DVK91235 busbar

Coreless Current Sensor Development Kit

Application Note

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Scope

The DVK has been engineered to enable comprehensive performance evaluation of the sensor's capabilities. The following Application Note outlines the components within the MLX91235 Development-Kit and aims to provide valuable guidance for the utilization of the DVK.

This application note is divided as following:

Introduction
A short presentation of the MLX91235 main features and of the coreless technology introduce the DVK purpose

Part I - Hardware
The MLX91235 Development-Kit (DVK) comprises a motherboard with a miro-controller, a daughterboard with a soldered MLX91235 IC and the elements required to make a current measurement up to 500A RMS. In this first part, a full description of the DVK hardware is given

Part II - Software
The second part explain the software in great details: software layers implemented in the motherboard with a block diagram, full GUI description, elaboration of calibration steps and advanced description of safety features

Closing chapters
Hardware/software/documentation revisions

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Introduction

The MLX91235 is a smart coreless high speed current sensor, part of the Melexis Gen3 portfolio. The term “coreless” refers to the integration of the current sensor function without any magnetic concentrator, in opposition to IMC-Hall and Conventional-Hall systems, relying on ferromagnetic “U-shields” and “C-cores”, respectively. The coreless solution is stray-field immune as the magnetic field measurement is differential, relying on two Hall elements distant of 2.5mm. This DVK is a plug-and-play hardware and software solution that allows to evaluate:

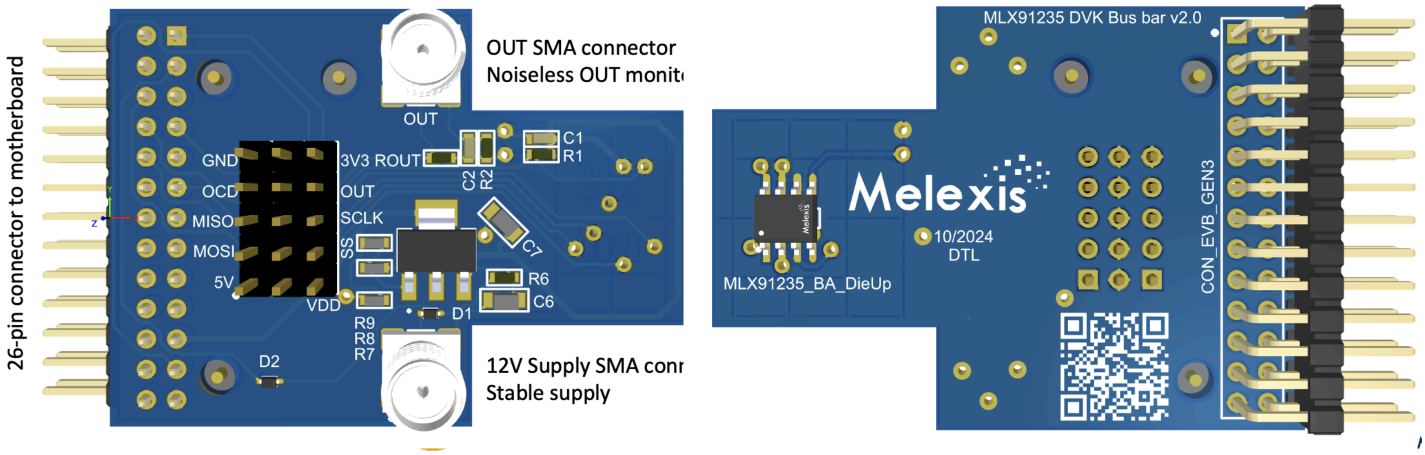
- The MLX91235: SPI communication with calibration of the offset, sensitivity, and OCD as well as advanced safety features: diagnostic and self-test step response.
- The coreless technology: independently of the IC, the coreless technology can be evaluated in terms of amount of signal measured, resilience to mechanical tolerances, thermal dissipation, etc. The DVK has been made to be used in any setups, including demanding conditions (e.g., 800V SiC inverter)

Part I - Hardware

Being a plug-and-play solution, the DVK contains everything needed to connect and program the IC as well as to assemble the IC on the given current conductor. The daughterboard can also be assembled with any other current conductor or plastic holder.

Daughterboard

Top view | **Bottom view**



The daughterboard contains:

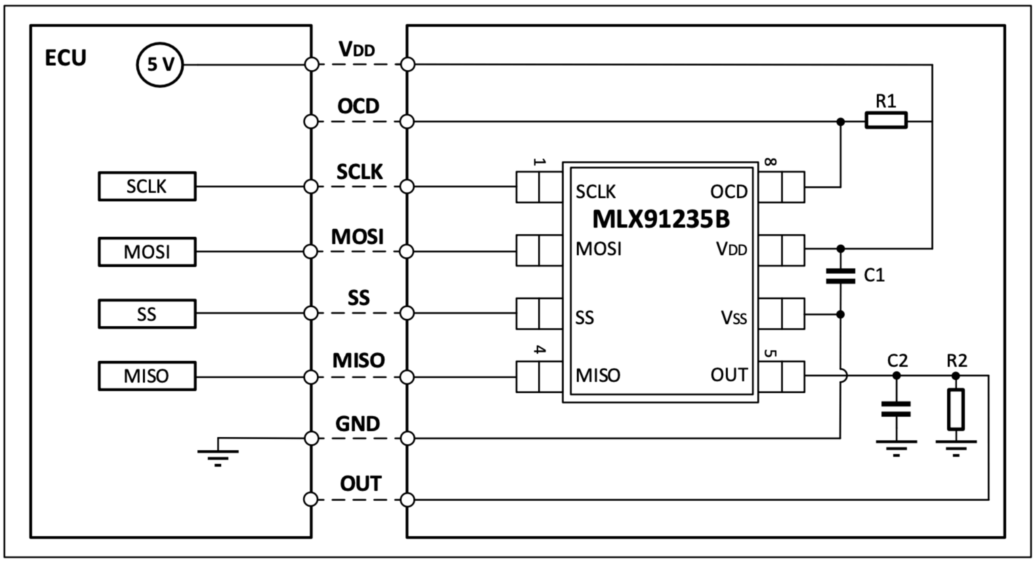
- 1 MLX91235 IC, soldered on the back face (more information about the IC can be found in the "IC revision" section)
- 1 SMA connector for shielded 12V external supply connection
- 1 SMA connector for shielded OUT readings
- 10-pin header for direct IC pin access and supply monitoring
- 26-pin connector to the motherboard

The daughterboard can be used in standalone (for example once implemented in a custom setup) with an independent 12V supply thanks to 12V-to-5V and 12V-to-3.3V regulator. The 12V supply can also be used to bypass the supply from the motherboard if it is needed to keep the SPI communication with the IC while being in a noisy environment (for instance to try out the self-test step response feature). In the second case, a parameter has to be set in GUI (explained in the section "Main window") to disable the supply from the motherboard. The regulator will ensure that a stable 5V or 3.3V is given to the IC.

Important note: when an external supply is used, the output of the sensor should be read via the SMA connector, not via the GUI.

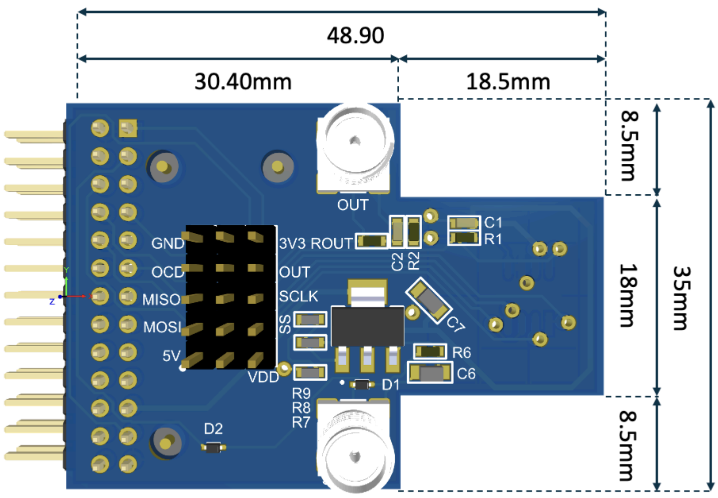
Regarding the 10-pin header, the "3V3" and "5V" pins can be used to monitor the IC supply (5V or 3.3V depending on the IC version) when a 12-V external supply is connected to the SUPPLY SMA connector. The other 8 pins are directly connected to the IC pins, depending on their name.

Pinout and application diagram:



Part	Description	Value	Unit
C1	Supply capacitor, EMC	220	nF
C2 (CL)	Capacitive Load, for optimal noise management	470	pF
R1	OCD pull-up	100	kΩ
R2	Pull-down to VSS	100	kΩ

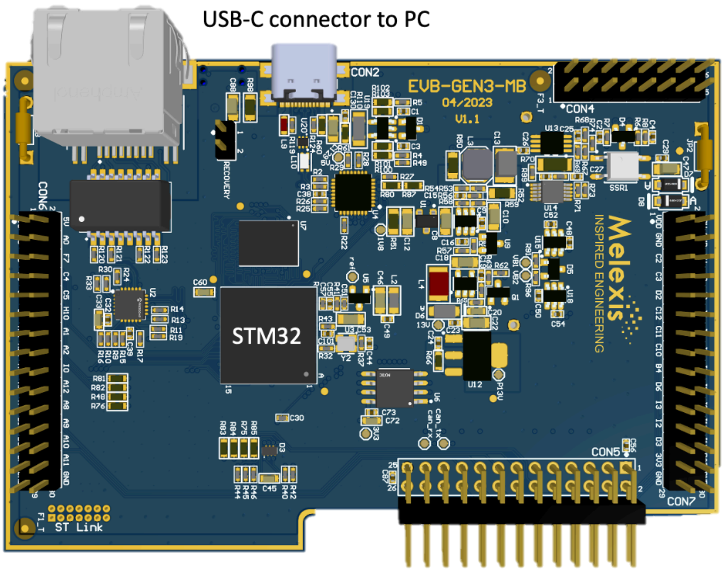
If the PCB were to be evaluated in a custom setup, perhaps custom parts need to be developed (e.g., a plastic holder). For such purpose, the PCB dimensions are given below:



Motherboard

Top view

USB-C connector to PC



26-pin connector to daughterboard

The motherboard is used to establish the communication between the IC and the GUI. Important elements are:

- A microcontroller STM32
- 26-pin connector to daughterboard
- USB-C connector to PC

This motherboard can be replaced by a custom board with a microcontroller, as it will eventually be in application. Implementation of the SPI protocol thanks to firmware and library written by Melexis will be the subject of another application note. The software layers implemented in the motherboard are depicted in the section “Block diagram” later in this application note

Current conductor

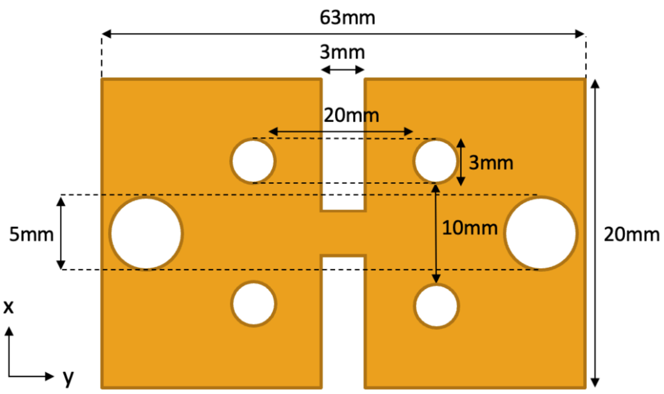
The included current conductor is a copper bus bar with a so-called neckdown, which consists of a lower cross-section part at the center of the bus bar. When a current flows in the bus bar, the neckdown allows to create a magnetic field that can be measured differentially by the coreless IC.

The 3-mm holes are made for correct alignment with the plastic holder (e.g., with the use of plastic screws) and the 5-mm holes at each end of the bus bar allow convenient extra-conductor connection.

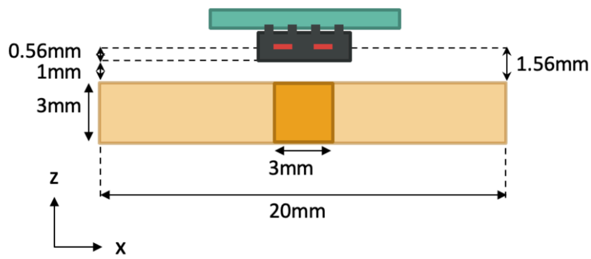
Due to thermal dissipation, Melexis does not recommend currents higher than 500A RMS.

The conductor dimensions along with the sensor position are displayed below:

Top view



Cross-section



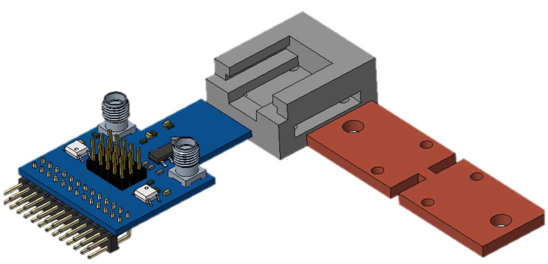
Plastic holder and assembly

The plastic holder can be assembled with the daughterboard and the current conductor. It is designed so that the sensor fits perfectly in the center of the current conductor.

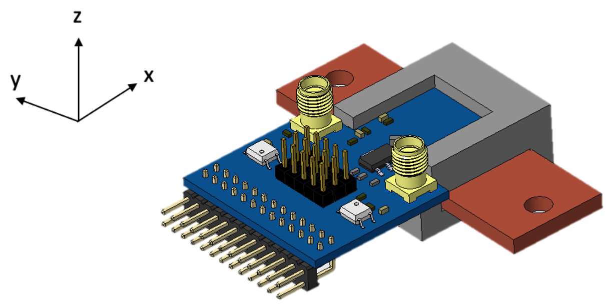
Once assembled, the sensor is not visible, being in the back face of the PCB, directly facing the conductor. The distance from the IC top mold compound to the bus bar is 1mm and the distance from the Hall elements to the bus bar is 1.56mm.

The assembly of the plastic holder, daughterboard and current conductor is displayed below:

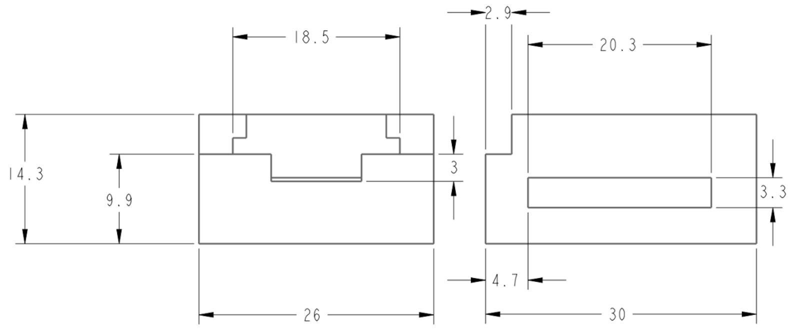
Exploded view



Assembled



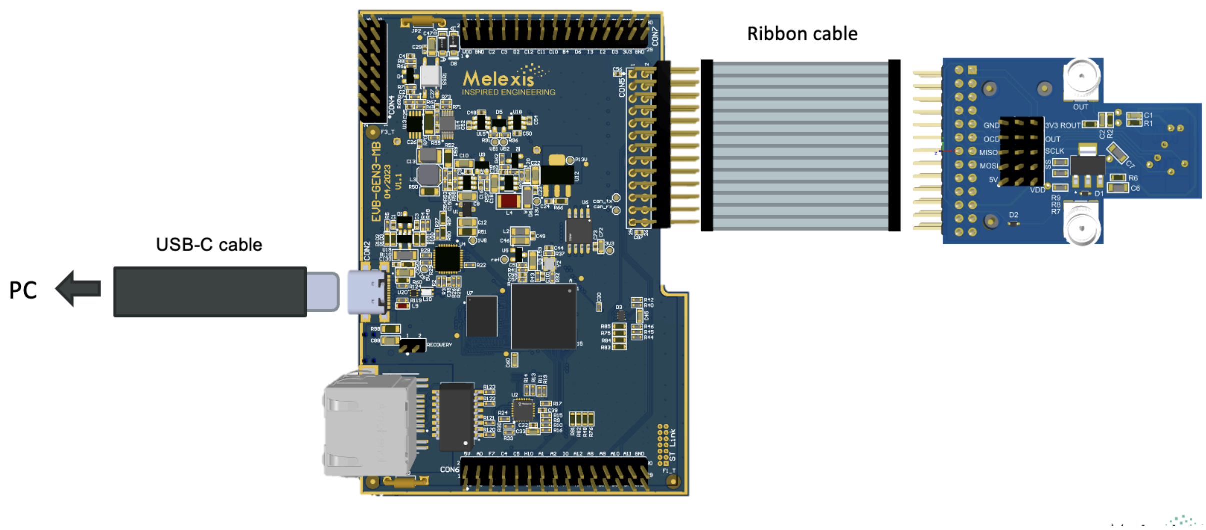
The plastic holder dimensions are, in mm:



Cable and connections

The connection between the daughterboard and the motherboard can be done with the provided ribbon cable. The USB-C cable is used to connect the PC.

The ribbon cable should be straight when the boards are both seen from the top, as shown below:



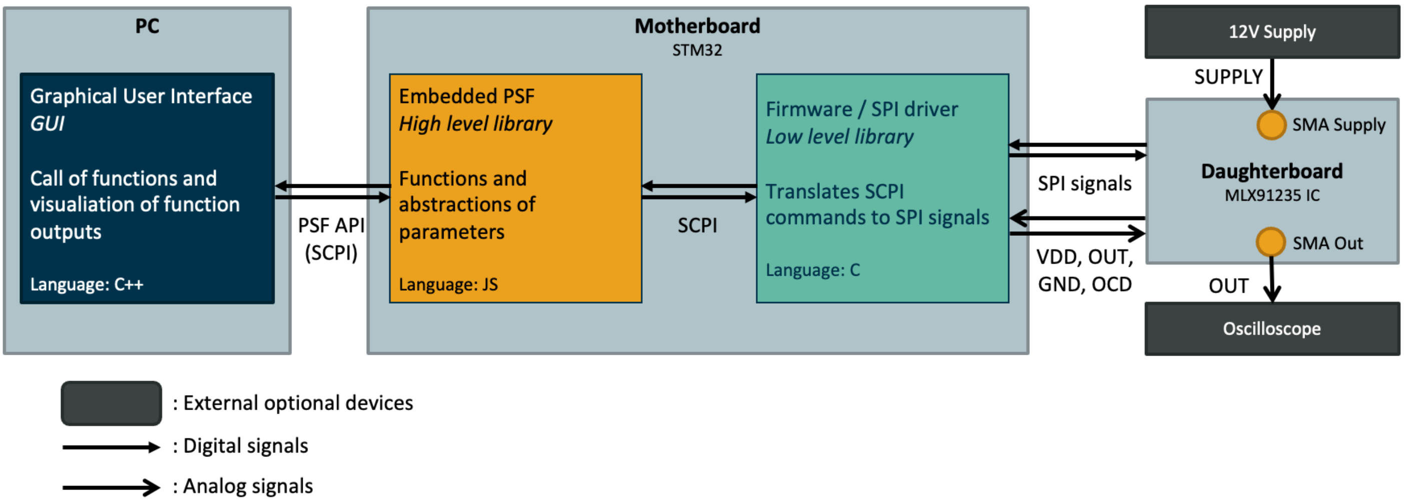
The 26-pin header pins that are needed to communicate with the IC are displayed in the below table:

Parameter	VDD	GND	OUT	OCD	MOSI	MISO	SCLK	SS
Pin	21	2, 25	23	7	6	11	8	10

Part II - Software

Block diagram

The following block diagram shows the different elements of the DVK along with the different software layers:



The embedded PSF and firmware / SPI driver can be shared on demand in order to facilitate the implementation of the MLX91235 with any microcontroller for any current sensing application.

The SPI protocol used by the MLX91235 is described in the application note “MLX91235 SPI protocol”. "For access, please check with your local representative.

Graphical User Interface (GUI)

Compatibility, installation and connection

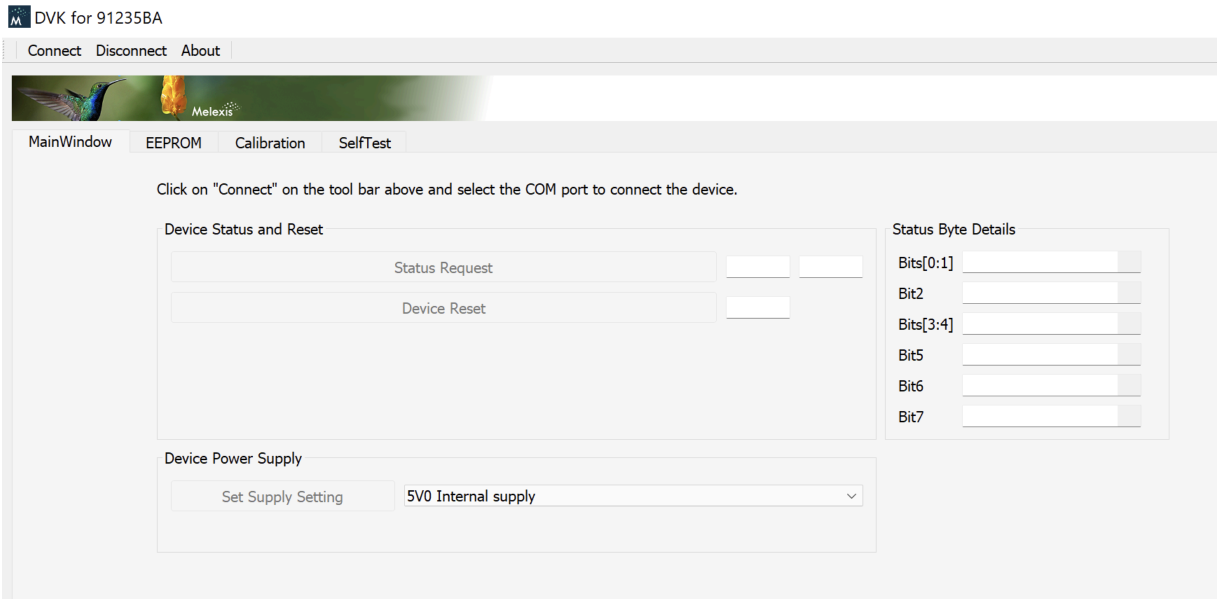
The GUI is compatible with PCs running Windows 10 or higher.

Resolution and sizing of the GUI may depend on the user’s screen size and resolution. If you encounter compatibility issues or any problems using the software, please reach out to your usual Melexis point of contact.

The software and documentation are released on the Melexis software distribution platform: SoftDist. If you have not been granted access to the platform and to the MLX91235 folder yet, please reach out to your usual Melexis point of contact.

The GUI is installed with the single executable “MLX91235_DVK_GUI.exe”. After the connection is done as shown in “Cable and connections”, the GUI can be launched..

Main window



The "Status Request" button can be used to verify that the connection is working properly .

The communication to the IC can be reset with "Device Reset" button. This will abort the communication with the IC and initiate a new one.

If the IC is used in a noisy environment (e.g. inverter setup) but the SPI communication is still desired during the operation of the IC (e.g., to try out the self-test or diagnostic features), it is preferred to use an external 12V supply instead of the supply from the motherboard. In the main window, the "Device Power Supply" parameter should be set to "5V0 external supply". The external supply can be directly plugged to the VDD SMA connector on the daughterboard. The regulator on the daughterboard will ensure that a stable 5V is given to the IC.

Important note: when an external supply is used, the output of the sensor should be read via the SMA connector, not via the GUI.

The status byte represents the current status of the chip itself and information to the current communication frame.

Bit 0-1: Indicates the current running mode of the chip
- 0: Main Application is running
- 1: Memory Access Mode

Bit 3-4: Indicates communication error
- 0: no error
- 1: checksum error
- 2: framing error
  - Frame size mismatch
  - Timeouts
  - Attempts to communicate during SPI blocking time

3: data error

The validity check of the payload fails

- out of address range
- wrong address / key
- unexpected command / key

Bit 5: if 1, indicates that a reset occurred (will be reseted after first master read)

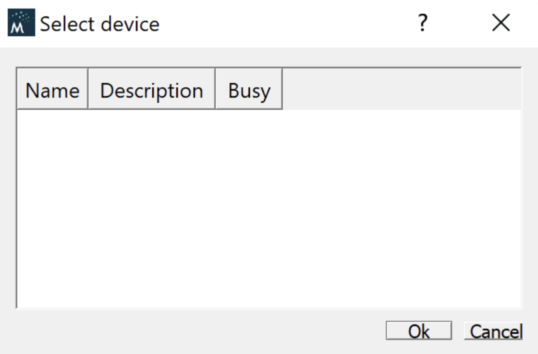
Bit 6: if 1, indicates that the programming of the IC is needed

- Something is wrong with EEPROM data and reprogramming is required.
- Programing session terminated unexpectedly

Bit 7: If 1, indicates that a DTI (Detection Time Interval) error occured

Connect, Disconnect and About

The top bar allows the user to connect and disconnect the IC anywhere in the GUI.



After clicking on “Connect”, a pop-up window will open. The port to which the motherboard is connected should be selected, then clicking on “OK” will establish the connection. If the connection is successful, the pop-window will close without displaying an error message.

The device can be disconnected by clicking on “Disconnect” in the top bar.

The “About” button allows the user to verify the version of the GUI that the computer is running on. If running into issues, the user should first verify that the software version is the latest that can be found on SoftDist.

EEPROM

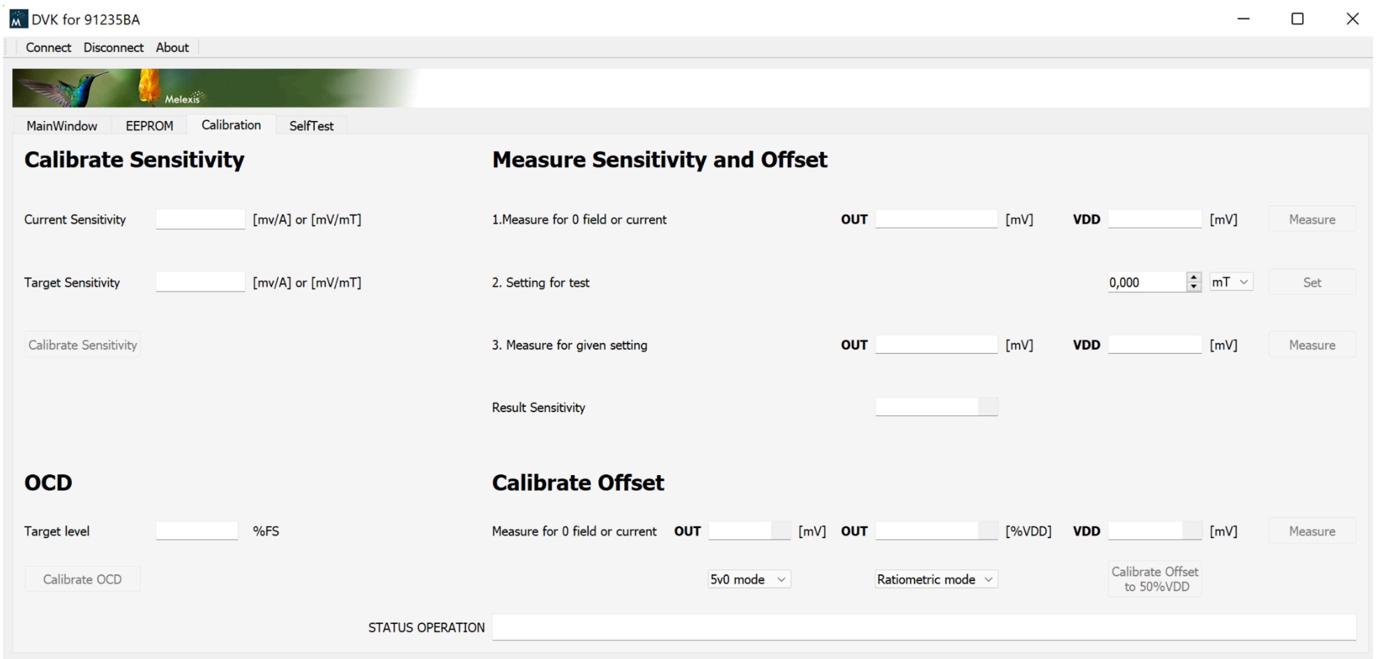
The EEPROM registers can be read and written in this panel. It is advised to first click on “Read EEPROM” before making any changes to save the content of the EEPROM and to avoid writing “0”s.

CUST_LOCK should never be overwritten as it will block the IC

The table below describes the parameters and links them to the relevant section in this application note:

Parameter	Support	Format	Bits	Description	Conversion
HP_SENS_CORR_FRAC	Yes	Signed	13	Fine tuning hall plate sensitivity correction	Included in Melexis SPI driver Used in Sensitivity trimming
OUT_OFFS_CUST	Yes	Signed	11	Output offset customer programmability	Included in Melexis SPI driver Used in Offset (VOQ) trimming
OCD_THR_POS	Yes	Signed	16	Positive threshold for Over Current Detection	Included in Melexis SPI driver Used in OCD trimming
OCD_THR_NEG	Yes	Signed	16	Negative threshold for Over Current Detection	Included in Melexis SPI driver Used in OCD trimming
DGA1_GAIN	Yes	Unsigned	5	Digital gain fine tuning (after compensations)	Included in Melexis SPI driver Used in Sensitivity trimming
DGA0_GAIN	Yes	Unsigned	1	Digital gain (after demodulation)	Included in Melexis SPI driver Used in Sensitivity trimming 0: x2 , 1: x1
FUSA_DAC_CODE_LOW	Yes	Signed	5	FUSA DAC low level for self-test step response	1.87mV/LSB Recommended values: 2 or 3
FUSA_DAC_CODE_HIGH	Yes	Signed	5	FUSA DAC high level for self-test step response	1.87mV/LSB Recommended values: -3 or -2
CUST_CRC	Yes	Unsigned	8	Customer area CRC	
OCD_LEN_MIN	No	Unsigned	5	OCD pulse minimum length	Not supported
OCD_DEB	No	Unsigned	4	OCD debounce time	Not supported
DAC_UNI_BIPB	No	Unsigned	1	DAC unipolar/bipolar mode Unipolar mode not supported	0: Bipolar mode 1: Unipolar mode
APP_FILT_SEL	No	Unsigned	4	Phase-spinning and bandwidth	Fixed to 4 phases spinning, BW=500kHz
OCD_BW	No	Unsigned	2	OCD mode Broken-wire not supported	0: Normal mode 1: Broken wire mode
CUST_LOCK	No			Lock customer EEPROM	SHOULD NEVER BE OVERWRITTEN

Calibration



Note: It is recommended to save the EEPROM content at first start-up, before attempting any trimming.

The DVK allows the user to trim the magnetic parameters of the IC.

Since the MLX91235 has a digital architecture, the trimming is done numerically.

Sensitivity (gain) and offset measurement

The sensitivity and the offset (value of the output at 0 current, also called VOQ) of the IC can be computed by following the steps on the right panel. Two measurements are needed.

1. Make sure no current/magnetic field is applied and click on “Measure” to measure the offset/VOQ.
2. Enter the current [A] or magnetic field [mT] value that will be applied during the second measurement and select the correct unit

   Apply the current [A] or magnetic field [mT] in your setup

3. Click on “Measure”, the software will show the output value

The result sensitivity in [mV/A] or in [mV/mT] is computed and displayed by the software.

The MLX91235 having a ratiometric output, VDD is displayed to have visibility on the variations on the output due to VDD variations. The sensitivity is computed taking into account those VDD variations.

Sensitivity trimming

DISCLAIMER: The sensitivity should not be trimmed to more than 100% or less than 50% of the original trimming. As there is no software control, it is the user's responsibility to respect this requirement. The trimming is done based on the ratio of the current sensitivity and the target sensitivity. This means the ratio can not be less than 0.5 and more than 2.

There are different ways to trim the sensitivity:

- Trimming to the maximum or minimum available sensitivity:
  - Set "Current Sensitivity" to 1
  - Set "Target sensitivity" to 2 (max) or 0.5 (min)
  - Click on "Calibrate sensitivity"
- Trimming based on a given ratio:
  - Knowing the multiplying factor that you need for your application, you can set "Current Sensitivity" to 1 and "Target Sensitivity" to that multiplying factor, between 0.5 and 2
    - For instance, if you need 20% more signal, you can enter "1" in the "Current Sensitivity" and "1.2" in the "Target Sensitivity"
- Trimming to a desired sensitivity
  - Measure the sensitivity as explained in the previous sub-chapter and set "Current Sensitivity" to the value you measured e.g. 4mV/A
  - Set "Target sensitivity" to the desired sensitivity e.g. 7mV/A
  - Click on "Calibrate sensitivity"

Offset (VOQ) trimming

By default, the offset is trimmed to 50%VDD.

- VDD = 5V → VOQ = 2.5V
- VDD = 3.3V → VOQ = 1.65V

OCD trimming

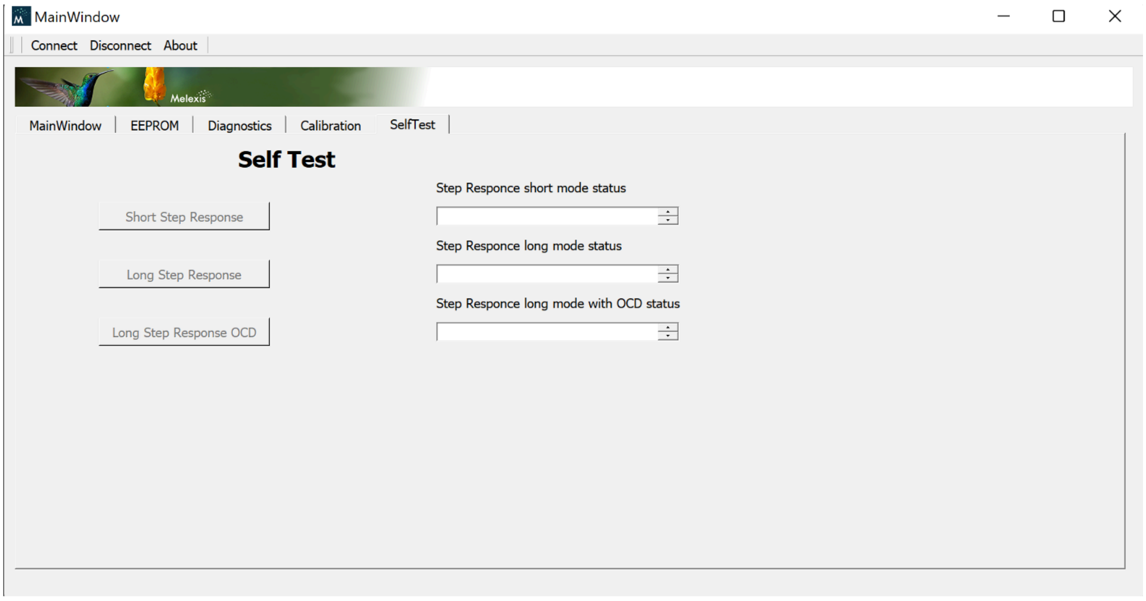
The OCD is trimmed in %FS. The unit "%FS" means "pourcentage of full-scale". The full scale of the IC is the current range that is mapped on the output range of the sensor (from 10%VDD to 90%VDD).

The OCD can not be trimmed to more than +/-150%FS.

To trim the OCD, simply write the desired OCD level in the field "Target level" and click on "Calibrate OCD".

- If the IC is trimmed to 1mV/A and to VDD=5V, the full scale of +/- 2000mV is mapped to a full scale of +/-2000A (+/-100%FS = +/-2000A). If the OCD is trimmed to 150%FS, it will trigger at 3000A (+/- 1%)
- If the IC is trimmed to 2mV/A and to VDD=3.3V, the full scale of +/- 1320 mV is mapped to a measurement of +/-660A (+/-100%FS = +/-660A). If the OCD is trimmed to 150%FS, it will trigger at 990A (+/- 1%)

Self-test step response



The GUI allows passing the self-test commands on demand. The entire sequence has been implemented in the embedded PSF in the motherboard (as illustrated in the Block diagram section), therefore detection of step response time error cannot be done accurately using the GUI (as the timings from the sequence are not explicit)

The status box simply confirms if the sequence has been passed on to the IC properly.

Revisions and changelogs

Date	Revision	Changelogs / Remarks
Nov 5th, 2023	001	First release
Nov 8th, 2023	002	Corrected self-test pulse sequence naming
May 14th, 2024	003	Updated IC pinout and application diagram, added MLX91235A mention
Sep 3rd, 2024	004	Divided the documents in 2 versions: 1 for A-silicon pinout (depreciated) and 1 for B-silicon pinout Added DB26-pin header connections from the motherboard to the daughterboard Updated IC pinout for B-silicon Updated IC application diagram Updated plastic dimensions Removed diagnostics description Updated GUI description Updated status byte description Updated sensitivity trimming chapter Updated offset trimming chapter
November 21st	005	Cosmetical change for product pre-launch

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