

### Features and Benefits

Absolute Rotary Position Sensor IC  
 Simple & Robust Magnetic Design  
 Tria $\otimes$ is™ Hall Technology  
 Programmable Angular Range up to 360 Degrees  
 Programmable Linear Transfer Characteristic  
 Selectable Analog (Ratiometric), PWM, Serial Protocol  
 12 bit Angular Resolution - 10 bit Angular Thermal Accuracy  
 40 bit ID Number  
 Single Die – SO8 Package RoHS Compliant  
 Dual Die (Full Redundant) – TSSOP16 Package RoHS Compliant

# Tria $\otimes$ is™



### Applications

Absolute Rotary Position Sensor  
 Pedal Position Sensor  
 Throttle Position Sensor  
 Ride Height Position Sensor

Steering Wheel Position Sensor  
 Motor-shaft Position Sensor  
 Float-Level Sensor  
 Non-Contacting Potentiometer

### Ordering Information<sup>1</sup>

| Part No. | Temperature Suffix    | Package Code  | Option code      |
|----------|-----------------------|---------------|------------------|
| MLX90316 | S (- 20°C to + 85°C)  | DC [SOIC-8]   | - <sup>2</sup>   |
| MLX90316 | E (- 40°C to + 85°C)  | DC [SOIC-8]   | - <sup>2</sup>   |
| MLX90316 | K (- 40°C to + 125°C) | DC [SOIC-8]   | - <sup>2</sup>   |
| MLX90316 | L (- 40°C to + 150°C) | DC [SOIC-8]   | - <sup>2</sup>   |
| MLX90316 | S (- 20°C to + 85°C)  | GO [TSSOP-16] | - <sup>2</sup>   |
| MLX90316 | E (- 40°C to + 85°C)  | GO [TSSOP-16] | - <sup>2</sup>   |
| MLX90316 | K (- 40°C to + 125°C) | GO [TSSOP-16] | - <sup>2</sup>   |
| MLX90316 | L (- 40°C to + 150°C) | GO [TSSOP-16] | - <sup>2</sup>   |
| MLX90316 | E (- 40°C to + 85°C)  | DC [SOIC-8]   | SPI <sup>3</sup> |
| MLX90316 | K (- 40°C to + 125°C) | DC [SOIC-8]   | SPI <sup>3</sup> |
| MLX90316 | L (- 40°C to + 150°C) | DC [SOIC-8]   | SPI <sup>3</sup> |
| MLX90316 | E (- 40°C to + 85°C)  | GO [TSSOP-16] | SPI <sup>3</sup> |
| MLX90316 | K (- 40°C to + 125°C) | GO [TSSOP-16] | SPI <sup>3</sup> |
| MLX90316 | L (- 40°C to + 150°C) | GO [TSSOP-16] | SPI <sup>3</sup> |
| MLX90316 | K (- 40°C to + 125°C) | DC [SOIC-8]   | PPA <sup>4</sup> |
| MLX90316 | K (- 40°C to + 125°C) | GO [TSSOP-16] | PPA <sup>4</sup> |
| MLX90316 | K (- 40°C to + 125°C) | DC [SOIC-8]   | PPD <sup>5</sup> |
| MLX90316 | K (- 40°C to + 125°C) | GO [TSSOP-16] | PPD <sup>5</sup> |

<sup>1</sup> Example: MLX90316KDC-PPA

<sup>2</sup> Fully end-user programmable version through the Melexis Programming Unit PTC-04

<sup>3</sup> SPI Version pre-programmed and locked for 360deg rotary position application in SPI mode (High Speed). The standard version can also be programmed in SPI but the application diagram described in section 17.4.3 is recommended.

<sup>4</sup> Pre-Programmed Analog – 360deg angular span for an analog output between 0.5V and 4.5V, Low Speed Mode (Locked)

<sup>5</sup> Pre-Programmed PWM – 360deg angular span, 10-90% at 1 kHz, High Speed Mode (Locked)

**1. Functional Diagram**

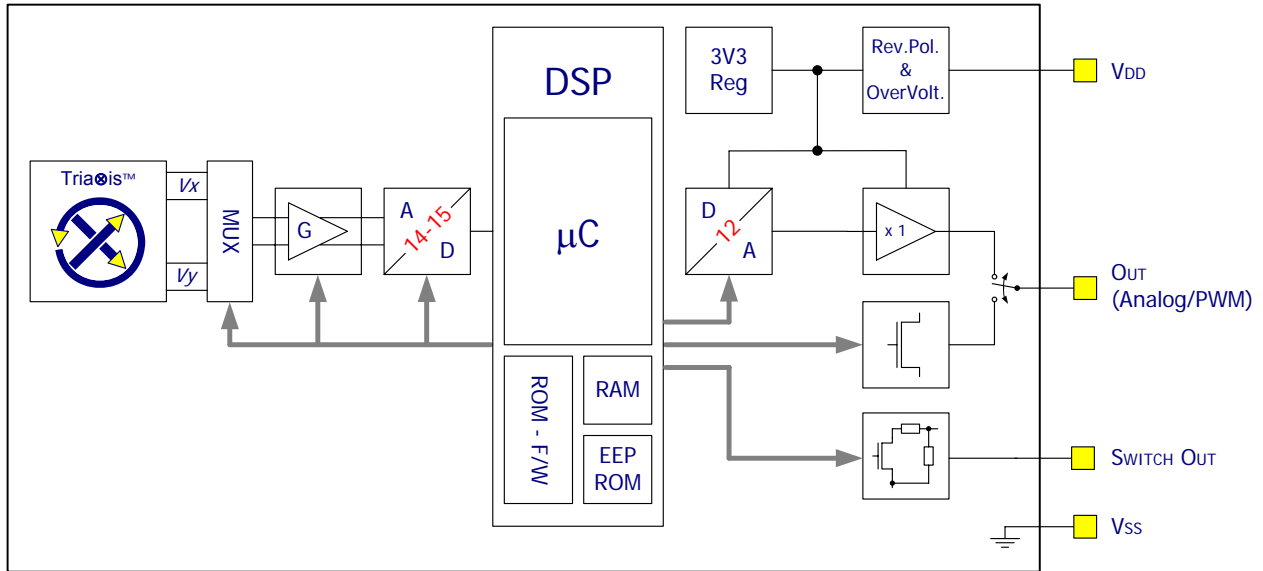


Figure 1 - Block Diagram (Analog & PWM)

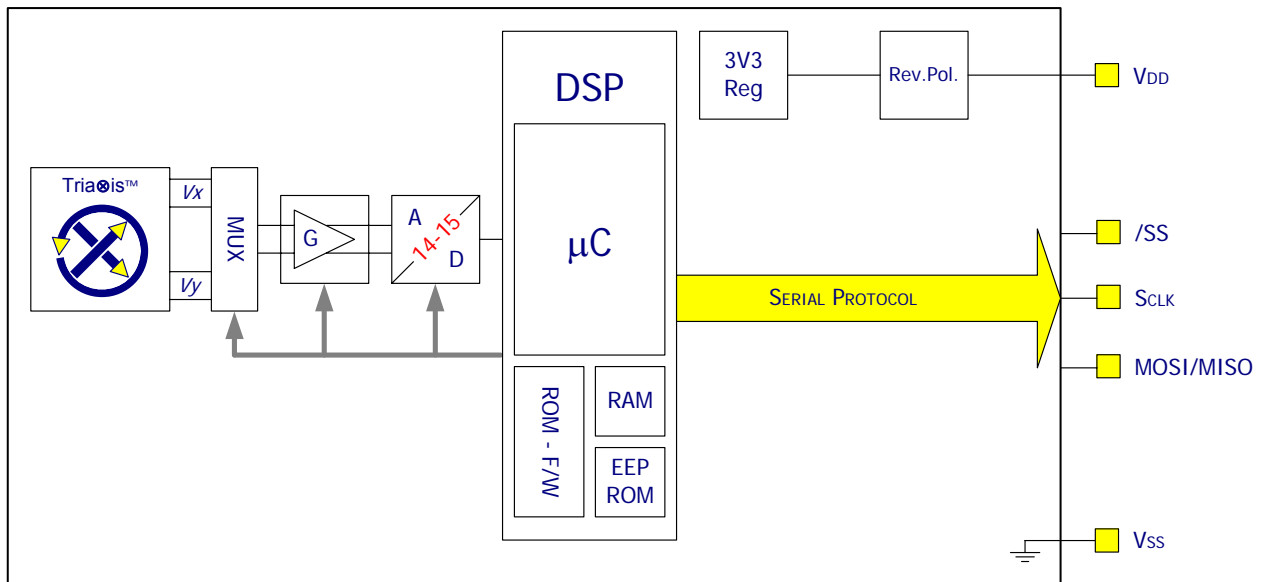


Figure 2 - Block Diagram (Serial Protocol)

## 2. Description

The MLX90316 is a monolithic sensor IC featuring the Tria $\otimes$ is™ Hall technology. Conventional planar Hall technology is only sensitive to the flux density applied orthogonally to the IC surface. The Tria $\otimes$ is™ Hall sensor is also sensitive to the flux density applied parallel to the IC surface. This is obtained through an Integrated Magneto-Concentrator (IMC®) which is deposited on the CMOS die (as an additional back-end step).

The MLX90316 is only sensitive to the flux density coplanar with the IC surface. This allows the MLX90316 with the correct magnetic circuit to decode the absolute rotary (angular) position from 0 to 360 Degrees. It enables the design of novel generation of non-contacting rotary position sensors that are frequently required for both automotive and industrial applications.

In combination with the appropriate signal processing, the magnetic flux density of a small magnet (diametral magnetization) rotating above the IC can be measured in a non-contacting way (Figure 3). The angular information is computed from both vectorial components of the flux density (i.e.  $B_x$  and  $B_y$ ). MLX90316 produces an output signal proportional to the decoded angle. The output is selectable between Analog, PWM and Serial Protocol.

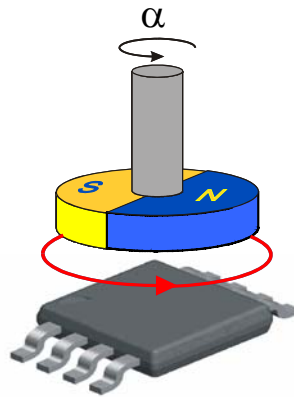


Figure 3 - Typical application of MLX90316

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### 3. Glossary of Terms – Abbreviations – Acronyms

- Gauss (G), Tesla (T): Units for the magnetic flux density – 1 mT = 10 G
- TC: **Temperature Coefficient** (in ppm/Deg.C.)
- NC: **Not Connected**
- PWM: **Pulse Width Modulation**
- %DC: **Duty Cycle** of the output signal i.e.  $T_{ON} / (T_{ON} + T_{OFF})$
- ADC: **Analog-to-Digital Converter**
- DAC: **Digital-to-Analog Converter**
- LSB: **Least Significant Bit**
- MSB: **Most Significant Bit**
- DNL: **Differential Non-Linearity**
- INL: **Integral Non-Linearity**
- RISC: **Reduced Instruction Set Computer**
- ASP: **Analog Signal Processing**
- DSP: **Digital Signal Processing**
- ATAN: trigonometric function: arctangent (or inverse tangent)
- IMC: **Integrated Magneto-Concentrator (IMC®)**
- CoRDIC: **Coordinate Rotation Digital Computer** (i.e. iterative rectangular-to-polar transform)
- EMC: **Electro-Magnetic Compatibility**

### 4. Pinout

| Pin # | SOIC-8       |                 | TSSOP-16                                |   |
|-------|--------------|-----------------|---|---|
|       | Analog / PWM | Serial Protocol | Analog / PWM                            | Serial Protocol                         |
| 1     | VDD          | VDD             | VDIG <sub>1</sub>                       | VDIG <sub>1</sub>                       |
| 2     | Test 0       | Test 0          | VSS <sub>1</sub> (Ground <sub>1</sub> ) | VSS <sub>1</sub> (Ground <sub>1</sub> ) |
| 3     | Switch Out   | /SS             | VDD <sub>1</sub>                        | VDD <sub>1</sub>                        |
| 4     | Not Used     | SCLK            | Test 0 <sub>1</sub>                     | Test 0 <sub>1</sub>                     |
| 5     | Out          | MOSI / MISO     | Switch Out <sub>2</sub>                 | /SS <sub>2</sub>                        |
| 6     | Test 1       | Test 1          | Not Used <sub>2</sub>                   | SCLK <sub>2</sub>                       |
| 7     | VDIG         | VDIG            | Out <sub>2</sub>                        | MOSI <sub>2</sub> / MISO <sub>2</sub>   |
| 8     | Vss (Ground) | Vss (Ground)    | Test 1 <sub>2</sub>                     | Test 1 <sub>2</sub>                     |
| 9     |              |                 | VDIG <sub>2</sub>                       | VDIG <sub>2</sub>                       |
| 10    |              |                 | VSS <sub>2</sub> (Ground <sub>2</sub> ) | VSS <sub>2</sub> (Ground <sub>2</sub> ) |
| 11    |              |                 | VDD <sub>2</sub>                        | VDD <sub>2</sub>                        |
| 12    |              |                 | Test 0 <sub>2</sub>                     | Test 0 <sub>2</sub>                     |
| 13    |              |                 | Switch Out <sub>1</sub>                 | /SS <sub>1</sub>                        |
| 14    |              |                 | Not Used <sub>1</sub>                   | SCLK <sub>1</sub>                       |
| 15    |              |                 | Out <sub>1</sub>                        | MOSI <sub>1</sub> / MISO <sub>1</sub>   |
| 16    |              |                 | Test 1 <sub>1</sub>                     | Test 1 <sub>1</sub>                     |

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 17).

## 5. Absolute Maximum Ratings

| Parameter   | Value  |
|---|--|
| Supply Voltage, VDD (overvoltage)                             | + 20 V   |
| Reverse Voltage Protection                                    | - 10 V   |
| Positive Output Voltage – Standard Version<br>(Analog or PWM) | + 10 V<br>+ 14 V (200 s max – T <sub>A</sub> = + 25°C) |
| Positive Output Voltage – SPI Version                         | VDD + 0.3V   |
| Positive Output Voltage (Switch Out)                          | + 10 V<br>+ 14 V (200 s max – T <sub>A</sub> = + 25°C) |
| Output Current (I <sub>OUT</sub> )                            | ± 30 mA  |
| Reverse Output Voltage  | - 0.3 V  |
| Reverse Output Current  | - 50 mA  |
| Operating Ambient Temperature Range, T <sub>A</sub>           | - 40°C ... + 150°C                                     |
| Storage Temperature Range, T <sub>S</sub>                     | - 40°C ... + 150°C                                     |
| Magnetic Flux Density   | ± 700 mT   |

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

## 6. Detailed Description

As described on the block diagram (Figure 1 and Figure 2), the magnetic flux density parallel to the IC surface (i.e. B<sub>||</sub>) is sensed through the Tria $\otimes$ is™ sensor front-end. This front-end consists into two orthogonal pairs (for each of the two directions parallel with the IC surface i.e. X and Y) of conventional planar Hall plates (blue area on Figure 4) and an Integrated Magneto-Concentrator (IMC® yellow disk on Figure 4).

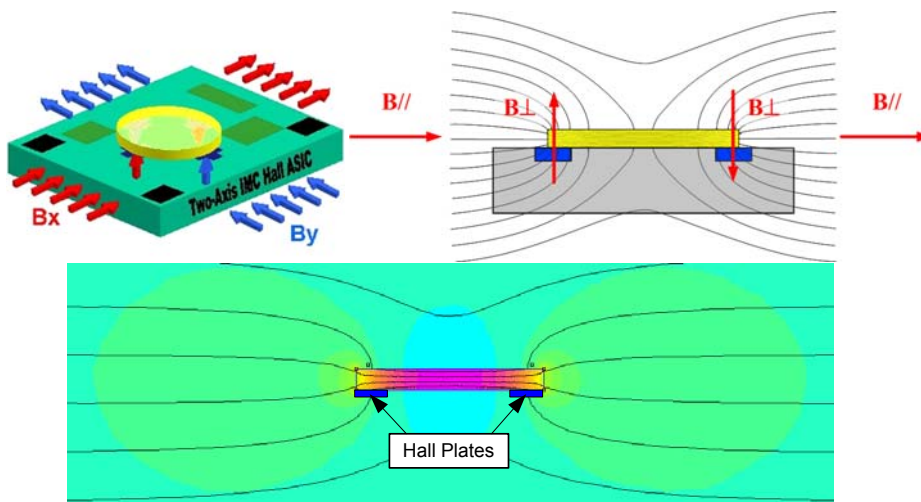


Figure 4 - Tria $\otimes$ is™ sensor front-end (4 Hall plates + IMC® disk)

Both components of the applied flux density  $B_{//}$  are measured individually i.e.  $B_{X//}$  and  $B_{Y//}$ . Two orthogonal components (respectively  $B_{X\perp}$  and  $B_{Y\perp}$ ) proportional to the parallel components (respectively  $B_{X//}$  and  $B_{Y//}$ ) are induced through the IMC and can be measured by both respective pairs of conventional planar Hall plates as those are sensitive to the flux density applied orthogonally to them and the IC surface.

While a magnet (diametrically magnetized) rotates above the IC as described on Figure 3, the sensing stage provides two differential signals in quadrature (sine and cosine – Figure 5 and Figure 6)

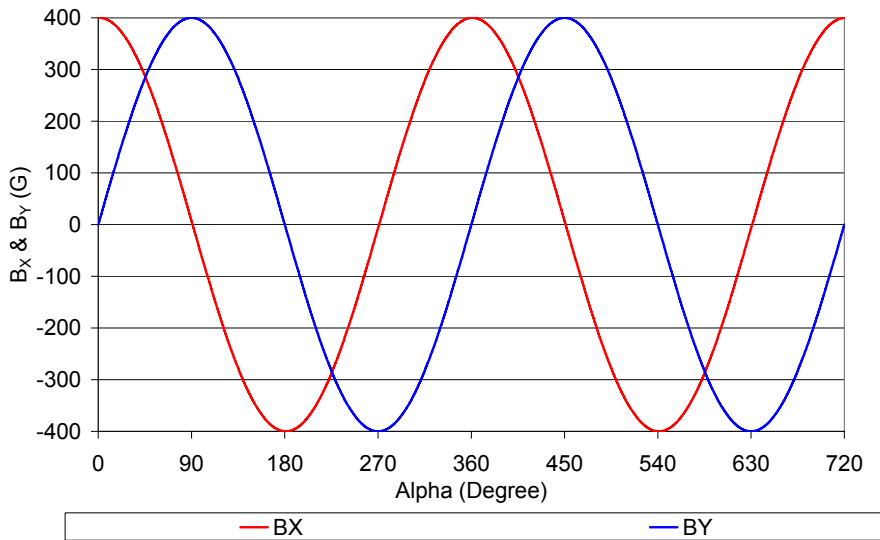


Figure 5 – Magnetic Flux Density –  $B_X \propto \cos(\alpha)$  &  $B_Y \propto \sin(\alpha)$

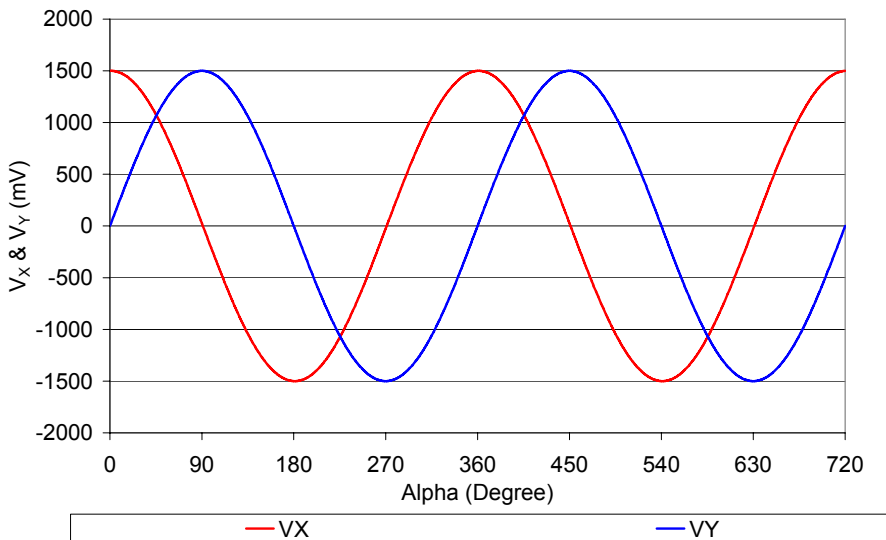


Figure 6 – Tria<sup>o</sup>is™ sensor front-end – Output signals –  $V_X \propto B_X \propto \cos(\alpha)$  &  $V_Y \propto B_Y \propto \sin(\alpha)$



Those Hall signals are processed through a fully differential analog chain featuring the classic offset cancellation technique (Hall plate quadrature spinning and chopper-stabilized amplifier).

The conditioned analog signals are converted through an ADC (configurable – 14 or 15 bits) and provided to a DSP block for further processing. The DSP stage is based on a 16 bit RISC micro-controller whose primary function is the extraction of the angular position from the two raw signals (after so-called front-end compensation steps) through the following operation:

$$\alpha = ATAN\left(\frac{V_Y}{V_X}\right)$$

The DSP functionality is governed by the micro-code (firmware – F/W) of the micro-controller which is stored into the ROM (mask programmable). In addition to the "ATAN" function, the F/W controls the whole analog chain, the output transfer characteristic, the output protocol, the programming/calibration and also the self-diagnostic modes.

In the MLX90316, the "ATAN" function is computed via a look-up table (i.e. it is not obtained through a CoRDIC algorithm).

Due to the fact that the "ATAN" operation is performed on the ratio " $V_Y/V_X$ ", the angular information is intrinsically self-compensated vs. flux density variations (due to airgap change, thermal or ageing effects) affecting both signals. This feature allows therefore an improved thermal accuracy vs. rotary position sensor based on conventional linear Hall sensors.

In addition to the improved thermal accuracy, the realized rotary position sensor is capable of measuring a complete revolution (360 Degrees) and the linearity performances are excellent taking into account typical manufacturing tolerances (e.g. relative placement between the Hall IC and the magnet).

Once the angular information is computed (over 360 degrees), it is further conditioned (mapped) vs. the target transfer characteristic and it is provided at the output(s) as:

- an analog output level through a 12 bit DAC followed by a buffer
- a digital PWM signal with 12 bit depth (programmable frequency 100 Hz ... 1 kHz)
- a digital Serial Protocol (SP – 14 bits computed angular information available)

For instance, the analog output can be programmed for offset, gain and clamping to meet any rotary position sensor output transfer characteristic:

$$\begin{aligned} V_{out}(\alpha) &= \text{ClampLo} && \text{for } \alpha \leq \alpha_{min} \\ V_{out}(\alpha) &= V_{offset} + \text{Gain} \times \alpha && \text{for } \alpha_{min} \leq \alpha \leq \alpha_{max} \\ V_{out}(\alpha) &= \text{ClampHi} && \text{for } \alpha \geq \alpha_{max} \end{aligned}$$

where  $V_{offset}$ , Gain, ClampLo and ClampHi are the main adjustable parameters for the end-user.

The linear part of the transfer curve can be adjusted through either a 2 point or a 3 point calibration depending on the linearity requirement.

A digital output is also available and used as a programmable angular switch.

The calibration parameters are stored in EEPROM featuring a Hamming Error Correction Coding (ECC).

The programming steps do not require any dedicated pins. The operation is done using the supply and output nodes of the IC. The programming of the MLX90316 is handled at both engineering lab and production line levels by the Melexis Programming Unit PTC-04 with the dedicated MLX90316 daughterboard and software tools (DLL – User Interface).

### 7. MLX90316 Electrical Specification

DC Operating Parameters at VDD = 5V (unless otherwise specified) and for TA as specified by the Temperature suffix (S, E, K or L).

| Parameter  | Symbol   | Test Conditions   | Min                        | Typ  | Max               | Units |
|--|----------|---|----------------------------|------|-------------------|-------|
| Nominal Supply Voltage   | VDD      |   | 4.5                        | 5    | 5.5               | V     |
| Supply Current <sup>(6)</sup>  | Idd      | Slow mode <sup>(7)</sup>                                  |                            | 8.5  | 11                | mA    |
|  |          | Fast mode <sup>(7)</sup>                                  |                            | 13.5 | 16                | mA    |
| POR Level  | VDD POR  | Supply Under Voltage                                      | 2                          | 2.7  | 3                 | V     |
| Output Current   | Iout     | Analog Output mode  | -8                         |      | 8                 | mA    |
|  |          | PWM Output mode   | -20                        |      | 20                | mA    |
| Output Short Circuit Current   | Ishort   | Vout = 0 V  |                            | 12   | 15                | mA    |
|  |          | Vout = 5 V  |                            | 12   | 15                | mA    |
|  |          | Vout = 14 V (TA = 25°C)                                   |                            | 24   | 45                | mA    |
| Output Load  | RL       | Pull-down to Ground                                       | 1                          | 10   | ∞ <sup>(9)</sup>  | kΩ    |
|  |          | Pull-up to 5V <sup>(8)</sup>                              | 1                          | 10   | ∞ <sup>(9)</sup>  | kΩ    |
| Analog Saturation Output Level   | Vsat_lo  | Pull-up load RL ≥ 10 kΩ                                   |                            |      | 3                 | %VDD  |
|  | Vsat_hi  | Pull-down load RL ≥ 10 kΩ                                 | 96                         |      |                   | %VDD  |
| Digital Saturation Output Level  | VsatD_lo | Pull-up Low Side RL ≥ 10 kΩ<br>Push-Pull (IOUT = -20mV)   |                            |      | 1.5               | %VDD  |
|  | VsatD_hi | Push-Pull (IOUT = 20mV)                                   | 97                         |      |                   | %VDD  |
| Active Diagnostic Output Level   | Diag_lo  | Pull-down load RL ≥ 10 kΩ<br>Pull-up load RL ≥ 10 kΩ      |                            |      | 1<br>1.5          | %VDD  |
|  | Diag_hi  | Pull-down load RL ≥ 10 kΩ<br>Pull-up load RL ≥ 10 kΩ      | 97<br>98                   |      |                   | %VDD  |
| Passive Diagnostic Output Level<br>(Broken Track Diagnostic) <sup>(10)</sup> | BVssPD   | Broken Vss <sup>(11)</sup> &<br>Pull-down load RL ≤ 10 kΩ |                            |      | 4 <sup>(10)</sup> | %VDD  |
|  | BVssPU   | Broken Vss <sup>(11)</sup> &<br>Pull-up load RL ≥ 1kΩ     | 99                         | 100  |                   | %VDD  |
|  | BVDDPD   | Broken VDD <sup>(11)</sup> &<br>Pull-down load RL ≥ 1kΩ   |                            | 0    | 1                 | %VDD  |
|  | BVDDPU   | Broken VDD &<br>Pull-up load to 5V                        | No Broken Track diagnostic |      |                   | %VDD  |

*MLX 90316 Electrical Specification continues...*

<sup>6</sup> For the dual version, the supply current is multiplied by 2

<sup>7</sup> See section 14.4.1 for details concerning Slow and Fast mode

<sup>8</sup> Applicable for output in Analog and PWM (Open-Drain) modes

<sup>9</sup> RL < ∞ for output in PWM mode

<sup>10</sup> For detailed information, see also section 15

<sup>11</sup> Not Valid for the SPI Version

| ...MLX 90316 Electrical Specification |          |                         |      |  |      |                      |
|---------------------------------------|----------|-------------------------|------|--|------|----------------------|
| Clamped Output Level                  | Clamp_lo | Programmable            | 0    |  | 100  | %VDD <sup>(12)</sup> |
|                                       | Clamp_hi | Programmable            | 0    |  | 100  | %VDD <sup>(12)</sup> |
| Switch Out <sup>(13)</sup>            | Sw_lo    | Pull-up Load 1.5k to 5V | 0.55 |  | 1.1  | V                    |
|                                       | Sw_hi    | Pull-up Load 1.5k to 5V | 3.65 |  | 4.35 | V                    |

As an illustration of the previous table, the MLX90316 fits the typical classification of the output span described on the Figure 7.

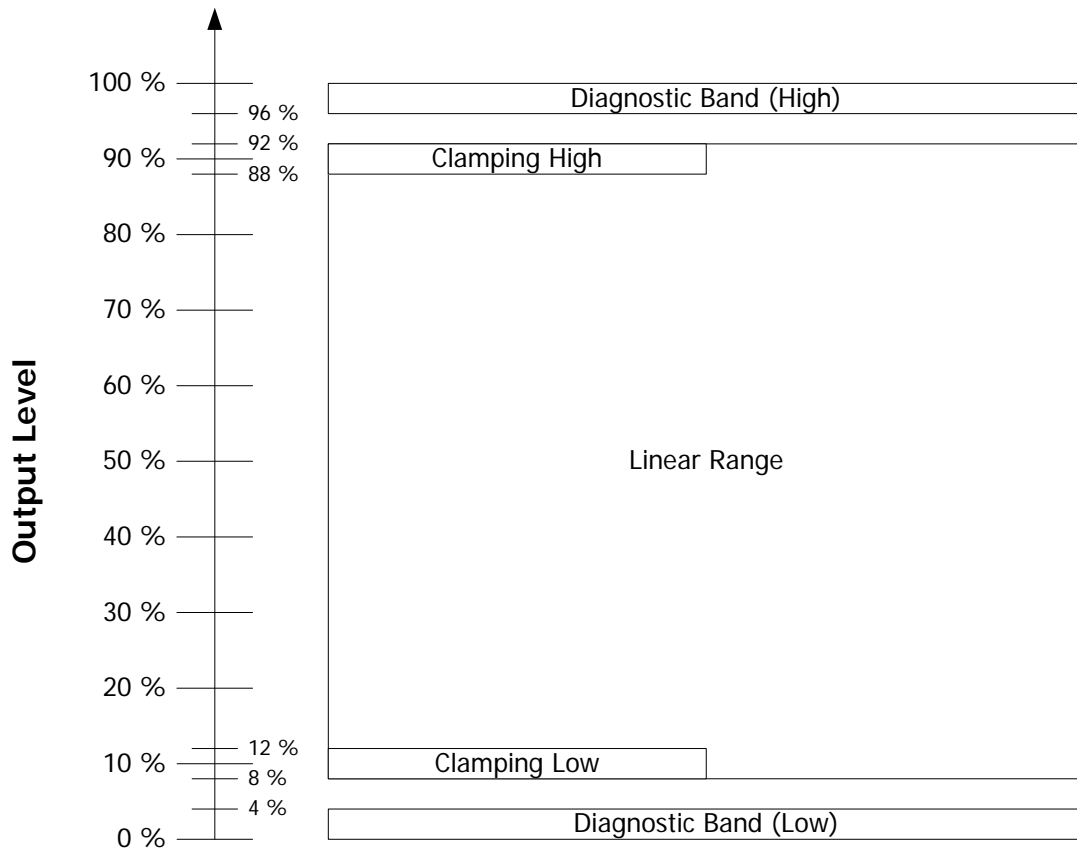


Figure 7 - Output Span Classification

<sup>12</sup> Clamping levels need to be considered vs the saturation of the output stage (see Vsat\_lo and Vsat\_hi)

<sup>13</sup> See section 14.1.4 for the application diagram

### 8. MLX90316 Isolation Specification

DC Operating Parameters at  $V_{DD} = 5V$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (S, E, K or L). Only valid for the package code GO i.e. dual die version.

| Parameter            | Symbol | Test Conditions | Min | Typ | Max | Units |
|----------------------|--------|-----------------|-----|-----|-----|-------|
| Isolation Resistance |        | Between 2 dies  | 4   |     |     | MΩ    |

### 9. MLX90316 Timing Specification

DC Operating Parameters at  $V_{DD} = 5V$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (S, E, K or L).

| Parameter                | Symbol           | Test Conditions                                      | Min | Typ | Max  | Units |
|--------------------------|------------------|--|-----|-----|------|-------|
| Main Clock Frequency     | Ck               | Slow mode <sup>(14)</sup>                            |     | 7   |      | MHz   |
|                          |                  | Fast mode <sup>(14)</sup>                            |     | 20  |      | MHz   |
| Sampling Rate            |                  | Slow mode <sup>(15)</sup>                            |     | 600 |      | μs    |
|                          |                  | Fast mode <sup>(15)</sup>                            |     | 200 |      | μs    |
| Step Response Time       | Ts               | Slow mode <sup>(14)</sup> , Filter=5 <sup>(15)</sup> |     |     | 4    | ms    |
|                          |                  | Fast mode <sup>(14)</sup> , Filter=0 <sup>(15)</sup> |     | 400 | 600  | μs    |
| Watchdog                 | Wd               | See Section 15                                       |     |     | 5    | ms    |
| Start-up Cycle           | Tsu              | Slow and Fast mode <sup>(14)</sup>                   |     |     | 15   | ms    |
| Analog Output Slew Rate  |                  | $C_{OUT} = 42 \text{ nF}$                            |     | 200 |      | V/ms  |
|                          |                  | $C_{OUT} = 100 \text{ nF}$                           |     | 100 |      |       |
| PWM Frequency            | F <sub>PWM</sub> | PWM Output Enabled                                   | 100 |     | 1000 | Hz    |
| Digital Output Rise Time |                  | Mode 5 – 10nF, R <sub>L</sub> = 10 kΩ                |     | 120 |      | μs    |
|                          |                  | Mode 7 – 10nF, R <sub>L</sub> = 10 kΩ                |     | 2.2 |      | μs    |
| Digital Output Fall Time |                  | Mode 5 – 10nF, R <sub>L</sub> = 10 kΩ                |     | 1.8 |      | μs    |
|                          |                  | Mode 7 – 10nF, R <sub>L</sub> = 10 kΩ                |     | 1.9 |      | μs    |

<sup>14</sup> See section 14.4.1 for details concerning Slow and Fast mode

<sup>15</sup> See section 14.5 for details concerning Filter parameter

### 10. MLX90316 Accuracy Specification

DC Operating Parameters at  $V_{DD} = 5V$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (S, E, K or L).

| Parameter   | Symbol    | Test Conditions  | Min  | Typ   | Max  | Units             |
|---|-----------|--|------|-------|------|-------------------|
| ADC Resolution on the raw signals sine and cosine                             | $R_{ADC}$ | Slow Mode <sup>(16)</sup>  |      | 15    |      | bits              |
|   |           | Fast Mode <sup>(16)</sup>  |      | 14    |      | bits              |
| Thermal Offset Drift #1 <sup>(17)</sup>                                       |           | Thermal Offset Drift at the DSP input (excl. DAC and output stage) |      |       |      |                   |
|   |           | Temperature suffix S, E and K                                      | -60  |       | +60  | LSB <sub>15</sub> |
|   |           | Temperature suffix L   | -90  |       | +90  | LSB <sub>15</sub> |
| Thermal Offset Drift #2<br>(to be considered only for the analog output mode) |           | Thermal Offset Drift of the DAC and Output Stage                   |      |       |      |                   |
|   |           | Temperature suffix S, E and K                                      | -0.3 |       | +0.3 | %VDD              |
|   |           | Temperature suffix L   | -0.4 |       | +0.4 | %VDD              |
| Thermal Drift of Sensitivity Mismatch <sup>(18)</sup>                         |           | Temperature suffix S, E and K                                      | -0.3 |       | +0.3 | %                 |
|   |           | Temperature suffix L   | -0.5 |       | +0.5 | %                 |
| Intrinsic Linearity Error <sup>(19)</sup>                                     | $Le$      | $T_A = 25^\circ C$   | -1   |       | 1    | Deg               |
| Analog Output Resolution  | $R_{DAC}$ | 12 bits DAC<br>(Theoretical – Noise free)                          |      | 0.025 |      | %VDD/LSB          |
|   |           | INL  | -4   |       | +4   | LSB               |
|   |           | DNL  | 0.05 | 1     | 2    | LSB               |
| Output stage Noise  |           | Clamped Output   |      | 0.05  |      | %VDD              |
| Noise pk-pk <sup>(20)</sup>   |           | RG = 9, Slow mode, Filter=5  |      | 0.03  | 0.06 | Deg               |
|   |           | RG = 9, Fast mode, Filter=0  |      | 0.1   | 0.2  | Deg               |
| Ratiometry Error  |           |  | -0.1 | 0     | 0.1  | %VDD              |
| PWM Output Resolution   | $R_{PWM}$ | 12 bits<br>(Theoretical – Jitter free)                             |      | 0.025 |      | %DC/LSB           |
| PWM Jitter <sup>(21)</sup>  | $J_{PWM}$ | RG = 6, $F_{PWM} = 250 \text{ Hz} - 800\text{Hz}$                  |      |       | 0.2  | %DC               |
| Serial Protocol Output Resolution   | $R_{SP}$  | 14 bits – 360 Deg. mapping<br>(Theoretical – Jitter free)          |      | 0.022 |      | Deg/LSB           |

<sup>16</sup> 15 bits corresponds to 14 bits + sign and 14 bits corresponds to 13 bits + sign. After angular calculation, this corresponds to 0.005Deg/LSB<sub>15</sub> in Low Speed Mode and 0.01Deg/LSB<sub>14</sub> in High Speed.

<sup>17</sup> For instance, Thermal Offset Drift #1 equal  $\pm 60\text{LSB}_{15}$  yields to max.  $\pm 0.3$  Deg. angular error for the computed angular information (output of the DSP). See Front End Application Note for more details. This is only valid if automatic gain is set (See Section 14.4.2)

<sup>18</sup> For instance, Thermal Drift of Sensitivity Mismatch equal  $\pm 0.4\%$  yields to max.  $\pm 0.1$  Deg. angular error for the computed angular information (output of the DSP). See Front End Application Note for more details.

<sup>19</sup> The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating 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 that is available on the MLX90316.

<sup>20</sup> The application diagram used is described in the recommended wiring. For detailed information, refer to section Filter in application mode (Section 14.5).

<sup>21</sup> Jitter is defined by  $\pm 3 \sigma$  for 1000 successive acquisitions and the slope of the transfer curve is 100%DC/360 Deg.

### 11. MLX90316 Magnetic Specification

DC Operating Parameters at  $V_{DD} = 5V$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (S, E, K or L).

| Parameter                      | Symbol | Test Conditions | Min   | Typ | Max                | Units  |
|--------------------------------|--------|-----------------|-------|-----|--------------------|--------|
| Magnetic Flux Density          | B      |                 | 20    | 50  | 70 <sup>(23)</sup> | mT     |
| Magnet Temperature Coefficient | TCm    |                 | -2400 |     | 0                  | ppm/°C |

### 12. MLX90316 CPU & Memory Specification

The DSP is based on a 16 bit RISC  $\mu$ Controller. This CPU provides 5 Mips while running at 20 MHz.

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Units |
|-----------|--------|-----------------|-----|-----|-----|-------|
| ROM       |        |                 |     | 10  |     | kB    |
| RAM       |        |                 |     | 256 |     | B     |
| EEPROM    |        |                 |     | 128 |     | B     |

<sup>23</sup> Above 70 mT, the IMC starts saturating yielding to an increase of the linearity error.

### 13. MLX90316 End-User Programmable Items

| Parameter   | Comments                           | Default Values |           |          |          |       |
|-------------|------------------------------------|----------------|-----------|----------|----------|-------|
|             |                                    | -              | SPI       | PPA      | PPD      | # bit |
| Output Mode | Define the output stage mode       | 4              | N/A       | 4        | 7        | 3     |
| PWMPOL1     | PWM Polarity                       | 0              | N/A       | N/A      | 1        | 1     |
| PWM_Freq    | PWM Frequency                      | 1000h          | N/A       | N/A      | 1kHz     | 16    |
| CLOCKWISE   |                                    | 0              | 0         | 0        | 1        | 1     |
| DP          | Discontinuity Point                | 0h             | 0h        | 0h       | 0h       | 15    |
| LNR_S0      | Initial Slope                      | 0h             | N/A       | N/A      | N/A      | 16    |
| LNR_A_X     | AX Coordinate                      | 8000h          | 0         | 0        | 0        | 16    |
| LNR_A_Y     | AY Coordinate                      | 0h             | 0%        | 10%      | 10%      | 16    |
| LNR_A_S     | AS Coordinate                      | 0h             | 100%/360d | 80%/360d | 80%/360d | 16    |
| LNR_B_X     | BX Coordinate                      | FFFFh          | FFFFh     | FFFFh    | FFFFh    | 16    |
| LNR_B_Y     | BY Coordinate                      | FFFFh          | FFFFh     | FFFFh    | FFFFh    | 16    |
| LNR_B_S     | BS Coordinate                      | 0h             | N/A       | N/A      | N/A      | 16    |
| LNR_C_X     | CX Coordinate                      | FFFFh          | FFFFh     | FFFFh    | FFFFh    | 16    |
| LNR_C_Y     | CY Coordinate                      | FFFFh          | FFFFh     | FFFFh    | FFFFh    | 16    |
| LNR_C_S     | CS Coordinate                      | 0h             | N/A       | N/A      | N/A      | 16    |
| CLAMP_HIGH  | Clamping High                      | 8%             | 0%        | 10%      | 10%      | 16    |
| CLAMP_LOW   | Clamping Low                       | 8%             | 100%      | 90%      | 90%      | 16    |
| KD          | Switch Out                         | FFFFh          | FFFFh     | FFFFh    | FFFFh    | 16    |
| KDHYST      | Hysteresis on the Switch Out       | 0              | N/A       | N/A      | N/A      | 8     |
| DEADZONE    |                                    | 0              | 0         | 0        | 0        | 8     |
| FHYST       |                                    | 4              | 0         | 0        | 0        | 8     |
| MELEXISID1  |                                    | MLX            | MLX       | MLX      | MLX      | 16    |
| MELEXISID2  |                                    | MLX            | MLX       | MLX      | MLX      | 16    |
| MELEXISID3  |                                    | MLX            | MLX       | MLX      | MLX      | 16    |
| CUSTOMERID1 |                                    | 1              | 1         | 1        | 1        | 8     |
| CUSTOMERID2 |                                    | 6              | 19        | 16       | 20       | 16    |
| CUSTOMERID3 |                                    | MLX            | MLX       | MLX      | MLX      | 16    |
| HIGHSPEED   |                                    | 0              | 1         | 0        | 1        | 1     |
| FSWAP       |                                    | 1              | 1         | 0        | 1        | 1     |
| FILTER      |                                    | 5              | 0         | 2        | 5        | 8     |
| FILTER A1   | Filter coefficient A1 for FILTER=6 | 6600h          | N/A       | N/A      | N/A      | 16    |
| FILTER A2   | Filter coefficient A2 for FILTER=6 | 2A00h          | N/A       | N/A      | N/A      | 16    |
| ARGC        | Auto Gain at Start Up              | 0              | 1         | 1        | 1        | 1     |
| AUTO_RG     | Automatic Rough Gain Selection     | 0              | 1         | 1        | 1        | 1     |
| RoughGain   |                                    | 9              | 0         | 3        | 0        | 8     |
| RGThresL    |                                    | 0              | 0         | 0        | 0        | 4     |
| RGThresH    |                                    | 15             | 15        | 15       | 15       | 4     |
| EEHAMHOLE   |                                    | 3131h          | 0         | 0        | 0        | 16    |
| RESONFAULT  |                                    | 0              | 1         | 1        | 1        | 2     |
| MLXLOCK     |                                    | 0              | 1         | 1        | 1        | 1     |
| LOCK        |                                    | 0              | 1         | 1        | 1        | 1     |

## 14. Description of End-User Programmable Items

### 14.1. Output Mode

The MLX90316 output type is defined by the Output Mode parameter.

| Parameter          | Value | Description         |
|--------------------|-------|---------------------|
| Analog Output Mode | 2, 4  | Analog Rail-to-Rail |
| PWM Output Mode    | 5     | Low Side (NMOS)     |
|                    | 7     | Push-Pull           |
| Serial             | N/A   | Low Side (NMOS)     |

#### 14.1.1. Analog Output Mode

The Analog Output Mode is a rail-to-rail and ratiometric output with a push-pull output stage configuration allows the use of a pull-up or pull-down resistor.

#### 14.1.2. PWM Output Mode

If one of the PWM Output modes is selected, the output signal is a digital signal with Pulse Width Modulation (PWM).

In mode 5, the output stage is an open drain NMOS transistor (low side), to be used with a pull-up resistor to VDD.

In mode 7, the output stage is a push-pull stage for which Melexis recommends the use of a pull-up resistor to VDD.

The PWM polarity is selected by the PWMPOL1 parameter:

- PWMPOL1 = 0 for a low level at 100%
- PWMPOL1 = 1 for a high level at 100%

The PWM frequency is selected by the PWM\_Freq parameter.

| PWM Frequency Code |                                       |       |       |       |
|--------------------|---------------------------------------|-------|-------|-------|
| Oscillator Mode    | Pulse-Width Modulation Frequency (Hz) |       |       |       |
|                    | 100                                   | 200   | 500   | 1000  |
| Low Speed          | 35000                                 | 17500 | 7000  | 3500  |
| High Speed         | -                                     | 50000 | 20000 | 10000 |

For instance, in Low Speed Mode, set PWM\_Freq = 7000 (decimal) to set the PWM frequency at 500Hz.

#### 14.1.3. Serial Protocol Output Mode

The MLX90316 features a digital Serial Protocol mode. The MLX90316 is considered as a Slave node. See the dedicated Serial Protocol section for a full description (Section 16).



**14.1.4. Switch Out**

| Parameter | Value        | Unit |
|-----------|--------------|------|
| KD        | 0...359.9999 | deg  |
| KDHYST    | 0 ... 1.4    | deg  |

The switch is activated (Sw\_lo) when the digital angle is greater than the value stored in the KD parameter. This angle refers to the internal angular reference linked to the parameter DP and not to the absolute physical 0° angle.

The KDHYST defines the hysteresis amplitude around the Switch point. The switch is actually activated if the digital angle is greater than KD+KDHYST. It is deactivated if the digital angle is less than KD-KDHYST.

The mandatory application diagram to use this feature is depicted in the Figure 8. See section 7 for the electrical characteristic.

If the Switch feature is not used in the application, the output pin needs to be connected to the ground.

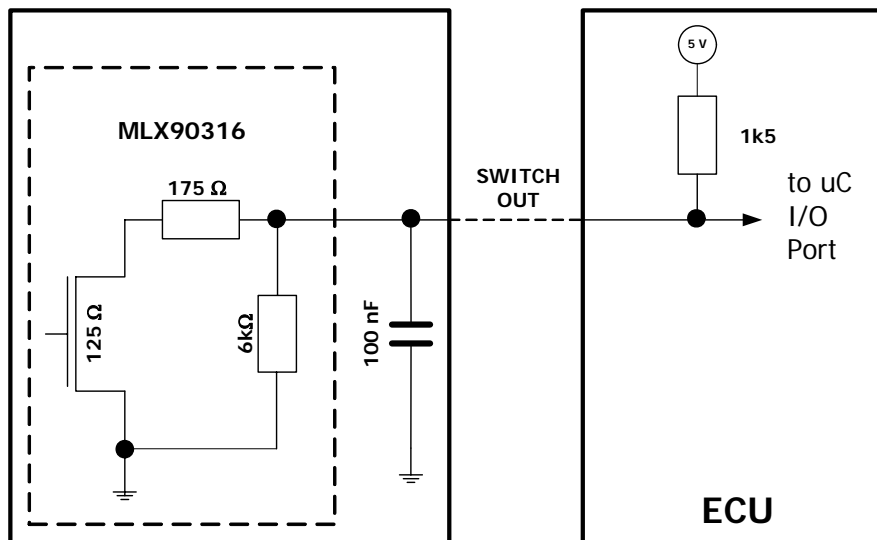


Figure 8 – Application Diagram for the Switch Out

## 14.2. Output Transfer Characteristic

| Parameter                     | Value             | Unit  |
|-------------------------------|-------------------|-------|
| CLOCKWISE                     | 0 → CCW<br>1 → CW |       |
| DP                            | 0 ... 359.9999    | deg   |
| LNR_A_X<br>LNR_B_X<br>LNR_C_X | 0 ... 359.9999    | deg   |
| LNR_A_Y<br>LNR_B_Y<br>LNR_C_Y | 0 ... 100         | %     |
| LNR_S0<br>LNR_A_S<br>LNR_B_S  | 0 ... 17          | %/deg |
| LNR_C_S                       | -17 ... 0 ... 17  | %/deg |
| CLAMP_LOW                     | 0 ... 100         | %     |
| CLAMP_HIGH                    | 0 ... 100         | %     |
| DEADZONE                      | 0 ... 359.9999    | deg   |

### 14.2.1. CLOCKWISE Parameter

The CLOCKWISE parameter defines the magnet rotation direction.

- CCW is defined by the 1-4-5-8 pin order direction for the SOIC8 package and 1-8-9-16 pin order direction for the TSSOP16 package.
- CW is defined by the reverse direction: 8-5-4-1 pin order direction for the SOIC8 and 16-9-8-1 pin order direction for the TSSOP16 package.

Refer to the drawing in the IMC positioning sections (Section 20.3 and 20.6).

### 14.2.2. Discontinuity Point (or Zero Degree Point)

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

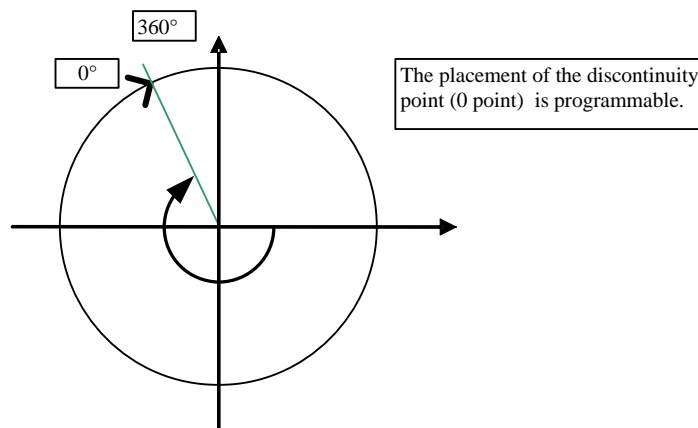


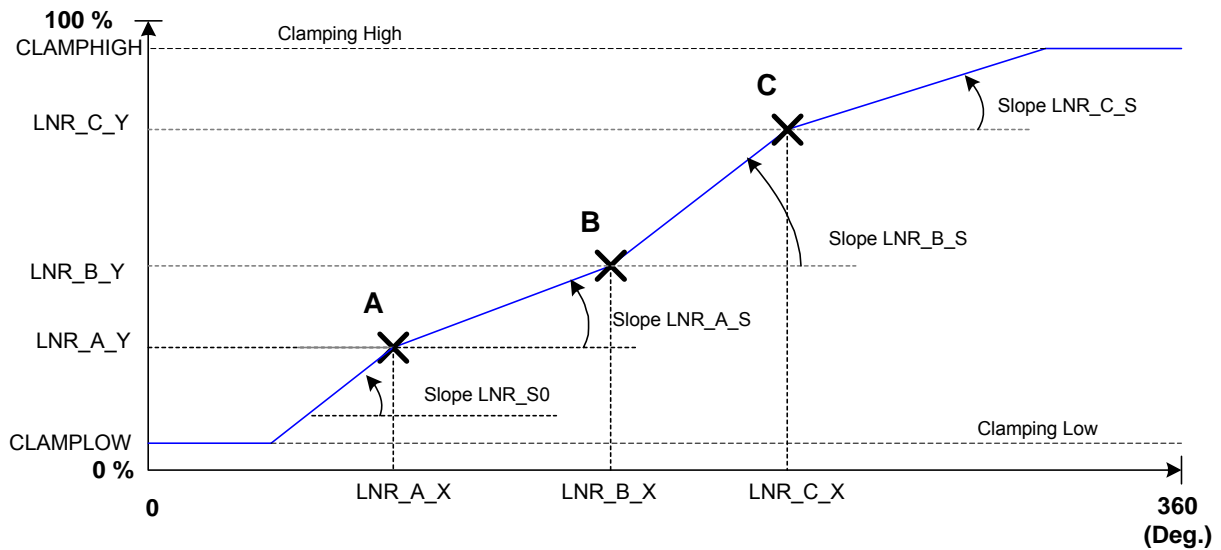
Figure 9 - Discontinuity Point Positioning

### 14.2.3. 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 MLX90316 transfer function from the digital angle value to the output voltage is described by the drawing below. Six segments can be programmed but the clamping levels are necessarily flat.

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



### 14.2.4. CLAMPING Parameters

The clamping levels are two independent values to limit the output voltage range. The CLAMP\_LOW parameter adjusts the minimum output voltage level. The CLAMP\_HIGH parameter sets the maximum output voltage level. Both parameters have 16 bits of adjustment. In analog mode, the resolution will be limited by the D/A converter (12 bits) to 0.024%VDD. In PWM mode, the resolution will be 0.024%DC. In SPI mode, the resolution is 14bits or 0.022deg over 360deg.

### 14.2.5. DEADZONE Parameter

The dead zone is defined as the angle window between 0 and 359.9999.

When the digital angle lies in this zone, the IC is in fault mode (RESONFAULT must be set to "1" – See 14.6.1).

## 14.3. Identification

| Parameter   | Value       | Unit |
|-------------|-------------|------|
| MELEXSID1   | 0 ... 65535 |      |
| MELEXSID2   | 0 ... 65535 |      |
| MELEXSID3   | 0 ... 65535 |      |
| CUSTOMERID1 | 0 ... 255   |      |
| CUSTOMERID2 | 0 ... 65535 |      |
| CUSTOMERID3 | 0 ... 65535 |      |

Identification number: 40 bits freely useable by Customer for traceability purpose.

### 14.4. Sensor Front-End

| Parameter | Value                          | Unit |
|-----------|--------------------------------|------|
| HIGHSPEED | 0 = Slow mode<br>1 = Fast mode |      |
| ARGC      | 0 = disable<br>1 = enable      |      |
| AUTO_RG   | 0 = disable<br>1 = enable      |      |
| RoughGain | 0 ... 15                       |      |
| RGThresL  | 0 ... 15                       |      |
| RGThresh  | 0 ... 15                       |      |

#### 14.4.1. HIGHSPEED Parameter

The HIGHSPEED parameter defines the main frequency for the DSP.

- HIGHSPEED = 0 selects the Slow mode with a 7 MHz master clock.
- HIGHSPEED = 1 selects the Fast mode with a 20 MHz master clock.

For better noise performance, the Slow Mode must be enabled.

#### 14.4.2. ARGC, AUTO\_RG, RoughGain Parameters

AUTO\_RG and ARGC parameters enable the automatic gain control (AGC) of the analog chain. The AGC loop is based on

$$(V_x)^2 + (V_y)^2 = (\text{Amplitude})^2 = (\text{Radius})^2$$

and it targets an amplitude of 90% of the ADC input span.

At Start-Up phase, the gain stored in the parameter RoughGain is always used. Depending of the AUTO\_RG and ARGC settings, the AGC regulation acts as follow:

- If ARGC is set, the regulation proceeds by jump to reach the target gain. Note that this regulation is only valid if the starting gain does not saturate the ADC. Melexis recommendation is to use  $\text{RoughGain} \leq 3$  if  $\text{ARGC}=1$ .
- If ARGC is "0" and AUTO\_RG is set to "1", the regulation adapts every cycle by one gain code the current gain to reach the 90% ADC span target. Note that if the value of RoughGain is too far from the actual gain, the chip will enter the normal operating mode (after the Start-Up phase) with an incorrect gain which will cause the device to go in diagnostic low (field too low/field too high – See section 15).
- If ARGC and AUTO\_RG are "0", the AGC regulation is off and the gain used is the value stored in the parameter RoughGain. Melexis does not advise the use of this mode.

The parameter AUTO\_RG activates the automatic regulation during normal operation of the device as background task.

Melexis strongly recommend to set  $\text{ARGC} = "1"$ ,  $\text{AUTO\_RG} = "1"$  and  $\text{RoughGain} \leq 3$  for all types of application. If the magnetic specifications of the application are well known and under control, the appropriate RoughGain can also be programmed with ARGC set to "0" and AUTO\_RG to "1".

Please note that the angular errors listed in the section 10 are only valid if the AUTO\_RG is activated. AUTO\_RG avoids also the saturation of the analog chain and the associated linearity error.

The current gain (RG) can be read out with the PTC-04 and gives a rough indication of the applied magnetic flux density (Amplitude).

### 14.4.3. RGThresL, RGThresH Parameters

RGThresL & RGThresH define the boundaries within the gain setting (Rough Gain) is allowed to vary. Outside this range, the output is set in diagnostic low.

### 14.5. FILTER

| Parameter | Value                | Unit |
|-----------|----------------------|------|
| FHYST     | 0 ... 11 ; step 0.04 | deg  |
| FILTER    | 0... 6               |      |
| FSWAP     | 0                    |      |
|           | 1                    |      |

The MLX90316 includes 3 types of filters:

- Hysteresis Filter: programmable by the FHYST parameter
- Low Pass FIR Filters controlled with the Filter parameter
- Low Pass IIR Filter controlled with the Filter parameter and the coefficients FILTER A1 and FILTER A2

Note: if the parameter FSWAP is set to "1", the filtering is active on the digital angle. If set to "0", the filtering is active on the output transfer function.

#### 14.5.1. Hysteresis Filter

The FHYST parameter is a hysteresis filter. The output value of the IC is not updated when the digital step is smaller than the programmed FHYST parameter value. The output value is modified when the increment is bigger than the hysteresis. The hysteresis filter reduces therefore the resolution to a level compatible with the internal noise of the IC. The hysteresis must be programmed to a value close to the noise level.

Please note that for the programmable version, the FHYST parameter is set to 4 by default. If you do not wish this feature, please set it to "0".

#### 14.5.2. FIR Filters

The MLX90316 features 6 FIR filter modes controlled with Filter = 0...5. The transfer function is described below:

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

The characteristics of the filters no 0 to 5 is given in the Table 1.

| Filter No (j)             | 0         | 1                       | 2      | 3      | 4      | 5      |
|---------------------------|-----------|-------------------------|--------|--------|--------|--------|
| Type                      | Disable   | Finite Impulse Response |        |        |        |        |
| Coefficients $a_0... a_5$ | N/A       | 110000                  | 121000 | 133100 | 111100 | 122210 |
| Title                     | No Filter | Extra Light             |        | Light  |        |        |
| 90% Response Time         | 1         | 2                       | 3      | 4      | 4      | 5      |
| 99% Response Time         | 1         | 2                       | 3      | 4      | 4      | 5      |
| Efficiency RMS (dB)       | 0         | 2.9                     | 4.0    | 4.7    | 5.6    | 6.2    |
| Efficiency P2P (dB)       | 0         | 2.9                     | 3.6    | 5.0    | 6.1    | 7.0    |

Table 1 - FIR Filters Selection Table

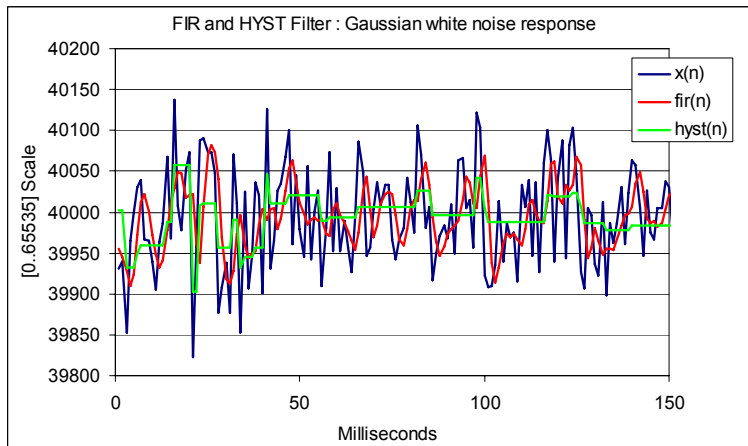
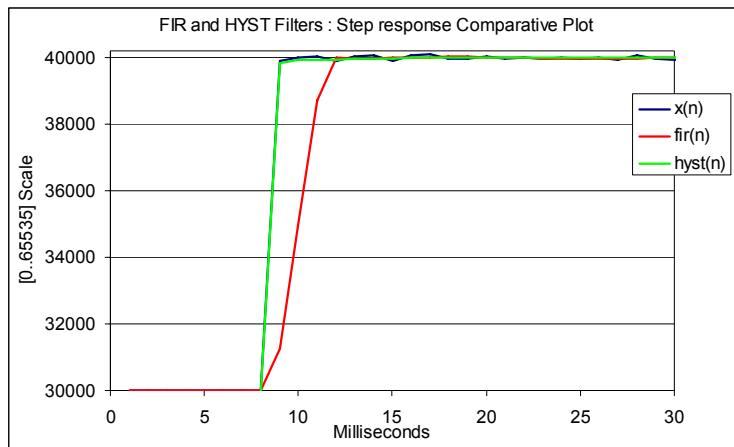


Figure 10 - Step Response and Noise Response for FIR (No 3) and FHYST=10

### 14.5.3. IIR Filters

The IIR Filter is enabled with Filter = 6. The diagram of the IIR Filter implemented in the MLX90316 is given in Figure 11. Only the parameter A1 and A2 are configurable (See Table 2).

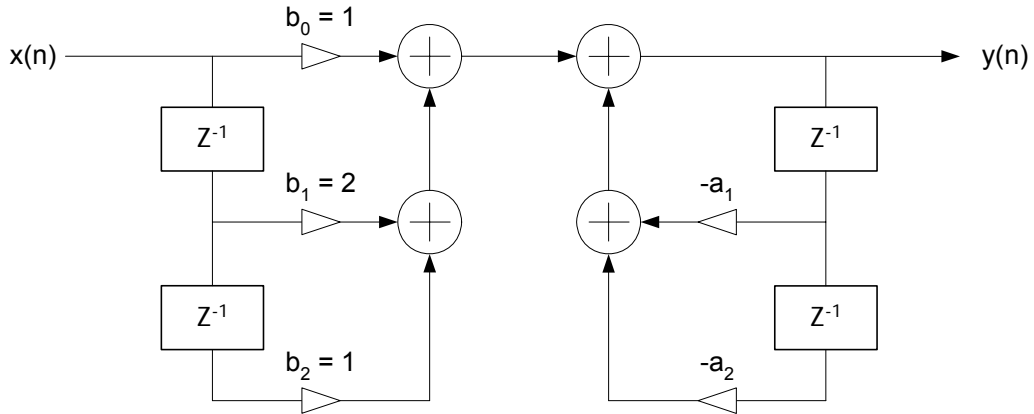


Figure 11 - IIR Diagram

| Filter No           | 6   |       |       |       |       |       |
|---------------------|---|-------|-------|-------|-------|-------|
| Type                | 2 <sup>nd</sup> Order Infinite Impulse Response (IIR) |       |       |       |       |       |
| Title               | Medium & Strong                                       |       |       |       |       |       |
| 90% Response Time   | 11  | 16    | 26    | 40    | 52    | 100   |
| Efficiency RMS (dB) | 9.9   | 11.4  | 13.6  | 15.3  | 16.2  | >20   |
| Efficiency P2P (dB) | 12.9  | 14.6  | 17.1  | 18.8  | 20    | >20   |
| Coefficient A1      | 26112   | 28160 | 29120 | 30208 | 31296 | 31784 |
| Coefficient A2      | 10752   | 12288 | 12992 | 13952 | 14976 | 15412 |

Table 2 - IIR Filter Selection Table

The Figure 12 shows the response of the filter to a Gaussian noise with default coefficient A1 and A2.

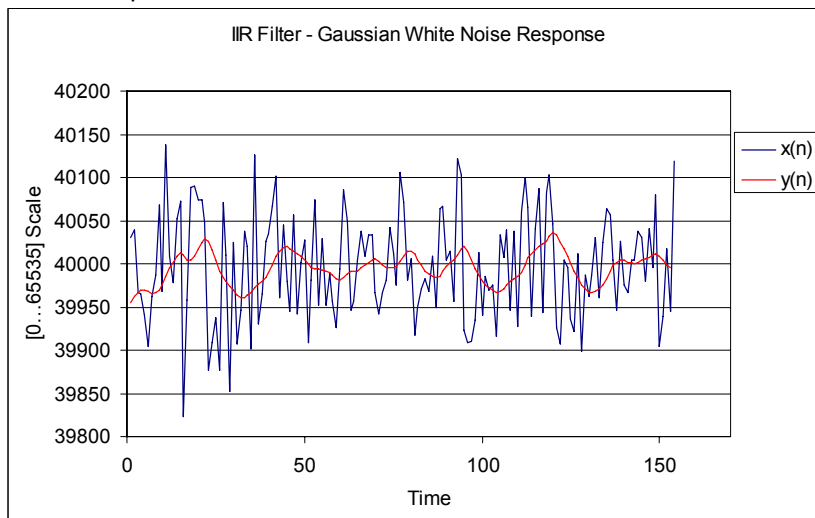


Figure 12 - Noise Response for the IIR Filter

### 14.6. Programmable Diagnostic Settings

| Parameter  | Value | Unit |
|------------|-------|------|
| RESONFAULT | 0     |      |
|            | 1     |      |
| EEHAMHOLE  | 0     |      |
|            | 3131h |      |

#### 14.6.1. RESONFAULT Parameter

This RESONFAULT parameter disables the soft reset when a fault is detected by the CPU when the parameter is set to 1. By default, the parameter is set to “0” but it is recommended to set it to “1” to activate the self diagnostic modes (See section 15).

Note that in the User Interface (MLX90316UI), the RESONFAULT is split in two bits:

- DRESONFAULT: disable the reset in case of a fault.
- DOUTINFALT: disable output in diagnostic low in case of fault.

#### 14.6.2. EEHAMHOLE Parameter

The EEHAMHOLE parameter disables the memory recovery (Hamming code) check when a fault is detected by the CRC when it is equal to 3131h. By default the parameter is set to 0 (enable memory recovery).

### 14.7. Lock

| Parameter | Value | Unit |
|-----------|-------|------|
| MLXLOCK   | 0     |      |
|           | 1     |      |
| LOCK      | 0     |      |
|           | 1     |      |

#### 14.7.1. MLXLOCK Parameter

MLXLOCK locks all the parameters set by Melexis.

#### 14.7.2. LOCK Parameter

LOCK locks all the parameters set by the user. Once the lock is enabled, it is not possible to change the EEPROM values anymore.

Note that the lock bit should be set by the solver function “MemLock”.



### 15. MLX90316 Self Diagnostic

The MLX90316 provides numerous self-diagnostic features. 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”).

|  | Action  | Effect on Outputs              | Remark  |
|--|---|--------------------------------|---|
| ROM CRC Error at start up (64 words including Intelligent Watch Dog - IWD) | CPU Reset <sup>(24)</sup>   | Diagnostic low <sup>(25)</sup> | All the outputs are already in Diagnostic low - (start-up)    |
| ROM CRC Error (Operation - Background task)                                | Enter Endless Loop:<br>- Progress (watchdog Acknowledge)<br>- Set Outputs in Diagnostic low | Immediate Diagnostic low       |   |
| RAM Test Fail (Start up)   | CPU Reset   | Diagnostic low                 | All the outputs are already in Diagnostic low (start-up)      |
| Calibration Data CRC Error (Start-Up)                                      | Hamming Code Recovery   |                                | Start-Up Time is increased by 3 ms if successful recovery     |
| Hamming Code Recovery Error (Start-Up)                                     | CPU Reset   | Immediate Diagnostic low       | See 14.6.2  |
| Calibration Data CRC Error (Operation - Background)                        | CPU Reset   | Immediate Diagnostic low       |   |
| Dead Zone  | Set Outputs in Diagnostic low. Normal Operation until the “dead zone” is left.              | Immediate Diagnostic low       | Immediate recovery if the “dead zone” is left                 |
| ADC Clipping (ADC Output is 0000h or 7FFFh)                                | Set Outputs in Diagnostic low Normal mode and CPU Reset If recovery                         | Immediate Diagnostic low       |   |
| Radius Overflow ( > 100% ) or Radius Underflow ( < 50% )                   | Set Outputs in Diagnostic low Normal mode and CPU Reset If recovery                         | Immediate Diagnostic low       | (50% - 100%)<br>No magnet / field too high<br>See also 14.4.2 |
| Fine Gain Clipping (FG < 0d or > 63d)                                      | Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery                        | Immediate Diagnostic low       |   |
| Rough Offset Clipping (RO is < 0d or > 127d)                               | Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery                        | Immediate Diagnostic low       |   |
| Rough Gain Clipping (RG < RGTHRESLOW or RG > RGTHRESHIGH)                  | Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery                        | Immediate Diagnostic low       | See also 14.4.2   |
| DAC Monitor (Digital to Analog converter)                                  | Set Outputs in Diagnostic low. Normal Mode with immediate recovery without CPU Reset        | Immediate Diagnostic low       |   |
| <i>MLX90316 Fault Mode continues...</i>                                    |   |                                |   |

<sup>24</sup> CPU reset means

1. Core Reset (same as Power-On-Reset). It induces a typical start up time.
2. Periphery Reset (same as Power-On-Reset)
3. Fault Flag/Status Lost
4. The reset can be disabled by clearing the RESONFAULT bit (See 14.6.1)

<sup>25</sup> Refer to section 7 for the Diagnostic Output Level specifications

| ...MLX90316 Fault Mode                            |  |  |   |
|---|--|--|---|
| Fault Mode  | Action   | Effect on Outputs  | Remark  |
| ADC Monitor (Analog to Digital Converter)         | Set Outputs in Diagnostic low. Normal Mode with immediate recovery without CPU Reset       | Immediate Diagnostic low   | ADC Inputs are Shorted  |
| Undervoltage Mode                                 | At Start-Up, wait Until VDD > 3V.<br><br>During operation, CPU Reset after 3 ms debouncing | - VDD < POR level => Outputs high impedance<br><br>- POR level < VDD < 3 V => Outputs in Diagnostic low. |   |
| Firmware Flow Error                               | CPU Reset  | Immediate Diagnostic low   | Intelligent Watchdog (Observer)   |
| Read/Write Access out of physical memory          | CPU Reset  | Immediate Diagnostic low   | 100% Hardware detection   |
| Write Access to protected area (IO and RAM Words) | CPU Reset  | Immediate Diagnostic low   | 100% Hardware detection   |
| Unauthorized entry in "SYSTEM" Mode               | CPU Reset  | Immediate Diagnostic low   | 100% Hardware detection   |
| VDD > 7 V   | Set Output High Impedance (Analog)   | Pull down resistive load => Diag. Low<br>Pull up resistive load => Diag. High <sup>(25)</sup>            | 100% Hardware detection   |
| VDD > 9.4 V                                       | IC is switched off (internal supply)<br>CPU Reset on recovery                              | Pull down resistive load => Diag. Low<br>Pull up resistive load => Diag. High                            | 100% Hardware detection   |
| Broken VSS <sup>(26)</sup>                        | CPU Reset on recovery  | Pull down resistive load => Diag. Low<br>Pull up resistive load => Diag. High                            | 100% Hardware detection.<br>Pull down load ≤ 10 kΩ to meet Diag Low spec:<br>- < 2% VDD (temperature suffix S and E)<br>- < 4% VDD (temperature suffix K)<br>- contact Melexis for temperature suffix L |
| Broken VDD <sup>(26)</sup>                        | CPU Reset on recovery  | Pull down resistive load => Diag. Low<br>Pull up resistive load => Diag. High                            | No valid diagnostic for VPULLUP = VDD.<br><br>Pull up load (≤ 10kΩ) to VPULLUP > 8 V to meet Diag Hi spec > 96% Vdd.  |

<sup>26</sup> Not Valid for SPI Version

## **16. Serial Protocol**

### **16.1. Introduction**

The MLX90316 features a digital Serial Protocol mode. The MLX90316 is considered as a Slave node. The serial protocol of the MLX90316 is a three wires protocol (/SS, SCLK, MOSI-MISO):

- /SS pin is a 5 V tolerant digital input
- SCLK pin is a 5 V tolerant digital input
- MOSI-MISO pin is a 5 V tolerant open drain digital input/output

The basic knowledge of the standard SPI specification is required for the good understanding of the present section.

### **16.2. SERIAL PROTOCOL Mode**

- CPHA = 1 → even clock changes are used to sample the data
- CPOL = 0 → active-Hi clock

The positive going edge shifts a bit to the Slave's output stage and the negative going edge samples the bit at the Master's input stage.

### **16.3. MOSI (Master Out Slave In)**

The Master sends a command to the Slave to get the angle information.

### **16.4. MISO (Master In Slave Out)**

The MISO of the slave is an open-collector stage. Due to the capacitive load (TBD) a >1 kΩ pull-up is used for the recessive high level (in fast mode). Note that MOSI and MISO use the same physical pin of the MLX90316.

### **16.5. /SS (Slave Select)**

The /SS pin enables a frame transfer (if CPHA = 1). It allows a re-synchronization between Slave and Master in case of communication error.

### **16.6. Master Start-Up**

/SS, SCLK, MISO can be undefined during the Master start-up as long as the Slave is re-synchronized before the first frame transfer.

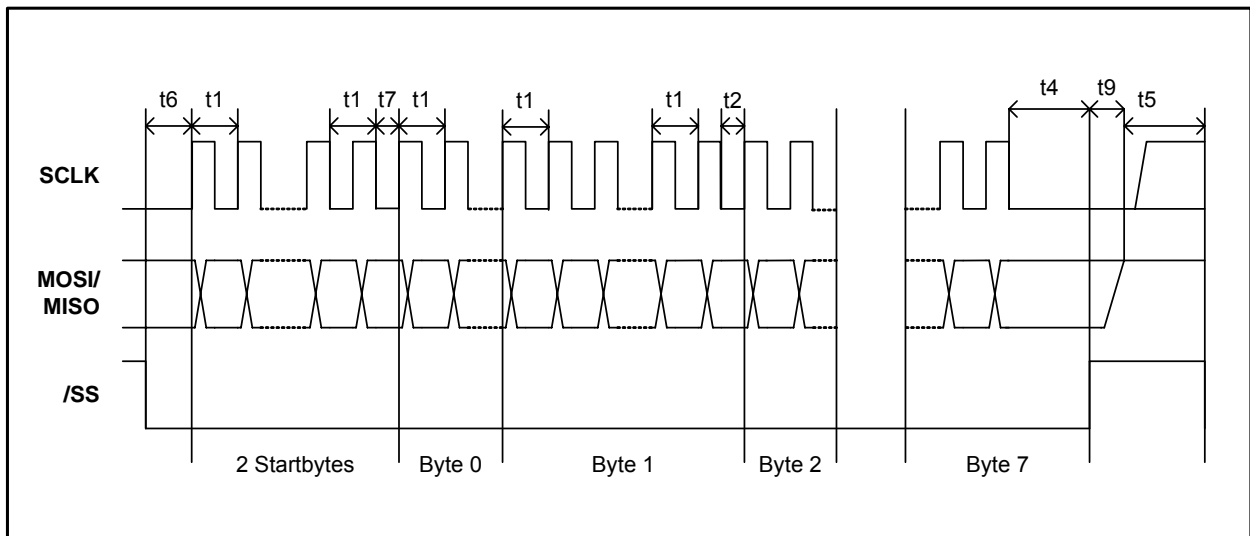
### **16.7. Slave Start-Up**

The slave start-up (after power-up or an internal failure) takes 16 ms. Within this time /SS and SCLK is ignored by the Slave. The first frame can therefore be sent after 16 ms. MISO is Hi-Z (i.e. Hi-Impedance) until the Slave is selected by its /SS input. MLX90316 will cope with any signal from the Master while starting up.

### 16.8. Timing

To synchronize communication, the Master deactivates /SS high for at least  $t_5$  (1.5 ms). In this case, the Slave will be ready to receive a new frame. The Master can re-synchronize at any time, even in the middle of a byte transfer.

Note: Any time shorter than  $t_5$  leads to an undefined frame state, because the Slave may or may not have seen /SS inactive.



| Timings              | Min <sup>(27)</sup>         | Max             | Remarks  |
|----------------------|-----------------------------|-----------------|--|
| t1                   | 2.3 $\mu$ s / 6.9 $\mu$ s   | -               | No capacitive load on MISO.<br>t1 is the minimum clock period for any bits within a byte.      |
| t2                   | 12.5 $\mu$ s / 37.5 $\mu$ s | -               | t2 the minimum time between any other byte   |
| t4                   | 2.3 $\mu$ s / 6.9 $\mu$ s   | -               | Time between last clock and /SS=high=chip de-selection   |
| t5                   | 300 $\mu$ s / 1500 $\mu$ s  | -               | Minimum /SS = Hi time where it's guaranteed that a frame re-synchronizations will be started.  |
| t5                   | 0 $\mu$ s                   | -               | Maximum /SS = Hi time where it's guaranteed that NO frame re-synchronizations will be started. |
| t6                   | 2.3 $\mu$ s / 6.9 $\mu$ s   | -               | The time t6 defines the minimum time between /SS = Lo and the first clock edge                 |
| t7                   | 15 $\mu$ s / 45 $\mu$ s     | -               | t7 is the minimum time between the StartByte and the Byte0                                     |
| t9                   | -                           | <1 $\mu$ s      | Maximum time between /SS = Hi and MISO Bus High-Impedance                                      |
| T <sub>StartUp</sub> | -                           | < 10 ms / 16 ms | Minimum time between reset-inactive and any master signal change                               |

<sup>27</sup> Timings shown for oscillator base frequency of 20MHz (Fast Mode) / 7 MHz (Slow Mode)

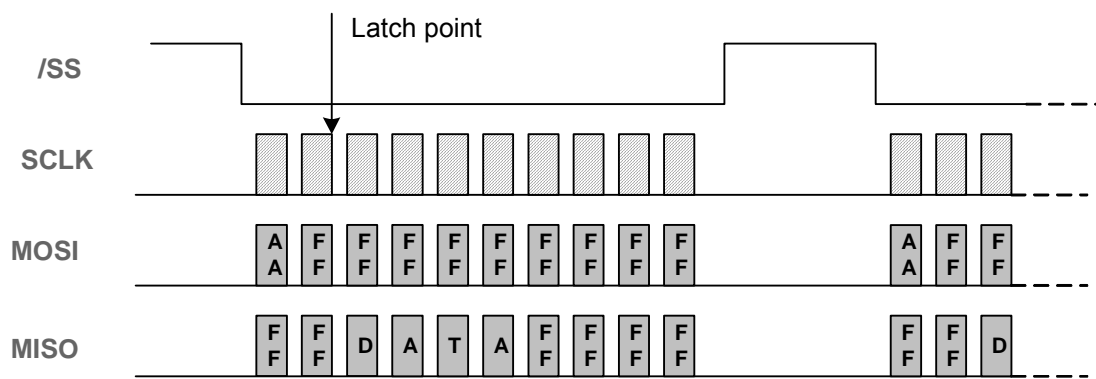
### 16.9. Slave Reset

On internal soft failures the Slave resets after 1 second or after an (error) frame is sent. On internal hard failures the Slave resets itself. In that case, the Serial Protocol will not come up. The serial protocol link is enabled only after the completion of the first synchronization (the Master deactivates /SS for at least  $t_5$ ).

### 16.10. Frame Layer

#### 16.10.1. Command Device Mechanism

Before each transmission of a data frame, the Master should send a byte AAh to enable a frame transfer. The latch point for the angle measurement is at the last clock before the first data frame byte.



Timing diagram

#### 16.10.2. Data Frame Structure

A data frame consists of 10 bytes:

- 2 start bytes (AAh followed by FFh)
- 2 data bytes (DATA16 – most significant byte first)
- 2 inverted data bytes (/DATA16 - most significant byte first)
- 4 all-Hi bytes

The Master should send AAh (55h in case of inverting transistor) followed by 9 bytes FFh. The Slave will answer with two bytes FFh followed by 4 data bytes and 4 bytes FFh.

#### 16.10.3. Timing

There are no timing limits for frames: a frame transmission could be initiated at any time. There is no inter-frame time defined.

### 16.10.4. Data Structure

The DATA16 could be a valid angle, or an error condition. The two meanings are distinguished by the LSB.

DATA16: Angle  $A[13:0]$  with  $(\text{Angle Span})/2^{14}$

| Most Significant Byte |     |     |     |    |    |    |     | Less Significant Byte |    |    |    |    |    |   |     |
|-----------------------|-----|-----|-----|----|----|----|-----|-----------------------|----|----|----|----|----|---|-----|
| MSB                   |     |     |     |    |    |    | LSB | MSB                   |    |    |    |    |    |   | LSB |
| A13                   | A12 | A11 | A10 | A9 | A8 | A7 | A6  | A5                    | A4 | A3 | A2 | A1 | A0 | 0 | 1   |

DATA16: Error

| Most Significant Byte |     |     |     |     |     |    |     | Less Significant Byte |    |    |    |    |    |    |     |
|-----------------------|-----|-----|-----|-----|-----|----|-----|-----------------------|----|----|----|----|----|----|-----|
| MSB                   |     |     |     |     |     |    | LSB | MSB                   |    |    |    |    |    |    | LSB |
| E15                   | E14 | E13 | E12 | E11 | E10 | E9 | E8  | E7                    | E6 | E5 | E4 | E3 | E2 | E1 | E0  |

| BIT | NAME         |   |
|-----|--------------|---|
| E0  | 0            |   |
| E1  | 1            |   |
| E2  | F_ADCMONITOR | ADC Failure   |
| E3  | F_ADCSATURA  | ADC Saturation (Electrical failure or field too strong)                   |
| E4  | F_RGTOOLOW   | Analog Gain Below Trimmed Threshold<br>(Likely reason : field too weak)   |
| E5  | F_MAGTOOLOW  | Magnetic Field Too Weak   |
| E6  | F_MAGTOOHIGH | Magnetic Field Too Strong   |
| E7  | F_RGTOOHIGH  | Analog Gain Above Trimmed Threshold<br>(Likely reason : field too strong) |
| E8  | F_FGCLAMP    | Never occurring in serial protocol  |
| E9  | F_ROCLAMP    | Analog Chain Rough Offset Compensation : Clipping                         |
| E10 | F_MT7V       | Device Supply VDD Greater than 7V   |
| E11 | -            |   |
| E12 | -            |   |
| E13 | -            |   |
| E14 | F_DACMONITOR | Never occurring in serial protocol  |
| E15 | -            |   |

### 16.10.5. Angle Calculation

All communication timing is independent (asynchronous) of the angle data processing. The angle is calculated continuously by the Slave:

- Slow Mode: every 1.5 ms at most.
- Fast Mode: every 350  $\mu$ s at most.

The last angle calculated is hold to be read by the Master at any time. Only valid angles are transferred by the Slave, because any internal failure of the Slave will lead to a soft reset.

### 16.10.6. Error Handling

In case of any errors listed in section 16.10.4, the Serial protocol will be initialized and the error condition can be read by the master. The slave will perform a soft reset once the error frame is sent.

In case of any other errors (ROM CRC error, EEPROM CRC error, RAM check error, intelligent watchdog error...) the Slave's serial protocol is not initialized. The MOSI/MISO pin will stay Hi-impedant (no error frames are sent).

## 17. Recommended Application Diagrams

### 17.1. Analog Output Wiring with the MLX90316 in SOIC Package

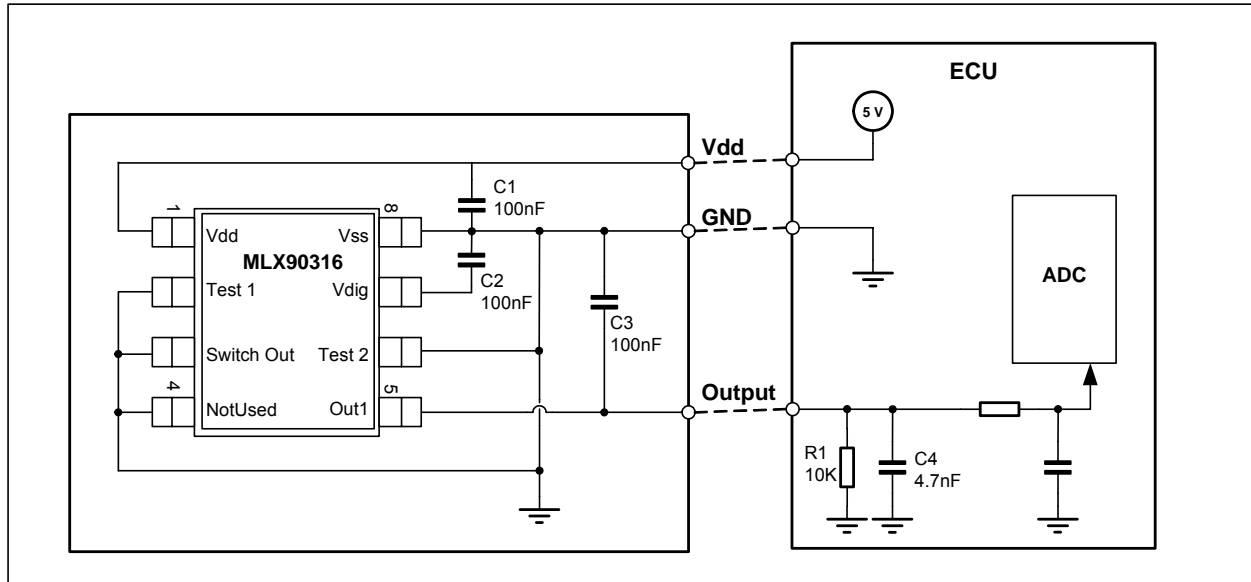


Figure 13 – Recommended wiring for the MLX90316 in SOIC8 package<sup>(28)</sup>.

### 17.2. Analog Output Wiring with the MLX90316 in TSSOP Package

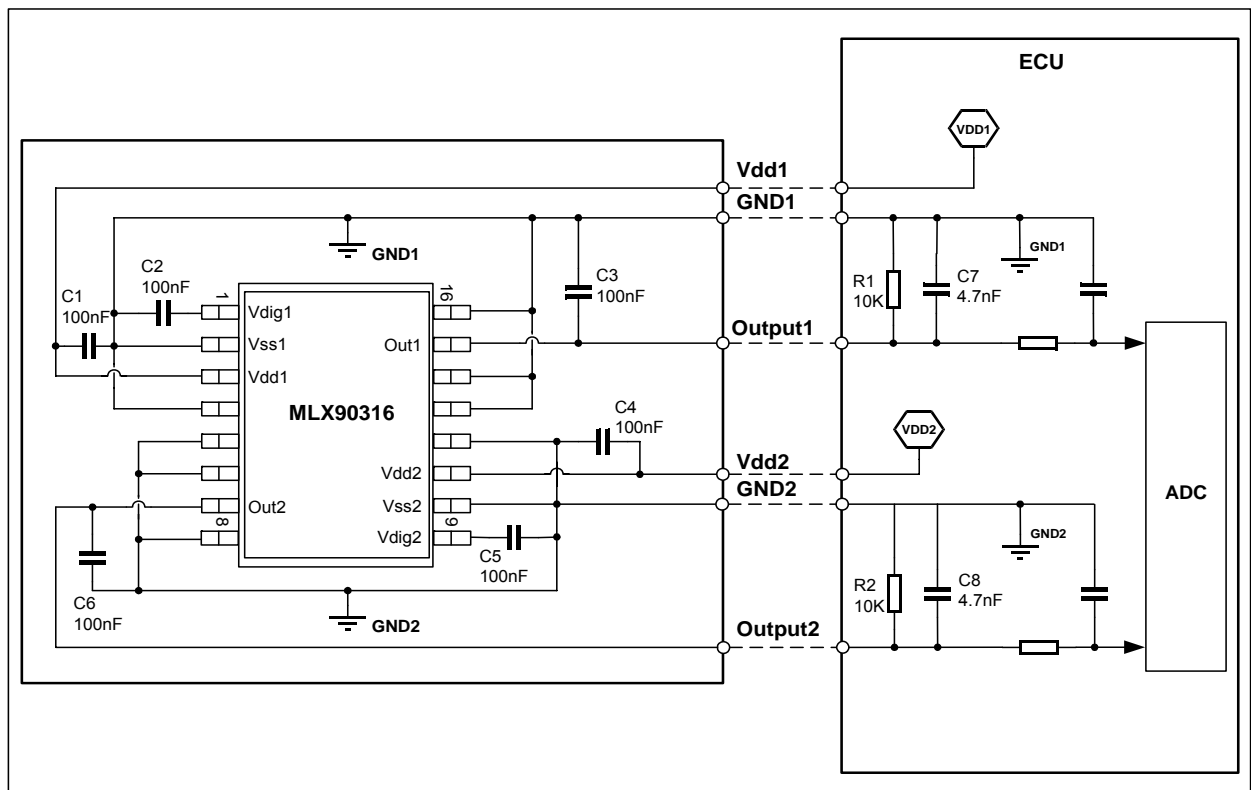


Figure 14 – Recommended wiring for the MLX90316 in TSSOP16 package (dual die).

<sup>28</sup> See section 14.1.4 if the Switch Output feature is used.

**17.3. PWM Low Side Output Wiring**

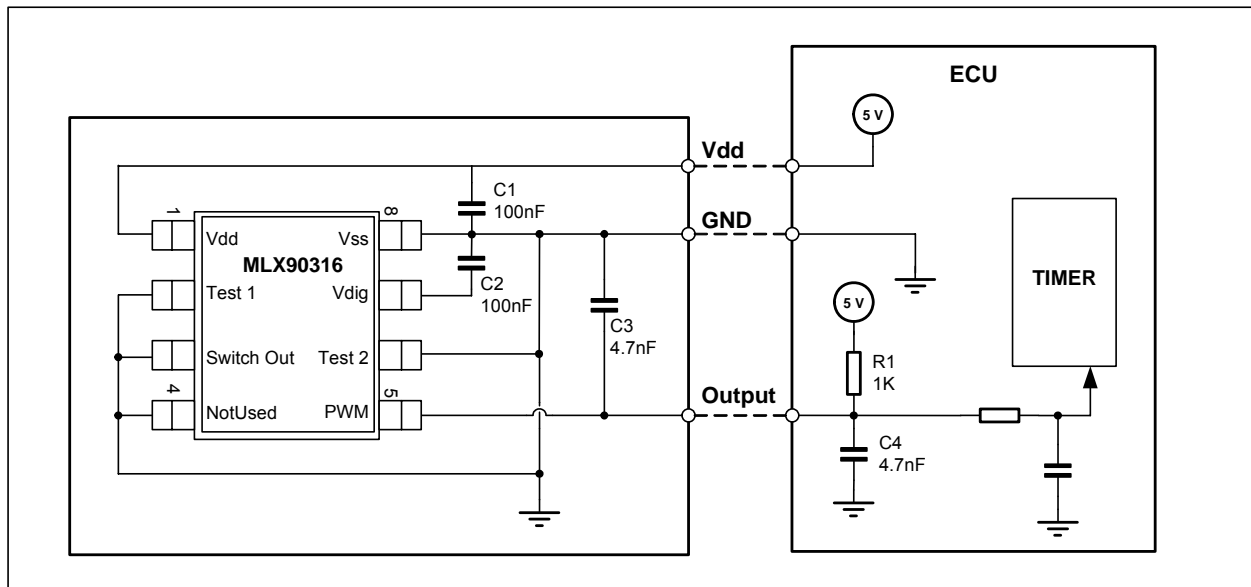


Figure 15 – Recommended wiring for a PWM Low Side Output configuration<sup>(29)</sup>.

**17.4. Serial Protocol**

Generic schematics for single slave and dual slave applications are described.

**17.4.1. SPI Version – Single Die**

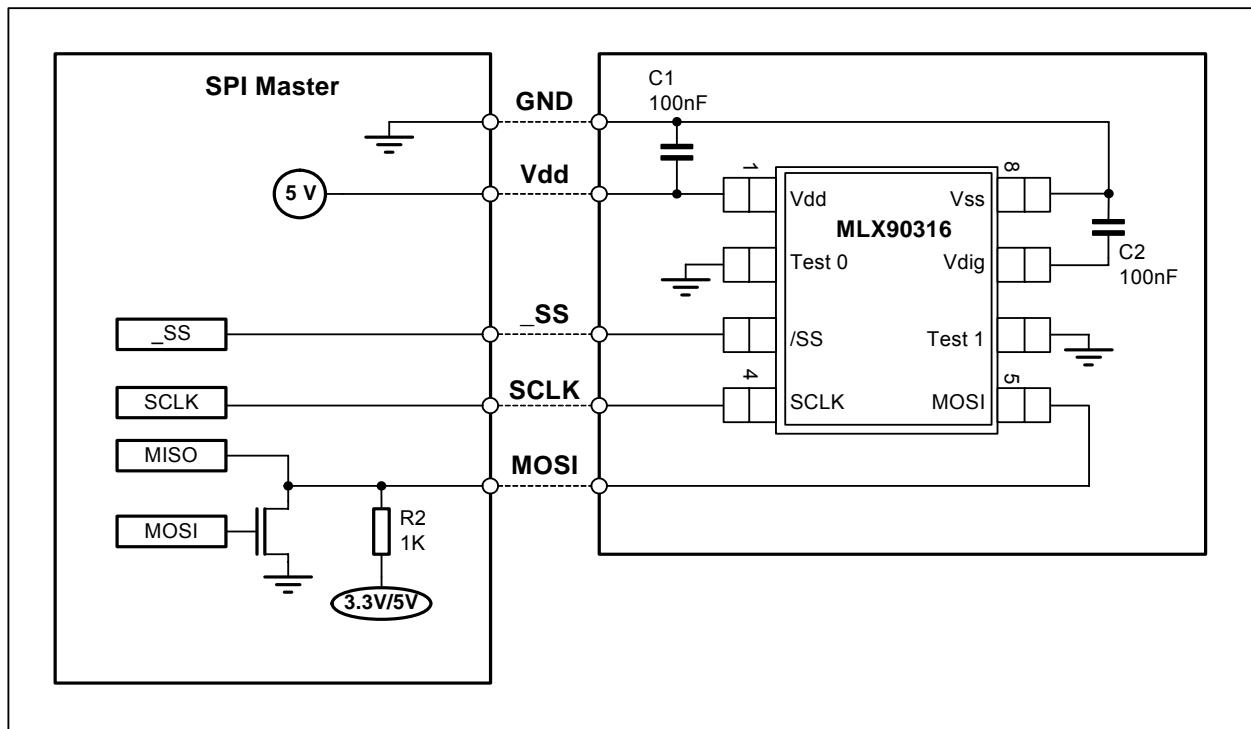


Figure 16 – MLX90316 SPI Version – Single Die – Application Diagram

<sup>29</sup> See section 14.1.4 if the Switch Output feature is used.



17.4.2. SPI Version – Dual Die

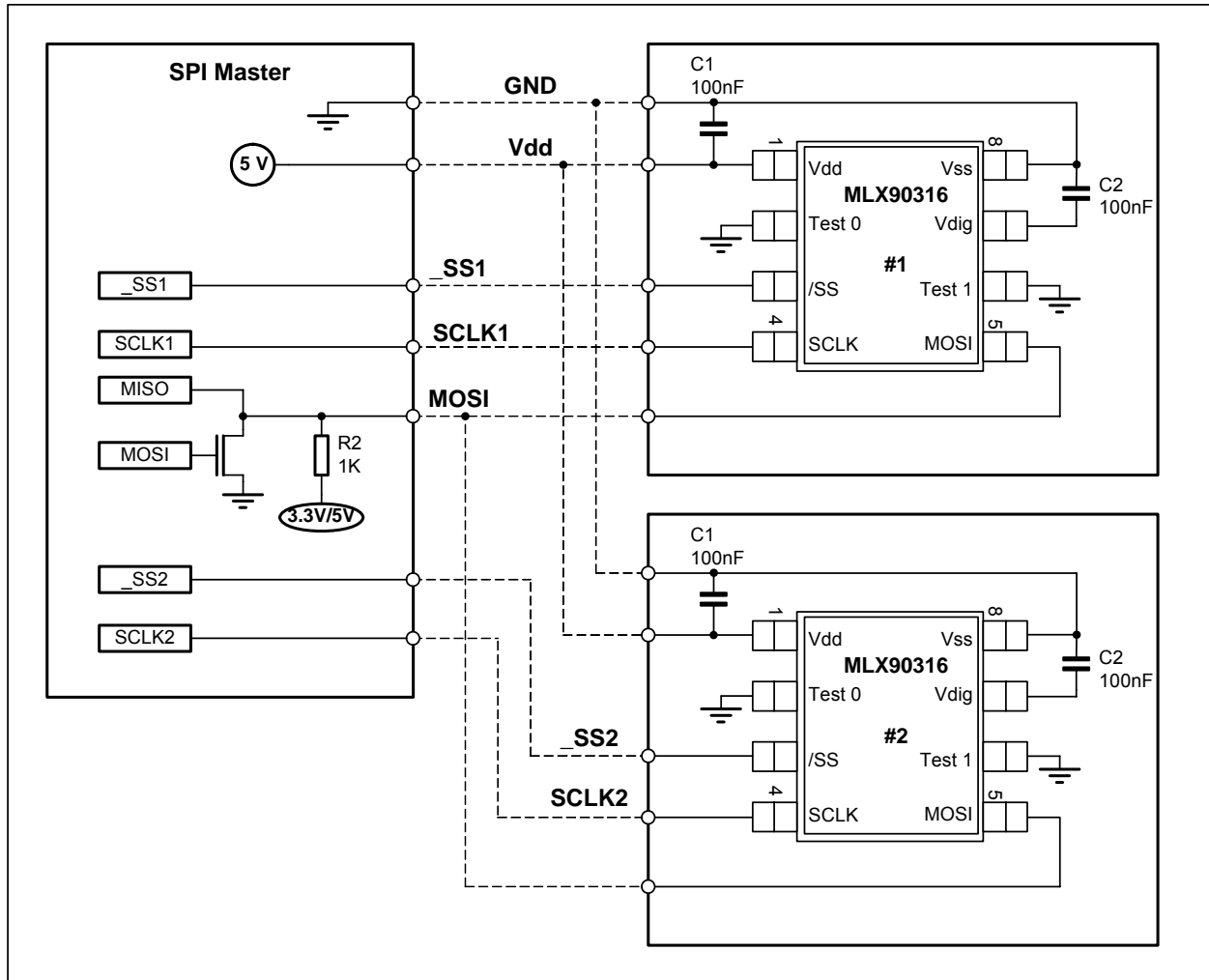


Figure 17 – MLX90316 SPI Version – Dual Die – Application Diagram

### 17.4.3. Non SPI Version (Standard Version)

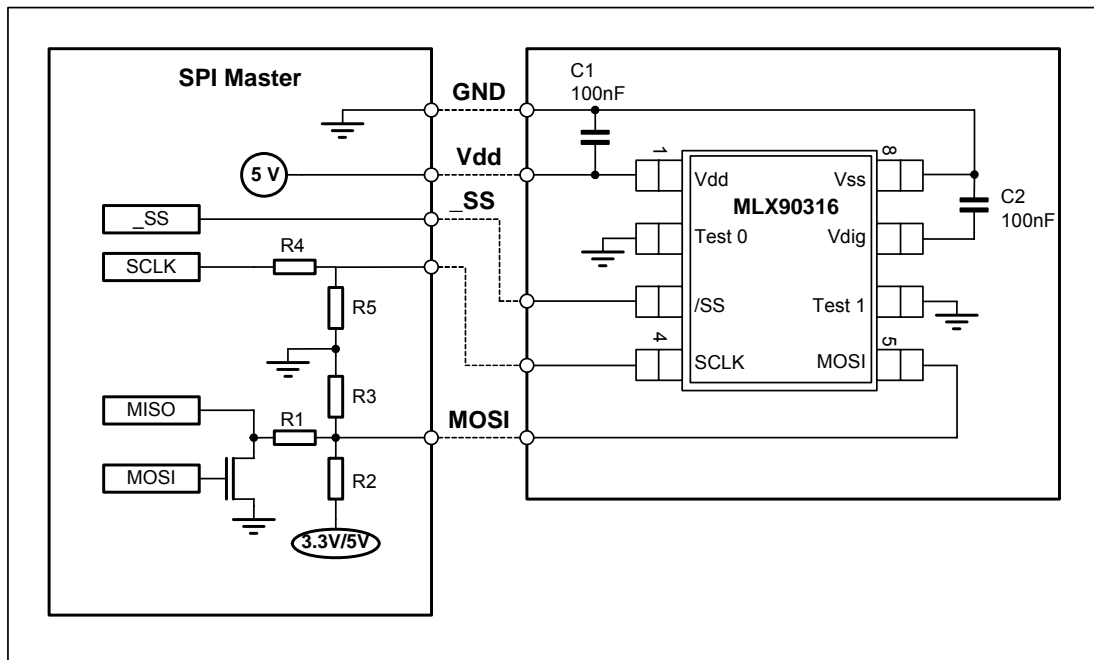


Figure 18 – MLX90316 – Single Die – Serial Protocol Mode

| Application Type                               | $\mu$ Ctrl Supply (V) | Pull-up Supply (V) | 90316 Supply (V) | R1 ( $\Omega$ ) | R2 ( $\Omega$ ) | R3 ( $\Omega$ ) | R4 ( $\Omega$ ) | R5 ( $\Omega$ ) | MOS Type |
|--|-----------------------|--------------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|----------|
| 5V $\mu$ Ctrl w/o O.D. w/o 3.3V                | 5V                    | 5V                 | 5V               | 100             | 1000            | 20,000          | 1000            | 20,000          | BS170    |
| 5V $\mu$ Ctrl w/o O.D. w/ 3.3V                 | 5V                    | 3.3V               | 5V               | 150             | 1000            | N/A             | 1000            | 20,000          | BS170    |
| 3.3V $\mu$ Ctrl w/o O.D. <sup>(30)</sup>       | 3.3V                  | 3.3V               | 5V               | 150             | 1000            | N/A             | N/A             | N/A             | BS170    |
| 5V $\mu$ Ctrl w/ O.D. w/o 3.3V <sup>(31)</sup> | 5V                    | 5V                 | 5V               | 100             | 1000            | 20,000          | 1000            | 20,000          | N/A      |
| 3.3V $\mu$ Ctrl w/ O.D.                        | 3.3V                  | 3.3V               | 5V               | 150             | 1000            | N/A             | N/A             | N/A             | N/A      |

Table 3 - Resistor Values for Common Specific Applications

<sup>30</sup>  $\mu$ Ctrl w/ O.D. : Micro-controller with open-drain capability (for instance NEC V850ES series)

<sup>31</sup>  $\mu$ Ctrl w/o O.D. : Micro-controller without open-drain capability (like TI TMS320 series or ATMEL AVR )

## **18. 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 following test methods:

### **Reflow Soldering SMD's (Surface Mount Devices)**

- IPC/JEDEC J-STD-020  
Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices (Classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113  
Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing (Reflow profiles according to table 2)
- Melexis Working Instruction 341901308

### **Wave Soldering SMD's (Surface Mount Devices) and THD's (Through Hole Devices)**

- EN60749-20  
Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15  
Resistance to soldering temperature for through-hole mounted devices
- Melexis Working Instruction 341901309

### **Iron Soldering THD's (Through Hole Devices)**

- EN60749-15  
Resistance to soldering temperature for through-hole mounted devices
- Melexis Working Instruction 341901309

### **Solderability SMD's (Surface Mount Devices) and THD's (Through Hole Devices)**

- EIA/JEDEC JESD22-B102 and EN60749-21  
Solderability
- Melexis Working Instruction 3304312

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

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

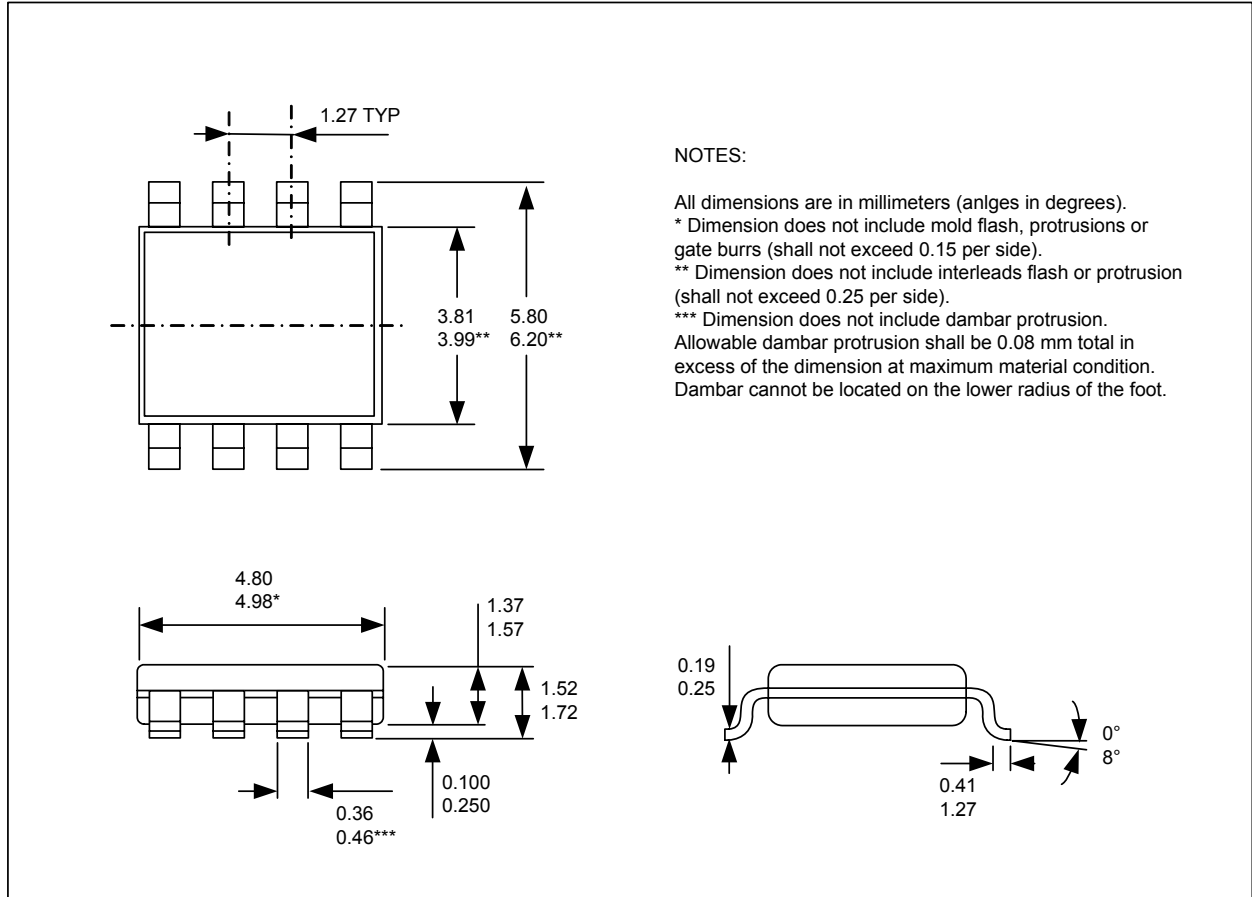
For more information on the lead free topic please see quality page at our website:  
<http://www.melexis.com/quality.aspx>

## **19. ESD Precautions**

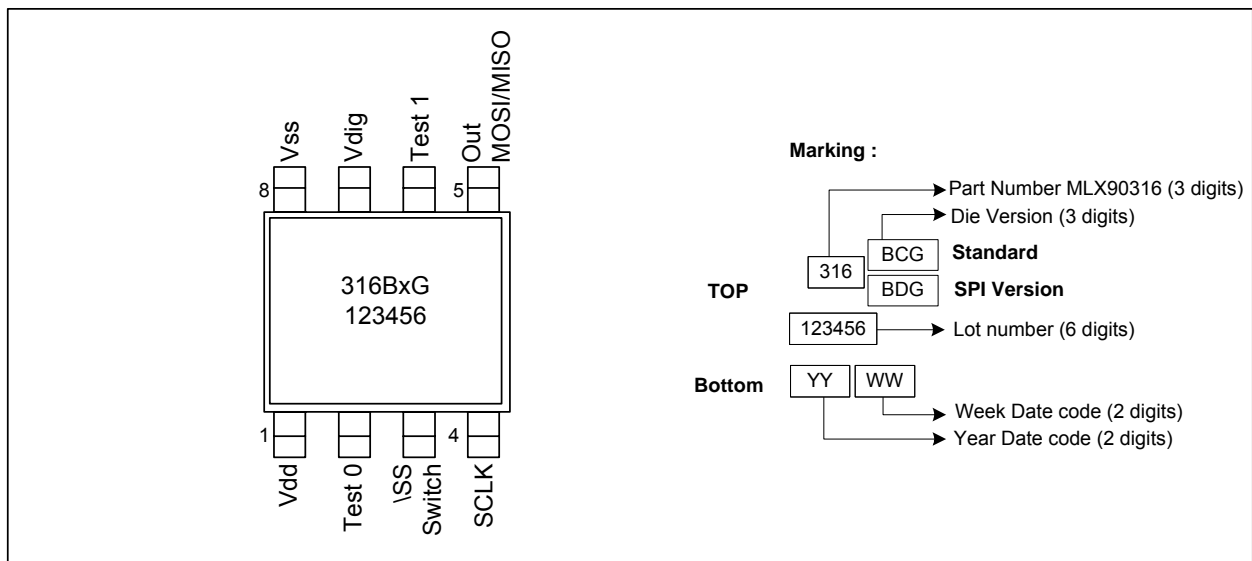
Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

### 20. Package Information

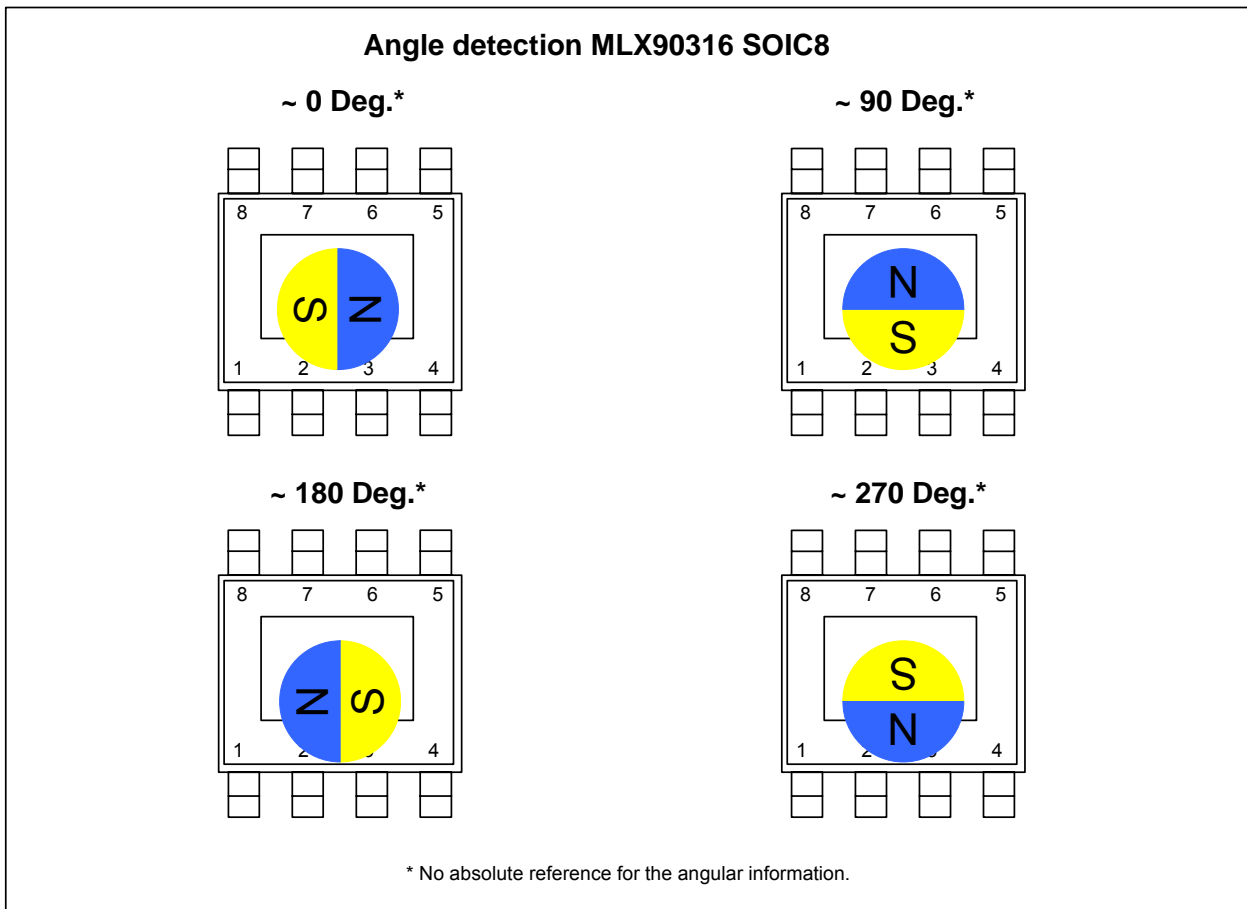
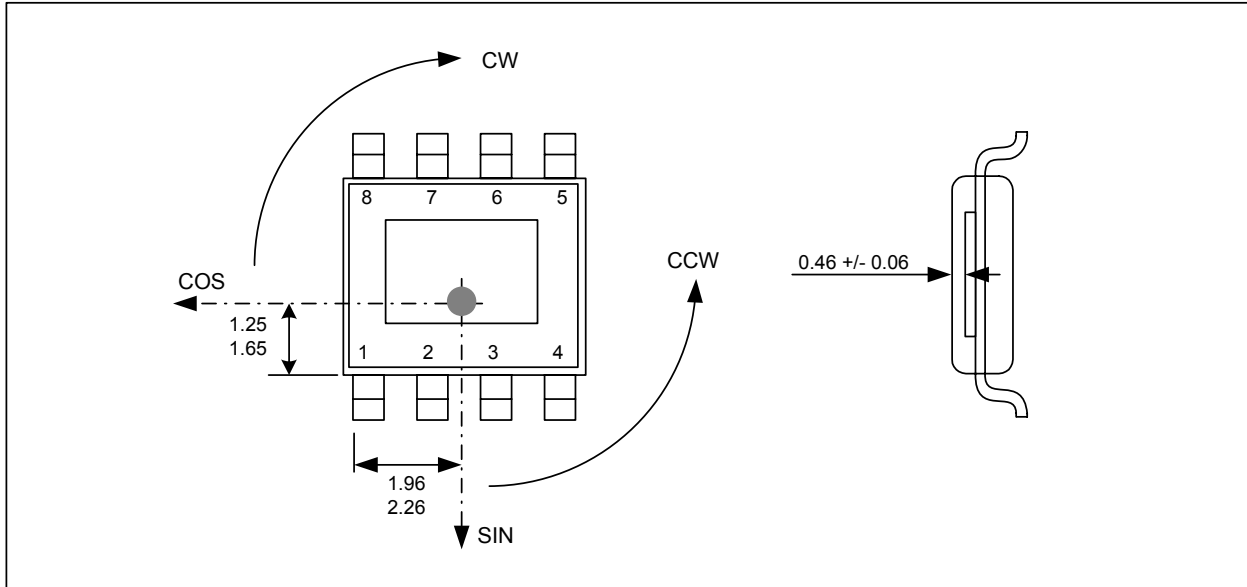
#### 20.1. SOIC8 - Package Dimensions



#### 20.2. SOIC8 - Pinout and Marking

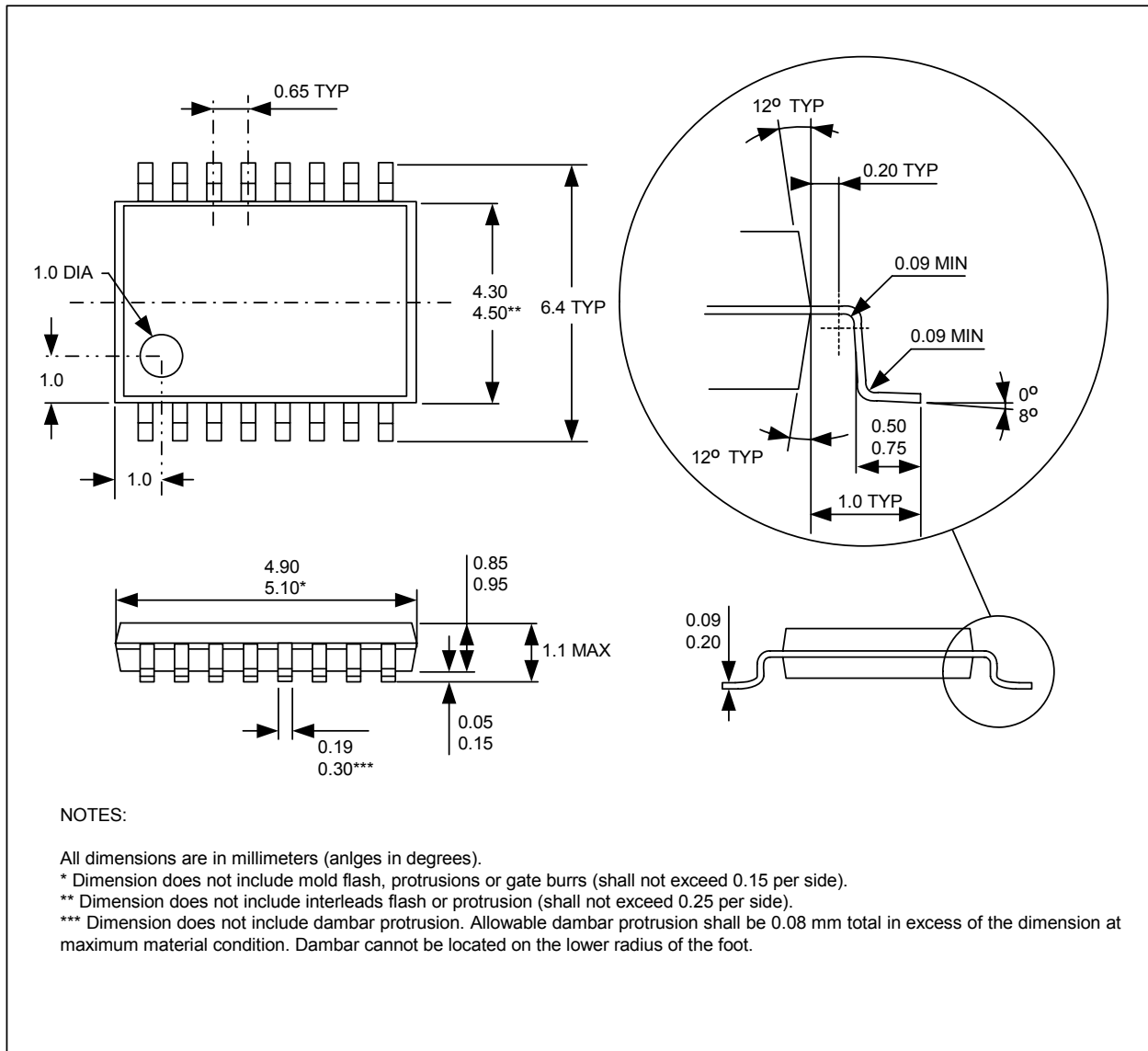


**20.3. SOIC8 - IMC Positioning**

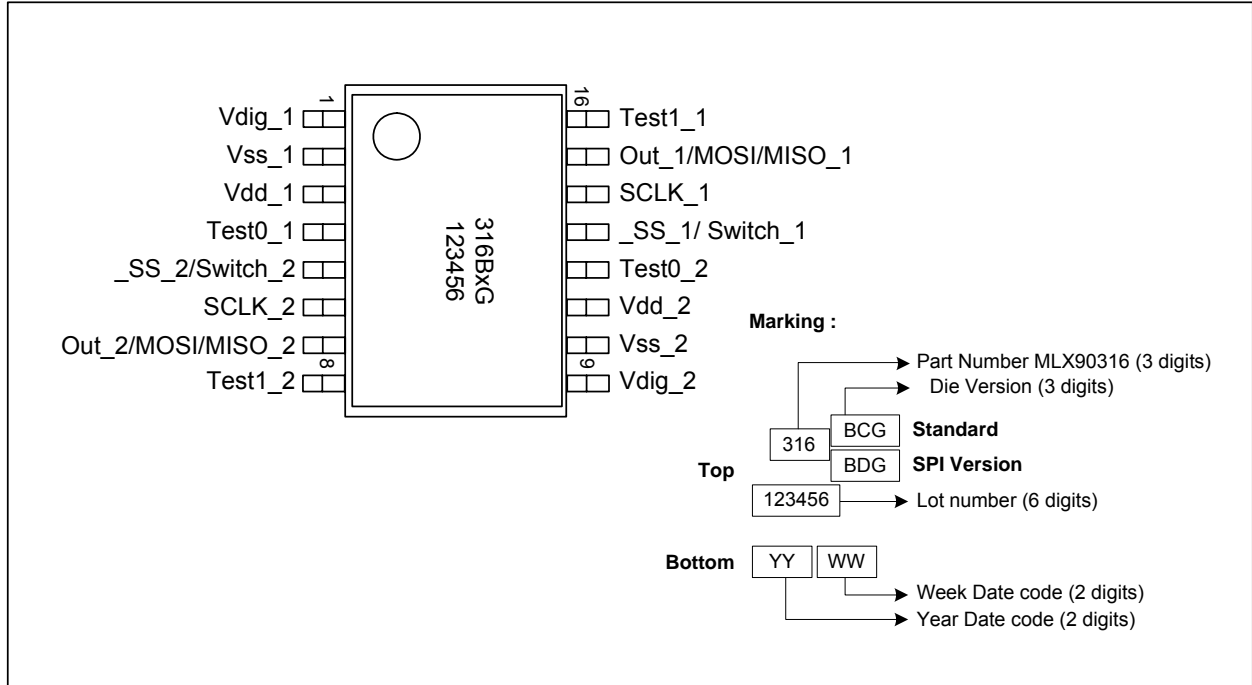


The MLX90316 is an absolute angular position sensor but the linearity error ( $L_e$  – See Section 10) does not include the error linked to the absolute reference 0 Deg (which can be fixed in the application through the discontinuity point – See 14.2.2).

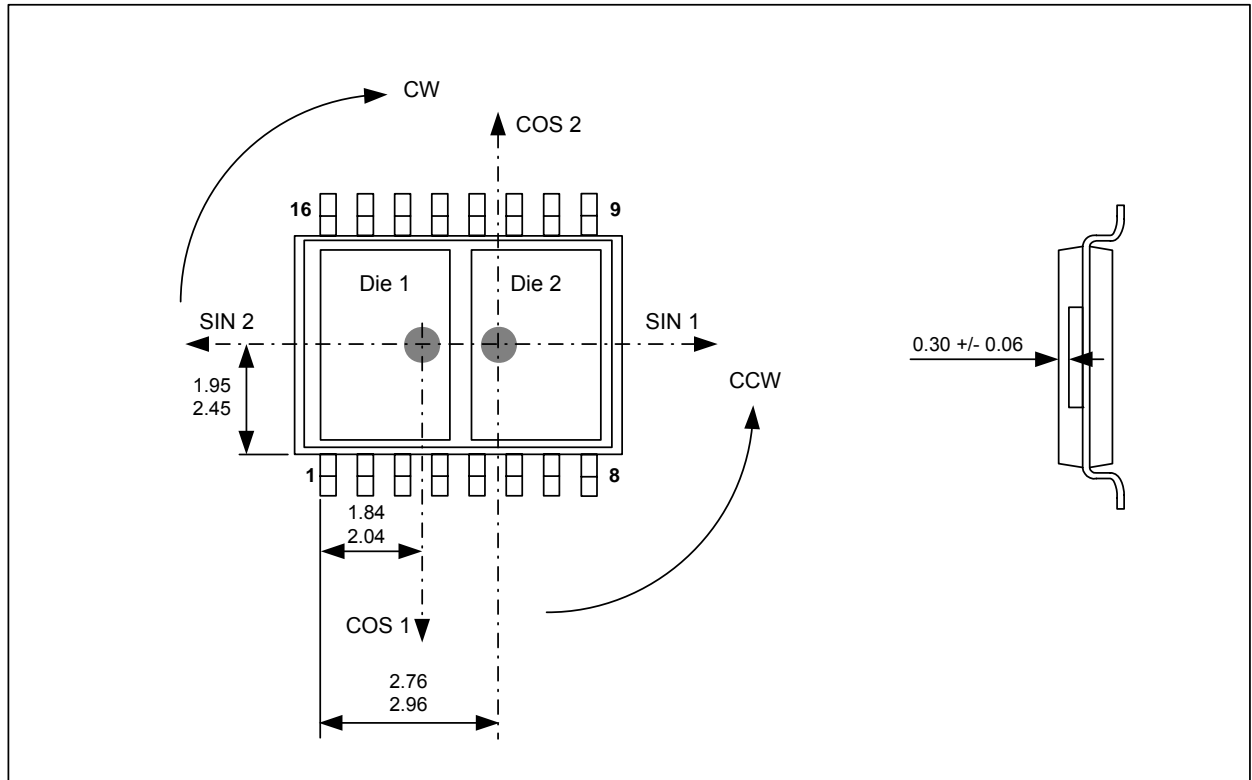
**20.4. TSSOP16 - Package Dimensions**

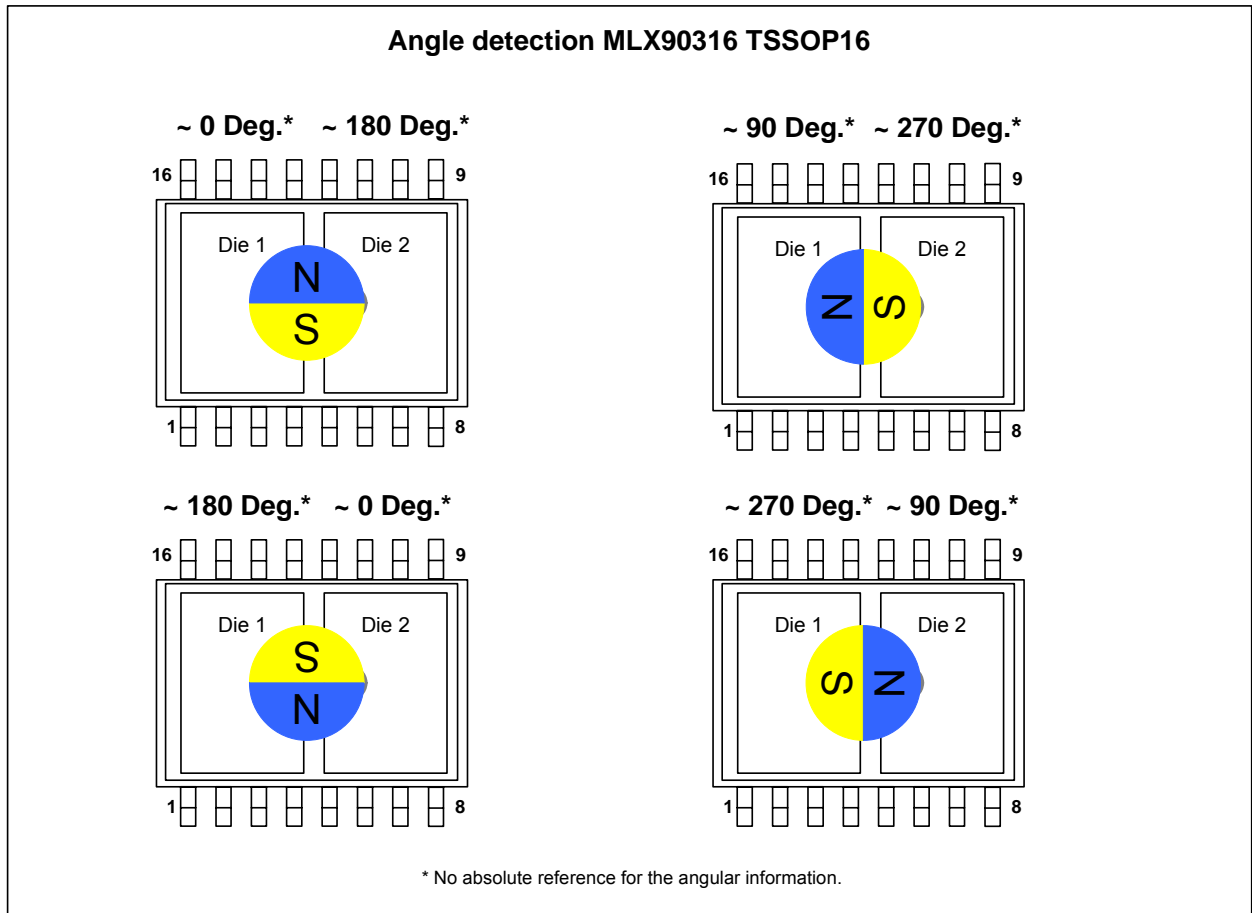


**20.5. TSSOP16 - Pinout and Marking**



**20.6. TSSOP16 - IMC Positioning**





The MLX90316 is an absolute angular position sensor but the linearity error (Le – See Section 10) does not include the error linked to the absolute reference 0 Deg (which can be fixed in the application through the discontinuity point – See 14.2.2).



## 21. Disclaimer

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