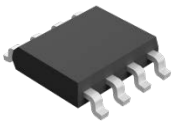
MLX90371 – Triaxis® Position Processor

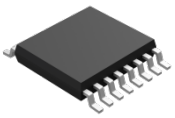
Datasheet

Features and Benefits

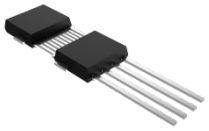
- Triaxis® Hall Technology
- On-Chip Signal Processing for Robust Absolute Position Sensing
- ISO26262 ASIL READY BY MELEXIS
  ASIL-B Safety Element out-of-Context
- Programmable Measurement Range
- Programmable Linear Transfer Characteristic (Multi-points 4 or 8 points or Piece-Wise-Linear 16 or 32 segments)
- Selectable Analog (Ratiometric) or PWM Output
- 12 bit Resolution - 10 bit Thermal Accuracy
- 48 bit ID Number option
- Robustness against Stray-Field



SOIC-8



TSSOP-16



DMP-4

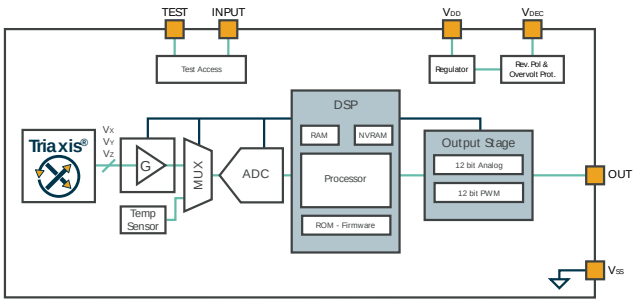
Application Examples

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

Description

The MLX90371 is a monolithic sensor sensitive to the three components of the flux density applied to the IC (i.e. B_X, B_Y and B_Z). This allows the MLX90371 with the correct magnetic circuit to decode the absolute position of any magnet moving in its vicinity (e.g. rotary position from 0 to 360 Degrees or linear displacement, see Figure 2).

The MLX90371 reports a programmable ratiometric analog output signal compatible with any resistive potentiometer or programmable linear Hall sensor. Through programming, the MLX90371 can provide a digital PWM (Pulse Width Modulation) output characteristic.



Ordering Information

Product	Temperature	Package	Option Code	Packing Form	Definition
MLX90371	G	DC	BCC-100	RE	Rotary Stray-Field Immune Mode
MLX90371	G	DC	BCC-200	RE	Linear Stray-Field Immune Mode
MLX90371	G	DC	BCC-300	RE	Standard / Legacy Mode
MLX90371	G	GO	BCC-100	RE	Rotary Stray-Field Immune Mode – Low-Field Variant
MLX90371	G	GO	BCC-200	RE	Linear Stray-Field Immune Mode
MLX90371	G	GO	BCC-300	RE	Standard / Legacy Mode
MLX90371	G	GO	BCC-500	RE	Rotary Stray-Field Immune Mode – High-Field Variant
MLX90371	G	VS	BCC-100	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-150	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-101	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-151	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-103	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-153	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-108	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-158	RE/RX	Rotary Stray-Field Immune Mode
MLX90371	G	VS	BCC-200	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-250	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-201	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-251	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-203	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-253	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-208	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-258	RE/RX	Linear Stray-Field Immune Mode
MLX90371	G	VS	BCC-300	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-350	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-301	RE/RX	Standard / Legacy Mode

Product	Temperature	Package	Option Code	Packing Form	Definition
MLX90371	G	VS	BCC-351	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-303	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-353	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-308	RE/RX	Standard / Legacy Mode
MLX90371	G	VS	BCC-358	RE/RX	Standard / Legacy Mode

Legend:

Temperature Code:	G: from -40°C to 160°C
Package Code:	"DC" for SOIC-8 package "GO" for TSSOP-16 package (dual die) "VS" for DMP-4 package (dual mold, PCB-less)
Option Code:	BCC-xxx: die Version xxx-**123**: **1**: Application – Magnetic configuration ▪ 1: Rotary Stray-Field Immune mode – Low-Field Variant ▪ 2: Linear Stray-Field Immune mode ▪ 3: Standard / Legacy mode (legacy backwards comparable to previous generation) ▪ 5: Rotary Stray-Field Immune mode – High-Field Variant **2**: Configuration for DMP package ▪ 0: 100nF output capacitor ▪ 5: 10nF output capacitor **3**: Trim-and-Form for DMP-4 ▪ 0: Standard straight leads. See section 18.3.1 ▪ 1: Trim-and-Form STD1 2.54. See section 18.3.2 (not recommended for new designs, prefer STD4 2.54) ▪ 3: Trim-and-Form STD2 2.54. See section 18.3.3 ▪ 8: Trim-and-Form STD4 2.54. See section 18.3.4
Packing Form:	-RE : Tape & Reel ▪ VS:2500 pcs/reel ▪ DC:3000 pcs/reel ▪ GO:4500 pcs/reel -RX : Tape & Reel, similar to RE with parts face-down (VS package only)
Ordering Example:	"MLX90371GDC-BCC-100-RE" For a Rotary Stray-Field Immune mode variant1 application in SOIC-8 package, delivered in Reel.

Table 1 – Ordering information legend

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1. Functional Diagram

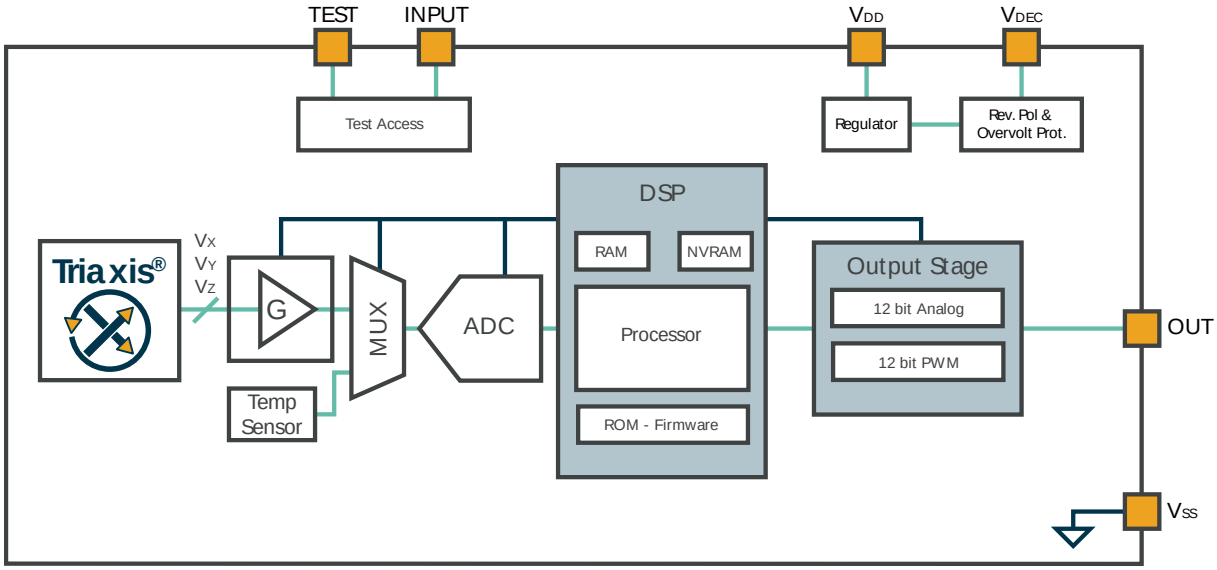


Figure 1 – MLX90371 Block Diagram

2. Glossary of Terms

Term	Description	Term	Description
Gauss (G), Tesla (T)	Units for the magnetic flux density: 1 mT = 10 G	SEooC	Safety Element Out of Context
TC	Temperature Coefficient (in ppm/Deg.C.)	FIR	Finite Impulse Response
PWM	Pulse Width Modulation	DCT	Diagnostic Cycle Time
%DC	Duty Cycle of the output signal. i.e. T_{ON} /(T_{ON} + T_{OFF})	PWL	Piece Wise Linear
ADC	Analog-to-Digital Converter	IWD	Intelligent Watchdog
DAC	Digital-to-Analog Converter	AWD	Absolute Watchdog
LSB	Least Significant Bit	CPU	Central Processing Unit
MSB	Most Significant Bit	POR	Power On Reset
DNL	Differential Non-Linearity	SW	Software
INL	Integral Non-Linearity	HW	Hardware
ASP	Analog Signal Processing	ECC	Error-Correcting Code
DSP	Digital Signal Processing	ROM	Read-only Memory
EMC	Electro-Magnetic Compatibility	RAM	Random-access Memory
DMP	Dual Mold Package	NVRAM	Non-volatile Random-access Memory
DP	Discontinuity Point	AoU	Assumptions of Use
EoL	End of Line	IMC	Integrated Magnetic Concentrator

Table 2 – Glossary of Terms

3. Pin Definitions

3.1. Pin Definition for SOIC-8 package

Pin #	Name	Description
1	V_{DD}	Supply
2	Test Input	For test
3	Test	For test
4	Not Used	
5	OUT	Output
6	V_{SS_D}	Ground
7	V_{DEC}	Decoupling pin (on-chip regulator)
8	V_{SS_A}	Ground

Table 3 – SOIC-8 Pin Definitions and Descriptions

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 15.1).

3.2. Pin Definition for TSSOP-16 package

Pin #	Name	Description
1	V_{DEC_1}	Decoupling pin
2	$V_{SS_{A1}}$	Ground
3	V_{DD_1}	Supply
4	$Test\ Input_1$	For test
5	$Test_2$	For test
6	OUT2	Output
7	$Not\ Used_2$	
8	$V_{SS_{D2}}$	Ground
9	V_{DEC_2}	Decoupling pin
10	$V_{SS_{A2}}$	Ground
11	V_{DD_2}	Supply
12	$Test\ Input_2$	For test
13	$Test_1$	For test
14	$Not\ Used_1$	
15	OUT1	Output
16	$V_{SS_{D1}}$	Ground

Table 4 – TSSOP-16 Pin Definitions and Descriptions

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 15.2).

3.3. Pin Definition for DMP-4 package

Pin #	Name	Description
1	VSS	Ground
2	VDD	Supply
3	OUT	Output
4	VSS	Ground

Table 5 – DMP-4 Pin Definitions and Descriptions

4. Absolute Maximum Ratings

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply Voltage	V_{DD}			28 45	V	<48h <1min
Reverse Voltage Protection	$V_{DD_{REV}}$	-14			V	At Room Temperature; <48h
Positive Output Voltage	V_{OUT}			18	V	<48h
Output Current	I_{OUT}	-30		30	mA	-1.5V< V_{OUT} <40V
Reverse Output Voltage	$V_{OUT_{REV}}$	-0.3			V	<48h
Operating Temperature	T_{AMB}	-40		+160	°C	Refer to the qualification profile
Junction Temperature	T_{JUNC}			+175	°C	
Storage Temperature	T_{ST}	-55		+170	°C	Refer to the qualification profile
Magnetic Flux Density		-1		1	T	

Table 6 – Absolute Maximum Ratings

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

5. Isolation Specification

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

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Isolation Resistance		4	-	-	MΩ	Between dice

Table 7 – Isolation Specification

6. General Electrical Specifications

General electrical specifications are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Electrical Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply Voltage	VDD	4.5	5	5.5	V	
Supply Current [1]	IDD	7	10	12	mA	Rotary Stray-Field Immune mode, Linear Stray-Field Immune mode, no resistive load at OUT PIN (OUT1 and OUT2 for TSSOP-16 package)
Supply Current [1]	IDD	6	9	10	mA	Standard/Legacy mode, no resistive load at OUT PIN (OUT1 and OUT2 for TSSOP-16 package)
Start-up Level (rising)		3.95	4.1	4.25	V	
Start-up Hysteresis		100	200	300	mV	
PTC Entry Level [2](rising)		6.2	6.5	6.8	V	
PTC Entry Level Hysteresis		400	500	600	mV	
Output Short Circuit Current	I_{short}	-25 10		-10 25	mA	VOUT = 0 V VOUT = 5 V or 18 V
Output Load	R_L	5 2	10 10	∞ ∞	kΩ	Analog mode Digital (PWM) mode
Analog Saturation Output Level	VsatA_lo		0.5 3.5	1 5	%VDD	Pull-up load $R_L \geq 10$ kΩ to 5 V Pull-up load $R_L \geq 5$ kΩ to 18 V
	VsatA_hi	96 97.5	97 98		%VDD	Pull-down load $R_L \geq 5$ kΩ Pull-down load $R_L \geq 10$ kΩ
Digital (PWM) Output Level	VsatD_lo		0.5 3.5 2.5	1 5 4	%VDD	Pull-up load $R_L \geq 10$ kΩ to 5 V Pull-up load $R_L \geq 5$ kΩ to 18 V Pull-up load $R_L \geq 2$kΩ to 5 V
	VsatD_hi	85 96 97.5	90 97 98		%VDD	Pull-down load $R_L \geq 2$ kΩ Pull-down load $R_L \geq 5$ kΩ Pull-down load $R_L \geq 10$ kΩ

[1] For the dual die version, the current is multiplied by 2

[2] IC to be programmed at room temperature

Electrical Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Active Diagnostic Output Level	Diag_lo		0.5 3.5 2.5	1 5 4	%VDD	Pull-up load $R_L \geq 10$ kΩ to 5 V Pull-up load RL ≥ 5 kΩ to 18 V Pull-up load RL ≥ 2 kΩ to 5 V
	Diag_hi	85 96 97.5	90 97 98		%VDD	Pull-down load $R_L \geq 2$ kΩ Pull-down load $R_L \geq 5$ kΩ Pull-down load $R_L \geq 10$ kΩ
Passive Diagnostic Output Level (Broken-Wire Detection) [3]	BVSSPD	97.5 95	98 96		%VDD	Broken VSS & Pull-down load $R_L \geq 10$ kΩ Pull-down load $R_L \geq 5$ kΩ
	BVSSPU	99.5	100		%VDD	Broken VSS & Pull-up load $R_L \geq 5$ kΩ
Passive Diagnostic Output Level (Broken-Wire Detection) [3]	BVDDPD		0	0.5	%VDD	Broken VDD & Pull-down load $R_L \geq 5$ kΩ
	BVDDPU			2	%VDD	Broken VDD & Pull-up load $R_L \geq 5$ kΩ
Clamped Output Level [4]	Clamp	0		100	%VDD	Programmable

Table 8 – Electrical specifications

As an illustration of the previous table, the MLX90371 fits the typical classification of the output span described on the Figure 2.

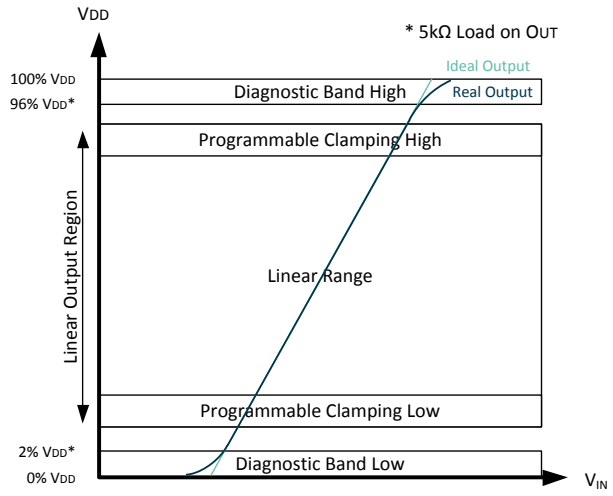


Figure 2 – Example of Output Span Classification for typical application.

[3] *For detailed information, see also section 14.1 Safety Mechanism*
[4] *Clamping levels need to be considered vs. the saturation of the output stage (see Analog Saturation Output level)*

7. Timing Specification

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

7.1. General Timing

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Main Clock Frequency	Ck	17.1	18	18.9	MHz	Including thermal drift and aging
Main Clock Frequency Thermal Drift	Δ^TCk	-3		3	% Ck	
Refresh Rate	τ_R			482	µs	
Latency Time	τ_L		440	462	µs	
Step Response Time [5]	τ_S	-	968 1474 2486 2486 5008	1127 1624 2617 2617 5099	µs	Filter=0 (FIR1) [6] Filter=1 (FIR11) Filter=2 (FIR1111) HYST=1/2 HYST=1/4

Table 9 – General Timing Specification

7.2. Latency Time Definition

The latency time is a suitable metric for the "delay" of the sensor in case of a slow ramp of the magnetic change, for instance, when the magnet has an angular frequency of 10 radians per second, i.e., 360 Deg. rotation within 100ms. A graphic illustration can be seen in Figure 3.

[5] Also include the main clock variations. Typical: Output already reached 50% settling in a first step (482µs earlier). Maximum: Output already reached 90% settling in a first step (482µs earlier)

[6] See section 13.4 for details concerning Filter parameter

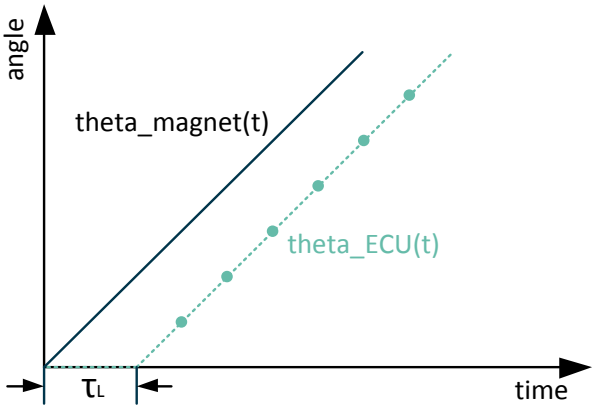


Figure 3 – Typical Latency illustration

7.3. Step Response Definition

The step response is a suitable metric for the "delay" of the sensor in case of an abrupt step in the magnetic change, considering 100% settling time without any DSP filter. Full settling is typically achieved in just two steps. The sensor is asynchronous with the magnetic step change: the 100% settling time will fall in a time window; worst case is given in the Table 9.

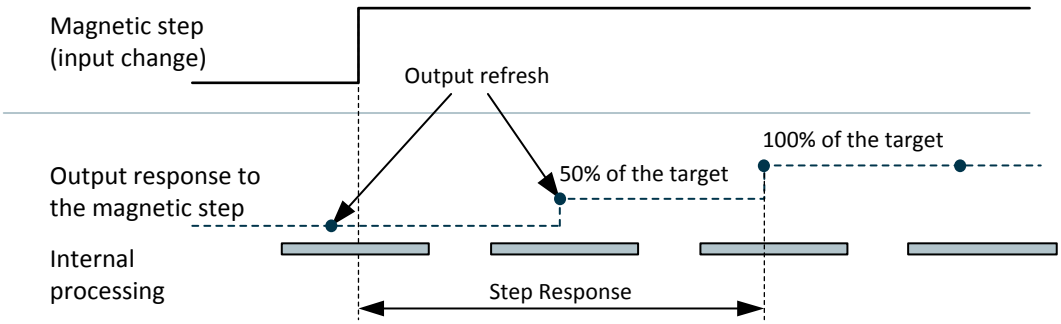


Figure 4 – Typical Step Response illustration

7.4. Analog timing

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Start-up Time	τ_{SU}			5	ms	Analog mode
Analog OUT Slew-rate	S_R		200		V/ms	no load, valid for both rising and falling edge
			120		V/ms	capacitor load C_L = 100 nF, valid for both rising and falling edge
			35		V/ms	capacitor load C_L = 330 nF, valid for both rising and falling edge

Table 10 – Analog timing specification

7.5. Digital (PWM) timing

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
PWM Frequency	F_{PWM}	150		2000	Hz	Ck = 18MHz
PWM Frequency tolerance	ΔF_{PWM}	-5		5	$\%F_{PWM}$	Including thermal drift and aging
PWM Frequency Thermal Drift	$\Delta^T F_{PWM}$	-3		3	$\%F_{PWM}$	
Digital (PWM) output rise time		2		11	µs	Push-Pull, C_L = 4.7 nF, R_L = 4.7kΩ PU
Digital (PWM) output fall time		2		11	µs	Push-Pull, C_L = 4.7 nF, RL = 4.7kΩ PU
Start-up Time	τ_{SU}			5[7] 15[7]	ms	PWM mode @1kHz PMW mode @150Hz

Table 11 – Digital (PWM) timing specification

[7] *For PWM the start-up time is defined as the first edge of the first valid PWM cycle*

8. Magnetic Field Requirements

This section describes the magnetic field requirements in order to meet the performance described in section 9.1.

8.1. Rotary Stray-Field Immune Mode – Low-Field Variant

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Number of magnetic poles	N_P		4		-	End-of-shaft rotation
Magnetic Flux Density in X or Y	B_X, B_Y[8]			25[9]	mT	$\sqrt{B_X^2 + B_Y^2}$ this is NOT the useful signal
Magnetic Flux Density in Z	B_Z			100	mT	this is NOT the useful signal
Magnetic In-plane gradient of In-plane field component	$\frac{\Delta B_{XY}}{\Delta XY}$	3.8			mT/ mm	$\frac{1}{2}\sqrt{\left(\frac{dB_X}{dX} - \frac{dB_Y}{dY}\right)^2 + \left(\frac{dB_X}{dY} + \frac{dB_Y}{dX}\right)^2}$ min. value represents the minimum gradient available at worst-case condition: biggest airgap, biggest offaxis position, highest temperature See Figure 5 below
Magnet Temperature Coefficient	TCm	-2400		0	ppm/ Deg.C.	
Field Too Low Threshold[10]	B_{TH_LOW}	1	1.5	2	mT/ mm	corresponding to TCm=0
Field Too High Threshold[10]	B_{TH_HIGH}	70	100	130	mT/ mm	corresponding to TCm=0. Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensors

Table 12 – Magnetic field requirements for rotary Stray-Field immune mode – Low-Field Variant

[8] *The condition must be fulfilled for at least one field B_X or B_Y*
[9] *Above this value, the IMC® starts saturating yielding to an increase of the linearity error*
[10] *Further details can be referred to section 11, see parameters "DIAG_FIELDTOOLOWTHRES" and "DIAG_FIELDTOOHIGHTHRES".*

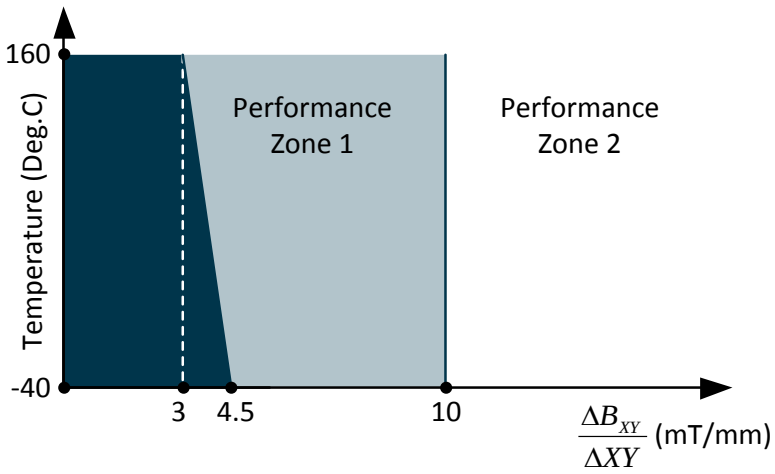


Figure 5 – Minimum useful signal definition for rotary Stray-Field immune mode – Low-Field Variant

8.2. Rotary Stray-Field Immune Mode – High-Field Variant

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Number of magnetic poles	N_P		4		-	End-of-shaft rotation
Magnetic Flux Density in X or Y	B_X, B_Y (8)			67 (9)	mT	$\sqrt{B_X^2 + B_Y^2}$ this is NOT the useful signal
Magnetic Flux Density in Z	B_Z			100	mT	this is NOT the useful signal
Magnetic In-plane gradient of In-plane field component	$\frac{\Delta B_{XY}}{\Delta XY}$	10		-	mT/ mm	$\frac{1}{2}\sqrt{\left(\frac{dB_X}{dX} - \frac{dB_Y}{dY}\right)^2 + \left(\frac{dB_X}{dY} + \frac{dB_Y}{dX}\right)^2}$ min. value represents the minimum gradient available at worst-case condition: biggest airgap, biggest offaxis position, highest temperature
Magnet Temperature Coefficient	TCm			0	ppm/ Deg.C.	
Field Too Low Threshold	B_{TH_LOW}	1	1.5	2	mT/ mm	corresponding to TCm=0
Field Too High Threshold	B_{TH_HIGH}	70	100	130	mT/ mm	corresponding to TCm=0. Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensors

Table 13 – Magnetic field requirements for rotary Stray-Field immune mode – High-Field Variant

8.3. Linear Stray-Field Immune Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Number of magnetic poles	N_P		2		-	Linear movement
Magnetic Flux Density in X	B_X			70[11]	mT	B_Y≤20mT
Magnetic Flux Density in X-Y	B_X, B_Y[12]			70	mT	$\sqrt{B_X^2 + B_Y^2}$ to be used when B_Y>20mT
Magnetic Flux Density in Z	B_Z			100	mT	
Magnetic input gradient of X-Z field components	$\frac{\Delta B_{XZ}}{\Delta X}$	6[13]			mT/ mm	$\sqrt{\left[\left(\frac{\Delta B_X}{\Delta X}\right)^2 + \left(\frac{1}{G_{IMC}}\frac{\Delta B_Z}{\Delta X}\right)^2\right]}$[14]
Distance between the two IMC®	ΔX		1.8		mm	
IMC gain	G_{IMC}		1.19			see[14]
Magnet Temperature Coefficient	TCm	-2400		0	ppm/ Deg.C.	
Field Too Low Threshold[10]	B_{TH_LOW}	2	3	4	mT/ mm	corresponding to TCm=0
Field Too High Threshold[10]	B_{TH_HIGH}	70	100	130	mT/ mm	corresponding to TCm=0. Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensors.

Table 14 – Magnetic field requirement for linear Stray-Field immune mode

[11] Above 70 mT, the IMC® starts saturating yielding to an increase of the linearity error.

[12] The condition must be fulfilled for all combinations of Bx and By.

[13] Below 6 mT/mm, the performances degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.

[14] IMC has better performance for concentrating in-plane (x-y) field components, resulting in a better overall magnetic sensitivity. A correction factor, (IMC Gain XY / IMC Gain Z), called IMC gain has to be applied to the z field component to account for this difference.

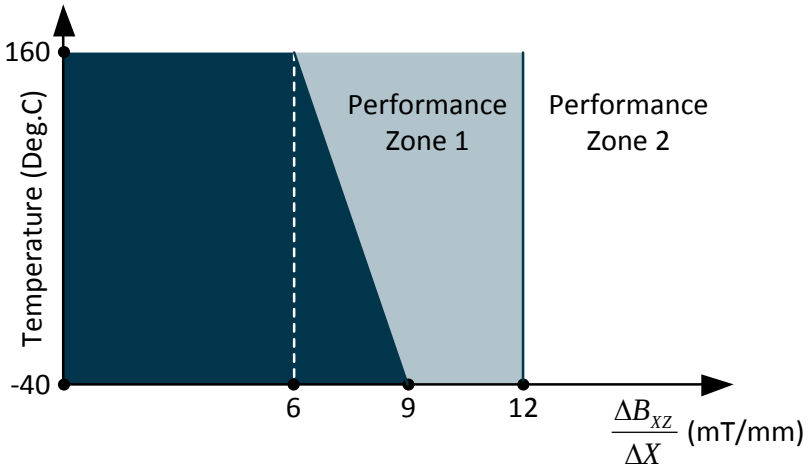


Figure 6 – Minimum useful signal definition for linear Stray-Field immune mode

8.4. Standard/Legacy Mode

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Number of magnetic poles	N_P		2		-	End of shaft rotation or Linear movement
Magnetic Flux Density in X or Y	B_X, B_Y[15]			70[16]	mT	$\sqrt{B_X^2 + B_Y^2}$
Magnetic Flux Density in Z	B_Z			100	mT	
Magnetic Flux	Norm	10[17]			mT	$\sqrt{B_X^2 + B_Y^2}$ (X-Y mode) $\sqrt{{B_X}^2 + \left(\frac{1}{G_{IMC}} B_Z\right)^2}$ (X-Z mode) $\sqrt{{B_Y}^2 + \left(\frac{1}{G_{IMC}} B_Z\right)^2}$ (Y-Z mode)
IMC gain	G_{IMC}		1.19			see[14]
Magnet Temperature Coefficient	TCm	-2400		0	ppm/ Deg.C	
Field Too Low Threshold[10]	B_{TH_LOW}	3.4	5	6.6	mT	corresponding to TCm=0
Field Too High Threshold[10]	B_{TH_HIGH}	70	100	130	mT	corresponding to TCm=0. Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensors.

Table 15 – Magnetic field requirement for standard / legacy mode

[15] The condition must be fulfilled for at least one field B_X or B_Y
[16] Above 70 mT, the IMC® starts saturating yielding to an increase of the linearity error
[17] Below 10 mT the performances degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio

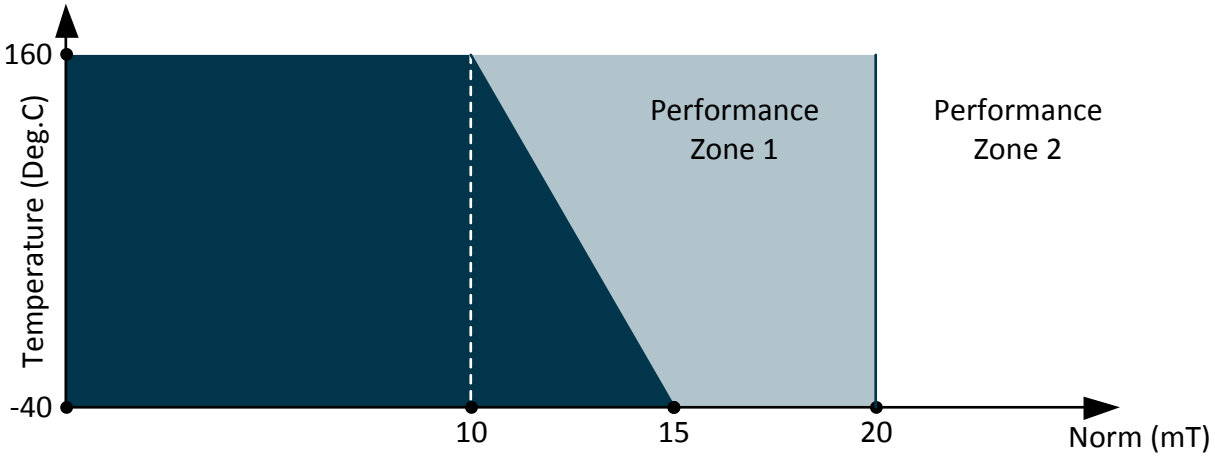


Figure 7 – Minimum useful signal definition for standard/legacy mode

9. Accuracy Specification

9.1. Magnetic Specification

9.1.1. Definition

This chapter defines several parameters, which will be used for the magnetic specification.

9.1.1.1. Intrinsic Linearity Error

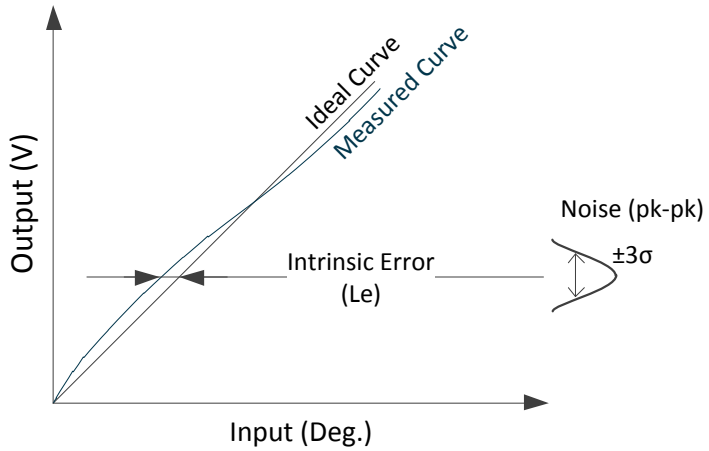


Figure 8 – Analog sensor accuracy definition

Figure 8 depicts the intrinsic linearity error in parts after Melexis factory calibration. The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating field for BX and BY. 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.

This error is typically not critical in application because it is calibrated away.

9.1.1.2. Total Drift

After calibration, the output angle of the sensor might still change due to temperature change, aging, etc.. This is defined as the total drift θ_{T_DRIFT}:

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

where θ_{IN} is the input angle, T is the temperature, T_{RT} is the room temperature, t is the elapsed lifetime after calibration, t_0 is the start of the operating life (right after calibration). Note the total drift θ_{T_DRIFT} is always defined with respect to angle at room temperature T_{RT} during calibration. In this datasheet, T_{RT} is typically defined at 30 Deg.C, unless stated otherwise. The total drift is valid for all angles along the full mechanical stroke.

9.1.2. Rotary Stray-Field Immune Mode – Low-Field Variant

Before EoL calibration. General performances are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
XY - Intrinsic Linearity Error	Le_{XY}	-1		1	Deg.	
Noise [18]				0.4	Deg.	Filter= 0 (FIR1), in performance zone 2[19]
				0.7	Deg.	Filter= 0 (FIR1), in performance zone 1[19]
				0.5	Deg.	Filter= 1 (FIR11), in performance zone 1[19]
				0.35	Deg.	Filter= 2 (FIR1111), in performance zone 1[19]
XY - Total Drift	$\theta_{T_DRIFT_XY}$			0.85	Deg.	
Hysteresis			0.1		Deg.	
Output Stray Field Immunity[20]	θ_{FF}			0.6	Deg.	In accordance of ISO 11452-8, at 30 Deg.C, with 10mT/mm magnetic In-plane gradient of In-plane field component, and stray-field strength of 4000A/m from any direction

Table 16 – Magnetic performances in Rotary Stray-Field Immune Mode – Low-Field Variant

9.1.3. Rotary Stray-Field Immune Mode – High-Field Variant

Before EoL calibration. General performances are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
XY - Intrinsic Linearity Error	Le_{XY}	-1		1	Deg.	
Noise [18]				0.5	Deg.	Filter= 0 (FIR1)
				0.35	Deg.	Filter= 1 (FIR11)
				0.25	Deg.	Filter= 2 (FIR1111)

[18] *±3σ*

[19] *Referred to section 8.1 and Figure 5.*

[20] *Stray field induced error is linearly proportional to the stray field strength.*

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
XY - Total Drift	$\theta_{T_DRIFT_XY}$			0.67	Deg.	Full temperature range
				0.6	Deg.	For max. temperature=140Deg.C
Hysteresis			0.1		Deg.	
Output Stray Field Immunity(20)	θ_{FF}			0.3	Deg.	In accordance of ISO 11452-8, at 30 Deg.C, with 21mT/mm magnetic In-plane gradient of In-plane field component, and stray-field strength of 4000A/m from any direction

Table 17 - Magnetic performances in Rotary Stray-Field Immune Mode – High-Field Variant

9.1.4. Linear Stray-Field Immune Mode

Before EoL calibration. General performances are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
XZ - Intrinsic Linearity Error	Le_{XZ}	-2.5	±1.25	2.5	Deg.	
Noise(18)				0.15	Deg.	Filter=0, in performance zone 2 (21)
				0.3	Deg.	Filter=0, in performance zone 1(21)
				0.25	Deg.	Filter=0, at 125 Deg.C in performance zone 1(21)
				0.2	Deg.	Filter=1, in performance zone 1(21)
				0.15	Deg.	Filter=2, in performance zone 1(21)
XZ - Total Drift	$\theta_{T_DRIFT_XZ}$			0.6	Deg.	For max. temperature=135Deg.C, in performance zone 2(21)
				0.8	Deg.	For max. temperature=135Deg.C, in performance zone 1(21)
				1.4	Deg.	Full temperature range in both performance zones

[21] *Referred to section 8.2 and Figure 6.*

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Hysteresis			0.1		Deg.	in performance zone 1[21]
Output Stray Field Immunity[20]	θ_{FF}			0.8	Deg.	In accordance of ISO 11452-8, at 30 Deg.C, with 6mT/mm magnetic In-plane gradient of In-plane field component, and stray-field strength of 4000A/m from any direction

Table 18 – Magnetic performances in Linear Stray-Field Immune Mode

9.1.5. Standard/Legacy Mode

Before EoL calibration. General performances are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
XY - Intrinsic Linearity Error	Le_{XY}	-1		1	Deg.	
XZ - Intrinsic Linearity Error	Le_{XZ}	-2.5	±1.25	2.5	Deg.	
YZ - Intrinsic Linearity Error	Le_{YZ}	-2.5	±1.25	2.5	Deg.	
Noise [18]			0.1	0.2	Deg.	Filter=0, in performance zone 2[22]
			0.2	0.4	Deg.	Filter=0, in performance zone 1[22]
			0.14	0.28	Deg.	Filter=1, in performance zone 1[22]
			0.1	0.2	Deg.	Filter=2, in performance zone 1[22]
XY - Total Drift	$\theta_{T_DRIFT_XY}$			0.45	Deg.	in performance zone 2[22]
				0.6	Deg.	in performance zone 1[22]
XZ - Total Drift	$\theta_{T_DRIFT_XZ}$			0.6	Deg.	in performance zone 2[22]
				0.8	Deg.	in performance zone 1[22]
YZ - Total Drift	$\theta_{T_DRIFT_YZ}$			0.6	Deg.	in performance zone 2[22]
				0.8	Deg.	in performance zone 1[22]

[22] *Referred to section 8.4 and Figure 7.*

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Hysteresis			0.1	0.2	Deg.	in performance zone 1[22]
			0.05	0.1	Deg.	in performance zone 2[22]

Table 19 – Magnetic performances in Standard/Legacy Mode

9.2. Analog Output Accuracy

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Thermal analog output Drift [18]				0.2	%VDD	
Analog Output Resolution	R_{DAC}		12		bit	12bit DAC (Theoretical)
		-2		+2	LSB_{12}	INL (before EoL calibration)
		0.05	1	3	LSB_{12}	DNL
Ratiometric Error		-0.1		0.1	%VDD	

Table 20 – Analog output accuracy

9.3. Digital (PWM) Output Accuracy

DC Operating Parameters at Nominal Supply Voltage V_{DD} = $V_{PULL-UP}$ = 5V.

9.3.1. Definition

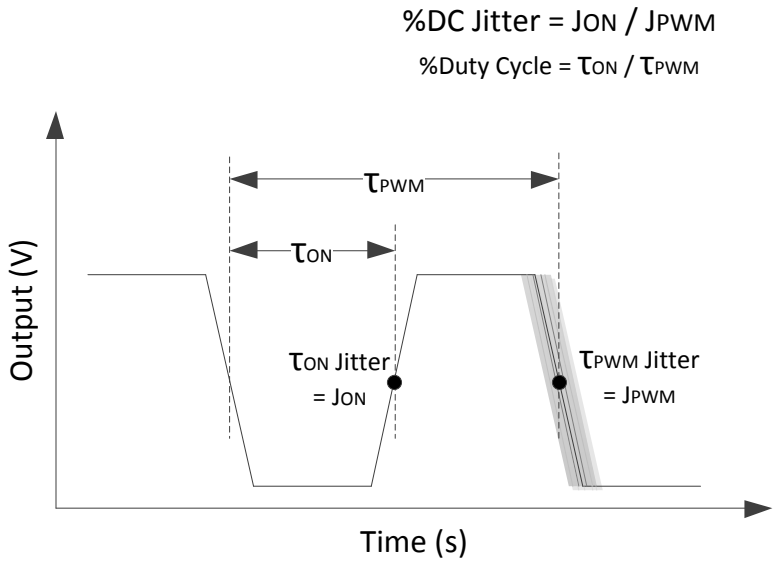


Figure 9 – Digital (PWM) sensor accuracy definition

Parameter	Name	Description
PWM period	τ_{PWM}	Trigger level = 50% V_{DD}
Rise time, Fall time		10% and 90% of amplitude
Jitter	J_{ON} J_{PWM}	±3σ for 1000 successive acquisitions with clamped output
Duty Cycle	DC	τ_{ON} / τ_{PWM}

Table 21 – PWM measurement conditions

9.3.2. Performances

General performances are valid for temperature range: -40 - 160 Deg.C, supply voltage range: 4.5 - 5.5V unless otherwise noted.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
PWM Output Resolution	R_{PWM}		12		bit	
PWM %DC Jitter	J_{DC}			0.03	%DC	Push-Pull, 1000Hz, C_L = 4.7 nF, R_L= 4.7 kΩ PU
PWM Period Jitter	J_{PWM}	-300		300	ns	Push-Pull, 1000Hz, C_L = 4.7 nF, R_L=4.7 kΩ PU
PWM %DC thermal drift				0.05	%DC	Push-Pull, 1000Hz, C_L = 4.7 nF, R_L=4.7 kΩ PU
PWM %DC Level drift				0.1	%DC	Push-Pull, 1000Hz, C_L = 4.7 nF, R_L = 4.7 kΩ PU

Table 22 – PWM performances

10. Memory Specification

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
ROM			32		KB	
RAM			1024		B	
NVRAM			256		B	

Table 23 – Memory specification

11. End-User Programmable Items

Parameter	PSF value	Description	Default Standard	# bit
PWMT	1	PWM period defined as (PWMT / 1.5) µsec	1000	16
PWM DC_FAULT	2	PWM Duty Cycle if Fault	1	8
PWM DC_FIELDTOOLOW	3	PWM Duty Cycle if Field Strength Too Low	1	8
PWM DC_WEAKMAG	4	PWM Duty Cycle if Weak Magnet	1	8
PWM WEAKMAGTHRESH	5	Weak Magnet threshold Byte	0	8
DIAG_FIELDTOOLOWTHRES[23]	6	Field limit under which a fault is reported	0	8
DIAG_FIELDTOOHIGHTHRES[23]	7	Field limit over which a fault is reported	255	8
GAINMIN	15	Low threshold for virtual gain	1	8
GAINMAX	16	High threshold for virtual gain	63	8
HYST	17	Hysteresis threshold filter	0	8
SENSING_MODE	19	Mapping fields for output angle Order code 1xx Order code 2xx Order code 3xx	 0 4 1	5
CW	20	Enables clockwise rotation direction	0	1
FILTER	21	FIR Filter mode selection	0	2
4POINTS	22	Select LNR method 4 / 8 pts	1	1
GAINSATURATION	25	Enable Gainmin & Gainmax as gain limiter instead of diagnostic thresholds.	0	1
DP	26	Discontinuity point, 0 degree position	0	16
LNRS0	28	4pts – Initial Slope	0 %/Deg.	16
LNRAX	30	4pts – AX Coordinate	0 Deg.	16
LNRAY	32	4pts – AY Coordinate	10 %	16
LNRAS	34	4pts – AS Coordinate	0.22%/Deg.	16
LNRBX	36	4pts – BX Coordinate	360 Deg.	16
LNRBY	38	4pts – BY Coordinate	100%	16

[23] To be adapted to the application to enable diagnostic "Lost magnet" by comparison with the Field Too Low/High Threshold defined in section 8.

Parameter	PSF value	Description	Default Standard	# bit
LNRBS	40	4pts – BS Coordinate	0 %/Deg.	16
LNRCX	42	4pts – CX Coordinate	360 Deg.	16
LNRCY	44	4pts – CY Coordinate	100%	16
LNRCS	46	4pts – CS Coordinate	0 %/Deg.	16
LNRDX	48	4pts – DX Coordinate	360 Deg.	16
LNRDY	50	4pts – DY Coordinate	100%	16
LNRDS	52	4pts – DS Coordinate	0 %/Deg.	16
LNR_Y0	27	17 pts - Y coordinate point 0	N/A	16
LNR_Y1	29	17 pts - Y coordinate point 1	N/A	16
LNR_Y2	31	17 pts - Y coordinate point 2	N/A	16
LNR_Y3	33	17 pts - Y coordinate point 3	N/A	16
LNR_Y4	35	17 pts - Y coordinate point 4	N/A	16
LNR_Y5	37	17 pts - Y coordinate point 5	N/A	16
LNR_Y6	39	17 pts - Y coordinate point 6	N/A	16
LNR_Y7	41	17 pts - Y coordinate point 7	N/A	16
LNR_Y8	43	17 pts - Y coordinate point 8	N/A	16
LNR_Y9	45	17 pts - Y coordinate point 9	N/A	16
LNR_Y10	47	17 pts - Y coordinate point 10	N/A	16
LNR_Y11	49	17 pts - Y coordinate point 11	N/A	16
LNR_Y12	51	17 pts - Y coordinate point 12	N/A	16
LNR_Y13	53	17 pts - Y coordinate point 13	N/A	16
LNR_Y14	55	17 pts - Y coordinate point 14	N/A	16
LNR_Y15	57	17 pts - Y coordinate point 15	N/A	16
LNR_Y16	60	17 pts - Y coordinate point 16	N/A	16
CLAMPLOW	61	Clamping Low	50 %	16
CLAMPHIGH	62	Clamping High	50 %	16
USEROPTION_SCALING	64	Enables the output scaling [-50..150%] vs [0..100%]	0	1
MEMLOCK	67	Enable CUST NVRAM write LOCK	0	2
DIAG_EN	68	Diagnostics enabling	1	1
DIAGDEBOUNCE_STEPDOWN	70	Diagnostic debouncing stepdown time	1	4

Parameter	PSF value	Description	Default Standard	# bit
DIAGDEBOUNCE_STEPUP	71	Diagnostic debouncing stepup time	5	4
DIAGDEBOUNCE_THRESH	72	Diagnostic debouncing threshold	15	6
DIAGSAFE_START	73	Force a complete diagnostic after an internal reset	1	1
DIAG_LOCK_FAIL	74	Diagnostic Latch Option after a fault	0	1
USER_ID0	75	User Id. Reference. Reserved for customer traceability	see section 12	8
USER_ID1	76	User Id. Reference. Reserved for customer traceability	see section 12	8
USER_ID2	77	User Id. Reference. Reserved for customer traceability	see section 12	8
USER_ID3	78	User Id. Reference. Reserved for customer traceability	see section 12	8
USER_ID4	79	User Id. Reference. Reserved for customer traceability	see section 12	8
USER_ID5	80	User Id. Reference. Reserved for customer traceability	see section 12	8
PWM_POL	83	Define the output stage mode	0	1
AOUT_STATE_DIAG	84	Define digital level in diagnostic	0	1
AOUT_MODE_DIAG	85	Define the diagnostic output stage mode	3	2
AOUT_MODE_NORMAL	86	Define the normal output stage mode	0	2
SEL_PWM	88	Enable PWM output	0	1
WORK_RANGE	90	Angle range selection for 16 / 32 segments	0	4
DENOISING_FILTER_FAST	92	Accelerate the Exponential Moving Average Filter	0	1
LNR_X00...X07	93…99	8 pts - X coordinate point 0..7	N/A	16
LNR_DELTA_Y01...Y32	103..134	32 pts - ΔY coordinate point 1..32	N/A	16
DSP_LNR_RESX2	135	Enable a doubled LNR method 0: 4-points or 16-segments 1: 8-points or 32-segments	0	1

Table 24 – End-user Programmable Items

12. End-User Identification Items

Parameter	PSF value	Description	Default Standard	# bit
MLX_ID1	583-584	Melexis identification reference: X- position code within wafer (8-bit) + Y-position code within wafer (8-bit)	-	16
MLX_ID2	585-586	Melexis identification reference: Wafer Id code (5 bit) + Lot id code (11-bit)	-	16
MLX_ID3	587-588	Melexis identification reference: Lot id code (6 bit) + Fab id code (4-bit) + CorDat Id code (6-bit)	-	16
CHIP_VERSION	609	IMC shape version identifier: Order code 100 Order code 200 Order code 300 Order code 500	 0 2 1 4	7
USER_ID0	75	Bin 1	1	8
USER_ID1	76		0	8
USER_ID2	77	product number: Rotary stray-field immune mode – High-Field Variant Rotary stray-field immune mode – Low-Field Variant : Linear stray-field immune mode: Standard / Legacy mode:	 5 1 3 2	8
USER_ID3	78		2	8
USER_ID4	79		3	8
USER_ID5	80		0	8

Table 25 – End-user identification items

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

13. Description of End-User Programmable Items

13.1. Output modes

13.1.1. OUT modes

Defines the Output Stage mode (analog, digital) in application through parameter AOUT_MODE_DIAG and AOUT_MODE_NORMAL.

Output Mode	Type	Description	Comments
0	Analog	Analog Rail-to-Rail	Analog Only
1	Digital	open drain NMOS/low side	PWM
2	Digital	open drain PMOS/high side	PWM
3	Digital	Push-Pull	PWM

Table 26 – Programmable items: Output modes

13.1.2. PWM Output Mode

If PWM output mode is selected (SEL_PWM=1), the output signal is a digital signal with Pulse Width Modulation (PWM). The PWM polarity is selected by the PWM_POL parameter:

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

The output PWM frequency f_{PWM} is defined by the PWMT parameter, and calculated as:

$$f_{PWM} = 1.5 \times \frac{10^6}{PWMT} \quad Hz$$

The PWMT parameter has a programmable range of [500…10000] in decimal, with a resolution of 1 integral, thus providing a programmable range of PWM period of [333.33…6666.67] [24] µsec with a resolution of 0.667 µsec, and PWM frequency of [150…3000] [24] Hz, respectively.

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^TCk).

[24] *It corresponds to the main clock frequency of 18MHz, another programmable range can be set with a different main clock frequency*

13.2. Output transfer characteristic

There are 4 different possibilities to define the transfer function (LNR):

- With 4 arbitrary points (defined on X and Y coordinates) and 5 slopes
- With 8 arbitrary points (defined on X and Y coordinates)
- With 17 equidistant points for which only the Y coordinates are defined
- With 32 equidistant points for which only the Y coordinates are defined

Output Mode	LNR Type	Value	Unit
CW	correspond to all 4 LNR types	0 → CCW 1 → CW	LSB
DP	correspond to all 4 LNR types	0 … 359.9999	Deg.
LNRAX LNRBX LNRCX LNRDX	Only 4 pts	0 … 359.9999	Deg.
LNRAY LNRBY LNRCY LNRDY	Only 4 pts	0 … 100 -50 … + 150	%VDD
LNRS0 LNRAS LNRBS LNRCS LNRDS	Only 4 pts	-17 … 0 … 17	%VDD/Deg.
LNRY0 …. LNRY7 … LNRY16	8 , 17 pts 17 pts	0..100 -50 … + 150	%VDD
LNR_X0 …. LNR_X7	8 pts	0..100 -50 … + 150	%VDD
LNR_DELTAY01 …. LNR_DELTAY32	32 pts	+/-3.125% +/-6.25% +/-12.5% +/-25%	%VDD
WORK_RANGE	17 , 32 pts	65.5 … 360	Deg.
CLAMPLOW	correspond to all 4 LNR types	0 … 100	%VDD
CLAMPHIGH	correspond to all 4 LNR types	0 … 100	%VDD

Table 27 – Programmable items: Output transfer characteristic

13.2.1. Enable scaling Parameter (USEROPTION_SCALING)

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

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

13.2.2. CLOCKWISE Parameter (CW)

The CLOCKWISE parameter defines the magnet rotation direction.

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

Refer to the drawing in the sensitive spot positioning sections (Section 18).

13.2.3. Discontinuity Point or Zero Degree Point (DP)

The Discontinuity Point defines the 0 Deg. 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.

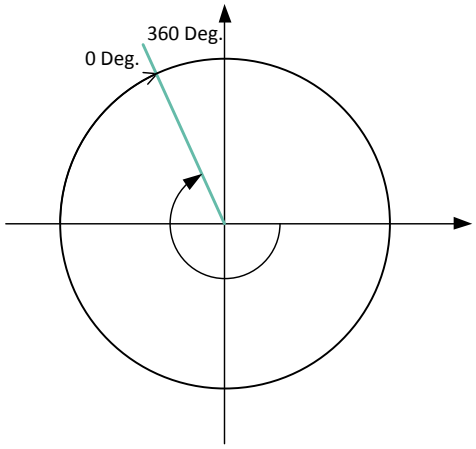


Figure 10 – The placement of the Discontinuity Point (Zero Degree Point) is programmable

13.2.4. 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 MLX90371 transfer function from the digital angle value to the output voltage is described by the drawing below. Seven segments can be programmed but the clamping levels are necessarily flat.

Two, three, or even six arbitrary 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 calibration will be preferred for a cheaper calibration set-up and shorter calibration time.

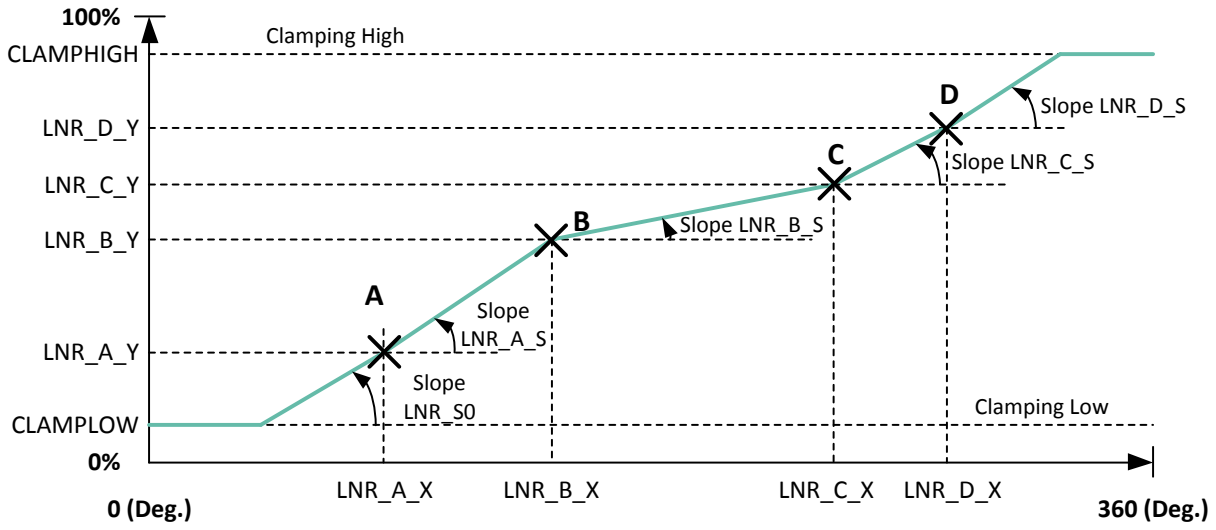


Figure 11 – 4-Points Transfer function

13.2.5. 8-Pts LNR Parameters

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

The shape of the MLX90371 transfer function from the digital angle value to the output voltage is described by the drawing below. Eight calibration points [LNRX0...7, LNRY0...7] together with 2 fix points [0 Deg., 0%] & [360 Deg., 100%], divides the transfer curve into 9 segments. Each segment is defined by 2 points and the output is calculated by linear interpolation.

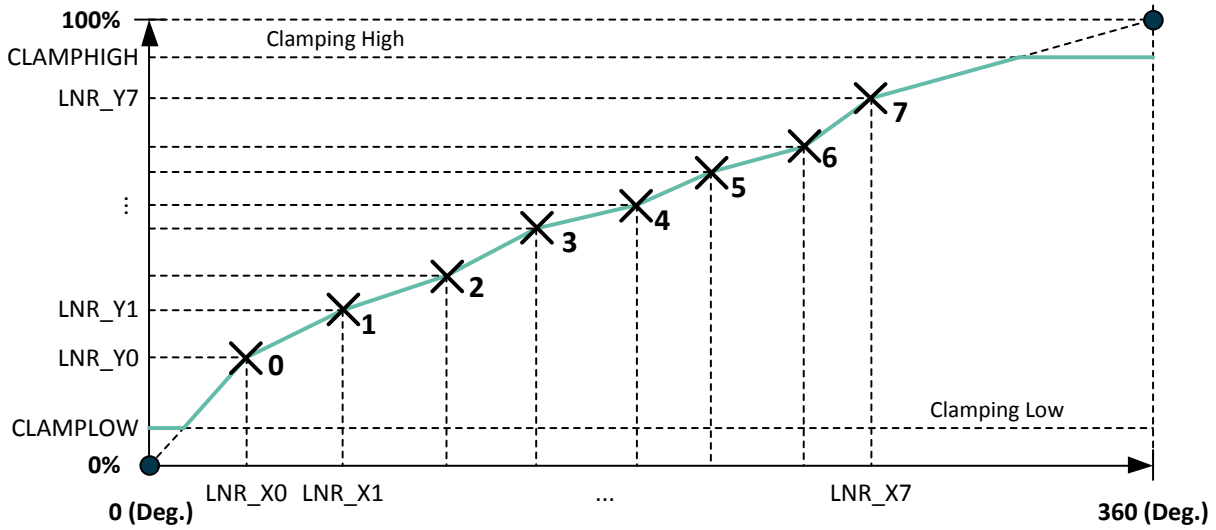


Figure 12 – 8-Points Transfer function

13.2.6. 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 MLX90371 transfer function from the digital angle value to the output voltage is described by the drawing below. In the 17-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

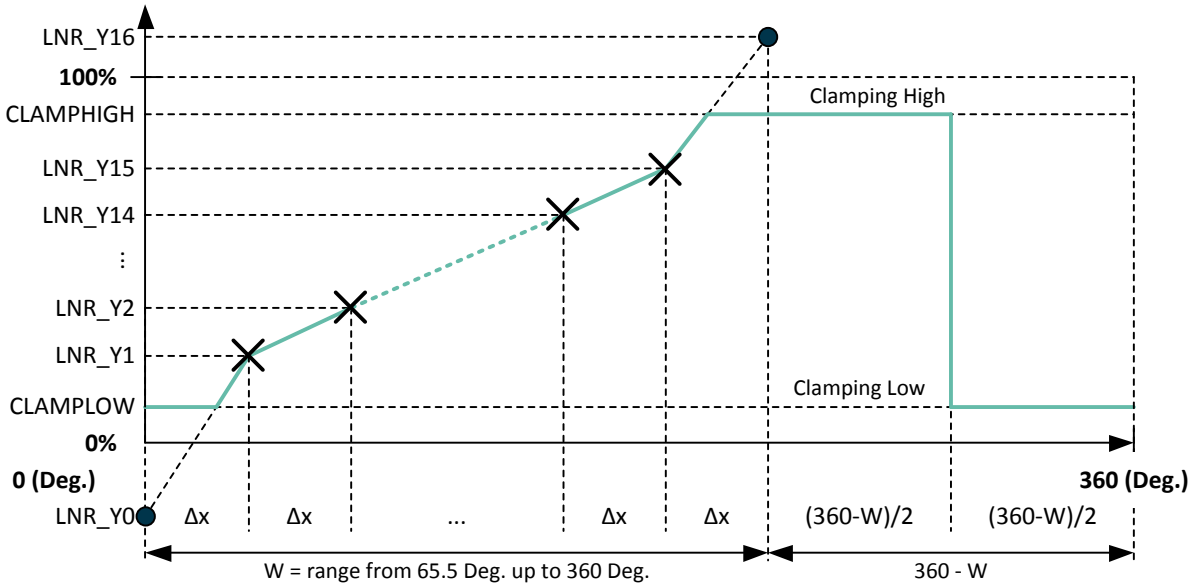


Figure 13 – 17-Points calibration transfer function

All the Y-coordinates can be programmed from -50% up to +150% to allow clamping in the middle of one segment (like on the figure), but the output value is limited to CLAMPLOW and CLAMPHIGH values. Between two consecutive points, the output characteristic is interpolated. The parameter W (WORKING RANGE) 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.

Table 28 – Programmable items: 17 points calibration

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

13.2.7. 32-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 MLX90371 transfer function from the digital angle value to the output voltage is described by the drawing below. In the 32-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

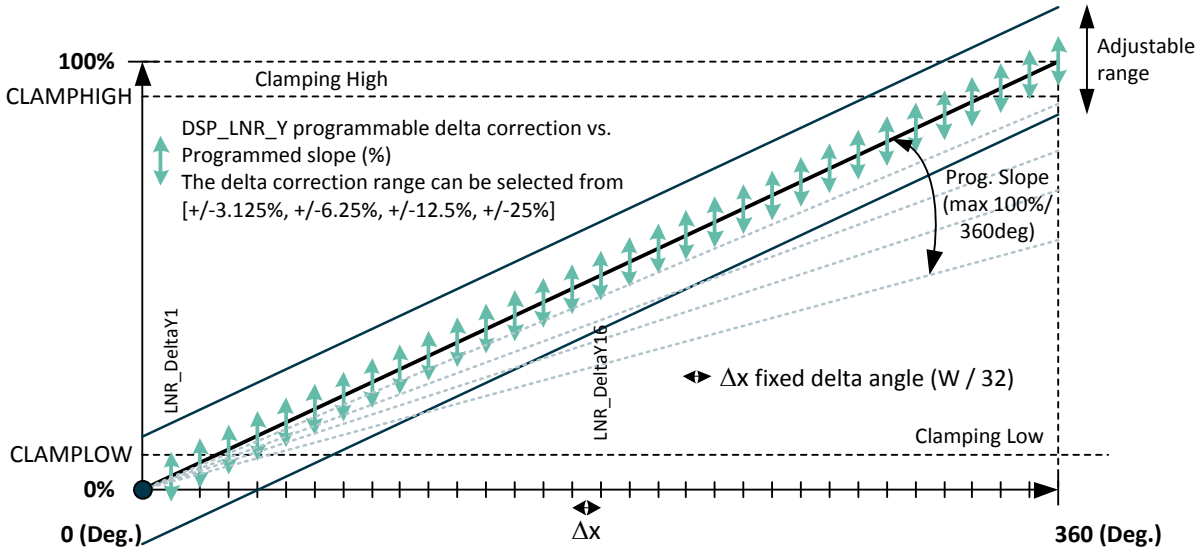


Figure 14 – 32-Points calibration transfer function

All the Y-coordinates can be programmed as a delta correction by adding an offset (±) to the programmed slope. The delta correction range can be selected from [±3.125%, ±6.25%, ±12.5%, ±25%] through the parameter LNR_DELTA_Y_EXPAND_LOG2

Between two consecutive points, the output characteristic is interpolated. The parameter W (WORKING_RANGE) determines the input range on which the 32 points are uniformly spread:

W	Range	Δx
0 (0000b)	360.0Deg.	11.2Deg.
1	320.0Deg.	10.0Deg.
2	288.0Deg.	9.0Deg.
3	261.8Deg.	8.2Deg.
4	240.0Deg.	7.5Deg.
5	221.5Deg.	6.9Deg.
6	205.7Deg.	7.5Deg.
7	192.0Deg.	6.0Deg.

W	Range	Δx
8	180.0Deg.	5.6Deg.
9	144.0Deg.	4.5Deg.
10	120.0Deg.	3.75Deg.
11	102.9Deg.	3.2Deg.
12	90.0Deg.	2.81Deg.
13	80.0Deg.	2.50Deg.
14	72.0Deg.	2.25Deg.
15 (1111b)	65.5Deg.	2Deg.

Table 29 – Programmable items: 32 points calibration

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

13.2.8. 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%V_{DD}. In PWM mode, the resolution will be 0.024%DC.

13.3. Sensor Front-End

Parameter	Value
SENSING MODE	0 … 5
GAINMIN GAINMAX GAINSATURATION	0 … 63 0 … 63 0 … 1

Table 30 – Programmable items: sensor front-end

13.3.1. SENSING MODE

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

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

SENSING MODE	B1	B2	Application
0	ΔX	ΔY	Rotary Stray-Field Immune
1	X	Y	XY Angular Position
2	Y	Z	YZ Angular Position
3	X	Z	XZ Angular Position
4	ΔX	ΔZ	Linear Stray-Field Immune
5	ΣX	ΣZ	Extended Linear Position Stray-Field Immune

Table 31 – Programmable items: sensing modes

13.3.2. GAINMIN and GAINMAX Parameters

GAINMIN and GAINMAX define the thresholds on the gain code outside which the fault “GAIN out of Spec.” is set.

If GAINSATURATION is set, then the virtual gain code is saturated at GAINMIN and GAINMAX.

13.4. Filter

Parameter	Value
FIR	0 … 2
HYST	0 … 255

The MLX90371 includes 2 types of filters:

- Exponential moving average Filter: programmable by the HYST parameter
- Low Pass FIR Filters controlled with the FILTER parameter

Filter	Steps	Noise improvement factor
FIR1 / no filter	1	1
FIR11	2	$\sqrt{2}$
FIR1111	4	2
HYST = ½	4	$\sqrt{3}$
HYST = ¼	9	$\sqrt{7}$

Table 32 – Filter improvement factor

13.4.1. FIR Filters

The MLX90371 features 2 FIR filter modes controlled with Filter = 1…2. Filter = 0 corresponds to no filtering. The transfer function is described below:

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

For information, 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
Description	No filter	ExtraLight	Light
DSP_cycle	1	2	4
Efficiency RMS (dB)	0	3.0	6.0

Table 33 – Programmable items: Step and impulse response of the different FIR filters

13.4.2. Exponential Moving Average Filter

The HYST parameter is a threshold to activate/de-activate the exponential moving average filter. The output value of the IC is updated with the applied filter when the digital step is smaller than the programmed HYST parameter value. The output value is updated without applying the filter when the increment is bigger than the threshold. This filter reduces therefore the noise but still allows a fast step response for bigger angle/position changes. The threshold must be programmed to a value close to the internal magnetic angle noise level. (1 LSB = 8 * 360 / 2^{16}).

DENOISING_FILTER_FAST		0 (HYST=1/2)	1 (HYST=1/4)
Type	$x_n = Angle$ $y_n = Output$	$y_n = \frac{x_n}{2} + \frac{y_{n-i}}{2}$	$y_n = \frac{x_n}{4} + \frac{3y_{n-i}}{4}$

Table 34 – Programmable items: denoising filter

13.5. Programmable Diagnostic Settings

13.5.1. DIAG mode

Parameter “AOUT_MODE_DIAG” defines the Output Stage mode (analog, digital) during startup and in case of diagnostic.

AOUT_MODE_DIAG [2:0]	Type	Descriptions	Comments
0	Disable	analog mode	Not recommended
1	Digital	digital push mode	
2	Digital	digital pull mode	
3	Digital	digital push-pull mode	

Table 35 – Programmable items - diagnostic settings

13.5.2. DIAG Level

Parameter “AOUT_STATE_DIAG” determines the reporting level (diagnostic low, diagnostic high) during start-up (both analog and PWM mode), or during a fault reporting.

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.

13.5.3. PWM Diagnostic

DC_FAULT

Defines the duty-cycle that is outputted in case of diagnostic reporting.

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.

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%DC till 100%DC by steps of (100/256)%.

DC_WEAK

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

13.5.4. DIAG Debouncing

A parametric debouncing algorithm insures that in case of reporting mode ANA (See section 14.1 Safety Mechanism)

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

The error is reported on the output, using predefined reporting level, reporting time and debouncing time. The debouncing algorithm is parameterized by the following NVRAM parameters:

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

Table 36 – Programmable diagnostic - DIAG debouncing

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

The debouncing algorithm uses a Diagnostic Cycle Time (DCT) of typ 9.4 msec, so the debouncing time and recovery time are defined as:

Parameter	Min	Max
Debounce Time	DCT * CEILING (Threshold / UP -1)	DCT * CEILING (Threshold / UP)
Reporting time	DCT * CEILING (Threshold / DOWN)	DCT * CEILING (Threshold / DOWN + 1)

Table 37 – Programmable diagnostic - debouncing & reporting time

14. Functional Safety

14.1. Safety Mechanism

The MLX90371 provides numerous self-diagnostic features (safety mechanisms). Those features increase the robustness of the IC functionality as it will prevent the IC to provide erroneous output signal in case of internal or external failure modes ("fail-safe").

Internal Safety Mechanisms	Coverage						
Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Supporting functions	DCT *	Reporting mode
Front-end hardware faults detection							
Magnetic Signal Conditioning Rough Offset Clipping check	●		○			9.4 ms	ANA
Magnetic Signal Conditioning Gain monitor	●		○			9.4 ms	ANA
A/D Converter Test Pattern		●				9.4 ms	ANA
ADC Conversion errors & Overflow Errors		●				9.4 ms	ANA
Rotary mode: Flux Monitor	●	○				9.4 ms	ANA
Weak magnet diagnostic	●	○				9.4 ms	ANA
DSP hardware faults detection							
RAM Test (run-time) ISO D.2.5.1			●			25.7 ms	DIG
ROM 24 bits signature (run-time) ISO D.2.4.3			●			25.7 ms	DIG
NVRAM 16 bits signature (run-time) ISO D.2.4.3			●			25.7 ms	DIG
NVRAM Single Error Correction			●			n/a	n/a
NVRAM Double Error Detection			●			25.7 ms	DIG
Logical Monitoring of program sequence ISO D.2.9.3 via Watchdog "IWD" (cpu clock) ISO D2.9.2			●			40 ms	DIG
Watchdog "AWD" (separate clock) ISO D2.9.1			●			40 ms	DIG
CPU Errors "Invalid Address","Wrong opcode"			●			<10 µs	DIG
Supporting functions: hardware faults detection							
Supply Voltage Monitors (all supply domains) except VS_OV & POR					●	9.4 ms	ANA
External Supply Overvoltage Monitor VS_OV					●	2.1 ms	HiZ
Digital Supply undervoltage monitor (Power-on reset)					●	<1 µs	HiZ
Bias Currents Monitors					●	9.4 ms	ANA

Internal Safety Mechanisms	Coverage						
Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Supporting functions	DCT *	Reporting mode
Overheating monitor	o	o	o	o	o	9.4 ms	ANA
Package/pin failures detection							
Broken-Wire Detection					o	<10 µs	BRO
Failure Reporting Mechanisms							
SW Safe Start-up mode + SW Fail-safe mode			n/a			n/a	DIG
Analog-type Error management (includes debouncing)			n/a			n/a	ANA
Executed at power-on only							
RAM March Test (not transparent)			●			n/a	DIG
NVRAM Configuration data integrity Check at power-on			●			n/a	DIG
NVRAM ECC at start-up			●			n/a	DIG
Self-test watchdog IWD			●			n/a	DIG

Table 38 – Safety mechanisms

Legend:
● : High failure detection coverage
o : Medium failure detection coverage
ANA : Programmable reporting level + IC operates as normal
DIG : Reporting of digital HW faults: Output in high-impedance + SW Fail-safe Mode Or SW Safe Start-up mode
BRO : Low-impedance output, see datasheet parameters BVddPU, BVddPD, BVssPU, BVssPD
DCT : Diagnostic Cycle Time

14.2. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90371 component in a safety related item, as Safety Element Out-of-Context (SEooC).

In particular it includes:

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

15. Recommended Application Diagrams

15.1. Wiring with the MLX90371 in SOIC-8 Package

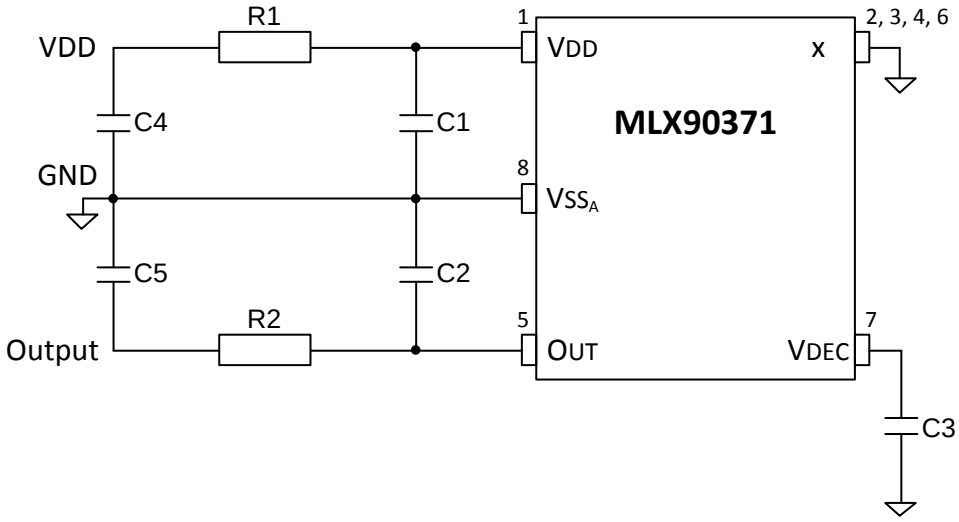


Figure 15 – Recommended wiring for the MLX90371 in SOIC-8 package

Output	Compact PCB routing			EMC robust PCB routing			
Analog Output	Min	Typ.	Max	Min	Typ.	Max	Remarks
C1	100 nF	440 nF	1 uF	100 nF	440 nF	1 uF	Close to the pin
C2 (C_L)	47 nF	100 nF	330 nF	47 nF	100 nF	330 nF	Close to the pin
C3	47 nF	100 nF	220 nF	47 nF	100 nF	220 nF	Close to the pin
C4	-	-	-	500 pF	1 nF	10 nF	Connector Side
C5	-	-	-	500 pF	1 nF	10 nF	Connector Side
R1	-	-	-	0 Ω	10 Ω	33 Ω	Increased ratiometry error
R2	-	-	-	10 Ω	50 Ω	100 Ω	

PWM Output	Min	Typ.	Max	Min	Typ.	Max	Remarks
C1	100 nF	440 nF	1 uF	100 nF	440 nF	1 uF	Close to the pin
C2 (C_L)	2.2 nF	10 nF	22 nF [25]	2.2 nF	10 nF	22 nF [25]	Close to the pin
C3	47 nF	100 nF	220 nF	47 nF	100 nF	220 nF	Close to the pin
C4	-	-	-	500 pF	1 nF	10 nF	Connector Side
C5	-	-	-	500 pF	1 nF	2.2 nF	Connector Side
R1	-	-	-	0 Ω	10 Ω	33 Ω	Impacts the Voltage on V_{DD} pin
R2	-	-	-	10 Ω	50 Ω	100 Ω	

Table 39 – SOIC-8 recommended components, values shown represent the typical value of the standard devices, additional ±10% tolerance is accepted

[25] *Can be extended for PWM Push pull applications with low PWM frequencies (i.e F_{PWM}<250Hz)*

15.2. Wiring with the MLX90371 in TSSOP-16 Package

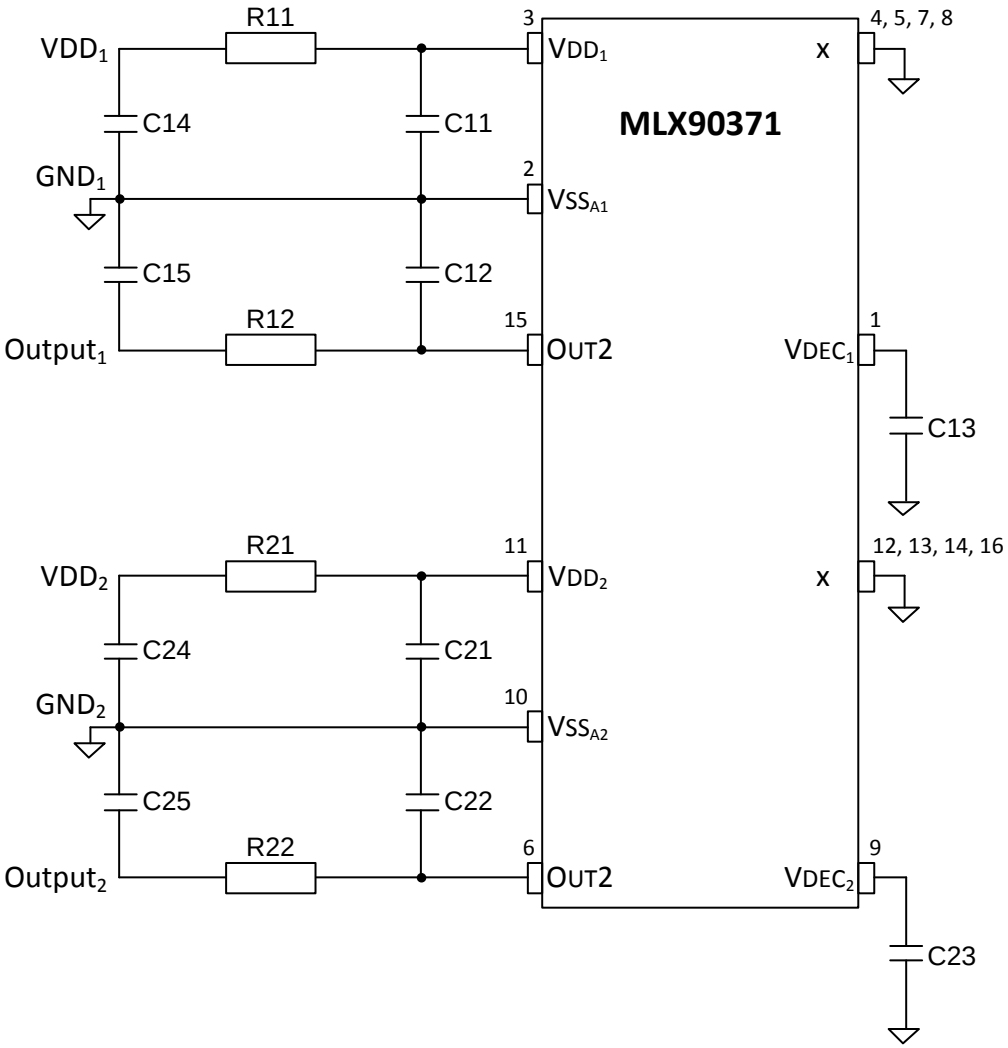


Figure 16 – Recommended wiring for the MLX90371 in TSSOP-16 package (dual die)

Output	Compact PCB routing			EMC robust PCB routing			
Analog Output	Min	Typ.	Max	Min	Typ.	Max	Remarks
C11, C21	100 nF	440 nF	1 uF	100 nF	440 nF	1 uF	Close to the pin
C12,C22(C_L)	47 nF	100 nF	330 nF	47 nF	100 nF	330 nF	Close to the pin
C13, C23	47 nF	100 nF	220 nF	47 nF	100 nF	220 nF	Close to the pin
C14, C24	-	-	-	500 pF	1 nF	10 nF	Connector Side
C15, C25	-	-	-	500 pF	1 nF	10 nF	Connector Side
R11, R21	-	-	-	0 Ω	10 Ω	33 Ω	Increased ratiometry error
R12, R22	-	-	-	10 Ω	50 Ω	100 Ω	

PWM Output	Min	Typ.	Max	Min	Typ.	Max	Remarks
C11, C21	100 nF	440 nF	1 uF	100 nF	440 nF	1 uF	Close to the pin
C12,C22(C_L)	2.2 nF	10 nF	22 nF [26]	2.2 nF	10 nF	22 nF [26]	Close to the pin
C13, C23	47 nF	100 nF	220 nF	47 nF	100 nF	220 nF	Close to the pin
C14, C24	-	-	-	500 pF	1 nF	10 nF	Connector Side
C15, C25	-	-	-	500 pF	1 nF	2.2 nF	Connector Side
R11, R21	-	-	-	0 Ω	10 Ω	33 Ω	Impacts the Voltage on V_{DD} pin
R12, R22	-	-	-	10 Ω	50 Ω	100Ω	

Table 40 – TSSOP-16 recommended components, values shown represent the typical value of the standard devices, additional ±10% tolerance is accepted

[26] *Can be extended for PWM Push pull applications with low PWM frequencies (i.e F_{PWM}<250Hz)*

15.3. Wiring with the MLX90371 in DMP-4 Package (built-in capacitors)

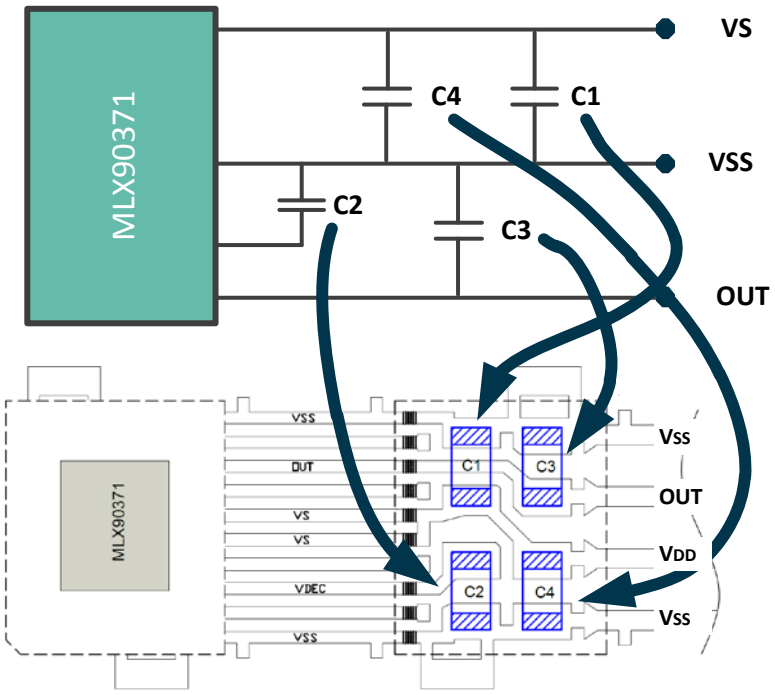


Figure 17 – Capacitor configurations in DMP-4 package

In order to reach the best EMC performance, it is recommended to use PIN4 for ground connection, and leave PIN1 floating. Built-in capacitors are ceramic multilayer type X8R, with a maximum rated voltage of 50V.

Ordering code	Recommended Output Mode	C1	C2	C3=C_L	C4
MLX90371GVS-BCC-100-RE	Analog	220 nF	100 nF	100 nF	220 nF
MLX90371GVS-BCC-200-RE	Analog	220 nF	100 nF	100 nF	220 nF
MLX90371GVS-BCC-300-RE	Analog	220 nF	100 nF	100 nF	220 nF
MLX90371GVS-BCC-150-RE	PWM	220 nF	100 nF	10 nF	220 nF
MLX90371GVS-BCC-250-RE	PWM	220 nF	100 nF	10 nF	220 nF
MLX90371GVS-BCC-350-RE	PWM	220 nF	100 nF	10 nF	220 nF

Table 41 – DMP-4 variants

16. Standard Information Regarding Manufacturability of Melexis Products with Different Soldering Processes

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

For further details about test method references and for compliance verification of selected soldering method for product integration, Melexis recommends reviewing on our web site the General Guidelines soldering recommendation (http://www.melexis.com/en/quality-environment/soldering)

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

For package technology embedding trim and form post-delivery capability, Melexis recommends consulting the dedicated trim&forming recommendation application note: lead trimming and forming recommendations (http://www.melexis.com/en/documents/documentation/application-notes/lead-trimming-and-forming-recommendations).

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

17. ESD Precautions

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

18. Package Information

18.1. SOIC-8 Package

18.1.1. SOIC-8 - Package Dimensions

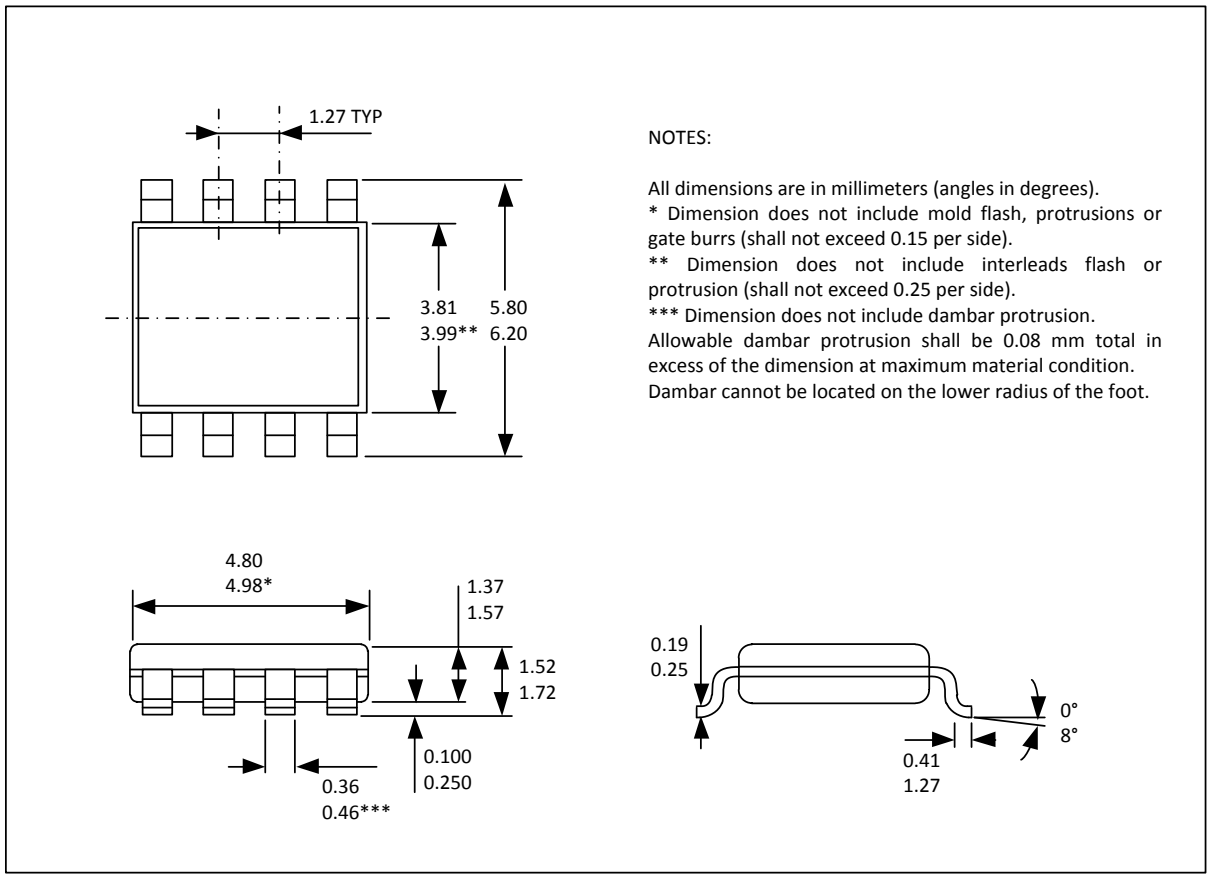


Figure 18 – SOIC-8 Package Dimensions

18.1.2. SOIC-8 - Pinout and Marking

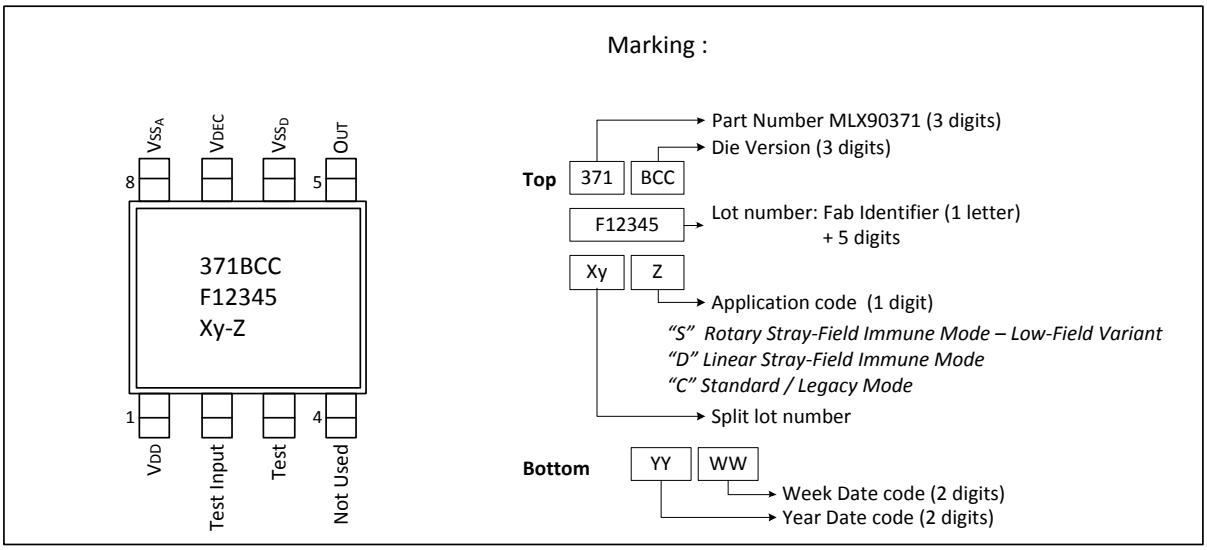


Figure 19 – SOIC-8 pinout & marking

18.1.3. SOIC-8 - Sensitive Spot Positioning

18.1.3.1. Rotary Stray-Field Immune & Standard/Legacy Mode

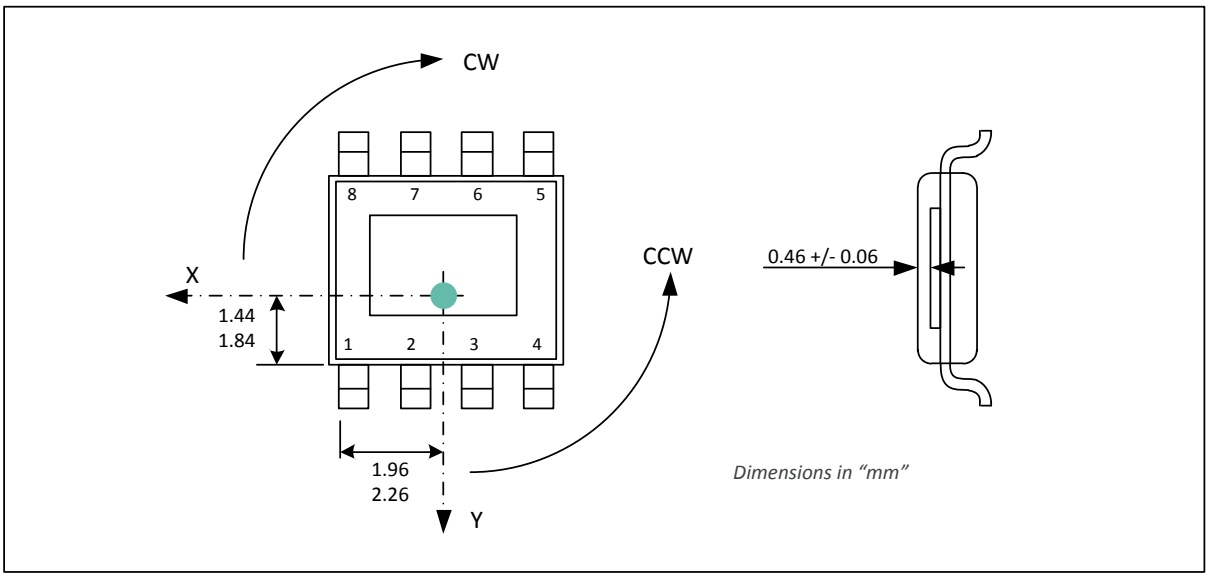


Figure 20 – SOIC-8 sensitive spot for rotary Stray-Field immune and standard/legacy modes

18.1.3.2. Linear Stray-Field Immune

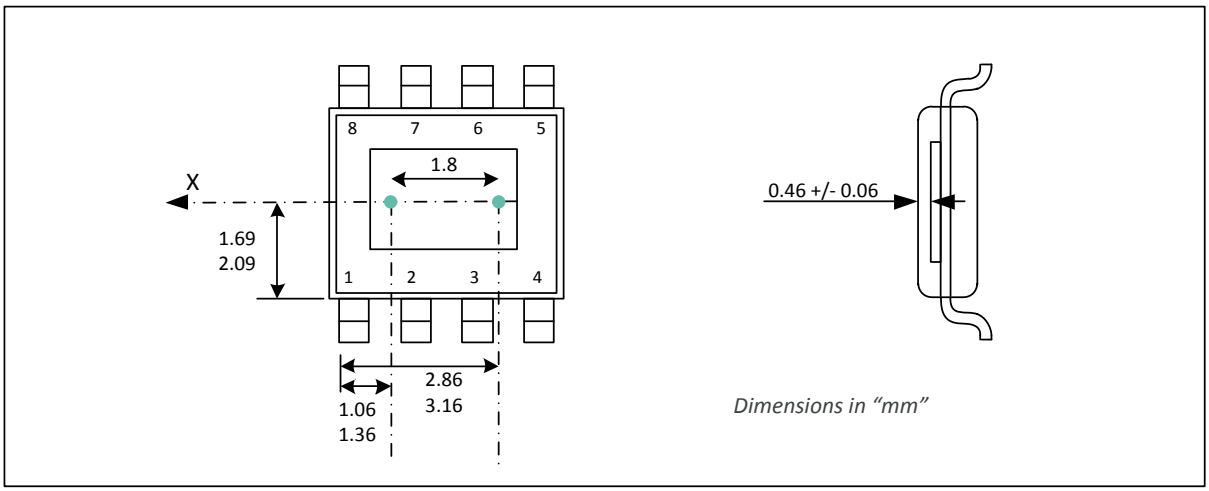


Figure 21 – SOIC-8 sensitive spot for linear Stray-Field immune mode

18.1.4. SOIC-8 - Angle Detection

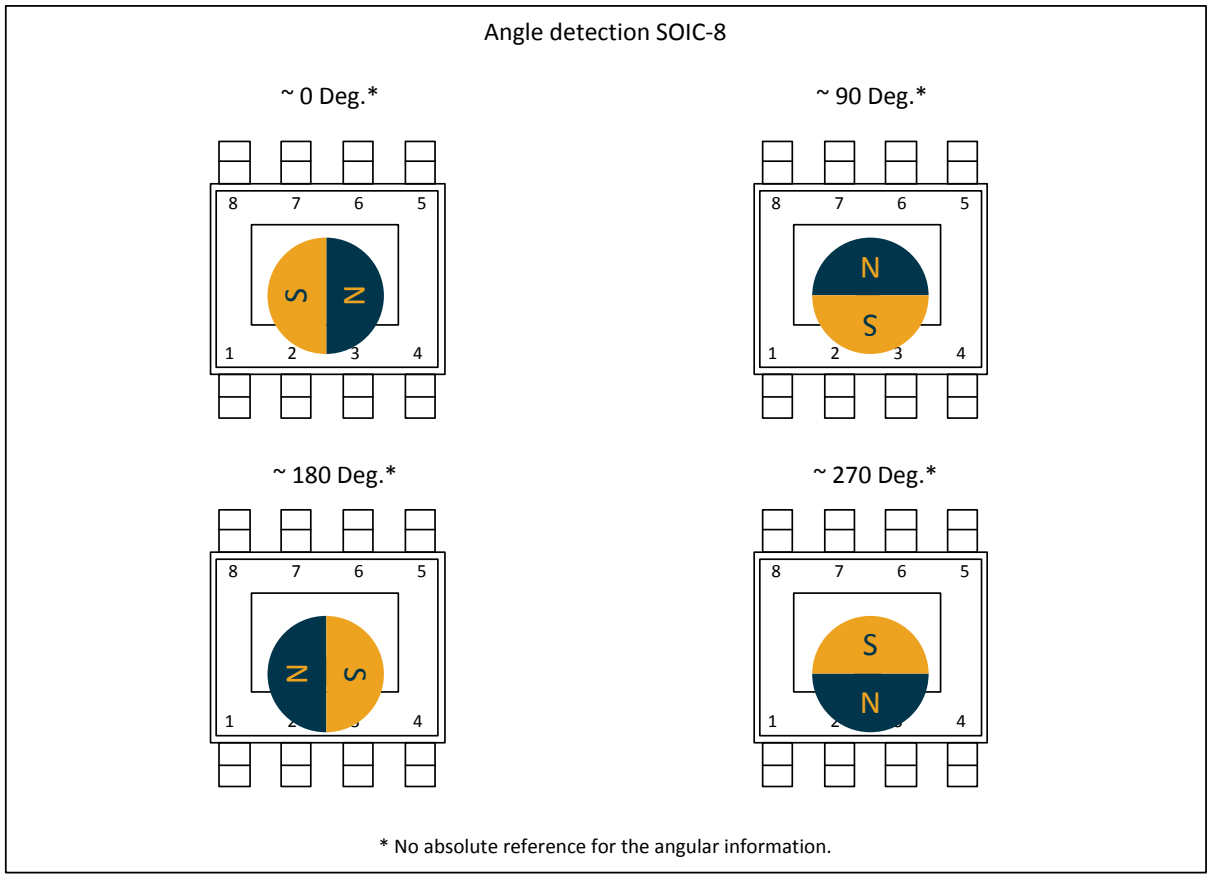
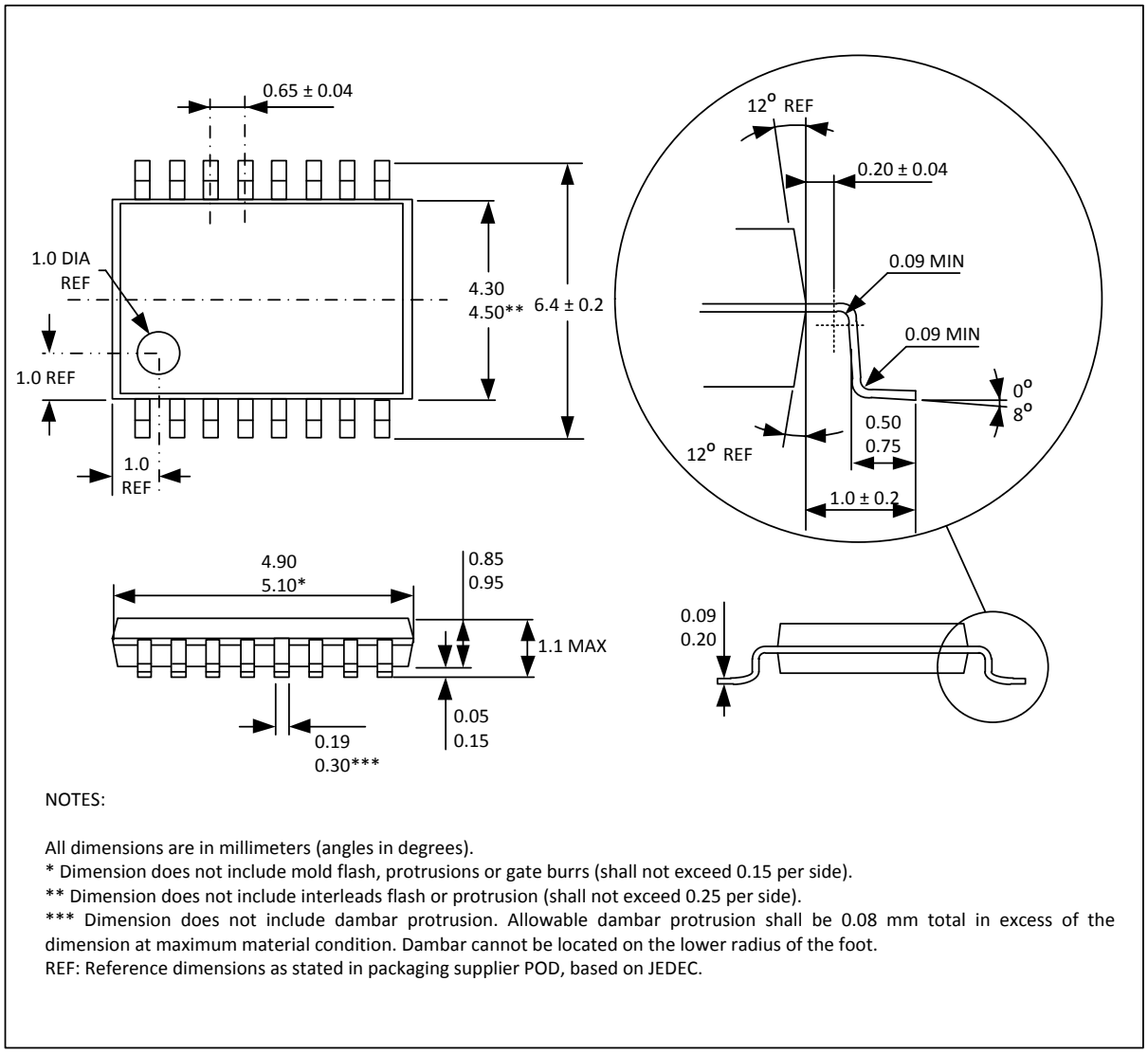


Figure 22 – SOIC-8 angle detection

The MLX90371 is an absolute angular position sensor. Note that the intrinsic linearity error (See section 9.1.1.1) does not include the error linked to the absolute reference 0 Deg., which can be fixed in the application through the discontinuity point.

18.2. TSSOP-16 Package

18.2.1. TSSOP-16 - Package Dimensions



NOTES:

All dimensions are in millimeters (angles 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.

Figure 23 – TSSOP-16 Package Dimensions

18.2.2. TSSOP-16 - Pinout and Marking

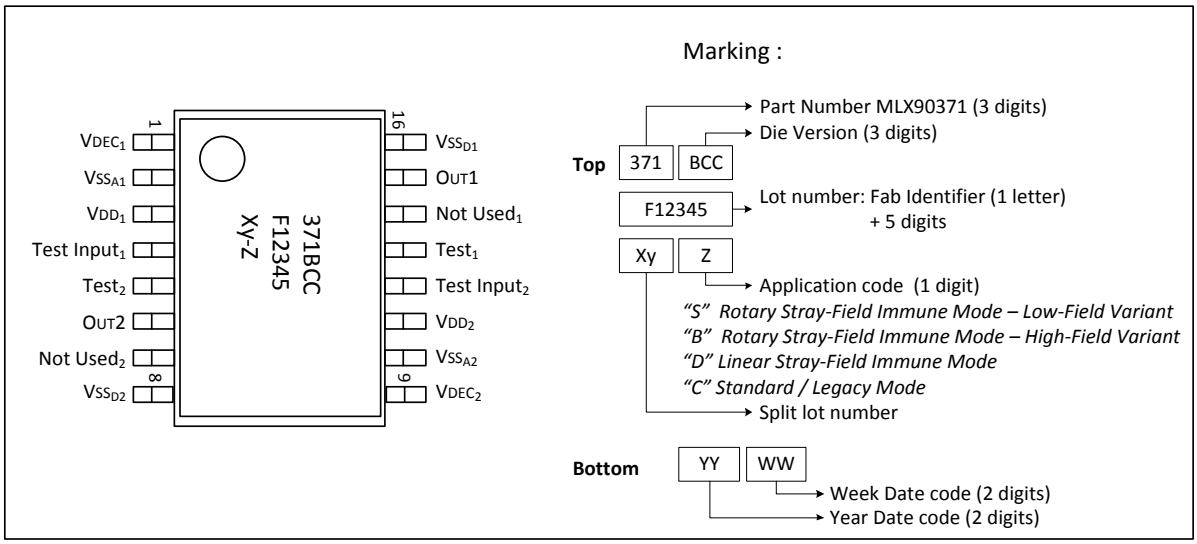


Figure 24 – TSSOP-16 pinout & marking

18.2.3. TSSOP-16 - Sensitive Spot Positioning

18.2.3.1. Rotary Stray-Field Immune & Standard/Legacy Mode

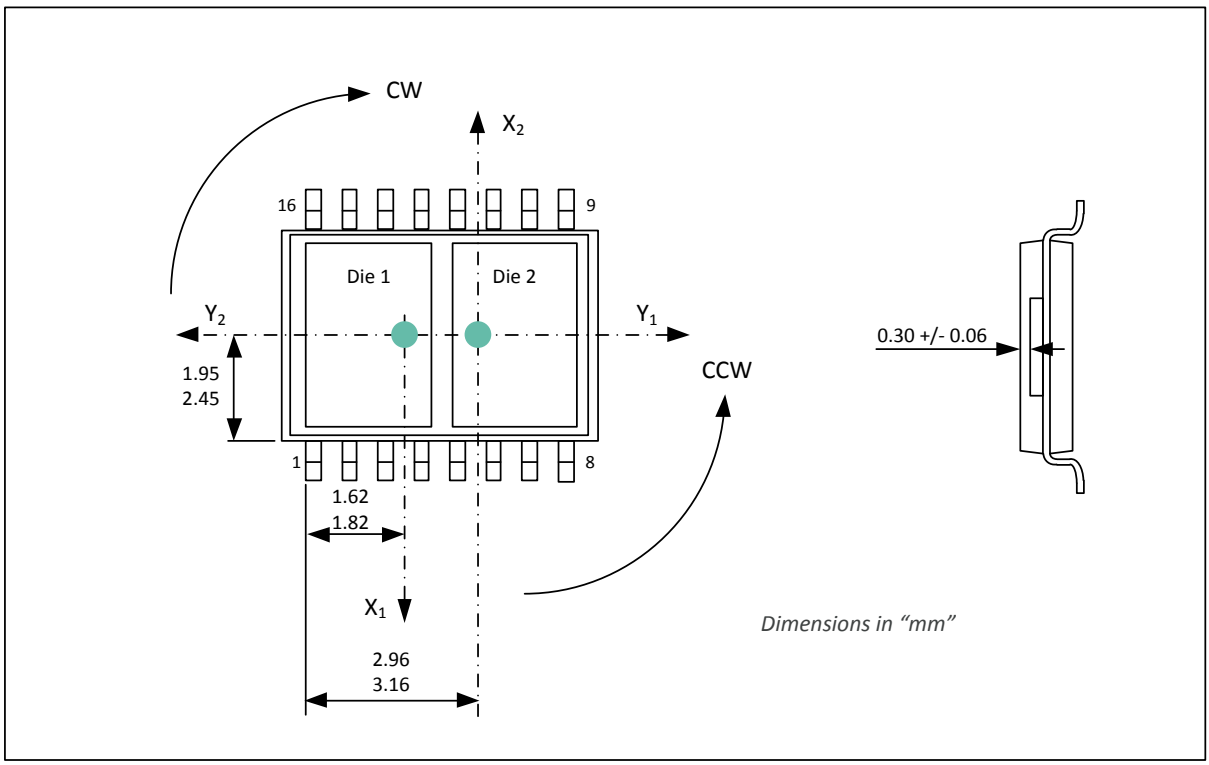


Figure 25 – TSSOP-16 sensitive spot for rotary Stray-Field immune and standard/legacy modes

18.2.3.2. Linear Stray-Field robust

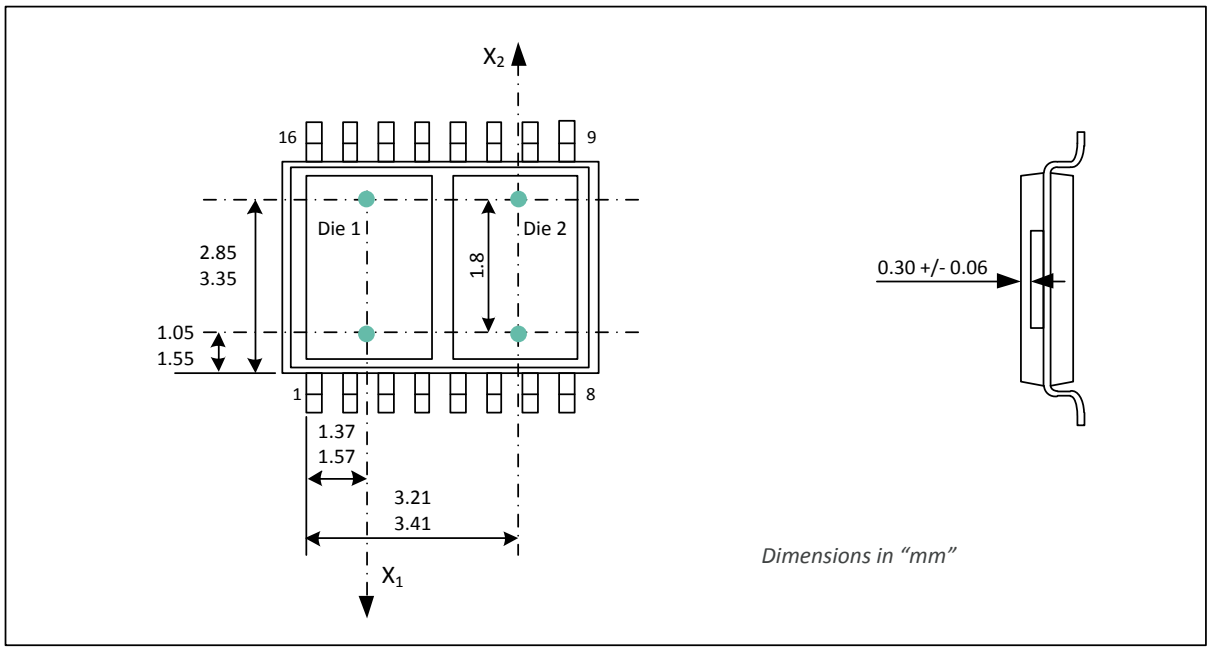


Figure 26 – TSSOP-16 sensitive spot for linear Stray-Field immune mode

18.2.4. TSSOP-16 - Angle detection

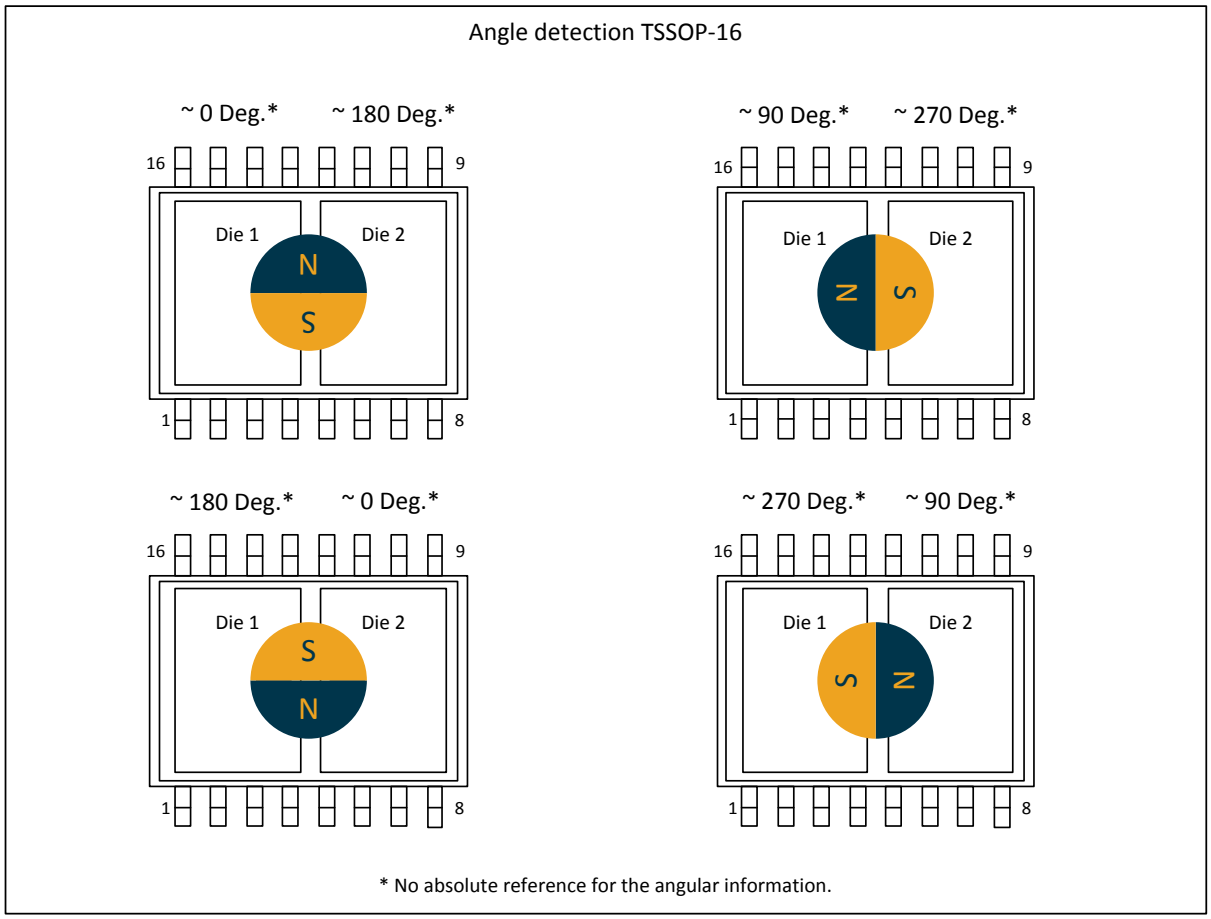


Figure 27 – TSSOP-16 angle detection

The MLX90371 is an absolute angular position sensor. Note that the intrinsic linearity error (See section 9.1.1.1) does not include the error linked to the absolute reference 0 Deg., which can be fixed in the application through the discontinuity point.

18.3. DMP-4 Package

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

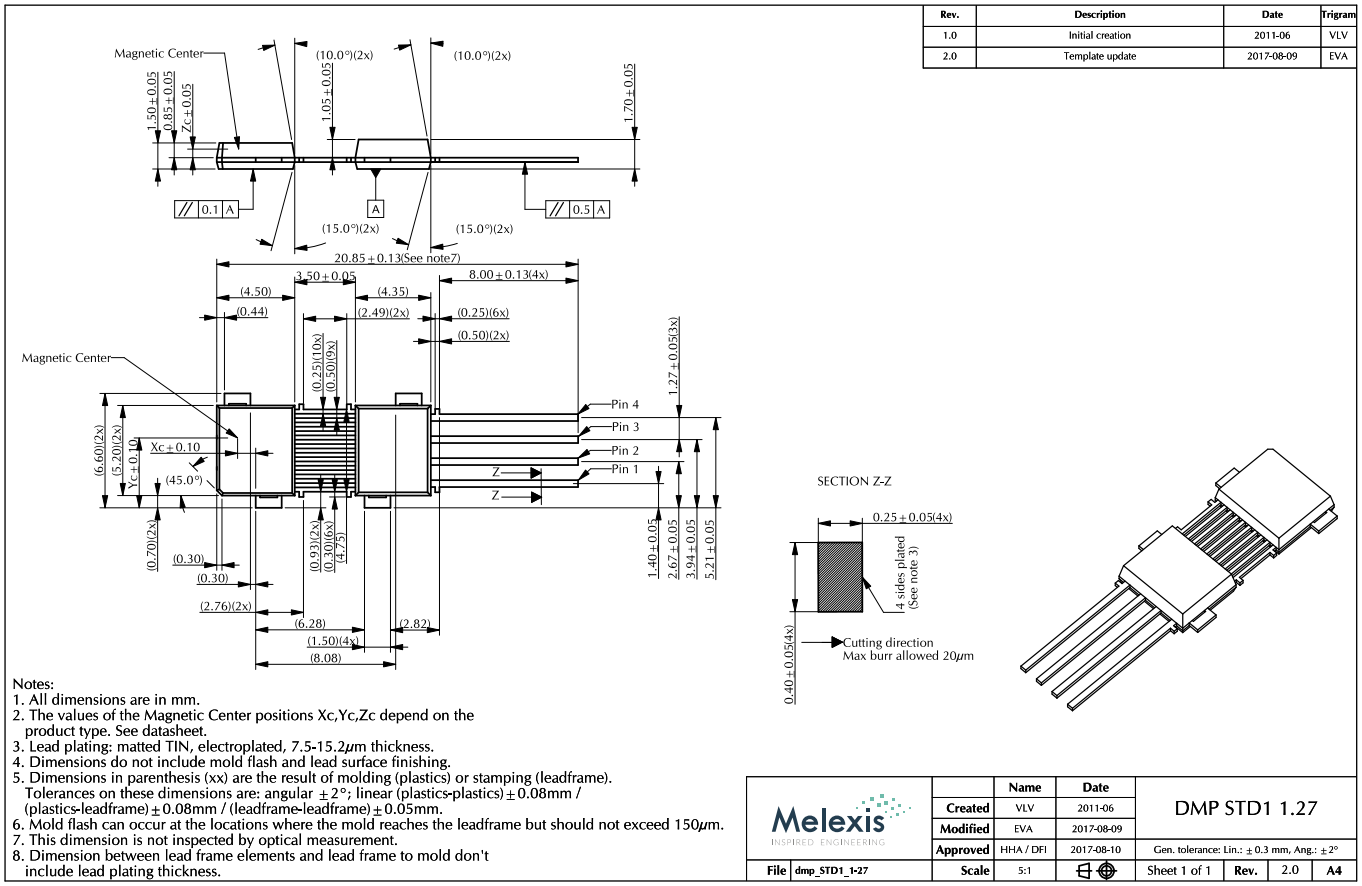


Figure 28 – DMP-4 information for straight leads

18.3.2. DMP-4 - Package Outline Dimensions (POD) – STD1 2.54

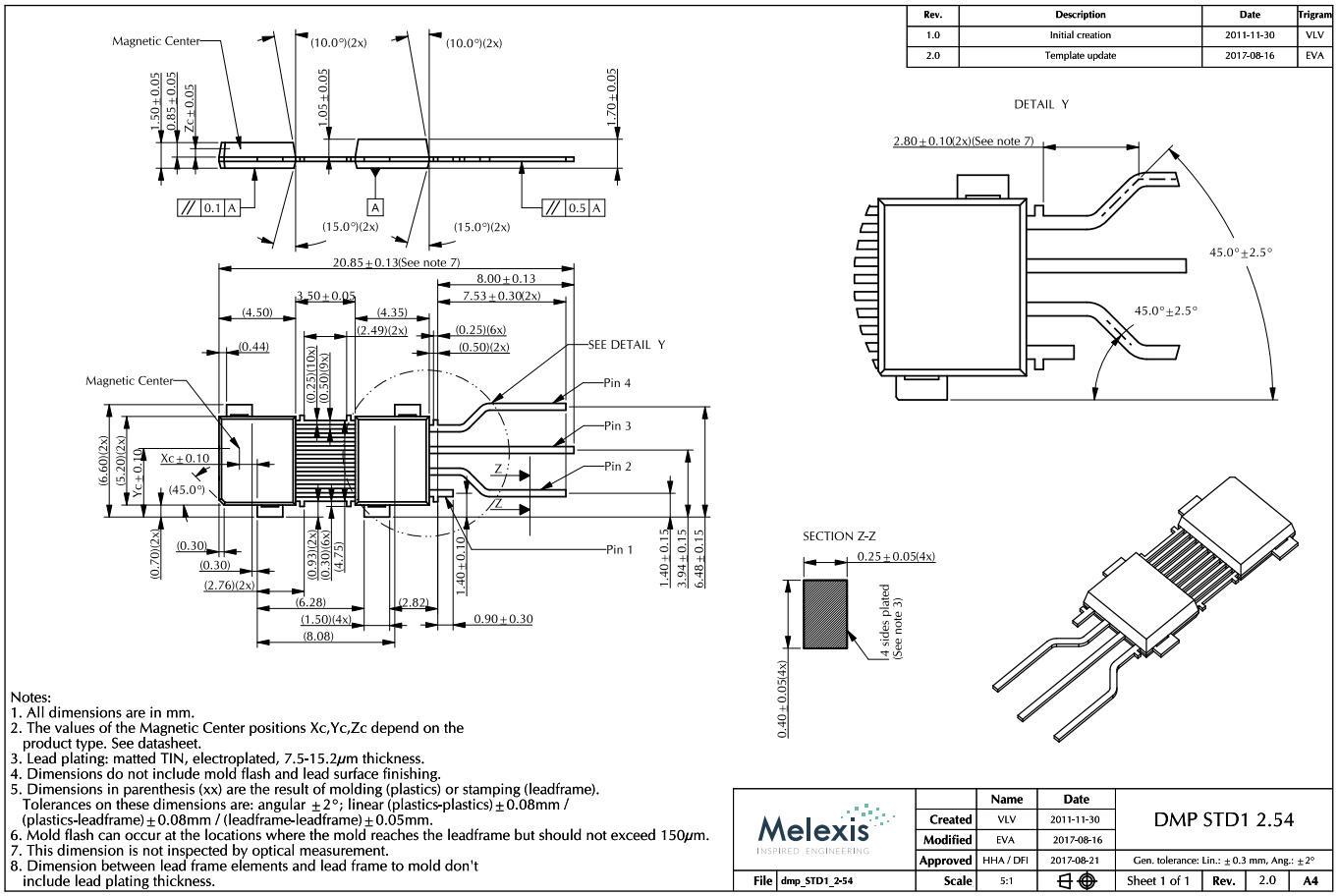


Figure 29 – DMP-4 Information for STD1 2.54

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

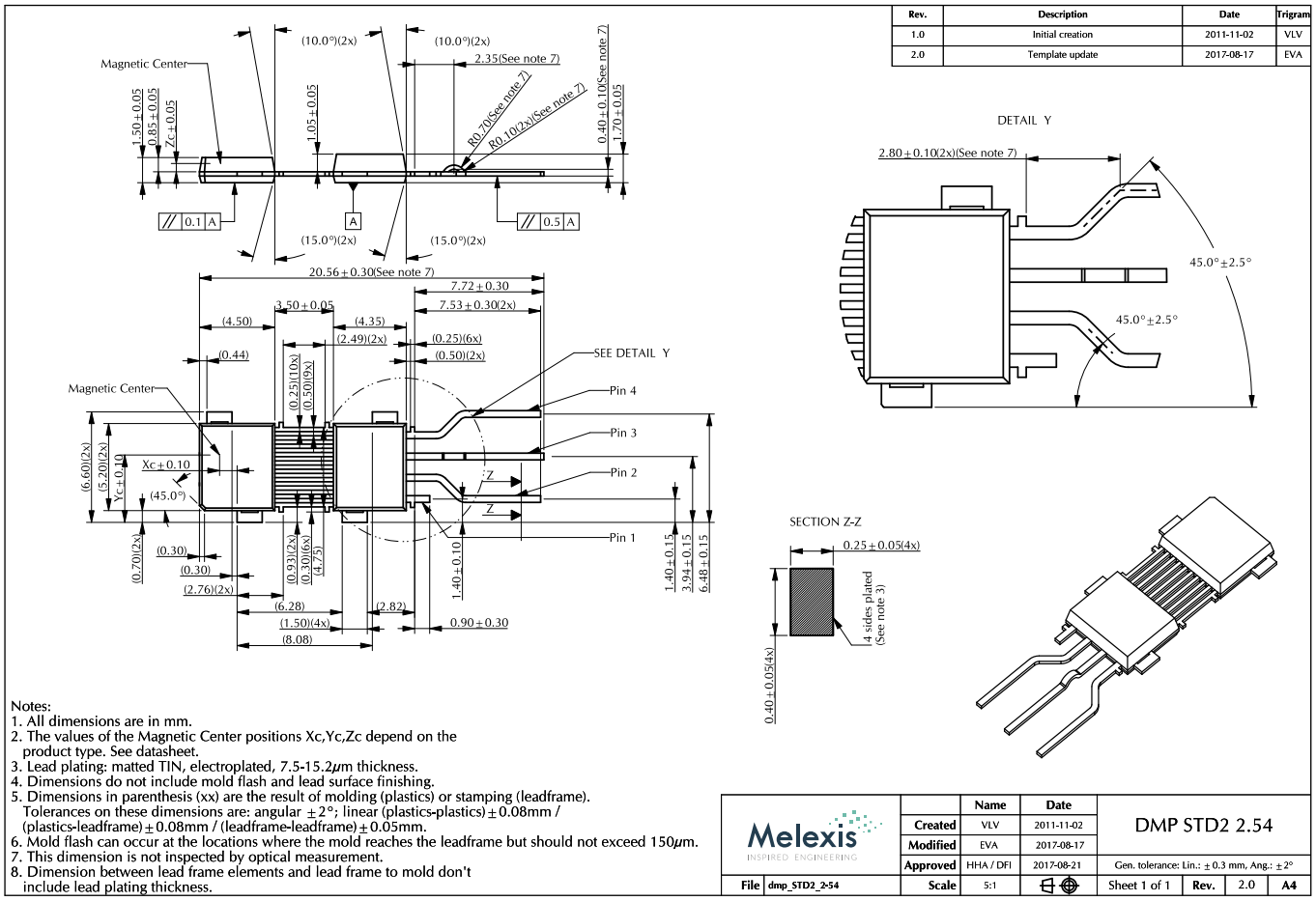


Figure 30 – DMP-4 information for STD2 2.54

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

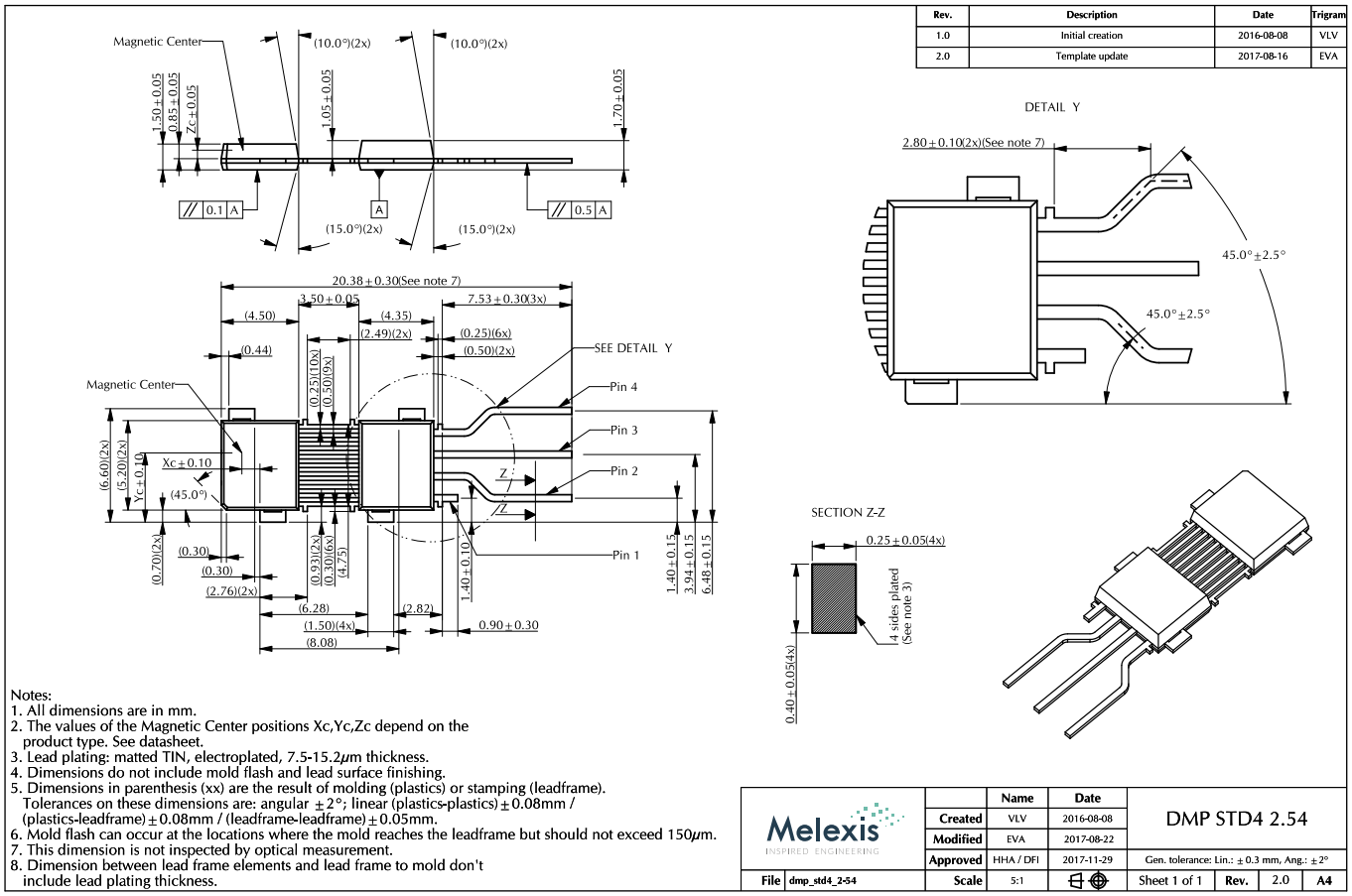


Figure 31– DMP-4 information for STD4 2.54

18.3.5. DMP-4 - Pinout and Marking

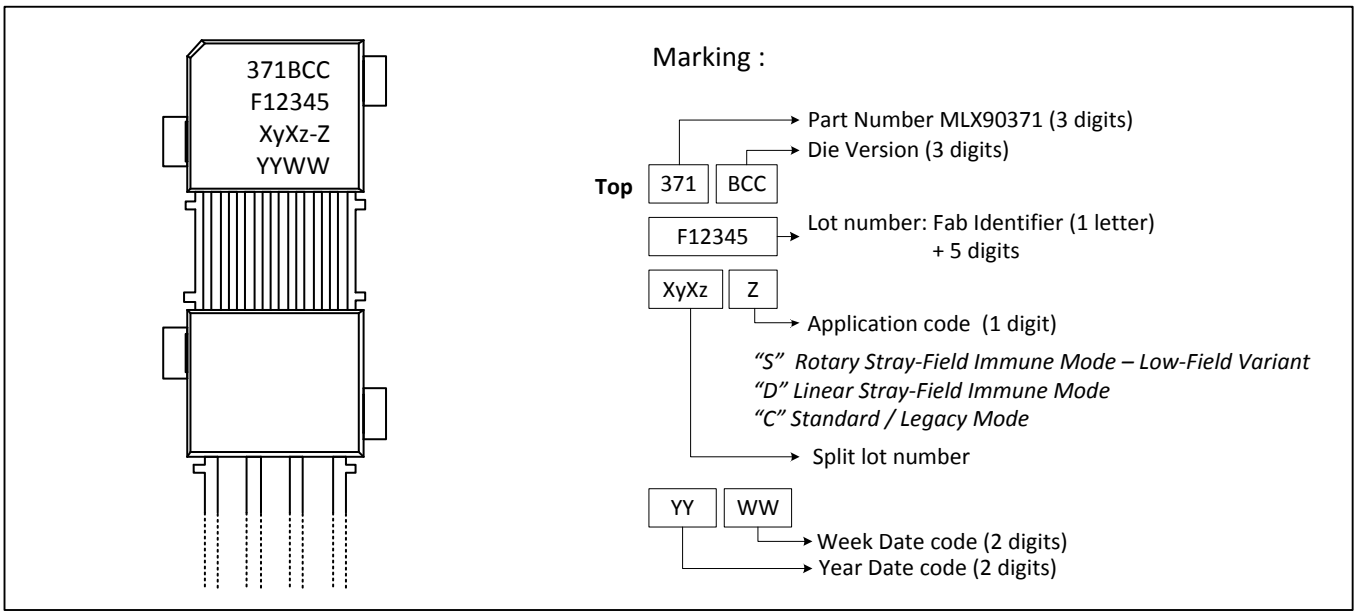


Figure 32 – DMP-4 pinout and marking

18.3.6. DMP-4 - Sensitive Spot Positioning & Sense direction

18.3.6.1. Rotary Stray-Field Immune or Standard/legacy

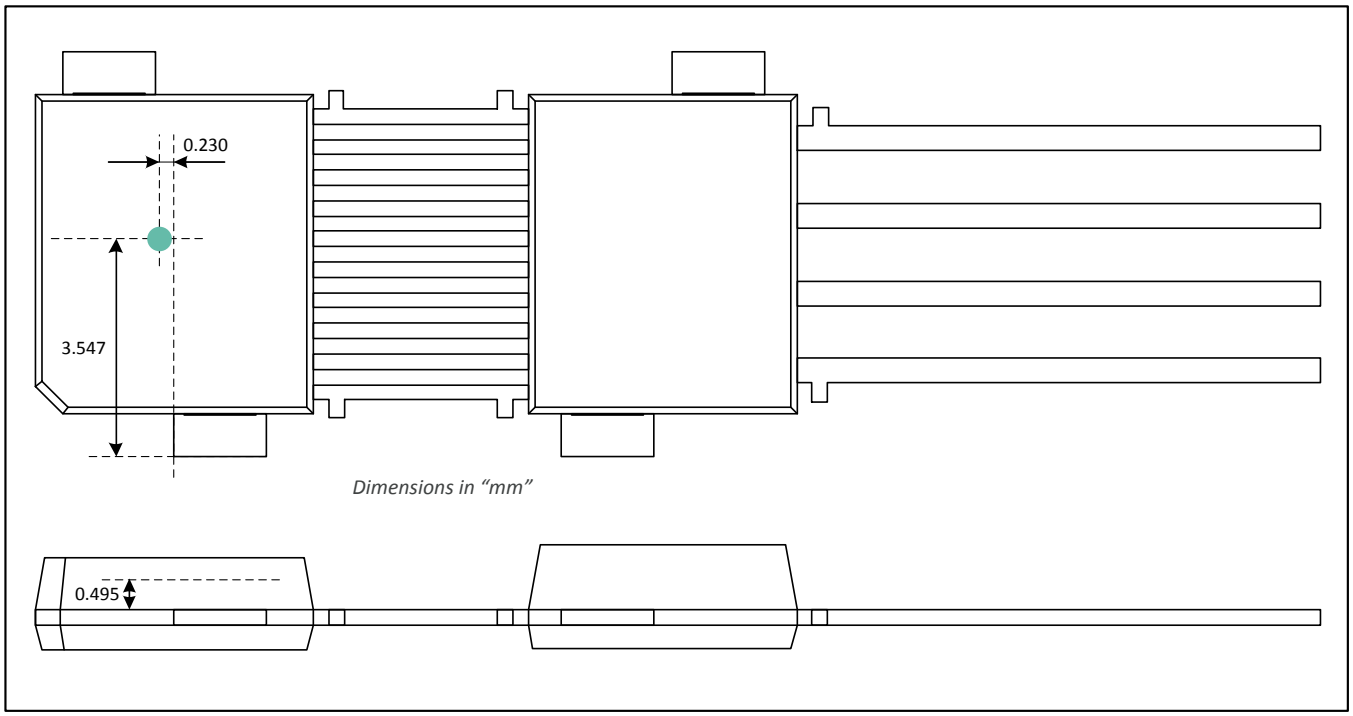


Figure 33 – DMP-4 sensitive spot for rotary Stray-Field immune and standard/legacy modes

18.3.6.2. Linear Stray-Field Immune

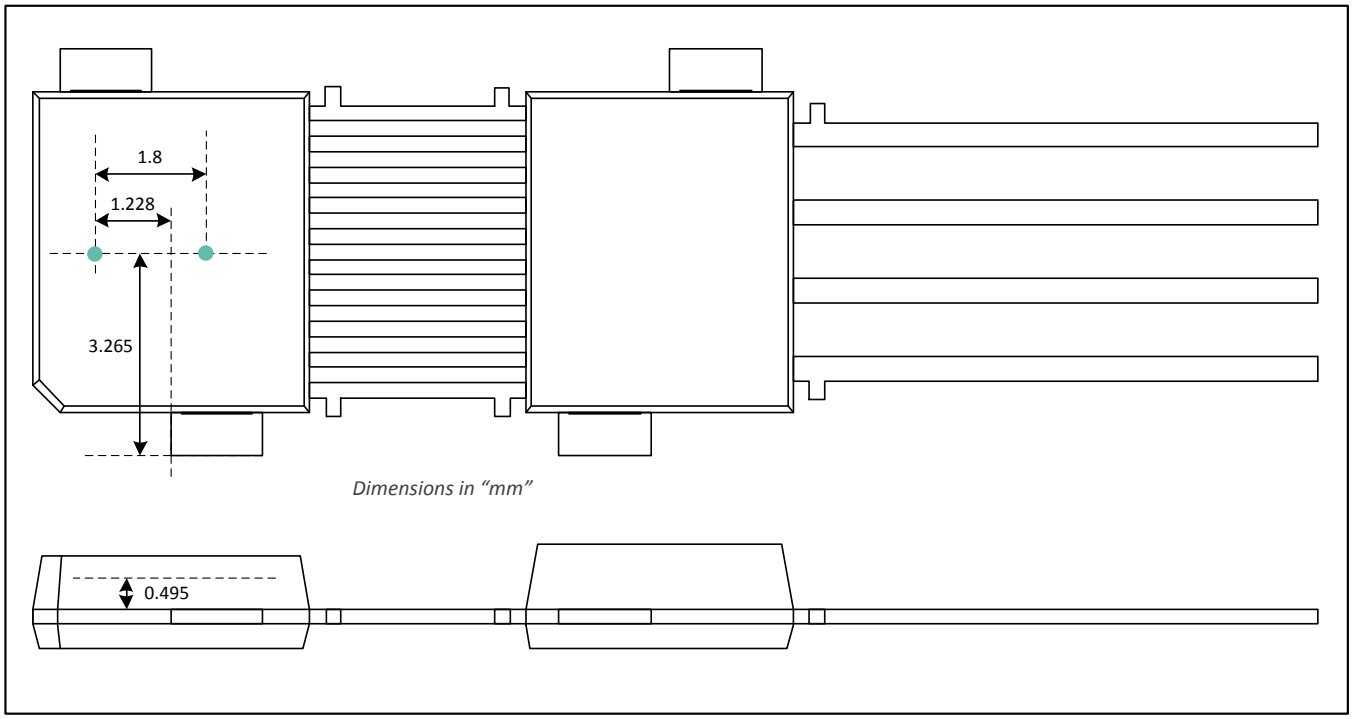


Figure 34 – DMP-4 sensitive spot for linear Stray-Field immune mode

18.3.7. DMP-4 - Angle detection

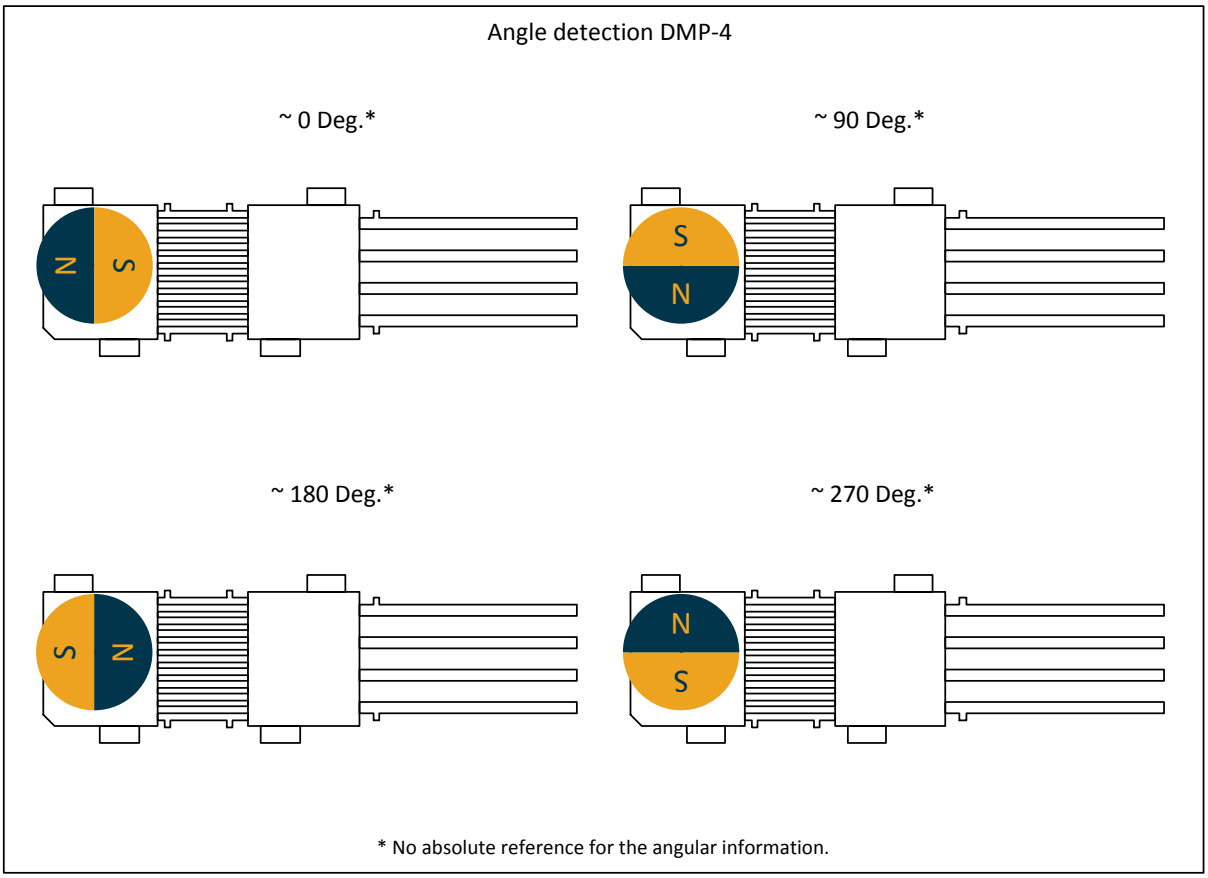


Figure 35 – DMP-4 angle detection

The MLX90371 is an absolute angular position sensor. Note that the intrinsic linearity error (See section 9.1.1.1) does not include the error linked to the absolute reference 0 Deg., which can be fixed in the application through the discontinuity point.

19. Contact

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For additional information, please contact our Direct Sales team and get help for your specific needs:

Europe, Africa	Telephone: +32 13 67 04 95
	Email : sales_europe@melexis.com
Americas	Telephone: +1 603 223 2362
	Email : sales_usa@melexis.com
Asia	Email : sales_asia@melexis.com

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