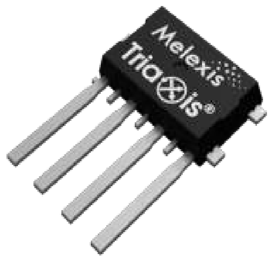
MLX90371EAC – Triaxis® Position Sensor

Datasheet

Features and Benefits

- Triaxis® Hall Technology
- Dual die, PCB-less package
- 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)
- Analog (Ratiometric) Output
- 12 bit Resolution - 10 bit Thermal Accuracy
- 48 bit ID Number option



SMP-4

Application Examples

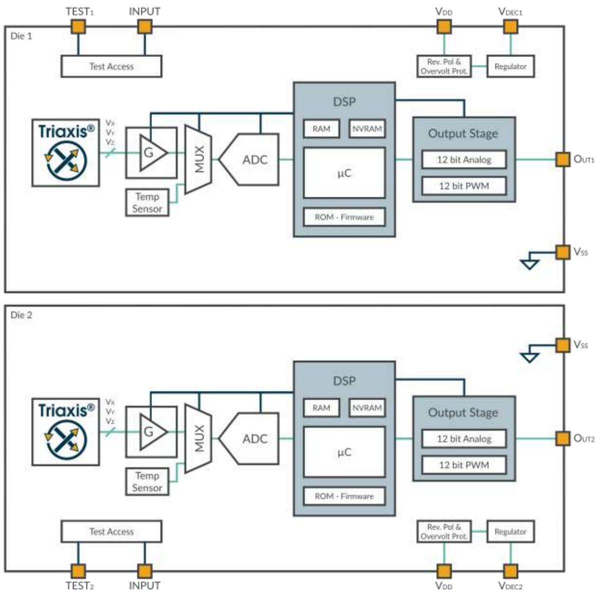
- Absolute Rotary Position Sensor
- Absolute Linear Position Sensor
- Throttle Position Sensor
- Steering Wheel Position Sensor
- Valve Position Sensor
- Non-Contacting Potentiometer

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 design, to decode the absolute position of any magnet moving in its vicinity (e.g. rotary position from 0 to 360 Degrees or linear displacement).

The MLX90371GVD-EAC outputs a programmable ratiometric analog output signal. The analog output is compatible with any resistive potentiometer or programmable linear Hall sensor and is configurable through multi-point calibration to tune the output to the desired motion and improve accuracy.

Unique to this variant, compared to the other MLX90371 products, is the dual die configuration in the Single Mold Package (SMP) for PCB-less integration. Configured with side-by-side mounting of the dies, the Single Mold Package provides independent outputs (1x per die) with shared power and ground. The Single Mold Package has been designed to provide improved mounting and integration to a housing and connector leadframe while reducing size compared to previous PCB-less packages.



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Ordering Information

Product	Temperature	Package	Option Code	Packing Form	Definition
MLX90371	G	VD	EAC-300	RE/RX	Standard / Legacy Mode

Table 1 – Ordering codes

Legend:

Temperature Code:	**G**: from -40°C to 160°C
Package Code:	“**VD**” for SMP-4 package (Single Mold, PCB-less) (see 17.1)
Option Code:	**EAC**-xxx: Die Version xxx-**123:** **1**: Application – Magnetic configuration ▪ 3: Standard / Legacy mode (legacy backwards comparable to previous generation) **2**: Not applicable for SMP-4 package variants **3**: Not applicable for SMP-4 package variants
Packing Form:	-**RE**: Tape & Reel, 2500 pcs/reel -**RX**: Tape & Reel, similar to RE with parts face-down
Ordering Example:	“**MLX90371GVD-EAC-300-RE**” For a standard mode application in SMP-4 package, delivered in Reel.

Table 2 – Ordering information legend

Contents

1. Functional Diagram

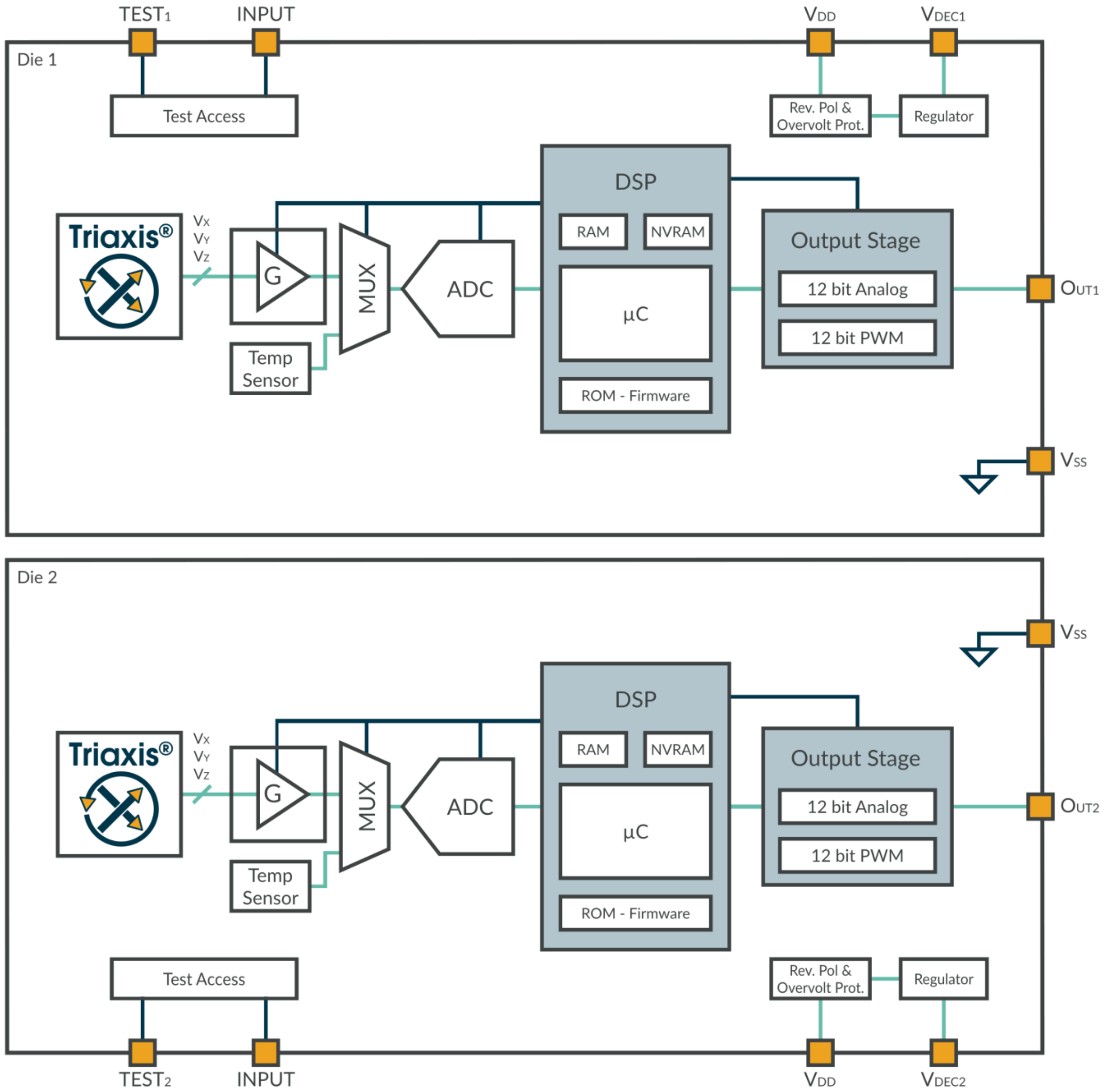

Figure 1 – MLX90371 Dual Die Block Diagram

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
SMP	Single Mold Package	NVRAM	Non-volatile Random-access Memory
DP	Discontinuity Point	AoU	Assumptions of Use
EoL	End of Line	IMC	Integrated Magnetic Concentrator

Table 3 – Glossary of Terms

3. Pin Definitions

3.1. Pin Definition for SMP-4 package

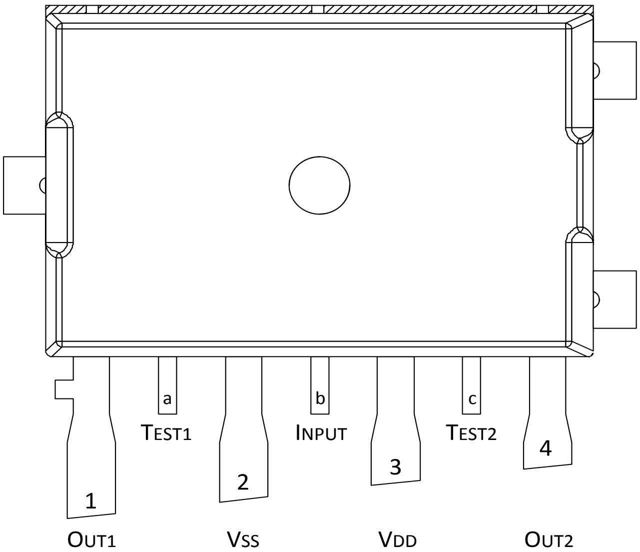

Figure 2 – Pin definition for SMP-4 Package

Pin #	Name	Description
1	OUT1	Output
2	VSS	Ground
3	VDD	Supply
4	OUT2	Output
a	TEST1	Test
b	INPUT	Test
c	TEST2	Test

Table 4 - SMP-4 Pin Definitions and Descriptions

4. Absolute Maximum Ratings

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply Voltage	VDD			28 45	V	<48h <1min
Reverse Voltage Protection	VDD_{REV}	-14 -7			V	At Room Temperature; <1s At Room Temperature; <48h
Positive Output Voltage	VOUT			18	V	<48h
Output Current	IOUT	-30		30	mA	-1.5V< VOUT <40V
Reverse Output Voltage	$VOUT_{REV}$	-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 5 – Absolute Maximum Ratings

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

5. General Electrical Specifications

General electrical specifications are valid for temperature range: -40 - 160 DegC, 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	IDD	12	18	20	mA	Standard/Legacy mode, no resistive load at OUT PIN (OUT1 and OUT2) – Both dies on.
Start-up Level (rising)		3.95	4.1	4.25	V	
Start-up Hysteresis		100	200	300	mV	
PTC Entry Level [(1)](rising)		6.2	6.5	6.8	V	

[1] *IC to be programmed at room temperature*

Electrical Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
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 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 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
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) (2)	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) (2)	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 (3)	Clamp	0		100	%VDD	Programmable

Table 6 – Electrical specifications

As an illustration of the previous table, the MLX90371 fits the typical classification of the output span described on the Figure 3.

[2] *For detailed information, see also section 13.1 Safety Mechanism*
[3] *Clamping levels need to be considered vs. the saturation of the output stage (see Analog Saturation Output level)*

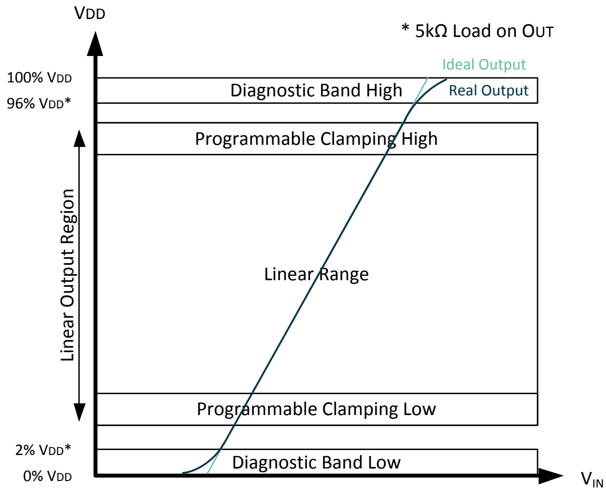

Figure 3 – Example of Output Span Classification for typical application.

6. Timing Specification

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

6.1. General Timing

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

Table 7 – General Timing Specification

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[4] *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)*

[5] *See section 12.4 for details concerning Filter parameter*

6.2. 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 4.

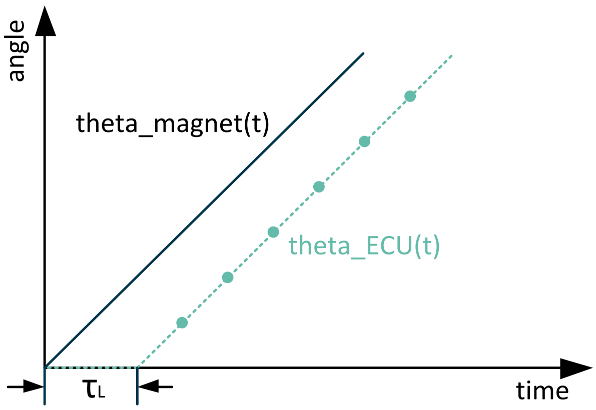

Figure 4 – Typical Latency illustration

6.3. 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 7.

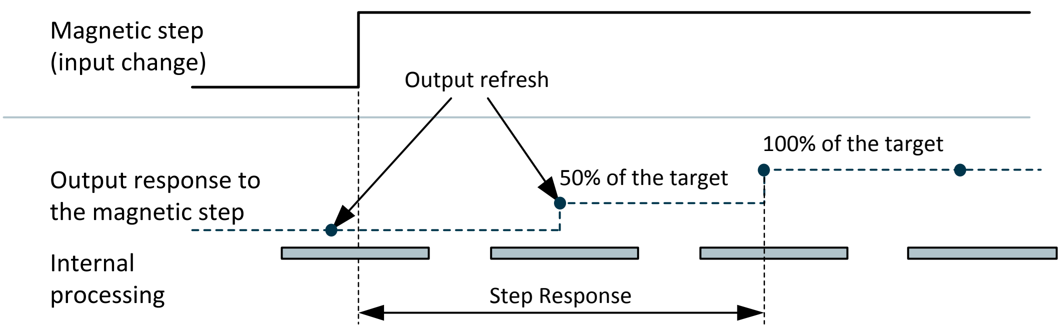

Figure 5 – Typical Step Response illustration

6.4. Analog timing

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Start-up Time	τ_{SU}			5	ms	Analog mode
Analog OUT Slew-rate[6]	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 8 – Analog timing specification

7. Magnetic Field Requirements

This section describes the magnetic field requirements in order to meet the performance described in section 8.1.

7.1. 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[7]			70[8]	mT	$\sqrt{B_X^2 + B_Y^2}$
Magnetic Flux Density in Z	B_Z			100	mT	
Magnetic Flux	Norm	10[9]			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)

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6 *The capacitors on the output are integrated in the SMP package, see Table 28*
7 *The condition must be fulfilled for at least one field B_X or B_Y*
8 *Above 70 mT, the IMC® starts saturating yielding to an increase of the linearity error*
9 *Below 10 mT the performances degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio*

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
IMC gain	G_{IMC}		1.19			See[10]
Magnet Temperature Coefficient	TCm	-2400		0	ppm/ Deg.C	
Field Too Low Threshold[11]	B_{TH_LOW}	3.4	5	6.6	mT	Corresponding to TCm=0
Field Too High Threshold[11]	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 9 – Magnetic field requirement for standard / legacy mode

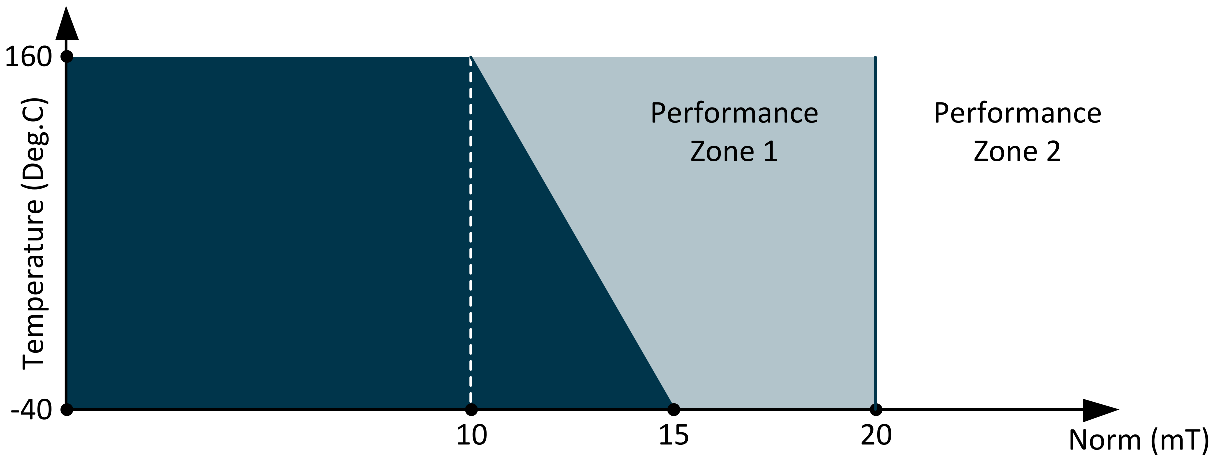

Figure 6 – Minimum useful signal definition for standard/legacy mode

8. Accuracy Specification

8.1. Magnetic Specification

8.1.1. Definition

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

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[10] *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*

[11] *Further details can be referred to section 10, see parameters "DIAG_FIELDTOOLOWTHRES" and "DIAG_FIELDTOOHIGHTHRES".*

8.1.1.1. Intrinsic Linearity Error

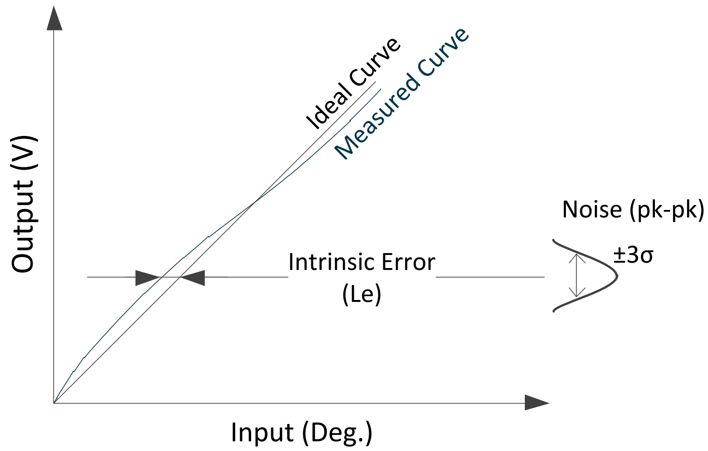

Figure 7 – Analog sensor accuracy definition

Figure 7 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.

8.1.1.2. 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.

8.1.2. 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 [12]			0.1	0.2	Deg.	Filter=0, in performance zone 2[13]
			0.2	0.4	Deg.	Filter=0, in performance zone 1[13]
			0.14	0.28	Deg.	Filter=1, in performance zone 1[13]
			0.1	0.2	Deg.	Filter=2, in performance zone 1[13]
XY - Total Drift	$\theta_{T\_DRIFT\_XY}$			0.45	Deg.	in performance zone 2[13]
				0.6	Deg.	in performance zone 1[13]
XZ - Total Drift	$\theta_{T\_DRIFT\_XZ}$			0.6	Deg.	in performance zone 2[13]
				0.8	Deg.	in performance zone 1[13]
YZ - Total Drift	$\theta_{T\_DRIFT\_YZ}$			0.6	Deg.	in performance zone 2[13]
				0.8	Deg.	in performance zone 1[13]
Hysteresis			0.1	0.2	Deg.	in performance zone 1[13]
			0.05	0.1	Deg.	in performance zone 2[13]

Table 10 – Magnetic performances in Standard/Legacy Mode

8.2. Analog Output Accuracy

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Thermal analog output Drift [12]				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 11 – Analog output accuracy

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[12] *±3σ*

[13] *Referred to section 7.1 and Figure 6*

9. Memory Specification

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

Table 12 – Memory specification

10. End-User Programmable Items

Parameter	PSF value	Description	Default Standard	# bit
PWMT	1	PWM period defined as (PWMT / 1.5) µsec [14]	1000	16
PWM DC_FAULT	2	PWM Duty Cycle if Fault [14]	1	8
PWM DC_FIELDTOOLOW	3	PWM Duty Cycle if Field Strength Too Low [14]	1	8
PWM DC_WEAKMAG	4	PWM Duty Cycle if Weak Magnet [14]	1	8
PWM WEAKMAGTHRESH	5	Weak Magnet threshold Byte [14]	0	8
DIAG_FIELDTOOLOWTHRES[15]	6	Field limit under which a fault is reported	0	8
DIAG_FIELDTOOHIGHTHRES[15]	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 3xx	1	5
CW	20	Enables clockwise rotation direction	0	1
FILTER	21	FIR Filter mode selection	0	2

[14] MLX90371EAC can also provide a digital PWM output signal through programming, which can be exploited but is not the main output protocol of the device; therefore it is not specified in detail in this datasheet.
[15] To be adapted to the application to enable diagnostic "Lost magnet" by comparison with the Field Too Low/High Threshold defined in section 7.

Parameter	PSF value	Description	Default Standard	# bit
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
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

Parameter	PSF value	Description	Default Standard	# bit
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
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 11	8
USER_ID1	76	User Id. Reference. Reserved for customer traceability	see section 11	8
USER_ID2	77	User Id. Reference. Reserved for customer traceability	see section 11	8
USER_ID3	78	User Id. Reference. Reserved for customer traceability	see section 11	8
USER_ID4	79	User Id. Reference. Reserved for customer traceability	see section 11	8
USER_ID5	80	User Id. Reference. Reserved for customer traceability	see section 11	8
PWM_POL	83	Define the output stage mode (14)	0	1
AOUT_STATE_DIAG (16)	84	Define digital level in diagnostic	0	1
AOUT_MODE_DIAG	85	Define the diagnostic output stage mode	3	2

[16] The defined digital level in diagnostic should correspond to the passive diagnostic level, see parameters "BVSSPD", "BVSSPU", "BVDDPD" and "BVDDSPU" in section 5 Table 6, i.e., "AOUT_STATE_DIAG" should be set to "0" when using pull-down resistor while "1" when using pull-up resistor

Parameter	PSF value	Description	Default Standard	# bit
AOUT_MODE_NORMAL	86	Define the normal output stage mode	0	2
SEL_PWM	88	Enable PWM output (14)	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 13 – End-user Programmable Items

11. 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 300	1	7
USER_ID0	75	Bin 1	1	8
USER_ID1	76	Identifier for full mask set version: MLX90371Exx	2	8
USER_ID2	77	Identifier for magnetic mode: Standard / Legacy mode	2	8
USER_ID3	78	Identifier for the default factory setting revision for the corresponding full mask set	1	8
USER_ID4	79	Identifier for embedded software revision: C	3	8
USER_ID5	80	reserved	0	8

Table 14 – End-user identification items

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

12. Description of End-User Programmable Items

12.1. Output modes

12.1.1. OUT modes

Output Stage mode (analog, digital) defined 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	
2	Digital	open drain PMOS/high side	
3	Digital	Push-Pull	

Table 15 – Programmable items: Output modes

12.2. 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

Output Mode	LNR Type	Value	Unit
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 16 – Programmable items: Output transfer characteristic

12.2.1. Enable scaling Parameter (USEROPTION_SCALING)

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

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

12.2.2. CLOCKWISE Parameter (CW)

The CLOCKWISE parameter defines the magnet rotation direction.

Refer to the drawing in the sensitive spot positioning sections (Section 17).

12.2.3. 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.

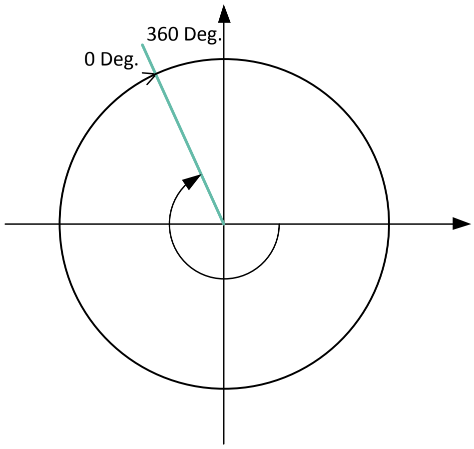


Figure 8 – The placement of the Discontinuity Point (Zero Degree Point) is programmable

12.2.4. 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.

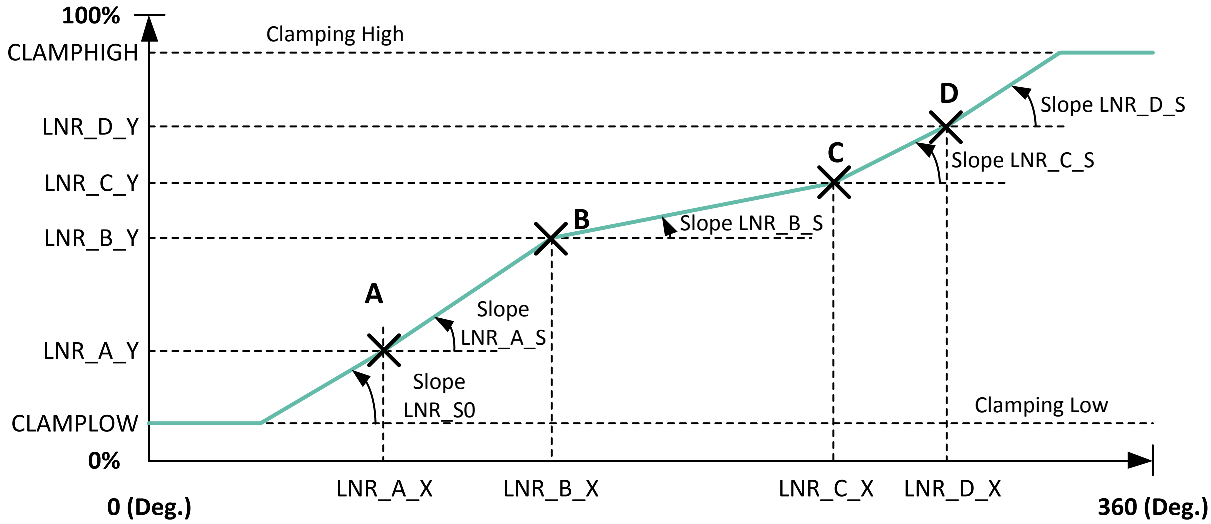


Figure 9 – 4-Points Transfer function

12.2.5. 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.

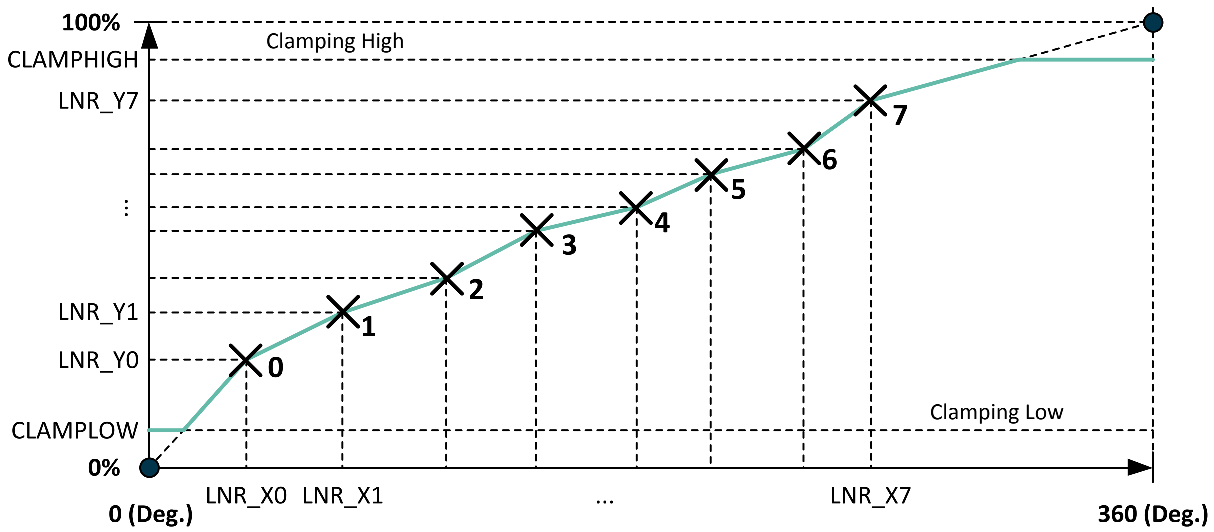


Figure 10 – 8-Points Transfer function

12.2.6. 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).

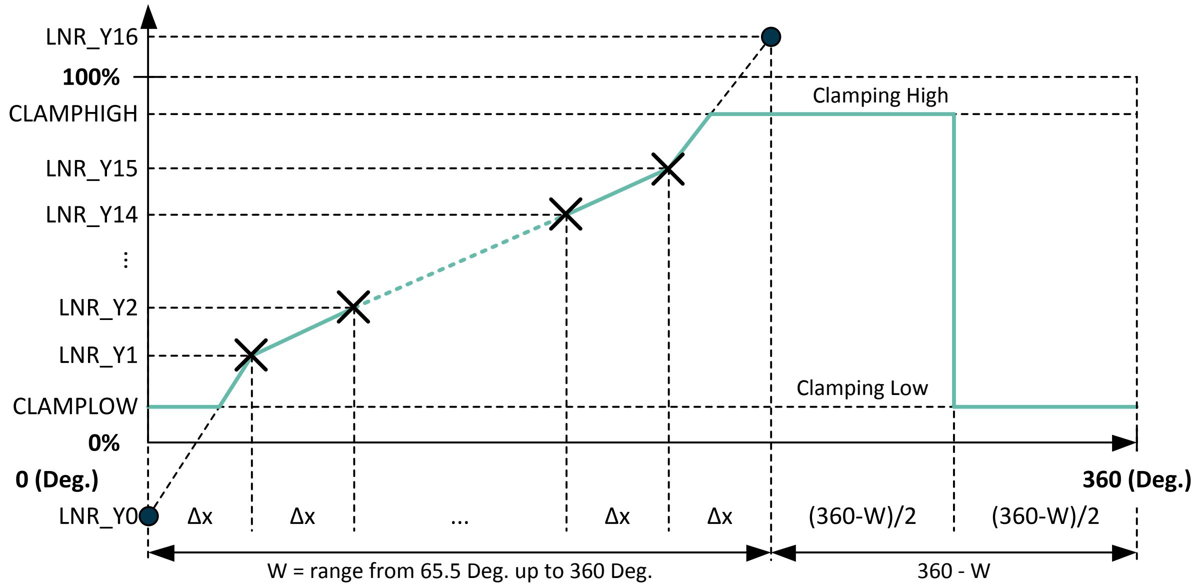


Figure 11 – 17-Points calibration transfer function

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	W	Range	Δx
0 (0000b)	360.0Deg.	22.5Deg.	8	180.0Deg.	11.3Deg.
1	320.0Deg.	20.0Deg.	9	144.0Deg.	9.0Deg.
2	288.0Deg.	18.0Deg.	10	120.0Deg.	7.5Deg.
3	261.8Deg.	16.4Deg.	11	102.9Deg.	6.4Deg.
4	240.0Deg.	15.0Deg.	12	90.0Deg.	5.6Deg.
5	221.5Deg.	13.8Deg.	13	80.0Deg.	5.0Deg.
6	205.7Deg.	12.9Deg.	14	72.0Deg.	4.5Deg.
7	192.0Deg.	12.0Deg.	15 (1111b)	65.5Deg.	4.1Deg.

Table 17 – Programmable items: 17 points calibration

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

12.2.7. 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).

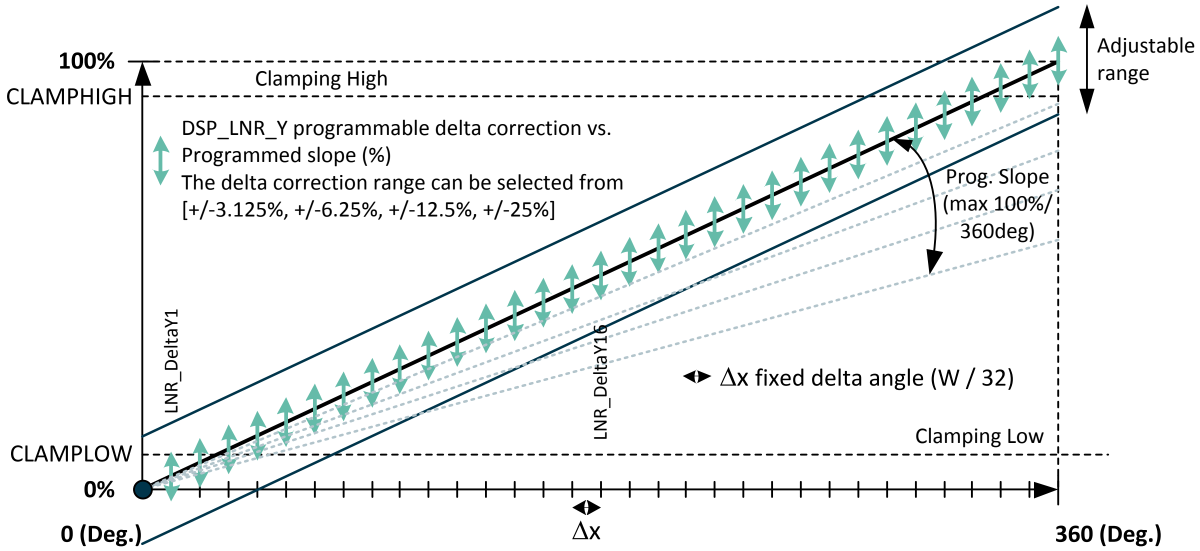


Figure 12 – 32-Points calibration transfer function

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 18 – Programmable items: 32 points calibration

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

12.2.8. 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.

12.3. Sensor Front-End

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

Table 19 – Programmable items: sensor front-end

12.3.1. 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 20 – Programmable items: sensing modes

12.3.2. 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.

12.4. 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 21 – Filter improvement factor

12.4.1. 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 22 – Programmable items: Step and impulse response of the different FIR filters

12.4.2. 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 23 – Programmable items: denoising filter

12.5. Programmable Diagnostic Settings

12.5.1. 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 24 – Programmable items - diagnostic settings

12.5.2. 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.

12.5.3. DIAG Debouncing

A parametric debouncing algorithm insures that in case of reporting mode ANA (See section 13.1 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 25 – 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 26 – Programmable diagnostic - debouncing & reporting time

13. Functional Safety

13.1. 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	○	○	○	○	○	9.4 ms	ANA
Package/pin failures detection							
Broken-Wire Detection					○	<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 27 – Safety mechanisms

Legend:
● : High failure detection coverage
○ : 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

13.2. 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.

14. Recommended Application Diagrams

14.1. Wiring with the MLX90371 in SMP-4 Package (built-in capacitors)

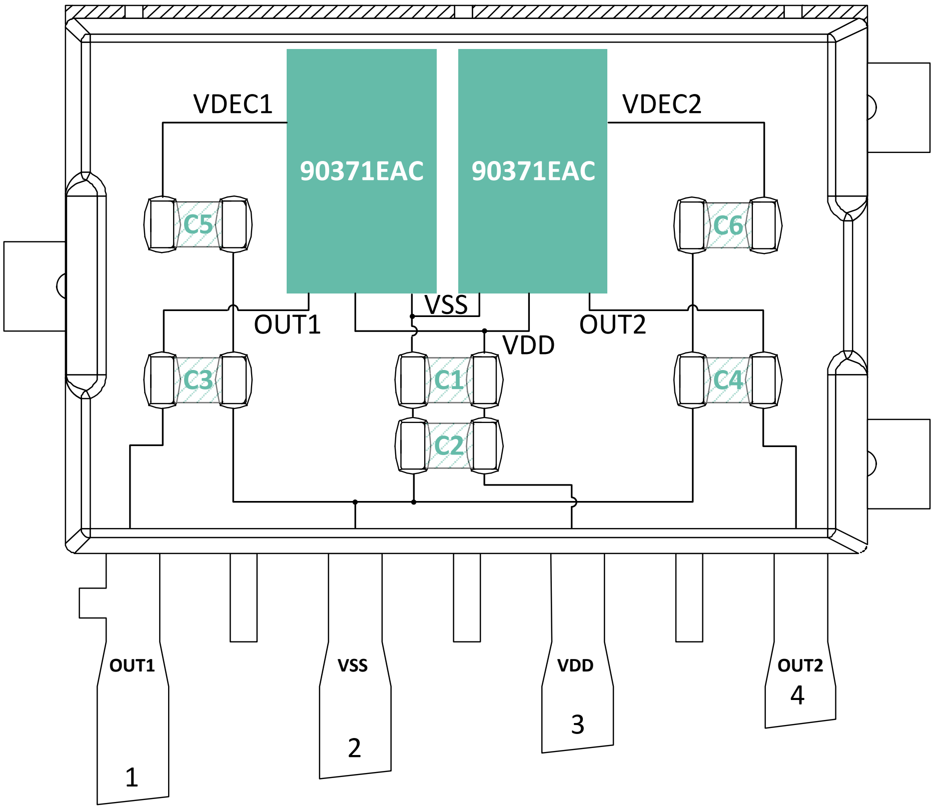


Figure 13 – Capacitor configurations in SMP-4 package

Component	Value	Remark
C1	220 nF	-
C2	220 nF	-
C3	100 nF	C_L
C4	100 nF	C_L
C5	100 nF	-
C6	100 nF	-

Table 28 – SMP-4 capacitors configuration

15. 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.

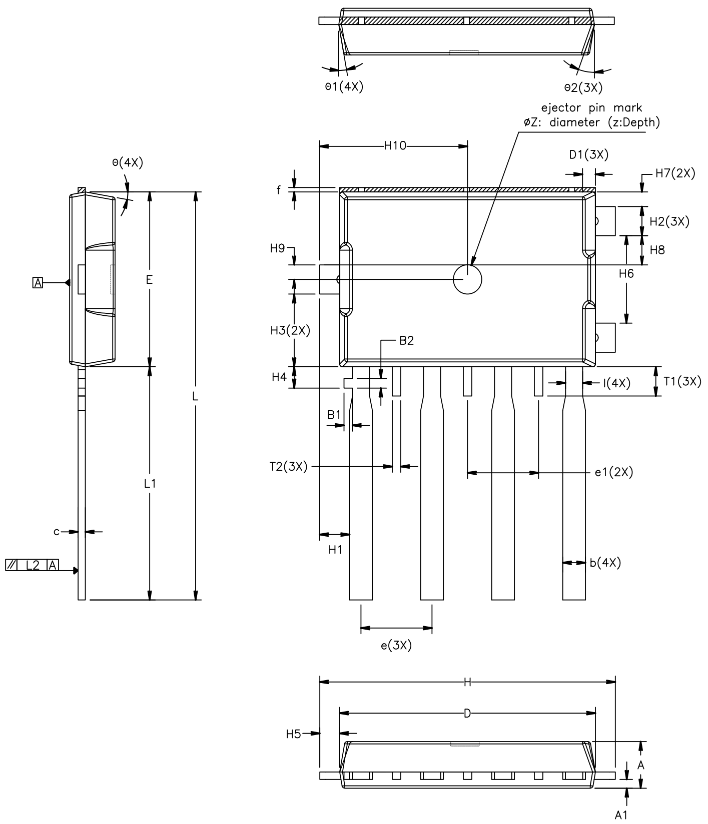
16. ESD Precautions

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

17. Package Information

17.1. SMP-4 Package

17.1.1. SMP-4 - Package Outline Dimensions (POD)



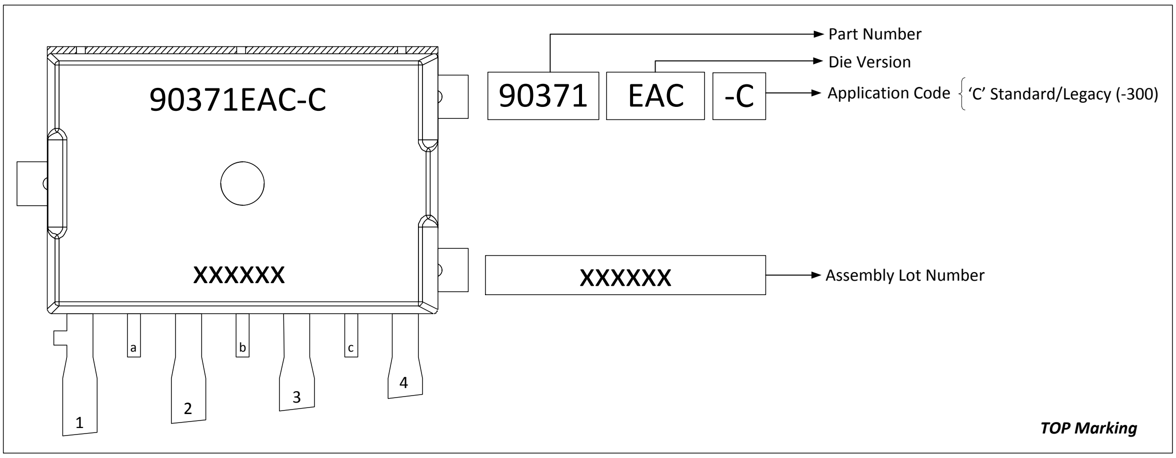
Dimension	MIN.	NOM.	MAX.	Dimension	MIN.	NOM.	MAX.
A	1.550	1.600	1.650	L	13.800	14.000	14.200
A1	0.235	0.300	0.365	L1	7.870	8.000	8.130
B1	0.235	0.300	0.365	L2	-0.325	0.000	0.325
B2	0.33 REF			I	0.525	0.600	0.675
c	0.179	0.254	0.329	b	0.725	0.800	0.875
D	8.920	9.000	9.080	e1	2.400	2.500	2.600
D1	0.450 REF			e	2.400	2.500	2.600
E	5.920	6.000	6.080	Θ	8°	10°	12°
f	0.000	---	0.152	Θ1	8°	10°	12°
H	10.250	10.400	10.550	Θ2	18°	20°	22°
H1	0.850	1.050	1.250	øZ	0.900	1.000	1.100
H2	0.925	1.000	1.075	z	0.000	---	0.152
H3	2.405	2.500	2.595	T1	0.870	1.000	1.130
H4	0.635	0.730	0.825	T2	0.225	0.300	0.375
H5	0.605	0.700	0.795				
H6	2.925	3.000	3.075				
H7	0.500 REF						
H8	0.925	1.000	1.075				
H9	0.350	0.500	0.650				
H10	5.050	5.200	5.350				

NOTES:

1. DIMENSIONS ARE IN MILLIMETER.
2. (△) PACKAGE WIDTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15MM PER END. PACKAGE LENGTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25MM PER SIDE.
3. (△) THE PACKAGE TOP MAY BE SMALLER THAN THE PACKAGE BOTTOM. PACKAGE WIDTH AND LENGTH ARE DETERMINED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY EXCLUSIVE OF MOLD FLASH, TIE BAR BURRS, GATE BURRS AND INTERLEAD FLASH.
4. ALL DIMENSIONS BETWEEN LEADFRAME ELEMENTS OR LEADFRAME AND PACKAGE SHALL EXCLUDE TIN PLATING THICKNESS.
5. PLATING SPECS: MATTED TIN, ELECTROPLATED, 7.6~15.2 MICRO METER THICKNESS
6. ALL "EARS" ARE SHORTED TO GND.

Figure 14 – SMP-4 Package Dimensions

17.1.2. SMP-4 - Pinout and Marking



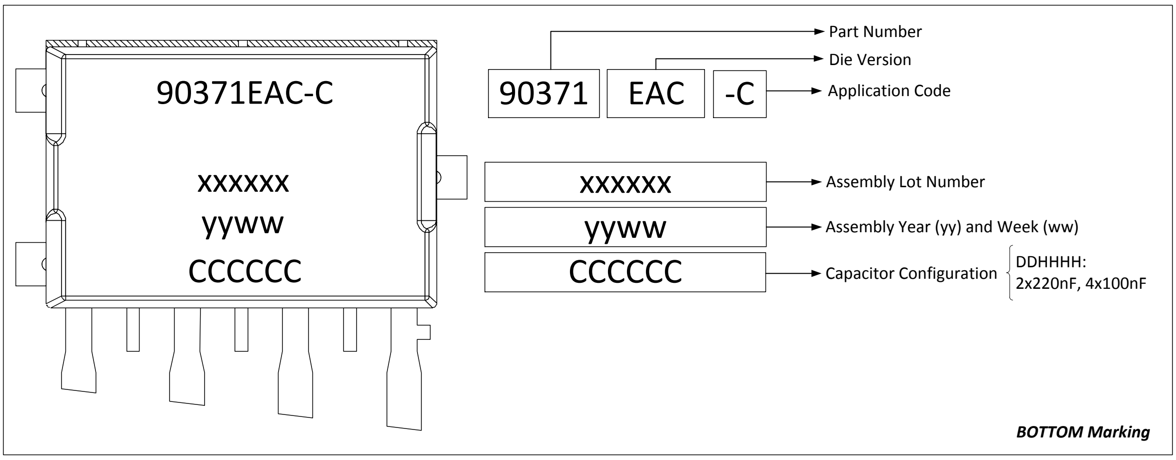


Figure 15 – SMP-4 pinout and marking

17.1.3. SMP-4 - Sensitive Spot Positioning

17.1.3.1. Standard/legacy Mode

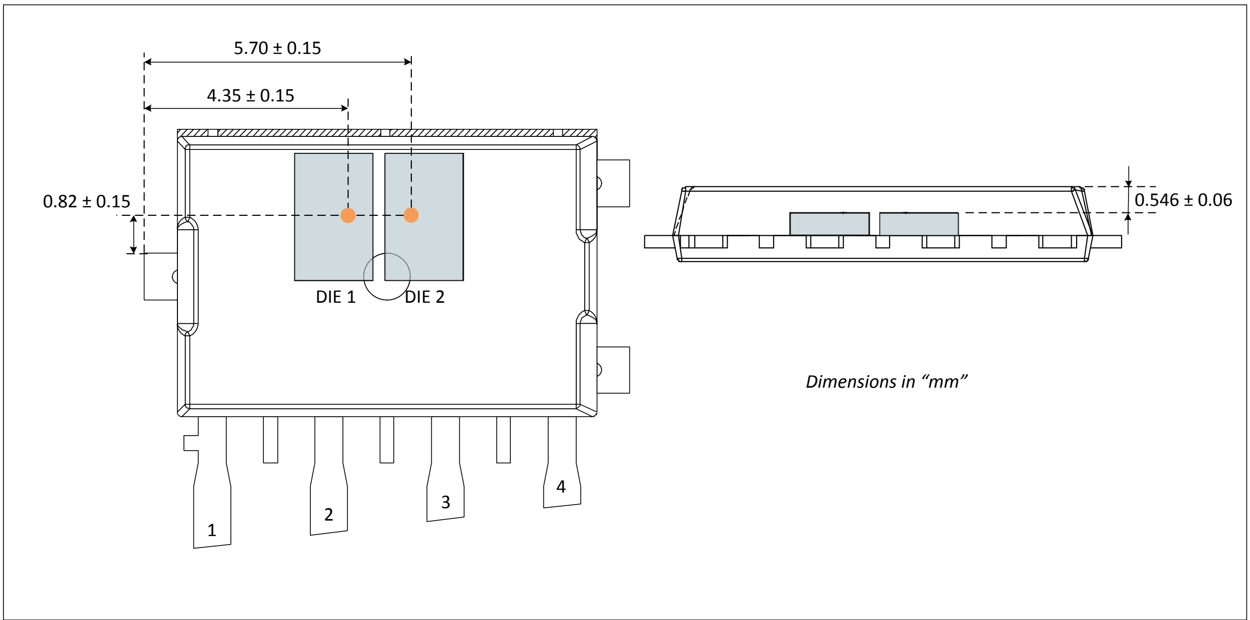


Figure 16 – SMP-4 sensitive spot for standard/legacy mode

17.1.4. SMP-4 - Angle detection

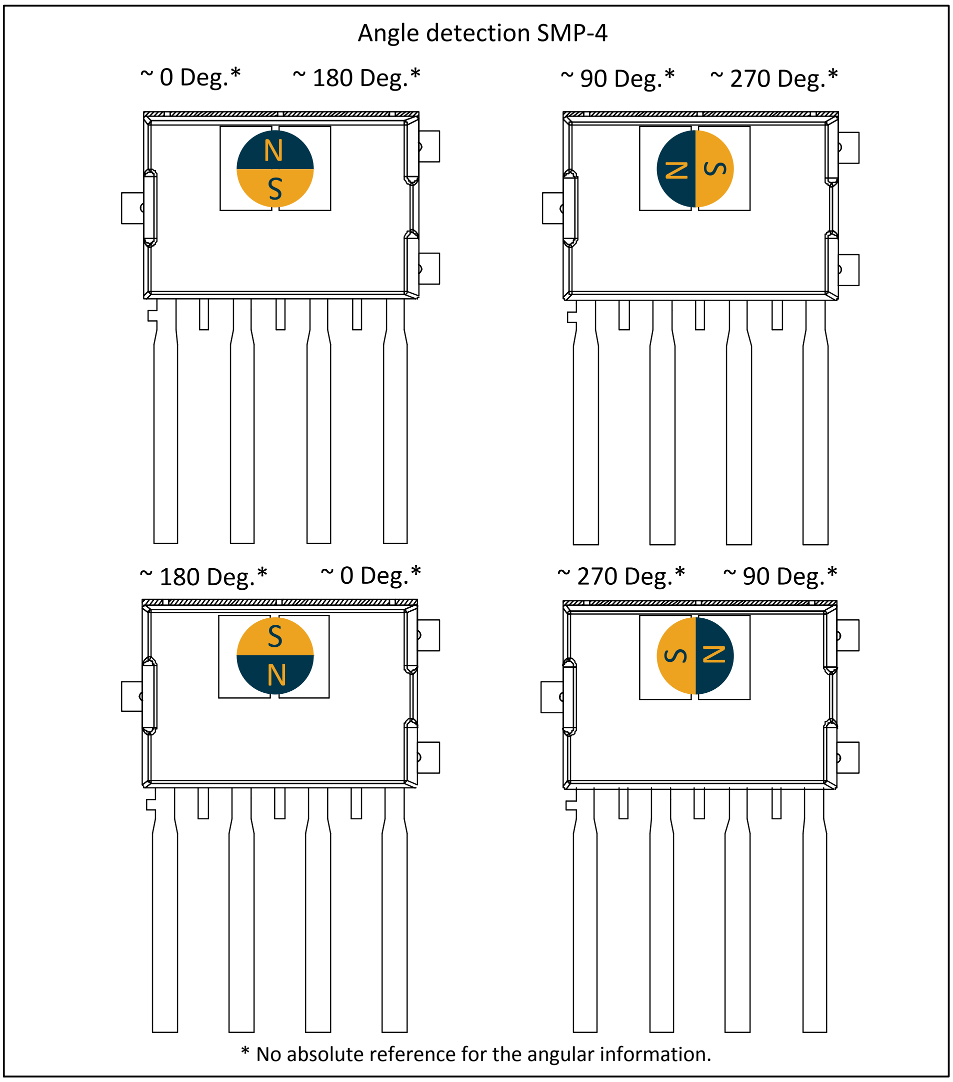


Figure 17 – SMP-4 angle detection

17.1.5. SMP-4 - Package Thermal Performance

The table below describe the thermal behaviour of SMP-4 Side-by-Side package following JEDEC EIA/JESD 51.X standard.

Package	Junction to case - θjc	Junction to ambient - θja (JEDEC 1s2p board)	Junction to ambient - θja (JEDEC 1s0p board)
SMP-4 Side-by-Side	20.82 K/W	-	139.9 K/W

Table 29 – SMP-4 Side-by-Side Package thermal performance

18. Contact

For the latest version of this document, go to our website at www.melexis.com.

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

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	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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