

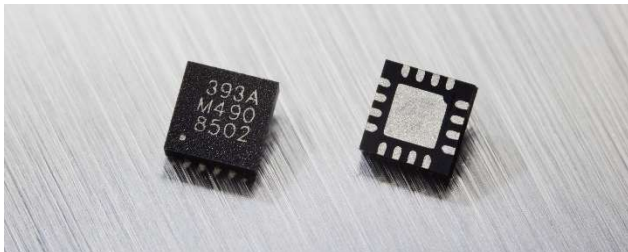
# MLX90393

Triaxis® Magnetic Node  
Datasheet



## 1. Features and Benefits

- Absolute Position Sensor IC featuring Triaxis® Hall Technology
- Simple & Robust Magnetic Design
- Miniature size for tiny assemblies
- Selectable SPI and I<sup>2</sup>C bus protocols
- Wide dynamic range (5-50mT) with on-the-fly programmable gain
- 2.2V-3.6V supply for battery powered applications, down to 1.8V IO voltage
- On board filter settings
- On the fly programmable operating modes and sleep times for micro-power use
- External and internal acquisition triggering modes
- External interrupt pin when the field changes
- On board temperature sensor



## 2. Application Examples

- Non-contacting HMI applications with push-pull functionality
  - Rotary knobs & dials
  - (Long stroke) Linear motion in one or two axes for levers & sliding switches
  - Joystick (gimbal or ball & socket)
- Home Security 3D closure detection
- Accurate liquid level sensing
- Factory automation position sensing
- Magnetic fingerprint detection

## 3. Description

The MLX90393 brings the highest flexibility in the Triaxis portfolio's smallest packaged assembly. Additionally, the MLX90393 is designed for micropower applications, with programmable duty cycles in the range of 0.1% to 100% allowing for configurable power consumption based on system requirements.

The MLX90393 magnetic field sensor can be reprogrammed to different modes and with different settings at run-time to fine-tune the performance and power consumed. The sensor offers a 16-bit output proportional to the magnetic flux density sensed along the X, Y, and Z axes using the Melexis proprietary Triaxis technology and offers a 16-bit temperature output signal. These digital values are available via I<sup>2</sup>C and SPI, where the MLX90393 is a slave on the bus. Multiple sensors can be connected to the same bus, by A<sub>0</sub> and A<sub>1</sub> hardwired connection (4x) but also through ordering codes with different SW address (4x).

By selecting which axes are to be measured, the raw data can be used as input for further post-processing, such as for joystick applications, rotary knobs, and more complex 3D position sensing applications. Unparalleled performance is achieved with this sensor, which is primarily targeting industrial and consumer applications.

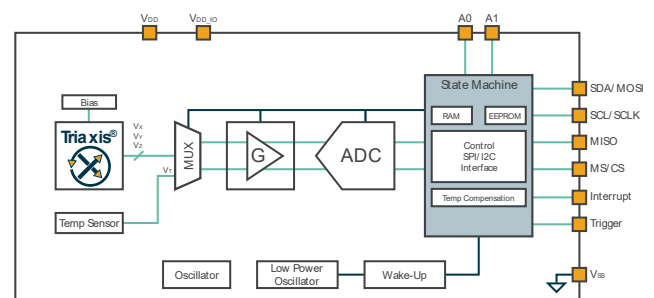


Figure 1: General Block Diagram

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## 4. Ordering Information

| Product  | Temperature       | Package | Option Code | Packing Form | Definition                         |
|----------|-------------------|---------|-------------|--------------|------------------------------------|
| MLX90393 | S (-20°C to 85°C) | LW      | ABA-011     | RE           | I <sup>2</sup> C address = 00011xx |
| MLX90393 | S (-20°C to 85°C) | LW      | ABA-012     | RE           | I <sup>2</sup> C address = 00100xx |
| MLX90393 | S (-20°C to 85°C) | LW      | ABA-013     | RE           | I <sup>2</sup> C address = 00101xx |
| MLX90393 | S (-20°C to 85°C) | LW      | ABA-014     | RE           | I <sup>2</sup> C address = 00110xx |
| MLX90393 | E (-40°C to 85°C) | LW      | ABA-011     | RE           | I <sup>2</sup> C address = 00011xx |
| MLX90393 | E (-40°C to 85°C) | LW      | ABA-012     | RE           | I <sup>2</sup> C address = 00100xx |
| MLX90393 | E (-40°C to 85°C) | LW      | ABA-013     | RE           | I <sup>2</sup> C address = 00101xx |
| MLX90393 | E (-40°C to 85°C) | LW      | ABA-014     | RE           | I <sup>2</sup> C address = 00110xx |
| MLX90393 | S (-20°C to 85°C) | LW      | ABA-111     | RE           | I <sup>2</sup> C address = 00011xx |
| MLX90393 | S (-20°C to 85°C) | LQ      | ABA-011     | RE           | I <sup>2</sup> C address = 0010000 |
| MLX90393 | S (-20°C to 85°C) | LQ      | ABA-014     | RE           | I <sup>2</sup> C address = 0011000 |

Table 1: Product Ordering Codes

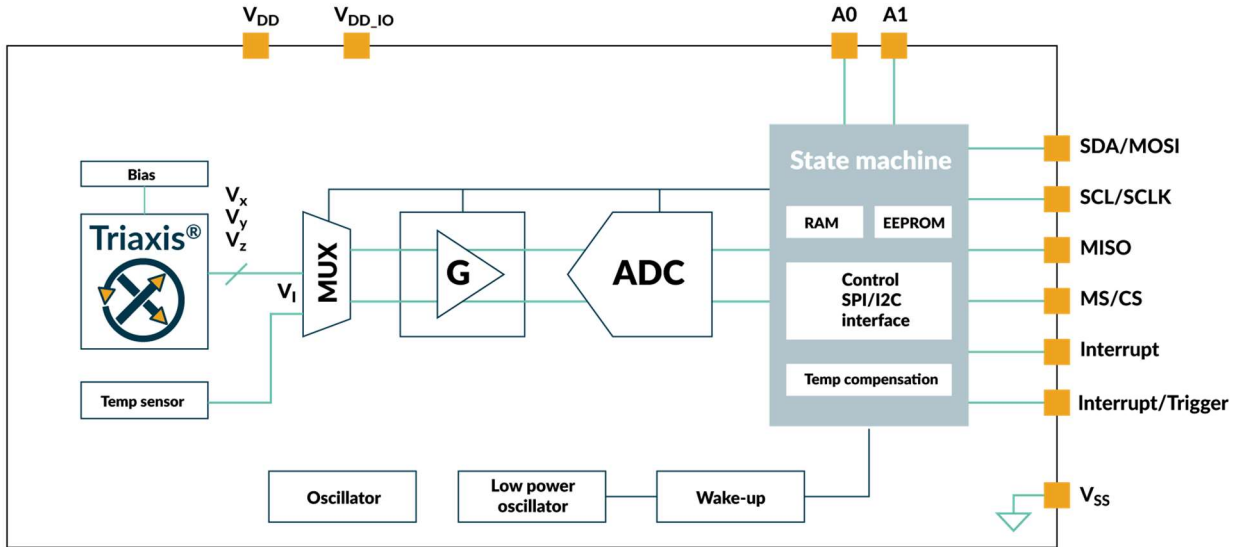
### Legend:

|                   |  |
|-------------------|--|
| Temperature Code: | S: from -20°C to 85°C<br>E: from -40°C to 85°C   |
| Package Code:     | “LW” for QFN-16 3x3x1mm package with wettable flanks<br>“LQ” for UTDFN-8 2.5x2mm package   |
| Option Code:      | ABA-xx1, ABA-xx2, ABA-xx3, ABA-xx4: Different I <sup>2</sup> C addresses – 5 most significant bits. The 2 least significant bits of the address are defined by the external address pins A <sub>0</sub> and A <sub>1</sub> .<br><br>ABA-0xx: Standard IMC, magnetic saturation onset at 50mT<br>ABA-1xx: Thin IMC, magnetic saturation onset at 25mT |
| Packing Form:     | “RE for Reel”  |
| Ordering Example: | “MLX90393-ELW-ABA-011-RE”<br>MLX90393 Micropower magnetometer with I <sup>2</sup> C address 00011xx where the last two bits are defined by external address pins A <sub>0</sub> and A <sub>1</sub> . In QFN package, temperature range -40°C to 85°C.  |

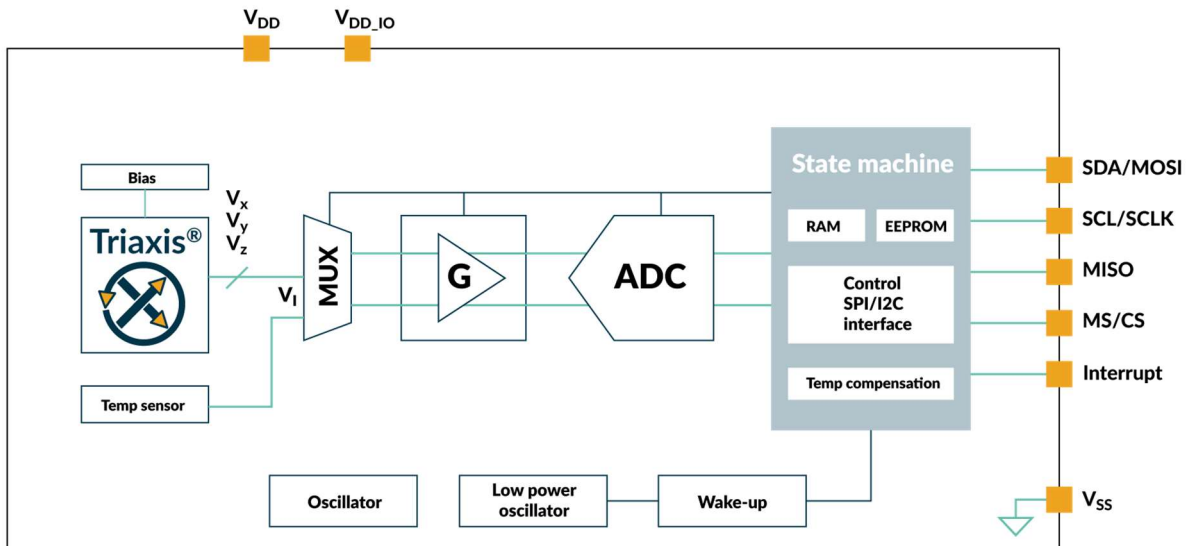
Table 2: Product Ordering Code Example

## 5. Functional Diagram

### 5.1. QFN-16 Block Diagram



### 5.2. UTDFN-8 Block Diagram



## 6. Glossary of Terms

| Term                 | Definition   |
|----------------------|--|
| TC                   | Temperature Coefficient (in ppm/°C)                                |
| Gauss (G), Tesla (T) | Units for the magnetic flux density – 1 mT = 10 G                  |
| NC                   | Not Connected  |
| PWM                  | Pulse Width Modulation   |
| %DC                  | Duty Cycle of the output signal i.e. $T_{ON} / (T_{ON} + T_{OFF})$ |
| ADC                  | Analog-to-Digital Converter  |
| DAC                  | Digital-to-Analog Converter  |
| LSb                  | Least Significant Bit  |
| MSb                  | Most Significant Bit   |
| DNL                  | Differential Non-Linearity   |
| INL                  | Integral Non-Linearity   |
| EMC                  | Electro-Magnetic Compatibility                                     |

## 7. QFN-16 Pinout

| Pin # | Name     | Type                         |           | Supply System | Wiring Recommendation |            |                |
|-------|----------|------------------------------|-----------|---------------|-----------------------|------------|----------------|
|       |          | Primary                      | Secondary | Reference To  | I <sup>2</sup> C      | 4-wire SPI | 3-wire SPI     |
| 1     | INT      | I/O out                      | N/A       | VDD_IO        | Optional              | Optional   | Optional       |
| 2     | MS/CS    | I/O in                       | MLX Test  | VDD_IO        | To VDD_IO             | Required   | Required       |
| 3     | SCL/SCLK | I/O in                       | MLX Test  | VDD_IO        | Required              | Required   | Required       |
| 4     | N/C      | --                           | --        | --            | --                    | --         | --             |
| 5     | SDA/MOSI | I/O bi                       | MLX Test  | VDD_IO        | Required              | Required   | Short together |
| 6     | MISO     | I/O out                      | MLX Test  | VDD_IO        | Floating              | Required   |                |
| 7     | INT/TRIG | I/O bi                       | N/A       | VDD_IO        | Optional              | Optional   | Optional       |
| 8     | VDD_IO   | Supply                       | N/A       |               | Required              | Required   | Required       |
| 9     | N/C      | --                           | --        | --            | --                    | --         | --             |
| 10    | N/C      | --                           | --        | --            | --                    | --         | --             |
| 11    | A1       | I <sup>2</sup> C Address LSB | MLX Test  | VDD           | To VDD/GND            | To GND     | To GND         |
| 12    | A0       | I <sup>2</sup> C Address LSB | MLX Test  | VDD           | To VDD/GND            | To GND     | To GND         |
| 13    | VSS      | Ground                       | N/A       |               | Required              | Required   | Required       |
| 14    | N/C      | --                           | --        | --            | --                    | --         | --             |
| 15    | VDD      | Supply                       | N/A       |               | Required              | Required   | Required       |
| 16    | N/C      | --                           | --        | --            | --                    | --         | --             |

Table 3: Pinout Description

It is recommended to connect the N/C pins (Not Connected) to Ground.

The exposed pad of the QFN package can be left floating or shorted to ground.

## 8. UTDFN-8 Pinout

| Pin # | Name     | Type    |           | Supply System | Wiring Recommendation |            |                |
|-------|----------|---------|-----------|---------------|-----------------------|------------|----------------|
|       |          | Primary | Secondary | Reference To  | I <sup>2</sup> C      | 4-wire SPI | 3-wire SPI     |
| 1     | SCL/SCLK | I/O in  | MLX Test  | VDD_IO        | Required              | Required   | Required       |
| 2     | SDA/MOSI | I/O bi  | MLX Test  | VDD_IO        | Required              | Required   | Short together |
| 3     | MISO     | I/O out | MLX Test  | VDD_IO        | Floating              | Required   |                |
| 4     | VDD_IO   | Supply  | N/A       |               | Required              | Required   | Required       |
| 5     | VSS      | Ground  | N/A       |               | Required              | Required   | Required       |
| 6     | VDD      | Supply  | N/A       |               | Required              | Required   | Required       |
| 7     | MS/CS    | I/O in  | MLX Test  | VDD_IO        | To VDD_IO             | Required   | Required       |
| 8     | INT      | I/O out | N/A       | VDD_IO        | Optional              | Optional   | Optional       |

*Table 4: UTDFN-8 Pinout Description*

The exposed pad of the UTDFN-8 package can be left floating or shorted to ground.

## 9. Absolute Maximum Ratings

| Parameter              | Symbol                            | Min. | Typ. | Max.                         | Unit |
|------------------------|-----------------------------------|------|------|------------------------------|------|
| V <sub>DD_MAX</sub>    | Analog Supply Voltage Limits      | -0.3 |      | 4                            | V    |
| V <sub>DD_IO_MAX</sub> | Digital IO Supply Limits          | -0.3 |      | min(4, V <sub>DD</sub> +0.3) | V    |
| T <sub>STORAGE</sub>   | Storage (idle) temperature range  | -50  |      | 125                          | °C   |
| ESD <sub>HBM</sub>     | According to AEC-Q100-002         |      |      | 2.5                          | kV   |
| ESD <sub>CDM</sub>     | According to AEC-Q100-011-B (QFN) |      |      | 750                          | V    |

*Table 5: Absolute Maximum Ratings*

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

## 10. General Electrical Specifications

| Parameter                  | Remark   | Min  | Nom  | Max             | Unit |
|----------------------------|--|------|------|-----------------|------|
| V <sub>DD</sub>            | Analog Supply Voltage  | 2.2  | 3    | 3.6             | V    |
| V <sub>DD_IO</sub>         | Digital IO Supply  | 1.65 | 1.8  | V <sub>DD</sub> | V    |
| V <sub>POR_LH</sub>        | Power-on Reset threshold<br>(rising edge)                          |      | 1.42 | 1.55            | V    |
| V <sub>POR_HL</sub>        | Power-on Reset threshold<br>(falling edge)                         | 1    | 1.31 |                 | V    |
| I <sub>DD,CONVXY</sub>     | Conversion Current XY-axis   |      | 2.29 | 3               | mA   |
| I <sub>DD,CONVZ</sub>      | Conversion Current Z-axis  |      | 2.96 | 4               | mA   |
| I <sub>DD,CONVT</sub>      | Conversion Current Temperature                                     |      | 1.60 | 2               | mA   |
| I <sub>DD, CONV_END</sub>  | Current during T <sub>CONV_END</sub>                               |      | 1.5  | 1.75            | mA   |
| I <sub>DD_ACTIVE</sub>     | Current during T <sub>ACTIVE</sub>                                 |      | 1.2  | 1.75            | mA   |
| I <sub>DD_IDLEtoSTBY</sub> | Current during T <sub>STBY</sub>                                   |      | 1.2  | 1.75            | mA   |
| I <sub>DD,STBY</sub>       | Standby Current <sup>(1)</sup>                                     |      | 43   | 60              | μA   |
| I <sub>DD,IDLE</sub>       | Idle Current <sup>(2)</sup>  | 1    | 2.4  | 5               | μA   |
| I <sub>DD,NOM</sub>        | Nominal Current (TXYZ, Datarate = 10Hz,<br>OSR=OSR2=0, DIG_FILT=4) |      | 100  |                 | μA   |

Table 6: General Electrical Specifications

<sup>1</sup> Standby current corresponds to the current consumed in the digital where only the low power oscillator is running. This standby current is present in burst mode, or whenever the IC is counting down to start a new conversion.

<sup>2</sup> Idle current corresponds to the current drawn by the IC in idle mode where all operating functions are disabled except communications.

## 11. Thermal Specification

The MLX90393 has an on-board temperature sensor which measures the temperature of the MLX90393 sensor. The temperature can be read out via the communication protocol in a digital format

| Parameter              | Symbol                               | Min. | Typ.  | Max. | Unit               |
|------------------------|--------------------------------------|------|-------|------|--------------------|
| T <sub>RES</sub>       | Temperature sensor resolution        |      | 45.2  |      | LSB/°C             |
| T <sub>25</sub>        | Temperature sensor output at 25°C    |      | 46244 |      | LSB <sub>16u</sub> |
| T <sub>LIN</sub>       | Temperature Linearity <sup>(3)</sup> |      | +/-3  |      | °C                 |
| T <sub>OPERATING</sub> | Operating temperature range [S code] | -20  | 25    | 85   | °C                 |
|                        | Operating temperature range [E code] | -40  | 25    | 85   | °C                 |

*Table 7: Thermal Specifications*

<sup>3</sup> The linearity is defined as the best fit curve through the digital temperature outputs over the entire temperature range. It includes ADC non-linearity effects

## 12. Timing Specification

The specifications are applicable at 25 DegC unless specified otherwise and for the complete supply range.

| Parameter                              | Remark  | Min   | Nom | Max   | Unit |
|--|---|---|-----|-------|------|
| Main Oscillator & Derived Timings      |   |   |     |       |      |
| T <sub>STBY</sub>                      | Time from IDLE to STBY  | 176   | 220 | 264   | μs   |
| T <sub>ACTIVE</sub>                    | Time from STBY to ACTIVE  | 288   | 360 | 432   | μs   |
| T <sub>CONVM</sub>                     | Single Magnetic axis conversion time <sup>(4)</sup><br>typical programming range  | 259   |     | 66627 | μs   |
|  |   | $67 + 64 \cdot 2^{OSR} \cdot (2 + 2^{DIG\_FILT})$                       |     |       |      |
| T <sub>CONVT</sub>                     | Temperature conversion time<br>typical programming range                          | 259   |     | 1603  | μs   |
|  |   | $67 + 192 \cdot 2^{OSR2}$   |     |       |      |
| T <sub>CONV_END</sub>                  | Time to end analog active mode  | 80  | 100 | 120   | μs   |
| T <sub>CONV_SMM</sub>                  | Total conversion time in Single<br>Measurement Mode                               | $T_{STBY} + T_{ACTIVE} + m \cdot T_{CONVM} + T_{CONVT} + T_{CONV\_END}$ |     |       | ms   |
| T <sub>CONV_BURST_NDL<br/>Y</sub>      | Total conversion time in BURST with burst<br>data rate = 0                        | $m \cdot T_{CONVM} + T_{CONVT} + T_{CONV\_END}$                         |     |       | ms   |
| T <sub>CONV_BURST_DLY</sub>            | Total conversion time in BURST with burst<br>data rate > 0                        | $T_{ACTIVE} + m \cdot T_{CONVM} + T_{CONVT} + T_{CONV\_END}$            |     |       | ms   |
| T <sub>CONV_WOC_NDL<br/>Y</sub>        | Total conversion time in WOC with burst<br>data rate = 0                          | $m \cdot T_{CONVM} + T_{CONVT} + T_{CONV\_END}$                         |     |       | ms   |
| T <sub>CONV_WOC_DLY</sub>              | Total conversion time in WOC with burst<br>data rate > 0                          | $T_{STBY} + T_{ACTIVE} + m \cdot T_{CONVM} + T_{CONVT} + T_{CONV\_END}$ |     |       | ms   |
| T <sub>OSC_TRIM</sub>                  | Trimming accuracy   | -5  |     | +5    | %    |
| T <sub>OSC_THD</sub>                   | Thermal drift (full temperature range)  | -5  |     | +5    | %    |
| Low-power Oscillator & Derived Timings |   |   |     |       |      |
| T <sub>INTERVAL</sub>                  | Time in between 2 conversions (Burst<br>mode or Wake-Up on Change) <sup>(5)</sup> | 0   |     | 1260  | ms   |
|  |   | $BURST\_DATA\_RATE \cdot 20$  |     |       |      |
| T <sub>LPOSC_TRIM</sub>                | Trimming accuracy   | -4  |     | +4    | %    |
| T <sub>LPOSC_THD</sub>                 | Thermal drift (full temperature range)  | -5  |     | +5    | %    |

<sup>4</sup> This conversion time is defined as the time to acquire a single axis of the magnetic flux density. When measuring multiple axes they are obtained through time multiplexing. The conversion time is programmable through parameters OSR and DIG\_FILT for magnetic values and OSR2 for the temperature value. The conversion sequence is TXYZ, opposite of the ZYXT argument of the command set.

<sup>5</sup> The time T<sub>INTERVAL</sub> is defined as the time between the end of one set of measurements (any combination of TXYZ) and the start of the following same set of measurements in BURST and WOC mode. As a result of this, the maximum output data rate is not only a function of T<sub>INTERVAL</sub> but equals  $1/(T_{CONV\_BURSTWOC} + T_{INTERVAL})$ .

| Parameter        | Remark  | Min  | Nom | Max | Unit          |
|------------------|---|------|-----|-----|---------------|
| $T_{INT\_RDY}$   | Time between INT rising and full accessibility <sup>(6)</sup> | 132  |     |     | $\mu\text{s}$ |
| Startup          |   |      |     |     |               |
| $T_{POR}$        | Power-on-reset completion time                                |      | 0.6 | 1.5 | ms            |
| External Trigger |   |      |     |     |               |
| $T_{TRIG}$       | Trigger pulse width (active high)                             | 0.01 |     | 250 | $\mu\text{s}$ |

*Table 8: Timing Specifications*

<sup>6</sup> Reading the measurements (once) sooner than this specified time after the rising INT will work, however the status byte can still show an active measurement mode (single measurement). Other commands are not allowed during this time.

## 13. Magnetic Specification

The specifications are applicable at 25 DegC unless otherwise specified and for the complete supply voltage range.

| Parameter                                  | Remark   | Min   | Nom     | Max   | Unit   |
|--|--|---|---------|-------|--------|
| N <sub>ADC</sub>                           | ADC span   |   | 17.4    |       | bits   |
| N <sub>OUT</sub>                           | Output span (taken from 19 by RES <sub>XYZ</sub> )   |   | 16      |       | bits   |
| B <sub>RANGE</sub>                         | Output range (function of RES <sub>XYZ</sub> )   | RANGE from Table 17:<br>Sensitivity table for given gain<br>and resolution selection for<br>HALLCONF=0xC / SENS <sub>ii</sub> |         |       | mT     |
| B <sub>SAT</sub>                           | Magnetic saturation onset<br>Option codes -011, -012, -013, -014   | 50  |         |       | mT     |
| B <sub>SAT</sub>                           | Magnetic saturation onset<br>Option code -111  | 25  |         |       | mT     |
| OFFS                                       | Deviation from expected 0mT output   |   | 0       |       | LSB    |
| OFFS <sub>THD</sub>                        | Offset thermal drift, Delta from 25°C <sup>(7)</sup>   |   | < ±1000 |       | LSB    |
| SENS <sub>XX</sub> ,<br>SENS <sub>YY</sub> | Programming range of magnetic resolution<br>(μT/LSB) or sensitivity (LSB/mT) <sup>(8)</sup><br>[modifying GAIN_SEL and RES <sub>XYZ</sub> ], cfr. Table<br>17: Sensitivity table for given gain and<br>resolution selection for HALLCONF=0xC | 3.220   |         | 0.161 | μT/LSB |
|  |  |   | 311     |       | 6211   |
| SENS <sub>ZZ</sub>                         |  | 5.872   |         | 0.294 | μT/LSB |
|  |  |   | 170     |       | 3406   |
| SENS <sub>XY</sub> ,<br>SENS <sub>YX</sub> | Cross-axis sensitivity (X/Y-axis sensitivity to<br>Y/X magnetic fields)  |   | < ±1    |       | %      |
| SENS <sub>XZ</sub> ,<br>SENS <sub>YZ</sub> | Cross-axis sensitivity (X/Y-axis sensitivity to Z<br>magnetic field)   |   | < ±1    |       | %      |

<sup>7</sup> The offset thermal drift is defined as the deviation at 0Gauss from the output with respect to the output at 25°C when sweeping the temperature. The highest gradient (μT/°C) typically occurs at 85°C. The spec value is based on characterization on limited sample size at GAIN\_SEL=0x7 and RES\_XYZ=0x00.

<sup>8</sup> The total axis sensitivity is programmable to support different applications, but has no Automatic Gain control on-chip as do the other angular position sensors from Melexis. The highest gain corresponds to at least the minimum +/-4.8mT magnetic measurement range and the magnetic resolution defined by SENS<sub>ii</sub>.

| Parameter                                  | Remark   | Min | Nom  | Max | Unit |
|--|--|-----|------|-----|------|
| SENS <sub>ZX</sub> ,<br>SENS <sub>ZY</sub> | Cross-axis sensitivity (Z-axis sensitivity to X and Y magnetic fields) |     | < ±1 |     | %    |
| SENS <sub>THD</sub>                        | Sensitivity thermal drift<br>Delta from 25°C <sup>(9)</sup>            | -3  |      | +3  | %    |

*Table 9: Magnetic Specifications*

<sup>9</sup> The sensitivity thermal drift is expressed as a band around the sensitivity at 25°C. It is applicable on wafer level trimming, but can be influenced by packaging (overmolding).

### 13.1. Noise vs Conversion Time

The MLX90393 provides configurable filters to adjust the tradeoff between current consumption, noise, and conversion time. See section 15.1.5 for details on selecting the conversion time by adjusting OSR and DIG\_FILT.

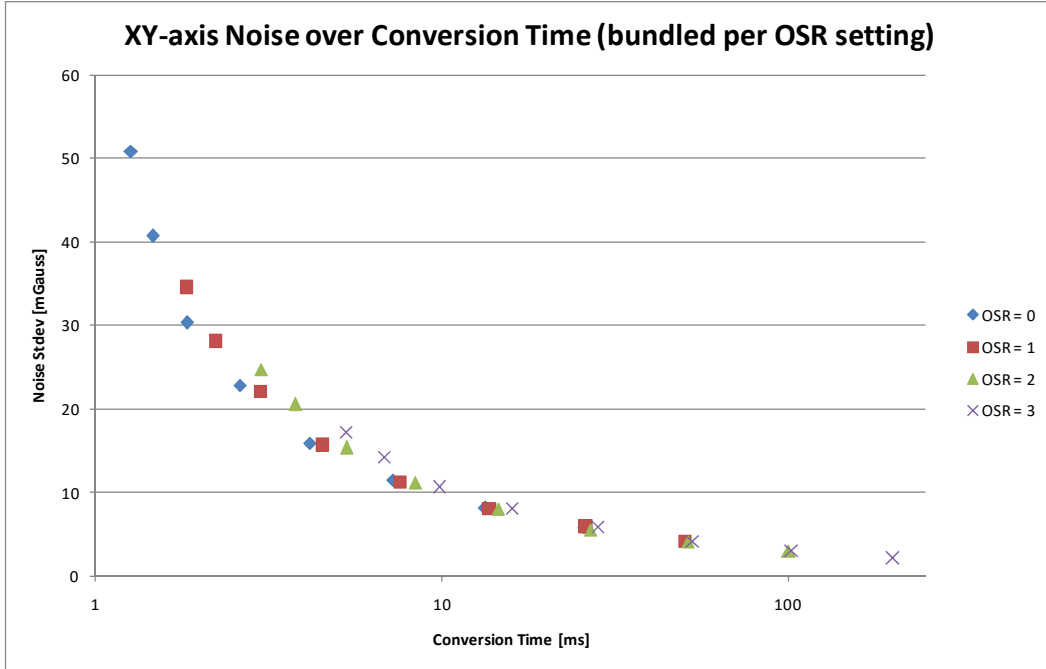


Figure 2: XY axis RMS noise versus conversion time, expressed in mGauss for GAIN\_SEL = 0x7 - Based on -0xx version

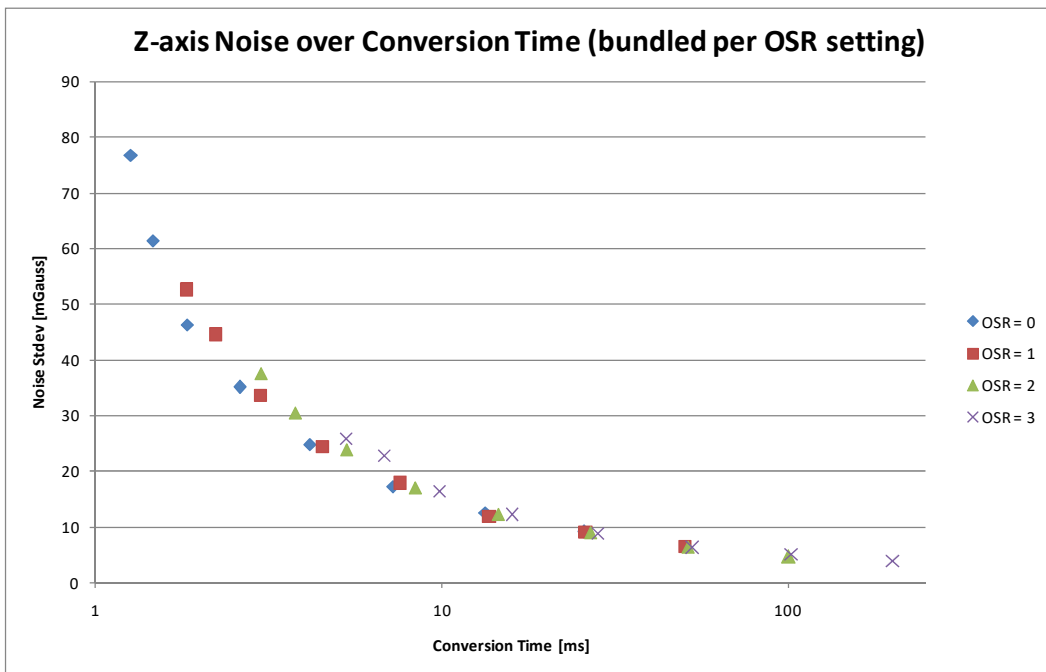


Figure 3: Z axis RMS noise versus conversion time, expressed in mGauss for GAIN\_SEL = 0x7 - Based on -0xx version

## 14. Mode Selection

The MLX90393 can operate in three modes. They are: Burst mode, Single Measurement mode, and Wake-On-Change mode.

- Burst mode

The ASIC will have a programmable data rate at which it will operate. This data rate implies auto-wakeup and sequencing of the ASIC, flagging that data is ready on a dedicated pin (INT/DRDY). The maximum data rate corresponds to continuous burst mode, and is a function of the chosen measurement axes. For non-continuous burst modes, the time during which the ASIC has a counter running but is not doing an actual conversion is called the Standby mode (STBY).

- Single Measure mode

The master will ask for data via the corresponding protocol (I<sup>2</sup>C or SPI), waking up the ASIC to make a single conversion, immediately followed by an automatic return to sleep mode (IDLE) until the next polling of the master. This polling can also be done by strobing the TRG pin instead, which has the same effect as sending a protocol command for a single measurement.

- Wake-Up on Change

This mode is similar to the burst mode in the sense that the device will be auto-sequencing, with the difference that the measured component(s) is/are compared with a reference and in case the difference is bigger than a user-defined threshold, the DRDY signal is set on the designated pin. The user can select which axes and/or temperature fall under this cyclic check, and which thresholds are allowed.

The user can change the operating mode at all time through a specific command on the bus. The device waits in IDLE mode after power-up, but with a proper user command any mode can be set after power-up. Changing to Burst or WOC mode, coming from Single Measure mode, is always accompanied by a measurement first. The top-level state diagram indicating the different modes and some relevant timing is shown below in Figure 4. In the Measure state, the MDATA flag will define which components will be measured (ZYXT). The order of conversion is defined as TXYZ and cannot be modified by the user, only the combination of axes is a degree of freedom.

Arrows indicated in grey are the direct result of an Exit command. The main difference between STANDBY and WOC\_IDLE is that in STANDBY mode, all analog circuitry is ready to make a conversion, but this is accompanied by a larger current consumption than IDLE mode. For burst mode this extra current consumption is justified because the emphasis is more on accurate timing intervals, avoiding the delay of  $T_{STBY}$  before conversion and supporting an efficient continuous burst mode without standby overhead.

It is the user's responsibility to read back the measured data as the MLX90393 is a slave device on the bus. Even in burst mode and WOC mode when the MLX90393 is auto-sequencing, the master will be responsible for collecting the acquired sensor data.

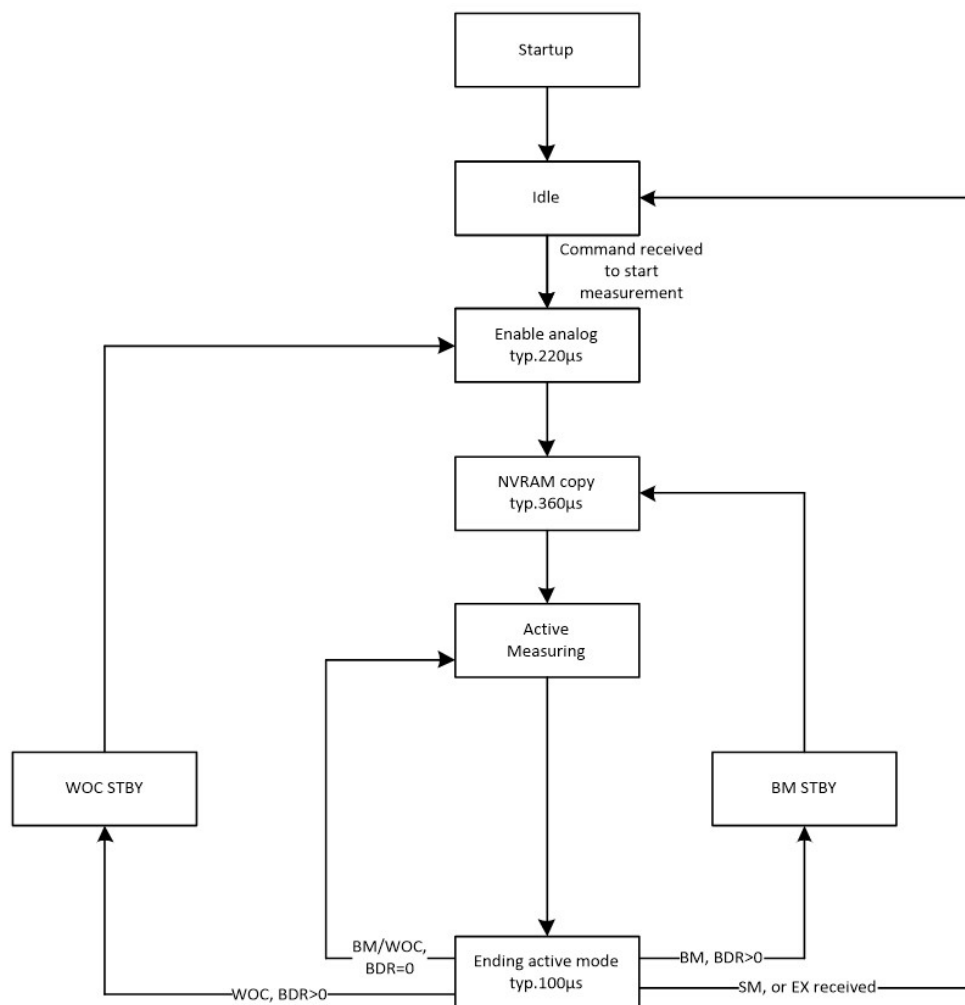


Figure 4: Top-level state diagram with indication of timings

## 14.1. Burst mode

When the sensor is operating in burst mode, it will make conversions at specific time intervals. The programmability of the user is the following:

- Burst speed ( $T_{\text{INTERVAL}}$ ) through parameter BURST\_DATA\_RATE
- Conversion time ( $T_{\text{CONV}}$ ) through parameters OSR, OSR2 and DIG\_FILT
- Axes/Temperature (MDATA) through parameter BURST\_SEL or via the command argument (ZYXT)

Whenever the MLX90393 has made the selected conversions (based on MDATA), the DRDY signal will be set (active H) on the INT and/or INT/TRG pin to indicate that the data is ready for readback. It will remain high until the master has sent the command to read out at least one of the converted quantities (ZYXT). Should the master have failed to read out any of them by the time the sensor has made a new conversion, the INT/DRDY pin will be strobed low for  $10\mu\text{s}$ , and the next rising edge will indicate a new set of data is ready.

## 14.2. Single Measurement mode

Whenever the sensor is set to this mode (or after startup) the MLX90393 goes to the IDLE state where it awaits a command from the master to perform a certain acquisition. The duration of the acquisition will be the concatenation of the  $T_{\text{STBY}}$ ,  $T_{\text{ACTIVE}}$ ,  $m \cdot T_{\text{CONVM}}$  (with  $m$  # of axes) and  $T_{\text{CONVT}}$ . The conversion time will effectively

be programmable by the user (see burst mode), but is equally a function of the required axes/temperature to be measured.

Upon reception of such a polling command from the master, the sensor will make the necessary acquisitions, and set the DRDY signal high to flag that the measurement has been performed and the master can read out the data on the bus at his convenience. The INT/DRDY will be cleared either when:

- The master has issued a command to read out at least one of the measured components
- The master issues an Exit (EX) command to cancel the measurement
- The chip is reset, after POR (Power-on reset) or Reset command (RT)

### 14.3. Wake-Up on Change mode

The Wake-Up on Change (WOC) functionality can be set by the master with as main purpose to only receive an interrupt when a certain threshold is crossed. The WOC mode will always compare a new burst value with a reference value to assess if the difference between both exceeds a user-defined threshold. The reference value is defined as one of the following:

- The first measurement of WOC mode is stored as reference value once. This measurement at “t=0” is then the basis for comparison or,
- The reference for acquisition(t) is always acquisition(t-1), in such a way that the INT signal will only be set if the derivative of any component exceeds a threshold.

The in-application programmability is the same as for burst mode, but now the thresholds for setting the interrupt are also programmable by the user, as well as the reference, if the latter is data(t=0) or data(t-1).

## 15. Digital Specification

The supported protocols are I<sup>2</sup>C and SPI. The MS/CS pin is used to define the protocol to be used:

- /CS = 0 for SPI, addressing the MLX90393 slave in SPI mode (3- and 4-wire), but releasing this line in between commands (no permanent addressing allowed)
- /CS = 1 for I<sup>2</sup>C, addressing the MLX90393 slave when the correct address is transmitted over the bus (permanently kept high)

To ensure the activity on the SPI bus cannot be accidentally interpreted as I<sup>2</sup>C protocol, programming bits are available in the memory of the MLX90393 to force the communication mode. It concerns the COMM\_MODE[1:0] bits with the following effect:

| COMM_MODE[1] | COMM_MODE[0] | Description  |
|--------------|--------------|--|
| 0            | X            | The mode in which the first valid command is transmitted to the MLX90393 defines the operating mode (SPI or I <sup>2</sup> C) for all its future commands, until a reset (hard or soft) is done. |
| 1            | 0            | SPI mode only  |
| 1            | 1            | I <sup>2</sup> C mode only   |

Table 10: Communication mode definition

## 15.1. Command List

The MLX90393 only listens to a specific set of commands. Apart from the Reset command, all commands generate a status byte that can be read out. The table below indicates the 10 different commands that are (conditionally) accepted by the MLX90393. The MLX90393 will always acknowledge a command in I<sup>2</sup>C, even if the command is not a valid command. Interpreting the associated status byte is the method for verification of command acceptance.

| Command Set                   |        |   |           |               |           |               |
|-------------------------------|--------|---|-----------|---------------|-----------|---------------|
| Command Name                  | Symbol | # | CMD1 byte | CMD2 byte     | CMD3 byte | CMD4 byte     |
| Start Burst Mode              | SB     | 1 | 0001 zyxt | N/A           | N/A       | N/A           |
| Start Wake-up on Change Mode  | SW     | 2 | 0010 zyxt | N/A           | N/A       | N/A           |
| Start Single Measurement Mode | SM     | 3 | 0011 zyxt | N/A           | N/A       | N/A           |
| Read Measurement              | RM     | 4 | 0100 zyxt | N/A           | N/A       | N/A           |
| Read Register                 | RR     | 5 | 0101 0abc | {A5...A0,0,0} | N/A       | N/A           |
| Write Register                | WR     | 6 | 0110 0abc | D15...D8      | D7...D0   | {A5...A0,0,0} |
| Exit Mode                     | EX     | 8 | 1000 0000 | N/A           | N/A       | N/A           |
| Memory Recall                 | HR     | D | 1101 0000 | N/A           | N/A       | N/A           |
| Memory Store                  | HS     | E | 1110 0000 | N/A           | N/A       | N/A           |
| Reset                         | RT     | F | 1111 0000 | N/A           | N/A       | N/A           |

Table 11: Command List

The argument for the volatile memory access commands (RR/WR) «abc» should be set to 0x0, in order to get normal read-out and write of the memory.

The argument in all mode-starting commands (SB/SW/SM) is a nibble specifying the conversions to be performed by the sensor in the following order «zyxt». For example, if only Y axis and temperature are to be measured in Single Measurement mode the correct command to be transmitted is 0x35. The sequence of measurement execution on-chip is inverted to «TXYZ», so T will be measured before X, followed by Y and finally Z. By issuing an all-zero «zyxt» nibble, the BURST\_SEL value from RAM will be used instead of the empty argument of the command.

## 15.2. Status Byte

The status byte is the first byte transmitted by the MLX90393 in response to a command issued by the master. It is composed of a fixed combination of informative bits:

| bit 7      | bit 6    | bit 5   | bit 4 | bit 3 | bit 2 | bit 1 | bit 0 |
|------------|----------|---------|-------|-------|-------|-------|-------|
| BURST_MODE | WOC_MODE | SM_MODE | ERROR | SED   | RS    | D1    | D0    |

Table 12: Status Byte Definition

- **MODE bits**  
These bits define in which mode the MLX90393 is currently set. Whenever a mode transition command is rejected, the first status byte after this command will have the expected mode bit cleared, which serves as an indication that the command has been rejected, next to the ERROR bit. The SM\_MODE flag can be the result of an SM command or from raising the TRG pin when TRG mode is enabled in the volatile memory of the MLX90393.
- **ERROR bit**  
This bit is set in case a command has been rejected or in case an uncorrectable error is detected in the memory, a so called ECC\_ERROR. A single error in the memory can be corrected (see SED bit), two errors can be detected and will generate the ECC\_ERROR. In such a case all commands but the RT (Reset) command are not allowed. For example, a RR/WR command is not allowed during burst mode, resulting in the ERROR bit being set yet the command is not actively rejected. The error bit is equally set when the master is reading back data while the DRDY flag is low.
- **SED bit**  
The single error detection bit simply flags that a bit error in the non-volatile memory has been corrected. It is purely informative and has no impact on the operation of the MLX90393.
- **RS bit**  
Whenever the RT command is issued, the status message indicates that the RT is going to be performed by setting this bit. Then the bit is cleared again during the reset.
- **D[1:0] bits**  
These bits only have a meaning after the RR and RM commands, when data is expected as a response from the MLX90393. The number of response bytes correspond to  $2 * D[1:0] + 2$ , so the expected byte counts are either 2, 4, 6 or 8. For commands where no response is expected, the content of D[1:0] should be ignored.

## 15.3. SPI Communication

The MLX90393 can handle SPI communication at a bitrate of 10Mhz. The SPI communication is implemented in a half-duplex way, showing high similarities with I<sup>2</sup>C communication, but addressing through the \CS (Chip Select) pin instead of through bus arbitration. The half-duplex nature is at the basis of the supported 3-wire

SPI operation. SPI mode 3 is implemented: CPHA=1 (data changed on leading edge and captured on trailing edge, and CPOL=1 (high level is inactive state). The Chip Select line is active-low.

The communication is also bundled in bytes, equally MSB first and MSByte first. A command can of course consist of more than 1 byte (refer to Table 10: Communication mode definition) as can the response be from the MLX90393 in the form of multiple bytes after the status byte (not shown in Figure 5: SPI communication example)

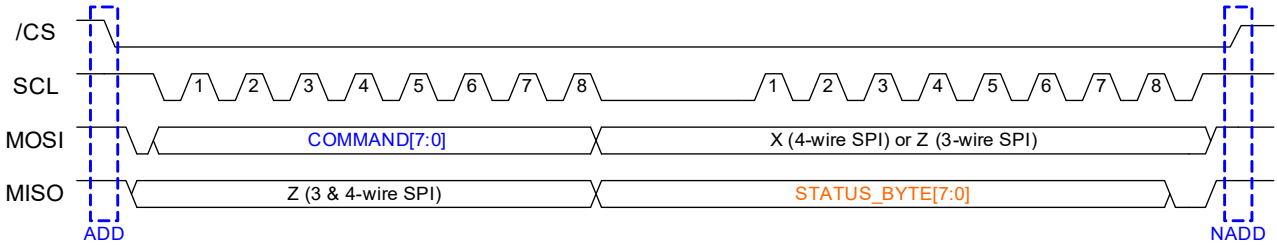


Figure 5: SPI communication example

### 15.3.1. Command implementation

For the examples give, the below convention is used.



Figure 6: SPI convention

#### 15.3.1.1. SB, SWOC, SM, EX, HR, HS

All the commands follow the structure below. The reply from the MLX90393 is only the status byte. The example below is for a start of a burst mode with X and Y being measured.

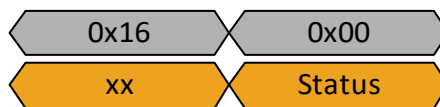


Figure 7: SB command, XY

After the HS command, wait at least 15ms before sending the next command to allow the IC to update the NVRAM correctly.

15.3.1.2. RT

This command will (warm-)reset the IC. The status byte of the command following will indicate the reset event. It is recommended to perform an ‘EX’ command and to wait 1ms, before issuing a ‘RT’ command. After the RT command, it is recommended to wait 1.5ms for the start-up sequence to complete.

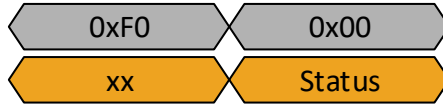


Figure 8: RT command

15.3.1.3. RM

This command differs depending on the value for zyxt. The data is returned in the order Status-TXYZ, where the components which are set to zero are skipped.

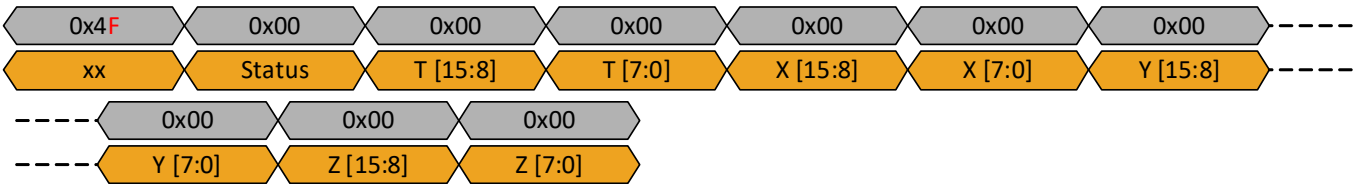


Figure 9: RM command, XYZT

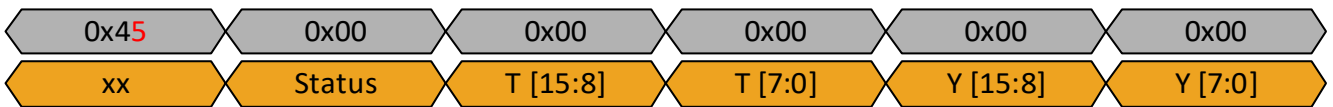


Figure 10: RM command, YT

15.3.1.4. RR

Important in this command is that the register address to be read needs to be shifted left by two bits. To read register 0x12 for example, the MOSI byte becomes 0x48.

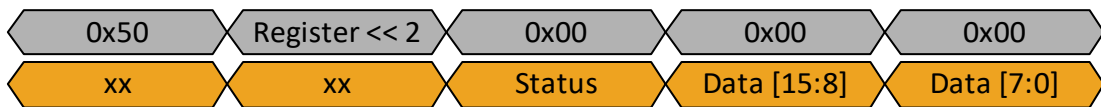


Figure 11: RR command

15.3.1.5. WR

Important in this command is that the register address to be read needs to be shifted left by two bits. To read register 0x12 for example, the MOSI byte becomes 0x48.

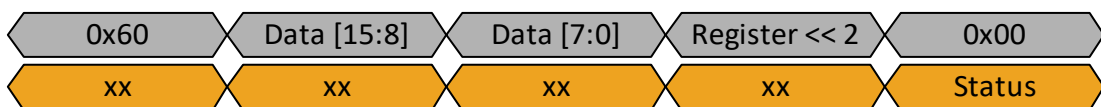


Figure 12: WR command

### 15.3.2. SPI Timing Specification

All timings are referred to the levels found in Table 6: General Electrical Specifications.

| Electrical Parameter    | Symbol         | Min. | Max. | Unit |
|-------------------------|----------------|------|------|------|
| SPI Clock Cycle         | $t_c$ (SPC)    | 100  |      | ns   |
| SPI Clock Cycle         | $t_c$ (SPC)    |      | 10   | MHz  |
| CS Setup Time           | $t_{su}$ (CS)  | 5    |      | ns   |
| CS Hold Time            | $t_h$ (CS)     | 10   |      | ns   |
| SDI Input Setup Time    | $t_{su}$ (SI)  | 5    |      | ns   |
| SDI Input Hold Time     | $t_h$ (SI)     | 15   |      | ns   |
| SDO Valid Output Time   | $t_v$ (SO)     |      | 50   | ns   |
| SDO Output Hold Time    | $t_h$ (SO)     | 5    |      | ns   |
| SDO Output Disable Time | $t_{dis}$ (SO) |      | 50   | ns   |

Table 13: General SPI Timing Specification

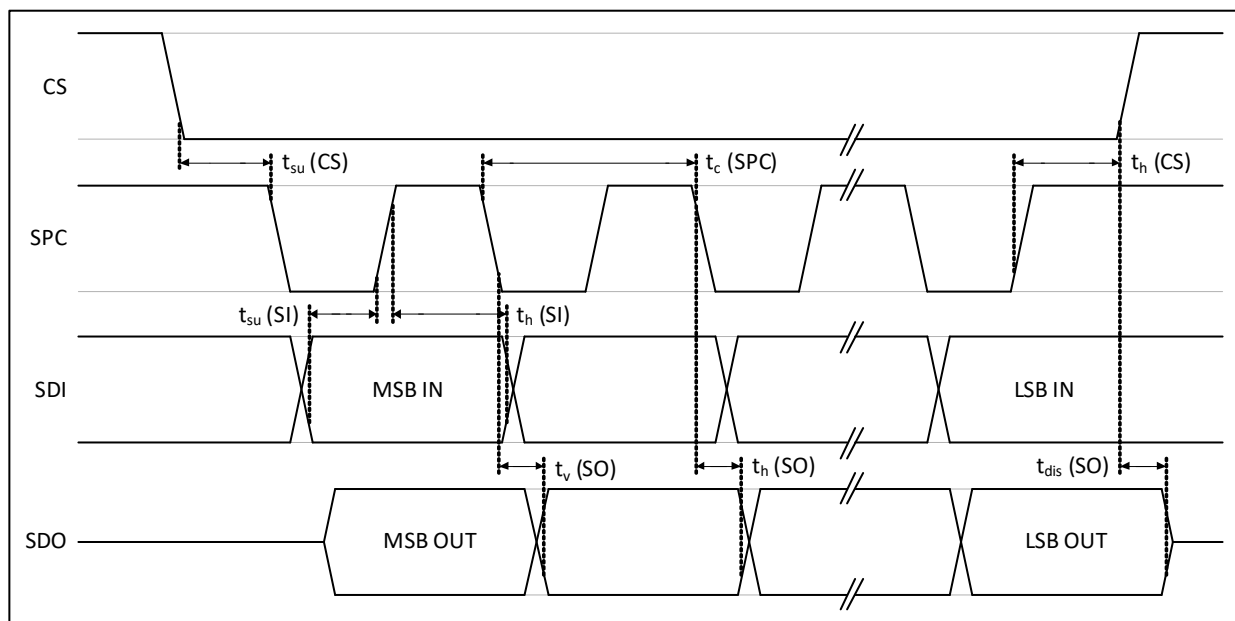


Figure 13: SPI Timing Diagram

### 15.4. I<sup>2</sup>C Communication

The I<sup>2</sup>C protocol is implemented such that the command is written to a specific register in the RAM, and the status and measurement data are read back from this RAM. The commands themselves are the same as for SPI (section 15.3) except for the read measurement commands and the memory read/write commands. For memory read/write commands, written can be done directly to the required register. Note that memory read/write commands are required to be word-wise, so always in multiples of 2 bytes. Read measurement is the same as a memory read, except starting from the status register. MSbits are sent first.

The 7-bit I<sup>2</sup>C-address is determined by the connection to the A0 and A1 pins. The 5 MSBs are programmed by Melexis in the MLX90393. Please contact Melexis in case other addressing is required.

| 7-bit I <sup>2</sup> C address |   |   |   |   |  |  | R/W bit   |
|--------------------------------|---|---|---|---|--|--|---|
| 7                              | 6 | 5 | 4 | 3 | 2  | 1  | 0   |
| 0                              | 0 | 0 | 1 | 1 | 0 if A1 shorted to ground<br>1 if A1 shorted to supply | 0 if A0 shorted to ground<br>1 if A0 shorted to supply | 0 for I <sup>2</sup> C write<br>1 for I <sup>2</sup> C read |

| Ordering Code          | EE_I2C_ADDR[4:0] | 7-bit I <sup>2</sup> C addresses possible |
|------------------------|------------------|---|
| MLX90393xLW-ABA-011-RE | 0x03             | 0x0C, 0x0D, 0x0E, 0x0F                    |
| MLX90393xLW-ABA-012-RE | 0x04             | 0x10, 0x11, 0x12, 0x13                    |
| MLX90393xLW-ABA-013-RE | 0x05             | 0x14, 0x15, 0x16, 0x17                    |
| MLX90393xLW-ABA-014-RE | 0x06             | 0x18, 0x19, 0x1A, 0x1B                    |
| MLX90393xLQ-ABA-011-RE | 0x04             | 0x10                                      |

Table 14: I<sup>2</sup>C address ordering codes

### 15.4.1. Command Implementation

For the examples given, the below convention is used.

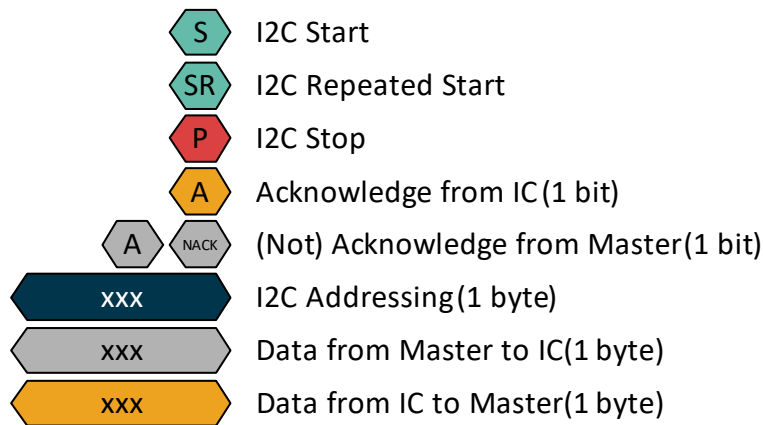


Figure 14: I<sup>2</sup>C Convention

#### 15.4.1.1. SB, SWOC, SM, EX, HR, HS

All the commands follow the structure below. The reply from the MLX90393 is only the status byte. The example below is for a start of a burst mode with X and Y being measured.



Figure 15: SB command, XY

After the HS command, wait at least 15ms before sending the next command to allow the IC to update the NVRAM correctly.

15.4.1.2. RT

This command will (warm-)reset the IC. The status byte of the command following will indicate the reset event. It is recommended to perform an ‘EX’ command and to wait 1ms, before issuing a ‘RT’ command. After the RT command, it is recommended to wait 1.5ms for the start-up sequence to complete.

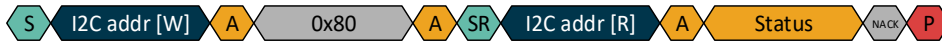


Figure 16: RT command

15.4.1.3. RM

This command differs depending on the value for zyxt. The data is returned in the order Status-TXYZ, where the components which are set to zero are skipped.

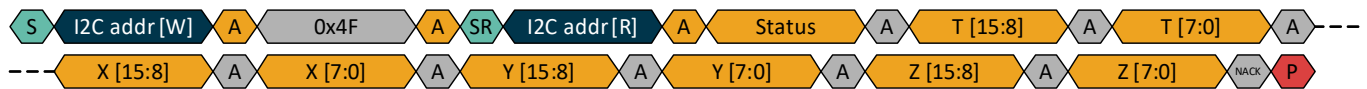


Figure 17: RM command-XYZT



Figure 18: RM command-YT

15.4.1.4. RR

Important in this command is that the register address to be read needs to be shifted left by two bits. To read register 0x12 for example, the SDA byte becomes 0x48.



Figure 19: RR command

15.4.1.5. WR

Important in this command is that the register address to be read needs to be shifted left by two bits. To read register 0x12 for example, the SDA byte becomes 0x48.

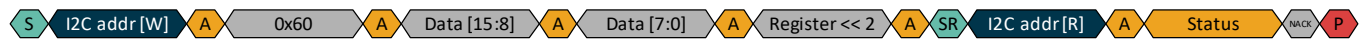


Figure 20: WR command

## 15.4.2. I<sup>2</sup>C Timing Specification

All timings are referred to the levels found in Table 6: General Electrical Specifications.

| Electrical Parameter                           | Symbol                 | I <sup>2</sup> C Standard Mode |      | I <sup>2</sup> C Fast Mode            |      | Unit |
|--|------------------------|--------------------------------|------|---------------------------------------|------|------|
|  |                        | Min.                           | Max. | Min.                                  | Max. |      |
| SCL Clock Frequency                            | f (SCL)                |                                | 100  |                                       | 400  | kHz  |
| SCL Clock Low Time                             | t <sub>w</sub> (SCLL)  | 4.7                            |      | 1.3                                   |      | μs   |
| SCL Clock High Time                            | t <sub>w</sub> (SCLH)  | 4                              |      | 0.6                                   |      | μs   |
| SDA Setup Time                                 | t <sub>su</sub> (SDA)  | 250                            |      | 100                                   |      | ns   |
| SDA Data Hold Time                             | t <sub>h</sub> (SDA)   |                                | 3.45 | 0                                     | 0.9  | μs   |
| SDA and SCL Rise Time                          | t <sub>r</sub> (SDA)   |                                | 1000 | 20+0.1*C <sub>b</sub> <sup>(10)</sup> | 300  | ns   |
|  | t <sub>r</sub> (SCL)   |                                |      |                                       |      |      |
| SDA and SCL Fall Time                          | t <sub>r</sub> (SDA)   |                                | 300  | 20+0.1*C <sub>b</sub> <sup>(10)</sup> | 300  | ns   |
|  | t <sub>r</sub> (SCL)   |                                |      |                                       |      |      |
| START Condition Hold Time                      | t <sub>h</sub> (ST)    | 4                              |      | 0.6                                   |      | μs   |
| REPEATED START Condition Setup Time            | t <sub>su</sub> (SR)   | 4.7                            |      | 0.6                                   |      | μs   |
| STOP Condition Setup Time                      | t <sub>su</sub> (SP)   | 4                              |      | 0.6                                   |      | μs   |
| Bus Free Time Between STOP and START Condition | t <sub>w</sub> (SP:ST) | 4.7                            |      | 1.3                                   |      | μs   |

Table 15: General I<sup>2</sup>C Timing Specification

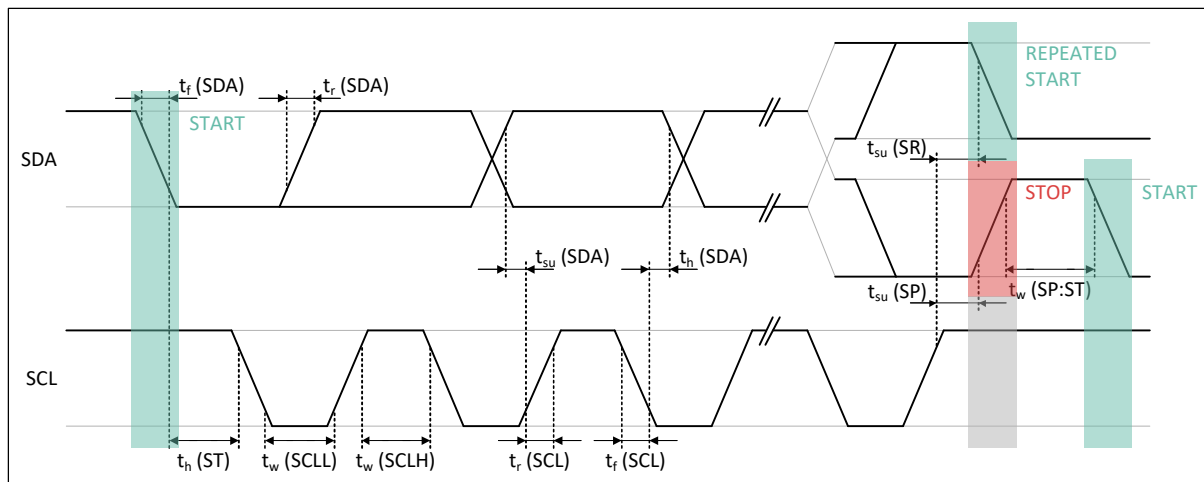


Figure 21: I<sup>2</sup>C Timing Diagram

<sup>10</sup> Where C<sub>b</sub> is the total bus capacitance (in pF)

## 16. Memory Map

### 16.1. General Description

The MLX90393 has 1kbit of non-volatile memory, and the same amount of volatile memory. Each memory consists out of 64 addresses containing 16 bit words. The non-volatile memory has automatic 2-bit error detection and 1-bit error correction capabilities per address. The handling of such corrections & detections is explained in Section 15.2.

The memory is split in 2 areas:

- Customer area [address 0x00 to 0x1F]
- Melexis area [address 0x20 to 0x3F]

The RR and WR commands impact the volatile memory only, there no direct access possible to the non-volatile memory. The customer area of the volatile memory is bidirectionally accessible to the customer; the Melexis area is write-protected. Only modifications in the blue area are allowed with the WR command. The adjustments in the customer area can be stored in the permanent non-volatile memory with the STORE command HS, which copies the entire volatile memory including the Melexis area to the non-volatile one. With the HR command the non-volatile memory content can be recalled to the volatile memory, which can restore any modifications due to prior WR commands. The HR step is performed automatically at start-up of the ASIC, either through cold reset or warm reset with the RT command.

The above is graphically shown in Figure 22.

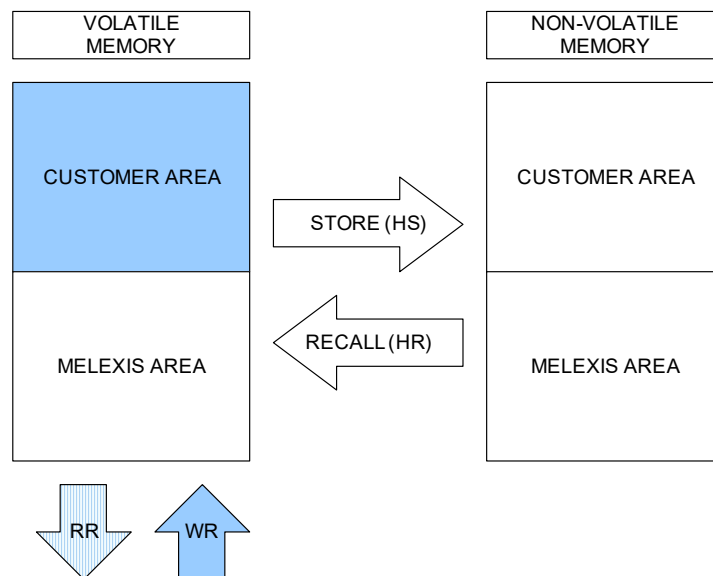


Figure 22: The memories of the MLX90393, their areas and the impacting commands.

The customer area houses 3 types of data:

- Analog configuration bits
- Digital configuration bits
- Informative (free) bits

The latter can be filled with customer content freely, and covers the address span from (and including) 0x0A to 0x1F, a total of 352 bits. The memory mapping of volatile and non-volatile memory on address level is identical. The volatile memory map is given in Figure 23.

The table below gives an overview of the customer area in the MLX90393's NVRAM.

In the register map, the 16-bit words are split into 2 bytes for the sake of readability. The general format is shown below in the yellow table.

| Register | Bit 7                   | Bit 6  | Bit 5  | Bit 4  | Bit 3  | Bit 2  | Bit 1 | Bit 0                  |
|----------|-------------------------|--------|--------|--------|--------|--------|-------|------------------------|
| 0x..     | Bit 7                   | Bit 6  | Bit 5  | Bit 4  | Bit 3  | Bit 2  | Bit 1 | Bit 0 <sub>(LSB)</sub> |
|          | Bit 15 <sub>(MSB)</sub> | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8                  |

| Register | Bit 7            | Bit 6     | Bit 5                 | Bit 4   | Bit 3    | Bit 2            | Bit 1 | Bit 0 |
|----------|------------------|-----------|-----------------------|---------|----------|------------------|-------|-------|
| 0x00h    | Z-SERIES         | GAIN_SEL  |                       |         | HALLCONF |                  |       |       |
|          | ANA_RESERVED_LOW |           |                       |         |          |                  |       | BIST  |
| 0x01h    | BURST_SEL (zyxt) |           | BURST_DATA_RATE (BDR) |         |          |                  |       |       |
|          | TRIG_INT         | COMM_MODE | WOC_DIFF              | EXT_TRG | TCMP_EN  | BURST_SEL (zyxt) |       |       |
| 0x02h    | RES_Y            | RES_X     | DIG_FILT              |         |          | OSR              |       |       |
|          |                  |           |                       | OSR2    | RES_Z    | RES_Y            |       |       |
| 0x03h    | SENS_TC_LT       |           |                       |         |          |                  |       |       |
|          | SENS_TC_HT       |           |                       |         |          |                  |       |       |
| 0x04h    | OFFSET_X         |           |                       |         |          |                  |       |       |
|          | OFFSET_X         |           |                       |         |          |                  |       |       |
| 0x05h    | OFFSET_Y         |           |                       |         |          |                  |       |       |
|          | OFFSET_Y         |           |                       |         |          |                  |       |       |
| 0x06h    | OFFSET_Z         |           |                       |         |          |                  |       |       |
|          | OFFSET_Z         |           |                       |         |          |                  |       |       |
| 0x07h    | WOXY_THRESHOLD   |           |                       |         |          |                  |       |       |
|          | WOXY_THRESHOLD   |           |                       |         |          |                  |       |       |
| 0x08h    | WOZ_THRESHOLD    |           |                       |         |          |                  |       |       |
|          | WOZ_THRESHOLD    |           |                       |         |          |                  |       |       |
| 0x09h    | WOT_THRESHOLD    |           |                       |         |          |                  |       |       |
|          | WOT_THRESHOLD    |           |                       |         |          |                  |       |       |
| 0x0Ah    | FREE             |           |                       |         |          |                  |       |       |
| ...      |                  |           |                       |         |          |                  |       |       |
| 0x1Fh    |                  |           |                       |         |          |                  |       |       |

Figure 23: Customer area memory map.

The non-volatile memory can only be written (HS store command) if pin VDD is supplied with 3.3V minimum, otherwise the write sequence cannot be performed in a reliable way. Additionally, this HS command was designed to be used as one-time calibration, but not as multi write-cycle memory within the application. In case memory is written within the application, the number of write cycles should be kept to a minimum. There is no limit to the write cycles in the volatile memory (WR write command).

## 16.2. Parameter Description

The meaning of each customer accessible parameter is explained in this section. The customer area of both the volatile and the non-volatile memory can be written through standard SPI and I<sup>2</sup>C communication, within the application. No external high-voltages are needed to perform such operations, nor access to dedicated pins that need to be grounded in the application. Note that the default settings are “illegal” in the filter settings.

| Parameter           | Description  | Default |
|---------------------|--|---------|
| ANA_RESERVED_LOW    | Reserved IO trimming bits  | 0x00    |
| BIST                | Enabled the on-chip coil, applying a Z-field [Built-In Self Test]                    | 0x0     |
| Z_SERIES            | Enable all plates for Z-measurement  | 0x0     |
| GAIN_SEL[2:0]       | Analog chain gain setting, factor 5 between min and max code                         | 0x7     |
| HALLCONF[3:0]       | Hall plate spinning rate adjustment  | 0xC     |
| TRIG_INT_SEL        | Puts TRIG_INT pin in TRIG mode when cleared, INT mode otherwise                      | 0x0     |
| COMM_MODE[1:0]      | Allow only SPI [10b], only I <sup>2</sup> C [11b] or both [0Xb] according to CS pin  | 0x0     |
| WOC_DIFF            | Sets the Wake-up On Change based on $\Delta\{\text{sample}(t), \text{sample}(t-1)\}$ | 0x0     |
| EXT_TRIG            | Allows external trigger inputs when set, if TRIG_INT_SEL = 0                         | 0x0     |
| TCMP_EN             | Enables on-chip sensitivity drift compensation                                       | 0x0     |
| BURST_SEL[3:0]      | Defines the MDATA in burst mode if SB command argument = 0                           | 0x0     |
| BURST_DATARATE[6:0] | Defines $T_{\text{INTERVAL}}$ as BURST_DATA_RATE * 20ms                              | 0x00    |
| OSR2[1:0]           | Temperature sensor ADC oversampling ratio  | 0x0     |
| RES_XYZ[5:0]        | Selects the desired 16-bit output value from the 19-bit ADC                          | 0x00    |
| DIG_FILT[1:0]       | Digital filter applicable to ADC   | 0x0     |
| OSR[1:0]            | Magnetic sensor ADC oversampling ratio   | 0x0     |
| SENS_TC_HT[7:0]     | Sensitivity drift compensation factor for $T < T_{\text{REF}}$                       | Trimmed |
| SENS_TC_LT[7:0]     | Sensitivity drift compensation factor for $T > T_{\text{REF}}$                       | Trimmed |
| OFFSET_i[15:0]      | Constant offset correction, independent for $i = X, Y, Z$                            | 0x0000  |
| WOi_THRESHOLD[15:0] | Wake-up On Change threshold, independent for $i = X, Y, Z$ and T                     | 0x0000  |

Table 16: NVRAM parameter description

### 16.2.1. ANA\_RESERVED\_LOW

Reserved bits for analog trimming at Melexis factory. Do not modify.

### 16.2.2. BIST

Enables (1) or disables (0) the built in self-test coil. In normal operation set to 0. A measurement with this coil enabled shows a change in magnetic field sensed on the Z-axis.

### 16.2.3. Z\_Series

Enables series connection of hall plates for Z axis measurement. In normal operation set to 0.

## 16.2.4. GAIN\_SEL[2:0]

Sets the analog gain to the desired value. The sensitivity is dependent on the axis (the X- and Y-axis have higher sensitivity, compared with the Z-axis, expressed in LSB/ $\mu$ T) as well as the setting of the RES\_XYZ[5:0] parameter. The relationship is given in the below table.

Table for HALLCONF<sup>(11)</sup> = 0xC, sensitivity in  $\mu$ T/LSB, TC off, T=25°C:

| GAIN_SEL | RES = 0            |                   | RES = 1            |                   | RES = 2            |                   | RES = 3            |                   |
|----------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|
|          | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> |
| 0        | 0.751              | 1.210             | 1.502              | 2.420             | 3.004              | 4.840             | 6.009              | 9.680             |
| 1        | 0.601              | 0.968             | 1.202              | 1.936             | 2.403              | 3.872             | 4.840              | 7.744             |
| 2        | 0.451              | 0.726             | 0.901              | 1.452             | 1.803              | 2.904             | 3.605              | 5.808             |
| 3        | 0.376              | 0.605             | 0.751              | 1.210             | 1.502              | 2.420             | 3.004              | 4.840             |
| 4        | 0.300              | 0.484             | 0.601              | 0.968             | 1.202              | 1.936             | 2.403              | 3.872             |
| 5        | 0.250              | 0.403             | 0.501              | 0.807             | 1.001              | 1.613             | 2.003              | 3.227             |
| 6        | 0.200              | 0.323             | 0.401              | 0.645             | 0.801              | 1.291             | 1.602              | 2.581             |
| 7        | 0.150              | 0.242             | 0.300              | 0.484             | 0.601              | 0.968             | 1.202              | 1.936             |

Table 17: Sensitivity table for given gain and resolution selection for HALLCONF=0xC

Table for HALLCONF<sup>(11)</sup> = 0xC, sensitivity in  $\mu$ T/LSB, TC off, T=35°C:

| GAIN_SEL | RES = 0            |                   | RES = 1            |                   | RES = 2            |                   | RES = 3            |                   |
|----------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------------------|
|          | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> | SENS <sub>XY</sub> | SENS <sub>Z</sub> |
| 0        | 0.787              | 1.267             | 1.573              | 2.534             | 3.146              | 5.068             | 6.292              | 10.137            |
| 1        | 0.629              | 1.014             | 1.258              | 2.027             | 2.517              | 4.055             | 5.034              | 8.109             |
| 2        | 0.472              | 0.760             | 0.944              | 1.521             | 1.888              | 3.041             | 3.775              | 6.082             |
| 3        | 0.393              | 0.634             | 0.787              | 1.267             | 1.573              | 2.534             | 3.146              | 5.068             |
| 4        | 0.315              | 0.507             | 0.629              | 1.014             | 1.258              | 2.027             | 2.517              | 4.055             |
| 5        | 0.262              | 0.422             | 0.524              | 0.845             | 1.049              | 1.689             | 2.097              | 3.379             |
| 6        | 0.210              | 0.338             | 0.419              | 0.676             | 0.839              | 1.352             | 1.678              | 2.703             |
| 7        | 0.157              | 0.253             | 0.315              | 0.507             | 0.629              | 1.014             | 1.258              | 2.027             |

Table 18: Sensitivity table for given gain and resolution selection for HALLCONF=0xC

<sup>11</sup> For HALLCONF = 0x0, the sensitivity scales with a factor 98/75. For example (0.150 $\mu$ T/LSB with HALLCONF 0xC becomes 0.196 $\mu$ T/LSB with HALLCONF 0x0)

### 16.2.5. HALLCONF[3:0]

Modifies the hall plate spinning (2-phase vs 4-phase) which has an effect on the minimum sampling rate achievable. Some configurations of OSR and DIG\_FILT are not permitted. The cells shown in red are not permitted with HALL\_CONF=0xC (default) but are allowed when HALL\_CONF=0x0.

| Typical $T_{CONV}(TXYZ)$<br>for $OSR_2=0x0$ [ms] |   | OSR   |       |        |        |
|--|---|-------|-------|--------|--------|
|  |   | 0     | 1     | 2      | 3      |
| DIG_FILT   | 0 | 1.27  | 1.84  | 3.00   | 5.30   |
|  | 1 | 1.46  | 2.23  | 3.76   | 6.84   |
|  | 2 | 1.84  | 3.00  | 5.30   | 9.91   |
|  | 3 | 2.61  | 4.53  | 8.37   | 16.05  |
|  | 4 | 4.15  | 7.60  | 14.52  | 28.34  |
|  | 5 | 7.22  | 13.75 | 26.80  | 52.92  |
|  | 6 | 13.36 | 26.04 | 51.38  | 102.07 |
|  | 7 | 25.65 | 50.61 | 100.53 | 200.37 |

Table 19:  $T_{CONV}$  as a function of OSR & DIG\_FILT

| Maximum ODR<br>for $OSR_2=0x0$ [Hz] |   | OSR   |       |       |       |
|-------------------------------------|---|-------|-------|-------|-------|
|                                     |   | 0     | 1     | 2     | 3     |
| DIG_FILT                            | 0 | 716.9 | 493.0 | 303.4 | 171.5 |
|                                     | 1 | 622.7 | 408.0 | 241.5 | 133.0 |
|                                     | 2 | 493.0 | 303.4 | 171.5 | 91.8  |
|                                     | 3 | 348.0 | 200.6 | 108.6 | 56.6  |
|                                     | 4 | 219.2 | 119.6 | 62.6  | 32.1  |
|                                     | 5 | 125.9 | 66.1  | 33.9  | 17.2  |
|                                     | 6 | 68.0  | 34.9  | 17.7  | 8.9   |
|                                     | 7 | 35.4  | 18.0  | 9.0   | 4.5   |

Table 20: Maximum Output Data Rate (ODR) as a function of OSR & DIG\_FILT

### 16.2.6. TRIG\_INT\_SEL

When set to 0 the TRIG\_INT pin is in trigger mode. When set to 1 the TRIG\_INT pin acts as an interrupt pin.

### 16.2.7. COMM\_MODE[1:0]

When set to 0x2 only SPI communication is allowed. When set to 0x3 only I<sup>2</sup>C communication is allowed. When set to 0x0 or 0x1 both communication modes can be used but the selection is made by the CS pin.

### 16.2.8. WOC\_DIFF

When wake-on-change mode is enabled this parameter defines the mode to use. When enabled, a comparison on the current measurement is made with the previous measurement. When disabled, the first initial measurement is used as a reference.

### 16.2.9. EXT\_TRIG

Allows for external trigger events when set to 1 and TRIG\_INT\_SEL = 0. When enabled an acquisition will start with the external trigger pin detects a high value. Acquisitions will continue to be triggered until the EXT\_TRIG pin is brought low.

### 16.2.10. TCMP\_EN

Enables (1) or disables (0) the on-chip sensitivity drift compensation. Enabling the temperature compensation will influence the way the magnetic values are encoded and transmitted to the system microcontroller as shown in the table below.

| ABA              |   | TCMP_EN = 0x0    |                                       | TCMP_EN = 0x1    |                                       |
|------------------|---|------------------|---------------------------------------|------------------|---------------------------------------|
|                  |   | RANGE            | TYPE                                  | RANGE            | TYPE                                  |
| RES <sub>i</sub> | 0 | ±2 <sup>15</sup> | 2's complement<br>0μT = 0LSB          | ±2 <sup>15</sup> | unsigned<br>0μT = 2 <sup>15</sup> LSB |
|                  | 1 | ±2 <sup>15</sup> | 2's complement<br>0μT = 0LSB          | ±2 <sup>15</sup> | unsigned<br>0μT = 2 <sup>15</sup> LSB |
|                  | 2 | ±22000           | unsigned<br>0μT = 2 <sup>15</sup> LSB | N/A              |                                       |
|                  | 3 | ±11000           | unsigned<br>0μT = 2 <sup>14</sup> LSB |                  |                                       |

Table 21: Output Range and Type as a function of TCMP\_EN and RES\_XYZ={RES<sub>x</sub>,RES<sub>y</sub>,RES<sub>z</sub>}

### 16.2.11. BURST\_SEL[3:0]

Defines the axes that will be converted in burst mode if the SB command argument is 0.

### 16.2.12. OSR2[1:0]

Selects the temperature sensor ADC oversampling ratio

### 16.2.13. RES\_XYZ[5:0]

See 16.2.4 for the relationship between the gain and resolution. Additionally, section 16.2.10 for the relationship between RES\_XYZ and the output data format.

### 16.2.14. DIG\_FILT[1:0]

See 16.2.5 for the selection of DIG\_FILT and the impact on conversion time.

### 16.2.15. OSR[1:0]

Oversampling ratio for the magnetic measurements. See 16.2.5 for the selection of OSR

### 16.2.16. SENS\_TC\_HT[7:0]

Sensitivity drift compensation factor for T > T<sub>REF</sub>

### 16.2.17. SENS\_TC\_LT[7:0]

Sensitivity drift compensation factor for T < T<sub>REF</sub>

### 16.2.18. OFFSET\_i[15:0]

Constant offset correction, independent of temperature, and programmable for each individual axis where  $i=X, Y, \text{ or } Z$ .

### 16.2.19. WOi\_THRESHOLD[15:0]

Wake-on-change threshold. Independently programmable for each magnetic axis ( $i=X, Y, Z$ ) and temperature ( $i=T$ )

## 17. Recommended Application Diagram

### 1.1 I<sup>2</sup>C

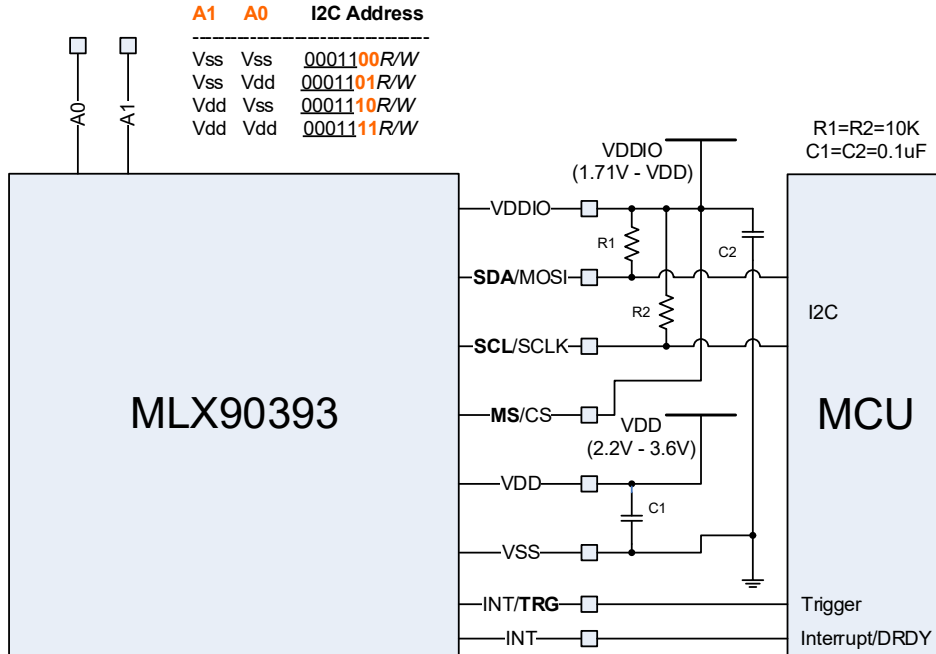


Figure 24: I<sup>2</sup>C recommended schematic

### 1.2 SPI

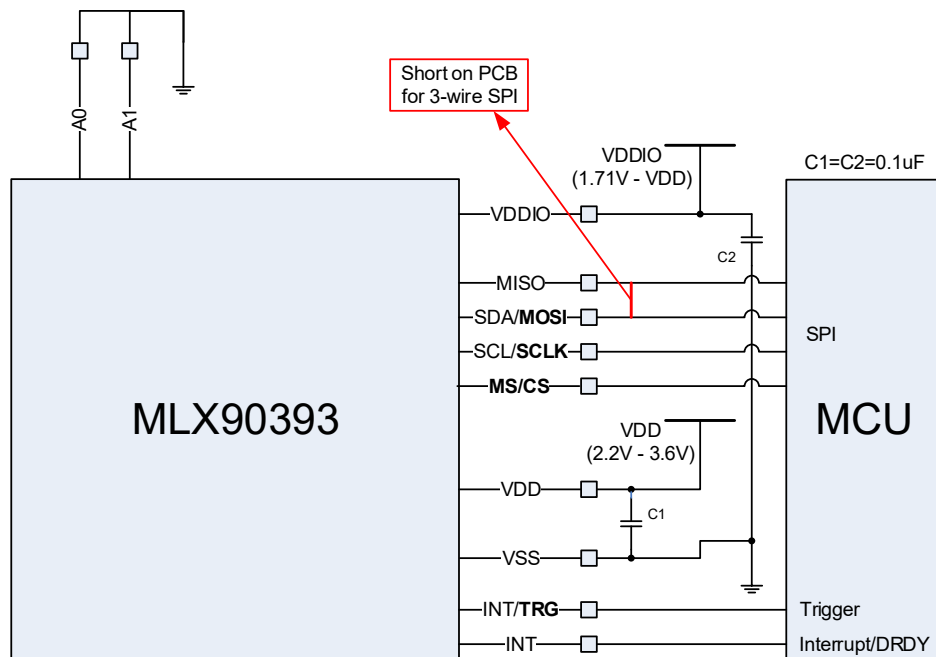


Figure 25: 3/4-wire SPI recommended schematic



### 18.1.2. QFN-16- Pinout and Marking

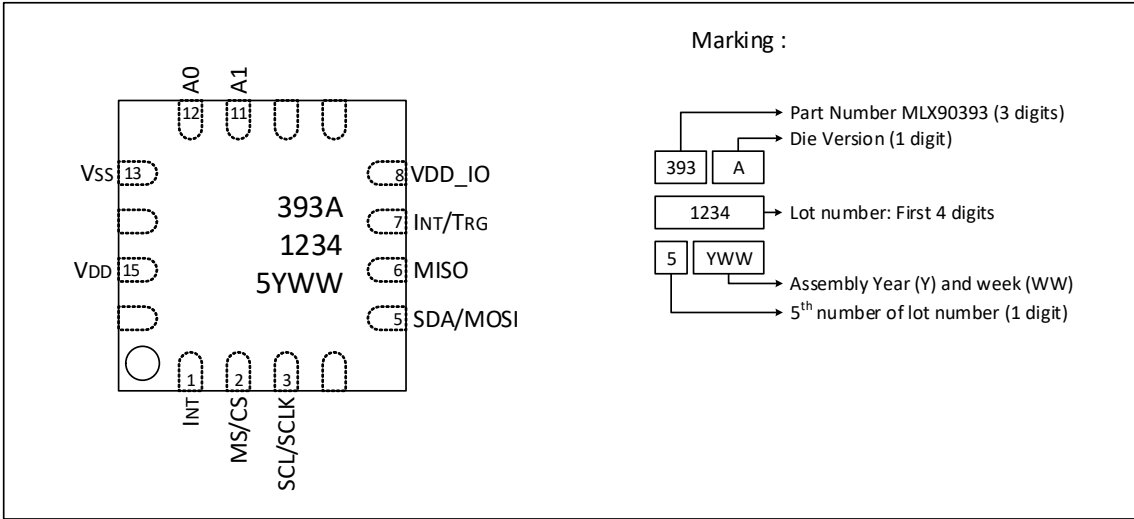


Figure 27: QFN-16 Pinout and Marking – Top view

## 18.2. UDFN-8 package

The MLX90393 shall be delivered in a UDFN-8 package as shown below in Figure 28:

### 18.2.1. Package dimensions and sensitive spot location

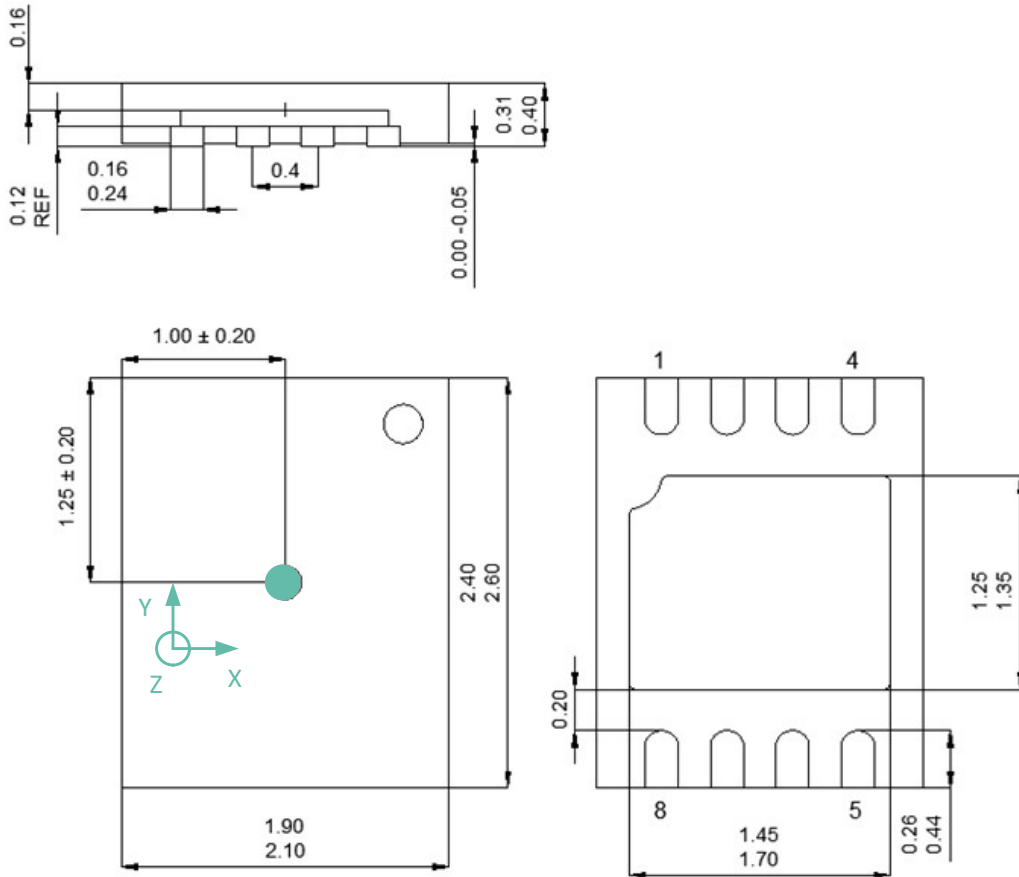


Figure 28: UDFN-8 - Package Outline Drawing

### 18.2.2. UTDFN-8- Pinout and Marking

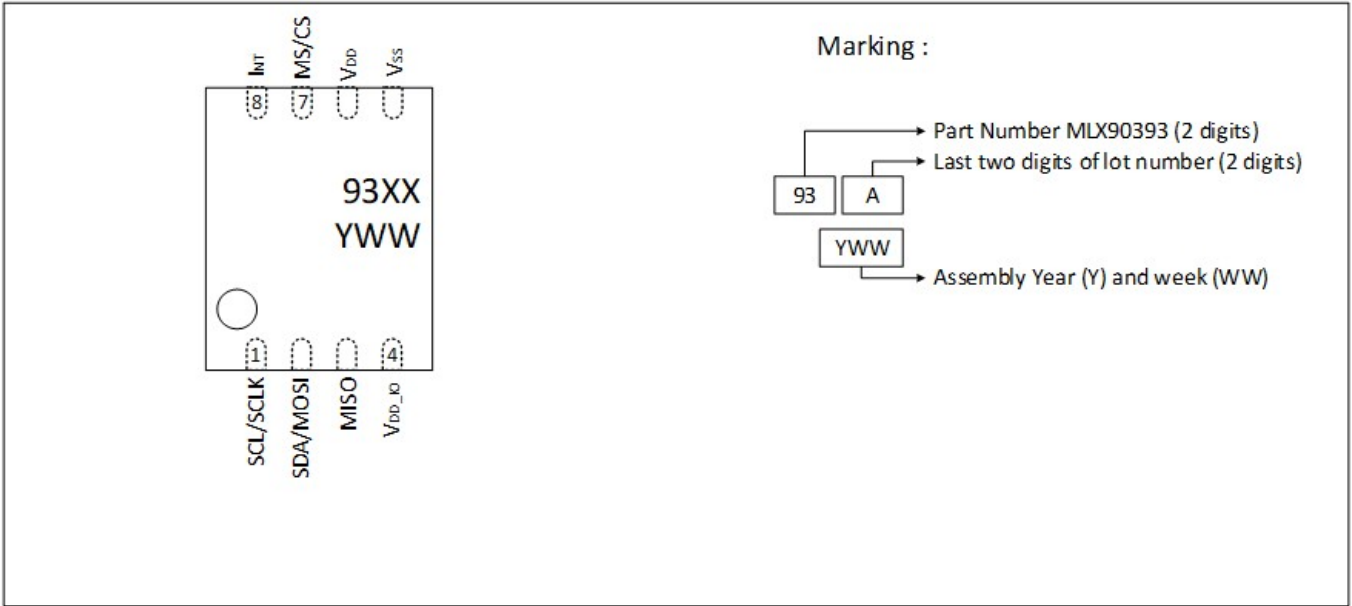


Figure 29: UTDFN-8 – Pinout and Marking (-011 version)

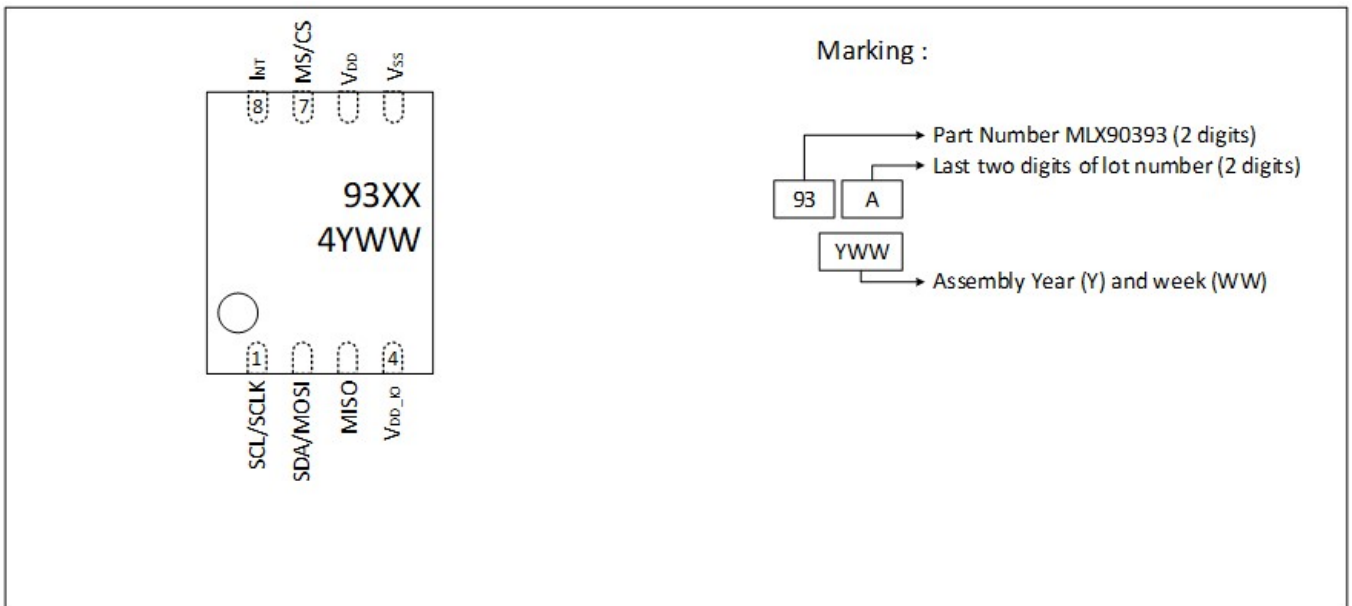


Figure 30: UTDFN-8 – Pinout and Marking (-014 version)

## 19. Standard Information

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For further details about test method references and for compliance verification of selected soldering method for product integration, Melexis recommends reviewing on our web site the General Guidelines [soldering recommendation](#). For all soldering technologies deviating from the one mentioned in above document (regarding peak temperature, temperature gradient, temperature profile, etc.), additional classification and qualification tests have to be agreed upon with Melexis.

For package technology embedding trim and form post-delivery capability, Melexis recommends to consult the dedicated trim & form recommendation application note: [lead trimming and forming recommendations](#)

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## 20. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).

Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

## 21. Revision History

| Date        | Revision | Remark   |
|-------------|----------|--|
| 11-Nov-2014 | 001      | <ul style="list-style-type: none"> <li>First Document Release</li> </ul>   |
| 16-Feb-2015 | 002      | <ul style="list-style-type: none"> <li>Changed Ordering Code to indicate QFN wettable flanks</li> <li>Update Document number</li> <li>Added description of yellow cells in Table 1 and Table 2.</li> </ul>   |
| 13-Jul-2017 | 003      | <ul style="list-style-type: none"> <li>Added additional ordering codes for up to 16 sensors on the same bus and their description in Table 2</li> <li>Added E temperature code for -40°C capable products and the associated update of the operating range in chapter 3</li> <li>Updated template to new Melexis format</li> </ul>   |
| 28-May-2019 | 004      | <ul style="list-style-type: none"> <li>UTDFN-8 Package / Pinout/ Marking</li> <li>Updated sensitivity tables</li> <li>Additional Communication commands details</li> <li>Functional flowchart updated</li> <li>Timings and current consumption updated</li> </ul>  |
| 08-Jan-2020 | 006      | <ul style="list-style-type: none"> <li>Additional specifications of Idd, IdletoStby, Idd, Active and Idd,Conv_end</li> </ul>   |
| 14-Jan-2021 | 007      | <ul style="list-style-type: none"> <li>RR + WR in I2C: typo (one bit-&gt;two bits)</li> <li>Sensitivity chapter: footer, and footnote corrected; uT to μT. Added note that sensitivity increase is in LSB/μT.</li> <li>RM commands: wrong explanation</li> <li>RES_XYZ[5:0] and DIG_FILT[1:0]: corrected cross references</li> <li>OSR[1:0]: link to HALLCONF added</li> <li>I2C timing diagram</li> <li>I2C address of UTDFN (was 0001100, now 0010000), in both option codes and table (I2C chapter)</li> <li>BIST: some more explanation</li> </ul> |
| 13-Jul-2022 | 008      | <ul style="list-style-type: none"> <li>Added version -111</li> <li>Pin number (8) missing in figure “QFN-16 Pinout and Marking – Top view”</li> <li>UTDFN coordinate system rotated 90 degrees</li> <li>Exposed pad (QFN-16 and UTDFN-8) explanation</li> <li>us to μs</li> </ul>  |
| 18-Jan-2023 | 009      | <ul style="list-style-type: none"> <li>Added version SLQ ABA-014</li> <li>UTDFN package marking update</li> <li>Correct temperature range in SLW ABA-111</li> </ul>  |

|             |     |  |
|-------------|-----|--|
| 20-Jul-2023 | 010 | <ul style="list-style-type: none"><li>▪ SENB pin changed to MS pin</li><li>▪ Error bit additional clarification</li><li>▪ Default NVRAM content added</li><li>▪ RT command and RS bit clarified</li><li>▪ Block diagram change</li></ul> |
| 24-Sep-2024 | 011 | <ul style="list-style-type: none"><li>▪ Added timing specification on INT pin</li></ul>  |

## 22. Contact

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