MLX90632 FIR sensor

Datasheet

Features and Benefits

- Small size of 3x3mm
- Easy to integrate
- Factory calibrated
- External ambient and object temperature calculation
- Standard measurement resolution 0.02°C
- Medical measurement resolution 0.01°C
- Supply voltage of 3.3V, supply current 1mA (sleep current less than 2.5uA)
- I²C compatible digital interface
- Software definable I²C address with 1 LSB bit external address pin
- Field of View of 50°
- Default refresh rate 0.5s, configurable between 16ms and 2s
- Integrated post-calibration option

Application Examples

- High precision non-contact temperature measurements
- Body temperature measurement
- Non-contact thermometer for mobile and IoT application
- Temperature sensing element for residential, commercial and industrial building air conditioning
- Industrial temperature control of moving parts
- Home appliances with temperature control
- Healthcare
- Livestock monitoring
- Drivers available at: https://github.com/melexis/mlx90632-library

Figure 1: Image of MLX90632
Description

The MLX90632 is a non-contact infrared temperature sensor in a small SMD SFN package. The device is factory calibrated with calibration constants stored in the EEPROM memory. The ambient and object temperature can be calculated externally based on these calibration constants and the measurement data.

A major strength of the MLX90632 is that the effect of temperature variations around the sensor package are reduced to a minimum. However, some extreme cases can still influence the measured temperature. The accuracy of the thermometer can be influenced by temperature differences in the package induced by causes like (among others): hot electronics behind the sensor, heaters/coolers behind or beside the sensor or by a hot/cold object very close to the sensor that not only heats the sensing element in the thermometer but also the thermometer package. The MLX90632 contains specific circuits to minimize the effect of these influences. In the same way, localized thermal variations -like turbulence in the air- will not generate thermal noise in the output signal of the thermopile.

The MLX90632 is available in two different versions: standard and medical accuracy. Both versions are calibrated in the ambient temperature range from -20 to 85°C. The difference between both versions is visible in accuracy and the object temperature range. The medical version is factory calibrated with an accuracy of ±0.2°C within the narrow object temperature range from 35 to 42°C for medical applications. This version also allows Extended range operation. This measurement type option is implemented in order to give additional range to the medical devices. The object temperature range is limited from -20 to 100°C. For more information see Section 11.2. On the other hand, the standard version covers an object temperature range from -20 to 200°C but offers an accuracy of ±1°C.

It is very important for the application designer to understand that these accuracies are guaranteed and achievable when the sensor is in thermal equilibrium and under isothermal conditions (no temperature differences across the sensor package). To obtain this accuracy, it is also important that the full Field of View (FOV) of the sensor is filled by the object.

The typical supply voltage of the MLX90632 is 3.3V. For the I²C communication with the master microcontroller, two versions of the sensor are available, working either at 3.3V or 1.8V I²C reference voltage. The communication to the chip is done by I²C up to fast mode plus (FM+). Through I²C the external microcontroller has access to the following blocks:

- RAM memory used for measurement data, in this document mainly referred to as ‘storage memory’
- EEPROM used to store the trimming values, calibration constants and device/measurement settings

Based on this data, the external microcontroller can calculate the object temperature and if needed the sensor temperature.

An optical filter (long-wave pass) that cuts off the visible and near infra-red radiant flux is integrated in the sensor to provide ambient light immunity. The wavelength pass band of this optical filter is from 2 till 14µm.
Contents

Features and Benefits ........................................................................................................... 1
Application Examples ........................................................................................................ 1
Description ............................................................................................................... 2
1. Ordering Information ...................................................................................................... 5
2. Glossary of Terms .......................................................................................................... 6
3. Absolute Maximum ratings ............................................................................................. 7
4. Pin definitions and descriptions ...................................................................................... 8
5. Electrical characteristics ................................................................................................. 9
6. Detailed General Description .......................................................................................... 10
   6.1. Block diagram ............................................................................................................ 10
   6.2. Description ................................................................................................................ 10
7. Memory map ...................................................................................................................... 11
   7.1. Product ID .................................................................................................................. 14
   7.2. Product Code (0x2409) ............................................................................................ 15
   7.3. Customer Data storage Area (0x24C0 to 0x24CF) ....................................................... 15
8. Control and configuration .................................................................................................. 16
   8.1. Measurement control ................................................................................................ 16
   8.2. Measurement type select ........................................................................................... 17
   8.3. Device status ............................................................................................................. 18
   8.4. Measurement settings ............................................................................................... 19
   8.4.1. Refresh rate .......................................................................................................... 19
9. I²C commands ................................................................................................................... 20
   9.1. I²C address ............................................................................................................... 21
   9.1.1. Slave Address change process flow ....................................................................... 21
   9.1.2. Slave Address change example ............................................................................. 22
   9.2. Addressed read ......................................................................................................... 23
   9.3. Addressed write ........................................................................................................ 24
   9.4. Global reset .............................................................................................................. 24
   9.5. Addressed reset ....................................................................................................... 25
   9.6. EEPROM unlock for customer access ...................................................................... 25
   9.7. Direct read .............................................................................................................. 25
   9.8. 1.8V I2C communication device .............................................................................. 25
## 10. Operating Modes

- 10.1. Measurement modes .................................................. 26
- 10.2. Measurement types .................................................... 27

## 11. Temperature calculation

- 11.1. Medical measurement .................................................. 28
  - 11.1.1. Pre-calculations .................................................... 29
  - 11.1.2. Ambient temperature .............................................. 29
  - 11.1.3. Object temperature ................................................. 30
  - 11.1.4. Example Medical measurement Temperature Calculation ............................................ 30
- 11.2. Extended range measurement ....................................... 35
  - 11.2.1. Pre-calculations .................................................... 35
  - 11.2.2. Ambient temperature .............................................. 36
  - 11.2.3. Object temperature ................................................. 36
  - 11.2.4. Example Extended range measurement Temperature Calculation ............................................ 37

## 12. Performance characteristics

- 12.1. Accuracy .................................................................. 41
  - 12.1.1. Ambient temperature .............................................. 41
  - 12.1.2. Standard Accuracy object temperature ...................... 41
  - 12.1.3. Medical Accuracy object temperature ..................... 42
- 12.2. Field of View (FoV) .................................................... 43
- 12.3. Noise ................................................................ 44

## 13. Mechanical Drawing

- 13.1. Package dimensions .................................................. 45
- 13.2. PCB footprint ............................................................ 46

## 14. Application schematic

- 14.1. 3V3 $^1\text{C}$ mode ....................................................... 47
- 14.2. 1V8 $^1\text{C}$ mode ....................................................... 48

## 15. Software

- ...................................................................................... 49

## 16. Standard information regarding manufacturability of Melexis products with different soldering processes

- ...................................................................................... 50

## 17. ESD Precautions

- ...................................................................................... 51

## 18. Application comments

- ...................................................................................... 51

## 19. Table of figures

- ...................................................................................... 52

## 20. Disclaimer

- ...................................................................................... 53
1. Ordering Information

<table>
<thead>
<tr>
<th>Product</th>
<th>Temperature Code</th>
<th>Package</th>
<th>Option Code</th>
<th>Packing Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLX90632</td>
<td>S</td>
<td>LD</td>
<td>BCB-000</td>
<td>RE</td>
</tr>
<tr>
<td>MLX90632</td>
<td>S</td>
<td>LD</td>
<td>DCB-000</td>
<td>RE</td>
</tr>
<tr>
<td>MLX90632</td>
<td>S</td>
<td>LD</td>
<td>DCB-100</td>
<td>RE</td>
</tr>
</tbody>
</table>

*Table 1: Ordering codes for MLX90632*

Legend:

<table>
<thead>
<tr>
<th>Temperature Code:</th>
<th>S: from -20°C to 85°C sensor temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package Code:</td>
<td>“LD” for SFN 3x3 package</td>
</tr>
<tr>
<td>Option Code:</td>
<td>XYZ-123</td>
</tr>
<tr>
<td></td>
<td>X: Accuracy</td>
</tr>
<tr>
<td></td>
<td>▪ B: Standard accuracy</td>
</tr>
<tr>
<td></td>
<td>▪ D: Medical accuracy</td>
</tr>
<tr>
<td></td>
<td>Y: Pixel type</td>
</tr>
<tr>
<td></td>
<td>▪ C: High stability version</td>
</tr>
<tr>
<td></td>
<td>Z: Field Of View</td>
</tr>
<tr>
<td></td>
<td>▪ B: 50 degrees</td>
</tr>
<tr>
<td>1: I²C level</td>
<td>▪ 0: 3V3</td>
</tr>
<tr>
<td></td>
<td>▪ 1: 1V8</td>
</tr>
<tr>
<td>2-3:</td>
<td>▪ 00: Standard configuration</td>
</tr>
<tr>
<td></td>
<td>▪ xx: Reserved</td>
</tr>
<tr>
<td>Packing Form:</td>
<td>“RE” for Reel</td>
</tr>
<tr>
<td>Ordering Example:</td>
<td>“MLX90632SLD-DCB-000-RE”</td>
</tr>
<tr>
<td></td>
<td>For a FIR Sensor type in SFN 3x3 package with medical accuracy, Field Of View of 50 degrees and 3V3 I²C level, delivered in Reel.</td>
</tr>
</tbody>
</table>

*Table 2: Coding legend*
2. Glossary of Terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>POR</td>
<td>Power On Reset</td>
</tr>
<tr>
<td>IR</td>
<td>InfraRed</td>
</tr>
<tr>
<td>I²C</td>
<td>Inter-Integrated Circuit</td>
</tr>
<tr>
<td>SDA</td>
<td>Serial DAta – I²C compatible communication pins</td>
</tr>
<tr>
<td>SCL</td>
<td>Serial CLock – I²C compatible communication pins</td>
</tr>
<tr>
<td>ACK / NACK</td>
<td>Acknowledge / Not Acknowledge</td>
</tr>
<tr>
<td>SOC</td>
<td>Start Of Conversion</td>
</tr>
<tr>
<td>EOC</td>
<td>End Of Conversion</td>
</tr>
<tr>
<td>FOV</td>
<td>Field Of View</td>
</tr>
<tr>
<td>Ta</td>
<td>Ambient Temperature measured from the chip – (the package temperature)</td>
</tr>
<tr>
<td>To</td>
<td>Object Temperature, ‘seen’ from IR sensor</td>
</tr>
<tr>
<td>SFN</td>
<td>Single Flat pack No-lead</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Defined</td>
</tr>
<tr>
<td>LSB</td>
<td>Least Significant Bit</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Bit</td>
</tr>
<tr>
<td>EMC</td>
<td>Electro-Magnetic Compatibility</td>
</tr>
<tr>
<td>ESD</td>
<td>Electro-Static Discharge</td>
</tr>
<tr>
<td>HBM</td>
<td>Human Body Model</td>
</tr>
<tr>
<td>CDM</td>
<td>Charged Device Model</td>
</tr>
</tbody>
</table>

*Table 3: List of abbreviations*
### 3. Absolute Maximum ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage, (over voltage)</td>
<td>$V_{DD}$</td>
<td>5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Supply Voltage, (operating)</td>
<td>$V_{DD}$</td>
<td>3.6</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Reverse Voltage</td>
<td>$V_R$</td>
<td>-1.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Address-pin Voltage</td>
<td>$V_{ADDR}$</td>
<td>$V_{DD} + 0.6$</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature Range,</td>
<td>$T_A$</td>
<td>-20</td>
<td></td>
<td>+85</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range,</td>
<td>$T_S$</td>
<td>-40</td>
<td></td>
<td>+105</td>
<td>°C</td>
</tr>
<tr>
<td>ESD Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- HBM (acc. AEC Q100 002)</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>kV</td>
</tr>
<tr>
<td>- CDM (acc. AEC Q100 011)</td>
<td></td>
<td>750</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>- Air discharge (acc. IEC61000-4-2)</td>
<td></td>
<td>+4</td>
<td></td>
<td></td>
<td>kV</td>
</tr>
<tr>
<td>- Contact discharge (acc. IEC61000-4-2)</td>
<td></td>
<td>+2</td>
<td></td>
<td></td>
<td>kV</td>
</tr>
<tr>
<td>DC current into SCL</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>DC sink current, SDA pin</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>DC clamp current, SDA pin</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>DC clamp current, SCL pin</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>EEPROM re-writes</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute maximum-rated conditions for extended periods may affect device reliability.
4. Pin definitions and descriptions

![MLX90632 TOP view](image)

**Figure 2: MLX90632 TOP view**

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SDA</td>
<td>In/Out</td>
<td>I²C Data line</td>
</tr>
<tr>
<td>2</td>
<td>VDD</td>
<td>POWER</td>
<td>Supply</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>4</td>
<td>SCL</td>
<td>In</td>
<td>I²C Clock line</td>
</tr>
<tr>
<td>5</td>
<td>ADDR</td>
<td>In</td>
<td>LSB of I²C address</td>
</tr>
</tbody>
</table>

*Table 5: Pin definition*
### 5. Electrical characteristics

All parameters are valid for $T_A = 25 \, ^\circ\text{C}$, $V_{DD} = 3.3\, \text{V}$ (unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supplies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External supply</td>
<td>$V_{DD}$</td>
<td></td>
<td>3</td>
<td>3.3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>Supply current</td>
<td>$I_{DD}$</td>
<td>No load</td>
<td>0.5</td>
<td>1</td>
<td>1.4</td>
<td>mA</td>
</tr>
<tr>
<td>Sleep current</td>
<td>$I_{DDpr}$</td>
<td>No load, erase/write EEPROM operations</td>
<td>1.5</td>
<td>2.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td><strong>Power On Reset</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POR level</td>
<td>$V_{POR, up}$</td>
<td>Power-up (full temp range)</td>
<td>1.3</td>
<td>2.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>POR level</td>
<td>$V_{POR, down}$</td>
<td>Power-down (full temp range)</td>
<td>1.1</td>
<td>2.1</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>POR hysteresis</td>
<td>$V_{POR, hys}$</td>
<td>Full temp range</td>
<td>200</td>
<td>500</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$V_{DD}$ rise time (10% to 90% of specified supply voltage)</td>
<td>$T_{POR}$</td>
<td>Ensure POR signal</td>
<td></td>
<td></td>
<td>20</td>
<td>ms</td>
</tr>
<tr>
<td>Output valid (result in RAM)</td>
<td>$T_{valid}$</td>
<td>After POR</td>
<td></td>
<td></td>
<td>64</td>
<td>ms</td>
</tr>
</tbody>
</table>

| **I²C compatible 2-wire interface** | | | | | | |
| $V_{I2C}$ | | $V_{I2C}$ version = 1.8V | 1.65 | 3 | 1.8 | $V_{DD}$ |
| $V_{I2C}$ version = 3.3V | | | 1.95 | | 3.6 | |
| Input high voltage | $V_{IH}$ | Over temperature and supply | 0.7* $V_{I2C}$ | | $V_{I2C}+0.5$ | V |
| Input low voltage | $V_{IL}$ | Over temperature and supply | -0.5 | | 0.3* $V_{I2C}$ | V |
| Output low voltage | $V_{OL}$ | Over temperature and supply | 0 | | 0.4 | V |
| Address pin voltage (“1”) | $V_{ADDR, HI}$ | | 2 | | $V_{DD}$ | $V_{DD}+0.5$ | V |
| Address pin voltage (“0”) | $V_{ADDR, LO}$ | | 0 | | | 0.5 | V |
| ADDR leakage | $I_{ADDR, lka}$ | | | | | 1 | μA |
| SCL leakage | $I_{SCL, lka}$ | $V_{SCL}=3.6\, \text{V}, T_a=+85^\circ\text{C}$ | | | 1 | μA |
| SDA leakage | $I_{SDA, lka}$ | $V_{SDA}=3.6\, \text{V}, T_a=+85^\circ\text{C}$ | | | 1 | μA |
| SCL capacitance | $C_{SCL}$ | | 10 | | | pF |
| SDA capacitance | $C_{SDA}$ | | 10 | | | pF |
| Slave address | $SA$ | Factory default, ADDR-pin grounded | | | 3A | hex |

*Table 6: Electrical characteristics*
6. Detailed General Description

6.1. Block diagram

![Block diagram](image)

**Figure 3: Block diagram**

6.2. Description

The MLX90632 is a far infrared, non-contact temperature sensor which is factory calibrated to a high accuracy. Internally, electrical and thermal precautions are taken to compensate for thermally harsh external conditions. The thermopile sensing element voltage signal is amplified and digitized. After digital filtering, the raw measurement result is stored in the RAM memory. Furthermore, the MLX90632 contains a sensor element to measure the temperature of the sensor itself. The raw information of this sensor is also stored in RAM after processing. All above functions are controlled by a state machine. The result of each measurement conversion is accessible via I^2C.

The communication to the chip is done by I^2C up to fast mode plus (FM+). The requirement of the standard is to run at frequencies up to 1MHz. Through I^2C the external unit can have access to the following blocks:

- The control registers of the internal state machines
- RAM (96 cells x 16bit) for pixel and auxiliary measurement data, in this document mainly referred to as ‘storage memory’.
- EEPROM (256 cells x 16bit) used to store the trimming values, calibration constants and various device/measurement settings.

From the measurement data and the calibration data the external unit can calculate both the sensor temperature and the object temperature. The calculation allows the customer to adjust the calibration for his own application in case an optical window or obstructions are present.
7. Memory map

Some bits in the registers below are Melexis reserved. Those bits need to be read and masked, prior to writing operation.

<table>
<thead>
<tr>
<th>Access</th>
<th>Address</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EEPROM</td>
<td></td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2400~0x2404</td>
<td>Melexis reserved</td>
<td></td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2405</td>
<td>ID[15:0]</td>
<td>Chip ID</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2406</td>
<td>ID[15:0]</td>
<td>Chip ID</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2407</td>
<td>ID[15:0]</td>
<td>Chip ID</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2408</td>
<td>ID_CRC16</td>
<td>CRC</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2409</td>
<td>EE_PRODUCT_CODE</td>
<td>Sensor information</td>
</tr>
<tr>
<td>Read-only</td>
<td>-</td>
<td>Melexis reserved</td>
<td></td>
</tr>
<tr>
<td>Read-only</td>
<td>0x240B</td>
<td>EE_VERSION</td>
<td>EEPROM version</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x240C</td>
<td>EE_P_R [15:0]</td>
<td>P_R calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x240D</td>
<td>EE_P_R [31:16]</td>
<td>P_R calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x240E</td>
<td>EE_P_G [15:0]</td>
<td>P_G calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x240F</td>
<td>EE_P_G [31:16]</td>
<td>P_G calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2410</td>
<td>EE_P_T [15:0]</td>
<td>P_T calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2411</td>
<td>EE_P_T [31:16]</td>
<td>P_T calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2412</td>
<td>EE_P_O [15:0]</td>
<td>P_O calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2413</td>
<td>EE_P_O [31:16]</td>
<td>P_O calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2414</td>
<td>EE_Aa [15:0]</td>
<td>Aa calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2415</td>
<td>EE_Aa [31:16]</td>
<td>Aa calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2416</td>
<td>EE_Ab [15:0]</td>
<td>Ab calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2417</td>
<td>EE_Ab [31:16]</td>
<td>Ab calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2418</td>
<td>EE_Ba [15:0]</td>
<td>Ba calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2419</td>
<td>EE_Ba [31:16]</td>
<td>Ba calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241A</td>
<td>EE_Bb [15:0]</td>
<td>Bb calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241B</td>
<td>EE_Bb [31:16]</td>
<td>Bb calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241C</td>
<td>EE_Ca [15:0]</td>
<td>Ca calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241D</td>
<td>EE_Ca [31:16]</td>
<td>Ca calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241E</td>
<td>EE_Cb [15:0]</td>
<td>Cb calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x241F</td>
<td>EE_Cb [31:16]</td>
<td>Cb calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2420</td>
<td>EE_Da [15:0]</td>
<td>Da calibration constant (16-bit, Least Significant Word)</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x2421</td>
<td>EE_Da [31:16]</td>
<td>Da calibration constant (16-bit, Most Significant Word)</td>
</tr>
<tr>
<td>Address</td>
<td>Description</td>
<td>Access</td>
<td>Notes</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>0x2422</td>
<td>EE_Db [15:0] Db calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2423</td>
<td>EE_Db [31:16] Db calibration constant (16-bit, Most Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2424</td>
<td>EE_Ea [15:0] Ea calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2425</td>
<td>EE_Ea [31:16] Ea calibration constant (16-bit, Most Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2426</td>
<td>EE_Eb [15:0] Eb calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2427</td>
<td>EE_Eb [31:16] Eb calibration constant (16-bit, Most Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2428</td>
<td>EE_Fa [15:0] Fa calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x2429</td>
<td>EE_Fa [31:16] Fa calibration constant (16-bit, Most Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x242A</td>
<td>EE_Eb [15:0] Ga calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td>0x242F</td>
<td>EE_Ka [15:0] Ga calibration constant (16-bit, Least Significant Word)</td>
<td>Read-only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x2480</td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x2481</td>
<td>EE_Ha [15:0] Ha Customer calibration constant (16 bit)</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x2482</td>
<td>EE_Hb [15:0] Hb Customer calibration constant (16 bit)</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x24C0…0x24CF</td>
<td>Customer data</td>
<td>R/W</td>
<td>Customer data storage area</td>
</tr>
<tr>
<td></td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x24D4</td>
<td>EE_CONTROL EEPROM Control register, measurement control</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x24D5</td>
<td>EE_I2C_ADDRESS I2C slave address &gt;&gt; 1 Example: standard address (= 0x003A) &gt;&gt; 1 = 0x001D</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x24E1</td>
<td>EE_MEAS_1 Measurement settings 1 (see section Measurement settings)</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td>0x24E2</td>
<td>EE_MEAS_2 Measurement settings 2 (see section Measurement settings)</td>
<td>R/W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Melexis reserved</td>
<td>R/W</td>
<td></td>
</tr>
</tbody>
</table>
### REGISTER

<table>
<thead>
<tr>
<th>R/W</th>
<th>Address</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/W</td>
<td>0x3000</td>
<td>REG_I2C_ADDRESS</td>
<td>$^{1^C}$ slave address &gt;&gt; 1</td>
</tr>
<tr>
<td>R/W</td>
<td>0x3001</td>
<td>REG_CONTROL</td>
<td>Control register, measurement mode</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>Melexis reserved</td>
<td></td>
</tr>
<tr>
<td>R/W</td>
<td>0x3FFF</td>
<td>REG_STATUS</td>
<td>Status register: data available</td>
</tr>
</tbody>
</table>

### RAM

<table>
<thead>
<tr>
<th>Access</th>
<th>Address</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read-only</td>
<td>0x4000</td>
<td>RAM_1</td>
<td>Raw data 1</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4001</td>
<td>RAM_2</td>
<td>Raw data 2</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4002</td>
<td>RAM_3</td>
<td>Raw data 3</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4003</td>
<td>RAM_4</td>
<td>Raw data 4</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4004</td>
<td>RAM_5</td>
<td>Raw data 5</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4005</td>
<td>RAM_6</td>
<td>Raw data 6</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4006</td>
<td>RAM_7</td>
<td>Raw data 7</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4007</td>
<td>RAM_8</td>
<td>Raw data 8</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4008</td>
<td>RAM_9</td>
<td>Raw data 9</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4033</td>
<td>RAM_52</td>
<td>Raw data 52</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4034</td>
<td>RAM_53</td>
<td>Raw data 53</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4035</td>
<td>RAM_54</td>
<td>Raw data 54</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4036</td>
<td>RAM_55</td>
<td>Raw data 55</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4037</td>
<td>RAM_56</td>
<td>Raw data 56</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4038</td>
<td>RAM_57</td>
<td>Raw data 57</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x4039</td>
<td>RAM_58</td>
<td>Raw data 58</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x403A</td>
<td>RAM_59</td>
<td>Raw data 59</td>
</tr>
<tr>
<td>Read-only</td>
<td>0x403B</td>
<td>RAM_60</td>
<td>Raw data 60</td>
</tr>
</tbody>
</table>

*Table 7: Memory table*

**Important!** The width of the EEPROM is 16 bit.
Some calibration parameters are 32 bit and split up into two 16 bit numbers in EEPROM.
The least significant 16 bits of the parameter starts on the address shown in the Memory table.
**Example:** To retrieve value EE_Aa (32bit) = EE_Aa_MS (at 0x2415) << 16 | EE_Aa_LS (at 0x2414)
(Section **Example Temperature Calculation**)

**Important!** The EEPROM needs to be unlocked before each write command, e.g. all addresses with R/W access need the customer key for modification.
(Section **EEPROM unlock for customer access**)

---

MLX90632 FIR sensor
Datasheet

DOC#3901090632 | REVISION 12 – MAR, 2023
7.1. **Product ID**

A unique 48-bit product ID is stored in the EEPROM.

Addresses 0x2405 (ID0), 0x2406 (ID1) and 0x2407 (ID2) should be readout to know the ID of the product.

\[
\text{ProductID}[47:0] = \text{ID2}[15:0] \ll 32 \ | \ \text{ID1}[15:0] \ll 16 \ | \ \text{ID0}[15:0]
\]

Figure 4: ID0

Figure 5: ID1

Figure 6: ID2
7.2. Product Code (0x2409)

<table>
<thead>
<tr>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>FOV</td>
<td>Package</td>
<td>Accuracy range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **FOV**
  - 0: 50°
- **Package**
  - 0: -
  - 1: SFN 3x3
- **Accuracy range**
  - 0: -
  - 1: Medical
  - 2: Standard

Figure 7 EE_PRODUCT_CODE

7.3. Customer Data storage Area (0x24C0 to 0x24CF)

The EEPROM area dedicated for customer data storage consists of 16 EEPROM cell of 16-bit words in the address range from 0x24C0 to 0x24CF.

The customer data area in the MLX90632 EEPROM is **not** meant for storing intermittent data during production, calibration or normal application use. The purpose of having such an area is to enable the customer to store additional MLX90632 related calibration or tracking information. It is important that only the final data is written to the MLX90632 EEPROM in one go. In order to verify that the writing process was successful, the whole EEPROM data should be read-out prior to writing and compared to the EEPROM content after writing - only the customer data values should be different.

**Important note:** The maximum number of EEPROM re-writes is 10. Therefore, it is highly recommended that the writing of the data is done 1 time only.
8. Control and configuration

MLX90632 does multiple measurements in one table. Burst (SOB) enables automatic triggering of all measurement, while Single(SOC) allows one-by-one measurement triggering, thus more precise control. For more details refer to Application Note “AN MLX90632 measuring modes” available on Melexis Web.

Several bits in the EEPROM or register are available to control and configure the measurements:

8.1. Measurement control

---

**Figure 8: Register Measurement control settings**

REG_CONTROL controls the measurement handling and data storage. Changes will take immediate effect.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Parameter</th>
<th>Description</th>
<th>See section</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>sob</td>
<td>starts a full measurement table when being in (sleeping) step mode</td>
<td>Operating Modes</td>
</tr>
<tr>
<td>8:4</td>
<td>meas_select</td>
<td>select the type of measurement to be performed</td>
<td>Operating Modes</td>
</tr>
<tr>
<td>3</td>
<td>soc</td>
<td>starts a single measurement when being in (sleeping) step mode</td>
<td>Operating Modes</td>
</tr>
<tr>
<td>2:1</td>
<td>mode[1:0]</td>
<td>defines the operating mode</td>
<td>Operating Modes</td>
</tr>
</tbody>
</table>

Table 8: Register REG_CONTROL explained

Note that this register is initialized during POR by the EEPROM word EE_CONTROL.

Several measurement modes exist. These modes are controlled by bits mode[1:0] in register REG_CONTROL. In continuous mode the measurements are constantly running while in step mode the state machine will execute only one measurement which is initiated by soc bit. After finishing the measurement it will go in wait state until the next measurement is initiated by soc. The measurements are following the measurement sequence as defined in the measurement table.

The different possible operating modes are:

- mode[1:0] = 00: Enables the **HALT mode**. This is a special mode for EEPROM operations. Halt mode is aborting the current measurement. The device remains in active state all the time in this mode. Measurements are not executed.
- mode[1:0] = 01: Enables the **sleeping step mode**. In this mode the device will be in sleep. On request
(soc bit), the device will power-on, the state machine will do one measurement, will go into sleep and will wait for next command.

- mode[1:0] = 10: Enables the step mode. In this mode the state machine will do one measurement upon request (soc bit) and will wait for next command. The device remains in active state all the time in this mode.
- mode[1:0] = 11: Device is in continuous mode. Measurements are executed continuously. The device remains in active state all the time in this mode.

By default, the device is in continuous mode. Switching between the step modes and continuous mode has immediate effect after the current measurement has finished (not waiting till end of measurement table was reached).

8.2. Measurement type select

For the medical version, there are two possible measurements to select from:

- meas_select[4:0] = 0x00: Enables the medical measurement. In order to calculate the correct temperatures, the appropriate raw data values and formulas should be used. Refer to the medical measurement temperature calculations
- meas_select[4:0] = 0x11: Enables the extended range measurement. In order to calculate the correct temperatures, the appropriate raw data values and formulas should be used. Refer to the extended range measurement temperature calculations

Note: If other values are being used for meas_select, the resulting calculated temperatures will be invalid.

In order to switch to the desired measurement type the following routine should be performed:

1. Send an addressed reset to the MLX90632 device
2. Read the register (REG_CONTROL) value
3. Modify the REG_CONTROL value to:
   a. mode[1:0] = 00
   b. meas_select = 0x00 for medical or 0x11 for extended range
4. Read the register (REG_CONTROL) value
5. Modify the REG_CONTROL value mode[1:0] to the desired mode

The next measurement will be of the type that was programmed.

By default, for the medical version of MLX90632, the medical measurement is enabled.
8.3. Device status

REG_STATUS allows checking in which state the device is and indicates when measurements are finished. Changes will take immediate effect.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Parameter</th>
<th>Description</th>
<th>See section</th>
</tr>
</thead>
</table>
| 10   | device_busy   | Read-only
Flag indicating that a measurement is being executed (1 = measurement ongoing)
In sleep mode, this flag is always low.
In continuous mode, this flag is always high.
In soc-step mode, this flag is high during one measurement.
In sob-step mode, this flag is high till all measurements are finished. | Operating Modes                  |
| 9    | eeprom_busy   | Read-only
Flag indicating that the eeprom is busy (0: not busy)
Eeprom being busy is defined as follows:
- at start-up, the eeprom is busy and remains busy till the initialization phase (eeprom copy) has finished
- during eeprom write/erase, the eeprom is busy |                                             |
| 8    | brown_out     | Bit is set to 0
Customer should set this bit to 1 at startup
When the device would reset, the bit is set to 0 and a reset can be detected |                                             |
| 6:2  | cycle_position| Read-only
Indicates from which measurement (in the measurement table) the last written data is coming:
- cycle_position[4:0]=x, corresponds to measurement x, x=0->31 | Temperature calculation          |
| 0    | new_data      | Customer should set bit to 0
When a measurement is done and all data is available, the bit is set to 1
Customer can readout the data and reset the bit to 0 | Operating Modes                  |

Table 9: Register REG_STATUS explained
8.4. Measurement settings

8.4.1. Refresh rate

The refresh rate is the speed that the RAM will be updated with results and is configurable in “Measurement settings 1” and “Measurement settings 2”.

The refresh rate can be set with 3 bits and is located in EEPROM addresses 0x24E1 and 0x24E2. Changing the refresh rate will take immediate effect.

It is important to know that the refresh rate must be kept the same for both measurements.

The table below shows the available refresh rates and the corresponding result to be written in EEPROM addresses EE_MEAS_1 and EE_MEAS_2.

<table>
<thead>
<tr>
<th>EE_MEAS_1[10:8]</th>
<th>EE_MEAS_2[10:8]</th>
<th>Refresh rate [Hz]</th>
<th>Time [ms]</th>
<th>Burst meas time [ms]</th>
<th>EE_MEAS_1 (0x24E1)</th>
<th>EE_MEAS_2 (0x24E2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>2000</td>
<td>4000</td>
<td>0x800D</td>
<td>0x801D</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1000</td>
<td>2000</td>
<td>0x810D</td>
<td>0x811D</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>500</td>
<td>1000</td>
<td>0x820D</td>
<td>0x821D</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
<td>250</td>
<td>500</td>
<td>0x830D</td>
<td>0x831D</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>8</td>
<td>125</td>
<td>250</td>
<td>0x840D</td>
<td>0x841D</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>16</td>
<td>62.5</td>
<td>125</td>
<td>0x850D</td>
<td>0x851D</td>
</tr>
<tr>
<td>6</td>
<td>32</td>
<td>32</td>
<td>31.25</td>
<td>62.5</td>
<td>0x860D</td>
<td>0x861D</td>
</tr>
<tr>
<td>7</td>
<td>64</td>
<td>64</td>
<td>15.625</td>
<td>31.25</td>
<td>0x870D</td>
<td>0x871D</td>
</tr>
</tbody>
</table>

Figure 10: EEPROM Measurement settings

Table 10: EEPROM Refresh rate For Medical and Standard explained
### 9. \textsuperscript{1}C commands

This device is based on \textsuperscript{1}C specification Rev.5 – October 9\textsuperscript{th} 2012. \textsuperscript{1}C FM+ mode is supported.

The sensor has the following \textsuperscript{1}C features:

- Slave mode only
- 7-bits addressing
- Modes: Standard-mode, Fast-mode, Fast-mode Plus
- Incremental addressing – allowing a block of addresses to be accessed inside one \textsuperscript{1}C sequence

The following \textsuperscript{1}C commands are implemented:

- Read/write access to internal memories and registers
  - Addressed write
  - Addressed read
- Global reset
- Addressed reset
- EEPROM unlock for CUST access
- Direct read

---

**Table 11: Extended range EEPROM Refresh rate explained**

<table>
<thead>
<tr>
<th>EE_MEAS_17(10:8)</th>
<th>Refresh rate [Hz]</th>
<th>Time [ms]</th>
<th>Burst meas time [ms]</th>
<th>EE_MEAS_17 (0x24F1)</th>
<th>EE_MEAS_18 (0x24F2)</th>
<th>EE_MEAS_19 (0x24F3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.16</td>
<td>6000</td>
<td>6000</td>
<td>0x8000</td>
<td>0x8012</td>
<td>0x800C</td>
</tr>
<tr>
<td>1</td>
<td>0.32</td>
<td>3000</td>
<td>3000</td>
<td>0x8100</td>
<td>0x8112</td>
<td>0x810C</td>
</tr>
<tr>
<td>2</td>
<td>0.65</td>
<td>1500</td>
<td>1500</td>
<td>0x8200</td>
<td>0x8212</td>
<td>0x820C</td>
</tr>
<tr>
<td>3</td>
<td>1.3</td>
<td>750</td>
<td>750</td>
<td>0x8300</td>
<td>0x8312</td>
<td>0x830C</td>
</tr>
<tr>
<td>4</td>
<td>2.6</td>
<td>375</td>
<td>375</td>
<td>0x8400</td>
<td>0x8412</td>
<td>0x840C</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>200</td>
<td>200</td>
<td>0x8500</td>
<td>0x8512</td>
<td>0x850C</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>100</td>
<td>100</td>
<td>0x8600</td>
<td>0x8612</td>
<td>0x860C</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>0x8700</td>
<td>0x8712</td>
<td>0x870C</td>
</tr>
</tbody>
</table>
9.1. **I²C address**

By default, the device responds to the 7-bit slave address 0x3A. Configuration of the 7-bit slave address is possible at EEPROM address 0x24D5.

The least significant bit (bit0) of the address is determined by the status of the ADDR-pin (either connected to ground or supply) and is taken in after power-up or a reset command if a change is made in EEPROM.
- Bit0 = ‘0’ if ADDR-pin is connected to GND
- Bit0 = ‘1’ if ADDR-pin is connected to VDD

The remaining 6-bits can be used to configure the I2C address of the device.

<table>
<thead>
<tr>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Melexis reserved</td>
<td>Configurable 6-bit slave address (0x1D)</td>
<td>External status of ADDR-pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 11: EEPROM I²C address configuration**

**Important!** The device will not respond if the I²C address is changed to 0 (and ADDR pin is low). The only way to get the device to respond in this condition is to pull the ADDR pin high. The slave address will be changed to 1 and communication is possible.

**Important!** The device shall not execute measurements when performing EEPROM memory operations (I²C read/erase/write instructions in EEPROM address range)! Hence, the device must be put in HALT or Step mode before doing EEPROM write/erase operations. EEPROM read can be done in HALT, STEP or Sleeping STEP mode.

### 9.1.1. Slave Address change process flow

- Put device in Halt mode, use current slave address
  - Read Control Register
  - Mask Control register value – change only the power mode bits
  - Write the new value to Control register
- Write Slave address to EEPROM, use current slave address
  - Send EEPROM unlock key
  - Write 0x0000 to address 0x24D5
**Important!** Do not power down the device at this point

- Wait at least 5ms
- Send EEPROM unlock key
- Write New slave address [6:1] to address 0x24D5
- Wait at least 5ms
- It is advised to read back and verify the written address value at this point

It is now safe to power-down the device

⇒ After power-down of the device the new slave address will be in operation.

### 9.1.2. Slave Address change example

```c
#include <mlx90632.h>

#define OLD_SLAVE_ADDRESS 0x3A
#define NEW_SLAVE_ADDRESS 0x42
#define ADDR_PIN 0

// i2c read/write functions – i2ca parameter is the Slave address
int32_t mlx90632_i2c_read_SA(uint8_t i2ca, int16_t register_address, uint16_t *value)
int32_t mlx90632_i2c_write_SA(uint8_t i2ca, int16_t register_address, uint16_t value)
int32_t mlx90632_i2c_write_EE(uint8_t i2ca, int16_t register_address, uint16_t value)
{
    // Send EEPROM unlock key
    // Write 0x0000
    // Wait 5ms
    // Send EEPROM unlock key
    // Write value
    // Wait 5ms
}

int main()
{
    uint16_t rData;
    // Put the device in Halt mode
    mlx90632_i2c_read_SA(OLD_SLAVE_ADDRESS, MLX90632_REG_CTRL, &rData);
    rData = rData & (~MLX90632_CFG_PWR_MASK);
    rData |= (MLX90632_PWR_STATUS_HALT);
    mlx90632_i2c_write_SA(OLD_SLAVE_ADDRESS,MLX90632_REG_CTRL, rData);

    // Write new Slave address to EEPROM
    mlx90632_i2c_write_EE(OLD_SLAVE_ADDRESS, MLX90632_EE_I2C_ADDRESS, NEW_SLAVE_ADDRESS>>1);
    // It is now safe to power down the device in order load the new Slave address
    // After POR the new slave address should be used for i2c communication
    mlx90632_i2c_read_SA(NEW_SLAVE_ADDRESS, MLX90632_REG_CTRL, &rData);
}
```
9.2. **Addressed read**

The addressed read command allows an incremental read-out, starting from any given address within the memory space.

![Addressed read](image_url)

**Important!**

An addressed read is only valid when combining directly communicating the start address and a direct read through a repeated START condition. In case the read and write part are separated by a STOP condition, or in case the read is not directly following the write, or in case the slave address is not identical for both, the command will not be seen as an addressed read. As a result, the second read will in practice act as a direct read.

As soon as incremental addressing leaves the address space, the slave will respond with all 8’hFF.

![Addressed read - Oscilloscope Plot](image_url)
9.3. **Addressed write**

The addressed write command allows doing an incremental write, starting from any given address within the memory space.

The slave is sending ACK/NACK based on the fact whether it was able to write data (timing, end of register space, access rights).

The slave will automatically increment the address of the write byte, independent if it gave an ACK or a NACK to the master. It is up to the master to re-write the byte afterwards.

The device shall not execute measurements when performing EEPROM memory operations (I²C read/erase/write instructions in EEPROM address range)! Hence, the device must be put in HALT or Step mode before doing EEPROM write/erase operations. EEPROM read can be done in HALT, STEP or Sleeping STEP mode.

Before writing to EEPROM it is necessary to erase the specific address location in EEPROM. This is done by first writing 0x0000. Then the new data can be written.

When the device is busy with the write operation to EEPROM, new write commands will be ignored. A read operation will return invalid data. The fact that the device is busy is indicated via the bit device_busy in REG_STATUS.

9.4. **Global reset**

This command resets all devices on the I²C bus (based on the general call address 0x00).

Note: After this command, a delay at least 150us is needed before the next communication with the device.
9.5. **Addressed reset**

This command resets the addressed device only (based on the \( \text{I}^{2}\text{C} \) address).

![Figure 16: Addressed reset](image)

Note: After this command, a delay at least 150us is needed before the next communication with the device.

9.6. **EEPROM unlock for customer access**

This command unlocks the EEPROM allowing only one write operation to an EEPROM word in the customer part of the EEPROM.

After the EEPROM write, the EEPROM access goes back to the “NoKey” access mode.

![Figure 17: EEPROM unlock](image)

9.7. **Direct read**

The direct read command allows an incremental read out at a default start address. This default start address is fixed to the register location REG_STATUS (0x3FFF). According to the \( \text{I}^{2}\text{C} \) specification, the master will keep sending an acknowledge (A) until it want to stop. This is indicated by sending a NAK. As a result, the slave will stop driving the SDA-bus as soon as a NAK is received by the master.

As soon as the incremental addressing leaves the address space, the slave will respond with all 8’hFF.

![Figure 18: Direct read](image)

9.8. **1.8V \( \text{I}^{2}\text{C} \) communication device**

When using such device, it is recommended to start with a Stop condition or a dummy command before any other command after powering up the device.
10. Operating Modes

The device has 2 states of operation: **sleep state** and **active state**.

- **Sleep state**
  
  In this state, most of the circuitry is disabled to limit the current consumption to a few uA.

- **Active state**
  
  In this state, the sensor is active. The current consumption is $I_{DD}$ (about 1mA).

10.1. Measurement modes

Several measurement modes exist. These modes are controlled by bits mode[1:0] in register REG_CONTROL[2:1]. In continuous mode the measurements are constantly running while in step mode the state machine will execute only one measurement which is initiated by the soc bit or a full measurement set initiated by the sob bit. After finishing the measurement(s) the sensor will go in a wait state until the next measurement is initiated by the soc or sob bit. If soc is used to initiate a measurement, the measurements are following the measurement sequence as defined in the measurement table.

- mode[1:0] = 00: Enables the **HALT mode**. This is a special mode for EEPROM operations. Halt mode is aborting the current measurement. The device remains in active state all the time in this mode.
  Measurements are not executed.

The different possible measurement modes are:

- mode[1:0] = 01: Enables the **sleeping step mode**.
  
  The device will be in sleep mode. On request (soc or sob bit), the device will power-on, the state machine will perform one measurement(soc) or the full measurement table (sob), will go into sleep and wait for the next command.

  In the sleeping step mode all the measurements from the measurement table will be performed so that all data necessary for the calculations is refreshed. The two ways of using the device in this mode are:

  - **SOB bit**
    
    The SOB bit initiates a full measurement table measurement. Once the measurement is started, the SOB bit is cleared and the *device_busy* bit is set internally in the MLX90632. When all the measurements from the measurement table are performed, the *device_busy* bit is cleared indicating the end of measurements – the new data can be read. The flow should be:
    1. Set SOB bit
    2. Wait for all the measurements from the measurement table to finish - depending on the refresh rates (see Table 10 and Table 11)
    3. Make sure that the device_busy bit is cleared
    4. Read out the data
    5. Calculate the temperatures

- **SOC bit**
The SOC bit initiates a single measurement from the measurement table. The measurements are being performed consecutively as set in the measurement table. Once the measurement is started, the SOC bit is cleared internally in the MLX90632 and could be set again so that the next measurement from the measurement table is started right after the current one is done. When the current measurement is done, the new_data bit is set – the new data can be read and the bit should be cleared. The flow should be:

1. Set SOC bit
2. Wait for the 1st measurement from the measurement table to finish - depending on the refresh rate (see Table 10 and Table 11)
3. Make sure that the new_data bit is set and clear it
4. Set SOC bit
5. Wait for the 2nd measurement from the measurement table to finish - depending on the refresh rate (see Table 10 and Table 11)
6. Make sure that the new_data bit is set and clear it
7. If medical mode is selected proceed with step 11 (e.g. skip 8..10)
8. Set SOC bit
9. Wait for the 3rd measurement from the measurement table to finish - depending on the refresh rate (see Table 10 and Table 11)
10. Make sure that the new_data bit is set and clear it
11. Read out the data
12. Calculate the temperatures

- mode[1:0] = 10: Enables the step mode.
  The state machine will do one measurement upon request (soc bit) and will wait for the next command. The device remains powered all the time in this mode.
- mode[1:0] = 11: Device is in continuous mode.
  Measurements are executed continuously. The device remains powered all time in this mode.

By default, the device is in continuous mode.

Switching between the step modes and continuous mode has immediate effect after the current measurement has finished (not waiting until the end of the measurement table was reached, i.e. it is not guaranteed the whole measurement table is executed).

### 10.2. Measurement types

There are two possible measurement types to select from:

- meas_select[4:0] = 0x00: Enables the medical measurement. In order to calculate the correct temperatures, the appropriate raw data values and formulas should be used. Refer to the [medical measurement temperature calculations](#).
- meas_select[4:0] = 0x11: Enables the extended range measurement. In order to calculate the correct temperatures, the appropriate raw data values and formulas should be used. Refer to the [medical measurement temperature calculations](#).
temperatures, the appropriate raw data values and formulas should be used. Refer to the extended range measurement temperature calculations.

*Note: If other values are being used for meas_select, the resulting calculated temperatures will be invalid.*

## 11. Temperature calculation

### 11.1. Medical measurement

To calculate the ambient and object temperature, a set of 2 measurements is required:

- Measurement 1: RAM\_4, RAM\_5, RAM\_6;
- Measurement 2: RAM\_7, RAM\_8, RAM\_9;

One should notice this requires double the measurement time than specified (= 2 * 500ms) for the very first calculation. After the first calculation, TA and TO can be calculated with the next measurement.

**Example:**

| t0: Measurement 1 | (cycle_pos = 1) => no calculation of TA or TO possible because not all parameters are known |
| t1: Measurement 2 | (cycle_pos = 2) => calculate TA (RAM\_6, RAM\_9) calculate TO (RAM\_7, RAM\_8, RAM\_6, RAM\_9) => 1s. |
| t2: Measurement 3 | (cycle_pos = 1) => calculate TA (RAM\_6, RAM\_9) calculate TO (RAM\_4, RAM\_5, RAM\_6, RAM\_9) => 0.5s. |
| t3: Measurement 4 | (cycle_pos = 2) => calculate TA (RAM\_6, RAM\_9) calculate TO (RAM\_7, RAM\_8, RAM\_6, RAM\_9) => 0.5s. |
| t4: ... |

To calculate the new ambient and object temperature RAM\_6 and RAM\_9 have to be used. The choice between [RAM\_4 and RAM\_5] or [RAM\_7 and RAM\_8] depends on the current measurement. REG\_STATUS[6:2] (= “cycle_pos”) returns the current position of the measurement defined in the measurement table.

Using the current data and the data from measurement (x-1), TA and TO can be calculated every 500ms. The complete measurement sequence can be automated by using the new\_data bit in combination with cycle\_pos bits.

The sequence should look like the following:

- Write new\_data = 0
- Check when new\_data = 1
- Read cycle\_pos to get measurement pointer
  - If cycle\_pos = 1
    - Calculate TA and TO base on RAM\_4, RAM\_5, RAM\_6, RAM\_9
  - If cycle\_pos = 2
- Calculate TA and TO base on RAM_7, RAM_8, RAM_6, RAM_9
- Return to top

11.1.1. Pre-calculations

11.1.1.1. Ambient

\[
VR_{TA} = \text{RAM}_9 + Gb \times \frac{\text{RAM}_6}{12}
\]

\[
Gb = \text{EE}_G \times 2^{-10}
\]

\[
\text{AMB} = \left[\frac{\text{RAM}_6}{12}\right] / VR_{TA} \times 2^{19}
\]

The parameter EE_G is a signed 16-bit number.

11.1.1.2. Object

\[
S = \frac{\text{RAM}_4 + \text{RAM}_5}{2}
\]

OR

\[
S = \frac{\text{RAM}_7 + \text{RAM}_8}{2}
\]

\[
VR_{TO} = \text{RAM}_9 + Ka \times \frac{\text{RAM}_6}{12}
\]

\[
Ka = \text{EE}_K \times 2^{-10}
\]

\[
S_{TO} = \left[\frac{S}{12}\right] / VR_{TO} \times 2^{19}
\]

The parameter EE_K is a signed 16-bit number.

11.1.2. Ambient temperature

\[
T_a \text{ (sensor temperature in °C)} = \frac{\text{AMB} - P_R}{P_G} + P_T \times (\text{AMB} - P_R)^2
\]

With:
- Ta in degrees Celsius
- \(P_R = \text{EE}_P \times 2^{-8}\)
- \(P_O = \text{EE}_P \times 2^{-8}\)
- \(P_G = \text{EE}_P \times 2^{-20}\)
\[ P_T = EE_P_T \times 2^{-44} \]

The parameters EE_P_R, EE_P_O, EE_P_G and EE_P_T are signed 32-bit numbers.

### 11.1.3. Object temperature

**TO (object temperature in °C)**

\[
TO = \frac{\sqrt{c \times Fa \times Ha \times (1 + Ga \times (TO_{DUT} - TO_0) + Fb \times (TA_{DUT} - TA_0)) + Ta_{[K]}^4 - 273.15 - Hb}}{4}
\]

With:
- \( Fa = EE_Fa \times 2^{-46} \)
- \( Fb = EE_Fb \times 2^{-36} \)
- \( Ga = EE_Ga \times 2^{-36} \)
- \( Ha = EE_Ha \times 2^{-14} \)
- \( Hb = EE_Hb \times 2^{-10} \)
- \( TO_0 = 25°C \)
- \( TA_0 = 25°C \)
- \( TADUT = \frac{Ea}{(AMB - Eb) + 25} \)
- \( Eb = EE_Eb \times 2^{-8} \)
- \( Ta_{[K]} = TADUT + 273.15 \) in Kelvin
- \( TO_{DUT} = \) Object temperature in 25°C
- \( c = 1 = \) Object Emissivity parameter (not stored in EEPROM, but part of the ‘app’)

The parameters EE_Ea, EE_Eb, EE_Fa, EE_Fb, EE_Ga are signed 32-bit numbers.
The parameters EE_Gb, EE_Ka, EE_Ha and EE_Hb are signed 16-bit numbers.

**Note:**
One can see that to compute “To (object temperature)”, “To” already needs to be known.
“To (object temperature)” is computed in an iterative manner. In the first iteration “To” is assumed to be 25°C.
In the 2\(^{nd}\) iteration the result of first iteration is used, and in the 3\(^{rd}\) iteration the end result is obtained.
(See example on next page).

### 11.1.4. Example Medical measurement Temperature Calculation

Assumed are the following calibration parameters read from EEPROM:

<table>
<thead>
<tr>
<th>ADDR</th>
<th>PARAM</th>
<th>DATA (hex)</th>
<th>hex to dec</th>
<th>Conversion to use in formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x240C</td>
<td>EE_P_R [15:0]</td>
<td>0103</td>
<td>EE_P_R = 005D0103\text{hex} = 6095107\text{dec}</td>
<td>( P_R = 6095107 \times 2^{-8} = 23809.01 )</td>
</tr>
<tr>
<td>0x240D</td>
<td>EE_P_R [31:16]</td>
<td>005D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x240E</td>
<td>EE_P_G [15:0]</td>
<td>FAE5</td>
<td>EE_P_G = 051CFAE5\text{hex} = 85785317\text{dec}</td>
<td>( P_G = 85785317 \times 2^{-20} = 81.81125 )</td>
</tr>
<tr>
<td>0x240F</td>
<td>EE_P_G [31:16]</td>
<td>051C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2410</td>
<td>EE_P_T [15:0]</td>
<td>0000</td>
<td>EE_P_T = 0000000\text{hex} = 0\text{dec}</td>
<td>( P_T = 0 \times 2^{-44} = 0 )</td>
</tr>
</tbody>
</table>
The returned values from the RAM (0x4000 to 0x4008):

<table>
<thead>
<tr>
<th>ADDR</th>
<th>PARAM</th>
<th>DATA (hex)</th>
<th>DATA (dec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x4003</td>
<td>RAM_4</td>
<td>FF9B</td>
<td>-101</td>
</tr>
<tr>
<td>0x4004</td>
<td>RAM_5</td>
<td>FF9D</td>
<td>-99</td>
</tr>
<tr>
<td>0x4005</td>
<td>RAM_6</td>
<td>57E4</td>
<td>22500</td>
</tr>
<tr>
<td>0x4006</td>
<td>RAM_7</td>
<td>FF97</td>
<td>-105</td>
</tr>
<tr>
<td>0x4007</td>
<td>RAM_8</td>
<td>FF99</td>
<td>-103</td>
</tr>
<tr>
<td>0x4008</td>
<td>RAM_9</td>
<td>59D8</td>
<td>23000</td>
</tr>
</tbody>
</table>

Table 13: Example RAM data
11.1.4.1. Ambient temperature calculation

\[ \text{VR}_{TA} = \text{RAM}_9 + Gb \times \frac{\text{RAM}_6}{12} = 23000 + 9.5 \times \frac{22500}{12} \]

\[ \text{VR}_{TA} = 40812.5 \]

\[ \text{AMB} = \left[ \frac{\text{RAM}_6}{12} \right] / \text{VR}_{TA} \times 2^{19} = \left[ \frac{22500}{12} \right] / 40812.5 \times 2^{19} \]

\[ \text{AMB} = 24086.73813 \]

\[ T_a \text{ (sensor temperature in °C)} = P_O + \frac{\text{AMB} - P_R}{P_G} + P_T \times (\text{AMB} - P_R)^2 \]

\[ T_a = 25 + \frac{24086.73813 - 23809.01}{81.81125} + 0 \times (24086.73813 - 23809.01)^2 \]

\[ T_a = 28.395°C \]

\[ T_a = 28.4°C \]
11.1.4.2. Object temperature calculation

\[
S = \frac{\text{RAM}_4 + \text{RAM}_5}{2} = \frac{(-101) + (-99)}{2} = -100
\]

OR

\[
S = \frac{\text{RAM}_7 + \text{RAM}_8}{2} = \frac{(-105) + (-103)}{2} = -104
\]

Assumed is that RAM_4 and RAM_5 are updated lastly by the device (cycle_pos = 1)

\[
\text{VR}_{T_0} = \text{RAM}_9 + K_a \times \frac{\text{RAM}_6}{12} = 23000 + 10.5 \times \frac{22500}{12}
\]

\[
\text{VR}_{T_0} = 42687.5
\]

\[
S_{T_0} = \left[ \frac{S}{12} \right] / \text{VR}_{T_0} \times 2^{19} = \left[ \frac{-100}{12} \right] / 42687.5 \times 2^{19}
\]

\[
S_{T_0} = -102.35
\]

\[
T_{O_0} = 25^\circ C
\]

\[
T_{A_0} = 25^\circ C
\]

\[
\text{TA}_{DUT} = \frac{(\text{AMB} - E_b)}{E_a} + 25 = \frac{(24086.73813 - 23809.01)}{81.81125} + 25 = 28.3947
\]

\[
T_{a[K]} = \text{TA}_{DUT} + 273.15 = 28.3947 + 273.15 = 301.5447
\]
To (object temperature in °C)

\[
To = \sqrt{\frac{S_{TO}}{\varepsilon \cdot Fa \cdot Ha \cdot (1 + Ga \cdot (TO_{DUT} - TO_o) + Fb \cdot (TA_{DUT} - TA_o)) + Ta[K]^4 - 273.15 - Hb}}
\]

The emissivity parameter (\(\varepsilon\)) is controlled by the user and is assumed in this example equal to 1. TO\(_{DUT}\) = 25 for the first calculation

\[
To = \sqrt{\frac{-102.35}{1 * (7.9E-07) * 1 * (1 + (-0.00049) * (25 - 25) + (-0.00045) * (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0}
\]

To = 27.2048027°C

The object temperature needs to be calculated 3 times in order to get the end result. Next object temperature calculation uses previous obtained object temperature.

\[
To = \sqrt{\frac{-102.35}{1 * (7.9E-07) * 1 * (1 + (-0.00049) * (27.2048027 - 25) + (-0.00045) * (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0}
\]

To = 27.2035098°C

\[
To = \sqrt{\frac{-102.35}{1 * (7.9E-07) * 1 * (1 + (-0.00049) * (27.2035098 - 25) + (-0.00045) * (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0}
\]

To = 27.20351053°C

To = 27.2°C
11.2. **Extended range measurement**

This measurement type option is implemented in order to give additional range to the medical devices.

When using the extended range measurement the following should be done:

1. Switch the device to extended range measurement mode
2. Wait for the whole measurement to finish
3. Use the following routine to read the data of interest and calculate the temperatures.

All the necessary functions are available at [https://github.com/melexis/mlx90632-library](https://github.com/melexis/mlx90632-library)

To calculate the ambient and object temperature, a set of 3 measurements is required:

- Measurement 1: RAM_52, RAM_53, RAM_54;
- Measurement 2: RAM_55, RAM_56, RAM_57;
- Measurement 3: RAM_58, RAM_59, RAM_60;

All three measurements should be available for proper temperature calculation.

**11.2.1. Pre-calculations**

**11.2.1.1. Ambient**

\[
VR_{TA} = RAM_{57} + Gb \times \frac{RAM_{54}}{12}
\]

\[
Gb = EE_{Gb} \times 2^{-10}
\]

\[
AMB = \left[ \frac{RAM_{54}}{12} \right] / VR_{TA} \times 2^{19}
\]

The parameter EE_{Gb} is a signed 16-bit number.

**11.2.1.2. Object**

\[
S = \frac{RAM_{52} - RAM_{53} - RAM_{55} + RAM_{56}}{2} + RAM_{58} + RAM_{59}
\]

OR

\[
VR_{TO} = RAM_{57} + Ka \times \frac{RAM_{54}}{12}
\]

\[
Ka = EE_{Ka} \times 2^{-10}
\]
The parameter $EE_{Ka}$ is a signed 16-bit number.

### 11.2.2. Ambient temperature

$$ Ta \text{ (sensor temperature in } ^\circ\text{C}) = P_O + \frac{AMB - P_R}{P_G} + P_T \cdot (AMB - P_R)^2 $$

With:

- $Ta$ in degrees Celsius
- $P_R = EE_{P_R} \cdot 2^{8}$
- $P_O = EE_{P_O} \cdot 2^{8}$
- $P_G = EE_{P_G} \cdot 2^{20}$
- $P_T = EE_{P_T} \cdot 2^{44}$

The parameters $EE_{P_R}$, $EE_{P_O}$, $EE_{P_G}$ and $EE_{P_T}$ are signed 32-bit numbers.

### 11.2.3. Object temperature

$$ TO \text{ (object temperature in } ^\circ\text{C}) = 4 \left[ \frac{S_{TO}}{\varepsilon \cdot \frac{Fa}{2} \cdot Ha \cdot (1 + Ga \cdot (TO_{DUT} - TO_0) + Fb \cdot (TA_{DUT} - TA_0))} \right] + Ta_{[K]} - 273.15 - Hb $$

With:

- $Fa = EE_{Fa} \cdot 2^{-46}$
- $Fb = EE_{Fb} \cdot 2^{-36}$
- $Ga = EE_{Ga} \cdot 2^{-36}$
- $Ha = EE_{Ha} \cdot 2^{-14}$
- $Hb = EE_{Hb} \cdot 2^{-10}$
- $TO_0 = 25 ^\circ\text{C}$
- $TA_0 = 25 ^\circ\text{C}$
- $TA_{DUT} = \frac{(AMB - Eb)}{Ea} + 25$
- $Ea = EE_{Ea} \cdot 2^{-16}$
- $Eb = EE_{Eb} \cdot 2^{8}$
- $Ta_{[K]} = TA_{DUT} + 273.15$ in Kelvin
- $TO_{DUT} = \text{Object temperature in } 25 ^\circ\text{C}$
- $\varepsilon = 1 = \text{Object Emissivity parameter (not stored in EEPROM, but part of the ‘app’)}$

The parameters $EE_{Ea}$, $EE_{Eb}$, $EE_{Fa}$, $EE_{Fb}$, $EE_{Ga}$ are signed 32-bit numbers.
The parameters $EE_{Gb}$, $EE_{Ka}$, $EE_{Ha}$ and $EE_{Hb}$ are signed 16-bit numbers.
One can see that to compute “To (object temperature)”, “To” already needs to be known.
“To (object temperature)” is computed in an iterative manner. In the first iteration “To” is assumed to be 25°C.
In the 2nd iteration the result of first iteration is used, and in the 3rd iteration the end result is obtained.
(See example on next page).

11.2.4. Example Extended range measurement Temperature Calculation

Assumed are the following calibration parameters read from EEPROM:

<table>
<thead>
<tr>
<th>ADDR</th>
<th>PARAM</th>
<th>DATA (hex)</th>
<th>hex to dec</th>
<th>Conversion to use in formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x240C</td>
<td>EE_P_R [15:0]</td>
<td>0103</td>
<td>EE_P_R = 005D0103_hex = 6095107_dec</td>
<td>P_R = 6095107 * 2^-8 = 23809.01</td>
</tr>
<tr>
<td>0x240D</td>
<td>EE_P_R [31:16]</td>
<td>005D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x240E</td>
<td>EE_P_G [15:0]</td>
<td>FAES</td>
<td>EE_P_G = 051CFAES_hex = 85785317_dec</td>
<td>P_G = 85785317 * 2^-20 = 81.81125</td>
</tr>
<tr>
<td>0x240F</td>
<td>EE_P_G [31:16]</td>
<td>051C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2410</td>
<td>EE_P_T [15:0]</td>
<td>0000</td>
<td>EE_P_T = 00000000_hex = 0_dec</td>
<td>P_T = 0 * 2^-44 = 0</td>
</tr>
<tr>
<td>0x2411</td>
<td>EE_P_T [31:16]</td>
<td>0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2412</td>
<td>EE_P_O [15:0]</td>
<td>1900</td>
<td>EE_P_O = 00001900_hex = 6400_dec</td>
<td>P_O = 6400 * 2^-8 = 25</td>
</tr>
<tr>
<td>0x2413</td>
<td>EE_P_O [31:16]</td>
<td>0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2424</td>
<td>EE_Ea [15:0]</td>
<td>CFAE</td>
<td>EE_Ea = 0051CFAE_hex = 5361582_dec</td>
<td>Ea = 5361582 * 2^-16 = 81.81125</td>
</tr>
<tr>
<td>0x2425</td>
<td>EE_Ea [31:16]</td>
<td>0051</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2426</td>
<td>EE_Eb [15:0]</td>
<td>0103</td>
<td>EE_Eb = 005D0103_hex = 6095107_dec</td>
<td>Eb = 6095107 * 2^-8 = 23809.01</td>
</tr>
<tr>
<td>0x2427</td>
<td>EE_Eb [31:16]</td>
<td>005D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x2428</td>
<td>EE_Fa [15:0]</td>
<td>6351</td>
<td>EE_Fa = 03506351_hex = 5559995_dec</td>
<td>Fa = 5559995 * 2^-36 = 7.9E-07</td>
</tr>
<tr>
<td>0x2429</td>
<td>EE_Fa [31:16]</td>
<td>0350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x242A</td>
<td>EE_Fb [15:0]</td>
<td>71F1</td>
<td>EE_Fb = FE2571F1_hex = -31100431_dec</td>
<td>Fb = -31100431 * 2^-36 = -0.00045</td>
</tr>
<tr>
<td>0x242B</td>
<td>EE_Fb [31:16]</td>
<td>FE25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x242C</td>
<td>EE_Ga [15:0]</td>
<td>A7A4</td>
<td>EE_Ga = FDFFA7A5_hex = -33577052_dec</td>
<td>Ga = -33577052 * 2^-36 = -0.00049</td>
</tr>
<tr>
<td>0x242D</td>
<td>EE_Ga [31:16]</td>
<td>FDFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x242E</td>
<td>EE_Gb [15:0]</td>
<td>2600</td>
<td>EE_Gb = 2600_hex = 9728_dec</td>
<td>Gb = 9728 * 2^-10 = 9.5</td>
</tr>
<tr>
<td>0x242F</td>
<td>EE_Ka [15:0]</td>
<td>2A00</td>
<td>EE_Ka = 2A00_hex = 10752_dec</td>
<td>Ka = 10752 * 2^-10 = 10.5</td>
</tr>
<tr>
<td>0x2481</td>
<td>EE_Ha [15:0]</td>
<td>4000</td>
<td>EE_Ha = 4000_hex = 16384_dec</td>
<td>Ha = 16384 * 2^-14 = 1</td>
</tr>
<tr>
<td>0x2482</td>
<td>EE_Hb [15:0]</td>
<td>0000</td>
<td>EE_Hb = 0000_hex = 0_dec</td>
<td>Hb = 0 * 2^-10 = 0</td>
</tr>
</tbody>
</table>

Table 14: Example EEPROM calibration parameters
The returned values from the RAM (0x4033 to 0x403A):

<table>
<thead>
<tr>
<th>ADDR</th>
<th>PARAM</th>
<th>DATA (hex)</th>
<th>DATA (dec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x4033</td>
<td>RAM_52</td>
<td>FE64</td>
<td>-412</td>
</tr>
<tr>
<td>0x4034</td>
<td>RAM_53</td>
<td>FEAB</td>
<td>-341</td>
</tr>
<tr>
<td>0x4035</td>
<td>RAM_54</td>
<td>57E4</td>
<td>22500</td>
</tr>
<tr>
<td>0x4036</td>
<td>RAM_55</td>
<td>FEA3</td>
<td>-349</td>
</tr>
<tr>
<td>0x4037</td>
<td>RAM_56</td>
<td>FE6A</td>
<td>-406</td>
</tr>
<tr>
<td>0x4038</td>
<td>RAM_57</td>
<td>59D8</td>
<td>23000</td>
</tr>
<tr>
<td>0x4039</td>
<td>RAM_58</td>
<td>000B</td>
<td>11</td>
</tr>
<tr>
<td>0x403A</td>
<td>RAM_59</td>
<td>0009</td>
<td>9</td>
</tr>
</tbody>
</table>

*Table 15: Example RAM data*

### 11.2.4.1. Ambient temperature calculation

\[ VR_{TA} = RAM_57 + Gb \times \frac{RAM_54}{12} = 23000 + 9.5 \times \frac{22500}{12} \]

\[ VR_{TA} = 40812.5 \]

\[ AMB = \left[ \frac{RAM_54}{12} \right] / VR_{TA} \times 2^{19} = \left[ \frac{22500}{12} \right] / 40812.5 \times 2^{19} \]

\[ AMB = 24086.73813 \]

\[ T_a \text{ (sensor temperature in °C)} = P_O + \frac{AMB - P_R}{P_G} + P_T \times (AMB - P_R)^2 \]

\[ T_a = 25 + \frac{24086.73813 - 23809.01}{81.81125} + 0 \times (24086.73813 - 23809.01)^2 \]

\[ T_a = 28.395°C \]

\[ T_a = 28.4°C \]
11.2.4.2. Object temperature calculation

\[
S = \frac{\text{RAM}_52 - \text{RAM}_53 - \text{RAM}_55 + \text{RAM}_56}{2} + \text{RAM}_58 + \text{RAM}_59
\]

\[
S = \frac{-412 - (-341) - (-349) + (-406)}{2} + 11 + 9
\]

\[S = -44\]

\[
\text{VR}_{TO} = \text{RAM}_57 + K_a \cdot \frac{\text{RAM}_54}{12} = 23000 + 10.5 \cdot \frac{22500}{12}
\]

\[\text{VR}_{TO} = 42687.5\]

\[
S_{TO} = \left(\frac{S}{12}\right) / \text{VR}_{TO} \cdot 2^{19} = \left[\frac{-44}{12}\right] / 42687.5 \cdot 2^{19}
\]

\[S_{TO} = -45.034\]

\[\text{TO}_0 = 25 ^\circ\text{C}\]
\[\text{TA}_0 = 25 ^\circ\text{C}\]

\[
\text{TA}_{DUT} = \frac{\text{AMB} - \text{Eb}}{\text{Ea}} + 25 = \frac{(24086.73813 - 23809.01)}{81.81125} + 25 = 28.3947
\]

\[\text{Ta}_{[K]} = \text{TA}_{DUT} + 273.15 = 28.3947 + 273.15 = 301.5447\]
The emissivity parameter (Ɛ) is controlled by the user and is assumed in this example equal to 1.

\[ T_0 = 25 \] for the first calculation

\[ To = \sqrt{\frac{F_a}{2} \cdot Ha \cdot (1 + Ga \cdot (T_{DUT} - T_0) + Fb \cdot (T_{DUT} - TA))} + Ta[K]^4 - 273.15 - Hb \]

The object temperature needs to be calculated 3 times in order to get the end result. Next object temperature calculation uses previous obtained object temperature.

\[ To = \sqrt{\frac{7.9 \times 10^{-7}}{2} \cdot 1 \cdot (1 + (-0.00049) \cdot (25 - 25) + (-0.00045) \cdot (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0 \]

\[ To = 27.34837117^\circ C \]

\[ To = \sqrt{\frac{7.9 \times 10^{-7}}{2} \cdot 1 \cdot (1 + (-0.00049) \cdot (27.34837117 - 25) + (-0.00045) \cdot (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0 \]

\[ To = 27.3471655^\circ C \]

\[ To = \sqrt{\frac{7.9 \times 10^{-7}}{2} \cdot 1 \cdot (1 + (-0.00049) \cdot (27.3471655 - 25) + (-0.00045) \cdot (28.3947 - 25))} + (301.5447)^4 - 273.15 - 0 \]

\[ To = 27.34715818^\circ C \]

\[ To = 27.35^\circ C \]
12. Performance characteristics

12.1. Accuracy

All accuracy specifications apply under settled isothermal conditions only.

12.1.1. Ambient temperature

The calculated ambient temperature has an accuracy of ±3°C between -20°C and 85°C of ambient temperature. Between 15°C and 45°C the accuracy is ±1°C.

12.1.2. Standard Accuracy object temperature

*Figure 19: Standard accuracy table*
12.1.3. Medical Accuracy object temperature


Figure 20: Medical accuracy table
12.2. Field of View (FoV)

The 50° is measured at the 50% level of sensitivity. For high accuracy applications, one should take care that the field of view is not obstructed by the enclosure of the application. For this, one has to take care that no obstruction is in a cone of at least 70° wide. For medical applications the obstacle free zone should be at least 110° wide.
12.3. **Noise**

Measurement conditions for noise performance are $T_o = T_a = 25^\circ C$.

Note:
Due to the nature of thermal infrared radiation, it is normal that the noise will decrease for high object temperatures and increase for lower temperatures.

![Figure 23: NETD vs. Refresh rate](image)
13. Mechanical Drawing

13.1. Package dimensions

**Table 17: Package dimensions for MLX90632 (FoV = 50°)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD=EE</td>
<td>2.9</td>
<td>3.0 BSC</td>
<td>3.1</td>
</tr>
<tr>
<td>AT</td>
<td>0.90</td>
<td>0.95</td>
<td>1.00</td>
</tr>
<tr>
<td>Ra</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>2.40</td>
<td>2.50</td>
<td>2.60</td>
</tr>
<tr>
<td>E2</td>
<td>2.00</td>
<td>2.10</td>
<td>2.20</td>
</tr>
<tr>
<td>Lo1</td>
<td>0.15 Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kk</td>
<td>0.20</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>NXL</td>
<td>0.35</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>e1</td>
<td>0.50 BSC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NminOne_e</td>
<td>(5-1)*e1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ti</td>
<td>0.18</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>Tolerance (A_CC – A_CP)</td>
<td>-0.15</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Tolerance (A_CC – A_CD)</td>
<td>-0.1</td>
<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>

*BSC = basic dimension   *A_CC = Center of silicon Cap   *A_CD = Center of Die frame   *A_CP = Center of Package

Figure 24: Package dimensions for MLX90632 (FoV = 50°)

Marking:

```
.xxxxxxD
```

“xxxxx” = last 5 digits from lot #
13.2. **PCB footprint**

**Footprint design**

![Footprint design diagram]

**Stencil design**

- Stencil opening: 0.25x0.25
- PTH, 8*0.2mm
- 0.5mm pitch
- Tented or plugged

**Recommended**
1) PCB finish: OSP, ENIG, ENEPIG
2) Stencil thickness max 100um
3) Solderpaste – noclean, halogen free

*Figure 25: PCB footprint and stencil design for MLX90632*

**Decoupling capacitor C1 placement**

*Figure 26a: Decoupling capacitor C1 placement*
14. Application schematic

14.1. 3V3 \textit{i}^2\textit{C} mode

![Application schematic diagram]

\textit{Figure 27: Typical application schematic for 3V3 \textit{i}^2\textit{C} communication with MLX90632}

\textit{Note: C1 should be placed within 10mm from the device}
14.2. **1V8 I²C mode**

![Typical application schematic for 1V8 I²C communication with MLX90632](image)

*Note: C1 should be placed within 10mm from the device*
15. Software

MLX90632 library on Github:
https://github.com/melexis/mlx90632-library

Example usage of the MLX90632 Library with Keil IDE:
https://github.com/melexis/mlx90632-example

Evaluation board EVB90632:
16. Standard information regarding manufacturability of Melexis products with different soldering processes

The MLX90632 is a MSL-3 device. Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to following test methods:

**Reflow Soldering SMD’s (Surface Mount Devices)**
- IPC/JEDEC J-STD-020
  - Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices (Classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113
  - Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing (Reflow profiles according to table 2)

**Wave Soldering SMD’s (Surface Mount Devices) and THD’s (Through Hole Devices)**
- EN60749-20
  - Resistance of plastic- encapsulated SMD’s to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15
  - Resistance to soldering temperature for through-hole mounted devices

**Iron Soldering THD’s (Through Hole Devices)**
- EN60749-15
  - Resistance to soldering temperature for through-hole mounted devices

**Solderability SMD’s (Surface Mount Devices) and THD’s (Through Hole Devices)**
- EIA/JEDEC JESD22-B102 and EN60749-21
  - Solderability

For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile etc.) additional classification and qualification tests have to be agreed upon with Melexis.

The application of Wave Soldering for SMD’s is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.


Melexis is contributing to global environmental conservation by promoting lead free solutions. For more information on qualifications of RoHS compliant products (RoHS = European directive on the Restriction Of the use of certain Hazardous Substances) please visit the quality page on our website: http://www.melexis.com/quality.aspx
17. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

18. Application comments

1. Significant contamination at the optical input side (sensor filter) might cause unknown additional filtering/distortion of the optical signal and therefore results in unspecified errors.

2. IR sensors are inherently susceptible to errors caused by thermal gradients. There are physical reasons for these phenomena and, in spite of the careful design of the MLX90632, it is recommended not to subject the MLX90632 to heat transfer and especially transient conditions.

3. The MLX90632 is designed and calibrated to operate as a non-contact thermometer in settled conditions.

4. Upon power-up the MLX90632 passes embedded checking and calibration routines. During these routines the output is not defined and it is recommended to wait for the specified POR time before reading the module. Very slow power-up may cause the embedded POR circuitry to trigger on inappropriate levels, resulting in unspecified operation which is not recommended.

5. Capacitive loading on an I²C bus can degrade the communication. Improvement is possible with use of current sources compared to resistors in the pull-up circuitry. Further improvement is possible with specialized commercially available bus accelerators.

6. A sleep mode is available in the MLX90632. This mode is entered and exited via the I²C compatible 2-wire communication.

7. A power supply and decoupling capacitor is needed as with most integrated circuits. The MLX90632 is a mixed-signal device with sensors, small analog signals, digital parts and I/O circuitry. In order to keep the noise low, power supply switching noise needs to be decoupled. High noise from external circuitry can also affect the noise performance of the device. In many applications a 10nF SMD ceramic capacitor close to the Vdd and Vss pins would be a good choice. It should be noted that not only the trace to the Vdd pin needs to be short, but also the one to the Vss pin.

8. Do not perform measurements in oily or helium environments
19. Table of figures

Figure 1: Image of MLX90632 ........................................................................................................... 1
Figure 2: MLX90632 TOP view ....................................................................................................... 8
Figure 3: Block diagram .................................................................................................................. 10
Figure 4: ID0 ..................................................................................................................................... 14
Figure 5: ID1 ..................................................................................................................................... 14
Figure 6: ID2 ..................................................................................................................................... 14
Figure 7 EE_PRODUCT_CODE ....................................................................................................... 15
Figure 8: Register Measurement control settings .......................................................................... 16
Figure 9: Register Device status settings ...................................................................................... 18
Figure 10: EEPROM Measurement settings .................................................................................. 19
Figure 11: EEPROM I2C address configuration .......................................................................... 21
Figure 12: Addressed read .............................................................................................................. 23
Figure 13 Addressed read - Oscilloscope Plot .............................................................................. 23
Figure 14: Addressed write ............................................................................................................ 24
Figure 15: Global reset .................................................................................................................... 24
Figure 16: Addressed reset ............................................................................................................. 25
Figure 17: EEPROM unlock .......................................................................................................... 25
Figure 18: Direct read .................................................................................................................... 25
Figure 19: Standard accuracy table .............................................................................................. 41
Figure 20: Medical accuracy table ............................................................................................... 42
Figure 21: Field of View measurement principle ........................................................................ 43
Figure 22: Field of View of MLX90632 (FoV = 50°) ..................................................................... 43
Figure 23: NETD vs. Refresh rate .................................................................................................. 44
Figure 24: Package dimensions for MLX90632 (FoV = 50°) .......................................................... 45
Figure 25: PCB footprint and stencil design for MLX90632 ............................................................ 46
Figure 26a: Decoupling capacitor C1 placement .......................................................................... 46
Figure 27: Typical application schematic for 3V3 I\(^2\)C communication with MLX90632 ........ 47
Figure 28: Typical application schematic for 1V8 I\(^2\)C communication with MLX90632 .......... 48
20. Disclaimer

The content of this document is believed to be correct and accurate. However, the content of this document is furnished "as is" for informational use only and no representation, nor warranty is provided by Melexis about its accuracy, nor about the results of its implementation. Melexis assumes no responsibility or liability for any errors or inaccuracies that may appear in this document. Customer will follow the practices contained in this document under its sole responsibility. This documentation is in fact provided without warranty, term, or condition of any kind, either implied or expressed, including but not limited to warranties of merchantability, satisfactory quality, non-infringement, and fitness for purpose. Melexis, its employees and agents and its affiliates' and their employees and agents will not be responsible for any loss, however arising, from the use of, or reliance on this document. Notwithstanding the foregoing, contractual obligations expressly undertaken in writing by Melexis prevail over this disclaimer.

This document is subject to change without notice, and should not be construed as a commitment by Melexis. Therefore, before placing orders or prior to designing the product into a system, users or any third party should obtain the latest version of the relevant information.

Users or any third party must determine the suitability of the product described in this document for its application, including the level of reliability required and determine whether it is fit for a particular purpose.

This document as well as the product here described may be subject to export control regulations. Be aware that export might require a prior authorization from competent authorities. The product is not designed, authorized or warranted to be suitable in applications requiring extended temperature range and/or unusual environmental requirements. High reliability applications, such as medical-life-support or life-sustaining equipment or avionics application are specifically excluded by Melexis. The product may not be used for the following applications subject to export control regulations: the development, production, processing, operation, maintenance, storage, recognition or proliferation of:

1. chemical, biological or nuclear weapons, or for the development, production, maintenance or storage of missiles for such weapons;
2. civil firearms, including spare parts or ammunition for such arms;
3. defense related products, or other material for military use or for law enforcement;
4. any applications that, alone or in combination with other goods, substances or organisms could cause serious harm to persons or goods and that can be used as a means of violence in an armed conflict or any similar violent situation.

No license nor any other right or interest is granted to any of Melexis’ or third party's intellectual property rights.

If this document is marked "restricted" or with similar words, or if in any case the content of this document is to be reasonably understood as being confidential, the recipient of this document shall not communicate, nor disclose to any third party, any part of the document without Melexis' express written consent. The recipient shall take all necessary measures to apply and preserve the confidential character of the document. In particular, the recipient shall (i) hold document in confidence with at least the same degree of care by which it maintains the confidentiality of its own proprietary and confidential information, but no less than reasonable care; (ii) restrict the disclosure of the document solely to its employees for the purpose for which this document was received, on a strictly need to know basis and providing that such persons to whom the document is disclosed are bound by confidentiality terms substantially similar to those in this disclaimer; (iii) use the document only in connection with the purpose for which this document was received, and reproduce document only to the extent necessary for such purposes; (iv) not use the document for commercial purposes or to the detriment of Melexis or its customers. The confidentiality obligations set forth in this disclaimer will have indefinite duration and in any case they will be effective for no less than 10 years from the receipt of this document.

This disclaimer will be governed by and construed in accordance with Belgian law and any disputes relating to this disclaimer will be subject to the exclusive jurisdiction of the courts of Brussels, Belgium.

The invalidity or ineffectiveness of any of the provisions of this disclaimer does not affect the validity or effectiveness of the other provisions.

The previous versions of this document are repealed.

Melexis © - No part of this document may be reproduced without the prior written consent of Melexis. (2023)

IATF 16949 and ISO 14001 Certified

For the latest revision of this document, visit www.melexis.com/90632

Happy to help you! www.melexis.com/contact