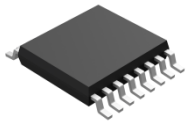


# MLX90373 Triaxis® Position Processor

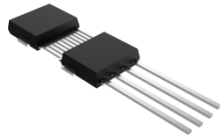
Datasheet

## Features and Benefits

- **Triaxis®** Hall Technology.
- On-Chip Signal Processing for Robust Absolute Position Sensing.
- **ASIL READY** BY MELEXIS ISO26262 ASIL-C Safety Element out of Context (SEooC).
- Programmable Measurement Range.
- Programmable Linear Transfer Characteristic (Multi-points 4 or 8 points or Piece-Wise-Linear 17 or 32 points).
- 2-wire PSi5 protocol (v1.3 and v2.1).
- 48 bit ID Number option.
- Dual Die (Full Redundant) - TSSOP-16 Package (RoHS).
- PCB-less DMP-4 Package (RoHS).
- Robustness against Stray-Field.



TSSOP-16



DMP-4

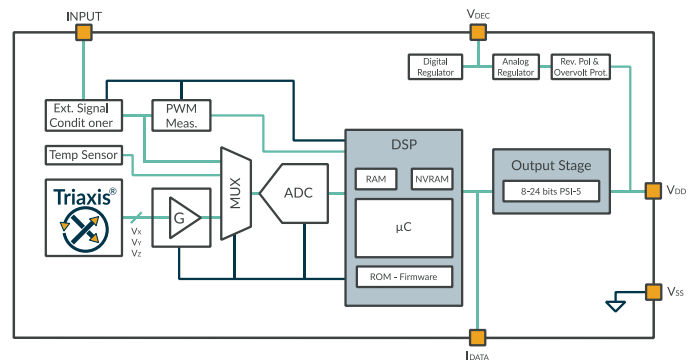
## Application Examples

- Absolute Rotary Position Sensor.
- Absolute Linear Position Sensor.
- Pedal Position Sensor.
- Throttle Position Sensor.
- Ride Height Position Sensor.
- Steering Wheel Position Sensor.
- Fuel Level Sensor.
- Non-Contacting Potentiometer.

## Description

The MLX90373 is a monolithic sensor sensitive to the three components of the flux density applied to the IC (i.e.  $B_x$ ,  $B_y$  and  $B_z$ ). This allows the MLX90373 with the correct magnetic circuit to decode the absolute position of any magnet moving in its vicinity (e.g. rotary position from 0 to 360 Degrees or linear displacement, see Figure 2).

The MLX90373 provides a 2-wires PSi5 (Peripheral Sensor Interface 5) output protocol over the supply line. The protocol is compatible with v1.3 and v2.1 PSi5 specifications.



## Ordering Information

| Product  | Temp | Package | Option Code | Packing Form | Definition                          |
|----------|------|---------|-------------|--------------|-------------------------------------|
| MLX90373 | K    | VS      | ABA-100     | RE/RX        | Angular Position Stray-Field Immune |
| MLX90373 | K    | VS      | ABA-103     | RE/RX        | Angular Position Stray-Field Immune |
| MLX90373 | K    | VS      | ABA-108     | RE/RX        | Angular Position Stray-Field Immune |
| MLX90373 | K    | VS      | ABA-300     | RE/RX        | Linear / Angular Position           |
| MLX90373 | K    | VS      | ABA-303     | RE/RX        | Linear / Angular Position           |
| MLX90373 | K    | VS      | ABA-308     | RE/RX        | Linear / Angular Position           |
| MLX90373 | K    | GO      | ABA-300     | RE           | Linear / Angular Position           |

### Legend:

|                   |  |
|-------------------|--|
| Temperature Code: | <b>K</b> : from -40°C to 125°C   |
| Package Code:     | <b>GO</b> : TSSOP-16 package (fully redundant dual die, see 18.1)<br><b>VS</b> : DMP-4 package (dual mold PCB-less, see 18.2)  |
| Option Code:      | <b>ABA</b> : die Version<br><b>xxx-123</b> :<br><b>1</b> : Application – Magnetic configuration <ul style="list-style-type: none"> <li>▪ 1: Angular Rotary Stray-Field Immune</li> <li>▪ 3: Legacy / Angular Rotary / Linear position</li> </ul> <b>2</b> : SW Configuration <ul style="list-style-type: none"> <li>▪ 0 : Default Configuration</li> </ul> <b>3</b> : Trim-and-Form for DMP-4 package <ul style="list-style-type: none"> <li>▪ 0: Standard straight leads. See 18.2.1.1</li> <li>▪ 3: Trim-and-Form STD2 2.54. See 18.2.1.2</li> <li>▪ 8: Trim-and-Form STD4 2.54. See 18.2.1.3</li> </ul> |
| Packing Form:     | <b>RE</b> : Tape & Reel<br><b>RX</b> : Tape & Reel, similar to RE with parts face-down (DMP-4 package only)  |
| Ordering Example: | “MLX90373KVS-ABA-100-RE”<br>For an Angular Rotary Stray-Field Immune application in DMP-4 package, delivered in Reel, face-up.   |

Table 1: Ordering information legend

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# 1. Functional Diagram and Application Modes

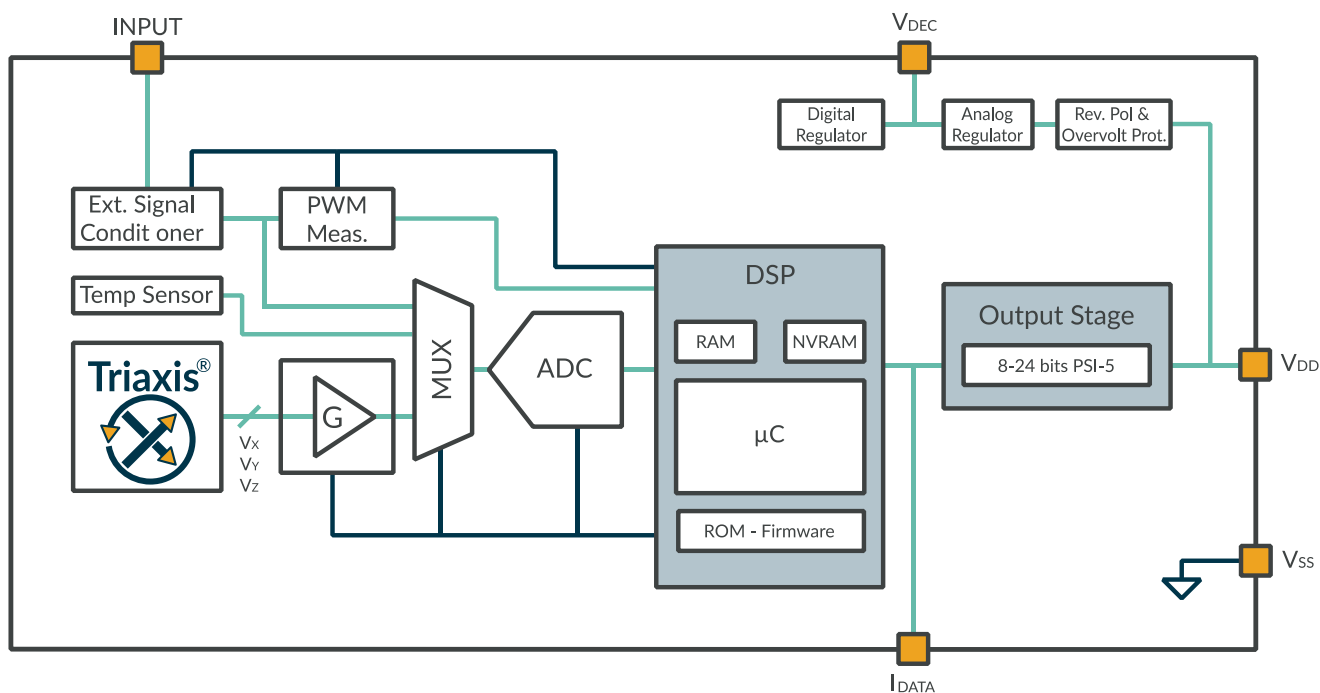


Figure 1: MLX90373 Block Diagram

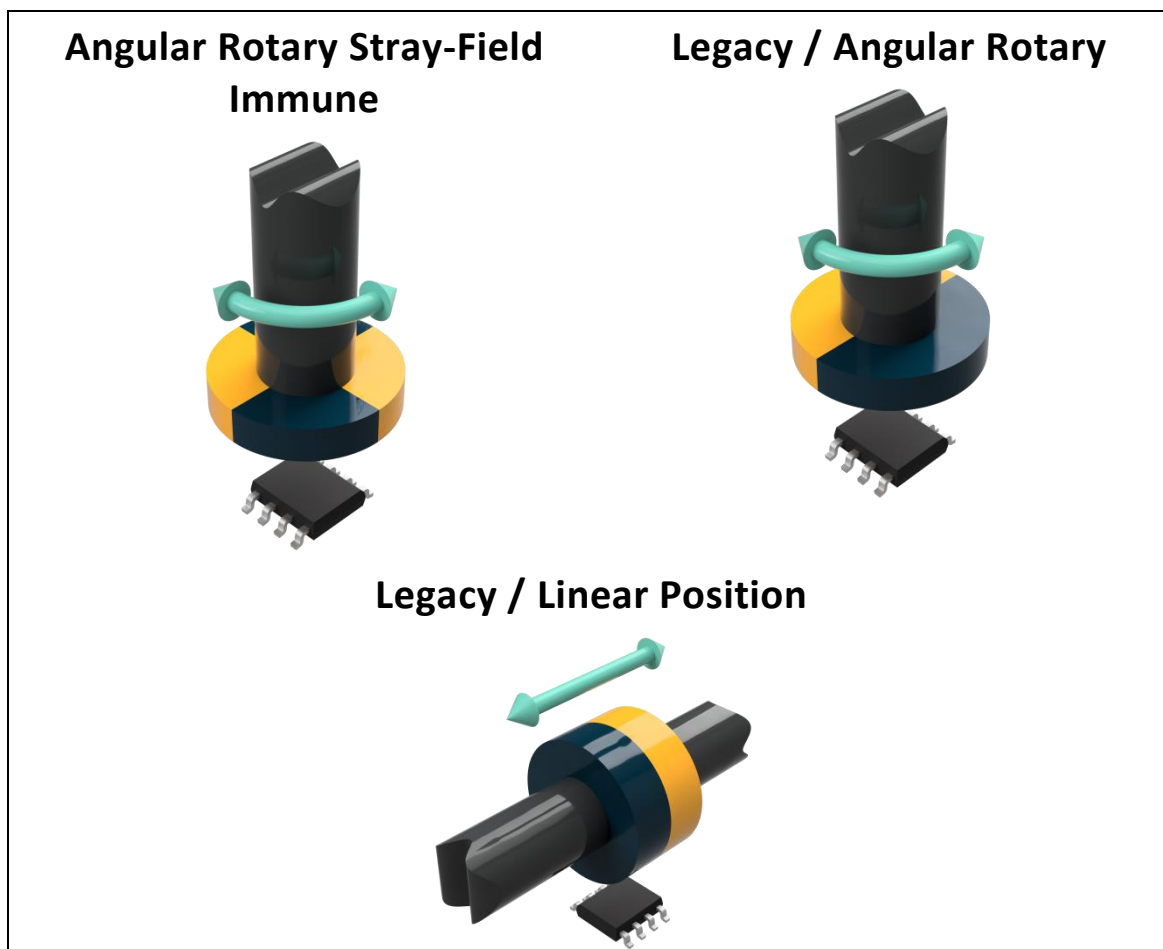


Figure 2: Application Modes

## 2. Glossary of Terms

| Name      | Description  |
|-----------|--|
| ADC       | Analog-to-Digital Converter  |
| AWD       | Absolute Watchdog  |
| CPU       | Central Processing Unit  |
| CRC       | Cyclic Redundancy Check  |
| DMP       | Dual Mould Package   |
| DP        | Discontinuity Point  |
| DSP       | Digital Signal Processing  |
| ECC       | Error Correcting Code  |
| ECU       | Electronic Control Unit  |
| EMA       | Exponential Moving Average   |
| EMC       | Electro-Magnetic Compatibility                                     |
| EoL       | End of Line  |
| FIR       | Finite Impulse Response  |
| Gauss (G) | Alternative unit for the magnetic flux density (10G = 1mT)         |
| HW        | Hardware   |
| IMC       | Integrated Magnetic Concentrator                                   |
| IWD       | Intelligent Watchdog   |
| LSB/MSB   | Least Significant Bit / Most Significant Bit                       |
| NC        | Not Connected  |
| NVRAM     | Non Volatile RAM   |
| PSF       | Product Specific Functions   |
| PSI5      | Peripheral Sensor Interface 5                                      |
| PTC       | Programming Through Connector                                      |
| PWL       | Piecewise Linear   |
| RAM       | Random Access Memory   |
| ROM       | Read-Only Memory   |
| SEooc     | Safety Element out of Context                                      |
| TC        | Temperature Coefficient (in ppm/°C)                                |
| Tesla (T) | SI derived unit for the magnetic flux density (Vs/m <sup>2</sup> ) |

Table 2: Glossary of Terms

## 3. Pin Definitions and Descriptions

### 3.1. Pin Definition for TSSOP-16 Package

| Pin # | Name               | Description                 |
|-------|--------------------|-----------------------------|
| 1     | V <sub>DEC1</sub>  | Decoupling pin die 1        |
| 2     | V <sub>SS1</sub>   | Ground die 1                |
| 3     | V <sub>DD1</sub>   | Supply die 1                |
| 4     | IN <sub>1</sub>    | External sensor input die 1 |
| 5     | TEST <sub>2</sub>  | Test pin die 2              |
| 6     | IDATA <sub>2</sub> | Current sensing die 2       |
| 7     | N.C.               | Not connected               |
| 8     | N.C.               | Not connected               |
| 9     | V <sub>DEC2</sub>  | Decoupling pin die 2        |
| 10    | V <sub>SS2</sub>   | Ground die 2                |
| 11    | V <sub>DD2</sub>   | Supply die 2                |
| 12    | IN <sub>2</sub>    | External sensor input die 2 |
| 13    | TEST <sub>1</sub>  | Test pin die 1              |
| 14    | N.C.               | Not connected               |
| 15    | IDATA <sub>1</sub> | Current sensing die 1       |
| 16    | N.C.               | Not connected               |

*Table 3: TSSOP-16 Pin definition and description*

Pins Input and Test are internally grounded in application. For optimal EMC behavior always connect the unused pins to the ground of the PCB. Pins IDATA must be non-connected.

### 3.2. Pin Definition for DMP-4 Package

| Pin # | Name            | Description     |
|-------|-----------------|-----------------|
| 1     | V <sub>SS</sub> | Ground          |
| 2     | V <sub>DD</sub> | Supply/PSI5-OUT |
| 3     | N.C.            | Not connected   |
| 4     | V <sub>SS</sub> | Ground          |

*Table 4: DMP-4 Pin definition and description*

## 4. Absolute Maximum Ratings

| Parameter                  | Symbol          | Min. | Max. | Unit             | Condition   |
|----------------------------|-----------------|------|------|------------------|---|
| Supply Voltage             | $V_{DD}$        |      | 27   | V                | < 24h ; $T_J < 175^\circ\text{C}$                             |
|                            | $V_{DD}$        |      | 37   | V                | < 60s ; $T_{AMB} \leq 35^\circ\text{C}$                       |
| Reverse Voltage Protection | $V_{DD-REV}$    | -14  |      | V                | < 24h ; $T_J < 175^\circ\text{C}$                             |
|                            | $V_{DD-REV}$    | -20  |      | V                | < 1h  |
| Internal Voltage           | $V_{DEC}$       |      | 3.6  | V                |   |
| Internal Voltage           | $V_{DEC-rev}$   | -0.3 |      | V                |   |
| Positive Input pin Voltage | $V_{Input}$     |      | 6    | V                |   |
| Reverse Input pin Voltage  | $V_{Input-rev}$ | -3   |      | V                |   |
| Operating Temperature      | $T_{AMB}$       | -40  | 125  | $^\circ\text{C}$ |   |
| Junction Temperature       | $T_J$           |      | 175  | $^\circ\text{C}$ | See 18.2.5 and 18.1.5 for packages thermal dissipation values |
| Storage Temperature        | $T_{ST}$        | -55  | 170  | $^\circ\text{C}$ | Refer to the qualification profile                            |
| Sensed magnetic field      | $B_{MAX}$       | -1   | 1    | T                |   |

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.

## 5. Isolation Specification

Only valid for the package code GO, i.e. TSSOP-16 package (dual die).

| Parameter            | Symbol     | Min. | Typ. | Max. | Unit      | Condition   |
|----------------------|------------|------|------|------|-----------|---|
| Isolation Resistance | $R_{isol}$ | 4    | -    | -    | $M\Omega$ | Between dice, measured between $V_{SS1}$ and $V_{SS2}$ with +/-20V bias |

Table 6: Isolation Specification

## 6. General Electrical Specifications

General electrical specifications are valid for temperature range [-40; 125]  $^\circ\text{C}$  and the supply voltage range inside their defined operating range unless otherwise noted.



| Electrical Parameter                               | Symbol            | Min   | Typ   | Max               | Unit | Condition   |
|--|-------------------|-------|-------|-------------------|------|---|
| Operating Supply Voltage during PSi5 communication | $V_{DD}$          | 6     | 12    | 18 <sup>(1)</sup> | V    | DMP-4 package   |
|  | $V_{DD}$          | 4.1   | 5     | 6 <sup>(1)</sup>  | V    | TSSOP-16 and DMP-4 package                            |
| Quiescent Supply current <sup>(2)</sup>            | $I_{DDQ}$         | 10    | 11.5  | 13.5              | mA   | Rotary Stray-Field application (option code -10x).    |
| Quiescent Supply current <sup>(2)</sup>            | $I_{DDQ}$         | 9     | 10.5  | 12.5              | mA   | Legacy application (option code -30x).                |
| Start-up Level                                     | $V_{DDstart}$     | 3.6   |       |                   | V    | Minimal supply start-up voltage                       |
| Undervoltage detection                             | $V_{DDUVH}$       | 3.8   | 4.0   | 4.1               | V    | High threshold  |
| Undervoltage detection                             | $V_{DDUVL}$       | 3.70  | 3.90  | 4.00              | V    | Low threshold   |
| Start-up Hysteresis                                | $V_{DDstartHyst}$ | 0.05  | 0.10  | 0.15              | V    |   |
| PTC Entry Level (rising)                           | $V_{PROV1}$       | 22    | 24    | 26                | V    |   |
| PTC Entry Level Hysteresis                         | $V_{PROV1Hyst}$   | 0.8   | 1.4   | 2.0               | V    |   |
| Current settling error at startup                  | $I_{ERRSTART}$    | -2    |       | 2                 | mA   | Current consumption settling error 5ms after power-up |
| Microcut rejection                                 | $T_{ucut}$        |       | 10    |                   | μs   | PSi5 std.   |
| Regulated Voltage                                  | $V_{DEC}$         | 3.2   | 3.3   | 3.4               | V    | Internal analog voltage                               |
| Regulated Voltage Overvoltage detection            | $V_{DECOVH}$      | 3.65  | 3.75  | 3.85              | V    | High threshold  |
| Regulated Voltage Undervoltage detection           | $V_{DECUVL}$      | 2.70  | 2.85  | 2.92              | V    | Low threshold   |
| Regulated voltage UV / OV detection hysteresis     | $V_{DECOVHyst}$   | 100   | 150   | 200               | mV   |   |
|  | $V_{DECUVHyst}$   |       |       |                   |      |   |
| Digital supply                                     | $V_{DDD}$         | 1.80  | 1.85  | 1.95              | V    |   |
| Digital supply Overvoltage detection               | $V_{DDDOVH}$      | 2.00  | 2.10  | 2.20              | V    |   |
| Digital Supply Undervoltage detection              | $V_{DDDUVL}$      | 1.585 | 1.680 | 1.735             | V    | Power-on Reset low threshold                          |
| Digital Supply OV / UV detection Hysteresis        | $V_{PORHyst}$     | 30    | 100   | 200               | mV   |   |

*Table 7: General electrical specifications*

<sup>1</sup> The maximum PSi5 operating voltage, excluding Synchronization pulse, is limited by the die temperature and the thermal dissipation performance of the considered package.

<sup>2</sup> For the dual die version, the supply current is multiplied by 2.

## 7. Timing Specification

Timing conditions, including the variations of supply, temperature and aging, unless specified.

### 7.1. Definitions

#### 7.1.1. Latency

Latency is the average delay between the movement of the detected object (magnet) and the response of the sensor output. This value is representative of the time constant of the system for regulation calculations.

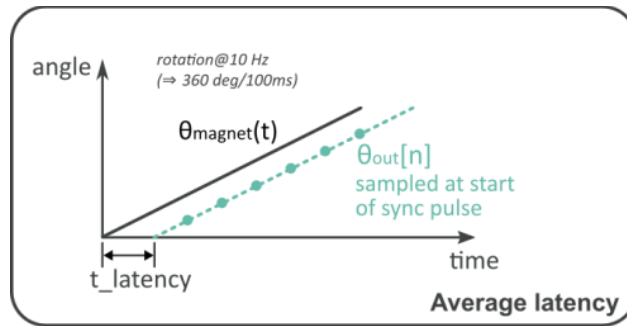


Figure 3: Definition of latency

#### 7.1.2. Step Response

Step response is defined as the delay between the movement of the detected object (magnet) and the 100% settling time of the sensor output with full angle accuracy with regards to filtering. Worst case is happening when the movement of the magnet occurs just after a measurement sequence has begun. Step response therefore consists of the sum of:

- $\delta_{mag,measSeq}$ : the delay between magnetic change and start of next measurement sequence.
- $T_{measSeq}$ : the measurement sequence length.
- $\delta_{measSeq,frameStart}$ : the delay between end of measurement sequence and start of next frame.
- $T_{frame}$ : the frame length.

Worst case happens when  $\delta_{mag,measSeq} = T_{measSeq}$ , which gives:  $T_{wcStep} = 2T_{measSeq,frameStart} + T_{frame}$

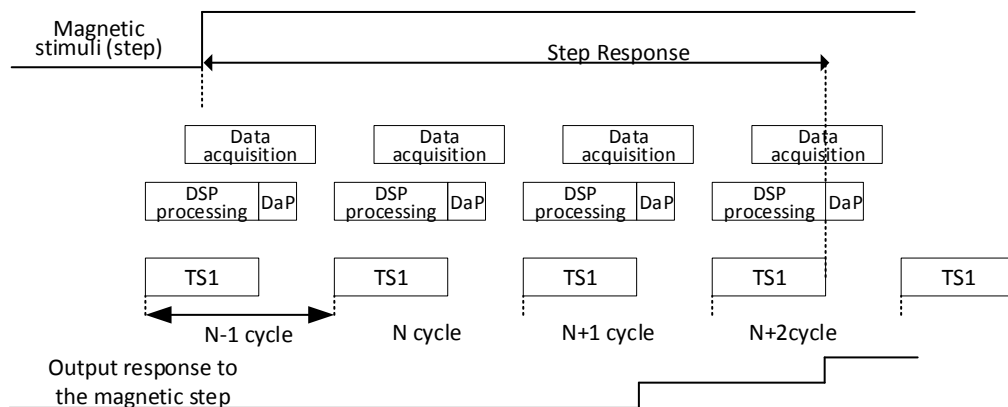


Figure 4: Step response and latency

## 7.2. General Timing

General electrical specifications are valid for temperature range [-40;125] °C and supply voltage range [4.1;5.5] V unless otherwise noted.

| Parameter  | Symbol             | Min. | Typ. | Max.        | Unit              | Condition  |
|--|--------------------|------|------|-------------|-------------------|--|
| Main Clock Frequency                             | F <sub>CK</sub>    | 22.8 | 24   | 25.2        | MHz               | Including thermal and lifetime drift                           |
|  |                    | -5   |      | 5           | % F <sub>CK</sub> | Relative tolerances, including thermal and lifetime drift      |
| Main Clock Frequency Thermal Drift               | ΔF <sub>CK,0</sub> | -2   |      | 2           | % F <sub>CK</sub> | Relative to clock frequency at 35°C. No ageing effects.        |
| 1MHz Clock Frequency                             | F <sub>1M</sub>    |      | 1    |             | MHz               |  |
| Intelligent Watchdog Timeout                     | T <sub>IWD</sub>   | 19   | 20   | 21          | ms                | F <sub>CK</sub> = 24MHz  |
| Absolute Watchdog Timeout                        | T <sub>AWD</sub>   | 19   | 20   | 21          | ms                | F <sub>1M</sub> = 1MHz   |
| Analog Diagnostics                               | DCT <sub>ANA</sub> |      |      | 15.5<br>9.3 | ms                | T <sub>cycle</sub> = 500μs<br>T <sub>cycle</sub> = 300μs       |
| Digital Diagnostics                              | DCT <sub>DIG</sub> |      |      | 20          | ms                |  |
| Current settling Time at start-up <sup>(3)</sup> | TSET               |      | 4    | 5           | ms                | Stabilization of the quiescent current after start-up power on |
| Start-up time                                    | TSU                | 5    |      |             | ms                | when no diagnostic is enabled                                  |
|  |                    |      |      | 20.5        | ms                | when all diagnostics are enabled                               |

Table 8: General Timing Specification

## 7.3. PSI5 Timing

| Parameter                          | Symbol               | Min. | Typ        | Max | Unit | Condition   |
|------------------------------------|----------------------|------|------------|-----|------|---|
| Cycle time                         | T <sub>cycle</sub>   |      | 300<br>500 |     | μs   |   |
| Bit time                           | T <sub>bit</sub>     | 5    |            | 8.4 | μs   |   |
| Sync Pulse Hold Time               | TSHOLD               | 9    |            |     | μs   | Synchronous mode only   |
| Data acquisition                   |                      | 150  |            | 350 | μs   | 5 acquisitions at 4 MHz<br>9 acquisitions at 3 MHz            |
| DSP calculation + Data preparation |                      | 250  | 350        |     | μs   | 2 phase spinning + DSP trimming down<br>Default configuration |
| Latency Time                       | T <sub>latency</sub> |      | 850        |     | μs   | Default configuration, no filtering                           |
| Step Response Time <sup>(4)</sup>  | T <sub>wcStep</sub>  |      | 1480       |     | μs   | Rotary mode, default configuration, no filtering              |
|                                    |                      |      | 2125       |     |      | Velocity mode, default configuration, no filtering            |

Table 9: PSI5 Timing Specification

<sup>3</sup> Due to duration of initialization phases in PSI5 protocol no PSI5 data frame will be transmitted before initialization phase II.

<sup>4</sup> Main clock variations not included.

## 8. Magnetic Field Specifications

Magnetic field specifications are valid for temperature range [-40; 125] °C unless otherwise noted.

### 8.1. Rotary Stray-Field Immune (-10x code)

| Parameter  | Symbol                            | Min              | Typ                 | Max                 | Unit                        | Condition  |
|--|-----------------------------------|------------------|---------------------|---------------------|-----------------------------|--|
| Number of magnetic poles                               | $N_p$                             | 4 <sup>(5)</sup> | -                   | -                   |                             |  |
| Magnetic Flux Density in X-Y plane                     | $B_x, B_y$ <sup>(6)</sup>         |                  |                     | 25 <sup>(7)</sup>   | mT                          | $\sqrt{B_x^2 + B_y^2}$<br>(this is not the useful signal)  |
| Magnetic Flux Density in Z                             | $B_z$                             |                  |                     | 100                 | mT                          | (this is not the useful signal)  |
| Magnetic in-plane gradient of in-plane field component | $\frac{\Delta B_{XY}}{\Delta XY}$ | 4.1              | 10                  |                     | $\frac{mT}{mm}$             | $\frac{1}{2} \sqrt{\left(\frac{dB_x}{dX} - \frac{dB_y}{dY}\right)^2 + \left(\frac{dB_x}{dY} + \frac{dB_y}{dX}\right)^2}$<br>this is the useful signal (see Figure 5) |
| Magnet Temperature Coefficient                         | $TC_m$                            | -2400            |                     | 0                   | $\frac{ppm}{^\circ C}$      |  |
| Field Strength Resolution <sup>(8)</sup>               | $\frac{\Delta B_{XY}}{\Delta XY}$ | 0.075            | 0.100               | 0.125               | $\frac{mT}{mm \text{ LSB}}$ | Magnetic field gradient norm (12bits data)   |
| Field too Low Threshold <sup>(9)</sup>                 | $B_{TH\_LOW}$                     | 0.8              | 1.2                 | <sup>(10)</sup>     | $\frac{mT}{mm}$             | Typ. value recommended   |
| Field too High Threshold <sup>(9)</sup>                | $B_{TH\_HIGH}$                    | 70               | 100 <sup>(11)</sup> | 102 <sup>(11)</sup> | $\frac{mT}{mm}$             |  |

Table 10 Magnetic specification for rotary Stray-Field immune application

Nominal performances apply when the useful signal  $\Delta B_{XY}/\Delta XY$  is above the typical specified limit. Under this value, limited performances apply. See 9.1 for accuracy specifications.

<sup>5</sup> Due to 4 poles magnet usage, maximum angle measurement range is limited to 180°

<sup>6</sup> The condition must be fulfilled for all combinations of  $B_x$  and  $B_y$ .

<sup>7</sup> Above this limit, the IMC® starts to saturate, yielding to an increase of the linearity error.

<sup>8</sup> Only valid with default MAGNET\_SREL\_T[1..7] configuration

<sup>9</sup> See section 11 for the value set by default.

<sup>10</sup> Higher values of Field too Low threshold are not recommended by Melexis and shall only be set in accordance with the magnetic design and taking a sufficient safety margin to prevent false positive.

<sup>11</sup> Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensor

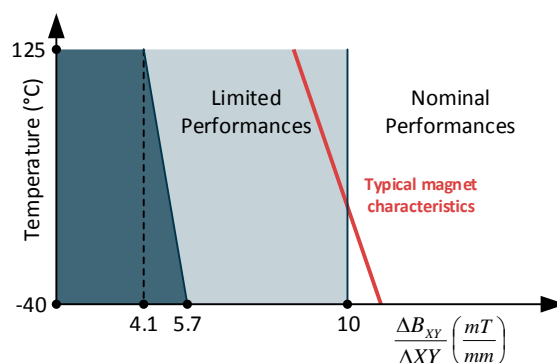


Figure 5: Minimum useful signal definition for rotary Stray-Field immune application

## 8.2. Standard/Legacy Mode (-30x code)

| Parameter                                | Symbol           | Min.               | Typ.                | Max.                | Unit                   | Condition   |
|--|------------------|--------------------|---------------------|---------------------|------------------------|---|
| Number of magnetic poles                 | $N_p$            | -                  | 2                   | -                   |                        |   |
| Magnetic Flux Density in X-Y plane       | $B_x, B_y^{(6)}$ |                    |                     | 70                  | mT                     | $\sqrt{B_x^2 + B_y^2}$  |
| Magnetic Flux Density in Z               | $B_z$            |                    |                     | 100                 | mT                     | in absolute value   |
| Useful Magnetic Flux Density Norm        | $B_{Norm}$       | 11 <sup>(12)</sup> | 20                  |                     | mT                     | $\sqrt{B_x^2 + B_y^2}$ (x-y mode)<br>$\sqrt{B_x^2 + \left(\frac{1}{G_{IMC}} B_z\right)^2}$ (x-z mode)<br>$\sqrt{B_y^2 + \left(\frac{1}{G_{IMC}} B_z\right)^2}$ (y-z mode)<br>See section 13.2.1 for sensing mode description. |
| IMC gain                                 | $G_{IMC}$        |                    | 1.19                |                     |                        | <sup>(13)</sup>   |
| Magnet Temperature Coefficient           | $TC_m$           | -2400              |                     | 0                   | $\frac{ppm}{^\circ C}$ |   |
| Field Strength Resolution <sup>(8)</sup> | $B_{Norm}$       | 0.075              | 0.100               | 0.125               | $\frac{mT}{LSB}$       | Magnetic field gradient norm expressed in 12bits words  |
| Field too Low Threshold <sup>(9)</sup>   | $B_{TH\_LOW}$    | 0.4                | 4.0                 | <sup>(10)</sup>     | mT                     | Typ. Value recommended  |
| Field too High Threshold <sup>(9)</sup>  | $B_{TH\_HIGH}$   | 70                 | 100 <sup>(11)</sup> | 100 <sup>(11)</sup> | mT                     |   |

Table 11: Magnetic specification for standard application

Nominal performances apply when the useful signal  $B_{Norm}$  is above the typical specified limit. Under this value, limited performances apply. See 9.1 for accuracy specifications.

<sup>12</sup> Below 11 mT the performances are degraded due to a reduction of the signal-to-noise ratio, signal-to-offset ratio

<sup>13</sup> IMC has better performance for concentrating in-plane (x-y) field components, resulting in a better overall magnetic sensitivity. A correction factor, called IMC gain has to be applied to the z field component to account for this difference.

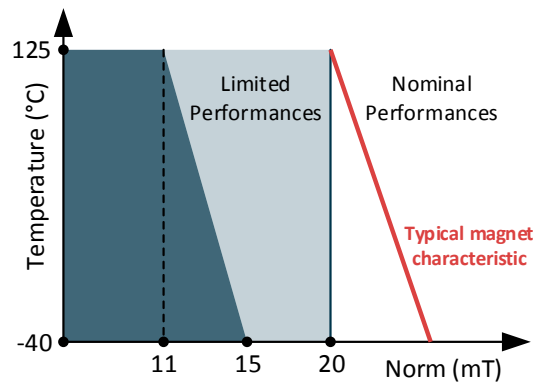


Figure 6: Minimum useful signal definition for Standard/Legacy application

## 9. Accuracy Specifications

Accuracy specifications are valid for temperature range [-40; 125] °C and supply voltage range specified in section 6 unless otherwise noted.

### 9.1. Angular accuracy

#### 9.1.1. Definitions

##### 9.1.1.1. Intrinsic Linearity Error

Figure 7 depicts the intrinsic linearity error in new parts. The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal magnetic field. Once associated to a practical magnetic construction and the associated mechanical and magnetic tolerances, the output linearity error increases. However, it can be improved with the multi-point end-user calibration (see 13.1). As a consequence, this error is not critical in application because it is calibrated away.

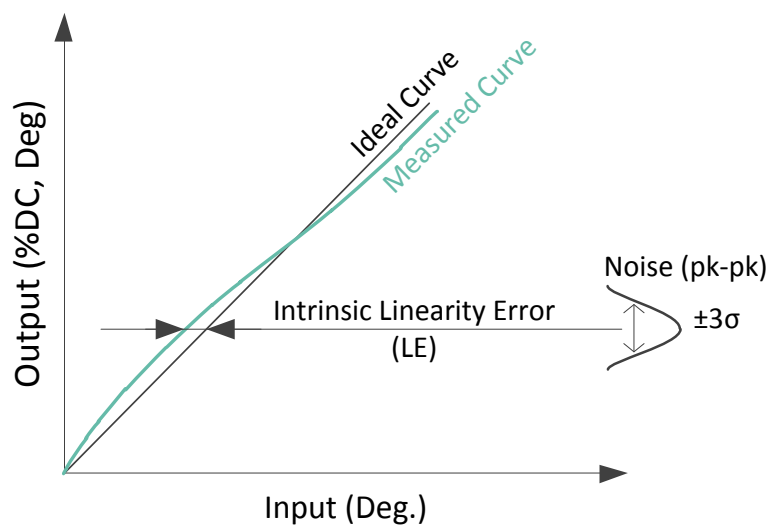


Figure 7: Sensor accuracy definition

### 9.1.1.2. Total Angle Drift

After calibration, the output angle of the sensor might still change due to temperature change, aging, etc.. This is defined as the total drift  $\partial\theta_{TT}$  :

$$\partial\theta_{TT} = \max\{\theta(\theta_{IN}, T, t) - \theta(\theta_{IN}, T_{RT}, t_0)\}$$

where  $\theta_{IN}$  is the input angle,  $T$  is the temperature,  $T_{RT}$  is the room temperature, and  $t$  is the elapsed lifetime after calibration.  $t_0$  represents the status at the start of the operating life. Note the total drift  $\partial\theta_{TT}$  is always defined with respect to angle at room temperature. In this datasheet,  $T_{RT}$  is typically defined at 35°C, unless stated otherwise. The total drift is valid for all angles along the full mechanical stroke.

### 9.1.1. Performances

Valid before EoL calibration and for all applications under nominal performances conditions described in sections 8.1 & 6.

| Mode                                  | Parameter                        | Symbol                  | Nominal performances |       |      | Limited performances |       |      | Unit             | Condition  |                  |
|---------------------------------------|----------------------------------|-------------------------|----------------------|-------|------|----------------------|-------|------|------------------|--|------------------|
|                                       |                                  |                         | Min                  | Typ   | Max  | Min                  | Typ   | Max  |                  |  |                  |
| Rotary Stray-Field Immune (-10x code) | XY - Intrinsic Linearity Error   | $L_{E\_XY}$             | -1                   |       | 1    | -1                   |       | 1    | Deg.             |  |                  |
|                                       | Noise <sup>(14)</sup>            |                         |                      |       | 0.4  |                      |       | 0.7  | Deg.             | Filter = 0 <sup>(15)</sup>   |                  |
|                                       |                                  |                         |                      |       | 0.2  |                      |       | 0.5  | Deg.             | Filter = 1   |                  |
|                                       |                                  |                         |                      |       |      |                      |       | 0.35 | Deg.             | Filter = 2   |                  |
|                                       | XY - Total Drift <sup>(16)</sup> | $\partial\theta_{TTXY}$ | -0.85                |       | 0.85 | -0.85                |       | 0.85 | Deg.             | Relative to 35°C   |                  |
|                                       | Hysteresis                       |                         |                      | 0.1   |      |                      | 0.1   | Deg. |                  |  |                  |
|                                       | Output Stray Field Immunity      | $\partial\theta_{FF}$   |                      |       | 0.6  |                      |       |      | Deg.             | with 10mT/mm useful gradient field and 4kA/m stray-field <sup>(17)</sup> |                  |
| Standard/Legacy (-30x code)           | XY - Intrinsic Linearity Error   | $L_{E\_XY}$             | -1                   |       | 1    | -1                   |       | 1    | Deg.             |  |                  |
|                                       | XZ - Intrinsic Linearity Error   | $L_{E\_XZ}$             | -2.5                 | ±1.25 | 2.5  | -2.5                 | ±1.25 | 2.5  |                  |  |                  |
|                                       | YZ - Intrinsic Linearity Error   | $L_{E\_YZ}$             | -2.5                 | ±1.25 | 2.5  | -2.5                 | ±1.25 | 2.5  |                  |  |                  |
|                                       | Noise <sup>(14)</sup>            |                         |                      |       | 0.05 | 0.1                  |       |      |                  | Deg.   | Filter = 0; 40mT |
|                                       |                                  |                         |                      |       | 0.1  | 0.2                  |       |      |                  | Deg.   | Filter = 0; 20mT |
|                                       |                                  |                         |                      |       |      |                      |       | 0.2  | 0.4              | Deg.   | Filter = 0       |
|                                       |                                  |                         |                      |       |      |                      | 0.14  | 0.28 | Deg.             | Filter = 1   |                  |
|                                       |                                  |                         |                      |       | 0.05 | 0.1                  |       | 0.1  | 0.2              | Deg.   | Filter = 2       |
| XY - Total Drift                      | $\partial\theta_{TTXY}$          | -0.45                   |                      | 0.45  | -0.6 |                      | 0.6   | Deg. | Relative to 35°C |  |                  |
| XZ - Total Drift                      | $\partial\theta_{TTXZ}$          | -0.6                    |                      | 0.6   | -0.8 |                      | 0.8   |      |                  |  |                  |
| YZ - Total Drift                      | $\partial\theta_{TTYZ}$          | -0.6                    |                      | 0.6   | -0.8 |                      | 0.8   |      |                  |  |                  |
|                                       | Hysteresis                       |                         |                      | 0.05  | 0.1  |                      | 0.1   | 0.2  | Deg.             | 10mT<br>20mT   |                  |

<sup>14</sup> ±3σ

<sup>15</sup> See section 13.3 for details concerning Filter parameter

<sup>16</sup> Verification done on aged devices after HTOL in uniform field gradient. The limit represents the peak to peak value of the measured distribution of the largest angle drift, calculated as 6σ of the output angle  $\vartheta_{out}$ . An additional application-specific error arises from the non-ideal magnet and mechanical tolerance drift.

<sup>17</sup> Tested in accordance with ISO 11452-8:2015 at 30°C, with stray-field strength of 4kA/m from any direction. This error scales linearly with both the useful field and the disturbing field.



## 9.2. Angular Velocity Accuracy

The MLX90373 device can calculate the velocity based on the angle measurement. The velocity algorithm must be enabled (VELOCITY\_ENABLE) (disabling is advised for "turbo" modes with no velocity information, where computation speed is critical).

The velocity algorithm is selectable (VELOCITY\_ALGORITHM, 0: simple, 1: tracking loop).

| Parameter   | Symbol | Min   | Typ      | Max      | Unit   | Condition   |
|---|--------|-------|----------|----------|--------|---|
| Angular velocity range  | ASFS   | -1000 | -        | +1000    | Deg./s |   |
| Angular velocity error  |        |       | 26       | 145      | Deg./s | Only error calculation is considered.<br>Max is considering abrupt velocity change 0 to 1000 Deg./s |
| Angular velocity noise <sup>(14)</sup><br>For VELOCITY_FILTER_FIR=0 |        |       | 31<br>23 | 43<br>41 | Deg./s | VELOCITY_ALGORITHM =0<br>VELOCITY_ALGORITHM =1  |

## 9.3. Temperature Accuracy

One can get the physical temperature of the die using following formula:

$$T_{PHY}[^{\circ}C] = \frac{T_{LIN}}{8} - 73.15$$

DIAG\_TEMP\_THR\_LOW/HIGH are encoded on 8-bit unsigned values with the following relationship towards  $T_{Lin}$

$$DIAG\_TEMP\_THR\_(LOW/HIGH) = \frac{T_{LIN}}{16}$$

Following table summarizes the characteristics of the linearized temperature sensor and the encoding of the temperature monitor thresholds.

| Parameter                        | Symbol              | Min | Typ   | Max | Unit   | Condition                               |
|----------------------------------|---------------------|-----|-------|-----|--------|---|
| TLIN resolution                  | Res <sub>TLIN</sub> | -   | 0.125 | -   | °C/LSB |   |
| TLIN refresh rate                | F <sub>S,TLIN</sub> | -   | 200   | -   | Hz     |   |
| TLIN linearity error             | T <sub>LinErr</sub> | -8  | -     | 8   | °C     | from -40 to 125°C                       |
| DIAG_TEMP_THR_LOW                |                     | -   | 8     | -   | LSB    | Recommended value, corresponds to -57°C |
| DIAG_TEMP_THR_HIGH               |                     | -   | 136   | -   | LSB    | Recommended value, corresponds to 199°C |
| Temperature threshold resolution | ResTthr             |     | 2     |     | °C/LSB |   |

Table 12: Linearized Temperature Sensor characteristics (die temperature)

## 10. Memory Specification

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Condition |
|-----------|--------|------|------|------|------|-----------|
| ROM       |        |      | 32   |      | kB   |           |
| RAM       |        |      | 1024 |      | B    |           |
| NVRAM     |        |      | 256  |      | B    |           |

Table 13: Memory specification

## 11. PSi5 Communication Interface

### 11.1. PSi5 Communication Supported Standards

The MLX90373 uses PSi5 communication protocol. The information is transmitted by modulating the current of the supply pin VDD according to PSi5 protocol specification. The sensor interface, electrical parameters and data transmission fully complies with v2.1 of the PSi5 protocol specifications. The backward compatibility to the operation modes described in v1.3 of PSi5 standard is also part of the MLX90373 implementation. The configuration of the sensor interface follows the "Chassis and Safety PSi5 Substandard".

The denomination of the PSi5 protocol is defined as follows:

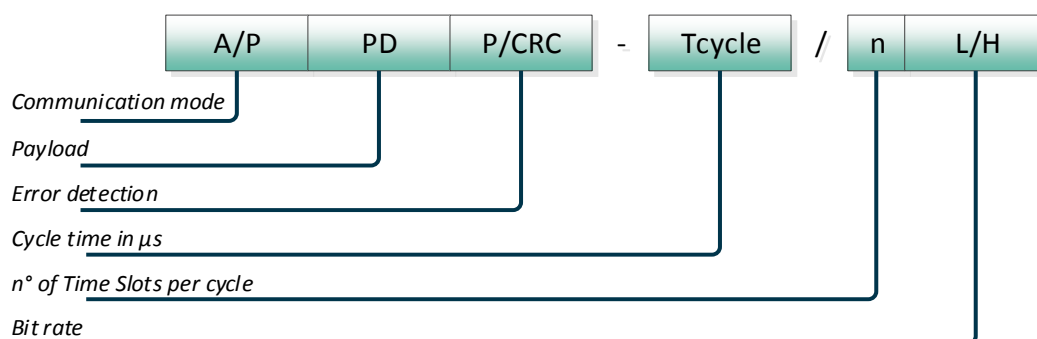


Figure 8: Denomination of PSi5 operation modes

### 11.2. Data Current Modulation

#### 11.2.1. PSi5 Current Modulation Method

The Data Frame is transmitted through a modulation of the current consumption. The Figure 9 shows the current modulation and bit encoding (Manchester encoding). A low level ( $I_{S_{low}}$ ) represents the quiescent current consumption of the sensor. A high level ( $I_{S_{high}}$ ) is generated by an increased Sink current of the sensor ( $I_{S_{low}} + \Delta I_S$ ). The sink current ( $\Delta I_S$ ) and the duration of the bit ( $T_{BIT}$ ) are selectable (see Table 14).

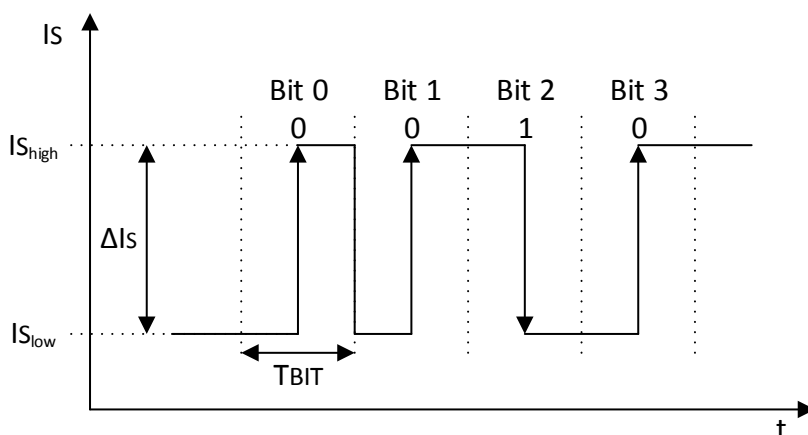


Figure 9: PSi5 current modulation

### 11.2.2. Current Modulation Specification

| Electrical Parameter                               | Symbol                | Min                | Typ  | Max                | Unit | Condition  |
|--|-----------------------|--------------------|------|--------------------|------|--|
| Sink current                                       | $\Delta I_s$          | 21                 | 26   | 30 <sup>(18)</sup> | mA   | Common power mode (see section 12)   |
|  |                       | 10                 | 13   | 15                 | mA   | Low power mode (see section 12)  |
| Quiescent current drift                            | DRIFT <sub>IS</sub>   | -4                 |      | 4                  | mA   |  |
| Quiescent current thermal drift rate               | DRIFT <sub>TRIS</sub> |                    |      | 0.3                | mA/s | Assuming a maximum temperature drift rate of 20K/s   |
| IS Current modulation Falling time <sup>(19)</sup> | T <sub>F</sub>        | 0.33               |      | 1                  | μs   | Time for IS to fall from 80% to 20% of $\Delta I_s$ . See section 15.  |
| IS Current modulation Rising time <sup>(19)</sup>  | T <sub>R</sub>        | 0.33               |      | 1                  | μs   | Time for IS to rise from 20% to 80% of $\Delta I_s$ . See section 15.  |
| Mark/Space Ratio at Sensor <sup>(21)</sup>         | MSR                   | 47 <sup>(22)</sup> | 50   | 53                 | %    | (t <sub>fall, 80</sub> - t <sub>rise, 20</sub> ) / T <sub>Bit</sub><br>(t <sub>fall, 20</sub> - t <sub>rise, 80</sub> ) / T <sub>Bit</sub> |
| Bit time   | T <sub>BIT</sub>      | 7.6                | 8    | 8.4                | μs   | Low speed transmission (125 kbit/s)  |
|  |                       | 5                  | 5.3  | 5.6                | μs   | High-speed transmission (189 kbit/s)   |
| Slope rate   |                       |                    | fast |                    |      | High-speed transmission (189 kbit/s)   |
|  |                       |                    | slow |                    |      | Low speed transmission (125 kbit/s)  |

Table 14: Data modulation specification table

For the power mode (PSI5\_LOWCOMMON\_MODE) and the speed transmission (PSI5\_TRANSMITSPEED) programming, see section 12.

<sup>18</sup> The maximum value is found at 125deg.C

<sup>19</sup> Small rise and fall times will lead to increased radiated emission. Sensors/Bus must meet the test conditions of PSi5 standard.

<sup>21</sup> Single sensor configuration shall satisfy the requirement for sending current rise/fall time such that rise from 20 to 80% of IS and t<sub>fall</sub> from 80 down to 20% of IS is reached within 1μs..

<sup>22</sup> Minimum value of duty cycle has been found at 125deg.C

## 11.3. Communication Mode

The sensor can be programmed to communicate in 2 possible modes: asynchronous mode and synchronous parallel bus mode (see Table 15). In asynchronous mode, the sensor transmits the Data Frames periodically without external synchronization, while in synchronous mode; the communication is synchronized by the ECU with a synchronization pulse.

| Protocol Parameter  | Option Id | Option                           | NVRAM parameters |
|---------------------|-----------|----------------------------------|------------------|
| Communication modes | A         | 2: Asynchronous Mode             | PROTOCOL         |
|                     | P         | 3: Synchronous Parallel Bus Mode |                  |

Table 15: Communication mode configuration synchronous/asynchronous

### 11.3.1. Asynchronous Communication

In asynchronous mode, the timing and repetition rate of the data transmission are controlled by the sensor. The sensor starts transmitting the data to the ECU periodically (see section 11.4) once the power supply is on.

The Figure 10 shows the periodic transmission from one PS15 Sensor with period  $T_{cycle}$ . The supply voltage must enter the operation voltage specified in the section 6.

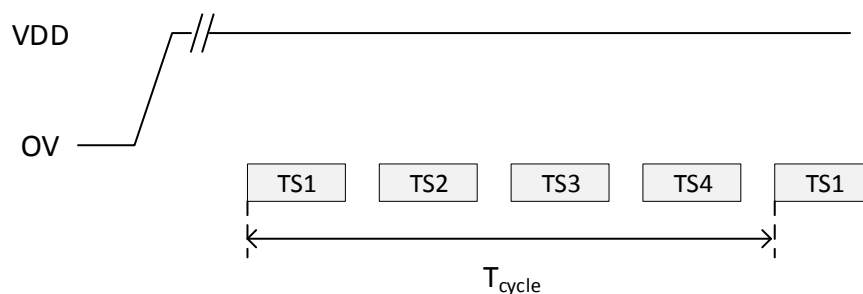


Figure 10: Asynchronous data transmission for x4 Time Slots per cycle

### 11.3.2. Synchronous Communication in Parallel Bus

In synchronous operation, the sensor data transmission is synchronized by the ECU using voltage modulation. Once the sync pulse received, each sensor starts the data transmission (see section 11.3.2.1).

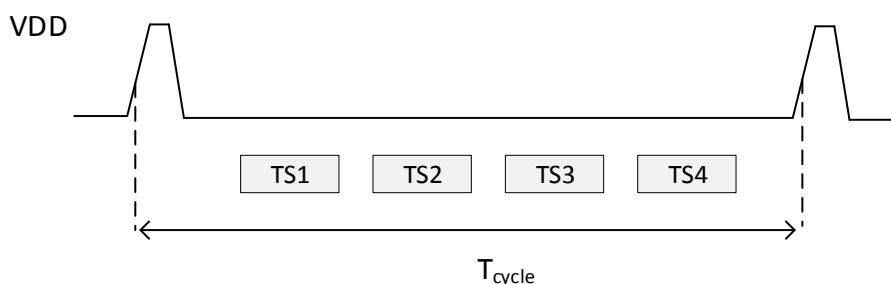


Figure 11: Synchronous Parallel bus data transmission for x4 Time Slots per cycle

### 11.3.2.1. Synchronization Pulse

The sync pulse generated by the ECU is detected by the sensor as soon as the variation in voltage on VDD is higher than the minimum sync pulse voltage. The sync pulse (reduced or standard, see Table 16) is selectable (PSI5\_TRIGGER\_STD).

| Electrical Parameter   | Symbol     | Min | Typ | Max | Unit | Condition                                |
|--|------------|-----|-----|-----|------|--|
| Sync Pulse Voltage   | VSYNC      | 2.5 |     |     | V    | For reduced sync pulse                   |
|  |            | 3.5 |     |     | V    | For standard sync pulse                  |
| Sensor Trigger threshold                                       | VTRIG      | 1.2 | 1.5 | 1.8 | V    | For reduced sync pulse                   |
|  |            | 1.4 | 2.0 | 2.6 | V    | For standard sync pulse                  |
| Tolerance of internal trigger detection timing delay at sensor | TTOLDETECT |     |     | 3   | µs   | See definition of parameter in PSI5 spec |
| Sync Pulse Hold Time   | TSHOLD     | 9   |     |     | µs   | For reduced sync pulse                   |
|  |            | 36  |     |     | µs   | For standard sync pulse                  |

Table 16: Synchronization pulse parameters

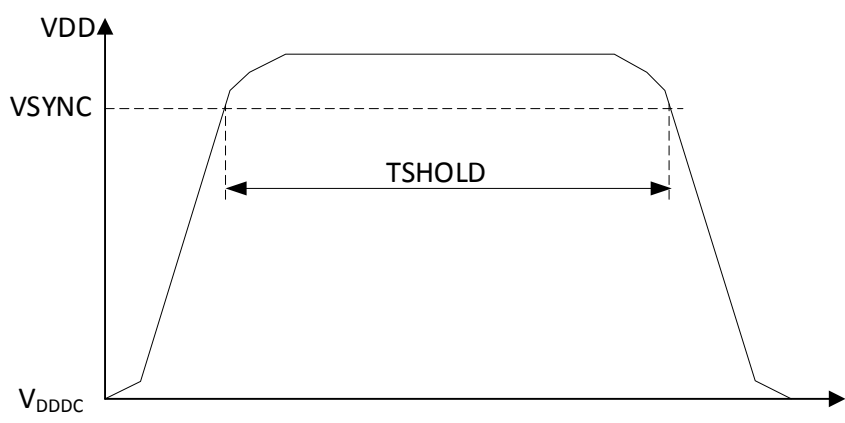


Figure 12: Sync pulse detection

VDDDC being the static value of the supply voltage before the synchronization pulse occurs.

## 11.4. Cycle Time

The periodicity of transmission (or Cycle Time) is programmable, see Figure 10. The maximum number of Time Slots (time allocation of a Data Frame within a Cycle) is 4. Each Time Slot must be enabled (PSI5\_TSx\_ENABLE) and a corresponding start time specified (PSI5\_TSx\_STARTTIME). The time separating two consecutive Time Slots, TGAP, must be higher than TBIT.

| Protocol Parameter        | Symbol             | Option               | NVRAM parameters |
|---------------------------|--------------------|----------------------|------------------|
| PSI5 Cycle time selection | $T_{\text{cycle}}$ | 0: 500 $\mu\text{s}$ | PSI5_CYCLETIME   |
|                           |                    | 1: 300 $\mu\text{s}$ |                  |

Table 17: Cycle time selection

## 11.5. Data Frame in Run-Time

### 11.5.1. Data Frame Content

The Data Frame consists in Start, Payload and Error Detection bits, see Table 18. The Payload consists in Control (optional), Status (optional) and Data bits.

| Data Frame content   | Bit Symbol   | Description  |
|----------------------|--------------|--|
| Start bits           | S0, S1       | Frame start bits, always coded as "0"  |
| Payload (PD)         | Control bits | Optional (only for High precision format).<br>Rolling counter, incremented once per Time Slot, during run-time and error transmission, with LSB transmission first. Overflow leads to a reset, e.g. 0x7+0x1=0x0. |
|                      | Status bit   | Optional (only for High precision format).<br>Error flag bit.  |
|                      | Data bits    | Data bits, transmitted LSB first. Recommended number of bits for data, $N \in \{8, 10, 16, 20\}$ .   |
| Error Detection bits | P            | Parity bit   |
|                      | C0-2         | CRC  |

Table 18: Description of data Content in run time

### 11.5.2. Data Frame Format

The Error Detection, the Payload size and the Format Precision are selectable, see Table 19.

| Protocol Parameter          | Option Id | Option  | NVRAM parameters     |
|-----------------------------|-----------|---|----------------------|
| Error Detection             | P/CRC     | 0: CRC mode<br>1: Parity Bit mode               | PSI5_ERRORDETECTION  |
| Payload (PD)                | N/A       | Selectable between 8 to 24 bits.                | PSI5_PAYLOAD_SIZE    |
| Data Frame Format precision | N/A       | 0: PSI5 low precision<br>1: PSI5 high precision | PSI5_FRAMEFORMAT_STD |

Table 19: Parameterization of the format data

### 11.5.2.1. Data Frame Format Supported by the MLX90373

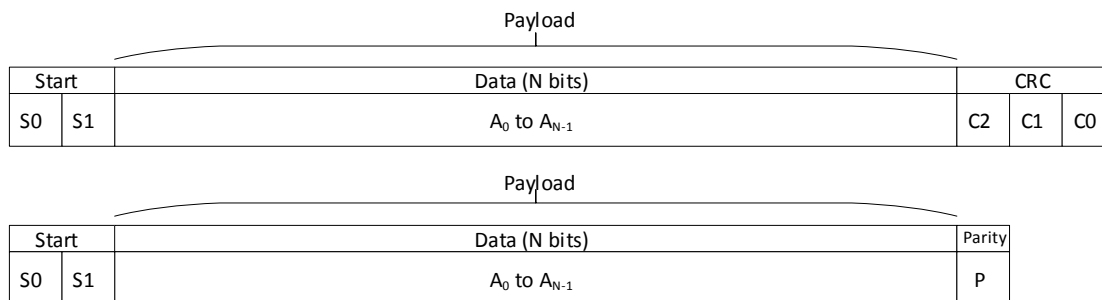


Figure 13: Low Precision Data Frame Format

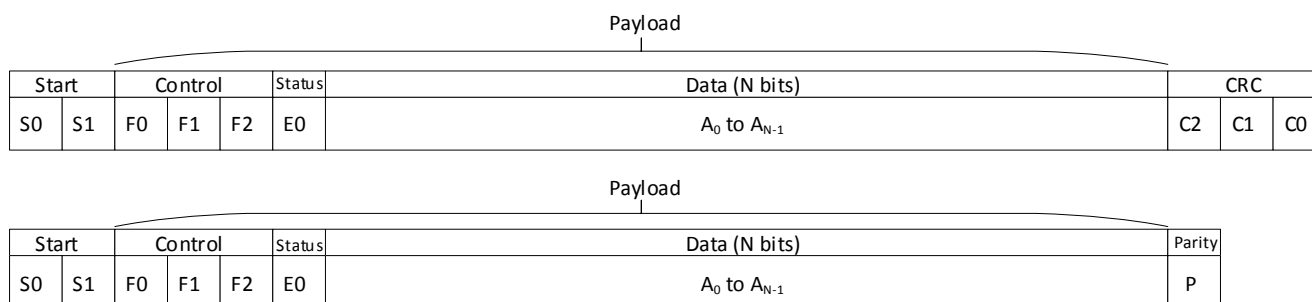


Figure 14: High Precision Data Frame Format

### 11.5.2.2. Example of Data Frame

| Start |    | Data (10 bits) |    |    |    |    |    |    |    |    |    | Parity |
|-------|----|----------------|----|----|----|----|----|----|----|----|----|--------|
| S0    | S1 | A0             | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | P      |

A10P-300/1L in Low Precision Format

| Start |    | Control |    |    | Status | Data (12 bits) |    |    |    |    |    |    |    |    |    |     | CRC |    |    |    |
|-------|----|---------|----|----|--------|----------------|----|----|----|----|----|----|----|----|----|-----|-----|----|----|----|
| S0    | S1 | F0      | F1 | F2 | E0     | A0             | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | C2 | C1 | C0 |

A16CRC-500/1L in High Precision Format

Figure 15: Example of Data Frame

## 11.5.3. Data

### 11.5.3.1. Data Selection

The data can be selected Time Slot by Time Slot (see Table 20).

| NVRAM parameter  | Number of bits | Description  |
|--|----------------|--|
| PSI5_TSx_SENSORPARAM with x=1, 2, 3, 4 (Time Slot)                               | 3              | Time Slot data to be transmitted:<br>0x0: Angular data<br>0x1: Angular velocity<br>0x2: Temperature<br>0x3: Bfield<br>0x4: Ramprobe data |
| PSI5_x_NBITS with x= ANGULARDATA, ANGULARVELOCITY, TEMPERATURE, BFIELD, RAMPROBE | 4              | Data size: (MSB), [1 - 16] bits  |

Table 20: Selection of sensor data

### 11.5.3.2. Data Padding

Sensor Data padding is performed:

- For High precision Frame Format, when  $PD > PSI5\_x\_NBITS + 4$
- For Low precision Frame Format, when  $PD > PSI5\_x\_NBITS$

Where  $x=ANGULARDATA, ANGULARVELOCITY, TEMPERATURE, BFIELD, RAMPROBE$ .

When the padding applies, extra MSBs of  $A[0:N-1]$  are transmitted from bit number  $PSI5\_x\_NBITS$  to bit number  $N-1$  and set to 0.

## 11.6. Sensor Start-Up

Normal or full safe start-up after power-on reset is selectable ( $COLD\_SAFE\_STARTUP\_EN$ ).

## 11.7. Sensor Initialization

After startup, three initialization phases are present before entering run-time operation mode. The initialization phases can be skipped or enabled and configured after reset or error recovery. The parameters associated are  $PSI5\_COLD\_INIT\_PHASES$  (normal and safe boot) and  $PSI5\_RECOVERY\_INIT\_PHASES$  (error recovery). Both are encoded as:

0x0: Phase II and III in succession

0x1: Skip phase II, go directly to phase III after phase I

0x2: Skip phase II and III, go directly to running mode after phase I

0x3: Reserved

### 11.7.1. Initialization Phase I

No sensor data is transmitted during this phase. The duration of this phase is configurable ( $PSI5\_INIT\_I\_DURATION$ ) in step of 1ms.

| Electrical Parameter            | Symbol        | Min | Typ | Max | Unit | Condition |
|---------------------------------|---------------|-----|-----|-----|------|-----------|
| Initialization Phase I duration | <b>DURPHI</b> | 50  | 100 | 200 | ms   |           |

*Table 21: Description of data content of phase I*

### 11.7.2. Initialization phase II

The content transferred during this phase includes mandatory fields (F1-F5) and optional fields (F6-F9) selectable ( $PSI5\_INIT\_II\_EXTRA\_FIELDS$ , MSbit enables F9). During this phase, the Status bit of the Payload (E0) is set to 0.

The initialization phase II can be sent more than once ( $PSI5\_INIT\_II\_REPETITIONCOUNT$ ).



| Field   | Name and NVRAM parameter   | Parameter definition  | Value  |
|---|--|---|--|
| F1-F5: Mandatory  |  |   |  |
| F1<br>(D1)  | Protocol Description<br>PSI5_INIT_METAINFO   | PSI5 Spec V1.x  | 0100   |
|   |  | PSI5 Spec V2.x, Data Range Initialization   | 0110   |
|   |  | PSI5 Spec V2.x, Serial Channel Initialization   | 0111   |
| F2<br>(D2, D3)  | Number of data nibbles transmitted (in phase II)<br>PSI5_INIT_INITLENGTH                   | Examples:<br>F1- F5 = 9 Nibbles<br>F1- F9 = 32 Nibbles                                | Examples:<br>0000 1001<br>0010 0000                  |
| F3<br>(D4, D5)  | Sensor Manufacturer Code<br>PSI5_INIT_VENDORID   | Information depending on the corresponding sensor type                                | Sensor specific information                          |
| F4<br>(D6, D7)  | Definition of sensor type<br>PSI5_INIT_SENSORTYPE  | Information depending on the corresponding sensor type                                | Sensor specific information                          |
| F5<br>(D8, D9)  | Definition of specific sensor parameters<br>PSI5_INIT_SENSORPARAMS                         | Information depending on the corresponding sensor type                                | Sensor specific information                          |
| F6 - F9 recommended information for automotive applications |  |   |  |
| F6<br>(D10, D11)  | Definition of sensor specific parameters or additional information<br>PSI5_INIT_SENSORCODE | To be specified by the sensor manufacturer  | Sensor specific definition                           |
| F7<br>(D12-D14)   | Sensor Code (Sensor application)<br>PSI5_INIT_SENSORAPPCODE                                | Usage e.g. for product revision information   | Sensor specific definition                           |
| F8<br>(D15-D18)   | Sensor production Date<br>PSI5_INIT_PRODUCTIONDATE   | Binary coded Julian date:<br>Year: 00-99 (7b)<br>Month: 01-12 (4b)<br>Day: 01-31 (5b) | Example<br>2006: 0000110<br>March: 0011<br>30: 11110 |
| F9<br>(D19-D32)   | Sensor Trace information<br>E.g. production lot/line/serial number                         | Specified by the sensor manufacturer<br>MLX_ID[0-2] will be sent here                 | Sensor specific definition                           |

Table 22: Description of data content of phase II

### 11.7.3. Initialization Phase III

During this phase, the Status bit of the Payload (E0) is used as an error flag and the sensor sends one of the status messages listed in the Table below.

| Status message  | Sent output value |
|-----------------|-------------------|
| "Sensor ready"  | 0x1E7             |
| "Sensor defect" | 0x1F4             |

Table 23: Description of data content of phase III

The number of messages is configurable (PSI5\_INIT\_III\_COUNT).

| Electrical Parameter                         | Symbol | Min | Typ | Max | Unit | Condition |
|--|--------|-----|-----|-----|------|-----------|
| Initialization Phase III, number of messages | NBMSG  | 2   | 10  | 200 | msgs |           |

Table 24: Configuration of initialization III duration

## 11.8. Error Reporting Mode

When the MLX90373 detects an internal error, the error is reported through the PSI5 Data Frame using the format depicted in section 11.8.1, transmitting the information described in section 11.8.2.

### 11.8.1. Error Reporting Data Format

The Data Frame content during error reporting depends on the Frame Format.

#### 11.8.1.1. High Precision Frame Format

In case of High precision frame format then the format is defined by the following picture.

| Start |   | Control |    |    | Status | Error Register (6 bits) |     |     |     |     |     | Status Data (10 bits) |  |  |  | CRC |    |    |
|-------|---|---------|----|----|--------|-------------------------|-----|-----|-----|-----|-----|-----------------------|--|--|--|-----|----|----|
| 0     | 0 | F0      | F1 | F2 | 1      | ER0                     | ER1 | ER2 | ER3 | ER4 | ER5 | A0 to A9              |  |  |  | C2  | C1 | C0 |

Figure 16: Error reporting in High precision Frame Format

#### 11.8.1.2. Low Precision Frame Format

| Status Data (10 bits) | Parity |
|-----------------------|--------|
| A0 to A9              | P      |

Figure 17: Error reporting in Low precision Frame Format

### 11.8.2. Error Register

The error register is computed as described in the table below depending on the error bits (See section 14.2 and safety manual for more information).

| Bit number in the error register | Calculation                      | Comment     |
|----------------------------------|----------------------------------|-------------|
| 0                                | GAINOOS    ROCLIP    HE_SYMMETRY | Aggregation |
| 1                                | FIELDTOOLOW    FIELDTOOHIGH      | Aggregation |
| 2                                | ADCCLIP    ADCDROP               | Aggregation |
| 3                                | ADC_TEST                         |             |
| 4                                | SUP_OV_VDDA    SUP_OV_V1V8       | Aggregation |
| 5                                | OVERTEMP                         |             |

Table 25: Error register and diagnostics

### 11.8.3. Status Data

The status data (D0-D9) from Figure 17 is used to transmit 10 bits status data, LSB being transmitted first, and the data value is specified in the table below.

| Value(dec) | Value(Hex) | Signification          |
|------------|------------|------------------------|
| +500       | 0x1F4      | Sensor Defect          |
| +489       | 0x1E9      | Sensor in service Mode |
| +487       | 0x1E7      | Sensor Ready           |
| +483       | 0x1E3      | Reserved Sensor used   |

Table 26: Status data

## 12. End-User Programmable Items

Default values marked in the table below are subject to change.

| Parameter                   | Description   | Default standard    | # bit |
|-----------------------------|---|---------------------|-------|
| USER_ID[0..5]               | User ID. Reference. Reserved for customers traceability   | see 12.1            | 8     |
| MEMLOCK                     | Enable NVRAM write LOCK   | 0x0                 | 2     |
| <b>SENSOR FRONT END</b>     |   |                     |       |
| GAINMIN                     | Low threshold for virtual gain  | 0x01                | 8     |
| GAINMAX                     | High threshold for virtual gain   | 0x3F                | 8     |
| GAINSATURATION              | Gain saturated on GAINMIN and GAINMAX   | 0x0                 | 1     |
| SENSING_MODE                | Mapping fields for output angle<br>- Rotary Stray-Field robust<br>- Legacy mode   | 0x0<br>0x1          | 3     |
| MAGNET_SREL_T[1..7]         | Magnet relative sensitivity at temperature Tx. This parameter is mainly used in linear Hall mode. It is advised to keep defaults for other modes. | 0xFF                | 8     |
| DSP_NB_CONV <sup>(23)</sup> | Number of phase spinning within ADC sequence  | 0x0 <sup>(23)</sup> | 2     |
| <b>PSI5 OUTPUT PROTOCOL</b> |   |                     |       |
| PROTOCOL                    | Selection of output protocol<br>0x2: PSI5 Asynchronous<br>0x3: PSI5 Synchronous   | 0x3                 | 2     |
| PSI5_PAYLOAD_SIZE           | Payload size  | 0x14                | 5     |
| PSI5_ERRORDETECTION         | Select CRC (0) or Parity (1) as error detection   | 0x0                 | 1     |

<sup>23</sup> Changing default value could impact the safety metrics. Default value shall be used.

| Parameter                   | Description   | Default standard          | # bit |
|-----------------------------|---|---------------------------|-------|
| PSI5_CYCLETIME              | Select 500us (0x0) or 300us (0x1) PSI5 cycle time   | 0x0                       | 2     |
| PSI5_TRANSMITSPEED          | PSI5 transmission speed selection<br>0: Low speed transmission (125 kbit/s)<br>1: High-speed transmission (189 kbit/s ) | 0x1                       | 1     |
| PSI5_FRAMEFORMAT_STD        | Select low (0) or high (1) precision PSI5 frame format  | 0x1                       | 1     |
| PSI5_TRIGGER_STD            | Trigger level selection<br>0: reduced sync pulse<br>1: standard sync pulse  | 0x1                       | 1     |
| PSI5_TS[1..4]_ENABLE        | Enable timeslot   | 0x0, 0x1,<br>0x1, 0x0     | 1     |
| PSI5_TS[1..4]_SENSORPARAM   | Content of timeslot   | 0x0, 0x0,<br>0x1, 0x0     | 3     |
| PSI5_TS[1..4]_STARTTIME     | Start time of timeslot (TTOLDETECT excluded)  | 0x0, 0x175,<br>0x2AC, 0x0 | 11    |
| PSI5_ANGULARDATA_NBITS      | Number of bits to represent angular data by [1..16]   | 0xB                       | 4     |
| PSI5_ANGULARVELOCITY_NBITS  | Number of bits to represent velocity data by [1..16]  | 0xB                       | 4     |
| PSI5_TEMPERATURE_NBITS      | Number of bits to represent temperature data by [1..16]   | 0x0                       | 4     |
| PSI5_BFIELD_NBITS           | Number of bits to represent field strength data by [1..16]  | 0x0                       | 4     |
| PSI5_RAMPROBE_NBITS         | Number of bits to represent ramprobe data by [1..16]  | 0xF                       | 4     |
| PSI5_ALTERNATE_A            | Alternate measurement, phase A  | 0x0                       | 3     |
| PSI5_ALTERNATE_B            | Alternate measurement, phase B  | 0x0                       | 3     |
| WARM_TRIGGER_LONG           | Add delay to enter PTC mode (MT7V)  | 0x0                       | 1     |
| PSI5_SYNC_ERROR_REPORT      | One (0) or three (1) error frames are sent for SYNC error reporting   | 0x1                       | 1     |
| PSI5_SYNC_TO_MIN_CNT_REPORT | Number of SYNC errors to be detected before reporting   | 0x0                       | 3     |
| PSI5_SYNC_MAX_TOL           | Set timeout for receiving sync pulses   | 0xC                       | 8     |
| PSI5_SYNC_MIN_TOL           | Set short condition for receiving sync pulses   | 0xC                       | 8     |
| PSI5_LOWCOMMON_MODE         | Low (0, 13mA) or common (1, 26mA) current modulation level  | 0x1                       | 1     |
| PSI5_REDUCEDCURRENT_MODE    | Reduced current modulation level  | 0x0                       | 1     |
| <b>FILTERING</b>            |   |                           |       |
| DSP_FILTER                  | Filter mode selection   | 0x1                       | 2     |

| Parameter                             | Description  | Default standard | # bit |
|---------------------------------------|--|------------------|-------|
| HYST                                  | Hysteresis threshold for EMA filter                                      | 0x0              | 8     |
| DENOISING_FILTER_ALPHA_SEL            | Select the alpha parameter of the IIR filter                             | 0x0              | 2     |
| PSI5_DPI_FILTER_ENABLE                | Enable DPI filter in analog interface                                    | 0x0              | 1     |
| VELOCITY_FILTER_FIR                   | Filter selection for velocity measurement                                | 0x1              | 2     |
| VELOCITY_DENOISING_FILTER_ALPHA_SEL   | Select the alpha parameter of the IIR filter of the velocity measurement | 0x0              | 2     |
| VELOCITY_HYST                         | Hysteresis threshold for EMA filter of velocity measurement              | 0x1              | 8     |
| <b>LINEAR TRANSFER CHARACTERISTIC</b> |  |                  |       |
| DSP_SEL_4PTS                          | Set for LNR selection  | 0x0              | 1     |
| DSP_LNR_RESX2                         | Set for LNR selection  | 0x0              | 1     |
| CW                                    | Set rotation to clockwise  | 0x0              | 1     |
| DP                                    | Discontinuity point  | 0x0000           | 16    |
| CLAMPLOW                              | Low clamping value of output signal                                      | 0x0010           | 16    |
| CLAMPHIGH                             | High clamping value of output signal                                     | 0xFF80           | 16    |
| USEROPTION_SCALING                    | Enables the output scaling<br>0 = [0..100%]<br>1 = [-50%..150%]          | 0x1              | 1     |
| LNR_S0                                | Slope before point A in 4-Pts LNR  | -                | 16    |
| LNR_A_S, LNR_B_S, LNR_C_S, LNR_D_S    | Slopes after point A/B/C/D in 4-Pts LNR                                  | -                | 16    |
| LNR_A_X, LNR_B_X, LNR_C_X, LNR_D_X    | X coordinates of point A/B/C/D in 4-Pts LNR                              | -                | 16    |
| LNR_A_Y, LNR_B_Y, LNR_C_Y, LNR_D_Y    | Y coordinates of point A/B/C/D in 4-Pts LNR                              | -                | 16    |
| LNR_X[00..07]                         | X coordinates for the 8-Pts LNR  | -                | 16    |
| LNR_Y[00..07]                         | Y coordinates for the 8-Pts LNR<br>Y coordinates for the 17-Pts LNR      | 0x4009 -         | 16    |
| GAIN_ANCHOR_MID                       | Re-scaling before the piece-wise linearization step                      | 0x1              | 1     |
| LNR_Y[08..16]                         | Y coordinates for the 17-Pts LNR   | - 0xBFC8         | 16    |
| LNR_S0_Q15                            | Slope for 32-Pts LNR   | -                | 16    |
| LNR_DELTA_Y[01..32]                   | Delta Y for 32-Pts LNR   | -                | 8     |
| LNR_DELTA_Y_EXPAND_LOG2               | Adjust the span of LNR_DELTA_Y[01..32], for 32-Pts LNR                   | 0x0              | 2     |
| WORK_RANGE_GAIN                       | Angle range in 17-Pts and 32-Pts LNR                                     | 0x10             | 8     |

| Parameter                          | Description  | Default standard      | # bit |
|------------------------------------|--|-----------------------|-------|
| <b>VELOCITY</b>                    |  |                       |       |
| VELOCITY_ALGORITHM                 | Enable tracking loop algorithm for angular velocity measurement  | 0x1                   | 1     |
| VELOCITY_ENABLE                    | Enable velocity measurement  | 0x1                   | 1     |
| <b>RAMPROBE</b>                    |  |                       |       |
| RAMPROBE_PTR                       | RAM address to be probed   | 0x0000                | 16    |
| <b>DIAGNOSTICS</b>                 |  |                       |       |
| DIAG_GLOBAL_EN <sup>(23)</sup>     | Diagnostics global enable. DO NOT MODIFY!  | 0x1 <sup>(23)</sup>   | 1     |
| DIAG_DEBOUNCE_STEPDOWN             | Diagnostic debouncing step-down time   | 0x1                   | 4     |
| DIAG_DEBOUNCE_STEPUP               | Diagnostic debouncing step-up time   | 0x2                   | 4     |
| DIAG_DEBOUNCE_THRESH               | Diagnostic debouncing threshold  | 0x02                  | 6     |
| DIAG_TEMP_THR_LOW <sup>(23)</sup>  | Temperature threshold for under-temperature diagnostic   | 0x08                  | 8     |
| DIAG_TEMP_THR_HIGH <sup>(23)</sup> | Temperature threshold for over-temperature diagnostic  | 0x88                  | 8     |
| DIAG_FIELDTOOLOWTHRES              | Field limit under which a fault is reported  | application dependant | 8     |
| DIAG_FIELDTOOHIGHTHRES             | Field limit over which a fault is reported   | 0xFF                  | 8     |
| OUT_DIAG_HIZ_TIME                  | Transient failure reporting time. When a transient digital failure is detected, the output drivers are disabled during N ms. The time-out is calculated as: timeout = (OUT_DIAG_HIZ_TIME+1) * 4 * 1ms. | 0x7                   | 3     |
| COLD_SAFE_STARTUP_EN               | Normal (0) or full safe (1) start-up after power-on reset  | 0x0                   | 1     |
| <b>INITIALIZATION</b>              |  |                       |       |
| PSI5_COLD_INIT_PHASES              | Initialization phase configuration, after normal and safe boot   | 0x0                   | 2     |
| PSI5_RECOVERY_INIT_PHASES          | Initialization phase configuration, after error recovery   | 0x2                   | 2     |
| PSI5_INIT_I_DURATION               | Duration of initialization phase I   | 0x32                  | 8     |
| PSI5_INIT_II_EXTRA_FIELDS          | Enable extra fields in initialization phase II   | 0x0                   | 4     |
| PSI5_INIT_II_REPETITIONCOUNT       | Repetition count of initialization phase II  | 0x4                   | 4     |
| PSI5_INIT_METAINFO                 | Initialization phase II, protocol description  | 0x6                   | 4     |
| PSI5_INIT_INITLENGTH               | Initialization phase II, number of nibbles   | 0x09                  | 8     |
| PSI5_INIT_VENDORID                 | Initialization phase II, vendor identification   | 0x06                  | 8     |
| PSI5_INIT_SENSORTYPE               | Initialization phase II, sensor type   | 0x06                  | 8     |

| Parameter                | Description   | Default standard | # bit |
|--------------------------|---|------------------|-------|
| PSI5_INIT_SENSORPARAMS   | Initialization phase II, sensor specific parameters       | 0x00             | 8     |
| PSI5_INIT_SENSORCODE     | Initialization phase II, sensor manufacturer              | 0x00             | 8     |
| PSI5_INIT_SENSORAPPCODE  | Initialization phase II, sensor application specific code | 0x000            | 12    |
| PSI5_INIT_PRODUCTIONDATE | Initialization phase II, production data                  | 0x0000           | 16    |
| PSI5_INIT_III_COUNT      | Message count for initialization phase III                | 0x2              | 8     |

Table 27: End-user Programmable Items

## 12.1. End-User Identification Items

| Parameter    | Description  | Default Standard | # bit |
|--------------|--|------------------|-------|
| MLX_ID0      | X-Y position on the wafer (8 bits each)                              | -                | 16    |
| MLX_ID1      | Wafer ID (5 bits); Lot ID [10..0] (11 bits)                          | -                | 16    |
| MLX_ID2      | Lot ID [16..11] (6 bits); Fab ID (4 bits); Test Database ID (6 bits) | -                | 16    |
| CHIP_VERSION | IMC shape version identifier<br>Order code 10x<br>Order code 30x     | 0<br>1           | 7     |
| TEST_STATUS  | Status of MLX final test (0: Fail and 1: Pass)                       | 1                | 1     |
| USER_ID0     | Program '1' at last step of FT to indicate a bin 1                   | 1                | 8     |
| USER_ID1     |  | 0                | 8     |
| USER_ID2     | Die version (1 = ABA)  | 1                | 8     |
| USER_ID3     |  | 2                | 8     |
| USER_ID4     |  | 0                | 8     |
| USER_ID5     |  | 0                | 8     |

Table 28: End-user identification items

## 13. Description of End-User Programmable Items

### 13.1. Output Transfer Characteristic

#### 13.1.1. Selection

The transfer function (LNR) is selectable (DSP\_SEL4PTS and DSP\_LNR\_RESX2) as per the Table 29.

| DSP_SEL4PTS | DSP_LNR_RESX2 | LNR type |
|-------------|---------------|----------|
| 1           | 0             | 4Pts     |
| 1           | 1             | 8Pts     |
| 0           | 0             | 17Pts    |
| 0           | 1             | 32Pts    |

Table 29: Output Transfer Characteristic Selection

### 13.1.2. Programmable Items

| Output Mode                         | LNR type |      |       |       | Value   | Unit                                |
|-------------------------------------|----------|------|-------|-------|---|-------------------------------------|
|                                     | 4pts     | 8pts | 17pts | 32pts |   |                                     |
| USEROPTION_SCALING                  | •        | •    | •     |       | 0: 0 ... 100<br>1: -50 ... 150                                | %                                   |
| CW                                  | •        | •    | •     | •     | 0: CCW<br>1: CW   | LSB                                 |
| DP                                  | •        | •    | •     | •     | 0 ... 359.9999  | Deg.                                |
| CLAMPLOW                            | •        | •    | •     | •     | 0 ... 100   | %                                   |
| CLAMPHIGH                           | •        | •    | •     | •     | 0 ... 100   | %                                   |
| LNR_x_X with x=A, B, C, D           | •        |      |       |       | 0 ... 359.9999  | Deg.                                |
| LNR_x_Y with x=A, B, C, D           | •        |      |       |       | see USEROPTION_SCALING  | %                                   |
| LNR_S0<br>LNR_x_S with x=A, B, C, D | •        |      |       |       | -17 ... 0 ... 17  | %/Deg.                              |
| LNR_Xx with x=0-7                   |          | •    |       |       | 0 ... 359.9999  | Deg.                                |
| LNR_Yx with x=0-7                   |          | •    | •     |       | see USEROPTION_SCALING  | %                                   |
| LNR_Yx with x=8-16                  |          |      | •     |       |   |                                     |
| LNR_DELTA_Yx with x=01-32           |          |      |       | •     | 0 ... 100%  | selectable offset range             |
| LNR_S0_Q15                          |          |      |       | •     | 0 ... 0.555   | % /Deg. (scales with working range) |
| LNR_DELTA_Y_EXPAND_LOG2             |          |      |       | •     | -3.125... 3.125<br>-6.25...6.25<br>-12.5... 12.5<br>-25... 25 | %                                   |
| GAIN_ANCHOR_MID                     |          |      |       | •     | Always use "1"  |                                     |
| WORK_RANGE_GAIN                     |          |      | •     | •     | -01x code: 11.29 ... 180<br>-03x code: 22.59 ... 360          | Deg.                                |

Table 30: Programmable items: Output transfer characteristic



### 13.1.3. Enable Scaling Parameter

The parameter USEROPTION\_SCALING enables to double the scale of Y coordinates linearization parameters, see the Table 31. This is valid for all Output Linear Characteristic except the 32 segments one.

| USEROPTION_SCALING | LNR_Y min value | LNR_Y max value |
|--------------------|-----------------|-----------------|
| 0                  | 0%              | 100%            |
| 1                  | -50%            | 150%            |

Table 31: Y coordinates scaling

### 13.1.4. CLOCKWISE Parameter

The CLOCKWISE parameter defines the magnet rotation direction (CW).

- CCW is the defined by 1-8-9-16 pin order direction for the TSSOP-16 package.
- CW is defined by the reverse direction: 16-9-8-1 pin order direction for the TSSOP-16 package.

Refer to the drawing in the sensitive spot positioning (see 18.1.3 and 18.2.3)

### 13.1.5. Discontinuity Point or Zero Degree Point

The Discontinuity Point (DP) defines the 0 Deg. point on the circle. The DP places the origin at any location of the trigonometric circle. The DP is used as reference for all the angular measurements.

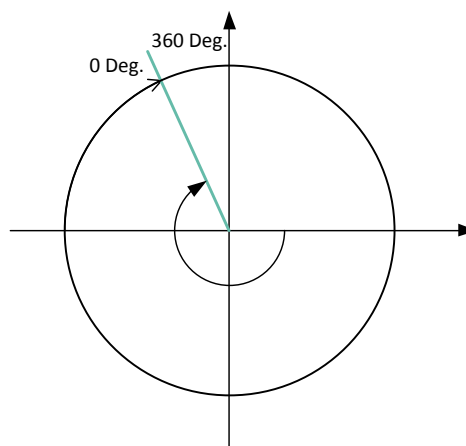


Figure 18: The placement of the DP is programmable

### 13.1.6. CLAMPING Parameters

The clamping levels are two independent values to limit the output voltage range. The CLAMPLOW parameter adjusts the minimum output voltage level. The CLAMPHIGH parameter sets the maximum output voltage level. Both parameters have 16 bits of adjustment and are available for all LNR modes.

### 13.1.7. WORKING RANGE (PWL only)

The range for the angle can be selected using the WORK\_RANGE\_GAIN parameter, which applies a fixed gain to the transfer characteristics. Using WORK\_RANGE\_GAIN parameter, the anchor point is kept at 180° and the range is symmetrically set around this value. It creates a zoom-in of the angle around this point. WORK\_RANGE\_GAIN is coded on 8 bits where the 4 MSB defines the integer part and the 4 LSB the fractional parts (in power of twos). Therefore, the following equation applies to define the angle range W:

$$w = \frac{16 \times FA}{WORK\_RANGE\_GAIN}$$

with FA=180° for -10x code and FA=360° for -30x code.

Both minimal and maximal angles are then defined by:

$$\theta_{min} = 180^\circ - \frac{w}{2} ; \theta_{max} = 180^\circ + \frac{w}{2}$$

where  $\theta_{min}$  corresponds to the angle yielding 0% output and  $\theta_{max}$  the angle giving a 100% output.

Following table gives the extreme values as example:

| WORK_RANGE_GAIN | code | Range (w) | $\theta_{min}$ | $\theta_{max}$ | $\Delta x$ 17 pts | $\Delta x$ 32 pts |
|-----------------|------|-----------|----------------|----------------|-------------------|-------------------|
| 0x10            | -10x | 180°      | 90°            | 270°           | 11.25°            | 5.63°             |
|                 | -30x | 360°      | 0°             | 360°           | 22.50°            | 11.25°            |
| 0xFF            | -10x | 11.29°    | 0°             | 360°           | 0.71°             | 0.35°             |
|                 | -30x | 22.59°    | 168.7°         | 191.3°         | 1.41°             | 0.71°             |

Table 32: Working range defined with GAIN parameter and option code

Outside of the working range, the output will remain at clamping levels.

### 13.1.8. 4-Pts LNR Parameters

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90373 four points transfer function from the digital angle value to the digital output is described in Figure 19. Seven segments can be programmed but the clamping levels are necessarily flat.

Two, three, or even six calibration points are then available, reducing the overall non-linearity of the IC by almost an order of magnitude each time. Three or six calibration point will be preferred by customers

looking for excellent non-linearity figures. Two-point calibrations will be preferred by customers looking for a cheaper calibration set-up and shorter calibration time.

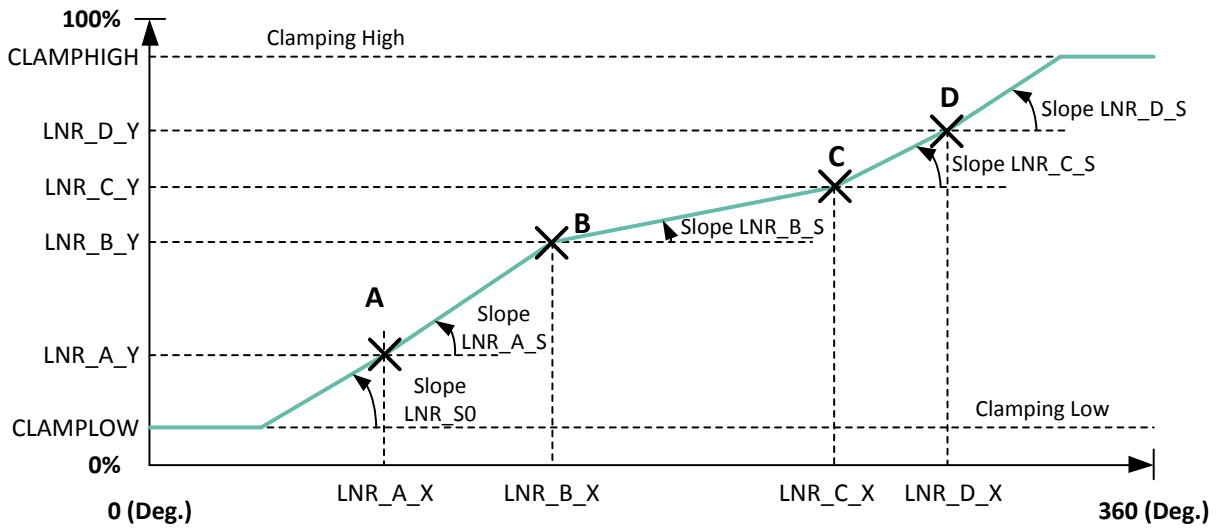


Figure 19: 4-Points Transfer function

### 13.1.9. 8-Pts LNR Parameters

The 8-Pts LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90373 eight points transfer function from the digital angle value to the output voltage is described in Figure 20. Eight calibration points [LNR\_X0...7, LNR\_Y0...7] together with 2 fixed points at the extremity of the range ([0°, 0%] ; [360°, 100%]) divides the transfer curve into 9 segments. Each segment is defined by 2 points and the values in between is calculated by linear interpolation.

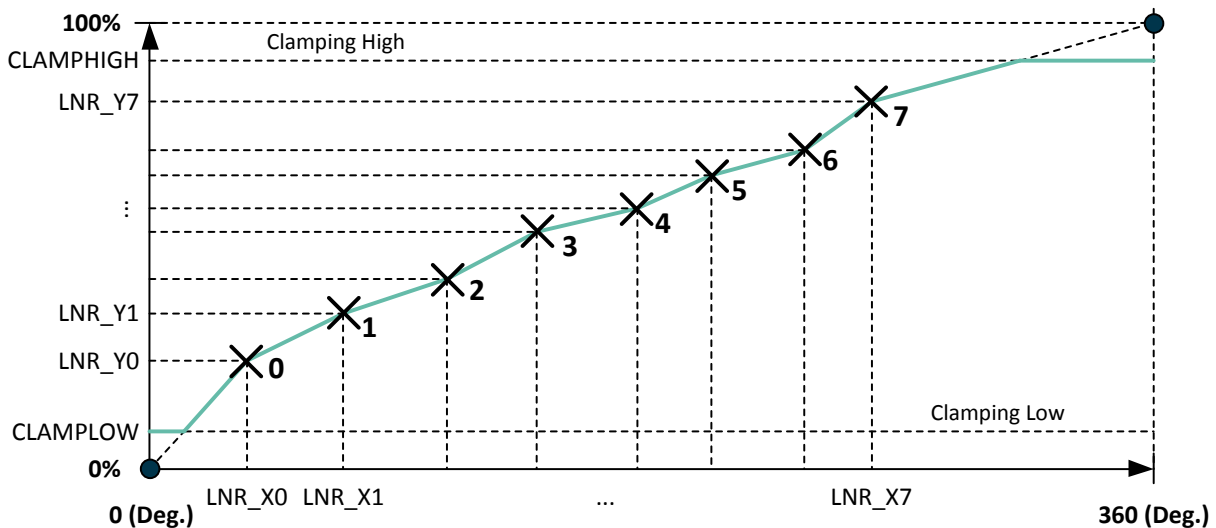


Figure 20: 8-Points Transfer function

### 13.1.10. 17-Pts LNR Parameters (PWL)

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90373 seventeen points transfer function from the digital angle value to the output voltage is described in Figure 21. In the 17-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

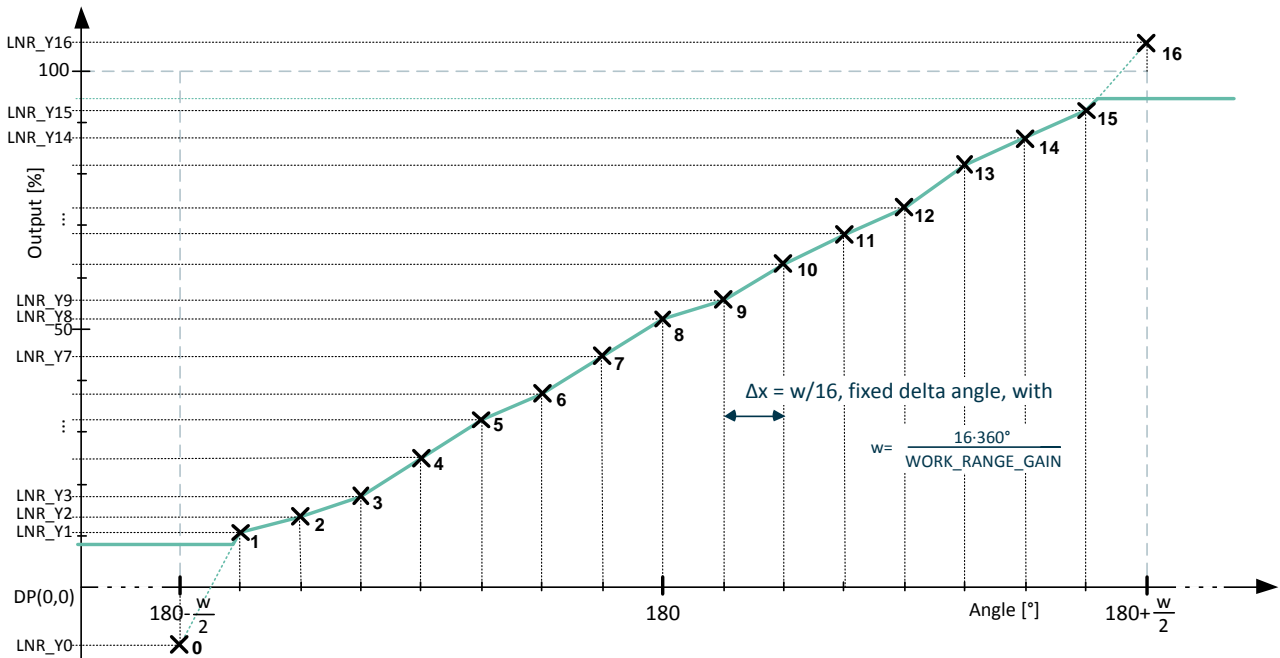


Figure 21: 16-Segments calibration transfer function

All the Y-coordinates can be programmed from -50% up to +150% to allow clamping in the middle of one segment (like on the figure), but the output value is limited to CLAMPLOW and CLAMPHIGH values.

Between two consecutive points, the output characteristic is interpolated.

### 13.1.11. 32-Pts LNR Parameters (PWL)

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90373 thirty-two points transfer function from the digital angle value to the output voltage is described in Figure 22. In the 32-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

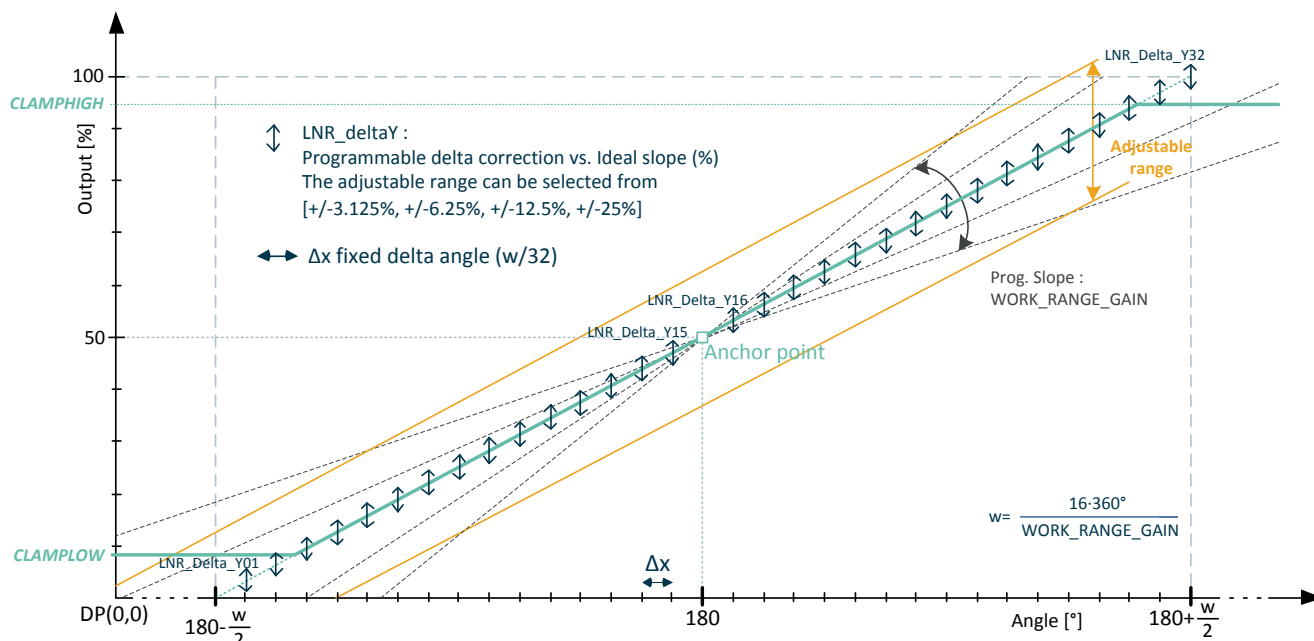


Figure 22: 32-Segments calibration transfer function

The points are spread evenly across the working range (see 13.1.7 for working range selection). The Y-coordinates can be offset from the ideal characteristic within an adjustable range defined by LNR\_DELTA\_Y\_EXPAND\_LOG2. The available values are summarized in the table below. All LNR\_delta\_Y## parameters are encoded in a fractional signed 8-bit value.

| LNR_DELTA_Y_EXPAND_LOG2 | Offset range % | Delta range [LSB12] | Resolution [LSB12] |
|-------------------------|----------------|---------------------|--------------------|
| 0                       | ±3.125         | -128..127           | 1                  |
| 1                       | ±6.25          | -256..254           | 2                  |
| 2                       | ±12.5          | -512..508           | 4                  |
| 3                       | ±25            | -1024..1016         | 8                  |

## 13.2. Sensor Front-End

| Parameter      | Value    |
|----------------|----------|
| SENSING_MODE   | [0 - 4]  |
| GAINMIN        | [0 - 63] |
| GAINMAX        | [0 - 63] |
| GAINSATURATION | [0, 1]   |

Table 33: Programmable items: sensor front-end

### 13.2.1. SENSING MODE

The SENSING\_MODE parameter defines which sensing mode and fields are used to calculate the angle. The different possibilities are described in the tables below.

This 2 bits value selects the first (B1) and second (B2) field components according the table below.

| SENSING_MODE | B1         | B2         | Application                       |
|--------------|------------|------------|-----------------------------------|
| 0            | $\Delta X$ | $\Delta Y$ | Angular Rotary Stray-Field Immune |
| 1            | X          | Y          | Legacy / XY Angular Rotary        |
| 2            | Y          | Z          | Legacy / YZ Angular Rotary        |
| 3            | X          | Z          | Legacy / XZ Angular Rotary        |

Table 34: Programmable items: sensing modes

### 13.2.2. GAINMIN and GAINMAX Parameters

GAINMIN and GAINMAX define the thresholds on the gain code outside which the fault “GAIN out of Spec.” is set. If GAINSATURATION is set, then the virtual gain code is saturated at GAINMIN and GAINMAX, and no Diagnostic fault is set since the saturations applies before the diagnostic check.

## 13.3. Filter

The MLX90373 includes 2 types of programmable filters:

- Low Pass FIR Filter.
- Exponential moving average Filter.

| Filter                     | Angular | Angular velocity           | parameter                           | Value     |
|----------------------------|---------|----------------------------|-------------------------------------|-----------|
| Low Pass                   | •       |                            | DSP_FILTER                          | [0 - 2]   |
|                            |         | •                          | VELOCITY_FILTER_FIR                 |           |
| Exponential moving average | •       |                            | HYST                                | [0 - 255] |
|                            |         | •                          | VELOCITY_HYST                       | [0 - 1]   |
|                            |         | •                          | VELOCITY_DENOISING_FILTER_ALPHA_SEL | [0 - 3]   |
| •                          |         | DENOISING_FILTER_ALPHA_SEL |                                     |           |

Table 35: Filtering configuration

#### 13.3.1. Low Pass FIR Filters

The MLX90373 features 2 FIR filter modes controlled with DSP\_FILTER or VELOCITY\_FILTER\_FIR. The transfer function is described below:

$$y_n = \frac{1}{\sum_{i=0}^j a_i} \sum_{i=0}^j a_i x_{n-i}$$

For information, the filters characteristic is given in the following table:

| DSP_FILTER or VELOCITY_FILTER_FIR parameter | 0         | 1                       | 2     |
|---|-----------|-------------------------|-------|
| Type  | Disable   | Finite Impulse Response |       |
| Coefficients $a_i$                          | 1         | 11                      | 1111  |
| Description                                 | No filter | ExtraLight              | Light |
| DSP_cycle (j= nb of taps)                   | 1         | 2                       | 4     |
| Efficiency RMS (dB)                         | 0         | 3.0                     | 6.0   |

Table 36: FIR Filter Characteristics

### 13.3.2. Exponential Moving Average (IIR) Filter

The HYST parameter is a threshold to activate/de-activate the exponential moving average filter.

- The output value of the IC is updated with the applied filter when the digital step is smaller than the programmed HYST parameter value.
- The output value is updated without applying the filter when the increment is bigger than the threshold.

The VELOCITY\_HYST parameter is Digital hysteresis (hide the small variation but lower resolution)  
0: no hysteresis (default), IIR filter disabled

This filter reduces therefore the noise but still allows a fast step response for bigger angle/position changes. The threshold must be programmed to a value close to the internal magnetic angle noise level. (1 LSB =  $8 * 360 / 2^{16}$ ).

$$y_n = a * x_n + (1-a) * y_{n-1} \quad \begin{matrix} x_n = \text{Angle} \\ y_n = \text{Output} \end{matrix}$$

The filter characteristic is selectable.

| DENOISING_FILTER_ALPHA_SEL or VELOCITY_DENOISING_FILTER_ALPHA_SEL parameter | 0    | 1   | 2    | 3     |
|---|------|-----|------|-------|
| Coefficients a  | 0.75 | 0.5 | 0.25 | 0.125 |
| Efficiency RMS (dB)   |      | 2.4 | 4.2  |       |

Table 37: IIR Filter characteristics

## 13.4. Programmable Diagnostics Settings

### 13.4.1. Diagnostics Global Enable

DIAG\_GLOBAL\_EN should be kept to its default value (1) to retain all functional safety abilities of the MLX90373. This feature shall not be disabled.

### 13.4.2. DIAG Debouncing

A debouncing algorithm is available for analog diagnostic reporting (See section 14.2)

1. The error is reported only if it is active for some user-defined amount of time.
2. The error reporting stays enabled on error recovery for some user-defined amount of time.

The error is reported in the output, using predefined reporting level, reporting time and debouncing time. The debouncing algorithm is parameterized by the NVRAM parameters as per the Table 38

| NVRAM Parameter       | Description  | Default |
|-----------------------|--|---------|
| DIAGDEBOUNCE_STEPDOWN | Decrement values for debouncer counter                   | 1       |
| DIAGDEBOUNCE_STEPUP   | Increment value for debouncer counter                    | 5       |
| DIAG_DEBOUNCE_THRESH  | Threshold for debouncer counter to enter diagnostic mode | 15      |

*Table 38: Programmable diagnostic - DIAG debouncing*

The debouncing algorithm will increment the debouncing counter w/ the STEPUP value in case of an diagnostic error, and decrement w/ STEPDOWN in case of no analog diagnostic error. If the debouncing counter is higher than the DEBOUNCE THRESHOLD, then an error is reported and the debouncing counter is clamped to the DEBOUNCE THRESHOLD value.

The debouncing time and recovery time are defined as per the Table 39.

| Parameter                      | Min                                     | Typ.  | Max                                      |
|--------------------------------|---|-------|--|
| Diagnostic Test Interval (DTI) |   | 9.4ms |  |
| Debouncing Time                | DTI * (CEILING ( Threshold / UP ) - 1 ) |       | DTI * CEILING ( Threshold / UP )         |
| Recovery time                  | DTI * CEILING ( Threshold / DOWN )      |       | DTI * (CEILING ( Threshold / DOWN) + 1 ) |

*Table 39: Programmable diagnostic - debouncing & reporting time*

### 13.4.3. Over/Under Temperature Diagnostic

DIAG\_TEMP\_THR\_HIGH defines the threshold for over temperature detection and is compared to the linearized value of the temperature sensor  $T_{LIN}$ . DIAG\_TEMP\_THR\_LOW defines the threshold for under temperature detection and is compared to the linearized value of the temperature sensor  $T_{LIN}$ .



## 14. Functional Safety

### 14.1. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90373 component in a safety related item, as Safety Element Out-of-Context (SEooC).

In particular it includes:

- The description of the Product Development lifecycle tailored for the Safety Element.
- An extract of the Technical Safety concept.
- The description of Assumptions-of-Use (AoU) of the element with respect to its intended use, including:
  - assumption on the device safe state;
  - assumptions on fault tolerant time interval and multiple-point faults detection interval;
  - assumptions on the context, including its external interfaces;
- The description of safety analysis results at the device level useful for the system integrator; HW architectural metrics and description of dependent failures initiators.
- The description and the result of the functional safety assessment process; list of confirmation measures and description of the independency level.

### 14.2. Safety Mechanisms

The MLX90373 provides numerous self-diagnostic features (safety mechanisms). Those features increase the robustness of the IC functionality as it will prevent the IC to provide erroneous output signal in case of internal or external failure modes (“fail-safe”).

#### Legend

● High coverage

○ Medium coverage

ANA : Analog hardware failure reporting, described in the safety manual

DIG : Digital hardware failure reporting, described in the safety manual

\* : Diagnostic Cycle Time

At Startup : HW fault present at time zero is detected before a first frame is transmitted.

*Table 40: Self Diagnostic Legend*

| Category and safety mechanism name   | Front-end | ADC | DSP | Back-end | Support Func. | Module & Package | DCT*       | Reporting mode | At startup |
|--|-----------|-----|-----|----------|---------------|------------------|------------|----------------|------------|
| <b>Signal-conditioning (AFE, External Sensor) Diagnostic</b>                                 | ●         | ●   |     |          |               | ●                |            | ANA            |            |
| Magnetic Signal Conditioning Voltage Test Pattern  | ●         | ○   | ○   |          |               |                  | DCT_Ana    | ANA            |            |
| Magnetic Signal Conditioning Rough Offset Clipping check                                     | ●         |     | ○   |          |               |                  | DCT_Ana    | ANA            | NO         |
| Magnetic Signal Conditioning Gain Monitor  | ●         |     | ○   |          |               | ●                | DCT_Ana    | ANA            | YES        |
| Magnetic Signal Conditioning Gain Clamping   | ●         |     | ○   |          |               | ●                | DCT_Ana    | ANA            | YES        |
| Mag. Sig. Cond. Failure control by the chopping technique                                    | ●         |     |     |          |               |                  | Continuous | n/a            | YES        |
| External Sensor Sig. Cond. Voltage Valid Range Check   | ●         |     |     |          |               | ●                | DCT_Ana    | ANA            | YES        |
| External Sensor Sig. Cond. Frequency Valid Range Check                                       | ●         |     |     |          |               | ●                | DCT_Ana    | ANA            | YES        |
| A/D Converter Test Pattern   |           | ●   |     |          |               |                  | DCT_Ana    | ANA            |            |
| ADC Conversion errors & Overflow Errors  |           | ●   |     |          |               |                  | DCT_Ana    | ANA            | YES        |
| Flux Monitor (Specific to Rotary mode)   | ●         | ○   |     |          |               | ●                | DCT_Ana    | ANA            | YES        |
| <b>Digital-circuit Diagnostic</b>  |           |     | ●   |          |               |                  |            | DIG            |            |
| RAM Parity, 1 bit per 16 bits word, ISO D.2.5.2  |           |     | ●   |          |               |                  | <10us      | DIG            | YES        |
| ROM Parity, 1 bit per 16 bits word, ISO D.2.5.2  |           |     | ●   |          |               |                  | <10us      | DIG            | YES        |
| NVRAM 16 bits signature (run-time) ISO D.2.4.3 by means of SW additive checksum              |           |     | ●   |          |               |                  |            | DIG            |            |
| NVRAM Double Error Detection ECC ISO   |           |     | ●   |          |               |                  | DCT_Dig    | DIG            |            |
| Logical Monitoring of program sequence ISO D.2.9.3 via Watchdog "IWD" (cpu clock) ISO D2.9.2 |           |     | ●   |          | ○             |                  | Tiwd       | DIG            |            |
| Watchdog "AWD" (separate clock) ISO D2.9.1   |           |     | ●   |          | ○             |                  | Tawd       | DIG            |            |
| CPU Errors "Invalid Address", "Wrong opcode"   |           |     | ●   |          | ○             |                  | <10us      | DIG            | YES        |
| ADC Interface Checksum   |           | ●   |     |          |               |                  | DCT_Dig    | DIG            | NO         |

| Category and safety mechanism name                          | Front-end | ADC | DSP | Back-end | Support Func. | Module & Package | DCT*    | Reporting mode | At startup |
|---|-----------|-----|-----|----------|---------------|------------------|---------|----------------|------------|
| DSP Test Pattern (atan2)                                    |           |     | ●   |          | ○             |                  | DCT_Dig | DIG            |            |
| Critical ports monitoring                                   |           |     | ●   |          |               |                  | DCT_Dig | DIG            | NO         |
| <b>Communication Interface Diagnostic</b>                   |           |     |     | ●        |               |                  |         | DIG            |            |
| PSI5 block: Protection against re-configuration at run-time |           |     |     | ●        |               |                  | <10us   | DIG            |            |
| PSI5 frame counter  |           |     |     | ●        |               |                  | 1 frame | n/a            | n/a        |
| <b>System-level diagnostic</b>                              |           |     |     |          | ●             | ●                |         | ANA            |            |
| Supply Voltage Monitors VS_OV, VDDA_OV, V1V8_OV             |           |     |     |          | ●             | ●                | DCT_Ana | ANA            |            |
| Supply Voltage Monitors VS_UV, VDDA_UV                      |           |     |     |          | ●             | ●                | DCT_Ana | DIG            |            |
| External Supply Overvoltage Monitor VS_OV                   |           |     |     |          | ●             | ●                | 2.1ms   | DIG            | YES        |
| Digital Supply under-voltage monitor (Power-on reset)       |           |     |     |          | ●             | ●                | <10us   | DIG            | YES        |
| Supply Bias Current Monitor                                 |           |     |     |          | ●             |                  | DCT_Ana | ANA            |            |
| Overheating monitor   | ○         | ○   | ○   | ○        | ○             | ●                | DCT_Ana | ANA            | YES        |
| <b>Warning/Reporting Mechanisms</b>                         |           |     |     |          |               |                  | n/a     | n/a            |            |
| HW Error Controller   |           |     | ●   | ●        | ●             |                  | n/a     | DIG            | YES        |
| HW Fail-safe mode with timeout                              |           |     | ●   | ●        | ●             |                  | n/a     | DIG            | YES        |
| Analog-type Error management                                | ●         | ●   |     |          | ●             |                  | n/a     | ANA            |            |
| Safe start-up mode  |           |     | ●   |          | ●             |                  | n/a     | DIG            | n/a        |
| <b>Mechanisms executed at start-up only</b>                 |           |     |     |          |               |                  |         |                |            |
| RAM March-C HW Test at start-up                             |           |     | ●   |          | ●             |                  | n/a     | DIG            | YES        |

Table 41: MLX90373 List of Self Diagnostics with Characteristics

## 15. Recommended Application Diagrams

### 15.1. Wiring in TSSOP-16 Package

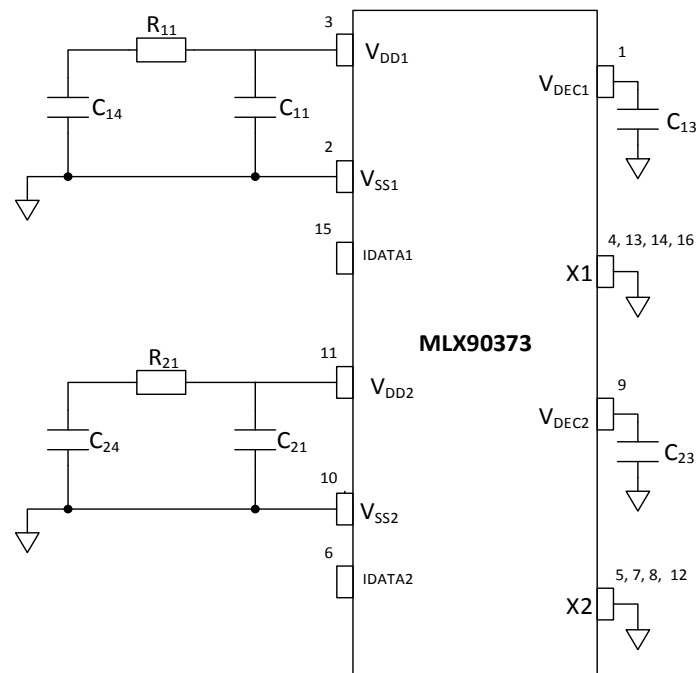


Figure 23: Recommended wiring for the MLX90373 in TSSOP-16 package (dual die)

| Output        | Compact PCB routing |        |        | EMC robust PCB routing |        |        | Remarks  |
|---------------|---------------------|--------|--------|------------------------|--------|--------|--|
|               | Min                 | Typ.   | Max    | Min                    | Typ.   | Max    |  |
| Analog Output |                     |        |        |                        |        |        |  |
| C11, C21      | 9 nF                | 10 nF  | 24nF   | 9 nF                   | 10 nF  | 24nF   | Close to the pin depending on the number of sensor on the psi5 bus |
| C13, C23      | 47 nF               | 100 nF | 220 nF | 47 nF                  | 100 nF | 220 nF | Close to the pin   |
| C14, C24      | -                   | -      | -      | 500 pF                 | -      | 1 nF   | Connector Side   |
| R11, R21      | -                   | -      | -      | 0 Ω                    | -      | 10 Ω   |  |

Table 42: TSSOP-16 recommended components, values shown represent the typical value of the standard devices; additional ±10% tolerance is accepted

## 15.2. Wiring in DMP-4 Package

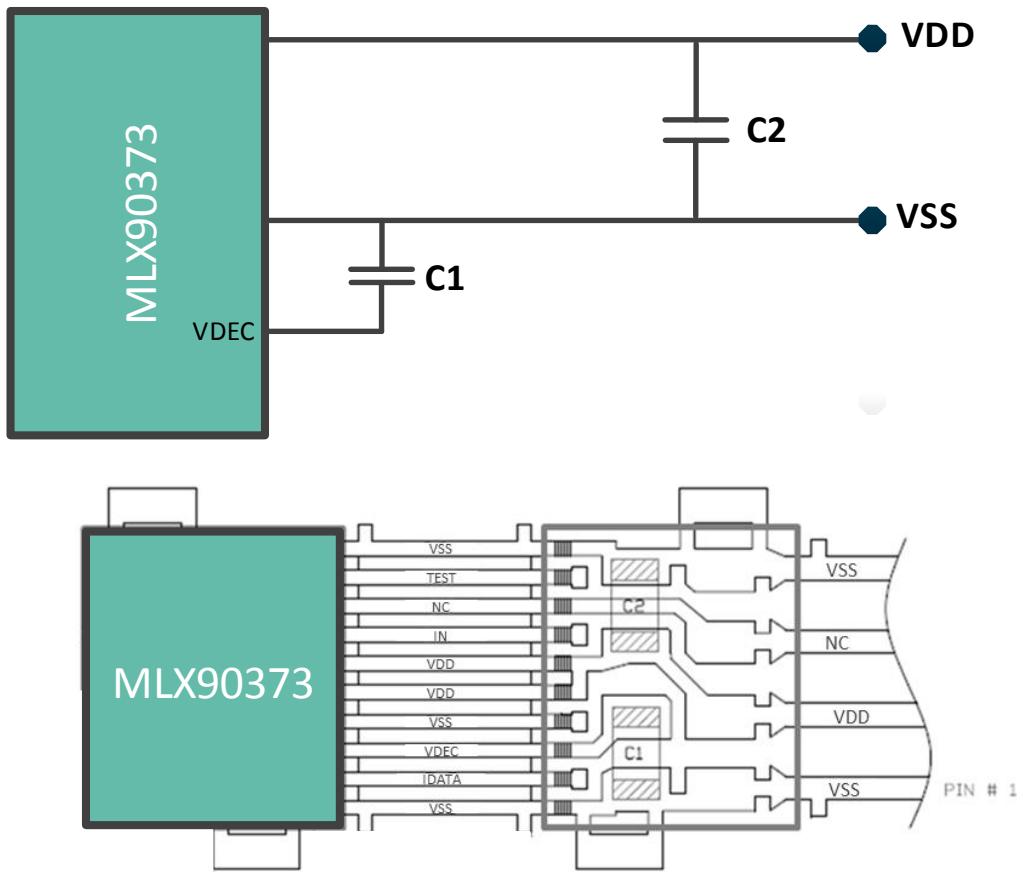


Figure 24: Capacitor configurations and recommended wiring for the MLX90373 in DMP-4 package

In this DMP-4 version, keep pin4 connected to Vss.

| Ordering code          | C1     | C2    |
|------------------------|--------|-------|
| MLX90373GVS-ABA-10x-xx | 100 nF | 10 nF |
| MLX90373GVS-ABA-30x-xx | 100 nF | 10 nF |

Table 43: DMP-4 capacitors configuration

## 16. Standard Information Regarding Manufacturability Of Melexis Products With Different Soldering Processes

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to standards in place in Semiconductor industry.

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 (<http://www.melexis.com/en/quality-environment/soldering>)

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 consulting the dedicated trim&forming recommendation application note: lead trimming and forming recommendations (<http://www.melexis.com/en/documents/documentation/application-notes/lead-trimming-and-forming-recommendations>).

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/en/quality-environment>.

## 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. Package Information

### 18.1. TSSOP-16 Package

#### 18.1.1. TSSOP-16 - Package Dimensions

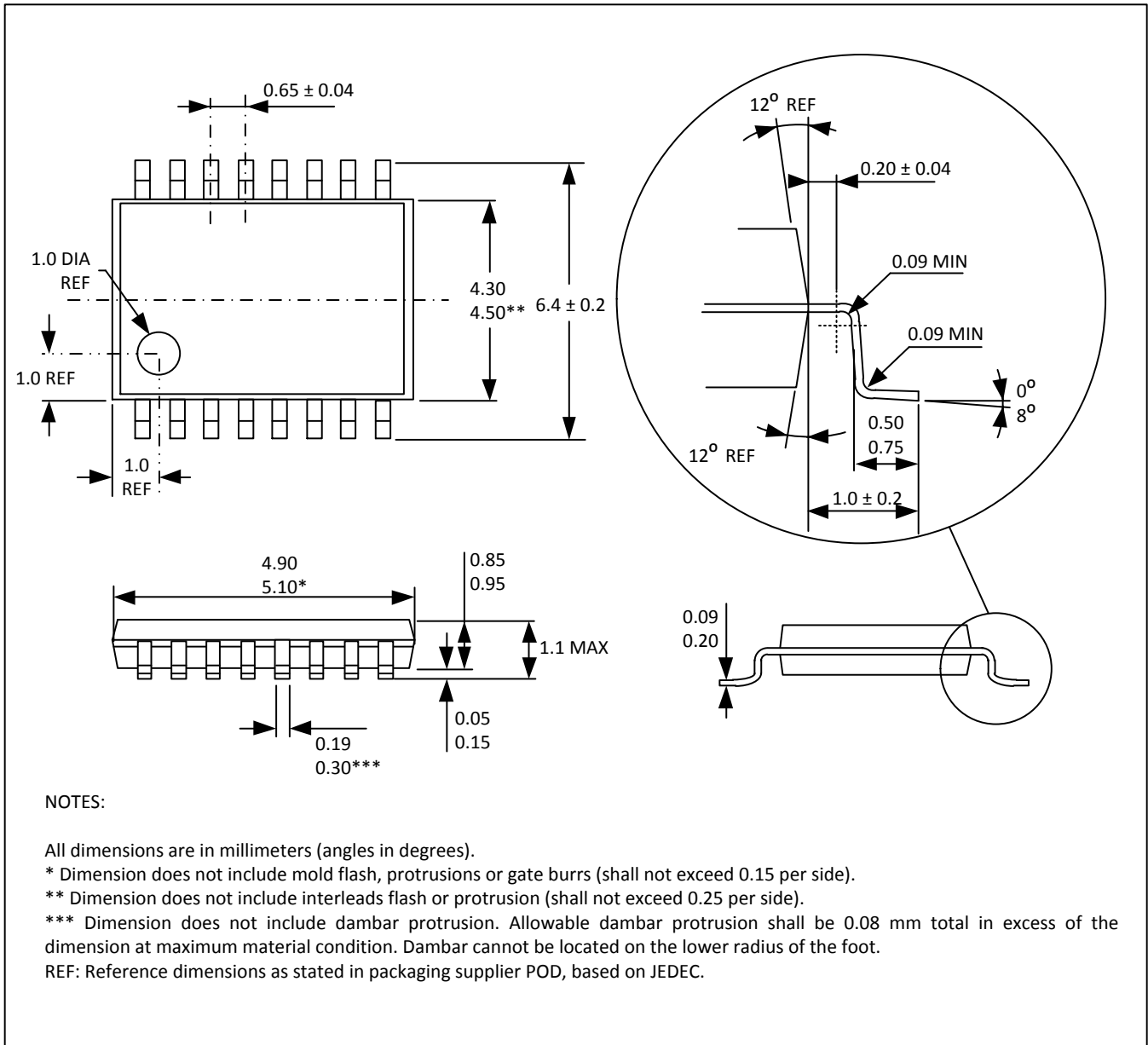


Figure 25: TSSOP-16 Package Dimensions

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

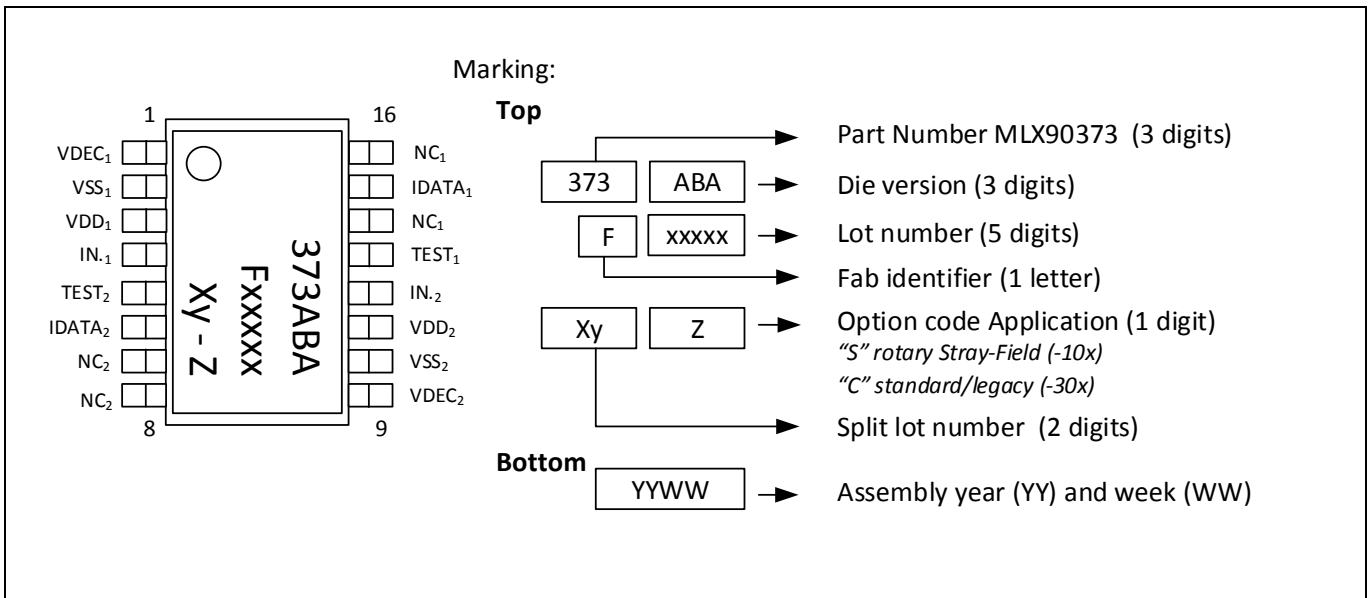


Figure 26: TSSOP-16 pinout & marking

### 18.1.3. TSSOP-16 - Sensitive Spot Positioning

#### 18.1.3.1. Angular Stray-Field Immune & Standard/Legacy Mode

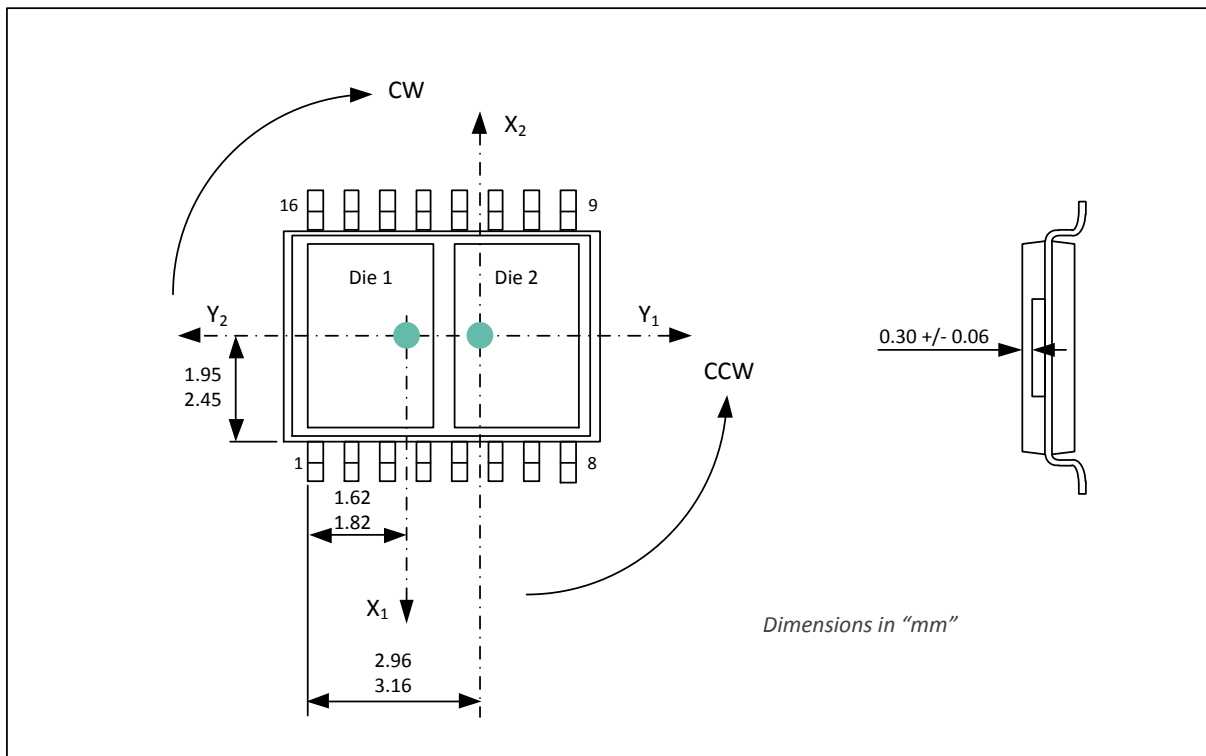


Figure 27: TSSOP-16 sensitive spot position



### 18.1.4. TSSOP-16 - Angle Detection

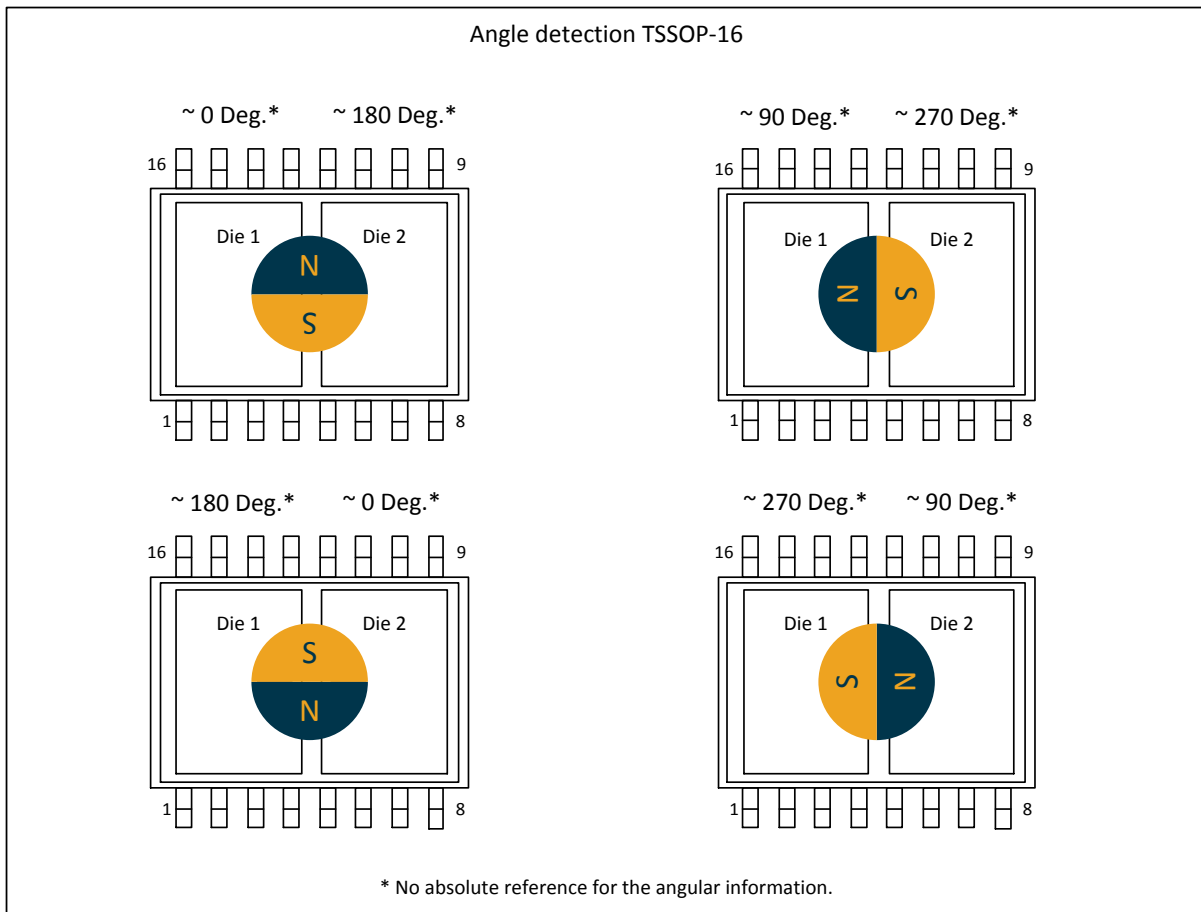


Figure 28: TSSOP-16 angle detection

The MLX90373 is an absolute angular position sensor. Note however that the linearity error (See section 9 Accuracy Specification) does not include the error linked to the absolute reference 0 Deg., which can be fixed in the application through the discontinuity point.

### 18.1.5. TSSOP-16 – Thermal Performances

The table below describe the thermal behaviour of available packages following JEDEC EIA/JESD 51.X standard.

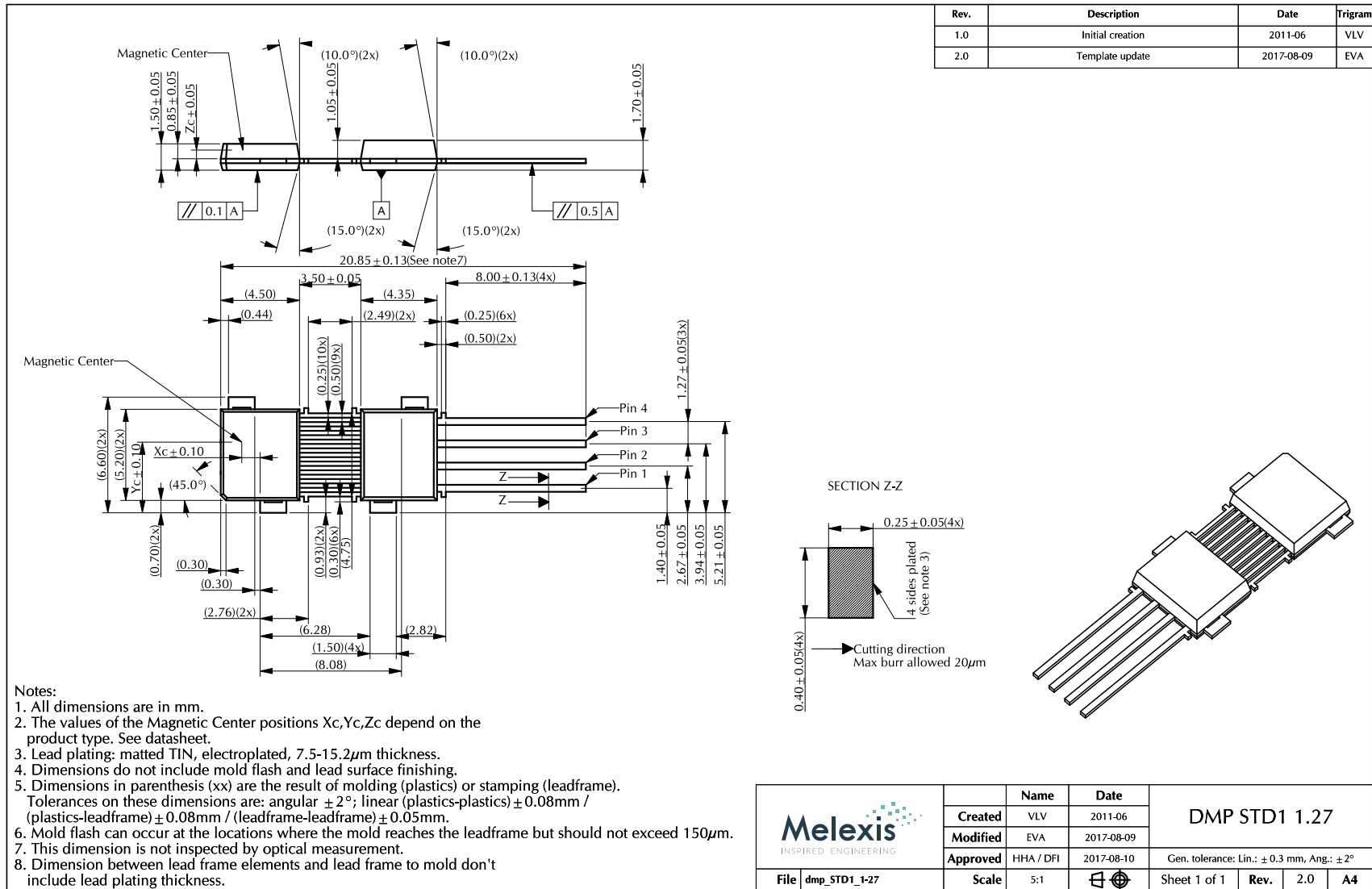
| Package  | Junction to case - $\theta_{jc}$ | Junction to ambient - $\theta_{ja}$<br>(JEDEC 1s2p board) | Junction to ambient - $\theta_{ja}$<br>(JEDEC 1s0p board) |
|----------|----------------------------------|---|---|
| TSSOP-16 | 27.6 K/W                         | 99.1 K/W  | 137 K/W   |

Table 44: TSSOP-16 Package Thermal Performances

## 18.2. DMP-4 Package

### 18.2.1. DMP-4 - Package Dimensions

18.2.1.1. DMP-4 - Package Outline Dimensions (POD) – Straight Leads



- Notes:
1. All dimensions are in mm.
  2. The values of the Magnetic Center positions Xc, Yc, Zc depend on the product type. See datasheet.
  3. Lead plating: matted TIN, electroplated, 7.5-15.2μm thickness.
  4. Dimensions do not include mold flash and lead surface finishing.
  5. Dimensions in parenthesis (xx) are the result of molding (plastics) or stamping (leadframe). Tolerances on these dimensions are: angular ± 2°; linear (plastics-plastics) ± 0.08mm / (plastics-leadframe) ± 0.08mm / (leadframe-leadframe) ± 0.05mm.
  6. Mold flash can occur at the locations where the mold reaches the leadframe but should not exceed 150μm.
  7. This dimension is not inspected by optical measurement.
  8. Dimension between lead frame elements and lead frame to mold don't include lead plating thickness.

Figure 29: DMP-4 information for straight leads

18.2.1.2. DMP-4 - Package Outline Dimensions (POD) – STD2 2.54

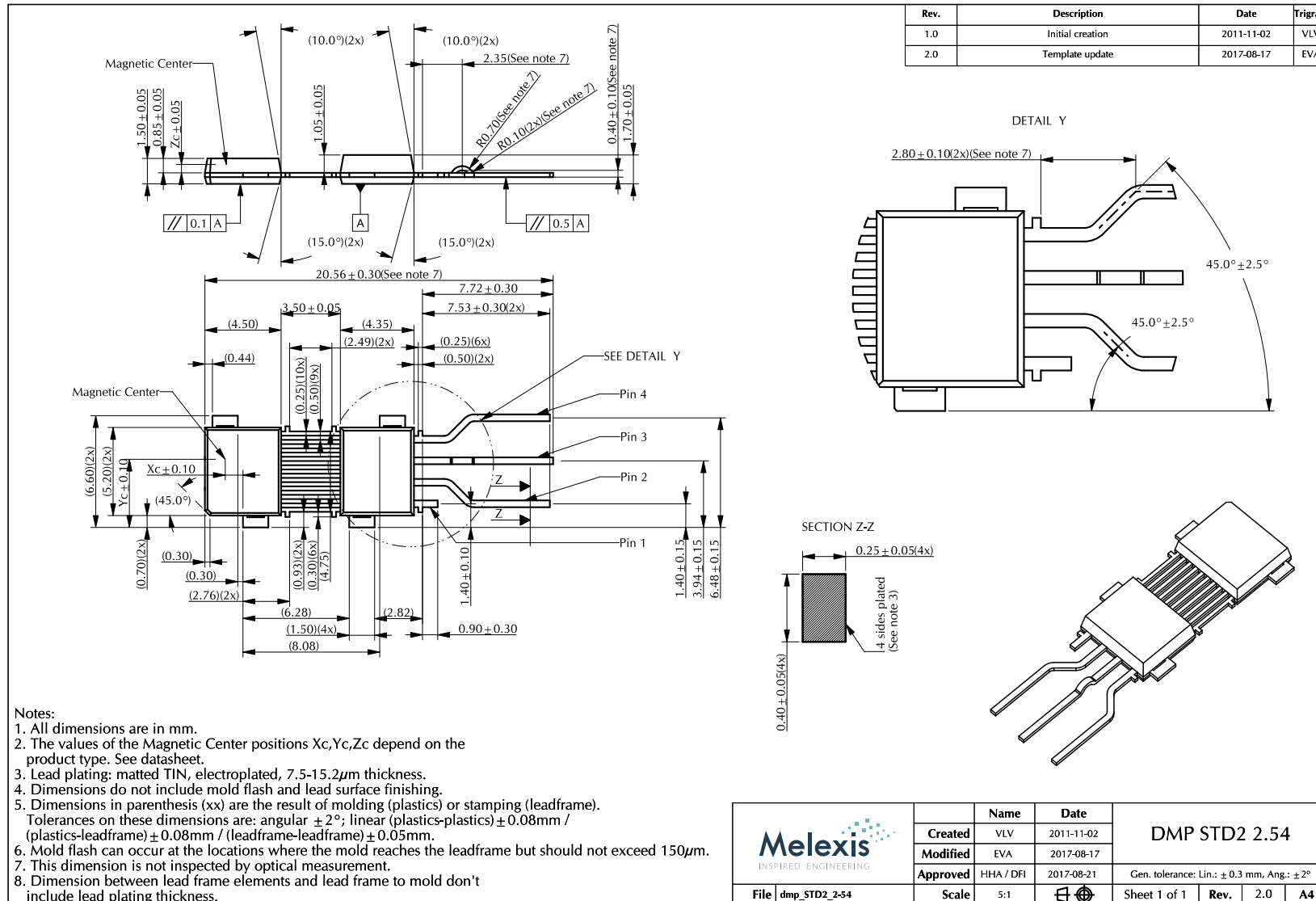


Figure 30: DMP-4 STD2 2.54 Package Outline Drawing

18.2.1.3. DMP-4 - Package Outline Dimensions (POD) – STD4 2.54

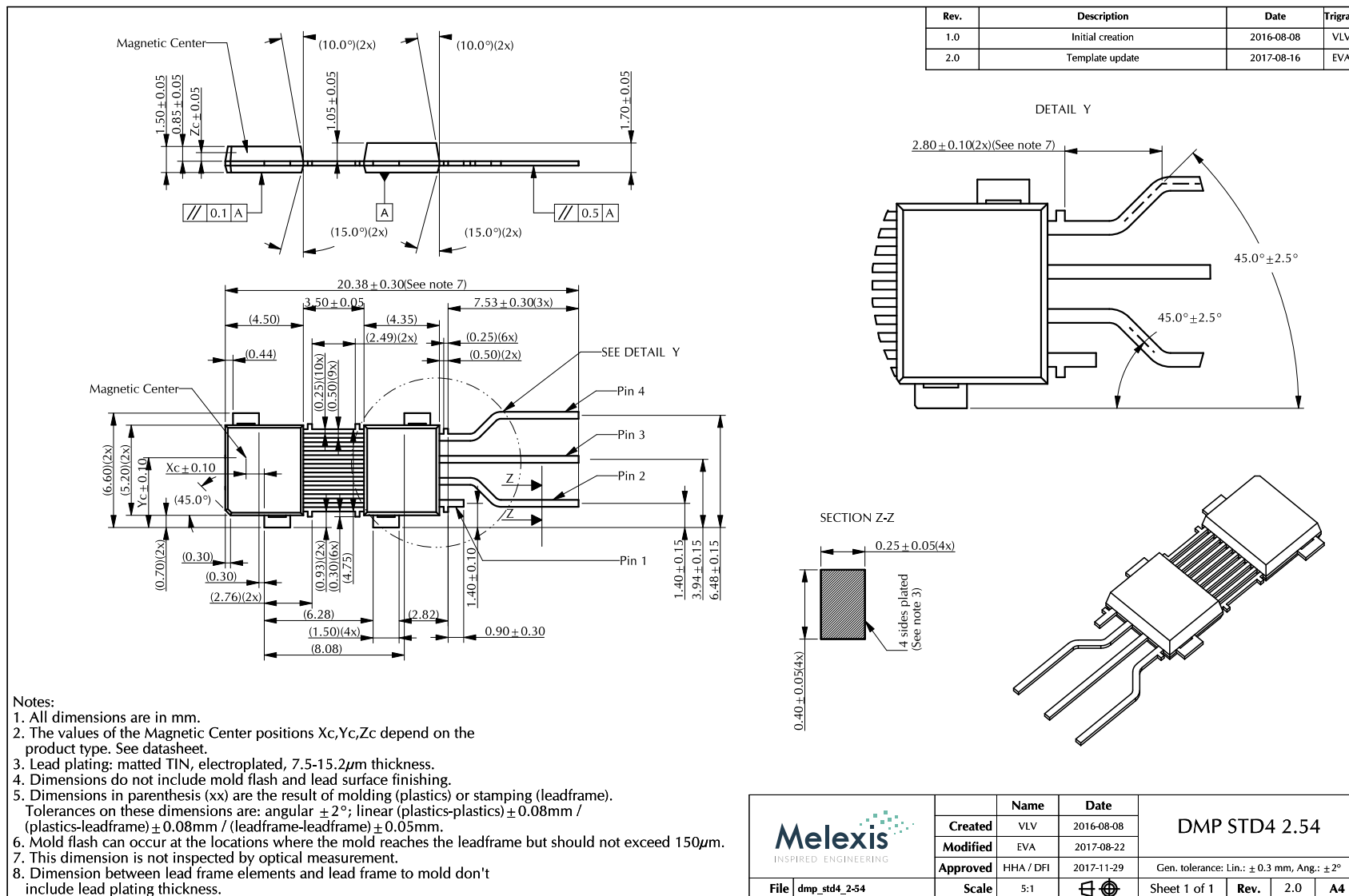


Figure 31: DMP-4 STD4 2.54 Package Outline Drawing

### 18.2.2. DMP-4 - Pinout and Marking

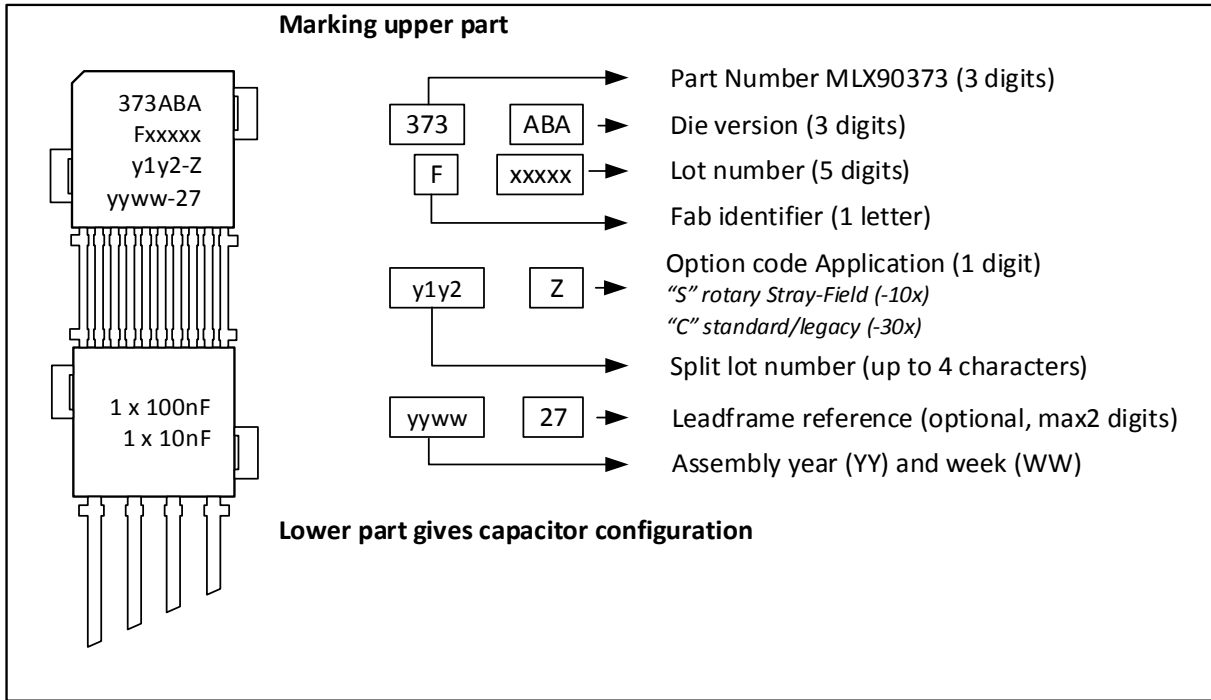


Figure 32: DMP-4 pinout and marking

### 18.2.3. DMP-4 - Sensitive Spot Positioning & Sense direction

#### 18.2.3.1. Angular Stray-Field Immune or Standard/legacy

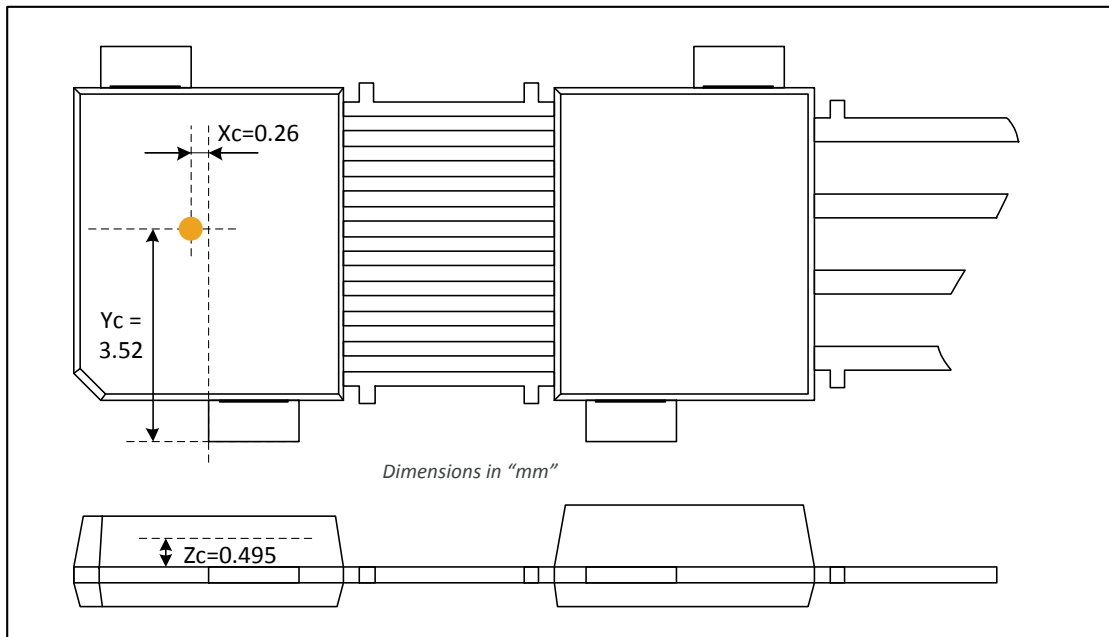


Figure 33: DMP-4 sensitive spot for angular position Stray-Field immune and standard/legacy modes

### 18.2.4. DMP-4 - Angle Detection

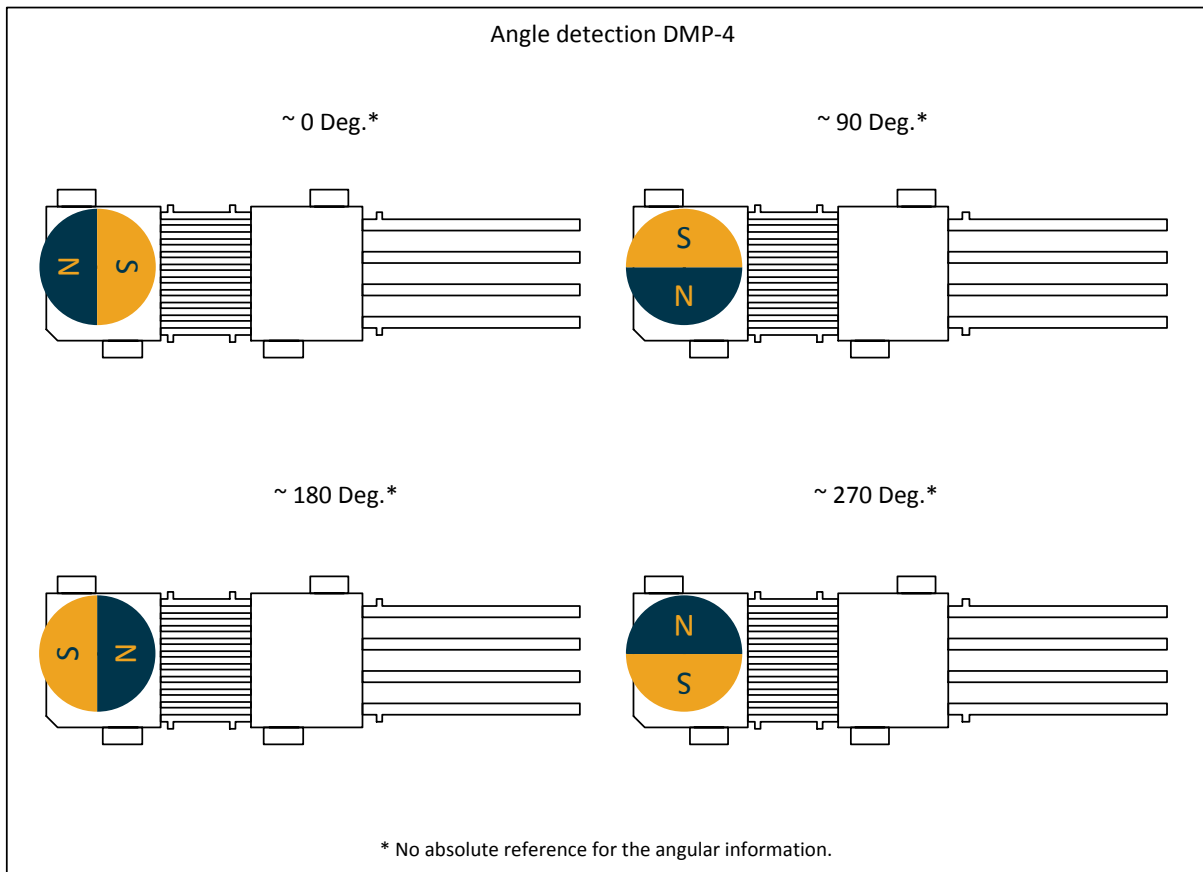


Figure 34: DMP-4 angle detection

The MLX90373 is an absolute angular position sensor. Note however that the linearity error (See section 9 Accuracy Specification) does not include the error linked to the absolute reference 0 Deg., which can be fixed in the application through the discontinuity point.

### 18.2.5. DMP-4 - Thermal Performances

The table below describe the thermal behaviour of available packages following JEDEC EIA/JESD 51.X standard.

| Package | Junction to case - $\theta_{jc}$ | Junction to ambient - $\theta_{ja}$<br>(JEDEC 1s2p board) | Junction to ambient - $\theta_{ja}$<br>(JEDEC 1s0p board) |
|---------|----------------------------------|---|---|
| DMP-4   | 32.2 K/W                         | 88.7 K/W  | done without PCB <sup>(24)</sup>                          |

Table 45: DMP-4 Package Thermal Performances

<sup>24</sup> DMP-4 as PCB-less solution has been evaluated in a typical application case. Values for this package are given as informative.

## 19. Contact

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