Melexis

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14.12.2016

APA, SHU, ROR

Current Sensors
Programming & Calibration

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Calibration Overview

	No calibration/ Blind Calibration	Frontend (sensor-level) Calibration		Backend (MCU-level) Calibration
		PTC mode	MUST mode	
Hardware	None/PTC04+DB	PTC-04, sensor-specific DB		MCU
Accuracy	≈5%	0.1%		ADC resolution
Pros	▪ plug & play ▪ factory TC calibration	▪ accurate analog output ▪ only 3 wires	▪ accurate analog output ▪ VDD=5V	▪ no specific HW ▪ factory TC calibration
Cons	▪ magnetic design ▪ low absolute accuracy	▪ VDD increases to 8V ▪ change from factory calib	▪ 4-wires ▪ change from factory calib	▪ magnetic design should match sensor sensitivity
Sensors	ALL	ALL	91208/09 91216/17	ALL

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Blind calibration

Concept

- The sensitivity of each Sensor is individually factory calibrated, using 2 EEPROM parameters RG and FG (RoughGain, FineGain), to reach the target sensitivity, as defined in the datasheet.

Blind calibration consists in recalibrating parts without performing measurements:

- To do so, it is needed to read and manually change the RG and FG values in the EEPROM.
- These 2 parameters codes for the amplification chain that amplify the signal from the hall plates.
- Modifying RG, FG allow to change the output sensitivity of a sensor.

Note : Blind calibration is not available for 91206/07 because the TC parameters need to be re-trim when RG/FG are changed. See slide 23 for more details.

Typical gains and sensitivities

- RG controls a **non-linear** amplification block
- FG controls a **linear attenuation** block going from 0.5 to 1

- Since all sensors are intrinsically different, the RG and FG values needed to reach the target sensitivity are different from one sensor to the other . However it is possible to relate RG/FG combination to typical sensitivities:

RG code [LSB]	Gain factor
0	1
1	4
2	6.25
3	9
4	12.25
5	20.25
6	30.25
7	49

Table 1: gain factor vs. RG code

FG code [LSB]	Gain factor
0	0.5
512	0.75
1023	1

Table 2: gain factor vs. FG code.

RG [LSB]	FG [LSB]	Sensitivity [mV/mT]			
		91209	91208CAV	91208CAH	91208CAL
1	0	7	13	21	35
1	1023	14	26	42	70
3	0	15	28	45	75
3	1023	30	56	90	150
5	0	32.5	61	87.5	162.5
5	1023	65	122	195	325
7	0	80	150	240	400
7	1023	160	300	480	800

Table 3: typical sensitivity vs. gain settings.

Blind calibration flow: Example

A sensor 91208CAH (S= 100mV/mT) needs to be recalibrated to 120mV/mT.
(i.e. 120% of the actual sensitivity)

1) Extraction of RG, FG values from the EEPROM

Results for this specific sensor: RG=3, FG=768

The actual amplification gain is:

$$G = G_{rg} * G_{fg} = 9 * \left(0.5 + \frac{1 - 0.5}{1023 - 0} * (768 - 0)\right) = 7.88$$

2) RG/FG have to be redefined to get a gain of G = 120%*7.88 = 9.46

We choose:

- RG=4 → $G_{rg} = 12.25$
- $G_{fg} = \frac{G}{G_{rg}} = \frac{9.46}{12.25} = 0.772 \rightarrow FG = \frac{0.772-0.5}{0.5} * 1023 = 557$
- **RG = 4, FG = 557**

RG code [LSB]	Gain factor
0	1
1	4
2	6.25
3	9
4	12.25
5	20.25
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7	49

Table 1: gain factor vs. RG code

FG code [LSB]	Gain factor
0	0.5
512	0.75
1023	1

Table 2: gain factor vs. FG code.

FG controls a **linear** attenuator

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Front-end (sensor level) Calibration

Hardware Structure

- Melexis PTC04:

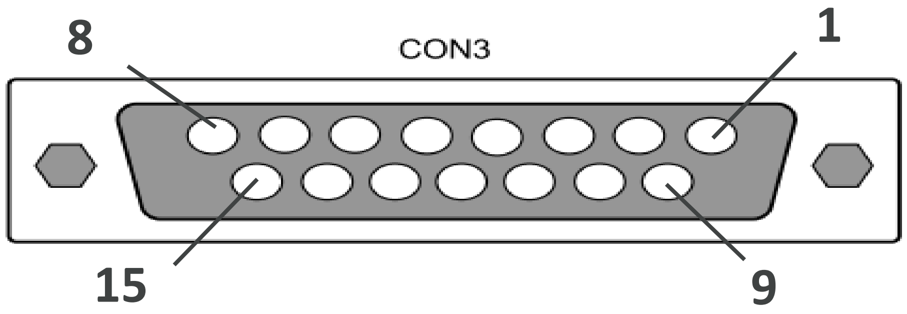
Universal Programmer for Melexis sensors calibration

- Sensor-specific Daughter-Board (DB):

Interface between PTC04 and application connector

Daughter Board	Compatible Current Sensors
PTC04-DB-HALL02	MLX91205
PTC04-DB-HALL03	MLX91206/07
PTC04-DB-HALL05	MLX91210 MLX91208/09 MLX91216/17
PTC04-DB-34103	MLX91220

- Application connector



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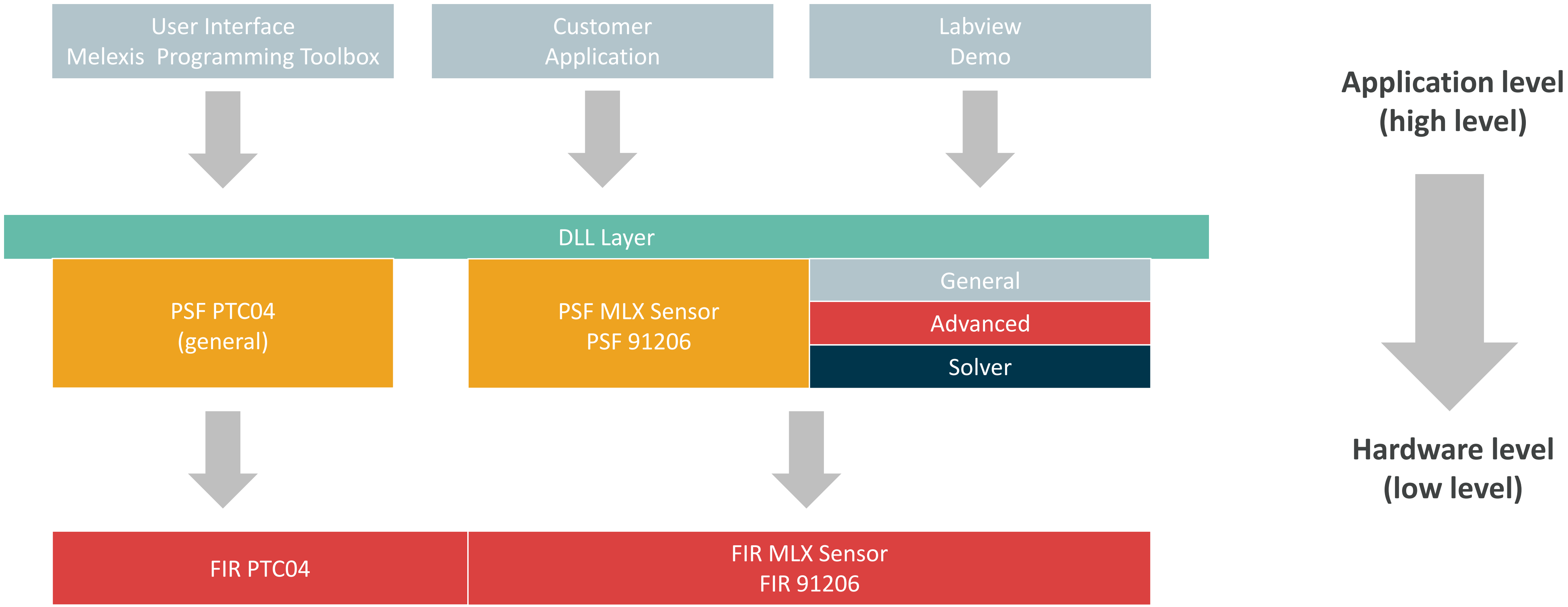
Software structure

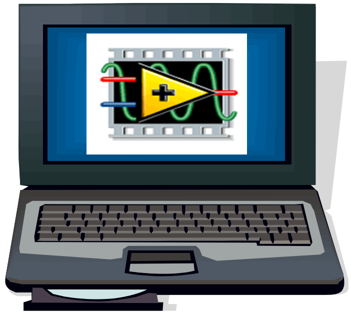


Setup

MLX PTC-04 + Sensor specific DB

Sensor in application

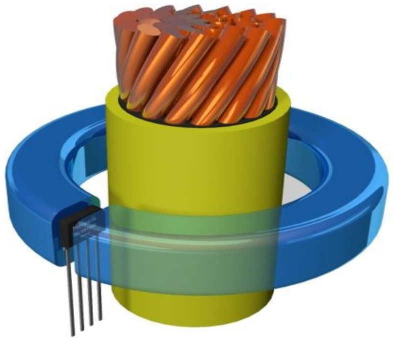
PC



USB/RS232

PTC or MUST mode*

3-wire or 4-wire



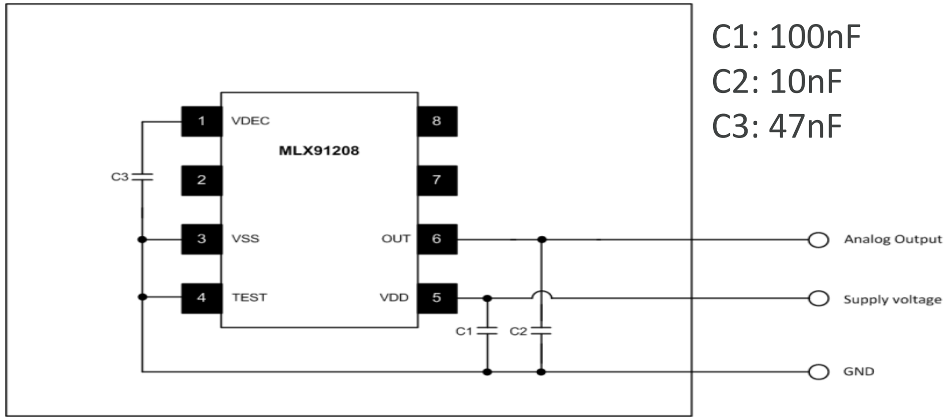
Software in Labview, C/C++, Python, VB, etc.

*To be selected in PSF/UI settings

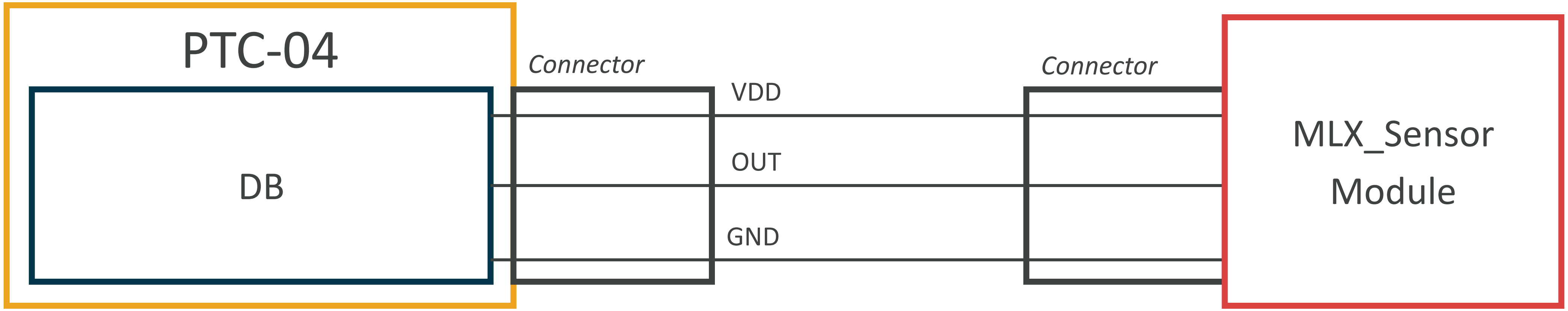
PTC Communication Mode

I. PTC MODE (3-wire) communication:

- Supply during communication: **VDD=8V**
- bi-directional communication on OUT line
- Available for: all current sensors families



C1: 100nF
C2: 10nF
C3: 47nF



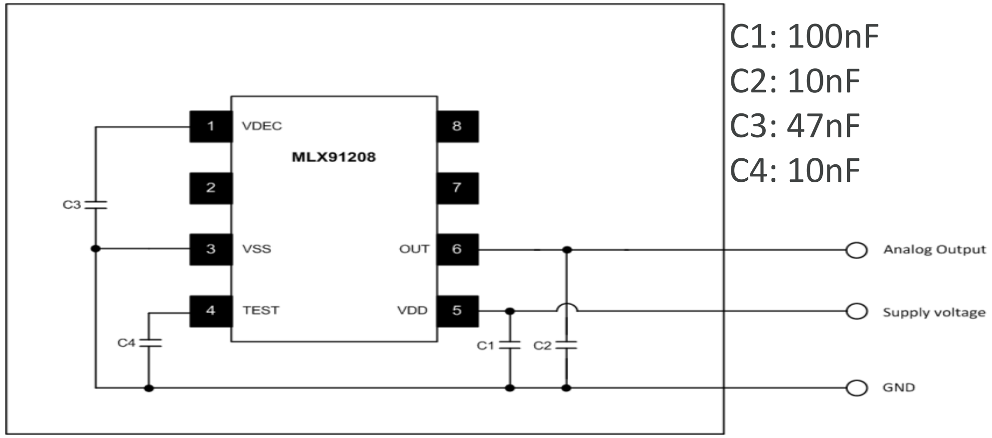
All unused pins (e.g.: TEST/MUST pin) can be connected to GND for better noise and EMC/ESD performance
GND connection of unused pins avoids coupling with the supply and ground loops

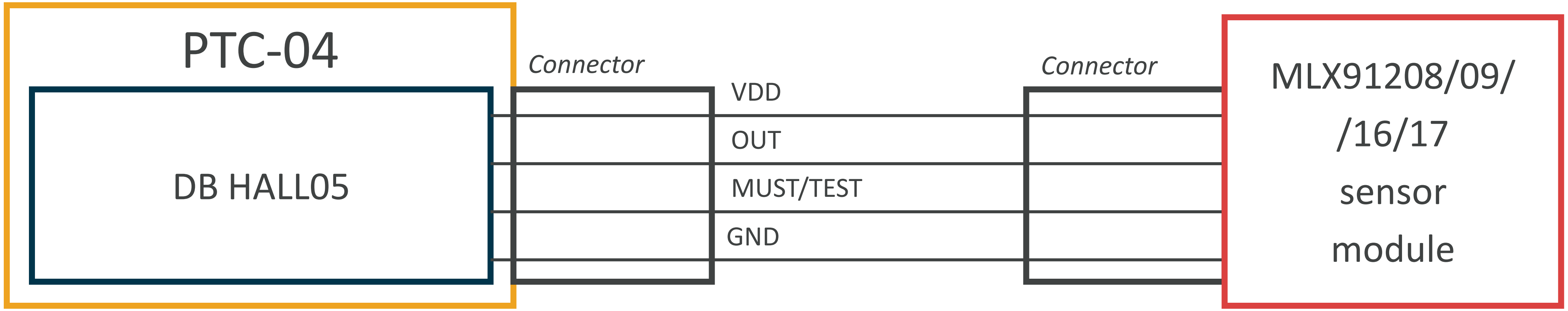
MUST Communication Mode

II. MUST MODE (4-wire) communication:

- Supply during communication: **VDD=5V**
- PTC-04 to sensor: communication on MUST line
- Sensors to PTC-04: communication on OUT line
- Available for: MLX91208/09/16/17

C1: 100nF
C2: 10nF
C3: 47nF
C4: 10nF

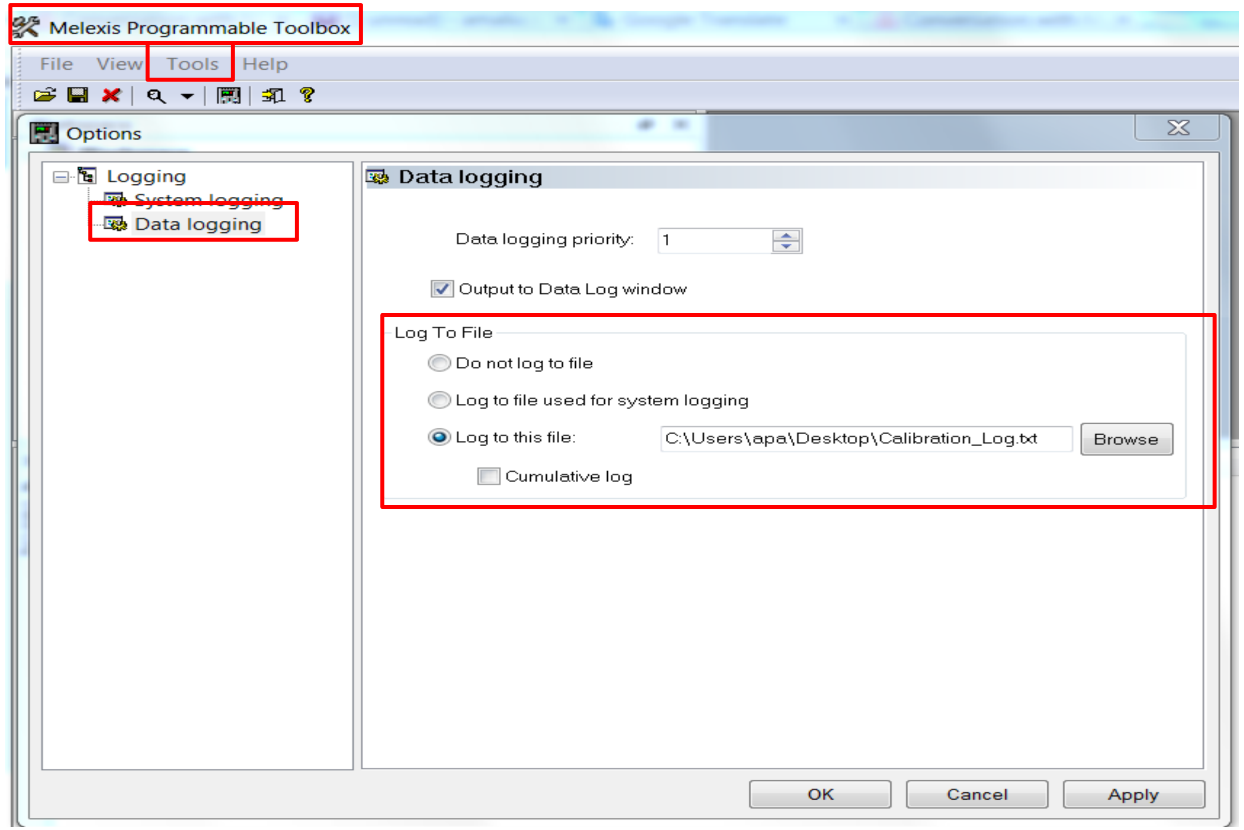




All unused pins (e.g.: TEST/MUST pin) can be connected to GND for better noise and EMC/ESD performance
GND connection of unused pins avoids coupling with the supply and ground loops

Calibration Log

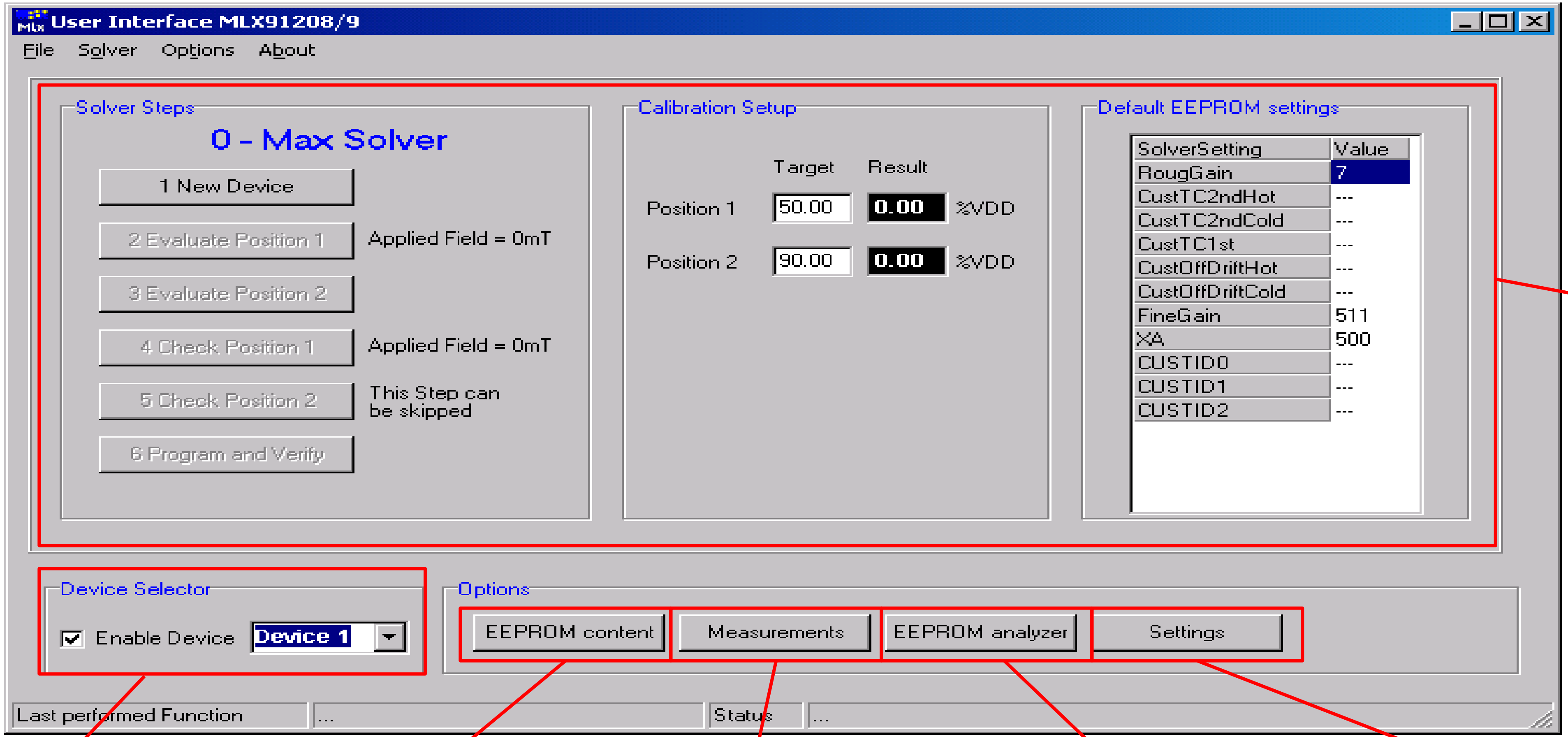
Before starting the Calibration Flow



Optional:
Keep a copy of Calibration measures, steps, calculations

By default, the option“Do not log to file” is ticked

User interface



Solver

multiple device selector

show/edit memory content

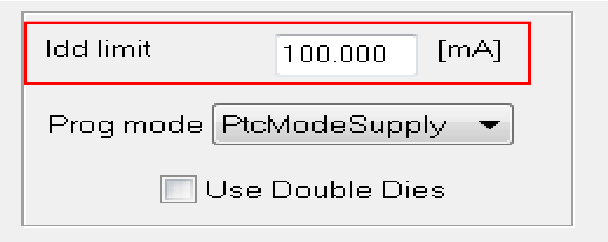
monitor sensor output

check binary memory content

edit general settings

Multiple Devices

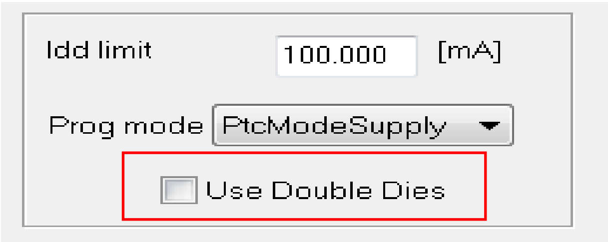
The software can store EEPROM information for up to 16 devices simultaneously. Each device can be selected/enabled with the device selector. However, only 1 device can be physically connected to the OUT1 line of the PTC04. An **external** hardware switch is required for this purpose. The solver will ask the user to switch between the devices at each step of the calibration process.



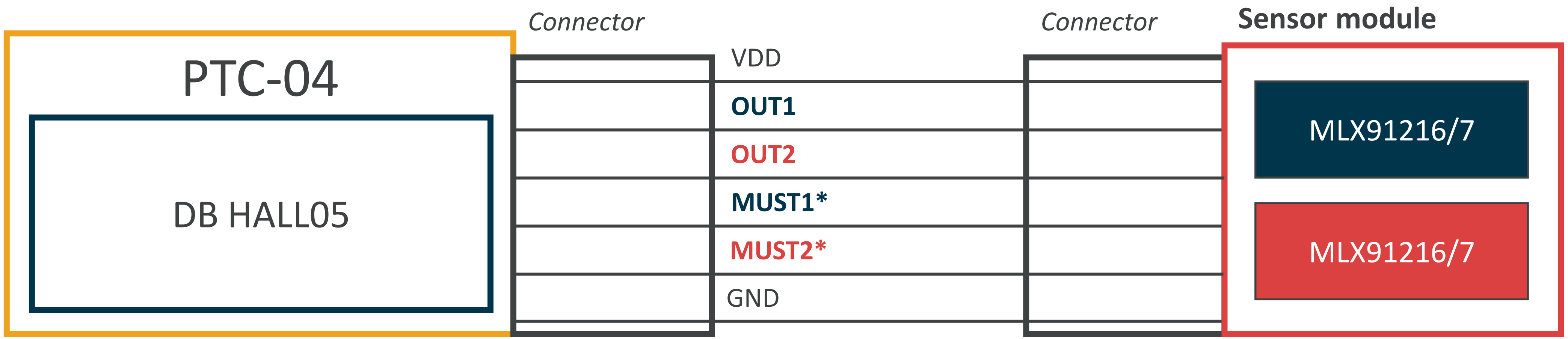
During communication, the current consumption increases significantly (short spikes/bursts). The default Idd limit of 100mA is sufficient for 2-3 devices only. For instance, a limit of 300mA is required for 8 devices (multi-socket).

Multiple Devices

Dual Die Configuration



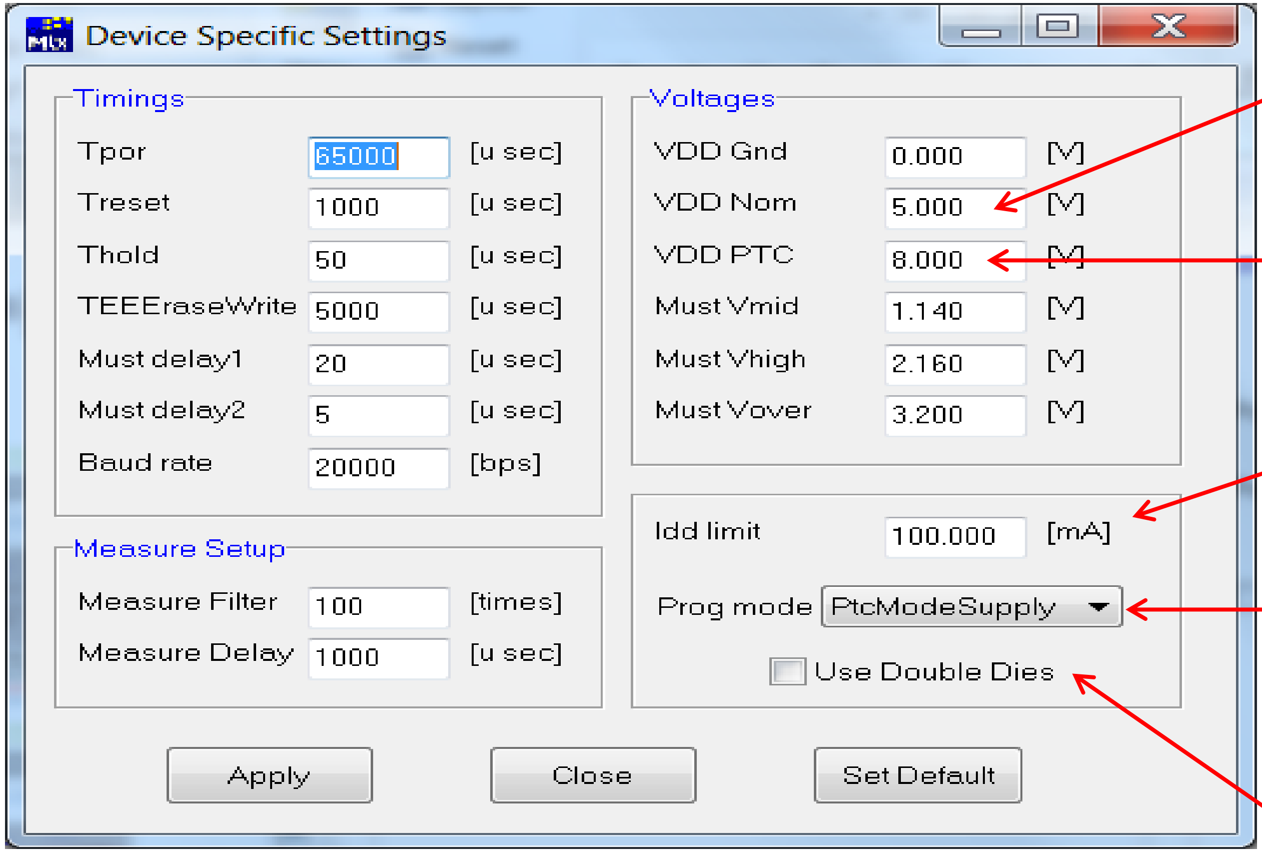
The “Use Double Dies” option in the “Settings” window allows to connect 2 devices to the PTC04 simultaneously. When this option is selected, “Device 1” is on OUT1 and “Device 2” is on OUT2.



*The MUST pins are only required for MUST mode communication.

Settings

Some of the most important settings are described here.



nominal chip supply (Vdd)

voltage level for «PtcMode» programming

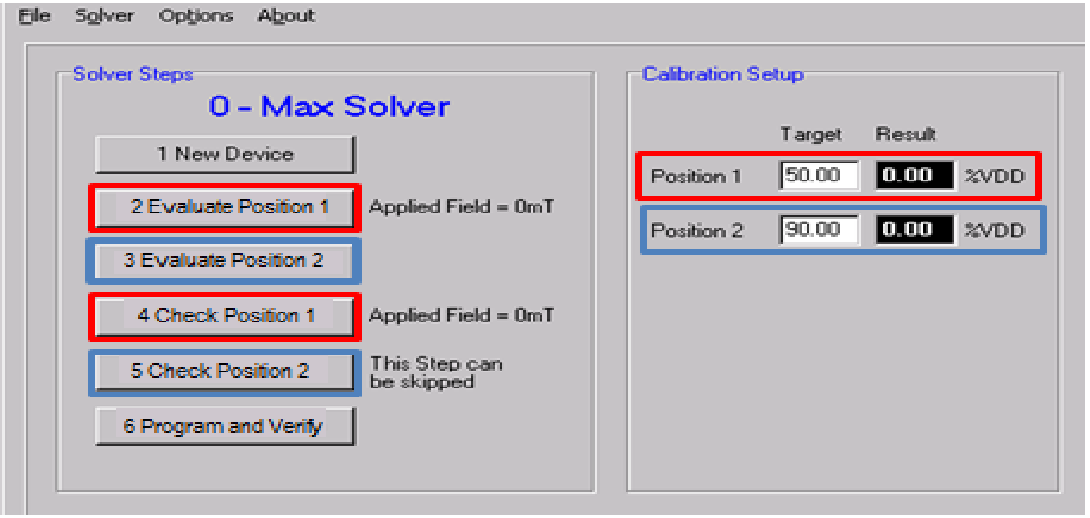
limit for PTC supply current (increase to supply several devices in parallel)

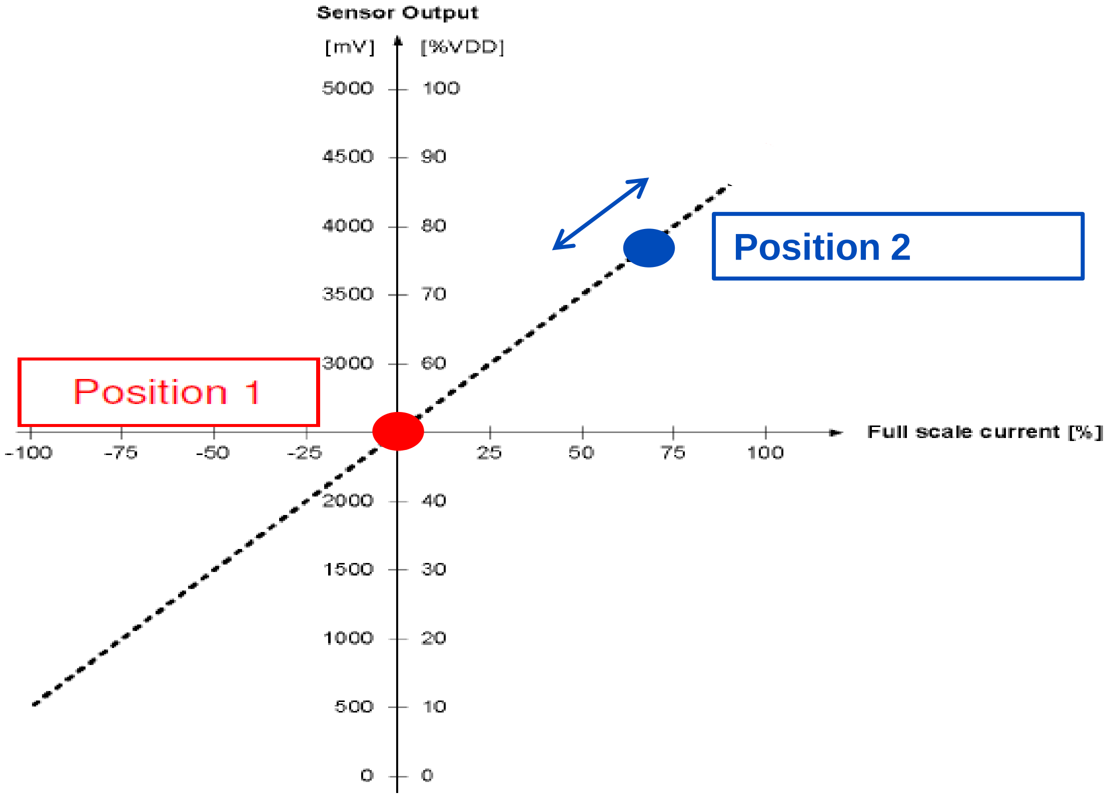
select **programming mode**:

- PtcModeSupply: use Vdd=8V to put chip in communication mode
- MUSTMode: use MUST/test pin to communicate (at nominal Vdd)

program two devices in parallel on OUT1 and OUT2

0-Max Solver





Concept: The solver starts from the preset gain and, if required, it sweeps through all allowed RG settings (max. +/- 1 for 91206/07)

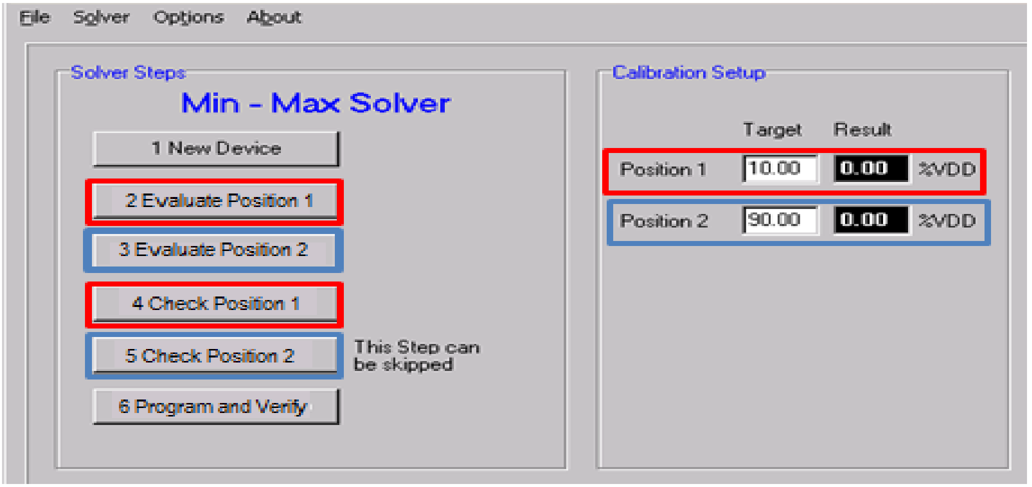
Two reference positions are needed for offset and gain parameters calibration

1) Zero field/current
2) Positive reference field/current

High accuracy for offset trimming

More sensitive to hysteresis and saturation

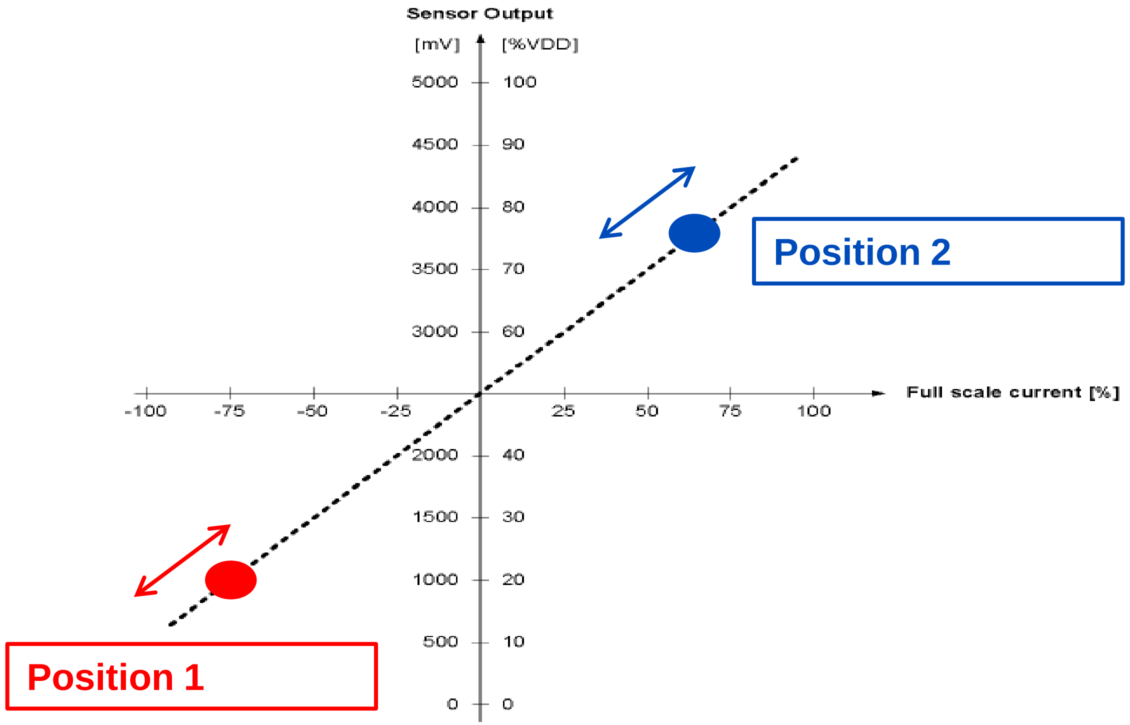
Min-Max Solver



Concept: The solver starts from the preset gain and decreases RG only if the output is clamped at Position 1. No RG adjustment is possible at position 2.

Two reference positions are needed for offset and gain parameters calibration

1) Negative reference field/current
2) Positive reference field/current



Low hysteresis, accurate fit

Offset is adjusted by interpolation

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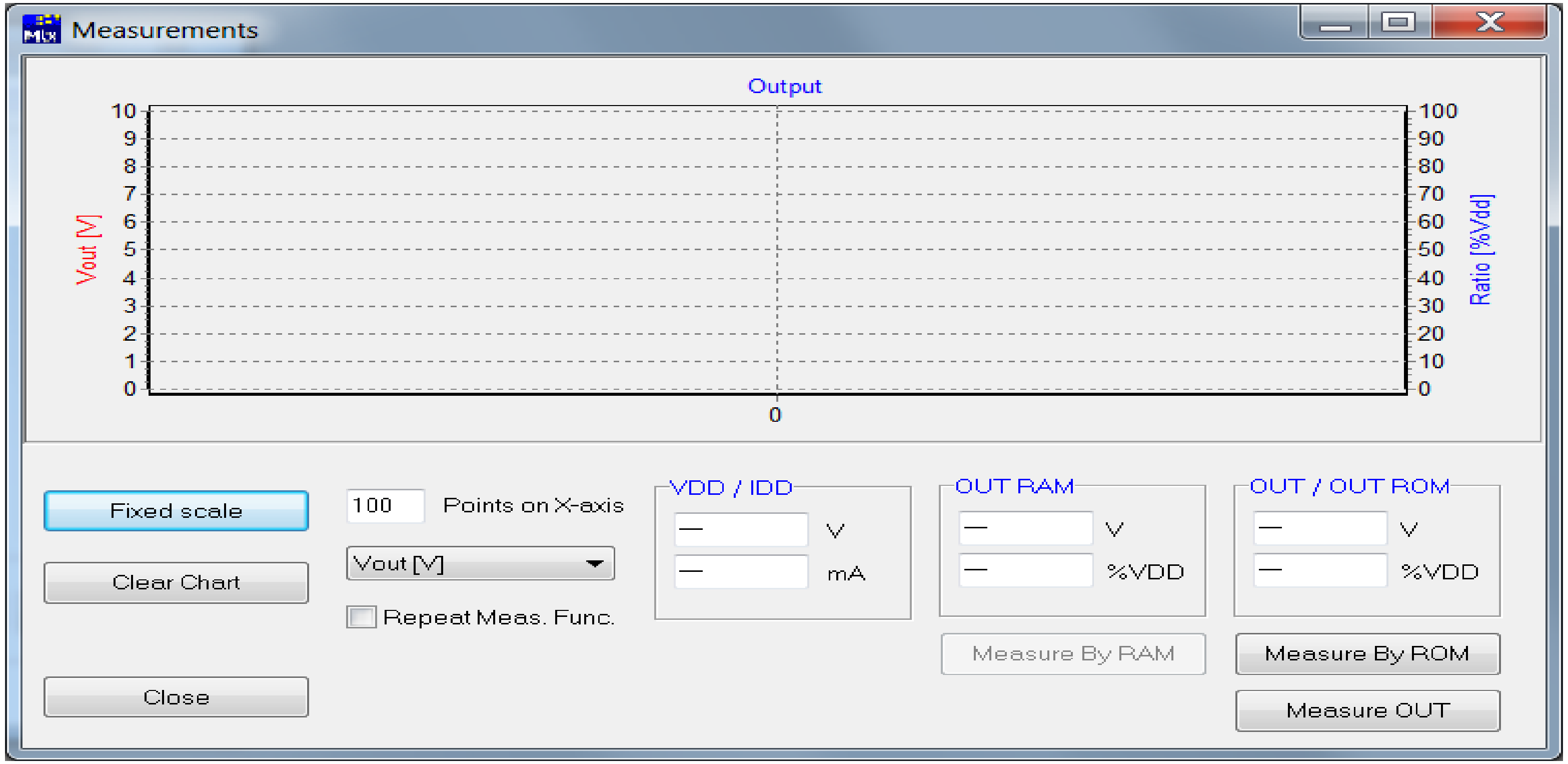
Measurements window

This window allows to monitor sensor supply and output. It is good practice to check that VDD and IDD are in the expected range before starting to program the sensor.

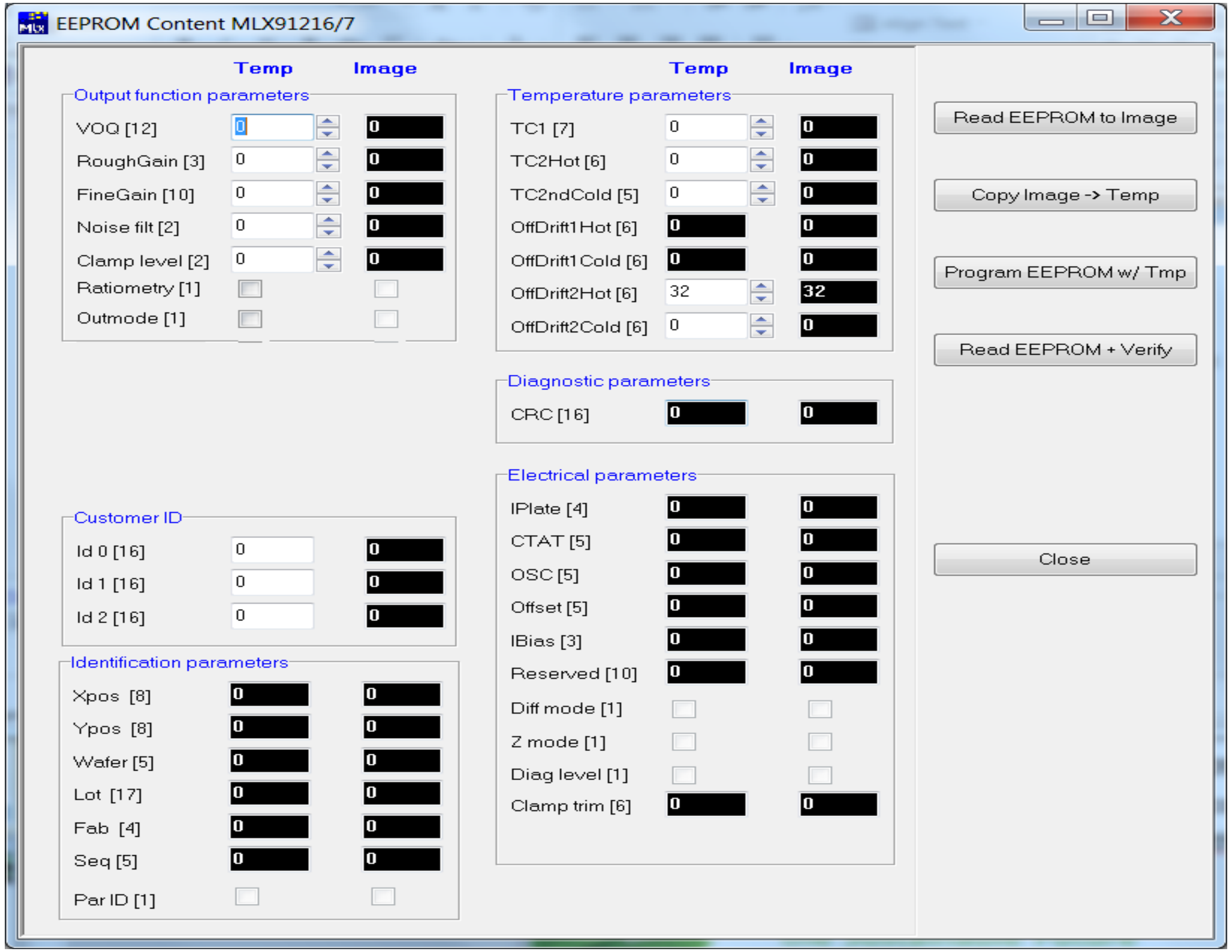


measure by RAM
program RAM with values from the TEMP register, then measure output

measure by ROM
reset device to program RAM with EEPROM values, then measure output

measure OUT
perform single measurement

EEPROM window



To change the value of one or several EEPROM parameter(s), always perform the following steps:

→ read EEPROM to Image
→ copy Image to Temp
→ edit the Temp value(s)
→ program EEPROM with Temp
→ read EEPROM and verify

The final verification step is required to readback the updated CRC code.

MLX91206 TC Particularity

- For MLX91206 only, the temperature compensation parameters TC1, TC2COLD, TC2HOT, OFFDRIFT COLD & HOT are re-trimmed when the gain (RG, FG) is changed in the application.

1) During Final Test

- Find optimal TC parameters for RG nominal, RG+1 and RG-1
- Store optimal TC parameters for nominal RG in EEPROM
- Store "delta TC" parameters for RG+1 and RG-1 in unused EEPROM bits

2) During EOL Front-End Calibration

- Find optimal gain settings based on applied field/current
- If RG and/or FG has changed: correct TC parameters for new gain settings based on "delta TC" parameters and look-up tables built based on the Final Test results

Note: the algorithm is based on relative gain/TC changes, therefore it will not work correctly if someone manually changes gain or TC between steps 1 and 2. If a setting is manually changed at any stage, the complete calibration is lost.

Back-end (MCU level) Calibration

MCU Correction Concept

- **Best Suited for:** multi-sensors applications, i.e. on power distribution units, where typically 12 to 24 sensors are on the same PCB in order to monitor the current of each channel.

All Melexis current sensors are already factory-calibrated over temperature!

- **The concept :**
  - assemble the factory-calibrated sensors on each channel
  - apply a reference current (for which a precise output is targeted) on each channel and store the output of each sensor
  - compare the obtained output to the reference one and calculate the required corrective factor
  - store and apply the corrective factor in the MCU

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