Melexis

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2 March 2020

Revision 1.5

# Current Sensors
# Programming and 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<br>▪ factory TC calibration | ▪ accurate analog output<br>▪ only 3 wires | ▪ accurate analog output<br>▪ VDD=5V | ▪ no specific HW<br>▪ factory TC calibration |
| **Cons** | ▪ magnetic design<br>▪ low absolute accuracy | ▪ VDD increases to 8V<br>▪ change from factory calib | ▪ 4-wires<br>▪ change from factory calib | ▪ magnetic design should match sensor sensitivity |
| **Sensors** | ALL | ALL | 91208/09<br>91216/17 | ALL |

# Blind Calibration

# Concept

The sensitivity of each sensor is individually factory calibrated, using 2 EEPROM parameters RG and FG (Rough Gain, Fine Gain), to reach the target sensitivity, as defined in the datasheet.

Blind calibration consists in recalibrating the sensitivity of the part without performing measurements.

- The operation is accomplished  by reading and manually changing the RG and FG values stored in the in the EEPROM.
- These  2 parameters, codes the amplification chain that amplify the signal from the Hall plates.
- Modifying  RG, FG allows 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-trimmed when RG/FG are changed. See slide 24 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 It’s possible to relate RG/FG combination to typical sensitivities:

| RG [LSB] | FG [LSB] | Sensitivity [mV/mT] | | | |
|---|---|---|---|---|---|
| | | 91209 | 91208CAV | 91208CAH | 91208CAL |
| 1 | 0 | 7 | 11 | 18 | 29 |
| 1 | 1023 | 14 | 22 | 35 | 59 |
| 3 | 0 | 17.5 | 28 | 44 | 73 |
| 3 | 1023 | 35 | 55 | 88 | 147 |
| 5 | 0 | 40.5 | 63 | 101 | 169 |
| 5 | 1023 | 81 | 127 | 203 | 338 |
| 7 | 0 | 95 | 150 | 240 | 400 |
| 7 | 1023 | 190 | 300 | 480 | 800 |

| RG Code [LSB] | Gain Factor |
|---|---|
| 0 | 2 |
| 1 | 3.6 |
| 2 | 6.25 |
| 3 | 9 |
| 4 | 12.4 |
| 5 | 20.7 |
| 6 | 30 |
| 7 | 49 |

Table 1: Gain Factor VS RG Code
(non linear amplifier)

| FG Code [LSB] | Gain Factor |
|---|---|
| 0 | 0.5 |
| 512 | 0.75 |
| 1023 | 1 |

Table 2: Gain Factor VS FG Code
(linear attenuator)

$$Gain\ Factor = 0.5 + (FG\ Code).\frac{0.5}{1023}$$

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# Blind calibration flow: Example

Recalibrate MLX 91208CAH from S= 100 [mV/mT] to 120 [mV/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 → $G_{rg} = 12.4$
   - $G_{fg} = \frac{G}{G_{rg}} = \frac{9.46}{12.4} = 0.763$ → $FG = \frac{0.763-0.5}{0.5} * 1023 = 538$
   - RG = 4, FG = 538

| RG Code [LSB] | Gain Factor |
|---|---|
| 0 | 2 |
| 1 | 3.6 |
| 2 | 6.25 |
| 3 | 9 |
| 4 | 12.4 |
| 5 | 20.7 |
| 6 | 30 |
| 7 | 49 |

Table 1: Gain Factor VS RG Code
(non linear amplifier)

| FG Code [LSB] | Gain Factor |
|---|---|
| 0 | 0.5 |
| 512 | 0.75 |
| 1023 | 1 |

Table 2: Gain Factor VS FG Code
(linear attenuator)

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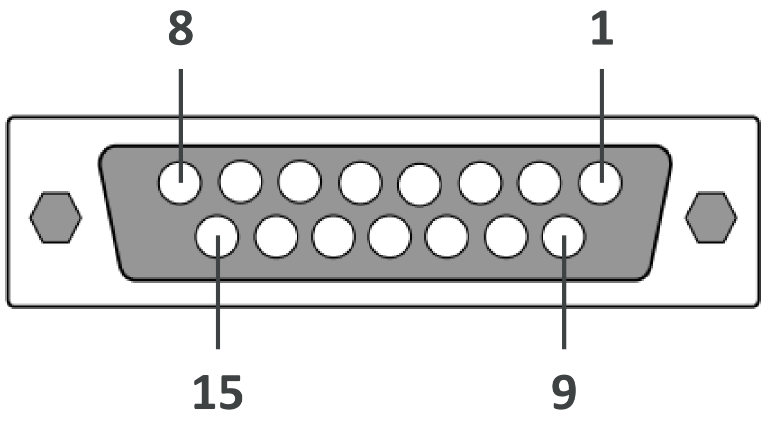
# Front-end (sensor level) Calibration

# Hardware Structure

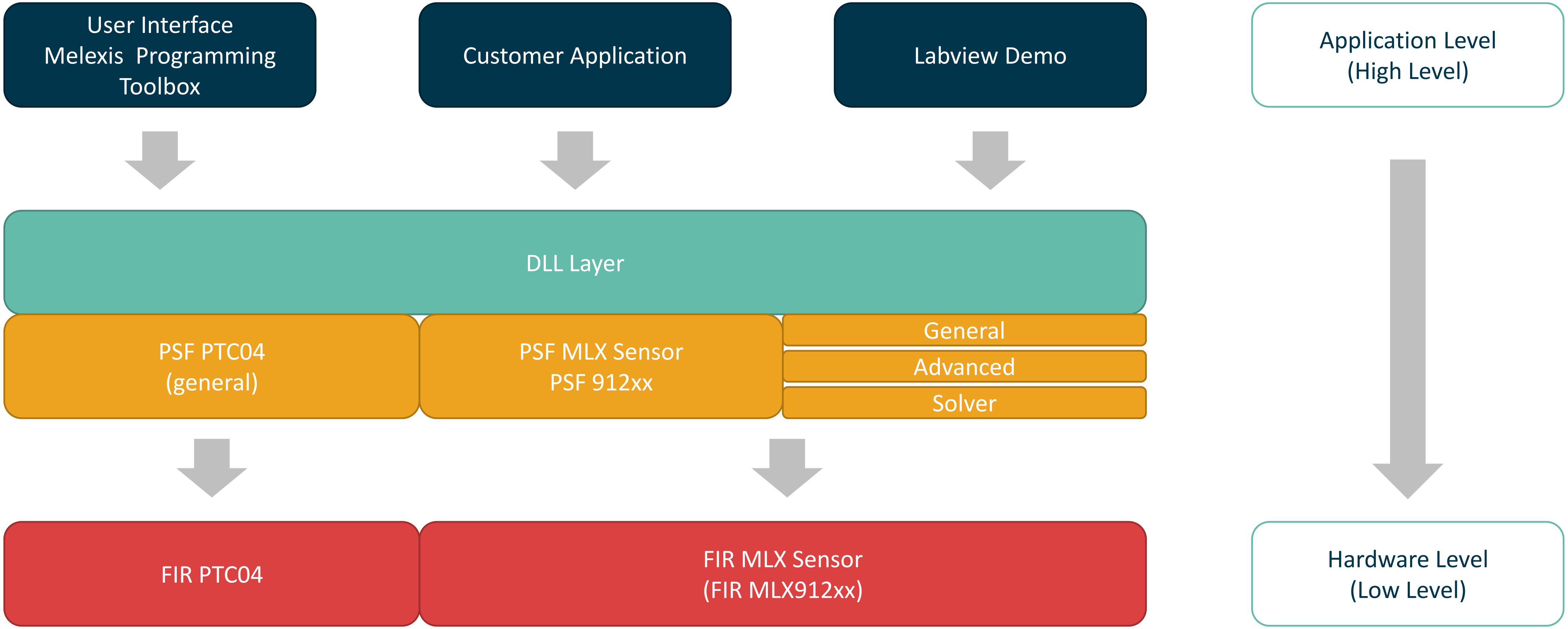
- Melexis PTC04: *Universal Programmer for Melexis sensors calibration*
- Sensor-specific Daughter-Board (DB): *Interface between PTC04 and application connector*

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



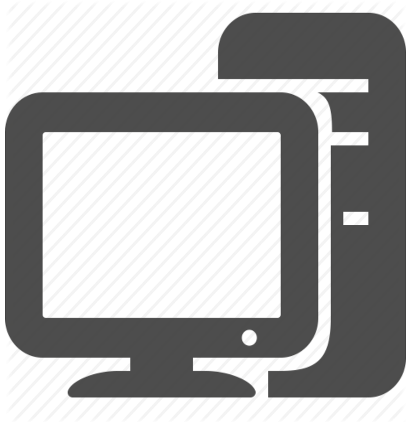

Daughterboard Connector Pinout

# Software structure



# Setup

**PC**



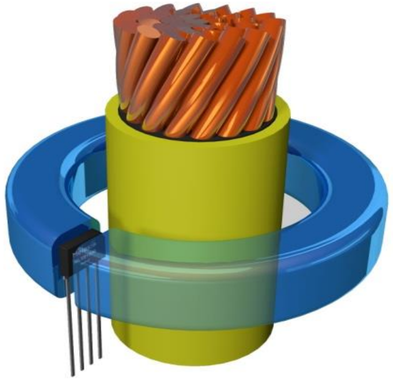
USB/RS232

**PTC04 + DB***

PTC/MUST mode**

3/4-wire

**Sensor**



SW implemented in:

- Labview, Python
- C++, VB
- etc..

*DB = Daughter Board

**Protocol to be selected in PSF/UI settings

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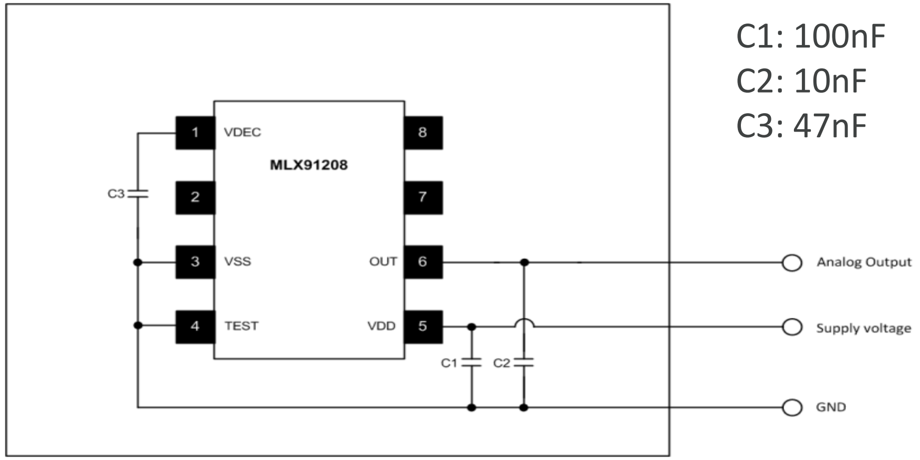
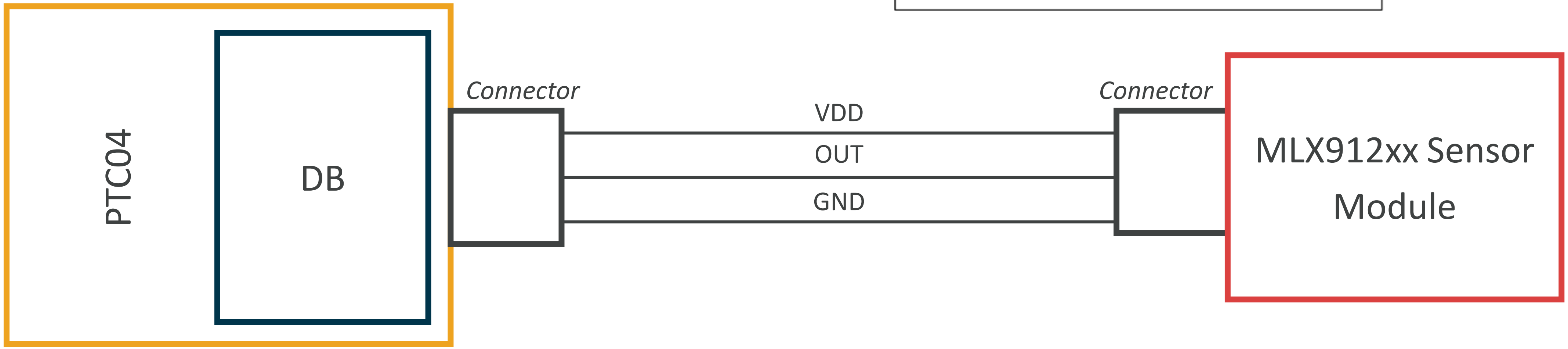
# PTC Communication Mode (3-wire)

- Supply during communication:
  - Vdd = 8 [V]
- Communication :
  - Bi-directional on OUT line
- Available on all current sensor family



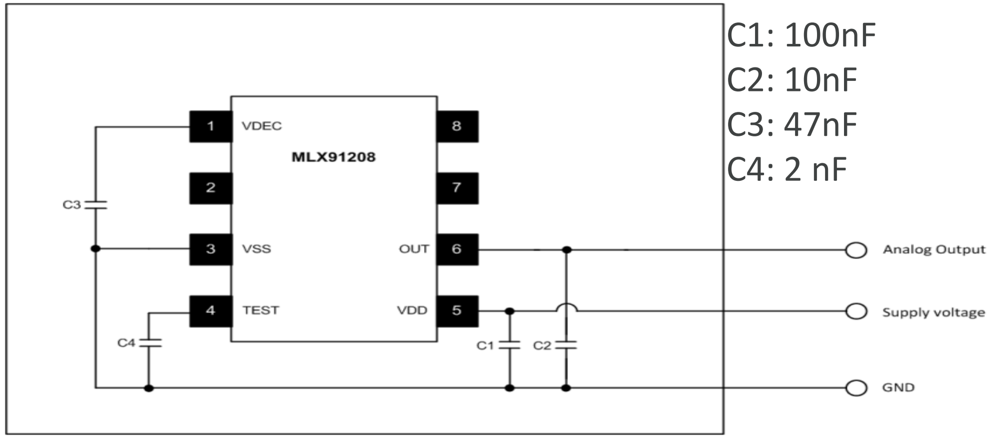

C1: 100nF
C2: 10nF
C3: 47nF



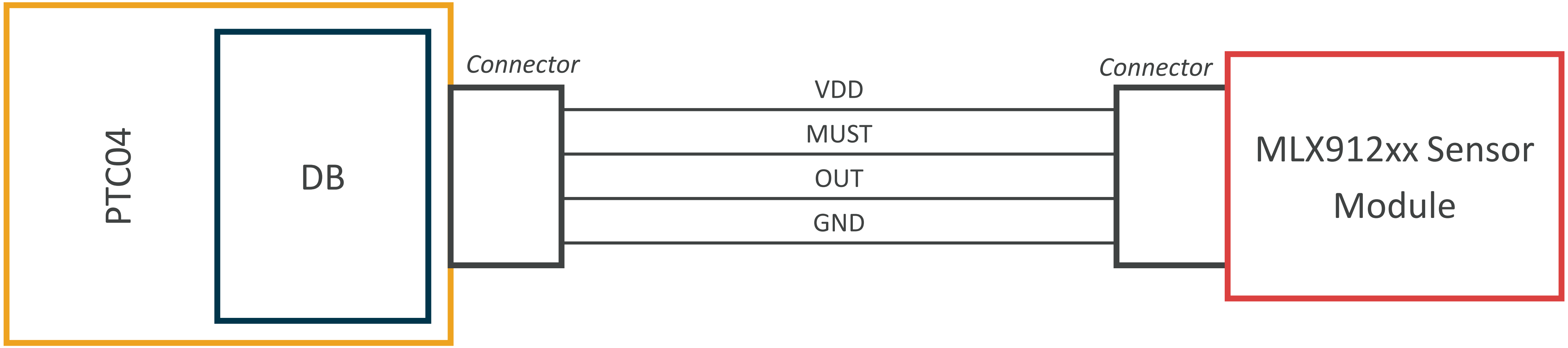

*All unused pins (e.g.: TEST/MUST pin) can be connected to GND for better noise and EMC/ESD performance*
*GND connection of unused pins avoids coupling with the supply and ground loops*

# MUST Communication Mode (4-wire)

- Supply during communication:
  - Vdd = 5 [V]
- PTC-04 to sensor communication: on MUST line
- Sensors to PTC-04 communication: on OUT line
- Available on MLX91208/09/16/17



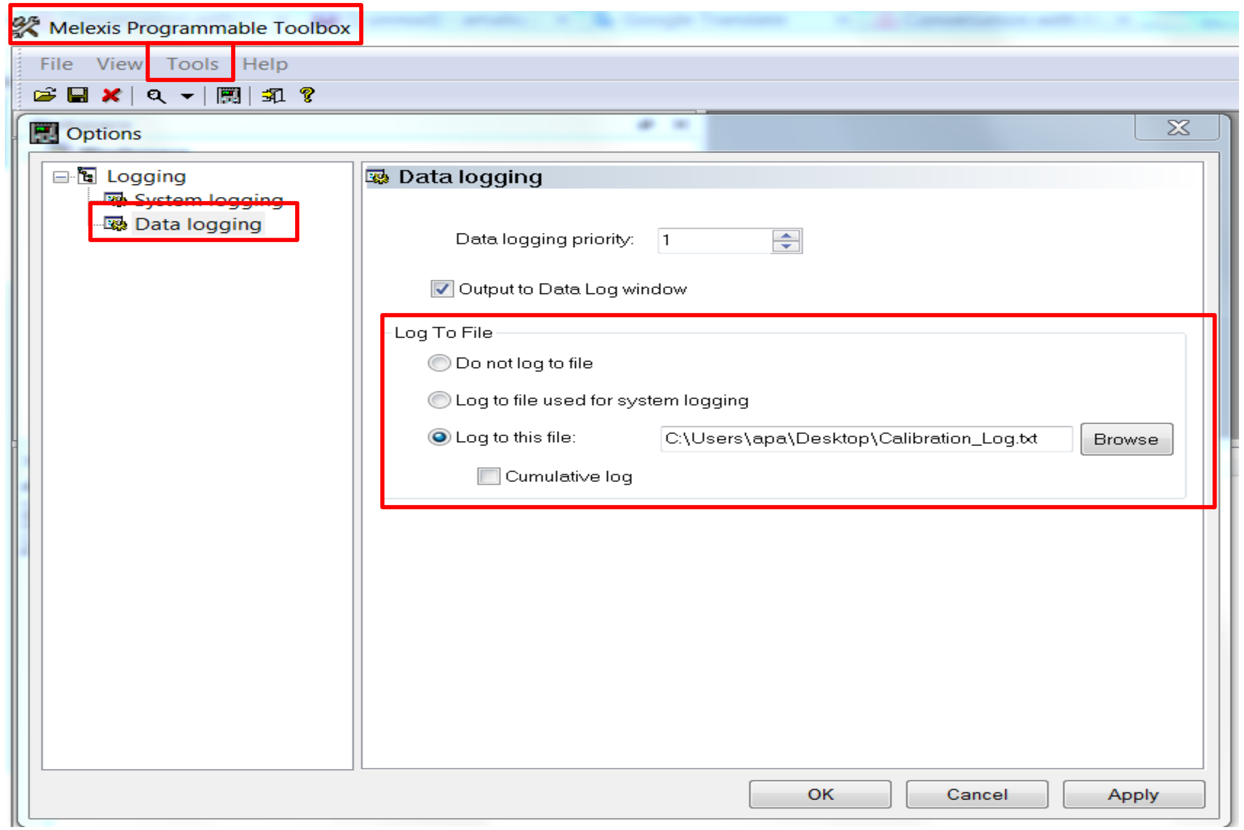

C1: 100nF
C2: 10nF
C3: 47nF
C4: 2 nF




*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* ***(except TEST pin)*** *avoids coupling with the supply and ground loops*
***Do not ground TEST pin.***

# Calibration Log

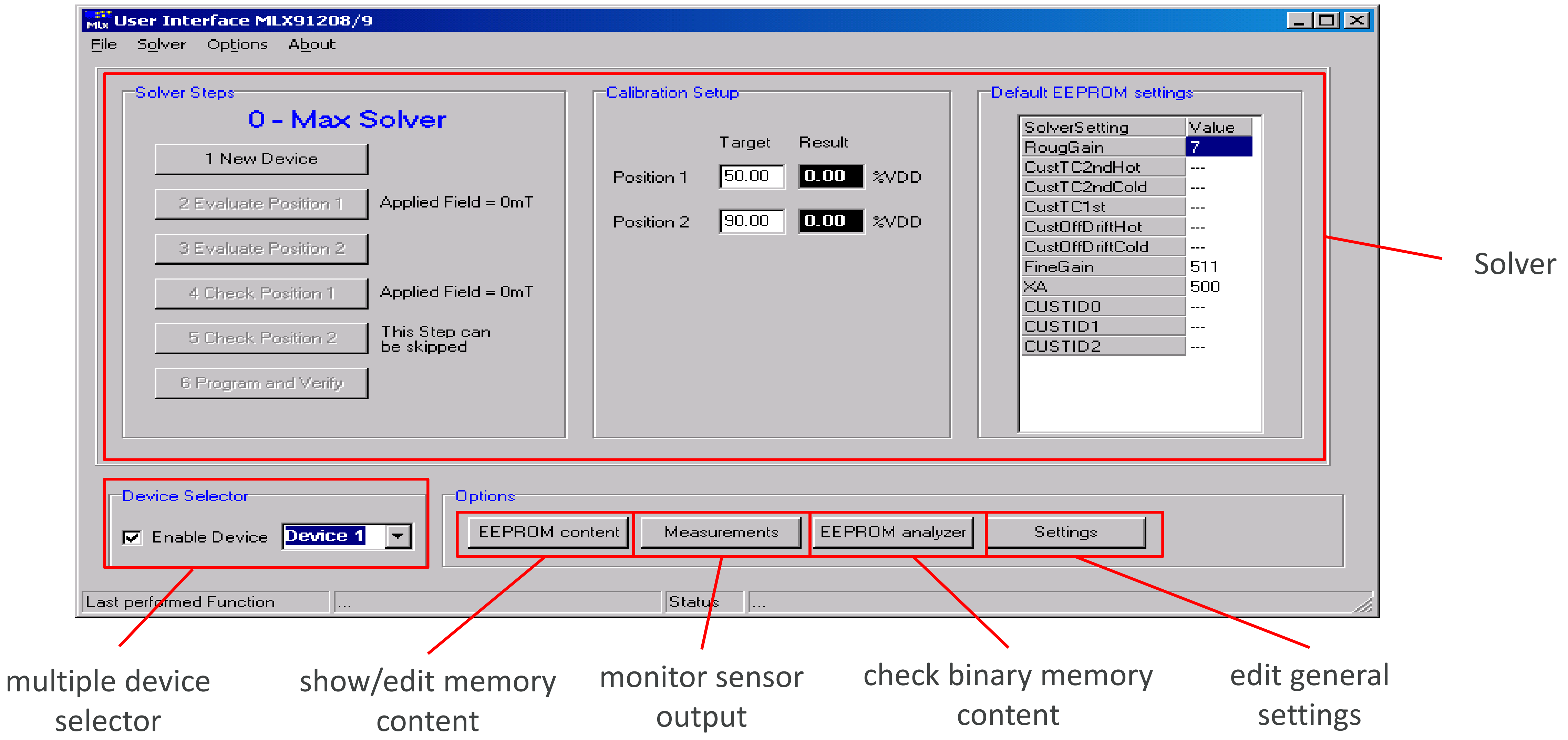
## Before starting the Calibration Flow




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

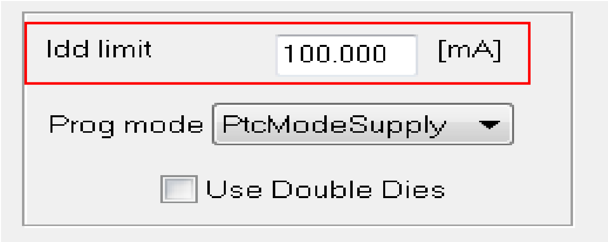
By default, the option“Do not log to file” is ticked

# User interface



# Multiple Devices

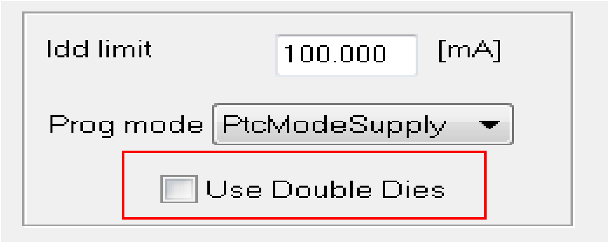

The software can store EEPROM information for up to 16 devices simultaneously. Each device can be selected/enabled with the device selector. However, only 1 device can be physically connected to the OUT1 line of the PTC04. An **external** hardware switch is required for this purpose. The solver will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



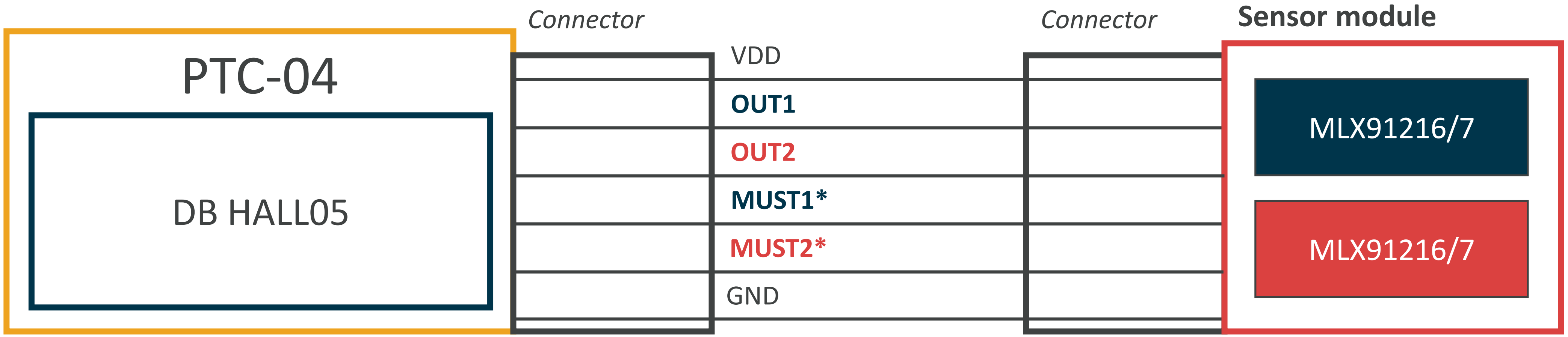

During communication, the current consumption increases significantly (short spikes/bursts). The default Idd limit of 100mA is sufficient for 2-3 devices only. For instance, a limit of 300mA is required for 8 devices (multi-socket).

# Multiple Devices

## Dual Die Configuration



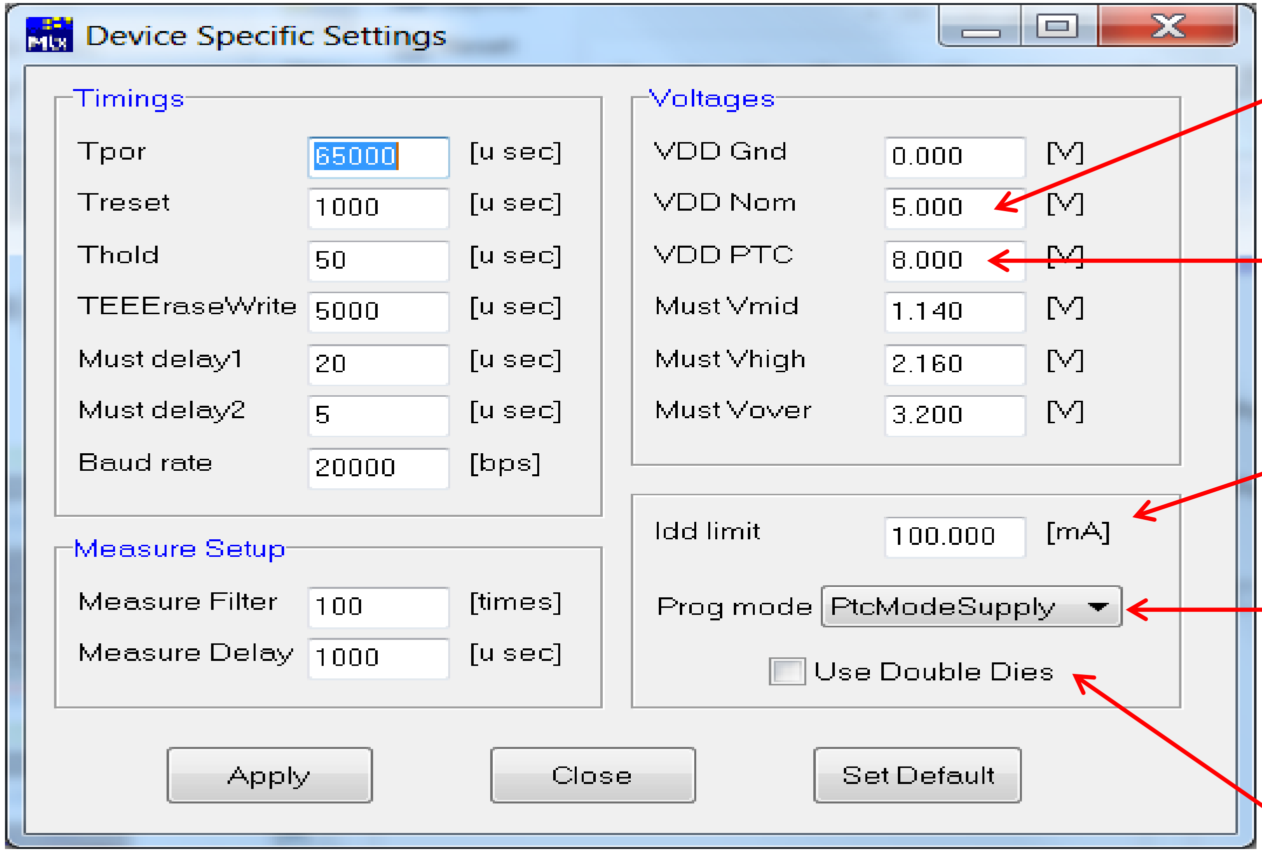

The “Use Double Dies” option in the “Settings” window allows to connect 2 devices to the PTC04 simultaneously. When this option is selected, “Device 1” is on OUT1 and “Device 2” is on OUT2.




*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

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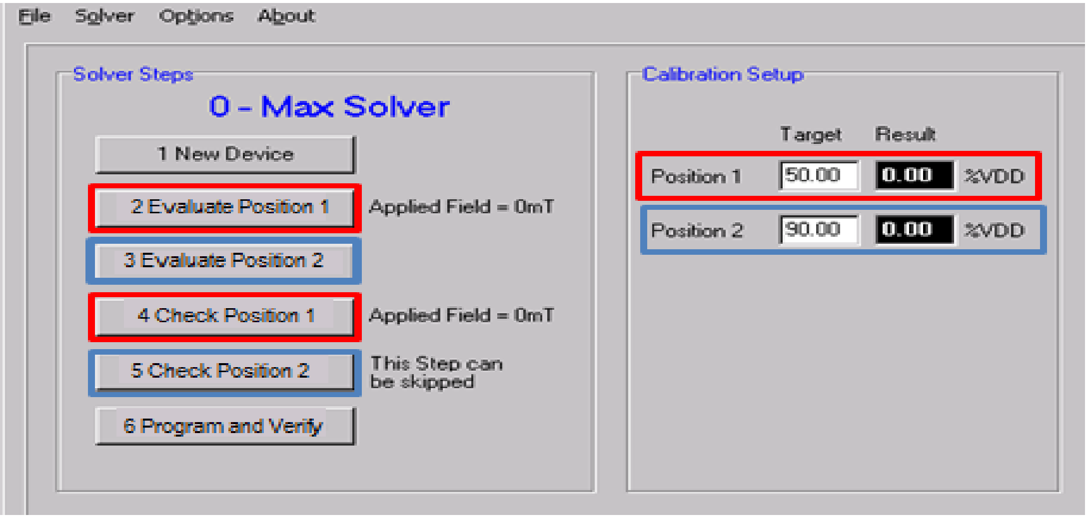
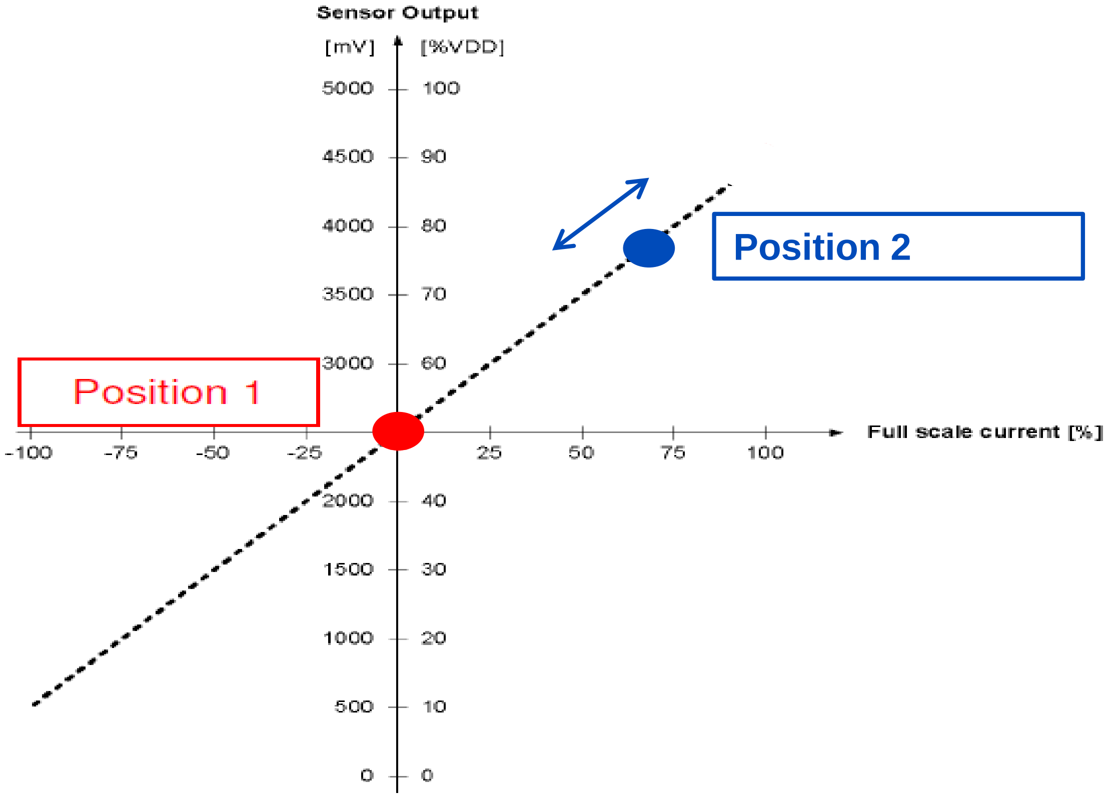
# 0-Max Solver



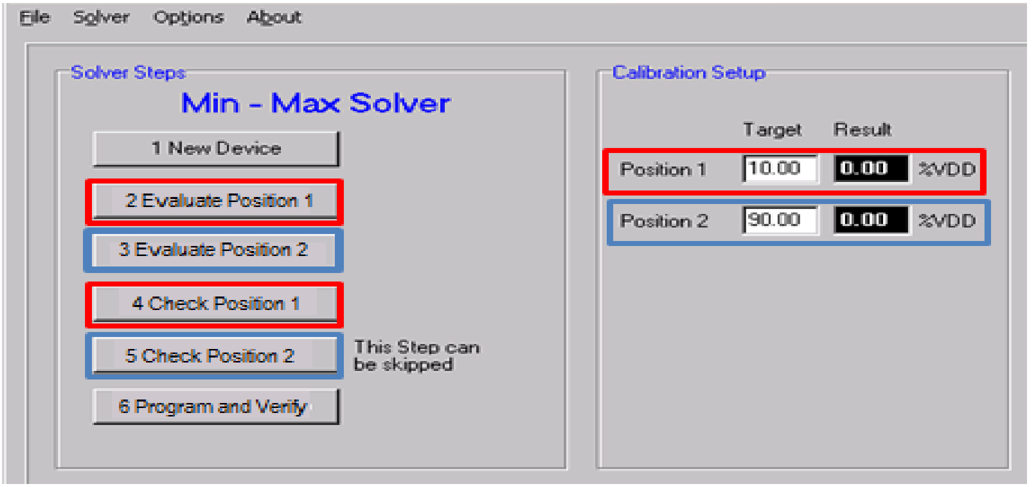

**Concept:** The solver starts from the preset gain and, if required, it sweeps through all allowed RG settings (max. +/-1 for 91206/07)

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

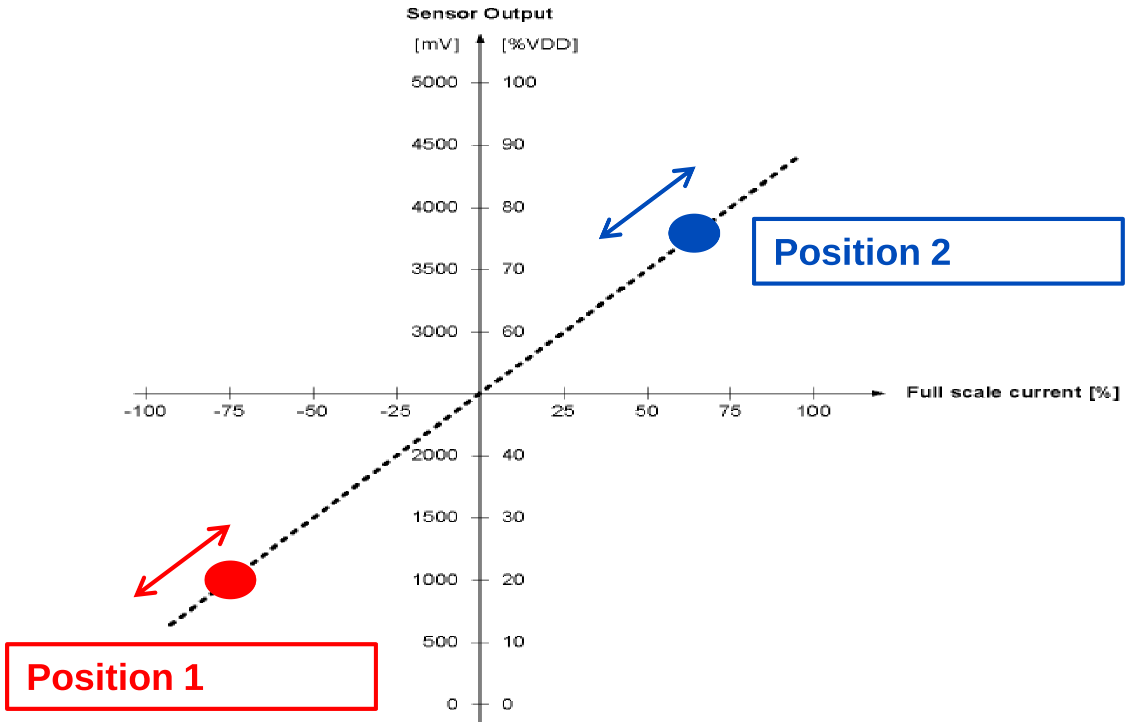
# Min-Max Solver




**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

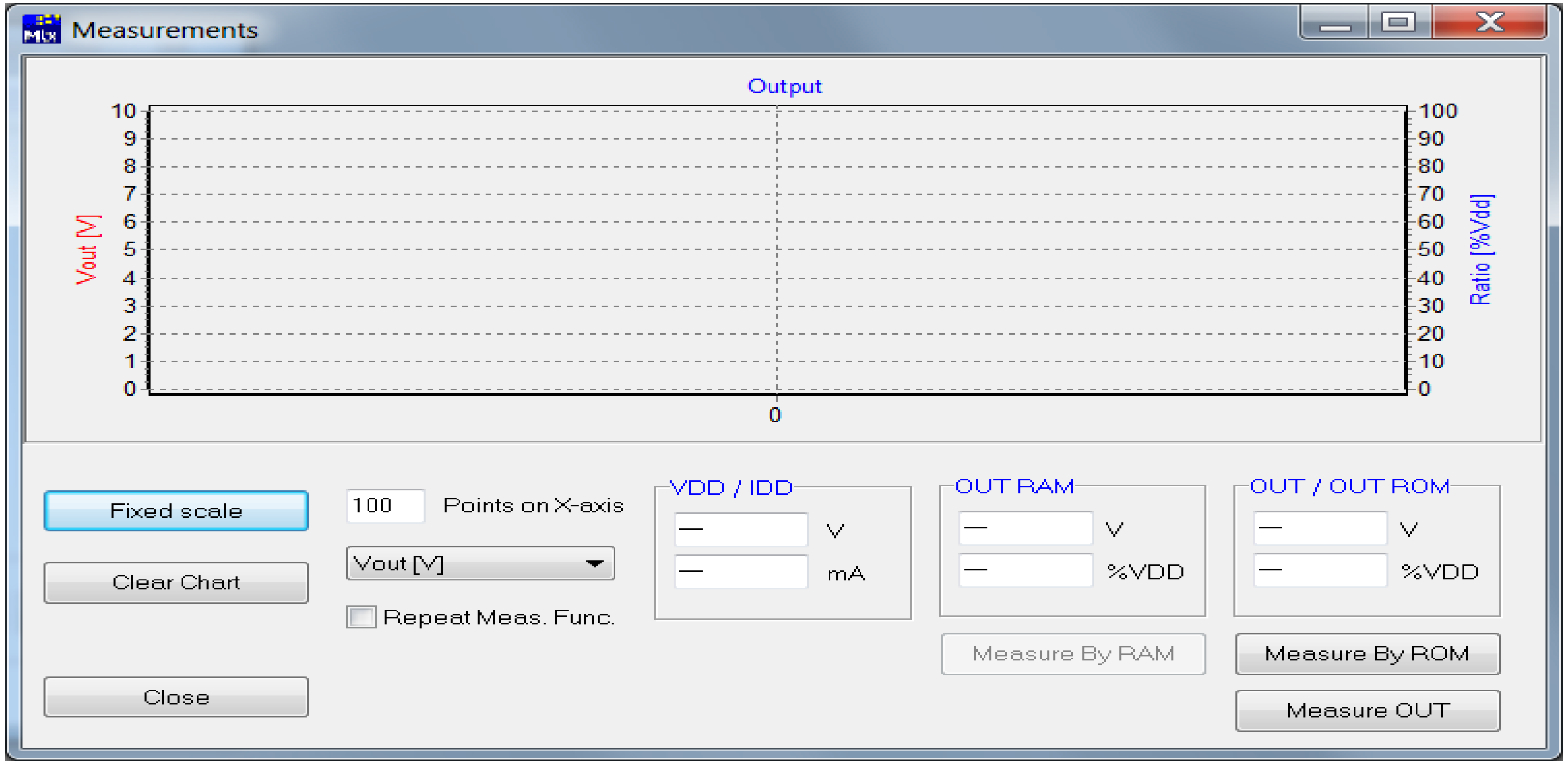



Low hysteresis, accurate fit

Offset is adjusted by interpolation

# 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.

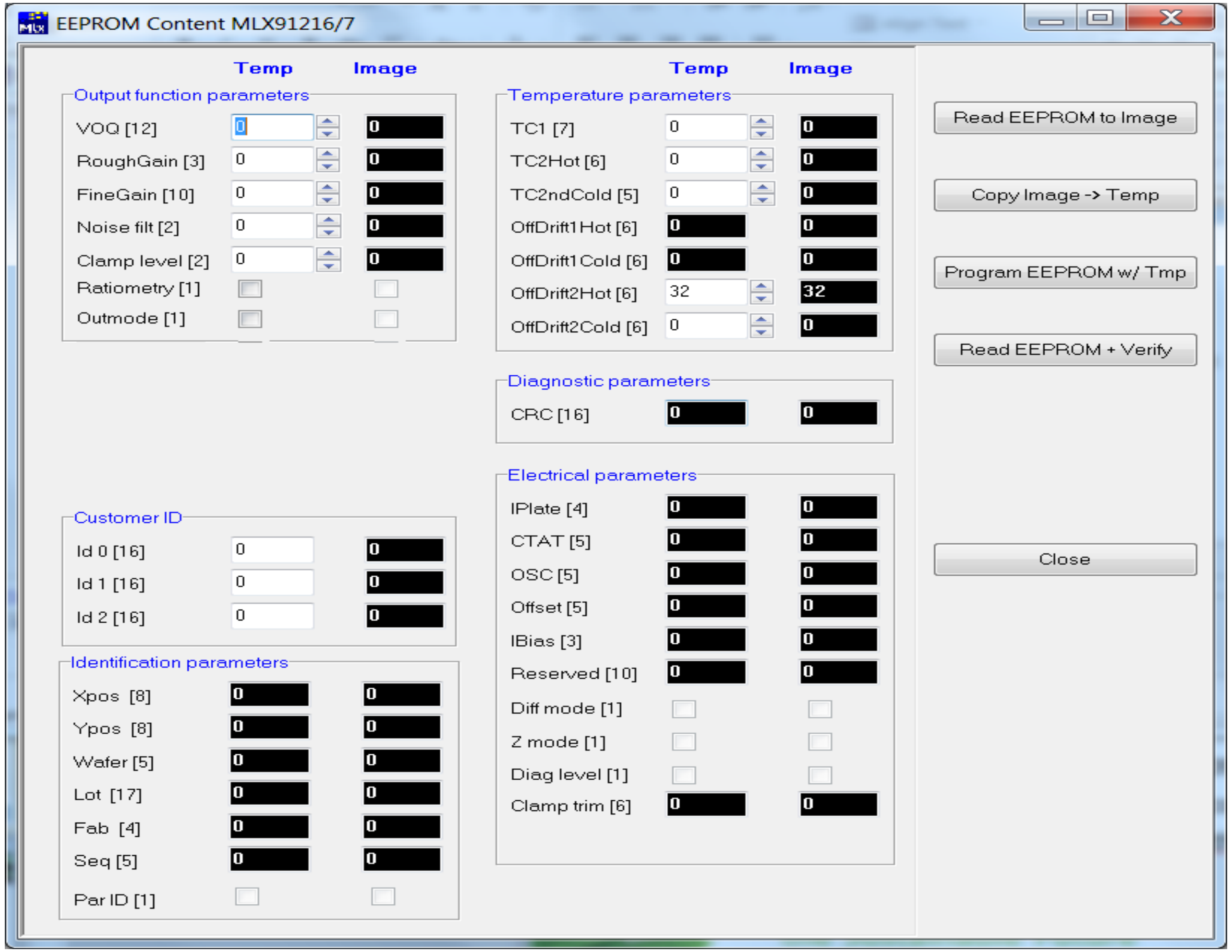



**measure by RAM**
program RAM with values from the TEMP register, then measure output

**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 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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