 200
Hysteresis [LSB]: 50
LPF cut-off (Motion): ODR/200
LPF cut-off (Presence & Motion): ODR/9

T_AMBIENT_SHOCK
Threshold [LSB]: 10
Hysteresis [LSB]: 2
LPF cut-off (Ambient Shock): ODR/50

The toolbar provides several essential functions for managing your configurations and simulations:

- [**Run processing**]: executes the simulation based on the current settings.
- [**Save log**]: saves the results of the simulation to a file.
- [**Read configuration from sensor**]: loads the current configuration settings from the sensor.
- [**Write configuration from sensor**]: writes the current configuration settings to the sensor.
- [**Load configuration from file**]: reads the configuration settings from a file.
- [**Save configuration from file**]: writes the current configuration settings to a file.
- [**Restore defaults**]: resets all settings to their default values.

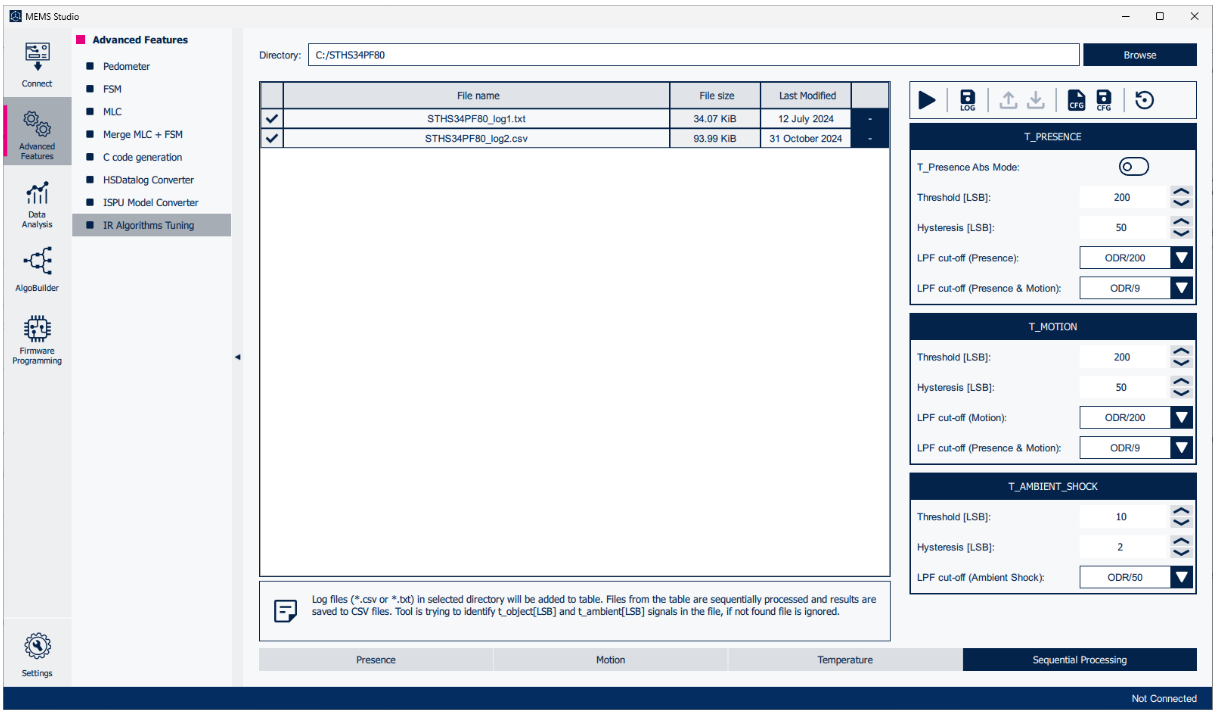
Figure 88. **IR Algorithms Tool toolbar**



The Sequential Processing tab is designed to process multiple files sequentially. Follow these steps:

1. Click on the [**Browse**] button.
2. Select a folder containing the files to be processed.
3. The tool processes each file one by one.
4. The results are saved to the respective files.

Figure 89. **Sequential Processing**



Directory: C:/STHS34PF80

	File name	File size	Last Modified	
✓	STHS34PF80_log1.txt	34.07 KiB	12 July 2024	-
✓	STHS34PF80_log2.csv	93.99 KiB	31 October 2024	-

T_PRESENCE

T_Presence Abs Mode: ○

Threshold [LSB]: 200

Hysteresis [LSB]: 50

LPF cut-off (Presence): ODR/200

LPF cut-off (Presence & Motion): ODR/9

T_MOTION

Threshold [LSB]: 200

Hysteresis [LSB]: 50

LPF cut-off (Motion): ODR/200

LPF cut-off (Presence & Motion): ODR/9

T_AMBIENT_SHOCK

Threshold [LSB]: 10

Hysteresis [LSB]: 2

LPF cut-off (Ambient Shock): ODR/50

Log files (*.csv or *.txt) in selected directory will be added to table. Files from the table are sequentially processed and results are saved to CSV files. Tool is trying to identify t_object[LSB] and t_ambient[LSB] signals in the file, if not found file is ignored.

Note: *The sequential processing expects `t_object[LSB]` and `t_ambient[LSB]` columns in all files. If the columns are not found, the particular file is ignored.*

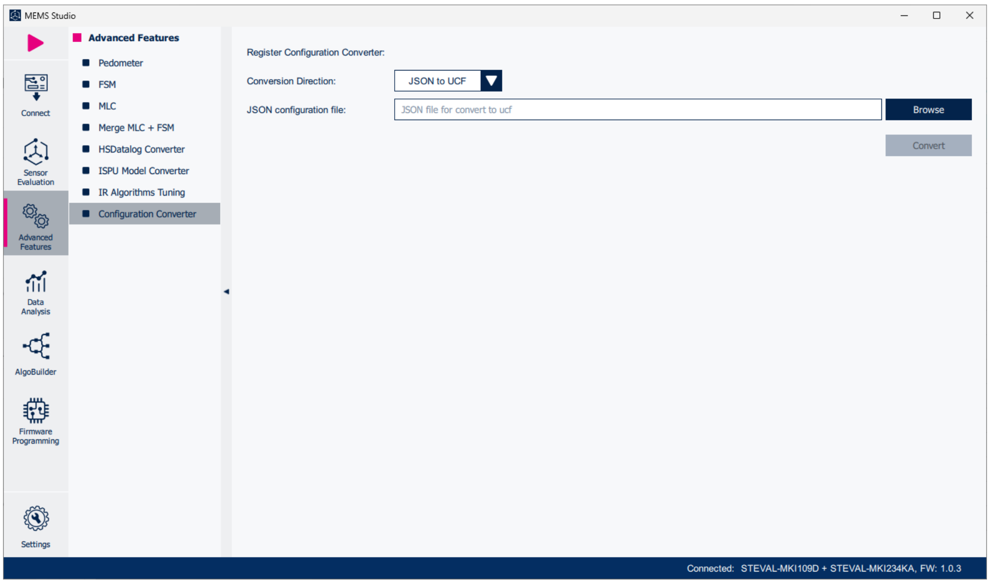
5.7 Configuration Convertor

The [**Configuration Convertor**] allows the conversion of sensor configuration from one file to another. The following options are supported:

- [**JSON to UCF**]: converts JSON configuration files to legacy UCF format. Please be aware that information and structures unsupported in UCF format will be omitted.
- [**UCF to JSON**]: converts legacy UCF format to JSON configuration files. The sensor name needs to be specified. There is an option to include also metadata from the UCF file.
- [**JSON to HEADER**]: converts JSON configuration files to .h header files intended for firmware projects written in C language. There is an option to include also metadata from the UCF file.

Attention: *In MEMS Studio 2.0.0 the UCF (Unico Configuration Format) configuration file format has been replaced with JSON (JavaScript Object Notation) format throughout the application. This change brings several significant benefits and improvements to the user experience and the overall functionality of the application.*

Figure 90. **Configuration Convertor**



Register Configuration Converter:

Conversion Direction: JSON to UCF

JSON configuration file: JSON file for convert to ucf

Connected: STEVAL-MKI109D + STEVAL-MKI234KA, FW: 1.0.3

6 Data analysis

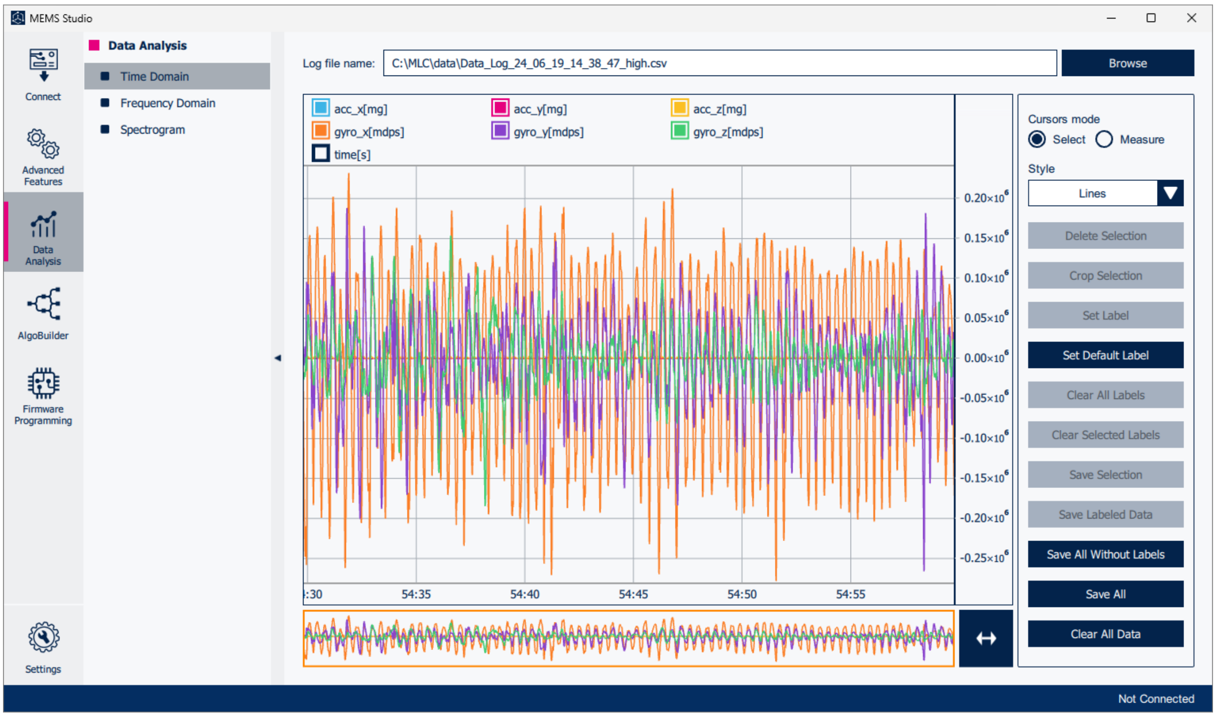
The data analysis feature allows visualizing and analyzing data in the time and frequency domains. In the frequency domain, the frequency spectrum from part of or the whole data log can be calculated using fast Fourier transform (FFT). Another option of frequency domain analysis is to use a spectrogram, which visualizes frequency spectrum progress over time.

6.1 Time domain

Time domain analysis is intended for data visualization, measuring, editing, and assigning labels to specific parts of the data.

Previously acquired data logs can be opened by clicking on the [**Browse**] button.

Figure 91. Time domain page



Log file name: C:\MLC\data\Data_Log_24_06_19_14_38_47_high.csv

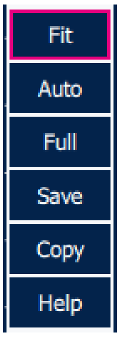
Cursors mode: ● Select ○ Measure

Style: Lines

After successfully loading the data log, data are visualized in the line chart. The user can navigate through the chart in the same way as other charts in the application. Moving the cursor to the Y-axis offers a context menu for the chart.

There are two options for data visualization. Data can be visualized as individual points or as lines connecting all the measured values.

Figure 92. Control options for the line chart

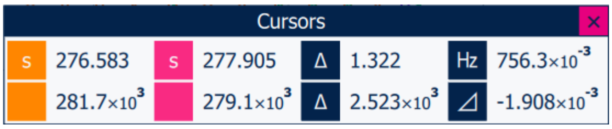


Available options are:

- [**Fit**]: adjusts the Y-axis range to display the whole signal
- [**Auto**]: enables/disables the option to automatically adjust the Y-axis range according to the visible data in the chart
- [**Full**]: adjusts the Y-axis range according to the min and max values, which can be modified by the user
- [**Save**]: saves the chart as an image in .png format
- [**Copy**]: saves the chart as an image in the system clipboard
- [**Help**]: displays help for working with the chart

The chart offers the possibility to measure various values. This can be enabled by switching from Cursor mode to [**Measure mode**]. Two cursors are displayed in the chart, their X and Y positions can be adjusted using the mouse. The corresponding X and Y values and their differences are displayed in the table bellow. Cursors can be hidden by closing the cursor table in the chart area.

Figure 93. Cursor value table



Cursors ×

s	276.583	s	277.905	Δ	1.322	Hz	756.3×10^{-3}
🟧	281.7×10^{3}	🟥	279.1×10^{3}	Δ	2.523×10^{3}	⊿	-1.908×10^{-3}

The data log can be edited and labels assigned if the Cursor mode is switched to [**Select mode**]. The start of the area is marked by clicking at the desired position in the graph, the start cursor is placed at this position, then the signal is selected by mousing over it, the next click defines the end of the selected area, and the end cursor is placed at this position. The following operations are available with the selected area:

- [**Delete Selection**]: deletes the selected part of the signal
- [**Crop Selection**]: deletes all parts except the selected area
- [**Set Label**]: assigns a label to the selected part, the existing label name can be selected, or a new label created
- [**Set Default Label**]: sets a label to all unlabeled parts
- [**Clear All Labels**]: removes all labels
- [**Clear Selected Labels**]: removes the label from the selected part
- [**Save Selection**]: saves the selected part to a new file

There are also other operations for data labeling:

- [**Save Labeled Data**]: saves each data for each label to a separate file
- [**Save All Without Labels**]: saves all changes without assigned labels to one file
- [**Save All**]: saves all changes including assigned labels to one file

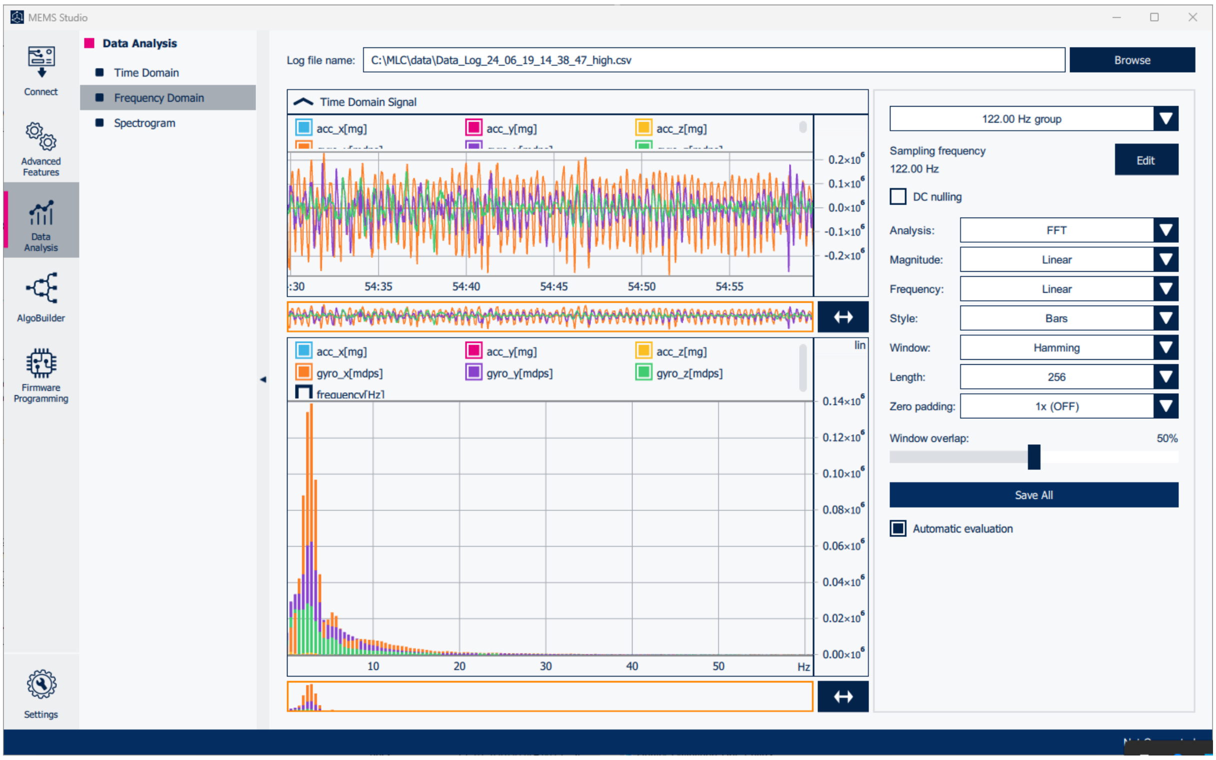
6.2 Frequency domain

Frequency domain analysis is used to analyze a frequency spectrum using fast Fourier transformation (FFT). If a data log was already selected on the [**Time Domain**] page, it is automatically used on the [**Frequency Domain**] page. Other data logs can be selected using the [**Browse**] button.

The application offers two types of [**Analysis**]:

- [**FFT**]: Fast Fourier Transform algorithm to compute the frequency spectrum of a signal
- [**PSD**]: Power Spectral Density, which represents how signal power is distributed over frequencies

Figure 94. **Frequency domain page**



Log file name: C:\MLC\data\Data_Log_24_06_19_14_38_47_high.csv

122.00 Hz group

Sampling frequency
122.00 Hz

□ DC nulling

Analysis: FFT
Magnitude: Linear
Frequency: Linear
Style: Bars
Window: Hamming
Length: 256
Zero padding: 1x (OFF)
Window overlap: 50%

☑ Automatic evaluation

It is very important to know the sampling rate of the data for frequency domain analysis. If there is a timestamp in the data log, the sampling rate is calculated from this value. In the case of several sampling rates used in one data log, the signals are grouped according to each sampling rate and are analyzed separately. The active group can be selected by the user. If the timestamp is not available, the sampling rate must be entered by the user.

The frequency spectrum can be calculated from the entire signal or from a selected area. If [**Automatic evaluation**] is enabled, these two modes are automatically switched with respect to the part of the signal that is selected. Otherwise, the following buttons can be used:

- [**Compute FFT / Compute PSD**]: calculates the frequency spectrum from the entire signal
- [**Selected Data FFT / Select Data PSD**]: calculates the frequency spectrum from the selected area

If the data log contains labels, a labeled part of the signal can be quickly selected by clicking on the label.

A graph with the frequency spectrum can be configured using the following options:

- [**Magnitude**] [Linear, dB]: specifies the scale on the Y-axis
- [**Frequency**] [Linear, Logarithmic]: specifies the scale on the X-axis
- [**Style**] [Bar, Lines]: specifies visualization of the values

A frequency domain analysis can be configured using the following options:

- [**DC nulling**]: removes the DC component from the signal
- [**Window**]: window function multiplied by the signal before frequency spectrum calculation in order to reduce the amplitude of the discontinuities at the boundaries of the signal part
- [**Length**]: number of samples used for the frequency spectrum calculation
- [**Zero padding**]: number of zeros added to the signal in order to increase resolution

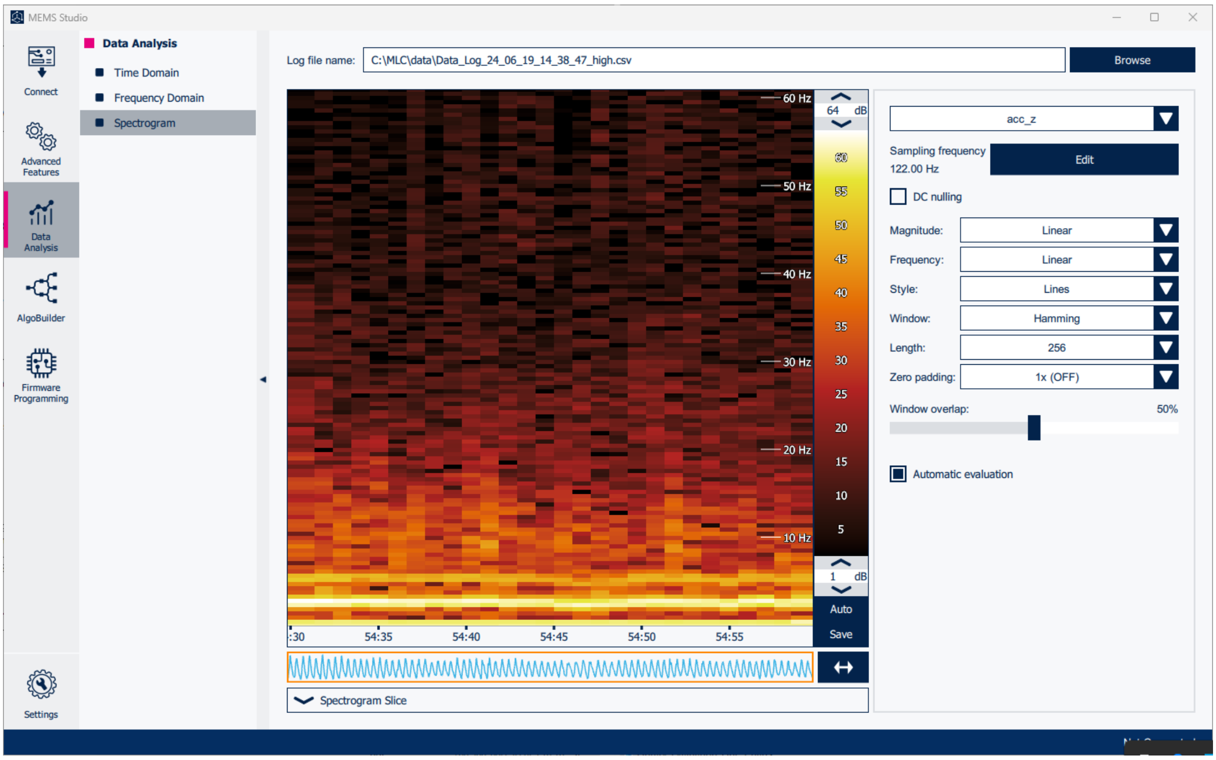
- [**Window overlap**]: percentage of the previous window reused for the evaluation of the next window

The calculated frequency spectrum can be stored in a file using the [**Save All**] button.

6.3 Spectrogram

A spectrogram analysis is used to analyze the evaluation of the frequency spectrum over time. If a data log was already selected on the [**Time Domain**] or [**Frequency Domain**] page, it is automatically used on the [**Spectrogram**] page. Other data logs can be selected using the [**Browse**] button.

Figure 95. **Spectrogram page**



Log file name: C:\MLC\data\Data_Log_24_06_19_14_38_47_high.csv

acc_z

Sampling frequency 122.00 Hz

□ DC nulling

Magnitude: Linear

Frequency: Linear

Style: Lines

Window: Hamming

Length: 256

Zero padding: 1x (OFF)

Window overlap: 50%

☒ Automatic evaluation

As the spectrogram utilizes the same fast Fourier transform as the frequency domain analysis, the same parameters can be configured also on the [**Spectrogram**] page.

7 AlgoBuilder

AlgoBuilder is a tool for the graphical design of algorithms.

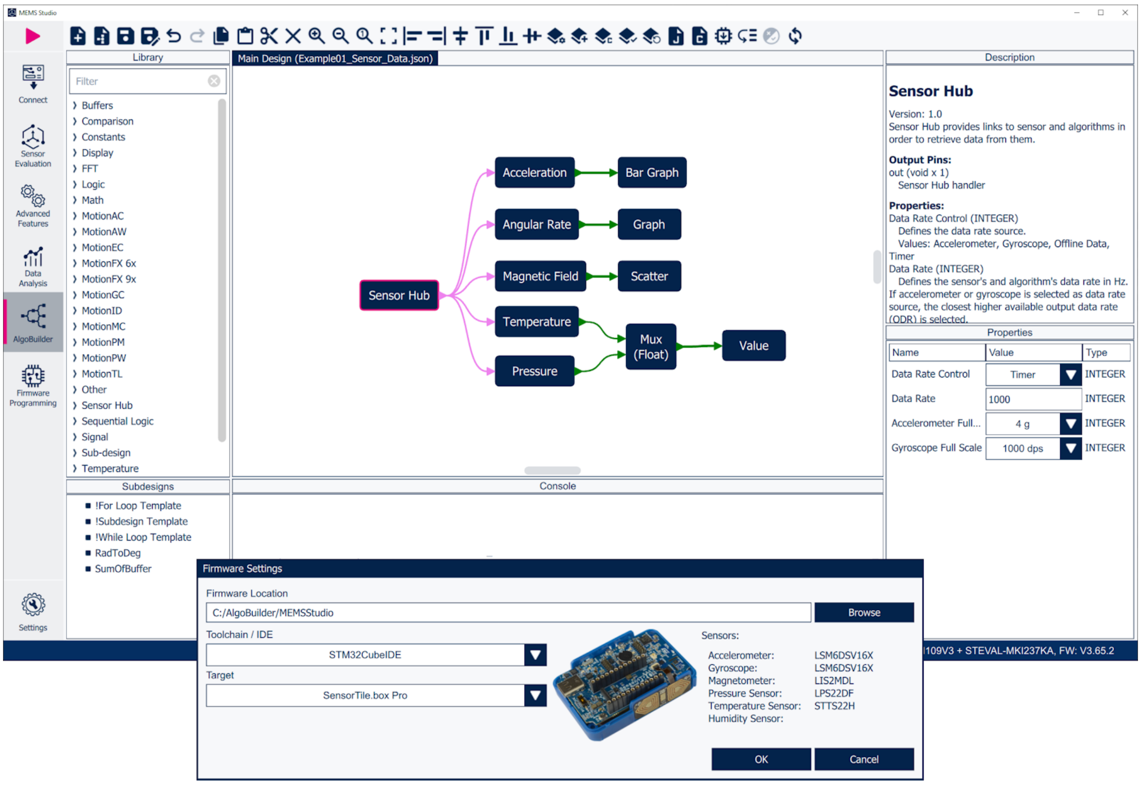
This tool quickly creates prototypes of applications for STM32 microcontrollers and MEMS sensors, including already existing algorithms (in the example of sensor fusion), user-defined data processing blocks, and additional functionalities.

The tool facilitates the process of implementing a proof of concept using a graphical interface without writing the code.

The key features of the application include:

- Simple graphical design of algorithms (drag and drop, connect, set properties, build, upload)
- Optional multilevel design
- Wide range of function blocks available in libraries, including motion sensor algorithms (for example, sensor fusion, gyroscope, magnetometer calibration, pedometer, and so forth)
- Integrated function blocks for FFT analysis
- Automatic validation of design rules
- C code generation from the graphical design
- Use of external compilers (STM32CubeIDE, IAR EWARM, Arm® Keil® µVision®)
- Possibility to integrate FSM, MLC, and ISPU in the design
- Open .json format for function blocks and design storage

Figure 96. **AlgoBuilder**



Sensor Hub

Version: 1.0
Sensor Hub provides links to sensor and algorithms in order to retrieve data from them.

Output Pins:
out (void x 1)
Sensor Hub handler

Properties:
Data Rate Control (INTEGER)
Defines the data rate source.
Values: Accelerometer, Gyroscope, Offline Data, Timer
Data Rate (INTEGER)
Defines the sensor's and algorithm's data rate in Hz. If accelerometer or gyroscope is selected as data rate source, the closest higher available output data rate (ODR) is selected.

Name	Value	Type
Data Rate Control	Timer	INTEGER
Data Rate	1000	INTEGER
Accelerometer Full...	4 g	INTEGER
Gyroscope Full Scale	1000 dps	INTEGER

Firmware Settings

Firmware Location: C:/AlgoBuilder/MEMSStudio

Toolchain / IDE: STM32CubeIDE

Target: SensorTile.box Pro

Sensors:

Accelerometer:	LSM6DSV16X
Gyroscope:	LSM6DSV16X
Magnetometer:	LIS2MDL
Pressure Sensor:	LPS22DF
Temperature Sensor:	STTS22H
Humidity Sensor:	

7.1 Principle of operation

The workflow starts from the graphical design of the desired functionality by using a simple "drag and drop" approach.

The flow diagram is composed of the predefined function blocks provided in the libraries. Custom function blocks can be created as well. Some function blocks have properties that can be adjusted.

Then, function blocks can be interconnected. AlgoBuilder automatically checks the compatibility between input and output and allows connecting only terminals with the same type and dimension.

When the design is finished, AlgoBuilder generates the C code from the defined graphical design. The final firmware project is created from the C code generator, combined with preprepared firmware templates and binary libraries.

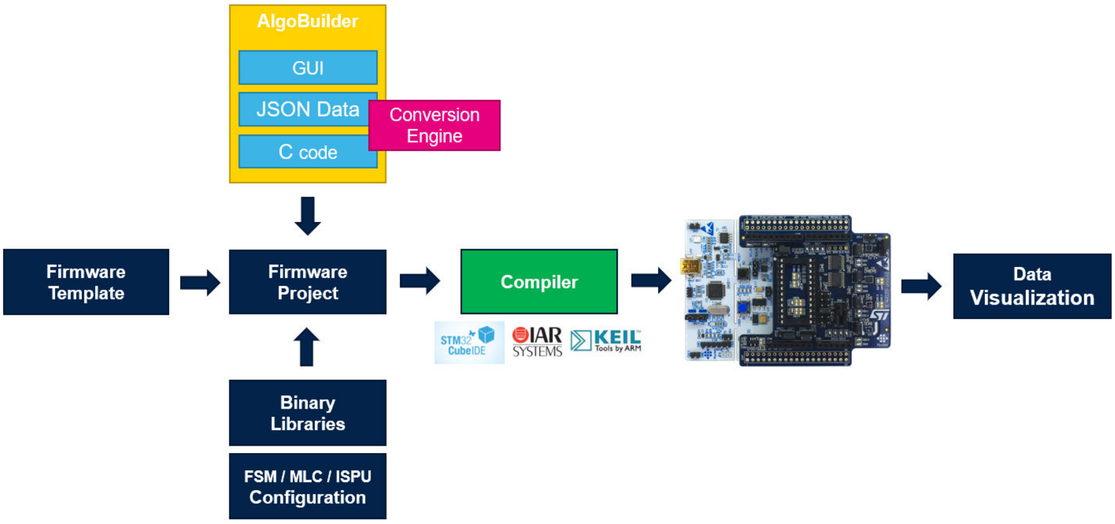
The project can be compiled using an external compiler tool and the most common compilers are supported (STM32CubeIDE, Arm® Keil® µVision®, IAR Embedded Workbench).

A development board is then programmed by the generated binary file.

When the firmware is executed, it starts reading data from the selected sensor, processes the data via the algorithm, and sends the results to the MEMS Studio application. During the graphical design, you can select how to see the results. Many options like graphs, logical analyzers, bar charts, 3D plots, scatter plots, and others are supported. During the startup, the firmware configures the UI to display the data in the desired format.

The graphical designs as well as the libraries are stored as .json files.

Figure 97. AlgoBuilder principle of operation



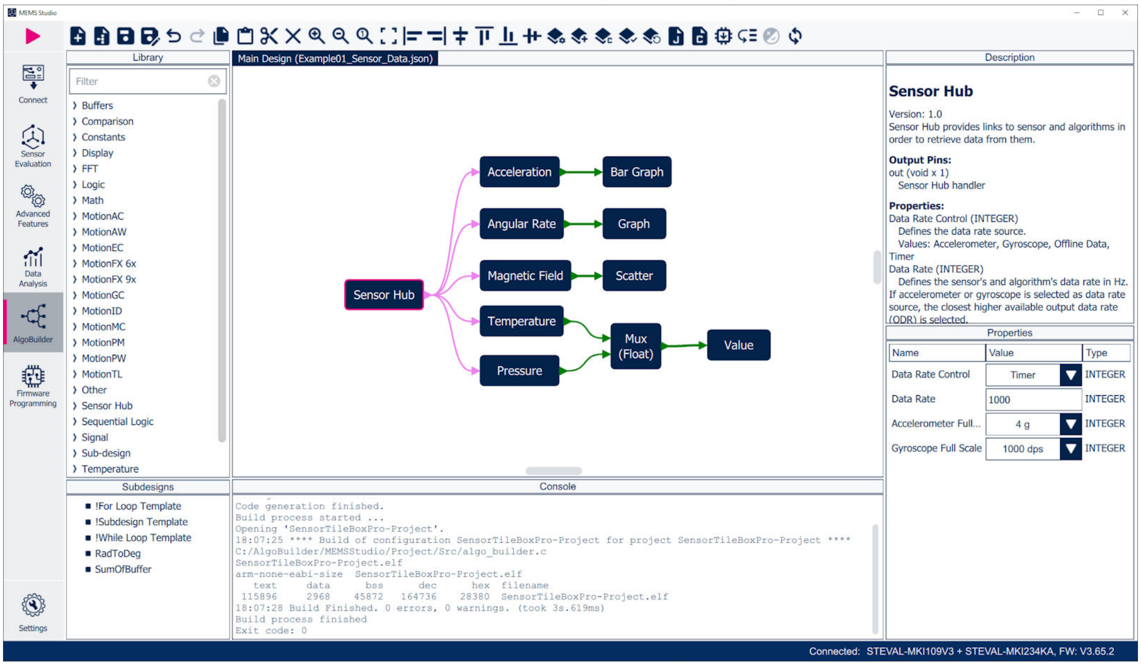
7.2 Overview

The AlgoBuilder tool contains the following:

- Central workspace where the algorithm is designed using function blocks
- [**Library**] dock with a list of available libraries and their function blocks, which can be dragged and dropped to the workspace window
- [**Subdesigns**] dock with a list of available subdesigns and subdesign templates
- [**Description**] dock that displays information about the selected component (function block, connection, and so forth)
- [**Properties**] dock that displays all available properties of the selected function block
- [**Console**] dock that displays messages from AlgoBuilder or an external compiler

The AlgoBuilder tool is controlled from a toolbar that offers all the necessary functions.

Figure 98. **AlgoBuilder main page**



Sensor Hub

Version: 1.0
Sensor Hub provides links to sensor and algorithms in order to retrieve data from them.

Output Pins:
out (void x 1)
Sensor Hub handler

Properties:
Data Rate Control (INTEGER)
Defines the data rate source.
Values: Accelerometer, Gyroscope, Offline Data, Timer
Data Rate (INTEGER)
Defines the sensor's and algorithm's data rate in Hz. If accelerometer or gyroscope is selected as data rate source, the closest higher available output data rate (ODR) is selected.

Name	Value	Type
Data Rate Control	Timer	INTEGER
Data Rate	1000	INTEGER
Accelerometer Full...	4 g	INTEGER
Gyroscope Full Scale	1000 dps	INTEGER

```
Code generation finished.
Build process started ...
Opening 'SensorTileBoxPro-Project'.
18:07:25 **** Build of configuration SensorTileBoxPro-Project for project SensorTileBoxPro-Project ****
C:/AlgoBuilder/MEMSStudio/Project/Src/algo_builder.c
SensorTileBoxPro-Project.elf
arm-none-eabi-size  SensorTileBoxPro-Project.elf
   text     data      bss      dec      hex  filename
 115896     2968    45872   164736    28380  SensorTileBoxPro-Project.elf
18:07:28 Build Finished. 0 errors, 0 warnings. (took 3s.619ms)
Build process finished
Exit code: 0
```

7.3 Workspace

The algorithm design under development is created in the workspace area.

7.4 Library dock

The [**Library**] dock gives you access to all the available libraries and function blocks located in a particular library.

AlgoBuilder scans [Install path]\release\Library\ and the user's home directory \STMicroelectronics\MEMS Studio\algobuilder\library during startup and loads all valid libraries located there.

7.5 Subdesigns dock

The [**Subdesigns**] dock gives you access to all the available subdesigns. AlgoBuilder scans [Install path]\release\Subdesigns\ and the user's home directory\STMicroelectronics\MEMS Studio\algobuilder\subdesigns during startup and loads all valid subdesigns located there. The subdesign templates are located in the [Install path]\release\Subdesigns\ directory.

7.6 Description dock

The [**Description**] dock provides information about the component selected in the workspace or in the [**Library**] dock.

If you select a function block, the following information is shown:

- Name
- Version
- Description of the function block functionality
- Type, size, and functionality of all inputs and outputs
- Description of all function block properties

7.7 Properties dock

If a function block has a property or properties, they are displayed in the [**Properties**] dock.

Each property has [**Name**], [**Value**], and [**Type**] fields.

The values can be modified.

AlgoBuilder automatically checks if the value is valid and does not allow setting an invalid value (for example, a value out of an available range).

For the STRING type, the % character is forbidden and is automatically deleted.

7.8 Toolbar

The toolbar provides quick access to all needed functions.

Table 6. **AlgoBuilder toolbar functions**

Toolbar icon	Function
🗋	Create new design
🗎	Open existing design
💾	Save design (subdesign)
💾	Save design (subdesign) as a different file
↶	Undo
↷	Redo
⎘	Copy
📋	Paste
✂	Cut
✕	Delete
🔍	Zoom in
🔍	Zoom out
🔍	Zoom to default
⛶	Fit whole design into the window
⇤	Align blocks to the left
⇥	Align blocks to the right
⇹	Center blocks horizontally
⤒	Align blocks to the top

Toolbar icon	Function
⊥	Align blocks to the bottom
╪	Center blocks vertically
⚙	Project configuration
+	Initialize project directory
C	Generate code
✓	Build project
↺	Rebuild project
J	View design source file
C	View generated source C file
⤓	Program device by automatic selected method
☰	Display order configuration
✕ ✓	Add or remove conditional input
+	Custom Block Creator

7.9 Libraries

The following libraries are available after the installation of MEMS Studio.

Table 7. AlgoBuilder libraries

Library	Content
Buffers	Function blocks for operations with data buffers
Comparison	Function blocks for two value comparisons (for example, >, <, =, and so forth)
Display	Function blocks for data visualization
FFT	Function blocks related to FFT analysis
Logic	Function blocks for logic operations (for example, And, Or, …, and so forth)
Math	Function blocks for various mathematical operations (for example, +, -, /, and so forth)
Other	Auxiliary function blocks (for example, mux, demux, type conversion, and so forth)
Sensor Hub	Sensor hub function block, which provides access to the sensors and prebuild algorithm, and function blocks that provide data from connected sensors
Sequential Logic	Function block for sequential logic (flip flops)
Signal	Function blocks for signal processing (for example, filters, and so forth)
Sub-design	Input and output terminals for subdesigns
Temperature	Function blocks for temperature unit conversions
User Input	Function blocks, which allow the user to send arbitrary data to the running firmware in real time
Vector	Function blocks for vector operation (for example, calculate magnitude, and so forth)

Already prepared algorithms in binary form can also be integrated in the user design.

Table 8. Motion libraries supported in AlgoBuilder

Library	Functionality
MotionAC	Accelerometer calibration algorithm
MotionAW	Activity recognition algorithm for wrist-worn devices
MotionEC	ecompass algorithm
MotionFX 6x	Sensor fusion algorithm using accelerometer and gyroscope
MotionFX 9x	Sensor fusion algorithm using accelerometer, gyroscope, and magnetometer
MotionGC	Real-time gyroscope calibration algorithm
MotionID	Motion intensity detection algorithm
MotionMC	Real-time magnetometer calibration algorithm
MotionPM	Pedometer algorithm for mobile devices
MotionPW	Pedometer algorithm for wrist-worn devices
MotionTL	Tilt sensing algorithm

Binary libraries are included in the firmware only if at least one function block is used in the design. This reduces occupied flash memory and RAM memory.

7.10 Data types

AlgoBuilder works with four data types:

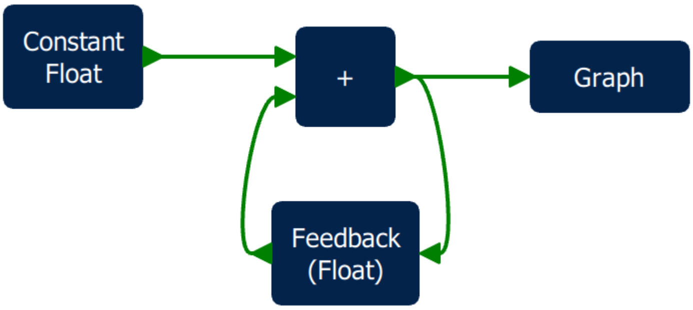
- **FLOAT** represents real numbers and is used for floating-point arithmetic (for example, in the acceleration function block output). In C code, the representation float variable is used. The size is 4 bytes.
- **INT** represents integer numbers (for example, in the counter function block). In C code, the int32_t variable is used. The size is 4 bytes.
- **VARIANT** is used for inputs of a set of function blocks; the variant changes its type on the basis of the type of output connected to this input (for example, the variant type is used for inputs of comparison function blocks).
- **VOID** is used exclusively for the connection between the sensor hub and its data outputs. This type cannot be visualized.

Each input or output is characterized by its type and size, the color of the connection line indicates the type.

Important: Only input and output with the same type and size can be connected together. The only exception is the VARIANT input, which gets the type of the connected output.

It is not possible to connect the input and output of the same function block. If this is desired, the [**Feedback**] function block for the particular data type needs to be used. The [**Feedback**] function block has an Init value, which defines the output value of the block for the first run.

Figure 99. **Using the Feedback function block**



7.11 Data visualization

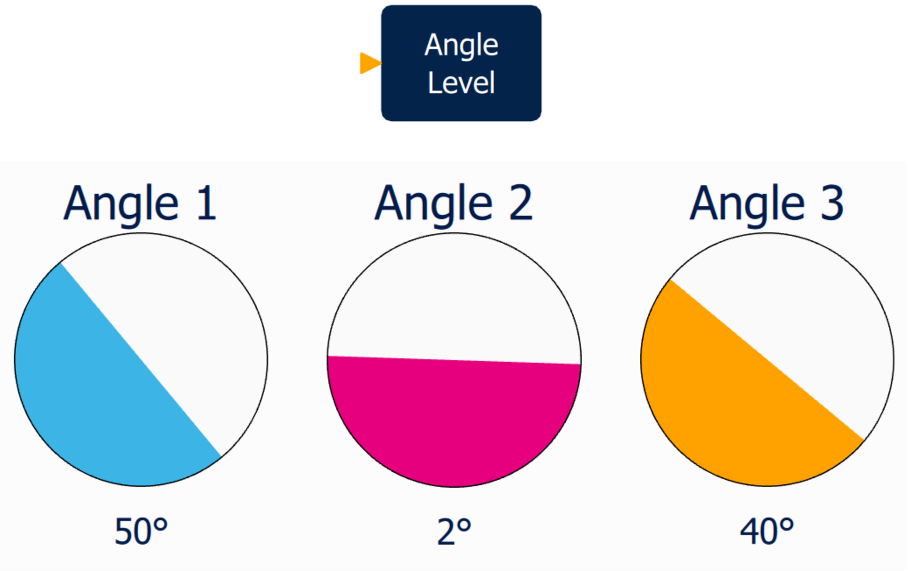
The application offers nine types of data visualization in the [**Display**] library:

- [**Angle Level**]
- [**Bar Graph**]
- [**FFT Plot**]
- [**Fusion**]
- [**Graph**]
- [**Logic Analyzer**]
- [**Plot3D**]
- [**Scatter Plot**]
- [**Value**]

Use the appropriate function block according to your requirements for data visualization.

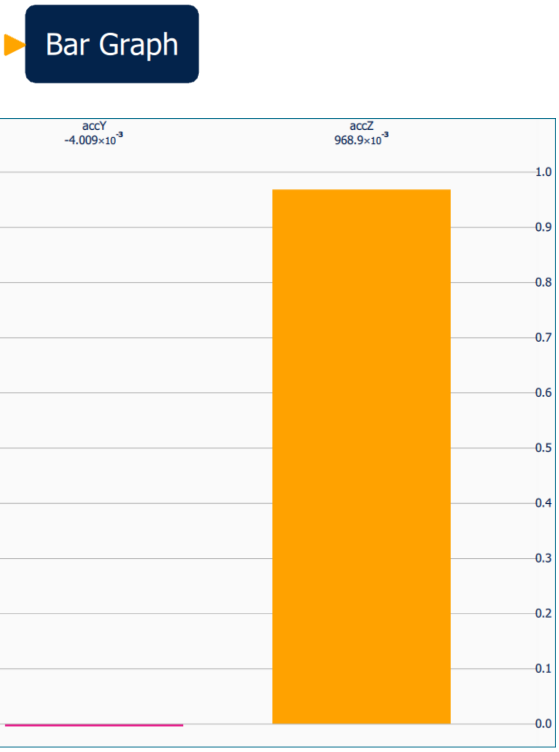
Use the [**Angle Level**] function block in the design to display data as an angle level indicator. This graph works with any floating or integer value and each of them can have up to three indicators. In the [**Properties**] field, you can set the name of the graph as well as the name of each angle level indicator with unit. Predefined configurations are available in the [**Preset Values**] property.

Figure 100. **Angle Level function block and example of data visualization**



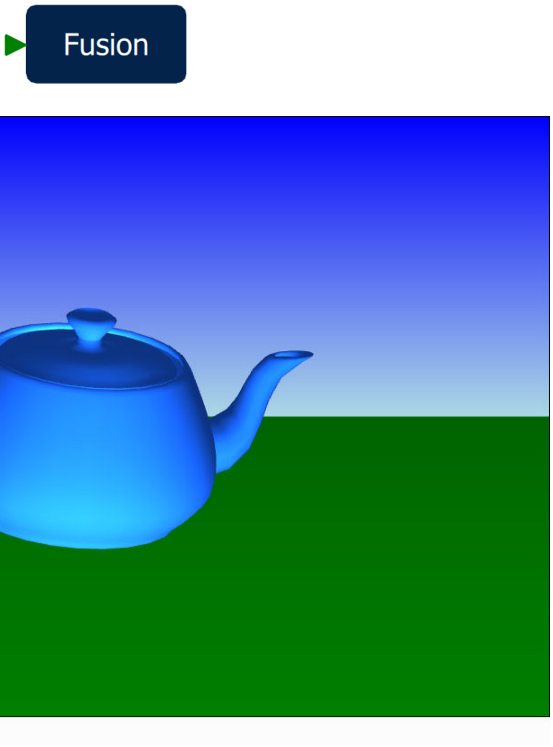
Use the [**Bar Graph**] function block in the design to display data as a bar graph. A bar graph is suitable for a quick check of an actual value without needing to see the history. This graph works with any floating or integer value and each of them can have up to six bars. In the [**Properties**] field, you can set the name of the graph as well as the name of each bar, unit on the Y-axis, position of 0 on the Y-axis, full scale, and enable or disable autoscale. Predefined configurations are available in the [**Preset Values**] property.

Figure 101. Bar Graph function block and example of data visualization



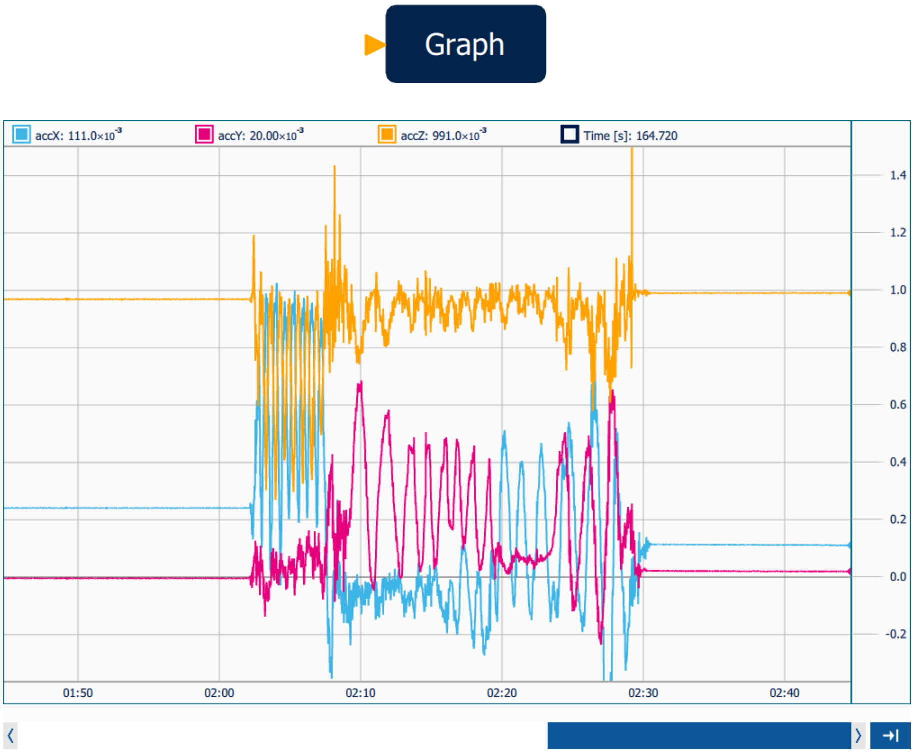
Use the [**Fusion**] function block in the design to display quaternion data on a 3D model. The 3D model (teapot, Nucleo board, car, head) is usually used to check device orientation in 3D space. This graph requires quaternions, which can be obtained, for example, from the sensor fusion (MotionFX) algorithm.

Figure 102. **Fusion function block and example of data visualization**



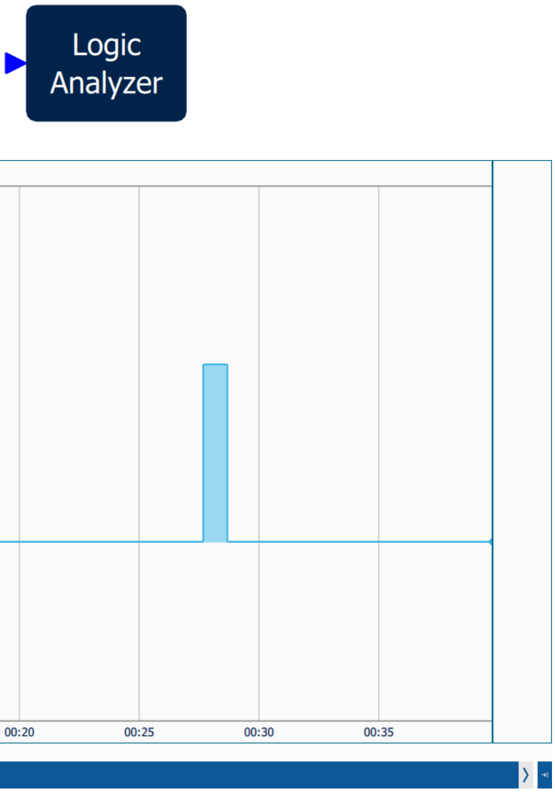
Use the [**Graph**] function block in the design to display data as a time graph. This graph works with any floating or integer value and each of them can have up to six waveforms. In the [**Properties**] field, you can set the name of the graph as well as the name of each waveform, unit on the Y-axis, position of the 0 on the Y-axis, full scale, and enable or disable autoscale. Predefined configurations are available in the [**Preset Values**] property.

Figure 103. Graph function block and example of data visualization



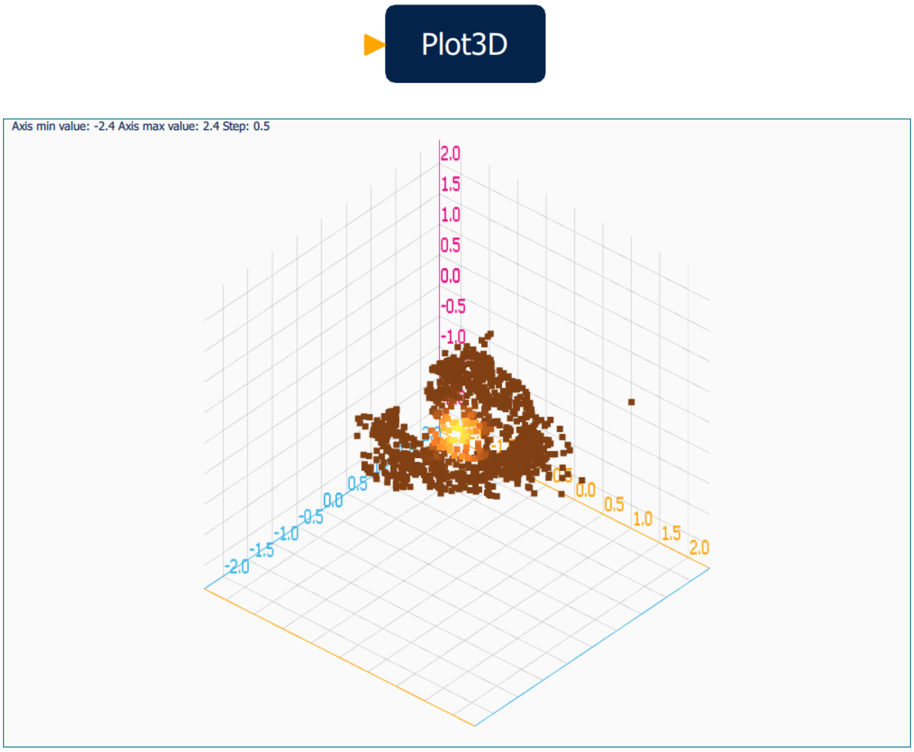
Use the [**Logic Analyzer**] function block in the design to display logic signals, which can have values of only 0 or 1. The logic analyzer can have up to 16 channels. In [**Properties**], you can change the name of each channel and the logic analyzer.

Figure 104. Logic Analyzer function block and example of data visualization



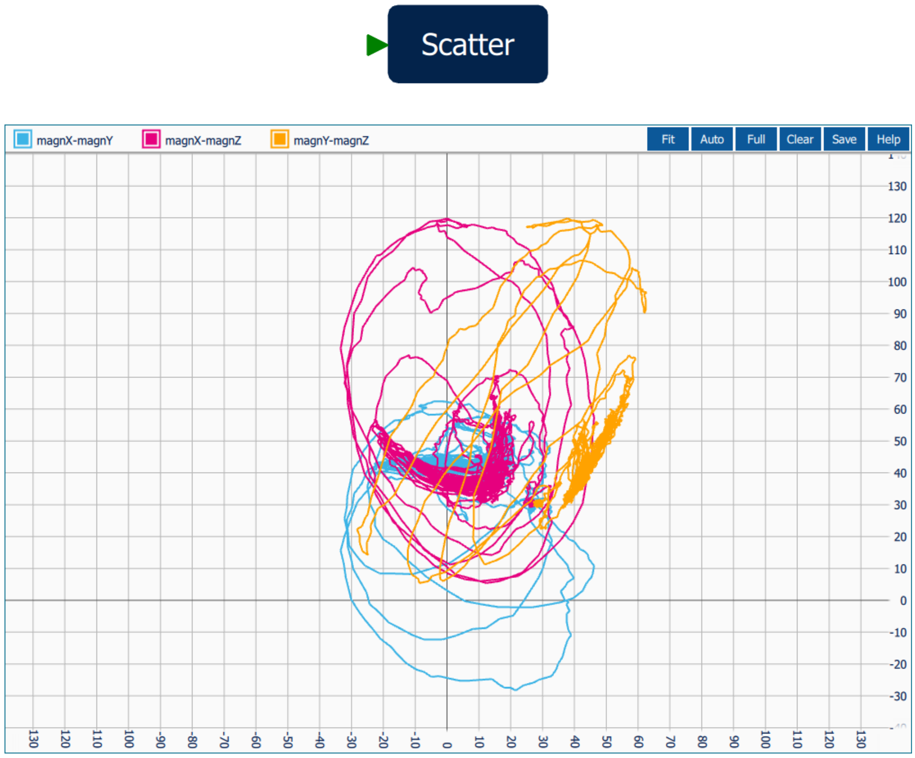
Use the [**Plot3D**] function block in the design to display X, Y, Z data as points in 3D space. This graph works with any floating or integer value. In the [**Properties**] field, you can set the name of the graph as well as the name of each value, unit, full scale, and enable or disable autoscale. Predefined configurations are available in the [**Preset Values**] property.

Figure 105. **Plot3D function block and example of data visualization**



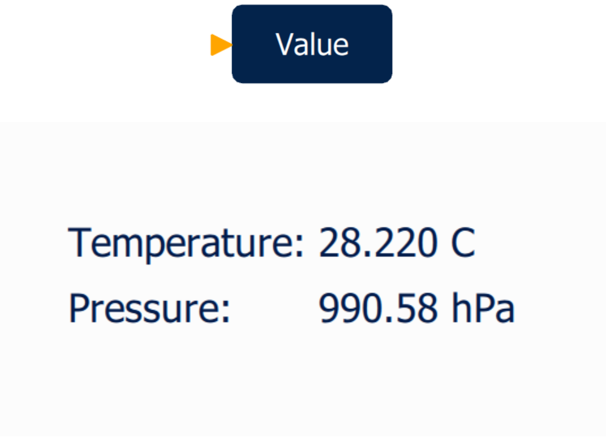
Use the [**Scatter**] function block in the design to display X, Y, Z data in 2D space (X-Y, X-Z, Y-Z charts). In the [**Properties**] field, you can set the name of the graph as well as the name of each value, unit, full scale, and enable or disable autoscale. Predefined configurations are available in the [**Preset Values**] property.

Figure 106. **Scatter function block and example of data visualization**



Use the [**Value**] function block in the design to display the exact float or integer value as text. Each function block can display up to eight values. In [**Properties**], you can change the name of the value and unit for each item.

Figure 107. **Value function block and example of data visualization**



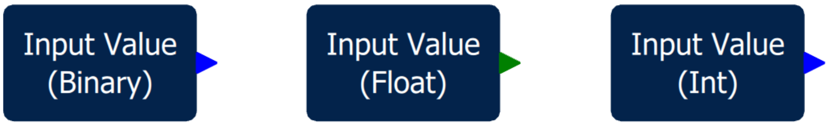
Temperature: 28.220 C

Pressure: 990.58 hPa

7.12 Data input

Three types of data can be sent from the MEMS Studio application to run the firmware: binary, integer, and float. This can be done by adding the [**Input Value**] function block (with the appropriate type) from the [**User Input**] library to the design. Each [**Input Value**] function block can represent up to four values. In the [**Properties**], it is possible to set the name of each value and the default value. The [**Input Value**] function block output size is defined by the [**Number of Values**] property.

Figure 108. **Input Value function blocks**



7.13 Conditional execution

In some cases, it is needed to execute the function block operation only if a certain condition is valid. For this case, it is possible to add [**Conditional Execution Input**] to the selected function block. This input then defines if the function block code is executed or not. To add or remove the conditional execution input to the selected function block, click on the (Add or Remove Conditional Input) icon in the toolbar.

7.14 Fast Fourier transform (FFT)

AlgoBuilder offers a function block for the frequency analysis of the sensor's output signal using FFT (fast Fourier transform). Fourier analysis converts a signal from the time domain to a representation in the frequency domain.

The [**FFT**] function block offers frequency analysis from 32, 64, 128, 256, 512 and 1024 samples. It is also possible to enable window usage to eliminate spectrum leakage. Hanning, Hamming, and Flat Top windows can be used.

Output from the [**FFT**] function block can be connected to the [**FFT plot**] function block, which visualizes the data as a frequency spectrum. To plot data only when the FFT calculation is finished, conditional execution input must be added to the [**FFT plot**] and connected to the full output of the [**FFT**] function block.

Figure 109. **FFT and FFT Plot connections**

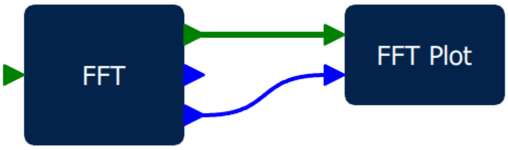
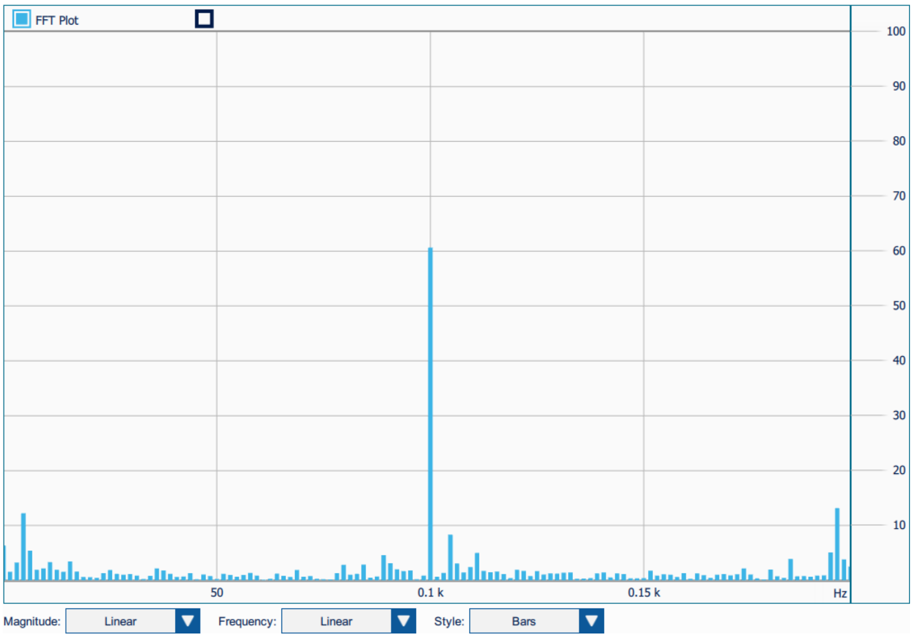


Figure 110. **FFT Plot visualization**



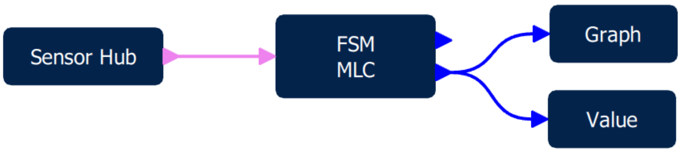
Magnitude: Linear
Frequency: Linear
Style: Bars

Note: *To get the correct frequency values, it is necessary to select the sensor whose data are analyzed (accelerometer or gyroscope) in the [**Data Rate Control**] property in the [**Sensor Hub**]. Real sensor ODR (output data rate) is measured during firmware initialization.*

7.15 Finite state machine (FSM) and machine learning core (MLC)

AlgoBuilder allows using outputs from the finite state machine (FSM) and/or machine learning core (MLC) in the design. The [**FSM/MLC**] function block is available in the [**Sensor Hub**] library.

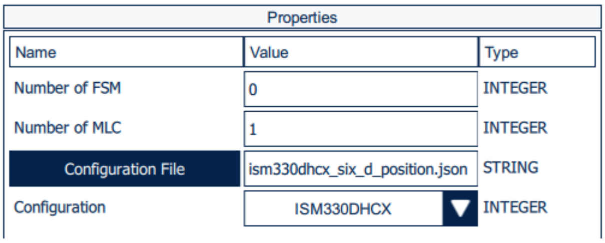
Figure 111. **Example of a design with FSM/MLC**



The configuration of the FSM and MLC is stored in the .json file. The .json file can be created in the [**Advanced Features**] page.

It is mandatory to specify the number of FSM and MLC outputs used and the sensor name in the .json file in case the .json contains more configurations. The size of the FSM/MLC output vector is adjusted accordingly.

Figure 112. **FSM/MLC function block properties**



Properties

Name	Value	Type
Number of FSM	0	INTEGER
Number of MLC	1	INTEGER
Configuration File	ism330dhcx_six_d_position.json	STRING
Configuration	ISM330DHCX	INTEGER

Warning:

The .json file usually contains settings of the sensor full scale (FS) and output data rate (ODR). These settings might be different than the settings required by the sensor hub. The firmware generated by AlgoBuilder contains a function to check if the FS and ODR set by the .ucf file is compatible with the sensor hub settings. If not, an error message is generated during connection to the device.

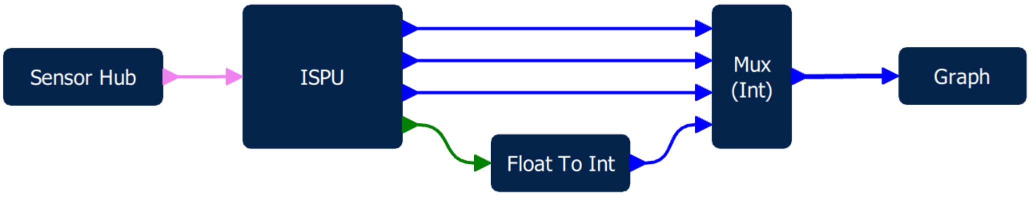
The interrupt pin INT1 is usually configured by the MLC tool in which case it is not possible to use the accelerometer or gyroscope as [**Data Rate Control**] in the sensor hub.

The [**FSM/MLC**] function block can be used only with sensors that are equipped with this functionality.

7.16 Intelligent sensor processing unit (ISPU)

AlgoBuilder also allows using outputs from the intelligent sensor processing unit (ISPU) in the design. The [**ISPU**] function block is available in the [**Sensor Hub**] library.

Figure 113. **Example of a design with ISPU**



The configuration of the ISPU is stored in the .json file. The path to the .json file is the [**Property**] of the [**ISPU**] function block. The .json file can be created using the ISPU-Toolchain software. An output description needs to be present in the same file with the ISPU configuration. The outputs of the [**ISPU**] function block are automatically adjusted according to the output description structure in the .json file.

Supported types of outputs are the following:

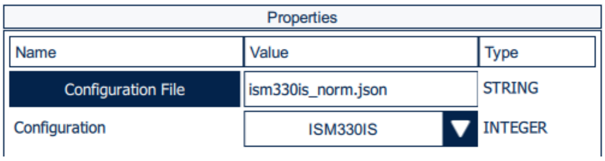
- int8_t, int16_t, int32_t, uint8_t, uint16_t, uint32_t
- float

Arrays might be defined using a size key (that is, “size”: 3).

An example of the output description file is as follows:

```
"outputs": [
  {
    "name": "Acc x [LSB]",
    "core": "ISPU",
    "type": "int16_t",
    "len": "1",
    "reg_addr": "0x10",
    "reg_name": "ISPU_DOUT_00_L",
    "results": [
    ]
  },
  {
    "name": "Acc y [LSB]",
    "core": "ISPU",
    "type": "int16_t",
    "len": "1",
    "reg_addr": "0x12",
    "reg_name": "ISPU_DOUT_01_L",
    "results": [
    ]
  },
  {
    "name": "Acc z [LSB]",
    "core": "ISPU",
    "type": "int16_t",
    "len": "1",
    "reg_addr": "0x14",
    "reg_name": "ISPU_DOUT_02_L",
    "results": [
    ]
  },
  {
    "name": "Acc norm [LSB]",
    "core": "ISPU",
    "type": "float",
    "len": "1",
    "reg_addr": "0x16",
    "reg_name": "ISPU_DOUT_03_L",
    "results": [
        ]
    }
]
```

Figure 114. **ISPU function block Properties**



Properties

Name	Value	Type
Configuration File	ism330is_norm.json	STRING
Configuration	ISM330IS ▼	INTEGER

During firmware startup, the ISPU is configured according to the .json file and the output values are then read by the MCU and used in the AlgoBuilder flow.

Warnings:

The .json file also usually contains settings of the sensor full scale (FS) and output data rate (ODR). These settings might be different than the settings required by the sensor hub. The firmware generated by AlgoBuilder contains a function to check if the FS and ODR set by the .ucf file is compatible with the sensor hub settings. If not, an error message is generated.

If the interrupt pin INT1 is used by the ISPU algorithm, it is not possible to use the accelerometer or gyroscope as [**Data Rate Control**] in the [**Sensor Hub**].

The [**ISPU**] function block can be used only with sensors that are equipped with this functionality.

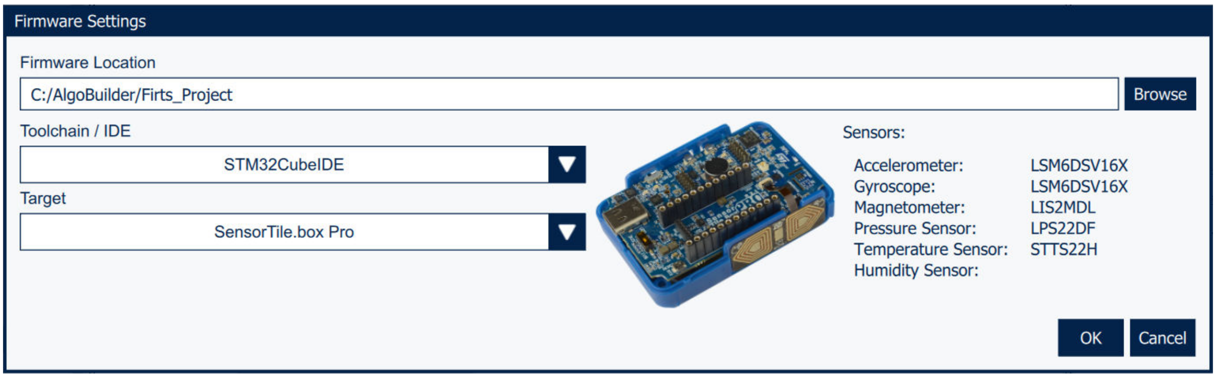
7.17 Creating your first design

As a first example, you can create a simple design to read acceleration data from the accelerometer sensor at a selected data rate and visualize the data in a line chart.

Step 1. Start with a new design by clicking on the 🗋 icon (New Design) in the toolbar. The [**Firmware Settings**] window is opened automatically or you can open it by clicking on the ⚙ icon (Firmware settings) in the toolbar.

Step 2. Set the path to the directory where the output firmware will be located, the toolchain to be used to compile the firmware, and the target to be used for testing.

Figure 115. AlgoBuilder Firmware Settings window



Firmware Settings

Firmware Location: C:/AlgoBuilder/Firts_Project

Toolchain / IDE: STM32CubeIDE

Target: SensorTile.box Pro

Sensors:

Accelerometer:	LSM6DSV16X
Gyroscope:	LSM6DSV16X
Magnetometer:	LIS2MDL
Pressure Sensor:	LPS22DF
Temperature Sensor:	STTS22H
Humidity Sensor:	

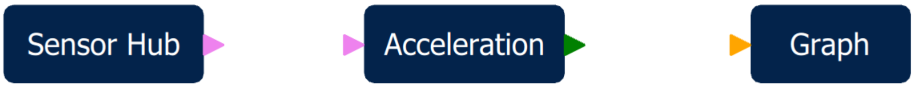
Step 3. [**Sensor Hub**] function block from the [**Sensor Hub**] library is automatically added to the workspace.

*Note: Each design must start with the [**Sensor Hub**] function block, which provides access to the sensors and prebuild algorithm.*

Step 4. Adjust the [**Sensor Hub**] properties. Select [**Timer**] as the source for [**Data Rate Control**], set the [**Data Rate**] to 50 Hz and [**Accelerometer Full Scale**] to 2 *g*.

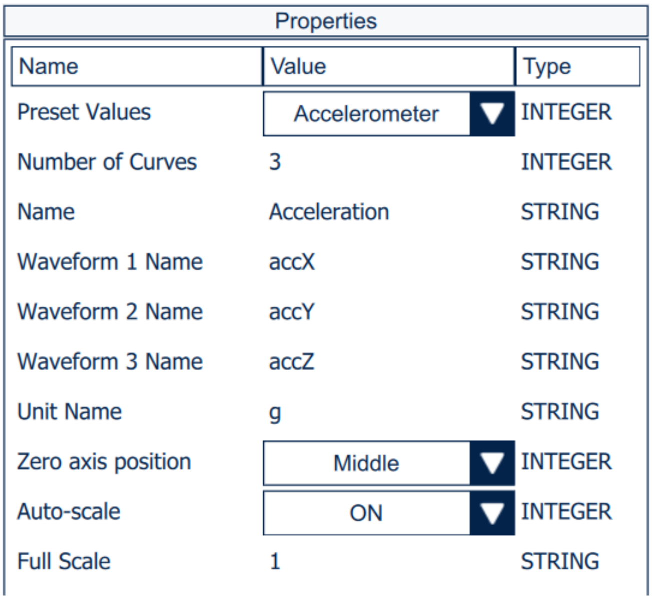
Step 5. Add the [**Acceleration**] [g] function block from the [**Sensor Hub**] library and the [**Graph**] function block from the [**Display**] library to the workspace.

Figure 116. Sensor Hub, Acceleration [g], Graph function blocks



Step 6. Adjust the [**Graph**] properties. The [**Number of Curves**] in [**Graph**] defines the size of its input. The value needs to be changed to 3 to match the [**Acceleration**] [*g*] output size. The graph, waveforms, and unit names can also be changed. You can also quickly configure the [**Graph**] by selecting [**Accelerometer**] in [**Preset Values**].

Figure 117. Graph Properties



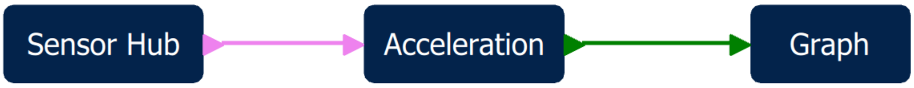
Properties

Name	Value	Type
Preset Values	Accelerometer ▼	INTEGER
Number of Curves	3	INTEGER
Name	Acceleration	STRING
Waveform 1 Name	accX	STRING
Waveform 2 Name	accY	STRING
Waveform 3 Name	accZ	STRING
Unit Name	g	STRING
Zero axis position	Middle ▼	INTEGER
Auto-scale	ON ▼	INTEGER
Full Scale	1	STRING

Step 7. Connect the function blocks by clicking on the [**Sensor Hub**] output, holding and mousing over the input of the [**Acceleration**] [*g*] block.

Step 8. Repeat the previous step to connect [**Acceleration**] [*g*] to the [**Graph**] block.

Figure 118. Connected Sensor Hub, Acceleration, Graph function blocks

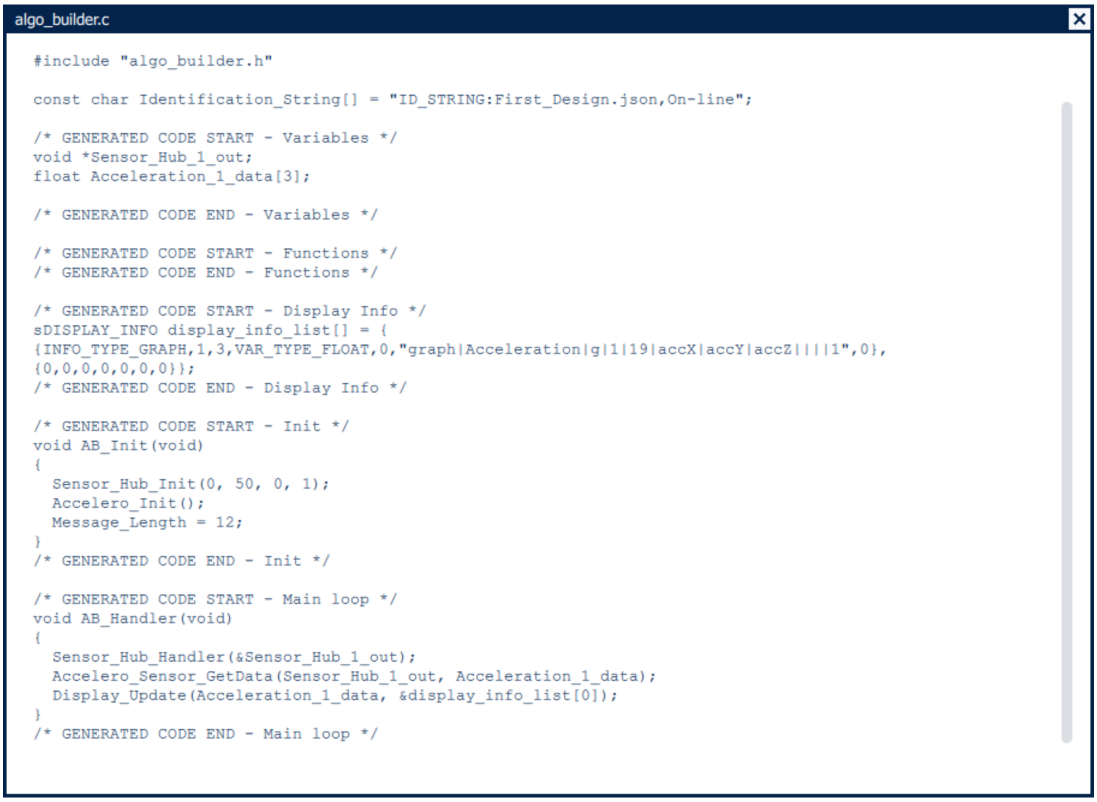


Step 9. Save the design by clicking on the 💾 icon (Save Design) in the toolbar.

Step 10. Your design is ready and you can generate C code from it. Click on the icon (Generate C Code) in the toolbar.

This function validates the flow diagram and creates the algo_builder.c file, which is the C code representation of the graphical design. You can check the generated C code by clicking on the icon (Show C Code) in the toolbar or [**Firmware**] menu.

Figure 119. Generated code in algo_builder.c file

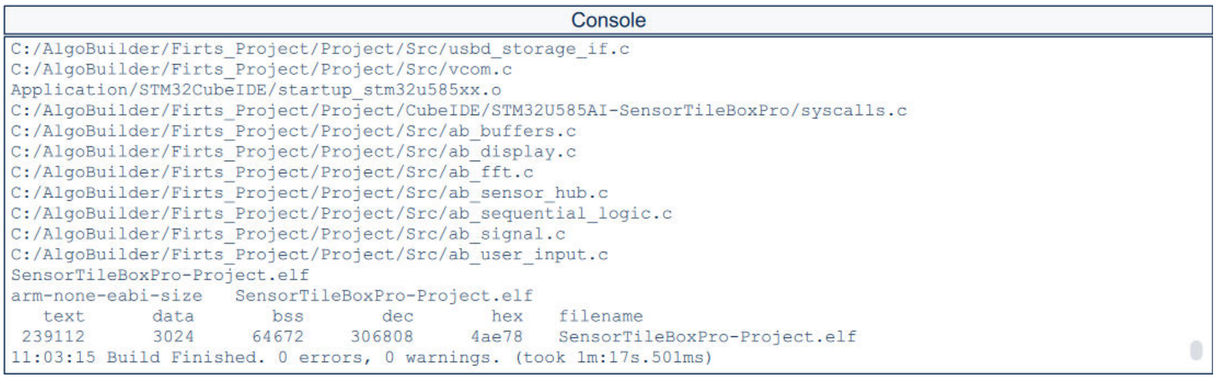


```
#include "algo_builder.h"

const char Identification_String[] = "ID_STRING:First_Design.json,On-line";

/* GENERATED CODE START - Variables */
void *Sensor_Hub_1_out;
float Acceleration_1_data[3];

/* GENERATED CODE END - Variables */

/* GENERATED CODE START - Functions */
/* GENERATED CODE END - Functions */

/* GENERATED CODE START - Display Info */
sDISPLAY_INFO display_info_list[] = {
{INFO_TYPE_GRAPH,1,3,VAR_TYPE_FLOAT,0,"graph|Acceleration|g|1|19|accX|accY|accZ||||1",0},
{0,0,0,0,0,0,0}};
/* GENERATED CODE END - Display Info */

/* GENERATED CODE START - Init */
void AB_Init(void)
{
  Sensor_Hub_Init(0, 50, 0, 1);
  Accelero_Init();
  Message_Length = 12;
}
/* GENERATED CODE END - Init */

/* GENERATED CODE START - Main loop */
void AB_Handler(void)
{
  Sensor_Hub_Handler(&Sensor_Hub_1_out);
  Accelero_Sensor_GetData(Sensor_Hub_1_out, Acceleration_1_data);
  Display_Update(Acceleration_1_data, &display_info_list[0]);
}
/* GENERATED CODE END - Main loop */
```

Note: *In case the firmware template in the target directory is accidentally broken or deleted, you can invoke reinitialization of the firmware template by clicking on the icon (Initialize Project Directory).*

Step 11. Click on the icon (Build) to call the external compiler to build the firmware project and generate a binary file for the STM32 microcontroller. The console shows an output from the compiler. Once the compilation finishes, a “Build Process Finished” message appears. If there is no error message from the compiler, the firmware is ready to be programmed in the target board.

Figure 120. Compiler output



```
C:/AlgoBuilder/Firts_Project/Project/Src/usbd_storage_if.c
C:/AlgoBuilder/Firts_Project/Project/Src/vcom.c
Application/STM32CubeIDE/startup_stm32u585xx.o
C:/AlgoBuilder/Firts_Project/Project/CubeIDE/STM32U585AI-SensorTileBoxPro/syscalls.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_buffers.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_display.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_fft.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_sensor_hub.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_sequential_logic.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_signal.c
C:/AlgoBuilder/Firts_Project/Project/Src/ab_user_input.c
SensorTileBoxPro-Project.elf
arm-none-eabi-size   SensorTileBoxPro-Project.elf
   text       data       bss       dec       hex    filename
 239112       3024     64672    306808     4ae78    SensorTileBoxPro-Project.elf
11:03:15 Build Finished. 0 errors, 0 warnings. (took 1m:17s.501ms)
```

7.18 Programming the target

The connected target can be programmed directly from the AlgoBuilder interface. After a successful build of the firmware, the target can be programmed by clicking on the icon (Program target by automatically selected method).

The following programming methods are supported:

- STLINK interface
- DFU (device firmware upgrade)
- Copy to flash drive

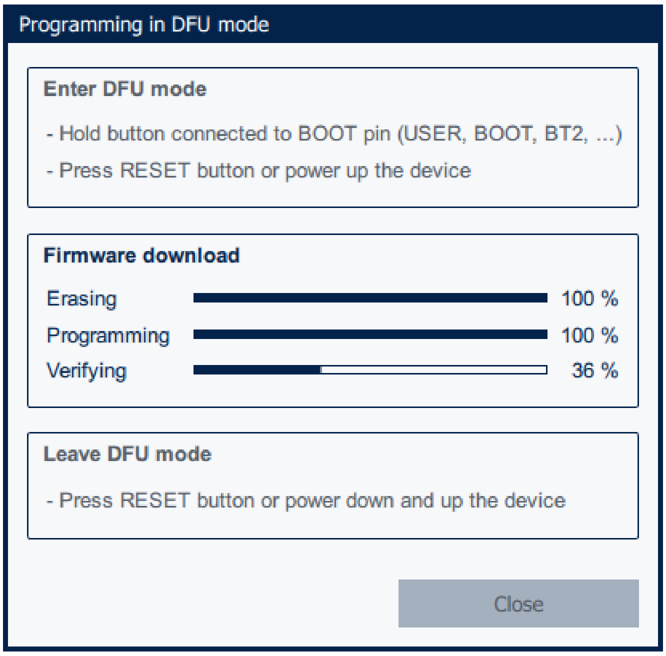
The STM32CubeProgrammer CLI application is used to program the STM32 microcontroller with an STLINK or DFU interface. The path to the STM32CubeProgrammer CLI application must be set in the MEMS Studio settings in the [**External Tools**] page. Copying to the flash drive is available for STM32 Nucleo boards and does not require an STM32CubeProgrammer CLI application.

The programming method is automatically selected with the following priority:

1. STLINK interface
2. Copy to flash drive
3. DFU (device firmware upgrade) interface

DFU mode allows programming the target without requiring a programmer. DFU mode is available for devices with a USB interface, for example SensorTile.box Pro. By pressing the [**Program**] button, a dedicated window for DFU is opened. There are two options for switching the device to DFU mode. The procedures are described in the window. After the device is switched to DFU mode, the memory is automatically erased and programmed by the new firmware.

Figure 121. **Programming target with DFU interface**



Programming in DFU mode

Enter DFU mode

- Hold button connected to BOOT pin (USER, BOOT, BT2, ...)
- Press RESET button or power up the device

Firmware download

Erasing 100 %
Programming 100 %
Verifying 36 %

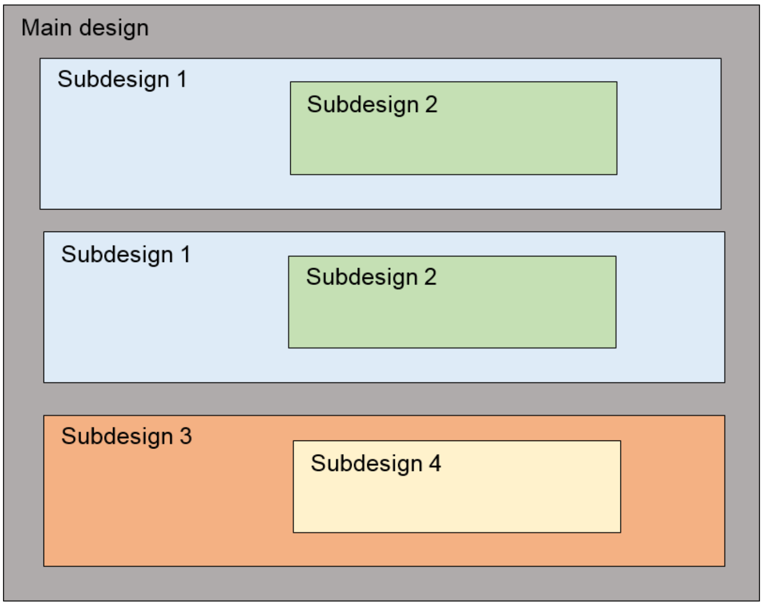
Leave DFU mode

- Press RESET button or power down and up the device

7.19 Subdesign

AlgoBuilder offers the possibility to create a multilevel design. This feature allows encapsulating part of the design into a standalone part called subdesign. This subdesign is represented by a single function block and can be used multiple times in the main design and in all other designs. The subdesign can be shared between users. The subdesigns significantly increase the clarity of a highly complex project.

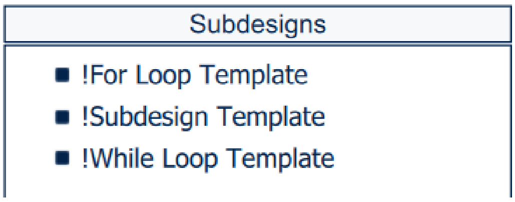
Figure 122. **Principle of multilevel design**



The subdesign allows implementing loops. By default AlgoBuilder offers three templates for subdesign creation:

- [**!Subdesign Template**]: a generic empty subdesign
- [**!For Loop Template**]: a subdesign intended for a loop, which is used if the number of iterations is known before entering the loop
- [**!While Loop Template**]: a subdesign intended for a loop, which is executed until a defined condition is valid

Figure 123. **Subdesigns dock**



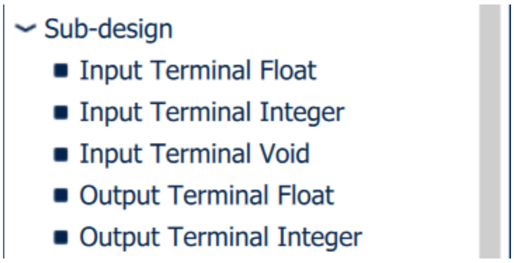
Subdesigns

- !For Loop Template
- !Subdesign Template
- !While Loop Template

Subdesigns can be created by double-clicking on the particular template. Existing subdesigns, listed in the [**Subdesigns**] dock or used in the design, can be opened in the same way. If a new or an existing subdesign is open, AlgoBuilder creates a dedicated tab in the workspace.

The subdesign can be saved in the same way as the main design by clicking on the icon 💾 (Save Design) or 💾(Save Design As). The subdesign can then be used in the main design or other subdesign. To use the subdesign, drag and drop the particular item from the [**Subdesigns**] dock to the workspace. To be able to connect a subdesign with another function block, input and output terminals must be defined for each subdesign. The terminals can be added from the [**Subdesign**] library, which is active only if a subdesign is being edited.

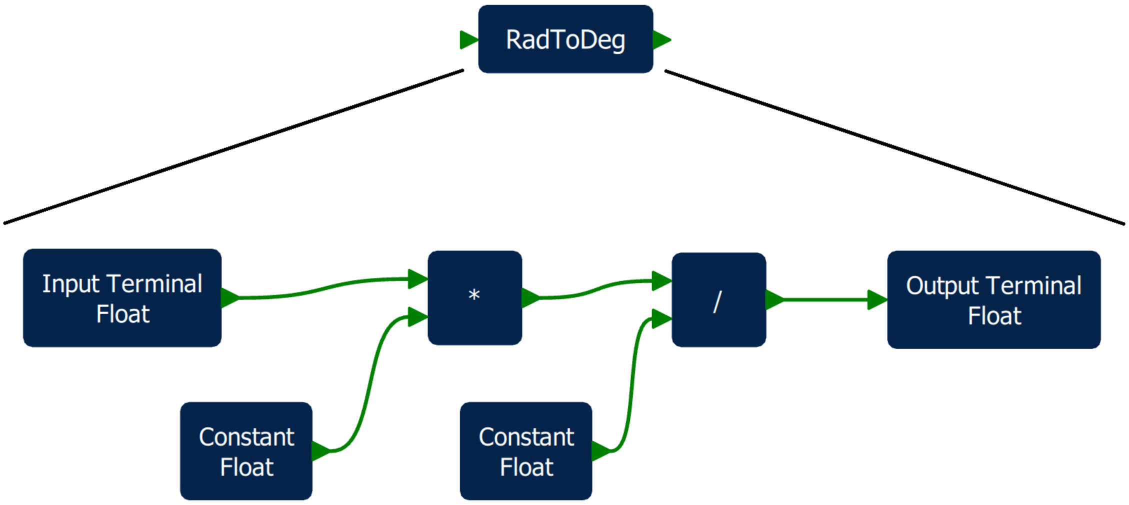
Figure 124. **Subdesign terminals**



- Sub-design
  - Input Terminal Float
  - Input Terminal Integer
  - Input Terminal Void
  - Output Terminal Float
  - Output Terminal Integer

Each terminal has three properties: size, name, and description. The size and name must be defined, moreover the name must be unique in the subdesign. The description is optional. In the graphical design, the subdesign is represented by the same rectangle with inputs and outputs as function blocks.

Figure 125. **Example of a subdesign block and its content**



Note: The following two cases of a subdesign are not allowed:

- *A subdesign shall not be embedded within itself as this would create recursive calls and an infinite loop. This is prevented by checking the subdesign name.*
- *A subdesign 2 is permitted to be embedded within a subdesign 1 (refer to Figure 122. Principle of multilevel design), but subdesign 1 shall not be further embedded in the subroutine.*

The templates for the [**for**] and [**while**] loop contain several function blocks that are mandatory. These blocks cannot be deleted. Mandatory function blocks consist of the following:

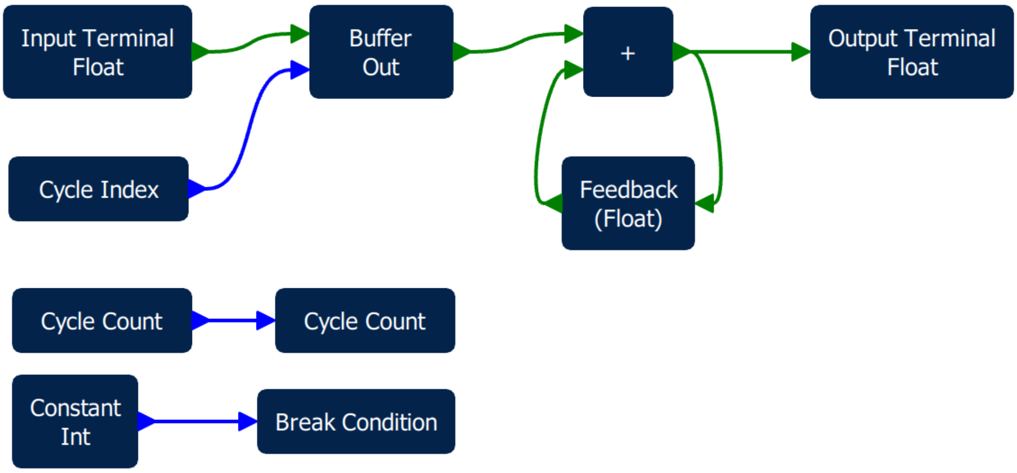
[**for**] loop:

- [**Cycle Count**] (input): defines the number of iterations that are executed
- [**Cycle Index**] (output): returns the number of current iterations
- [**Break Condition**] (input): allows terminating the loop execution before reaching the cycle count

[**while**] loop:

- [**Cycle Index**] (output): returns the number of current iterations
- [**Break Condition**] (input): terminates the loop execution

Figure 126. **Example of loop (calculates the sum of all items in the input buffer)**



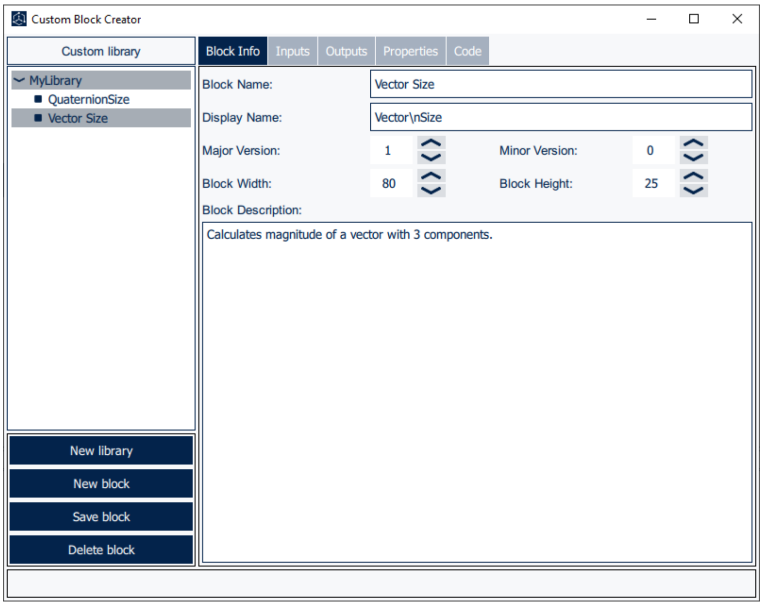
7.20 Custom Block Creator

AlgoBuilder offers a Custom Block Creator that allows creating user-defined function blocks. The [**Custom Block Creator**] can be opened from the toolbar by pressing the button. User-defined function blocks are stored in the user libraries, which are located in the user's home directory \STMicroelectronics\MEMS Studio\algobuilder\library. The Custom Block Creator also offers the possibility to edit or delete an already existing custom function block and custom libraries.

The custom block configuration is divided into several sections. In the [**Block Info**] section, [**Block Name**], [**Display Name**], [**Major Version**], [**Minor Version**], and [**Block Description**] can be defined.

*Note: [**Display Name**] can be redivided into several lines using **\n** separator.*

Figure 127. **Custom Block Creator - Block Info**



Custom Block Creator

Block Name: Vector Size

Display Name: Vector\nSize

Major Version: 1

Minor Version: 0

Block Width: 80

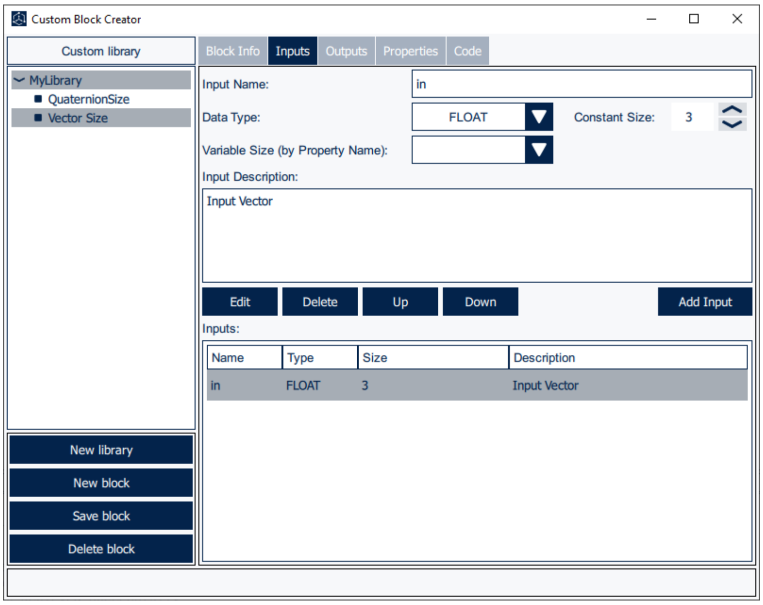
Block Height: 25

Block Description:

Calculates magnitude of a vector with 3 components.

In the [**Inputs**] section, [**Input Name**], [**Data Type**], [**Constant Size**], [**Variable Size**], and [**Input Description**] can be defined. The input parameters as well as the input order can be modified.

Figure 128. **Custom Block Creator - Inputs**



Input Name: in

Data Type: FLOAT   Constant Size: 3

Variable Size (by Property Name):

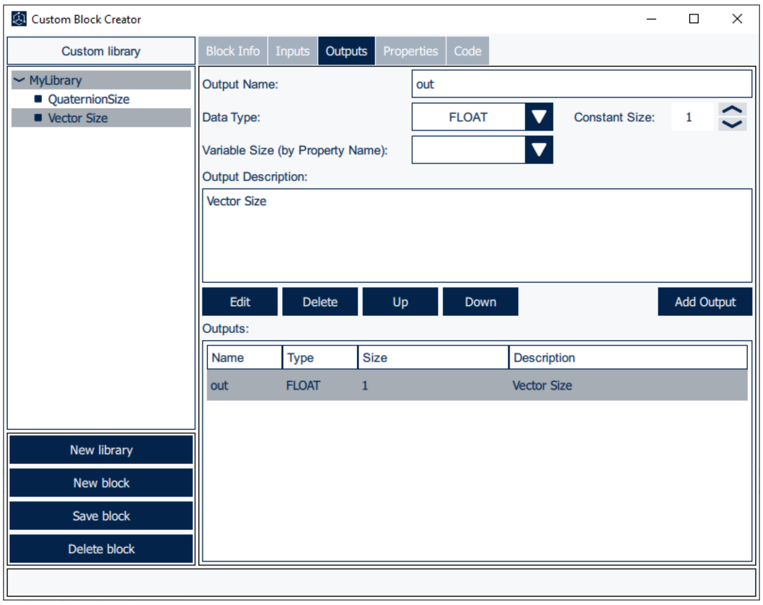
Input Description:
Input Vector

Inputs:

Name	Type	Size	Description
in	FLOAT	3	Input Vector

In the [**Outputs**] section, [**Output Name**], [**Data Type**], [**Constant Size**], [**Variable Size**], and [**Output Description**] can be defined. The output parameters as well as the output order can be modified.

Figure 129. **Custom Block Creator - Outputs**



Output Name: out

Data Type: FLOAT   Constant Size: 1

Variable Size (by Property Name):

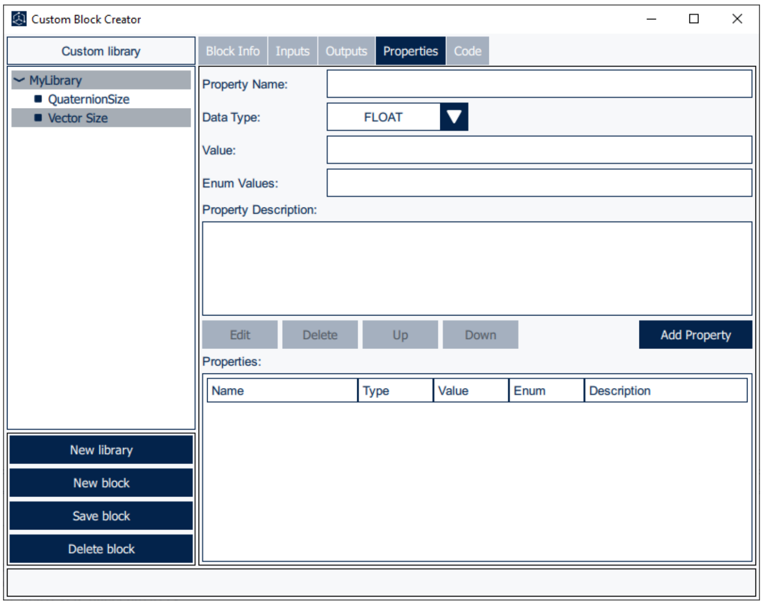
Output Description:
Vector Size

Outputs:

Name	Type	Size	Description
out	FLOAT	1	Vector Size

In the [**Properties**] section, [**Property Name**], [**Data Type**], [**Value**] (or [**Enum Values**]), and [**Property Description**] can be defined. The property parameters as well as the property order can be modified.

Figure 130. **Custom Block Creator - Properties**



Property Name:

Data Type: FLOAT

Value:

Enum Values:

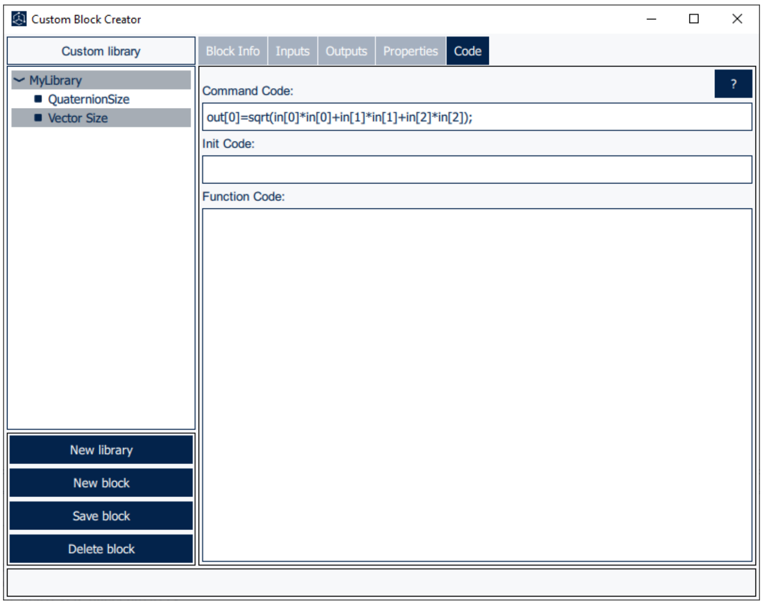
Property Description:

Properties:

Name	Type	Value	Enum	Description

In the [**Code**] section, a C code that represents the function block functionality can be entered. The input and output are referenced in C code using NAME[index] where NAME is the name of the input or output and index is the number of the item in the array. All inputs and outputs are represented by array so the index is mandatory even if only one item is in the array. Properties are scalar so the index is not used and only the property name is used as the reference.

Figure 131. **Custom Block Creator - Code**



Command Code:

```
out[0]=sqrt(in[0]*in[0]+in[1]*in[1]+in[2]*in[2]);
```

Init Code:

Function Code:

8 Firmware programming

The [**Firmware Programming**] page offers quick development board (STM32 microcontroller) programming in the example to update firmware in the ProfiMEMS board. The following programming methods are supported:

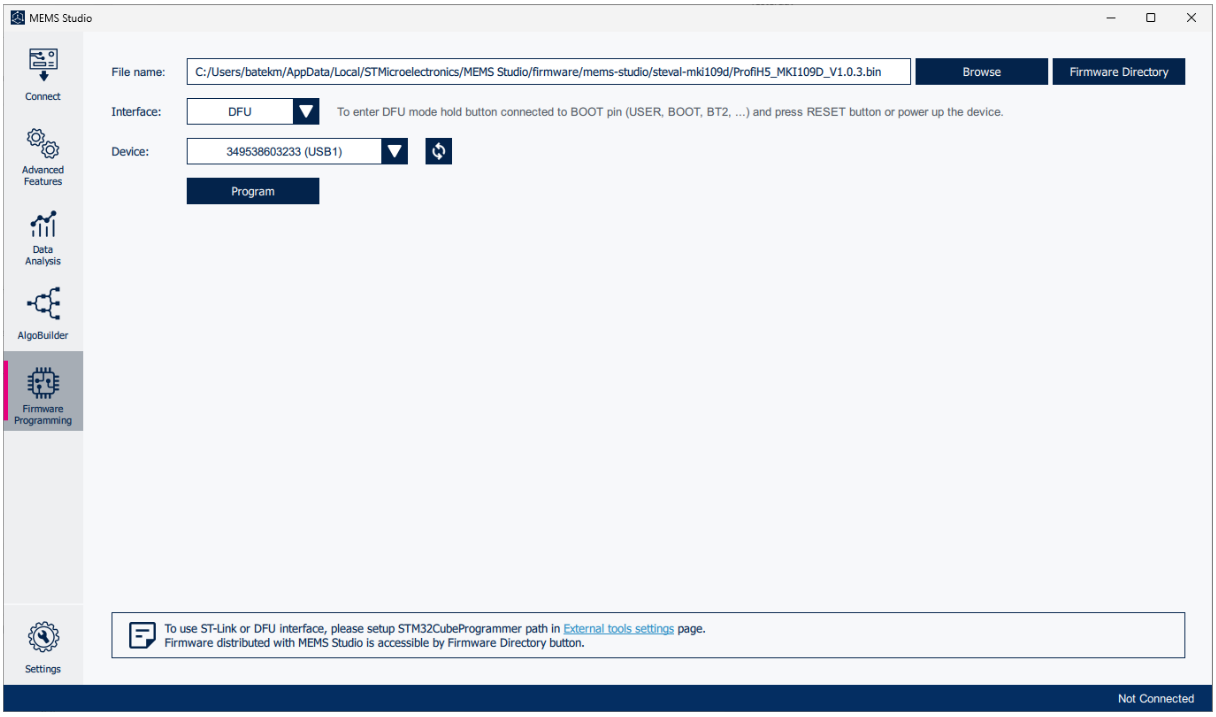
- STLINK interface
- DFU (device firmware upgrade)
- Mass storage

The STM32CubeProgrammer CLI application is used to program the STM32 microcontroller with an STLINK or DFU interface. The path to the STM32CubeProgrammer CLI application must be set in the MEMS Studio settings in the [**External Tools**] page. Copying the binary file with the firmware to the mass storage drive is available for the STM32 Nucleo boards and does not require the STM32CubeProgrammer CLI application.

The user first selects the binary file with the firmware for the STM32 microcontroller using the [**Browse**] button. Then the user selects the programming interface. Based on the selected interface, the list of devices is populated. The list can be updated by pressing the [**Refresh**] button. Programming is executed by clicking on the [**Program**] button.

The [**Firmware Directory**] button offers quick access to the folder where the firmware distributed together with MEMS Studio is located.

Figure 132. **Firmware programming page**



File name: C:/Users/batekm/AppData/Local/STMicroelectronics/MEMS Studio/firmware/mems-studio/steval-mki109d/ProfiH5_MKI109D_V1.0.3.bin

Interface: DFU

To enter DFU mode hold button connected to BOOT pin (USER, BOOT, BT2, ...) and press RESET button or power up the device.

Device: 349538603233 (USB1)

To use ST-Link or DFU interface, please setup STM32CubeProgrammer path in External tools settings page.
Firmware distributed with MEMS Studio is accessible by Firmware Directory button.

Not Connected

DFU mode allows programming the target without requiring a programmer. DFU mode is available for devices with a USB interface, for example the ProfiMEMS board (STEVAL-MKI109D, STEVAL-MKI109V3).

Revision history

Table 9. **Document revision history**

Date	Version	Changes
16-Nov-2023	1	Initial release
26-Mar-2024	2	Updated list of supported devices in Section 2.6: Hardware and firmware compatibility Updated Section 5.2: Machine learning core (MLC) tool
23-May-2024	3	Updated list of supported devices in Section 2.6: Hardware and firmware compatibility Added Section 7.20: Custom Block Creator
23-Jul-2024	4	Updated Section 2.3: External Tools Updated list of supported devices in Section 2.6: Hardware and firmware compatibility Updated Section 3: Sensor evaluation Updated Section 5: Advanced features Added Section 5.4: ISPU Model Converter Updated most of the figures to reflect the latest MEMS Studio application
18-Nov-2024	5	Updated Section 1: Overview Updated Section 2.4: External Tools Updated Section 2.7: Running the application for the first time Updated Section 2.8: Hardware and firmware compatibility Updated Section 3: Sensor evaluation Updated Section 5.2: Machine learning core (MLC) tool Updated Section 5.5: ISPU Model Converter Added Section 5.6: IR Algorithms Tuning
10-Apr-2025	6	Added Section 2.2: myST Login Updated Section 2.3: Application settings Updated Section 2.5: Updater settings Added Section 2.6: Network Settings Updated Section 2.7: Running the application for the first time Updated Section 2.8: Hardware and firmware compatibility Updated Section 3: Sensor evaluation Updated Section 5.1: Finite state machine (FSM) tool Updated Section 5.2: Machine learning core (MLC) tool Added Section 5.3: Merge MLC + FSM tool Updated Section 5.4: Pedometer Updated Section 5.5: ISPU Model Converter Added Section 5.7: Configuration Convertor Updated Section 6.1: Time domain Updated Section 6.2: Frequency domain Updated Section 7.15: Finite state machine (FSM) and machine learning core (MLC) Updated Section 7.16: Intelligent sensor processing unit (ISPU)
14-May-2025	7	Updated Section 2.7: Running the application for the first time Updated Section 2.8: Hardware and firmware compatibility Updated Section 3: Sensor evaluation

Date	Version	Changes
		Updated Section 6.1: Time domain
31-Oct-2025	8	Updated Section 2.8: Hardware and firmware compatibility

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