MLX90365

Triaxis® Position Sensor IC

Features and Benefits

- ☐ Absolute Rotary & Linear Position Sensor IC
- ☐ Triaxis® Hall Technology
- ☐ Simple Magnetic Design
- ☐ Programmable Transfer Characteristic (Multi-Points – Piece-Wise-Linear)
- ☐ Selectable Output Mode: Analog (Ratiometric) – Pulse Width Modulation (PWM)
- ☐ 12 bit Resolution - 10 bit Thermal Accuracy
- ☐ Open/Short Diagnostics
- ☐ On Board Diagnostics
- ☐ Over-Voltage Protection
- ☐ Under-Voltage Detection
- ☐ 48 bit ID Number option
- ☐ Automotive Temperature Range
- ☐ AEC-Q100 Qualified
- ☐ Single Die – SOIC-8 Package RoHS Compliant
- ☐ Dual Die (Full Redundant) – TSSOP-16 Package RoHS Compliant

Applications

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

Ordering Information

Part No.	Temperature Suffix	Package Code	Die Revision	Option code	Packing
MLX90365	E	DC	ABB	000	RE
MLX90365	E	DC	ABB	000	TU
MLX90365	K	DC	ABB	000	RE
MLX90365	K	DC	ABB	000	TU
MLX90365	L	DC	ABB	000	RE
MLX90365	L	DC	ABB	000	TU
MLX90365	L	DC	ABB	200	RE
MLX90365	L	DC	ABB	200	TU
MLX90365	E	GO	ABB	000	RE
MLX90365	E	GO	ABB	000	TU
MLX90365	K	GO	ABB	000	RE
MLX90365	K	GO	ABB	000	TU
MLX90365	L	GO	ABB	000	RE
MLX90365	L	GO	ABB	000	TU

Legend:

Temperature Code:	E for Temperature Range -40℃ to 85℃ K for Temperature Range -40℃ to 125℃ L for Temperature Range -40℃ to 150℃
Package Code:	DC for SOIC-8 Package GO for TSSOP-16 Package (Dual Die – Full Redundant)
Option Code:	XXX-000 – Standard XXX-200 – Preprogrammed – See Section 13 for Default Settings.
Packing Form:	RE for Reel TU for Tube
Ordering example:	MLX90365EDC-ABB-000-RE

1. Functional Diagram

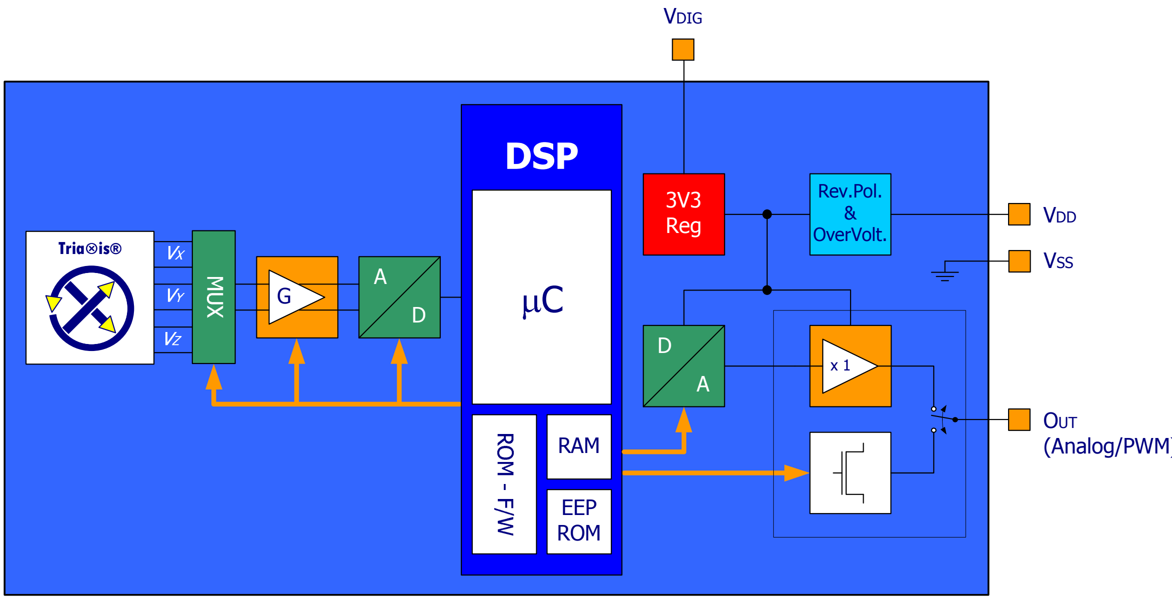


Figure 1 - MLX90365 Block Diagram

2. Description

The MLX90365 is a monolithic sensor IC sensitive to the flux density applied orthogonally and parallel to the IC surface.

The MLX90365 is 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 MLX90365 with the correct magnetic circuit to decode the absolute position of any moving magnet (e.g. rotary position from 0 to 360 Degrees or linear displacement, stroke - Figure 2). It enables the design of novel generation of non-contacting position sensors that are frequently required for both automotive and industrial applications.

MLX90365 reports a programmable ratiometric analog output signal compatible with any resistive potentiometer or programmable linear Hall sensor. Through programming, the MLX90365 provides also a digital PWM (Pulse Width Modulation) output characteristic.

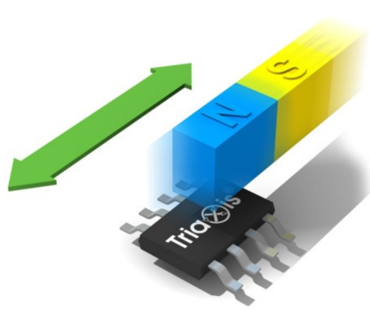


Figure 2 - Typical application of MLX90365 – Linear

TABLE of CONTENTS

3. Glossary of Terms – Abbreviations – Acronyms

- Gauss (G), Tesla (T): Units for the magnetic flux density – 1 mT = 10 G
- TC: **T**emperature **C**oefficient (in ppm/Deg.C.)
- NC: **N**ot **C**onnected
- PWM: **P**ulse **W**idth **M**odulation
- %DC: **D**uty **C**ycle of the output signal i.e. T_{ON} /(T_{ON} + T_{OFF})
- ADC: **A**nalog-to-**D**igital **C**onverter
- DAC: **D**igital-to-**A**nalog **C**onverter
- LSB: **L**east **S**ignificant **B**it
- MSB: **M**ost **S**ignificant **B**it
- DNL: **D**ifferential **N**on-**L**inearity
- INL: **I**ntegral **N**on-**L**inearity
- RISC: **R**educed **I**nstruction **S**et **C**omputer
- ASP: **A**nalog **S**ignal **P**rocessing
- DSP: **D**igital **S**ignal **P**rocessing
- EMC: **E**lectro-**M**agnetic **C**ompatibility
- IMC: **I**ntegrated-**M**agneto **C**oncentrator

4. Pinout

Pin #	SOIC-8	TSSOP-16
1	VDD	V_{DIG1}
2	Test 0	V_{SS1} (Ground₁)
3	Test 2	V_{DD1}
4	Not Used	Test 0_1
5	OUT	Test 2_2
6	Test 1	OUT_2
7	VDIG	Not $Used_2$
8	VSS (Ground)	Test 1_2
9		V_{DIG2}
10		V_{SS2} ($Ground_2$)
11		V_{DD2}
12		Test 0_2
13		Test 2_1
14		Not $Used_1$
15		OUT_1
16		Test 1_1

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 16).

5. Absolute Maximum Ratings

Parameter	Value
Supply Voltage, V_{DD} (overvoltage)	+ 24 V
Reverse Voltage Protection	– 12 V (breakdown at -14 V)
Positive Output Voltage	+ 18 V (breakdown at 24 V)
Output Current (I_{OUT})	+ 30 mA (in breakdown)
Reverse Output Voltage	– 0.3 V
Reverse Output Current	– 50 mA (in breakdown)
Operating Ambient Temperature Range, T_A	– 40°C … + 150°C
Storage Temperature Range, T_S	– 40°C … + 150°C
Magnetic Flux Density	± 1 T

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

6. Description

As described on the block diagram the three vector components of the magnetic flux density (B_X, B_Y and B_Z) applied to the IC are sensed through the sensor front-end. The respective Hall signals (V_X, V_Y and V_Z) are generated at the Hall plates and amplified.

The analog signal processing is based on a fully differential analog chain featuring the classic offset cancellation technique (Hall plate 2-Phases spinning and chopper-stabilized amplifier).

The conditioned analog signals are converted through an ADC (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 position from two (out of three) raw signals (after so-called front-end compensation steps) through the following function:

$$\alpha = \angle(V_1, k \cdot V_2)$$

where alpha is the magnetic angle $\angle$(B1, B2), V_1 = V_X or V_Y or V_Z , V_2 = V_X or V_Y or V_Z and k is a programmable factor to match the amplitude of V_1 and k V_2.

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 magnetic angle extraction, the F/W controls the whole analog chain, the output transfer characteristic, the output protocol, the programming/calibration and also the self-diagnostic modes.

The magnetic angular information is intrinsically self-compensated vs. flux density variations. This feature allows therefore an improved thermal accuracy vs position sensor based on conventional linear Hall sensors.

In addition to the improved thermal accuracy, the realized position sensor features excellent linearity performances taking into account typical manufacturing tolerances (e.g. relative placement between the Hall IC and the magnet).

Once the position (angular or linear stroke) information is computed, it is further conditioned (mapped) vs. the target transfer characteristic and it is provided at the output(s) as either a ratiometric analog output level through a 12 bit DAC followed by a buffer or a digital PWM output.

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

$$Vout(\alpha) = ClampLo \quad \text{for } \alpha \le \alpha min$$
$$Vout(\alpha) = Voffset + Gain \times \alpha \quad \text{for } \alpha min \le \alpha \le \alpha max$$
$$Vout(\alpha) = ClampHi \quad \text{for } \alpha \ge \alpha max$$

where Voffset, Gain, ClampLo and ClampHi are the main adjustable parameters for the end-user.

The linear part of the transfer curve can be adjusted through a multi-point calibration:

This back-end step consists into either

- up to 4 arbitrary points (5 segments + clamping levels) calibration or
- a Piece-Wise-Linear (PWL) output transfer characteristics - 17 equidistant points w/ programmable origin over 16 different angle ranges from 65 to 360 degrees.

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 MLX90365 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. MLX90365 Electrical Specification

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Nominal Supply Voltage	VDD		4.5	5	5.5	V
Supply Current[1]	Idd				10	mA
Isurge Current[2]	Isurge				20	mA
Power-On reset (rising)	HPOR_LH	Refer to internal voltage Vdig	2	2.25	2.5	V
Power-On reset Hysteresis	HPOR_Hyst		50		200	mV
Start-up Level (rising)	MT4V LH		3.8	4.0	4.2	V
Start-up Hysteresis	MT4V Hyst		50		200	mV
PTC Entry Level (rising)	MT7V_LH		5.8	6.2	6.6	V
PTC Entry Level Hysteresis	MT7V_Hyst		50		200	mV
Output Short Circuit Current	I_{short}	Vout = 0 V Vout = 5 V Vout = 18 V (T_A = 25°C)			15 15 18	mA mA mA
Output Load	R_L	Pull-down to Ground Pull-up to 5V	4.7 4.7	10 10	∞ ∞	kΩ kΩ
Analog Saturation Output Level	Vsat_lo	Pull-up load $R_L \geq 10$ kΩ to 5 V Pull-up load $R_L \geq 5$ kΩ to 18V		0.5 2	2 3	%VDD
	Vsat_hi	Pull-down load $R_L \geq 5$ kΩ Pull-down load $R_L \geq 10$ kΩ	94 96	96 98		%VDD
Active Diagnostic Output Level	Diag_lo	Pull-up load $R_L \geq 10$ kΩ to 5 V Pull-up load $R_L \geq 5$ kΩ to 18V		0.5 2	2 3	%VDD
	Diag_hi	Pull-down load $R_L \geq 5$ kΩ Pull-down load $R_L \geq 10$ kΩ	94 96	96 98		%VDD
Passive Diagnostic Output Level (Broken Track Diagnostic)[3]	BVSSPD	Broken VSS & Pull-down load $R_L \geq 10$ kΩ	97.5			%VDD
	BVSSPU	Broken VSS & Pull-up load $R_L \geq 1$kΩ	99.5	100		%VDD
	BVDDPD	Broken VDD & Pull-down load $R_L \geq 1$kΩ		0	0.5	%VDD
	BVDDPU	Broken VDD & Pull-up load $R_L \geq 5$kΩ			2	%VDD
Clamped Output Level	Clamp_lo	Programmable	0		100	%VDD[4]
	Clamp_hi	Programmable	0		100	%VDD[6]

[1] For the dual version, the supply current is multiplied by 2.
[2] The specified value is valid during early start-up time only; the current might dynamically exceed the specified value, shortly, during the Start-up phase.
[3] For detailed information, see also section 15
[4] Clamping levels need to be considered vs the saturation of the output stage (see Vsat_lo and Vsat_hi)

As an illustration of the previous table, the MLX90365 fits the typical classification of the output span described on the Figure 6.

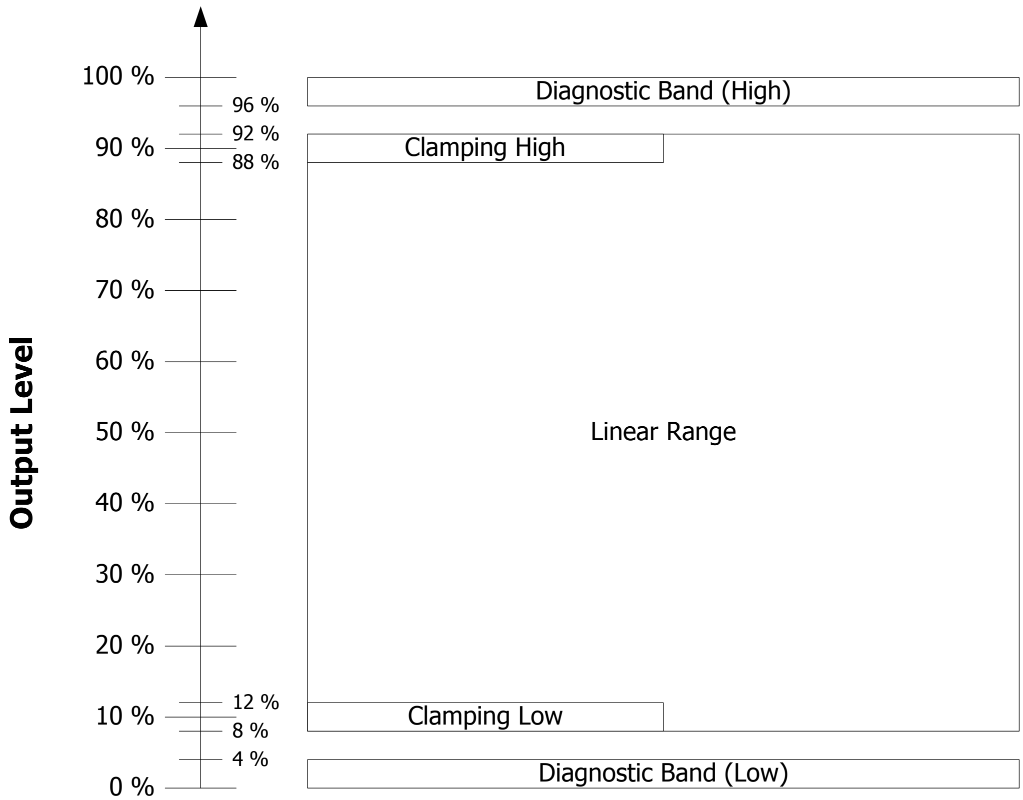


Figure 6 – Example of Output Span Classification for typical application.

8. MLX90365 Isolation Specification

DC Operating Parameters at VDD = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (E or 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. MLX90365 Timing Specification

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Main Clock Frequency	Ck	All contributors included thermal drfit	12.6	13.3	14	MHz
Main Clock Frequency Thermal Drift	$\Delta^T Ck$				± 3%	Ck_{NOM}
Refresh Rate			281	290	299	µs
Step Response Time	Ts	Filter=0[5] Filter=1 Filter=2	844 1125 1407	870 1160 1450	896 1195 1494	µs
Watchdog	Twd		114.5	118	121.5	ms
Start-up Cycle	Tsu	Analog OUT Slew-rate excluded			5	ms
Analog OUT Slew-rate		Mode 1 from C_{OUT} = 47 nF to 330 nF Mode 2 up to C_{OUT} = 10 nF Mode 3 up to C_{OUT} = 47 nF Mode 4 up to C_{OUT} = 330 nF	25 300 17 1.8	37 320 19 2.5		V/ms

[5] See section 14 for details concerning Filter parameter

10. MLX90365 Accuracy Specification

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ADC Resolution on the raw signals sine and cosine(6)	R_{ADC}			15		bits
Thermal Offset Drift #1(7) at the DSP input (excl. DAC and output stage)		Temperature suffix E Temperature suffix K Temperature suffix L	-60 -60 -90		+60 +60 +90	LSB_{15}
Thermal Offset Drift #2 (DAC and Output Stage)			-0.2		+0.2	%VDD
Thermal Drift of Sensitivity Mismatch(8)		XY axis – Temp. suffix E XY axis – Temp.suffix K & L XZ (YZ) axis – Temp. suffix E XZ (YZ) axis – Temp. suffix K & L	- 0.3 - 0.5 -1 -1		+ 0.3 + 0.5 +1 +1	%
Magnetic Angle phase error		T_A = 25°C – XY axis T_A = 25°C – XZ axis T_A = 25°C – YZ axis	-0.3 -2 -10		0.3 2 10	Deg.
Thermal Drift of Magnetic Angle phase error		XY axis, XZ (YZ) axis		0.01		Deg.
XY – Intrinsic Linearity Error(9)	Le	T_A = 25°C – factory trim. “SMISM”	-1		1	Deg
XZ - Intrinsic Lin. Error(11)	Le	T_A = 25°C – “k” trimmed for XZ	-2.5	±1.25	2.5	Deg
YZ - Intrinsic Lin. Error(11)	Le	T_A = 25°C – “k” trimmed for YZ	-10	±2.5	+10	Deg
Analog Output Resolution	R_{DAC}	12b DAC (Theoretical, Noise free) INL (before EOL calibration) DNL	 -4 0.05	0.025 1	 +4 3	%VDD/LSB_{12} LSB_{12} LSB_{12}
Output stage Noise		Clamped Output		0.05	0.075	%VDD
Noise pk-pk(10)		Filter = 0, 40mT Filter = 2, 20mT		0.10 0.10	0.2 0.2	Deg
Ratiometry Error (Analog output only)		4.5V ≤ VDD ≤ 5.5V LT4V ≤ VDD ≤ MT7V	-0.05 -0.1		+0.05 +0.1	%VDD

6 16 bits corresponds to 15 bits + sign. Internal computation is performed using 16 bits.

7 For instance, in case of a rotary position sensor application, Thermal Offset Drift #1 equal ± 60LSB_{15} yields to max. ± 0.3 Deg. angular error for the computed angular information (output of the DSP). This is only valid if k = 1. “MLX90365 Front-End Application Note” will be released for more details.

8 For instance, in case of a rotary position sensor application, Thermal Drift of Sensitivity Mismatch equal ± 0.5% yields to max. ± 0.15 Deg. angular error for the computed angular information (output of the DSP). See “MLX90365 Front-End Application Note” for more details.

9 The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating field for B_X and B_Y. 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. The intrinsic Linearity Error for Magnetic angle ∠XZ and ∠YZ can be reduced through the programming of the k factor.

10 Noise pk-pk (peak-to-peak) is here intended as 6 times the Noise standard Deviation. The application diagram used is described in the recommended wiring. For detailed information, refer to section Filter in application mode (Section 14).

11. MLX90365 Magnetic Specification

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Magnetic Flux Density	B_X, B_Y[11]	$\sqrt{[B_X{}^2 + B_Y{}^2]}$			70[12]	mT
Magnetic Flux Density	B_Z[14]				126	mT
Magnetic Flux Norm	Norm	$\sqrt{[B_X{}^2 + B_Y{}^2 + (Bz/1.2)^2]}$	20[13]			mT
IMC Gain[14]	GainIMC		1.2	1.5	1.8	
Magnet Temperature Coefficient	TCm		-2400		0	ppm/°C

12. MLX90365 CPU & Memory Specification

The DSP is based on a 16 bit RISC µController. This CPU provides 2.5 Mips while running at 10 MHz.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ROM				10		KB
RAM				384		B
EEPROM				128		B

[11] The condition must be fulfilled for at least one field BX or BY.
[12] Above 70 mT, the IMC starts saturating yielding to an increase of the linearity error. Below 20 mT, the performances slightly degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.
[13] Below 20 mT, the performances slightly degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.
[14] This is the magnetic gain linked to the Integrated Magneto Concentrator (IMC) structure. It applies to B_X and B_Y and not to B_Z. This is the overall variation. Within one lot, the part to part variation is typically ± 10% versus the average value of the IMC gain of that lot.

13. MLX90365 End-User Programmable Items

Parameter	Comments	Default Values Standard	PPAR	# bit
OUT mode	Define the output stage mode	1	1	3
DIAG mode	Diagnostic mode	7	7	3
DIAG Level	Diagnostic Level	0	0	1
MAPXYZ	Mapping fields for output angle	0	0	2
CLAMP_HIGH	Clamping High (50%)	50%	10%	16
CLAMP_LOW	Clamping Low (50%)	50%	90%	16
FILTER	Filter mode selection	0	1	2
SMISM	Sensitivity mismatch factor X,Y	MLX	MLX	15
k	Sensitivity mismatch factor X (Y) , Z	MLX	N/A	15
SEL_k	Affected signal component by k: B1 or B2 (in combination of MAPXYZ)	0	0	1
GAINMIN	Low threshold for virtual gain	01h	01h	8
GAINMAX	High threshold for virtual gain	28h	28h	8
GAINSATURATION	Gain Saturates on GAINMIX and GAINMAX	0h	0h	1
FIELDTHRESH	Field limit under which a fault is reported	00FFh	00FFh	16
PWM	PWM function	0h	N/A	1
PWMPOL	PWM polarity	0h	N/A	1
PWMT	PWM Frequency (trimmed at 200Hz)	MLX	N/A	8
DC_FAULT	PWM Duty Cycle if Fault	1h	N/A	8
DC_FTL	PWM Duty Cycle if Field Strength Too Low	1h	N/A	8
DC_WEAK	PWM Duty Cycle if Weak Magnet	1h	N/A	8
WEAKMAGTHRESH	Weak Magnet threshold Byte (1lsb = 1mT)	0h	N/A	8
DP	Discontinuity point	0h	0h	15
CW	Clock Wise	0h	0h	1
FHYST	Hysteresis filter	0h	0h	8
MELEXISID1	Melexis identification reference	MLX	MLX	16
MELEXISID2	Melexis identification reference	MLX	MLX	16
MELEXISID3	Melexis identification reference	MLX	MLX	16
4POINTS	Selection of correction method 4 or 16 pts	1h	1h	1
LNR_S0	4pts – Initial Slope	0 %/deg	0 %/deg	16
LNR_A_X	4pts – AX Coordinate	0 deg	0 deg	16
LNR_A_Y	4pts – AY Coordinate	10 %	10 %	16
LNR_A_S	4pts – AS Coordinate	0.22%/deg	0.22%/deg	16
LNR_B_X	4pts – BX Coordinate	360 deg	360 deg	16
LNR_B_Y	4pts – BY Coordinate	100%	100%	16
LNR_B_S	4pts – BS Coordinate	0 %/deg	0 %/deg	16
LNR_C_X	4pts – CX Coordinate	360 deg	360 deg	16
LNR_C_Y	4pts – CY Coordinate	100%	100%	16
LNR_C_S	4pts – CS Coordinate	0 %/deg	0 %/deg	16
LNR_D_X	4pts – DX Coordinate	360 deg	360 deg	16
LNR_D_Y	4pts – DY Coordinate	100%	100%	16
LNR_D_S	4pts – DS Coordinate	0 %/deg	0 %/deg	16
W	17pts – Output angle range	0h	N/A	4

CUSTOMERID1	Cust. id reference	Bin1	Bin1	16
CUSTOMERID2	Cust. id reference	202h	3h	16
CUSTOMERID3	Cust. id reference	0h	0h	16
LNR_Yn	17pts – Y-coordinate point n (n = 2,1,2 ...16)	N/A	N/A	16
DIAG Settings	16 Bit Diagnostics enablling	FDFFh	4080h	16
CRC_DISABLE	Enable EERPOM CRC check (3131h= disable)	0h	0h	16

Note: Ordering Information for PPAR: MLX90365EDC-ABB-000-RE or TU

14. Description of End-User Programmable Items

14.1. Output modes

14.1.1. OUT mode

Defines the Output Stage mode (analog, digital, high-impedance, standby) in application.

Output mode[2:0]	Type	Descriptions	Comments
0	Disable	Output HiZ	Not recommended
1	Analog	Analog Rail-to-Rail for $Cout_{min}$ = 47nF	Analog Only (Default)
2	Analog	Analog Rail-to-Rail for $Cout_{max}$ = 10nF	Analog Only
3	Analog	Analog Rail-to-Rail for $Cout_{max}$ = 68nF	Analog Only
4	Analog	Analog Rail-to-Rail for Coutmax = 330nF	Analog Only
5	Digital	open drain NMOS	PWM
6	Digital	open drain PMOS	PWM
7	Digital	Push-Pull	PWM

14.1.2. PWM Output Mode

If PWM output mode is selected, the output signal is a digital signal with Pulse Width Modulation (PWM). The PWM polarity is selected by the PWMPOL parameter:

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

The PWM frequency is selected by the PWMT parameter. The following table provides typical code for different target PWM frequency and for both low and high speed modes.

PWW F (Hz)	PWMT (LSB) @12.5MHz	PWM res. (us)	PWM res. (%)	PWM res. (bit)
125	33333	0.240	0.003	15.0
250	16666	0.240	0.006	14.0
500	8333	0.240	0.012	13.0
1000	4166	0.240	0.024	12.0

Notes:
- A more accurate trimming can be performed to take into account initial tolerance of the main clock.
- The PWM frequency is subjected to the same tolerances as the main clock (see Δ^{T}Ck).

14.2. Output Transfer Characteristic

There are 2 different possibilities to define the transfer function (LNR):

- With 4 arbitrary points (defined on X and Y coordinates) and 5 slopes
- With 17 equidistant points for which only the Y coordinates are defined.

Parameter	LNR type	Value	Unit
CLOCKWISE	**Both**	**0 → CounterClockWise 1 → ClockWise**	**LSB**
DP	Both	0 … 359.9999	deg
LNR_A_X LNR_B_X LNR_C_X LNR_D_X	Only 4 pts	0 … 359.9999	deg
LNR_A_Y LNR_B_Y LNR_C_Y LNR_D_Y	Only 4 pts	0 … 100	%
LNR_S0 LNR_A_S LNR_B_S LNR_C_S LNR_D_S	Only 4 pts	-17 … 0 … 17	%/deg
LNR_Y0 LNR_Y1 … LNR_Y16	Only 16 pts	-50 … + 150	%
W	Only 16 pts	65.5 … 360	Deg
CLAMP_LOW	Both	0 … 100	%
CLAMP_HIGH	Both	0 … 100	%

14.2.1. Enable scaling Parameter (only for LNR type 4 pts)

This parameter enables to scale LNR_x_Y from -50% - 150% according to the following formula

$$(\text{Scaled Out})\%V_{DD} = 2 \times \text{Out}\%V_{DD} - 50\%$$

14.2.2. CLOCKWISE Parameter

The CLOCKWISE parameter defines the magnet rotation direction.

- CCW is the 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 sensitive spot positioning sections (Section 19.3)

14.2.3. 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.

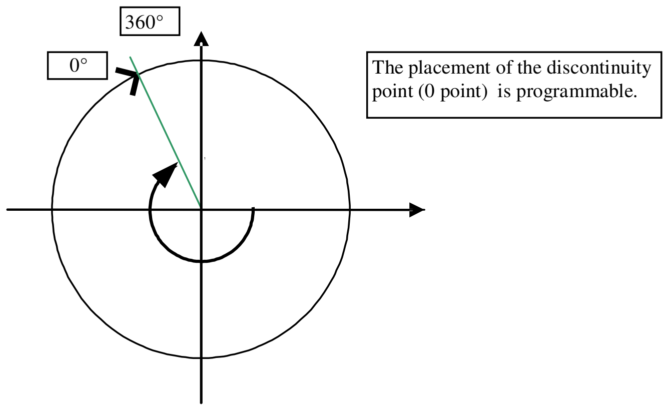


Figure 7 - Discontinuity Point Positioning

14.2.4. 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 MLX90365 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 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 8

14.2.5. 17-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 MLX90365 transfer function from the digital angle value to the output voltage is described by the drawing below. In the 16-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

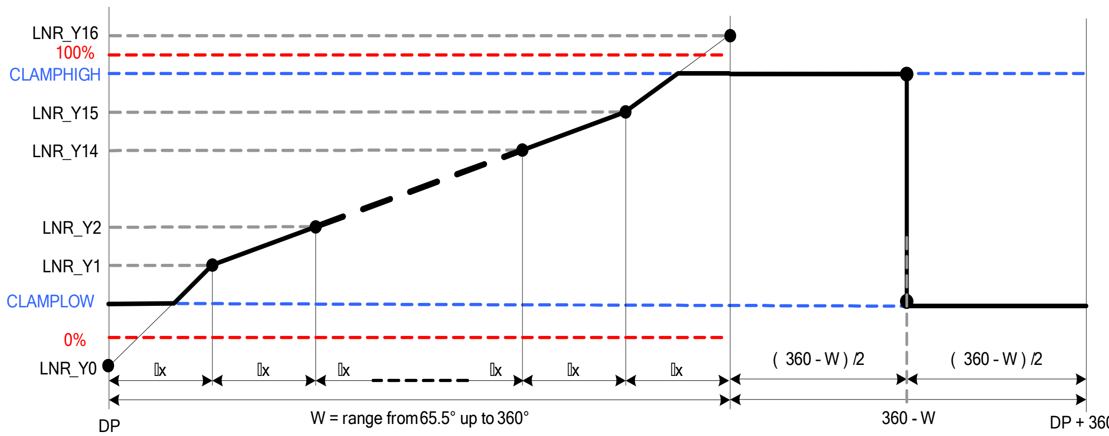


Figure 9 - Input range from 65.5° up to 360°

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.

The parameter W determines the input range on which the 17 points (16 segments) are uniformly spread:

W	Range	Δx
0 (0000b)	360.0deg	22.5deg
1	320.0deg	20.0deg
2	288.0deg	18.0deg
3	261.8deg	16.4deg
4	240.0deg	15.0deg
5	221.5deg	13.8deg
6	205.7deg	12.9deg
7	192.0deg	12.0deg

W	Range	Δx
8	180.0deg	11.3deg
9	144.0deg	9.0deg
10	120.0deg	7.5deg
11	102.9deg	6.4deg
12	90.0deg	5.6deg
13	80.0deg	5.0deg
14	72.0deg	4.5deg
15 (1111b)	65.5deg	4.1deg

Outside of the selected range, the output will remain in clamping levels.

14.2.6. 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 both LNR modes. 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.

14.3. Identification

Parameter	Value
MELEXISID1 MELEXISID2 MELEXISID3	0 … 65535 0 … 65535 0 … 65535
CUSTOMERID1 CUSTOMERID2 CUSTOMERID3	0 … 65535 0 … 65535 0 … 65535

Identification number: 48 bits (3 words) freely useable by Customer for traceability purpose.

14.4. Sensor Front-End

Parameter	Value
MAPXYZ	0 .. 3
SMISM	0 .. 32768
k	0 .. 32768
SEL_k	0 or 1
GAINMIN GAINMAX GAINSATURATION	0 … 41 0 … 41 0.. 1

14.4.1. MAPXYZ

The MAPXYZ parameter defines which 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.

MAPXYZ	B1	B2	Angular
0 – 00b	X	Y	XY mode
1 – 01b	Zx	X	XZx mode
2 – 10b	Y	Zx	YZx mode
3 – 11b	Y	Zy	YZy mode

Note: MAPXYZ = 3 is not recommended.

14.4.2. SMISM, k and SEL_k Parameters

(i) SMISM

When the mapping (B1=X, B2=Y) is selected, SMSIM defines the sensitivity mismatch factor that is applied on B1, B2; When another B1, B2 mapping is selected, this parameter is “don’t care”.
This parameter is trimmed at factory; Melexis strongly recommends TO NOT overwrite it for optimal performances.

(ii) k

When the mapping (B1=X, B2=Y) is **NOT** selected, k defines the sensitivity mismatch factor that is applied on B1or B2 (according to parameter SEL_k – see below). When the mapping (B1=X, B2=Y) is selected, this parameter is “don’t care”.
This parameter is trimmed at factory for mapping (B1=Z, B2=X). Melexis recommends to fine trim it when a smaller linearity error (Le) is required and a different mapping than (B1=X, B2=Y) is selected.

(iii) SEL_k

When the mapping (B1=X, B2=Y) is **NOT** selected, SEL_k defines the component on which the sensitivity mismatch factor k (see above): SEL_k = 0 means B1→ k · B1 and SEL_k = 1 means B2 → k · B2.

14.4.3. 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 Diag. check.

14.5. Filter

Parameter	Value
FILTER	0 … 2
FHYST	0 … 255

The MLX90365 includes 2 types of filters:

- Hysteresis Filter: programmable by the FHYST parameter
- Low Pass FIR Filters controlled with the FILTER parameter

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. (1 lsb = +/- 0.012%)

14.5.2. FIR Filters

The MLX90365 features 2 FIR filter modes controlled with Filter = 1…2. Filter = 0 corresponds to no filtering. 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 filters characteristic is given in the following table:

Filter No (j)	0	1	2
Type	Disable	Finite Impulse Response	
Coefficients a_i	1	11	1111
Title	No filter	ExtraLight	Light
99% Response Time	1	2	4
Efficiency RMS (dB)	0	3.0	6.0

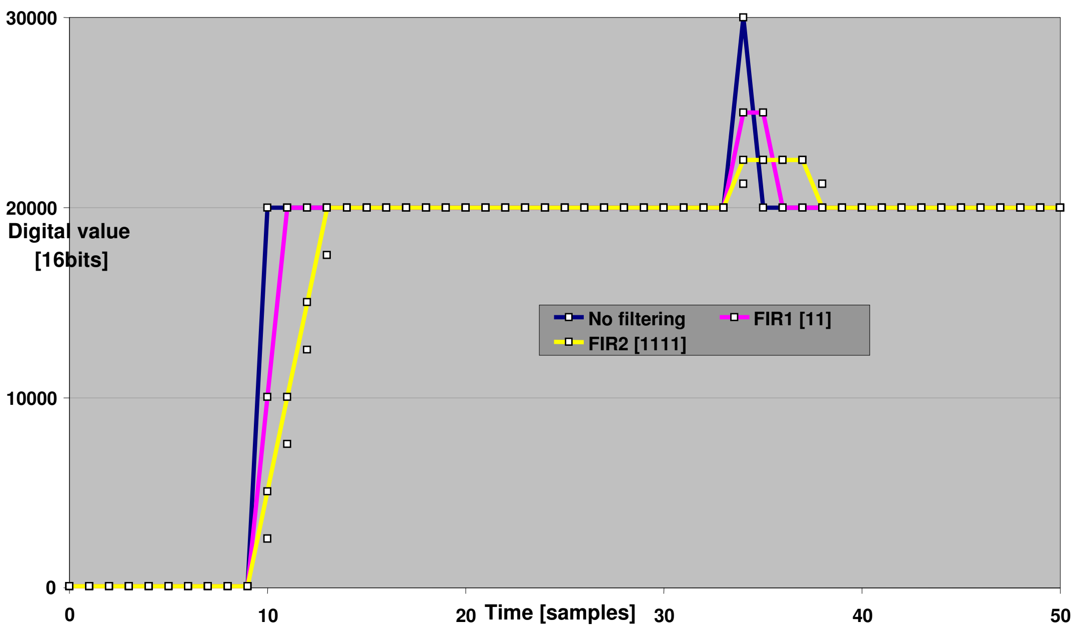


Figure 10 - Step and impulse response of the different filters

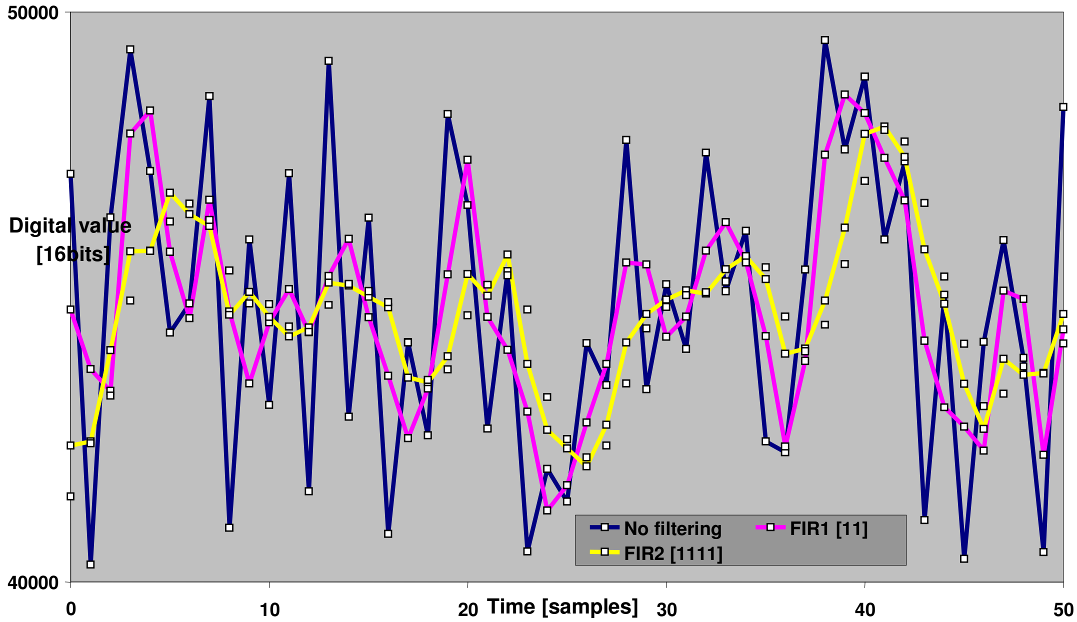


Figure 11 - Noise response of the different filter

14.6. Programmable Diagnostic Settings

14.6.1. DIAG mode

Defines the Output Stage mode in case of Diag.

DIAG mode [2:0]	Type	Descriptions	Comments
0	Disable	Output HiZ	Not recommended
5	Digital	open drain NMOS	
6	Digital	open drain PMOS	
7	Digital	Push-Pull	

14.6.2. DIAG Level

Determines the reporting level (diagnostic low, diagnostic high) during start-up (both analog and PWM mode), or during a fault reporting (Only in Analog mode).

In PWM mode, the fault reporting level shall in principle be 0 when the leading edge is a rising edge, (resp. 1 for a falling edge) in order to detect the first cycle after start-up. MLX recommends then DIAG Level = PWMPOL.

14.6.3. Field Strength Diagnostic (Feature under development)

(i) FIELDTHRESHLOW

Defines the field strength limit under which a fault is reported.
The run-time field strength estimation (FieldStrength) is compared to 64 * FIELDTHRESHLOW. The sensitivity of FieldStrength is expected to be: 15.6uV/LSB

The sensitivity of FIELDTHRESHLOW is to be defined

(ii) FIELDTHRESHHIGH

Defines the field strength limit under which a fault is reported. See above for more details.

14.6.4. PWM Diagnostic

(i) DC_FAULT
Defines the duty-cycle that is outputted in case of diagnostic reporting.

(ii) WEAKMAGTHRESH
Defines the threshold on the field strength which determines the weak magnet condition; when WEAKMAGTHRESH = 0, there is no reporting of weak magnet condition.

(iii) DC_FTL
Defines the duty-cycle that is outputted in case of Field Too Low; the Field Too Low Diagnostic is stronger than the Weak Magnet Diagnostic, from 0% till 255% by steps of (100/256)%

(iv) DC_WEAK
Defines the duty-cycle that is outputted in case of Weak Magnet, from 0% till 255% by steps of (100/256)%

14.6.5. Diagnostic Features

Refer to Application_note_Diagnostic_Behavior_90365 for EE_CRC_Enable function description and for Diagnostic features which can be enabled at user.

14.7. EEPROM endurance

Although the EEPROM is used for Calibration Data Storage (similarly to an OTPROM), the MLX90365 embedded EEPROM is qualified to guarantee an endurance of minimum 1000 write cycles at 125˚C for (engineering/calibration purpose).

15. MLX90365 Self Diagnostic

The MLX90365 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").

Diagnostic Item	Action	Effect on Outputs	Type	Monitoring Rate	Reporting Rate
ST-up phase Diagnostics					
RAM March C- 10N Test	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low/ high Reporting (optional)	Digi HW	n/applicable (start-up only)	n/applicable (start-up only)
Watchdog BIST	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low/ high Reporting (optional)	Digi HW	n/applicable (start-up only)	n/applicable (start-up only)
FieldTooLow, W/ Programmable Threshold	Diag. (No Debouncing)	Diagnostic low/high Reporting (optional)	Environ &Analog	n/applicable (start-up only)	n/applicable (start-up only)
FieldTooHigh w/ Programmable Threshold	Diag. (No Debouncing)	Diagnostic low/high Reporting (optional)	Environ &Analog	n/applicable (start-up only)	n/applicable (start-up only)
WeakMagnet Diagnostic	Diag. (No Debouncing)	Diagnostic low/high Reporting (optional)	Environ	n/applicable (start-up only)	n/applicable (start-up only)
Under Voltage Monitoring *SUPPLYMONI =* *(MT3VB) OR (MT4VB)*	St-up on Hold	Diagnostic low/high	Environ &Analog	n/applicable (start-up only)	n/applicable (start-up only)
Over Voltage Monitoring *MT7V*	PTC entry	OUT in HiZ	Environ	n/applicable (start-up only)	n/applicable (start-up only)
BG Loop Diag.					
ROM 16bit checksum (continuous)	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low//high Reporting (optional)	Digi HW	800ms	800ms
RAM Test (continuous)	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low//high Reporting (optional)	Digi HW	160ms	160ms
EEPROM 8 bit CRC Check (continuous)	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low/high Reporting (optional)	Digi HW	10ms	10ms
Watchdog (continuous)	CPU reset	--	Digi HW	120ms	n/a
DSP Loop Diag.					
ADC Clipping ADCCLIP	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ &Analog	5/DSP	6ms x INT (THRES/STEP_UP)
FieldTooLow, W/ Programmable Threshold	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ &Analog	1/DSP	6ms x INT (THRES/STEP_UP)
FieldTooHigh w/ Programmable Threshold	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ &Analog	1/DSP	6ms x INT (THRES/STEP_UP)
WeakMagnet Diagnostic	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ	1/DSP	6ms x INT (THRES/STEP_UP)
Virtual Gain Code Out-of-spec GAINOOS	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ &Analog	1/DSP	6ms x INT (THRES/STEP_UP)

Virtual Gain Code Saturation [GAINMIN..GAINMAX]	Saturation (optional)	Gain Saturated @ GAINMIN-GAINMAX	Environ &Analog	n/applicable Not a diagnostic	n/applicable Not a diagnostic
ADC Monitor (Analog to Digital Converter) *ADCMONI*	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Analog HW	1/DSP	6ms x INT (THRES/STEP_UP)
Under Voltage Monitoring *SUPPLYMONI = (MT3VB) OR (MT4VB)*	Supply Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Environ &Analog	1/DSP	6ms x INT (THRES/STEP_UP)
Over Voltage Monitoring *MT7V*	PTC entry after PTC Debouncing	OUT in HiZ	Environ	2ms	2ms
Temperature Sensor Monitor *TEMPMONI*	Debouncing (prog.)	Diagnostic low/high Reporting (optional)	Analog	1/DSP	6ms x INT (THRES/STEP_UP)
Temperature > 170degC (± 20) Temperature < -60degC (± 20)	Saturate value used for the compensations to -40degC and +150degC resp.	No effect	Environ &Analog		n/applicable Not a diagnostic
Hardware Diag. (continuously checked by dedicated Logic)					
Read/Write Access out of physical memory	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic Low/High	Digi HW	n/a immediate Diag	n/a immediate Diag
Write Access to protected area (IO and RAM Words)	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low/high	Digi HW	n/a immediate Diag.	n/a immediate Diag.
Unauthorized Mode Entry	Fail-safe mode ** ** CPU reset after 120ms	Diagnostic low/high	Digi HW	n/a immediate Diag	n/a immediate Diag
EEPROM Error Correcting Code (Hamming correction)	(Transparent) Error Correction	no effect	Digi HW	n/a.	n/a
Hardware Diag. (continuously checked by dedicated Analog circuits)					
Broken VSS	CPU Reset on recovery	Pull down load => Diag. Low Pull up load => Diag. High	Environ	n/a immediate Diag.	n/a immediate Diag.
Broken VDD	CPU Reset on recovery	Pull down load => Diag. Low Pull up load => Diag. High	Environ	n/a immediate Diag	n/a immediate Diag
Resistive Cable Test	St-up on Hold	Diagnostic low/high	Environ	n/a immediate Diag.	n/a immediate Diag.

16. Recommended Application Diagrams

16.1. Wiring with the MLX90365 in SOIC-8 Package

Compact PCB routing		
C1, C2, C3	100nF	Analog Out
C1, C3 C2	100nF 4.7nF	PWM Out
Optimal EMC/ESD performances		
C1, C2	1nF	Close to IC terminals
C3, C4 , C5	100nF	Analog Out - Close to connector
C5	4.7nF	PWM Out - Close to connector
R1	10 Ω	Not recommended for Analog Out Recommended for PWM Out
R2	50 Ω	Optional for Analog Out Recommended for PWM Out

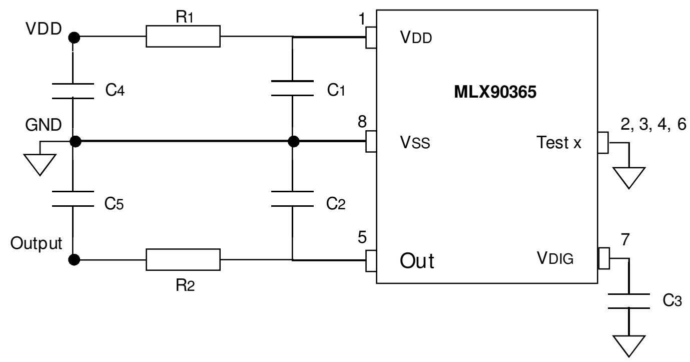


Figure 13 – Recommended wiring for the MLX90365 in SOIC8 package

16.2. Wiring with the MLX90365 in TSSOP-16 Package

Compact PCB routing		
C11, C12, C13 C21, C22, C23	100nF	Analog Out
C11, C13, C21, C23 C12, C22	100nF 4.7nF	PWM Out
Optimal EMC/ESD performance		
C11, C12 C21, C22	1nF	Close to IC terminals
C13, C14 , C15 C23, C24 , C25	100nF	Analog Out - Close to connector
C15 C25	4.7nF	PWM Out - Close to connector
R11 R21	10 Ω	Not recommended for Analog Out Recommended for PWM Out
R12 R22	50 Ω	Optional for Analog Out Recommended for PWM Out

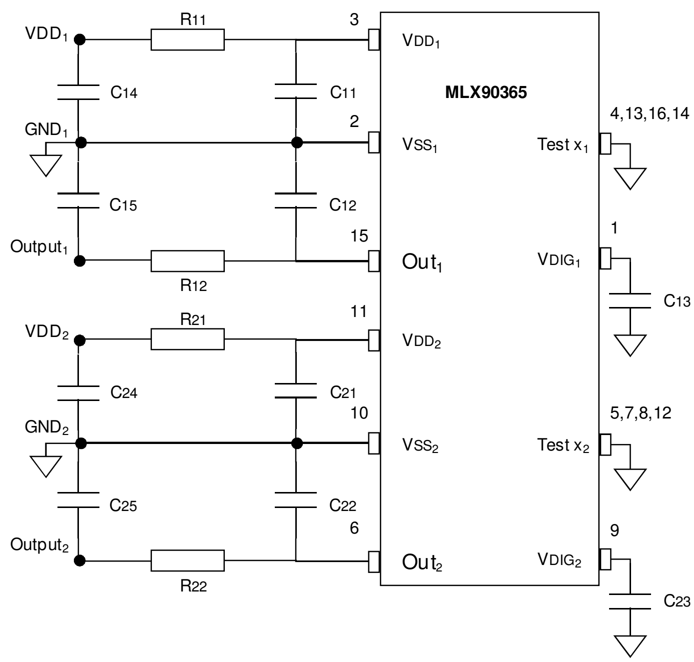


Figure 14 – Recommended wiring for the MLX90365 in TSSOP16 package (dual die)

17. 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.

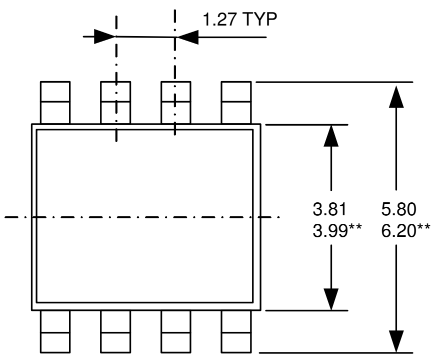
For more information on the lead free topic please see quality page at our website:
http://www.melexis.com/quality.aspx

18. ESD Precautions

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

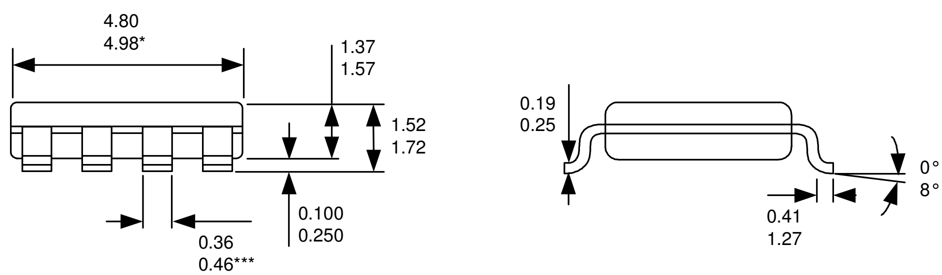
19. Package Information

19.1. SOIC8 - Package Dimensions

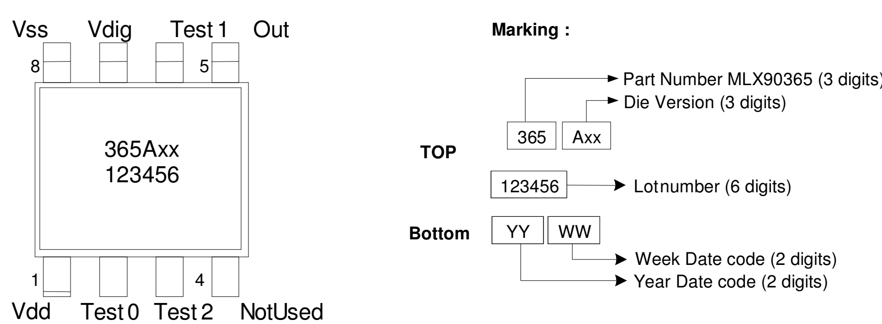


NOTES:

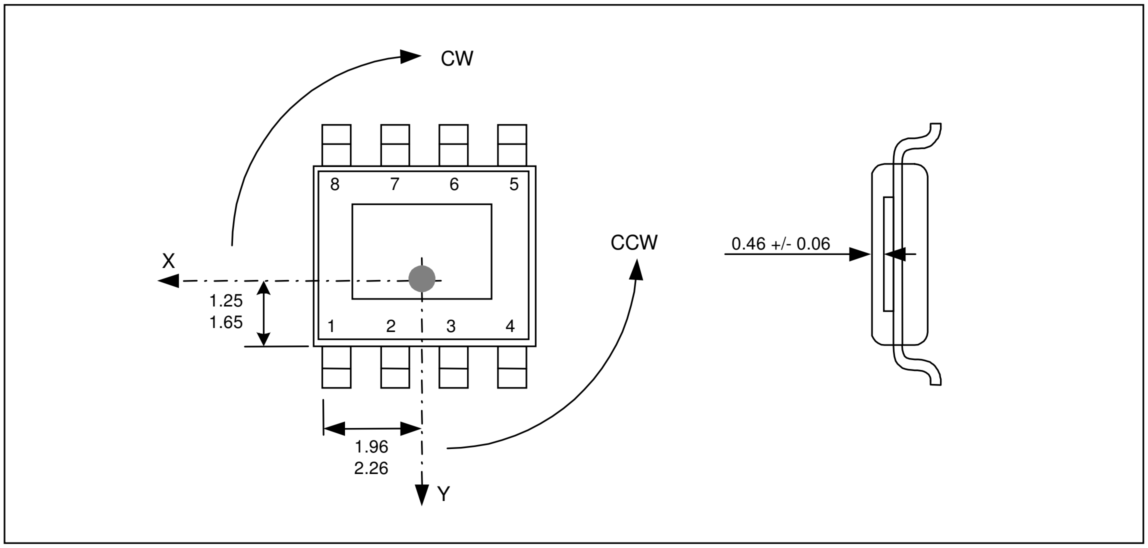
All dimensions are in millimeters (anlges in degrees).
* Dimension does not include mold flash, protrusions or gate burrs (shall not exceed 0.15 per side).
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side).
*** Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot.

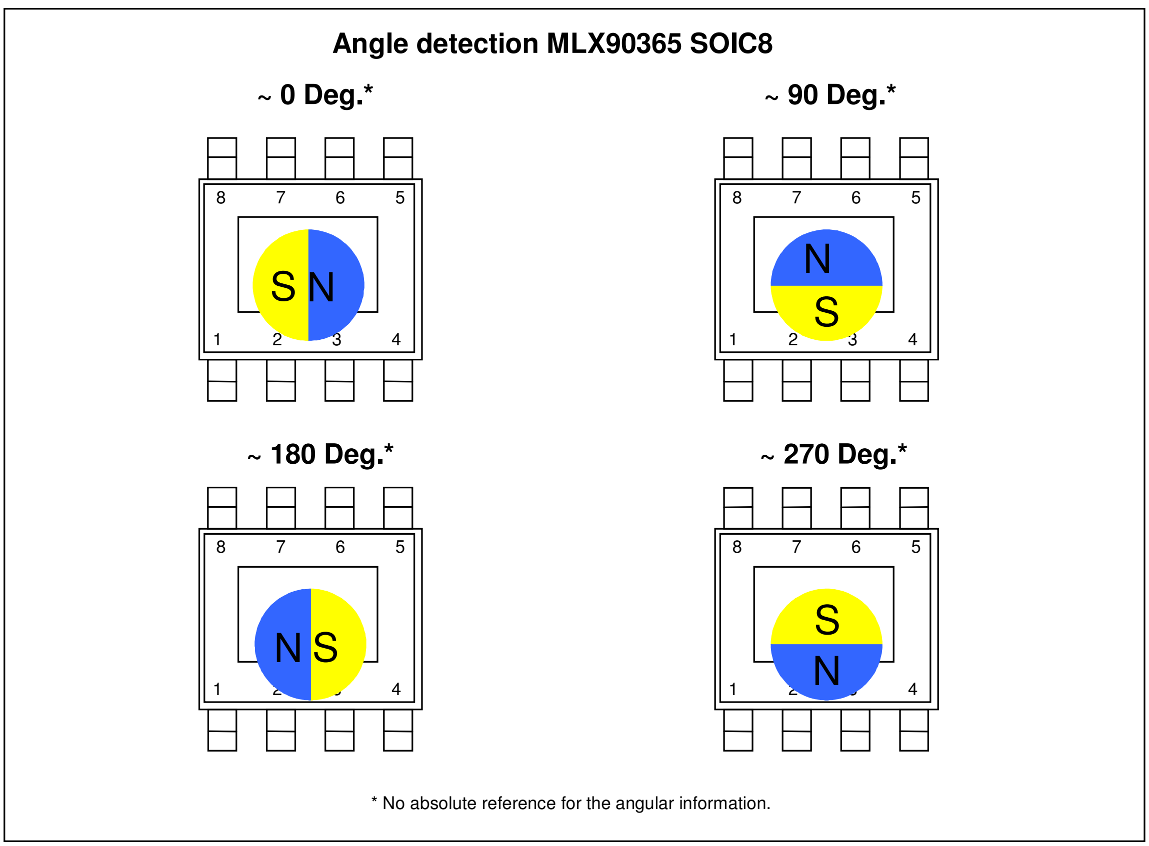


19.2. SOIC8 - Pinout and Marking



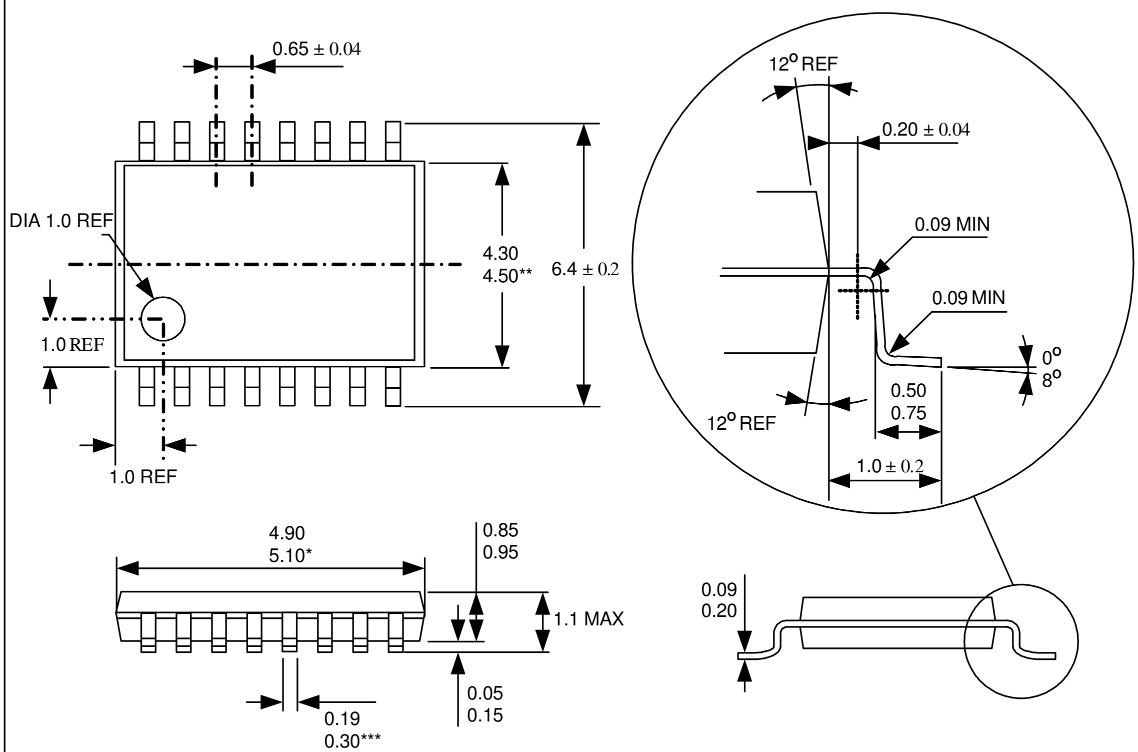
19.3. SOIC8 - Sensitive spot Positioning





The MLX90365 is an absolute angular position sensor but the linearity error (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).

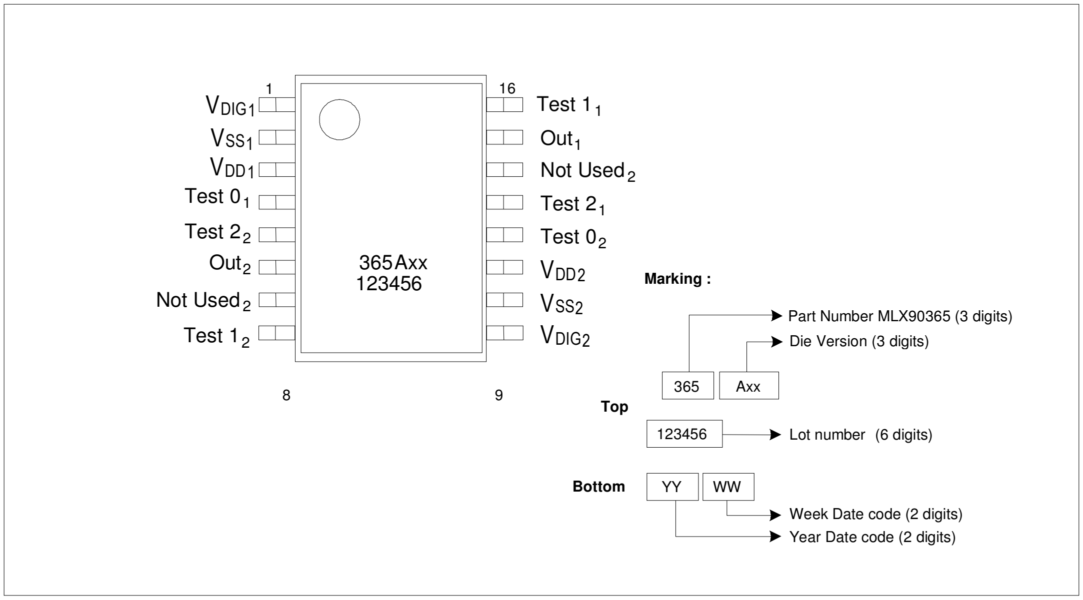
19.4. TSSOP16 - Package Dimensions



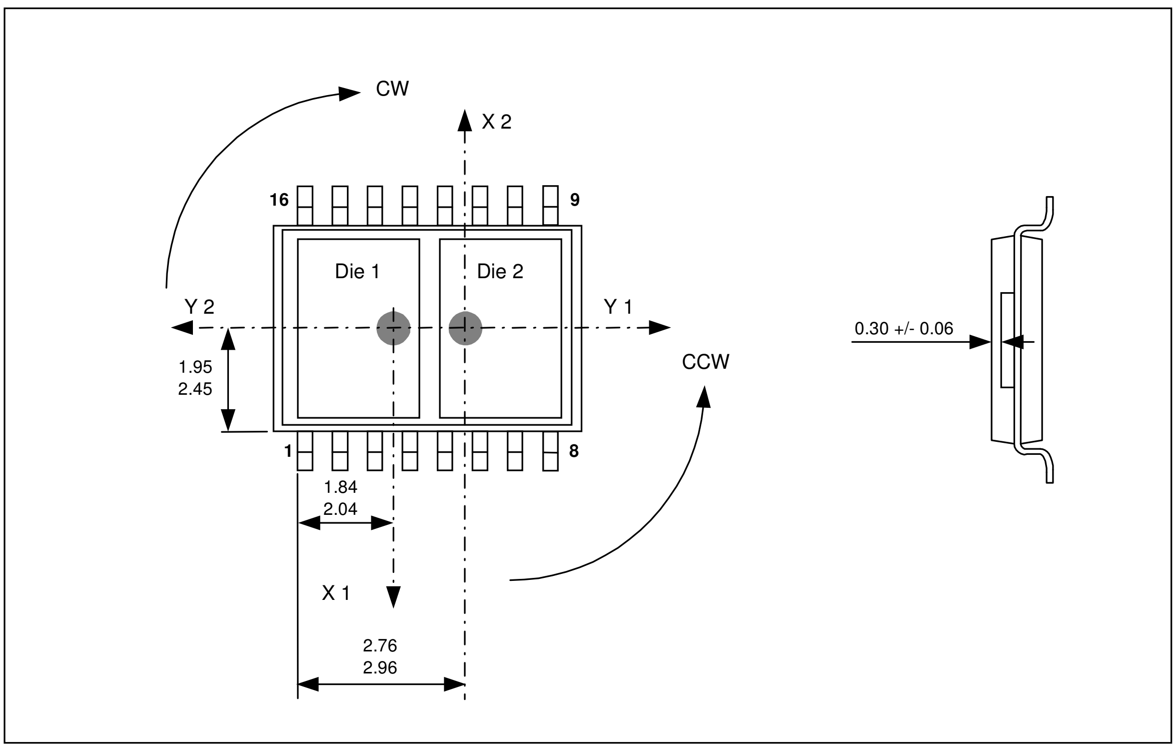
NOTES:

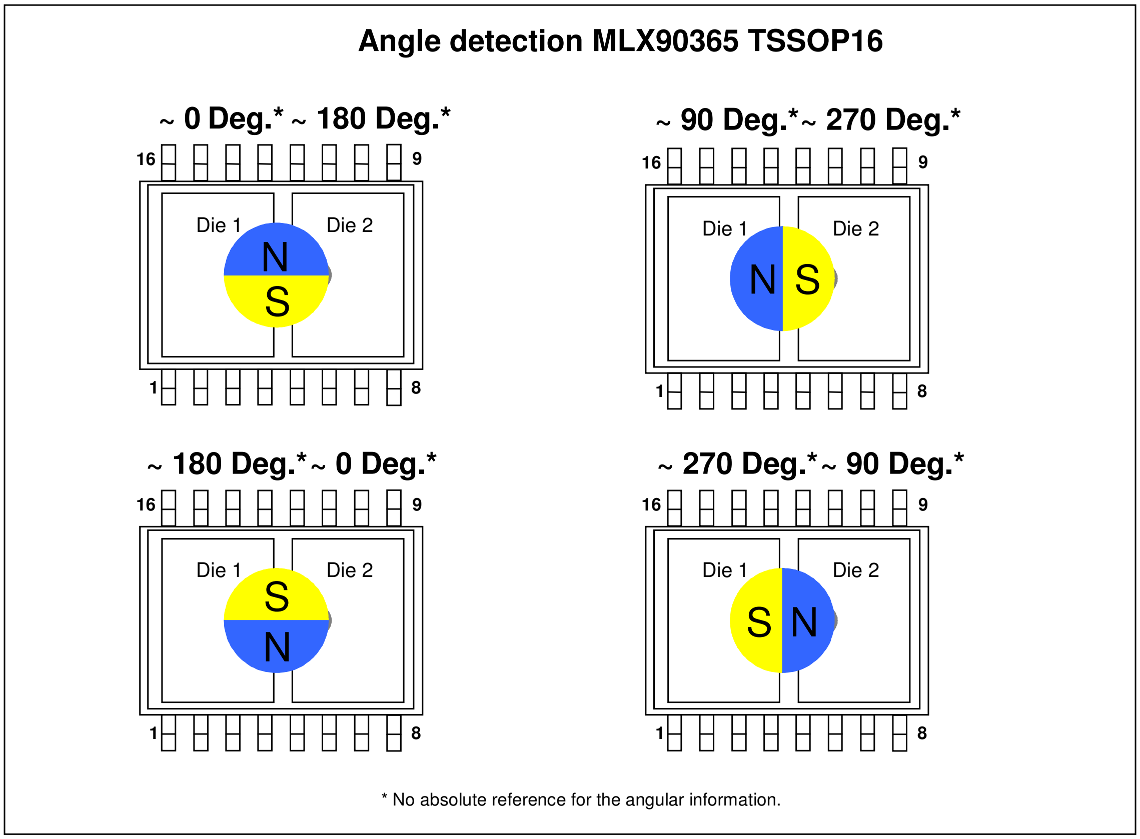
All dimensions are in millimeters (anlges in degrees).
* Dimension does not include mold flash , protrusions or gate burrs(shall not exceed 0.15 per side).
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side).
*** Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot
REF: Reference dimensions as stated in packaging supplier POD , based on JEDEC.

19.5. TSSOP16 - Pinout and Marking



19.6. TSSOP16 - Sensitive spot Positioning





The MLX90365 is an absolute angular position sensor but the linearity error (See section 10) does not include the error linked to the absolute reference 0Deg (which can be fixed in the application through the discontinuity point).

20. Disclaimer

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