## Calibration Overview

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

<table>
<thead>
<tr>
<th>RG [LSB]</th>
<th>FG [LSB]</th>
<th>Sensitivity [mV/mT]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>91209</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>1023</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>1023</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>1023</td>
<td>63</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>1023</td>
<td>150</td>
</tr>
</tbody>
</table>
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:
\[ G = G_{rg} \times G_{fg} = 9 \times \left( 0.5 + \frac{1 - 0.5}{1023 - 0} \times (768 - 0) \right) = 7.88 \]

2) RG/FG have to be redefined to get a gain of \( G = 120\% \times 7.88 = 9.46 \)  
We choose:

- RG=4  \( \rightarrow G_{rg} = 12.4 \)
- \( G_{fg} = \frac{G}{G_{rg}} = \frac{9.46}{12.4} = 0.763 \)  \( \rightarrow FG = \frac{0.763 - 0.5}{0.5} \times 1023 = 538 \)
- RG = 4, FG = 538

FG controls a linear attenuator
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*

<table>
<thead>
<tr>
<th>Daughter Board</th>
<th>Compatible Current Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC04-DB-HALL02</td>
<td>MLX91205</td>
</tr>
<tr>
<td>PTC04-DB-HALL03</td>
<td>MLX91206/07</td>
</tr>
<tr>
<td>PTC04-DB-HALL05</td>
<td>MLX91210, MLX91208/09, MLX91216/17</td>
</tr>
<tr>
<td>PTC04-DB-34103</td>
<td>MLX91220</td>
</tr>
</tbody>
</table>

✔ Application connector
Software structure

User Interface
Melexis Programming Toolbox

Customer Application

Labview Demo

Application level
(high level)

Hardware level
(low level)

DLL Layer

PSF PTC04 (general)

PSF MLX Sensor
PSF 91206

General
Advanced
Solver

FIR PTC04

FIR MLX Sensor
FIR 91206
Setup

MLX PTC-04 + Sensor specific DB

Sensor in application

PC

USB/RS232

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

PTC or MUST mode*

3-wire or 4-wire

*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

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: $V_{DD}=5V$
- PTC-04 to sensor: communication on MUST line
- Sensors to PTC-04: communication on OUT line
- Available for: MLX91208/09/16/17

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 steps:
  - 1 New Device
  - 2 Evaluate Position 1
  - 3 Evaluate Position 2
  - 4 Check Position 1
  - 5 Check Position 2

- Calibration Setup:
  - Position 1: Target 50.00, Result 0.00 %VDD
  - Position 2: Target 90.00, Result 0.00 %VDD

- Default EEPROM settings:

- Device Selector:
  - Enable Device
  - Device 1

- Options:
  - EEPROM content
  - Measurements
  - EEPROM analyzer
  - Settings

- 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.
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.
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
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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