MLX90422

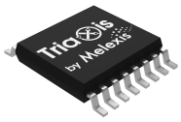
Triaxis® Position Sensor IC
Datasheet

Features and Benefits

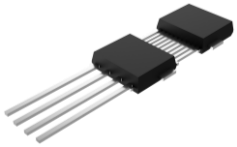
- Triaxis® Hall Technology
- On Chip Signal Processing for Robust Absolute Position Sensing
- ISO26262 ASIL B Safety Element out of Context
- AEC-Q100 Qualified (Grade 0)
- Programmable Measurement Range
- Programmable Linear Transfer Characteristic with up to 17 points
- SENT Output - SAE J2716 APR2016
- Enhanced serial data communication
- Packages RoHS compliant
  - Single Die - SOIC-8
  - Dual Die (Full Redundant) - TSSOP-16
  - PCB-less DMP-4 and SMP-3
  - PCB-less dual die SMP-4



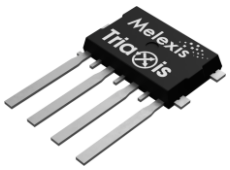
SOIC-8 (DC)



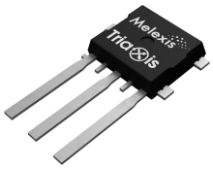
TSSOP-16 (GO)



DMP-4 (VS)



SMP-4 (VD)



SMP-3 (VE)

Application Examples

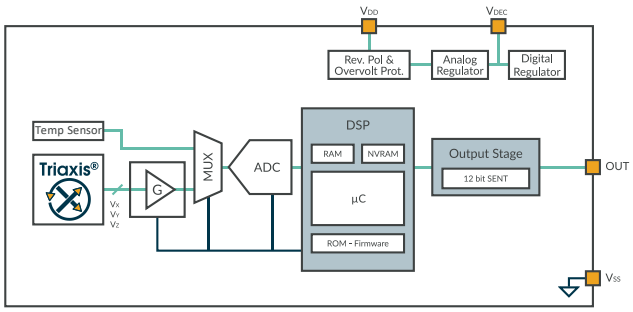
- Absolute Rotary and Linear Position Sensor
- Pedal Position Sensor
- Throttle Position Sensor
- Ride Height Position Sensor
- Transmission Position Sensor
- Steering Wheel Position Sensor
- Non-Contacting Potentiometer

Description

The MLX90422 is a monolithic magnetic position sensor IC. It consists of a Triaxis® Hall magnetic front end, an analog to digital signal conditioner, a DSP for advanced signal processing and a programmable output stage driver.

The MLX90422 is sensitive to the three components of the magnetic flux density applied to the ICs (i.e. Bx, By and Bz). Programming the sensor determines which axes are used to calculate a rotation or linear position. This allows the MLX90422 with the correct magnetic design to calculate the absolute position of any moving magnet (e.g. rotary position from 0 to 360 Degrees, see Figure 2). It enables the design of non-contacting position sensors that are frequently required for both automotive and industrial applications.

The MLX90422 provide SENT frames encoded according to a Single Secure Sensor A.3 (H.4) or Dual Throttle Position Sensor A.1 (H.1) format. The circuit delivers enhanced serial messages providing error codes, and user-defined values.



MLX90422 functional diagram

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Ordering Information

Product	Temp.	Package	Option Code	Packing Form	Definition
MLX90422	G	DC	ADD-030	RE	Angular Rotary SENT version
MLX90422	G	GO	ADD-030	RE	Angular Rotary SENT version
MLX90422	G	VS	ADD-030	RE/RX	Angular Rotary SENT version
MLX90422	G	VS	ADD-033	RE/RX	Angular Rotary SENT version
MLX90422	G	VS	ADD-038	RE/RX	Angular Rotary SENT version
MLX90422	G	VE	ADD-030	RE/RX	Angular Rotary SENT version
MLX90422	G	VD	ADD-030	RE/RX	Angular Rotary SENT version

Table 1 - Ordering codes

Temperature Code:	G : from -40°C to 160°C Some parts can be exposed to higher temperatures for a limited time [1]
Package Code:	DC : SOIC-8 package (see 18.1) GO : TSSOP-16 package (full redundancy dual die, see 18.2) VS : DMP-4 package (PCB-less dual mold, see 18.3) VE : SMP-3 package (PCB-less single mold, see 18.4) VD : SMP-4 package (PCB-less single mold dual die, see 18.5)
Option Code - Chip revision	**ADD-123 : Chip Revision** ▪ ADD: MLX90422 production version
Option Code - Application	**ADD-123 : 1-Application - Magnetic configuration** ▪ 0: Angular Rotary / Linear Position
Option Code	**ADD-123 : 2-Option** ▪ 3: Standard SENT
Option Code - Trim & Form	**ADD-123 : 3-DMP-4 Trim & Form configuration** ▪ 0: Standard straight leads. See section 18.3.1 ▪ 3: Trim and Form STD2 2.54. See section 18.3.2 ▪ 8: Trim and Form STD4 2.54. See section 18.3.3
Packing Form:	-RE : Tape & Reel ▪ VS/VE/VD: 2500 pcs/reel ▪ DC: 3000 pcs/reel ▪ GO: 4500 pcs/reel -RX : Tape & Reel, similar to RE with parts face-down
Ordering Example:	MLX90422GDC-ADD-030-RE For a SENT version in SOIC-8 package, delivered in Reel of 3000pcs.

Table 2 - Ordering codes information

[1] The devices can be used up-to an ambient temperature of +180°C. For a description of the conditions, refer to the sub-sections labelled "High-temperature Extension" (4.1, 9.2.3, 0).

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1. Functional Diagram and Application Modes

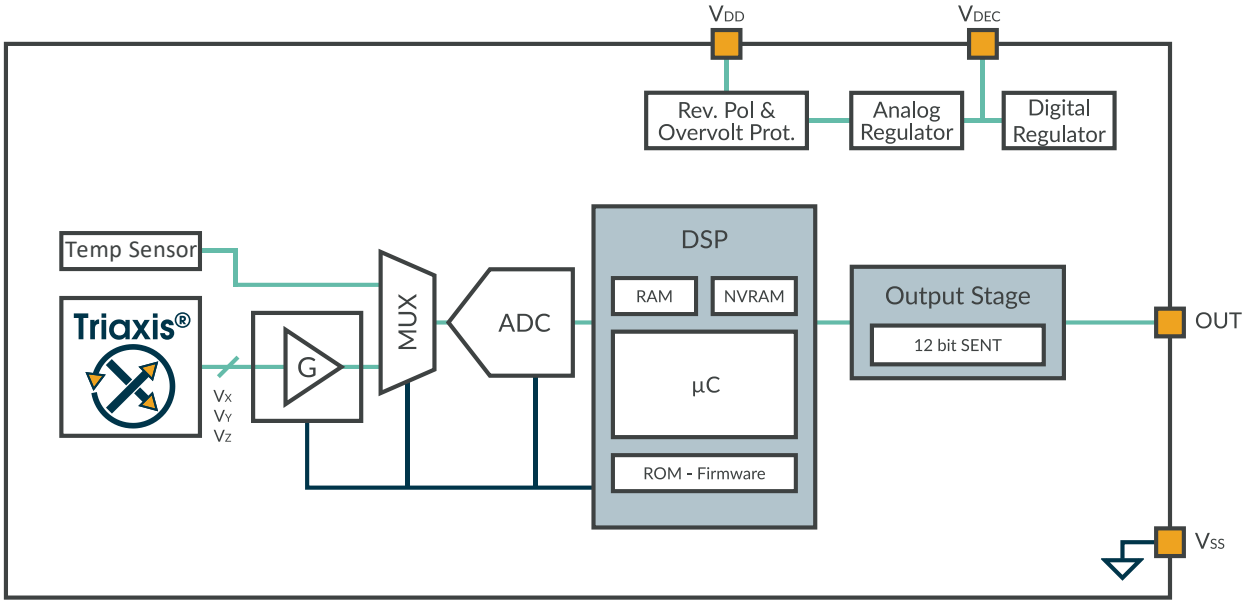


Figure 1 - MLX90422 block diagram

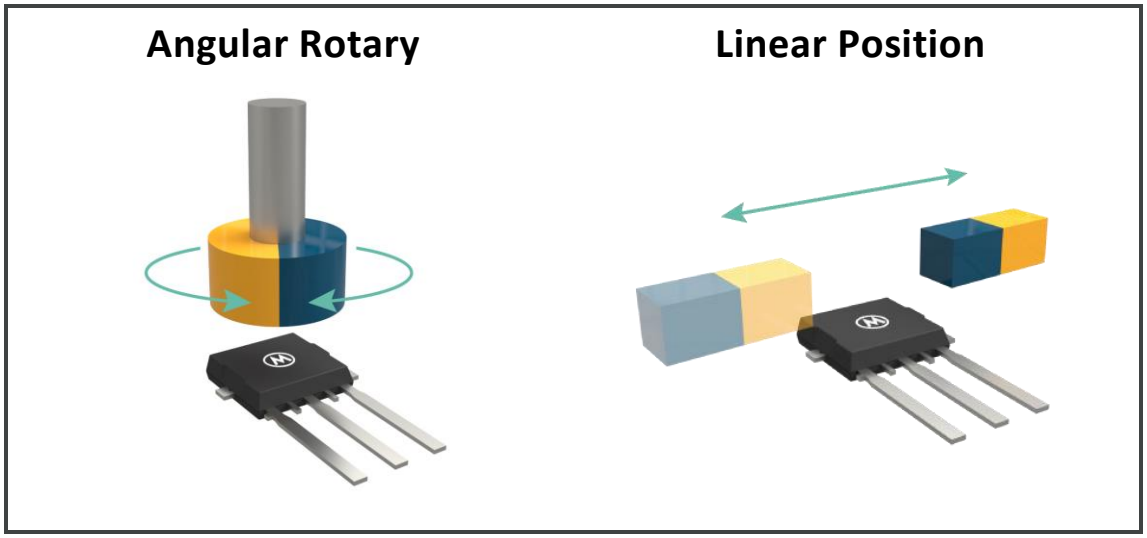


Figure 2 - Applications mode

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2. Glossary of Terms

Name	Description
ADC	Analog-to-Digital Converter
AoU	Assumption of Use
AWD	Absolute Watchdog
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
%DC	Duty Cycle of the output signal i.e. T_{ON} /(T_{ON} + T_{OFF})
DCT	Diagnostic Cycle Time
DMP	Dual Mold Package
DP	Discontinuity Point
DSP	Digital Signal Processing
ECC	Error Correcting Code
EMC	Electro-Magnetic Compatibility
EoL	End of Line
ESD	Electro-Static Discharge
FIR	Finite Impulse Response
Gauss (G)	Alternative unit for the magnetic flux density (10G = 1mT)
HW	Hardware
IMC	Integrated Magnetic Concentrator
INL / DNL	Integral Non-Linearity / Differential Non-Linearity
IWD	Intelligent Watchdog
LNR	LiNeaRization
LSB/MSB	Least Significant Bit / Most Significant Bit
N.C.	Not Connected
NVRAM	Non Volatile RAM
PCB	Printed Circuit Board
POR	Power On Reset
PSF	Product Specific Functions
RAM	Random Access Memory
ROM	Read-Only Memory
SEooC	Safety Element out of Context
SMP	Single-Mold Package
SOIC	Small Outline Integrated Circuit
TC	Temperature Coefficient (in ppm/°C)
TSSOP	Thin Shrink Small Outline Package
Tesla (T)	SI derived unit for the magnetic flux density (Vs/m^2)

Table 3 - Glossary of terms

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3. Pin Definitions and Descriptions

3.1. Pin Definition for SOIC-8

Pin #	Name	Description
1	V_{DD}	Supply
2	$Test_1$	For Melexis factory test
3	$Test_2$	For Melexis factory test
4	N.C.	Not connected
5	OUT	Output
6	N.C.	Not connected
7	V_{DEC}	Decoupling pin
8	V_{SS}	Ground

Table 4 - SOIC-8 pins definition and description

Test pins are internally grounded when in application mode. For improved EMC behavior, connect the Test and N.C. pins to the ground of the PCB.

3.2. Pin Definition for TSSOP-16

Pin #	Name	Description
1	V_{DEC1}	Decoupling pin die1
2	V_{SS1}	Ground die1
3	V_{DD1}	Supply die1
4	$Test_{11}$	For Melexis factory test, die 1
5	$Test_{22}$	For Melexis factory test, die 2
6	OUT_2	Output die2
7	N.C.	Not connected
8	N.C.	Not connected
9	V_{DEC2}	Decoupling pin die2
10	V_{SS2}	Ground die2
11	V_{DD2}	Supply die2
12	$Test_{12}$	For Melexis factory test, die 2
13	$Test_{21}$	For Melexis factory test, die 1
14	N.C.	Not connected
15	OUT_1	Output die1
16	N.C.	Not connected

Table 5 - TSSOP-16 pins definition and description

Test pins are internally grounded when in application mode. For improved EMC behavior, connect the Test and N.C. pins to the ground of the PCB.

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3.3. Pin Definition for DMP-4

DMP-4 package offers a pin-to-pin compatibility with the previous generation of Triaxis® products.

Pin #	Name	Description
1	V_{SS}	Ground
2	V_{DD}	Supply
3	OUT	Output
4	V_{SS}	Ground

Table 6 - DMP-4 pins definition and description

3.4. Pin Definition for SMP-3

SMP-3 package offers advanced components integration in a single mold compact form.

Pin #	Name	Description
1	V_{DD}	Supply
2	OUT	Output
3	V_{SS}	Ground

Table 7 - SMP-3 pins definition and description

3.5. Pin Definition for SMP-4

SMP-4 package offers a redundant dual-die package with advanced components integration in a single mold compact form.

Pin #	Name	Description
1	OUT_1	Output 1
2	V_{SS}	Ground
3	V_{DD}	Supply
4	OUT_2	Output 2

Table 8 - SMP-4 pins definition and description

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4. Absolute Maximum Ratings

Parameter		Symbol	Min	Max	Unit	Condition
Supply Voltage	Positive	V_{DD}		28 37	V	< 48h < 60s; T_{AMB} ≤ 35°C
	Reverse	V_{DD-rev}	-14 -18		V	< 48h < 1h
Output Voltage	Positive	V_{OUT}		28 34	V	< 48h < 1h
	Reverse	$V_{OUT-rev}$	-14 -18		V	< 48h < 1h
Internal Voltage	Positive	V_{DEC}		3.6	V	< 1h
	Reverse	$V_{DEC-rev}$	-0.3		V	< 1h
$Test_1$ pin Voltage	Positive	V_{Test1}		6	V	< 1h
	Reverse	$V_{Test1-rev}$	-3		V	< 1h
$Test_2$ pin Voltage	Positive	V_{test2}		3.6	V	< 1h
	Reverse	$V_{test2-rev}$	-0.3		V	< 1h
Operating Temperature		T_{AMB}	-40	+160	°C	
Junction Temperature [2]		T_J		+175	°C	
Storage Temperature		T_{ST}	-55	+170	°C	
Magnetic Flux Density		B_{max}	-1	1	T	

Table 9 - Absolute maximum ratings

Exceeding any of the absolute maximum ratings may cause permanent damage.

Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.

The voltages given in Table 9 are valid for a single die and will degrade when simultaneously applied to multiple dice in the same package.

[2] *Find package thermal dissipation values in section 18.4*

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4.1. High-Temperature Extension Absolute Maximum Ratings

The MLX90422 can be exposed to high-temperature within the range [160, 180] °C for a limited duration. The device continues to operate with degraded performances according to the values listed in the following table. This extension is only valid for the SMP-3, SMP-4 and DMP-4 packages.

Parameter		Symbol	Min	Max	Unit	Condition
Supply Voltage	Positive	V_{DD}		5.5	V	T_{AMB} = 180°C, see [3]
	Reverse	V_{DD-rev}	-14		V	T_{AMB} = 180°C, < 1h
Output Voltage	Positive	V_{OUT}		26	V	T_{AMB} = 180°C, < 1h
	Reverse	$V_{OUT-rev}$	-14		V	T_{AMB} = 180°C, < 1h
Operating Temperature		T_{AMB}	-40	+180	°C	< 250h
Junction Temperature		T_J		+190	°C	< 250h
Storage Temperature		T_{ST}	-55	+190	°C	< 250h

Table 10 - High-temperature extension absolute maximum ratings

Exceeding any of the absolute maximum ratings may cause permanent damage.

Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.

The voltages given in Table 10 are valid for a single die and will degrade when simultaneously applied to multiple dice in the same package.

5. Isolation Specification

The specified isolation resistance is only valid for the TSSOP-16 package (code GO).

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

Table 11 - Isolation specification

[3] *Higher supply voltages will increase the die temperature above the max junction temperature T_J*

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6. General Electrical Specifications

General electrical specifications are valid for temperature range [-40, 160] °C and supply voltage range [4.5, 5.5] V unless otherwise noted.

Electrical Parameter	Symbol	Min	Typ.	Max	Unit	Condition
Supply Voltage	V_{DD}	4.5	5	5.5	V	
Supply Current [4]	I_{DD}	7.5	8.5	10.0	mA	Single die
Start-up Level (rising)	$V_{DDstartH}$	3.85	4.00	4.15	V	
Start-up Hysteresis	$V_{DDstartHyst}$		100		mV	
PTC Entry Level (rising)	V_{PROV0}	5.85	6.05	6.25	V	Supply overvoltage detection
PTC Entry Level Hysteresis	$V_{PROV0Hyst}$	100	175	250	mV	
Under voltage detection	V_{DDUVL}	3.75	3.90	4.05	V	Supply voltage low threshold
Under voltage detection hysteresis	$V_{DDUVHyst}$		100		mV	
Regulated Voltage	V_{DEC}	3.2	3.3	3.4	V	Internal analog voltage

Table 12 - Supply system electrical specifications

Electrical Parameter	Symbol	Min	Typ.	Max	Unit	Condition
External pull-up Voltage	V_{ext}			V_{DD}	V	SENT Receiver supply voltage
Output Short Circuit Current Limit	$I_{OUTshort}$	10		35	mA	
Output Load	R_L	10		55	kΩ	Pull-up to V_{ext}
Low state voltage [5]	V_{OL}			0.5	V	0.52mA DC load current
High state voltage [5]	V_{OH}	4.1			V	0.10mA DC load current
Digital open-drain output leakage	I_{leakpu}			20	µA	With a pull-up to V_{ext}
Passive Diagnostic Output Level (Broken-Wire Detection) [6]	$BV_{SS}PU$	99.5	100		$\%V_{DD}$	Broken Vss & Pull-up $R_L \geq 1$ kΩ to V_{ext}
	$BV_{DD}PU$	92.5 97.0	98.7 99.5		$\%V_{DD}$	Broken V_{DD} & Pull-up $R_L \leq 25$ kΩ to V_{ext} Pull-up $R_L \leq 10$ kΩ to V_{ext}

Table 13 - Output electrical specifications

[4] *For the dual die version, the supply current is multiplied by 2.*

[5] *Compliant with SAE J2716 Revised APR2016*

[6] *Valid for dual-die configurations as well where the two dies have the same supply and ground level.*

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7. Timing Specification

Timing specifications are valid for temperature range [-40, 160] °C and supply voltage range [4.5, 5.5] V unless otherwise noted.

7.1. General Timing Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
Main Clock Frequency	F_{CK}	22.8 -5	24	25.2 5	MHz %F_{ck}	Including thermal and lifetime drift
Main Clock initial tolerances	$\Delta F_{CK,0}$	-1		1	MHz %F_{ck}	T=35°C, trimmed
Main Clock Frequency Thermal Drift	$\Delta F_{CK,T}$	-3.5		3.5	%F_{ck}	Relative to clock frequency at 35°C. Ageing effect not included
1MHz Clock Frequency	F_{1M}	0.95 -5	1	1.05 5	MHz %F_{1M}	Including thermal and lifetime drift

Table 14 - General timing specifications

7.2. Timing Definitions

7.2.1. Startup Behavior

In SENT mode, the startup time consists of two values. The first one, T_{init}, is the time needed for the circuit to be ready to start acquiring an angle. In SENT mode, at that time, the IC starts transmitting initialisation frames. The second value, T_{stup}, is the time when the first valid angle is transmitted.

These definitions are illustrated in the following figure (Figure 3) where τ_{init} represents the sensor internal initialization sequence.

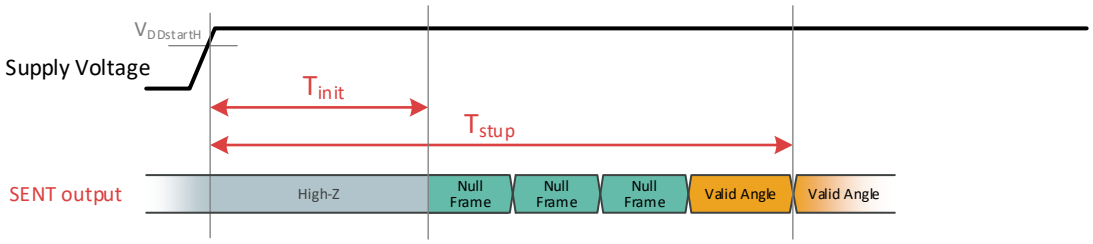


Figure 3 - Startup time definition

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7.2.2. Latency (average)

Latency is the average lag between the movement of the detected object (magnet) and the response of the sensor output. This value is representative of the time constant of the MLX90422 for regulation calculations.

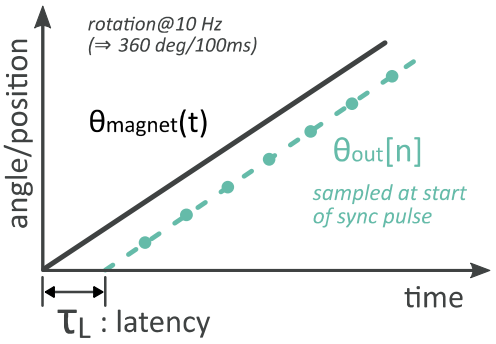


Figure 4 - Definition of latency

7.2.3. Step Response (worst-case)

Step response is defined as the delay between a change of position of the magnet and the 100% settling time of the sensor output with full angle accuracy with regards to filtering. Step response therefore consists of the sum of:

- $\delta_{mag,frameEnd}$, the delay between magnetic step and the end of the frame,
- $\delta_{frameEnd,frameEndPartial}$, the delay between the end of the frame when the magnetic step occurred and the end of the frame which carries the partial response,
- $T_{frame,no\ PP}$, the frame length excluding the pause pulse (PP), which carries the complete response.

Figure 5 depicts step response when applied to a SENT with pause output format.

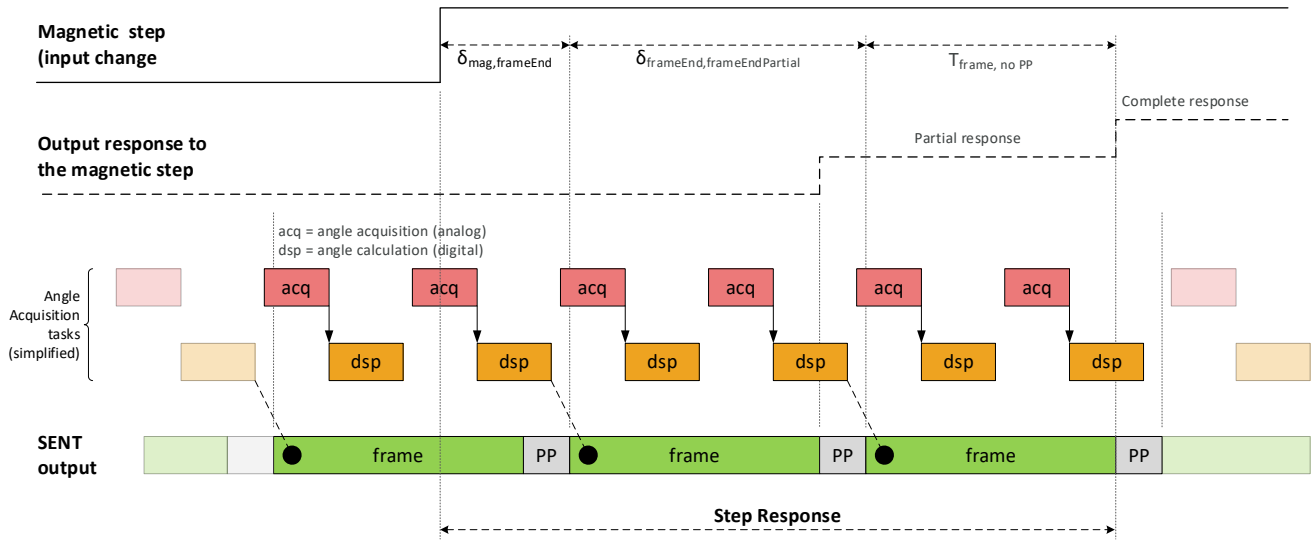


Figure 5 - Step response definition

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7.3. SENT Output Timing Specifications

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
Tick time [7]			3		µs	
SENT edge rise Time	T_{rise}		12.5	18	µs	between 1.1V and 3.8V
SENT edge fall Time	T_{fall}		5.3	6.5	µs	
Slow Message cycle length			576 432		frames	Extended sequence (32 frames) Short sequence (24 frames)

Table 15 - SENT Output timing specifications

7.3.1. Continuous Synchronous Acquisition Mode

In its default factory settings, the MLX90422 outputs a SENT frame of constant length, regardless of the data content (SENT with pause pulse). The length of the SENT frame is defined by T_{frame} and expressed in a number of ticks (see T_FRAME in sections 12 and 13.1). In continuous synchronous acquisition mode, the angle acquisition is synchronised with the SENT frame, as depicted in Figure 6.

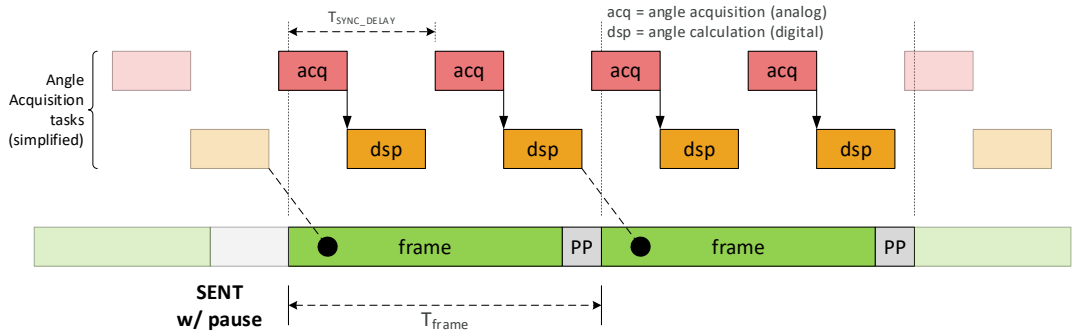


Figure 6 - Continuous synchronous timing mode

The detailed default setting of the SENT protocol is as follows. The corresponding timing specifications are listed in Table 16.

- Protocol: SENT with pause
- Tick time: 3µs
- SENT format: A.3 (H.4)
- Number of angle acquisitions per SENT frame: 2
- DSP linearization: 16 points

[7] *The MLX90422 has a fixed tick time of 3 µs. It cannot be changed.*

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Parameter	Symbol	Min	Typ.	Max	Unit	Condition
SENT frame tick count	N_{Tframe}	287			ticks	
Output refresh period	T_{frame}		861	905	µs	Ppc = N_{Tframe}= 287
SENT startup time	T_{stup}			5.93	ms	Until first valid angle received
Average Latency [8][9][10]	τ_L		1.32 1.75	1.58 2.03	ms	Filter 1, Filter 2 (see 13.4 Filtering)
Step Response [9][10]	T_{wcStep}			2.71 3.61	ms	Filter 1, Filter 2 (see 13.4 Filtering)
Analog Diagnostics Cycle	DCT_{ANA}			10.4	ms	Ppc = N_{Tframe}= 287
Digital Diagnostics Cycle	DCT_{DIG}			19.7	ms	
Safe startup Time	$T_{SafeStup}$	5		33	ms	

Table 16 - Synchronous SENT mode timing specifications

7.3.2. Continuous Asynchronous Acquisition Mode

Optionally, the MLX90422 can be configured to operate with variable SENT frame length (SENT without pause). In continuous asynchronous acquisition mode, the sensor acquires angles at a fixed internal rate. At the beginning of each new SENT frame, the sensor fetches the latest calculated angle and transmits it in the SENT frame according to the selected format. In this mode, latency and step response depend on the data content and the delay between the angle availability and its transmission.

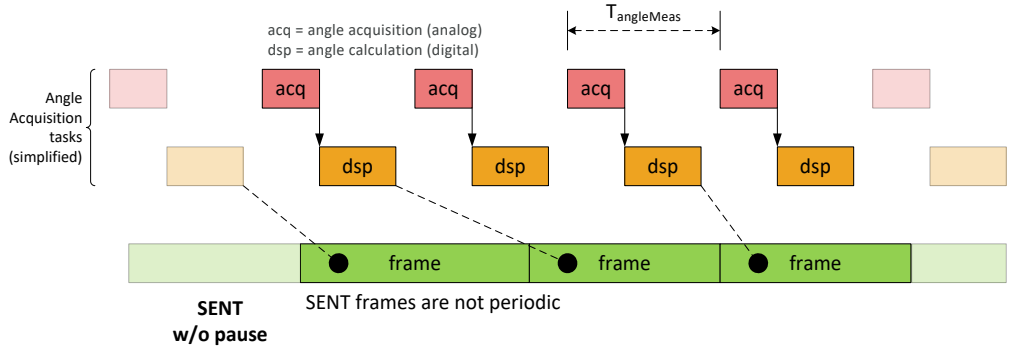


Figure 7 - Continuous asynchronous timing mode

When configured in the continuous asynchronous acquisition mode, the detailed default setting is as follows. The corresponding timing specifications are listed in Table 17.

- Protocol: SENT without pause
- Tick time: 3µs
- SENT format: A.3 (H.4)
- DSP linearization: 16 points

[8] *Typ. values assumes no clock drift and an average SENT frame (212 ticks, excluding pause pulse).*

[9] *Max values assumes a clock drift of 5% and the longest SENT frame (270 ticks, excluding pause pulse).*

[10] *Data is assumed available after the CRC nibble and before the pause pulse.*

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Parameter	Symbol	Min	Typ.	Max	Unit	Condition
Internal angle measurement period	$T_{angleMeas}$		512	537	µs	Asynchronously to the output protocol
Output refresh period	T_{frame}		810	851	µs	Npp = 270, longest frame w/o pause
SENT startup time	T_{stup}			5.9	ms	Until first valid angle received
Average Latency [11]	τ_L	0.83 1.07 1.56	1.30 1.56 2.08	1.83 2.10 2.64	ms	Filter 0, Filter 1, Filter 2 (see 13.4 Filtering)
Step Response [12]	T_{wcStep}			2.68 3.22 4.29	ms	Filter 0, Filter 1, Filter 2 (see 13.4 Filtering)
Analog Diagnostics Cycle	DCT_{ANA}			12.4	ms	
Digital Diagnostics Cycle	DCT_{DIG}			19.7	ms	
Safe startup Time	$T_{SafeStup}$	5		33	ms	

Table 17 - Asynchronous SENT mode timing specifications

[11] The range for the average latency is provided (including clock drift). The average latency varies based on the programmable items configuration and the data being transmitted.

[12] Max values assumes a clock drift of 5% and the longest SENT frame (270 ticks).

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8. Magnetic Field Specifications

Magnetic field specifications are valid for temperature range [-40, 160] °C unless otherwise noted.

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
Number of magnetic poles	N_P		2			
Magnetic Flux Density in X-Y plane	B_x, B_y [13]			70	mT	$\sqrt{B_X^2 + B_Y^2}$
Magnetic Flux Density in Z	B_z			126	mT	in absolute value
Useful Magnetic Flux Density Norm	B_{Norm}	10[14]	20		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) see 13.3 for sensing mode description.
IMC gain [15]	G_{IMC}		1.19			
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{ppm}{°C}$	
Field Too Low Threshold	B_{TH_LOW}	2	4	30	mT	Typ. is recommended value to be set by user (see 13.5.5)
Field Too High Threshold [16]	B_{TH_HIGH}	70	126	126	mT	Typ. is recommended value to be set by user (see 13.5.5)

Table 18 - Magnetic specifications for standard application

The magnetic performances are listed in chapter 9.2. The Figure 8 defined under which conditions nominal, limited or high-temperature performances apply.

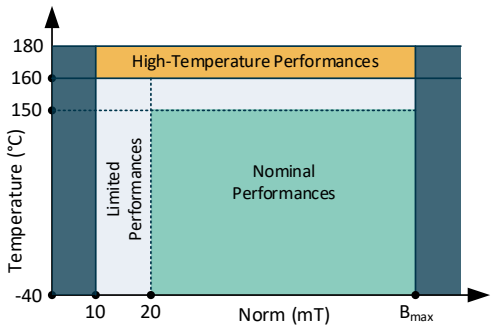


Figure 8 - Useful magnetic signal definition

[13] *The condition must be fulfilled for all combinations of B_x and B_y.*

[14] *Only valid under the conditions of Figure 8. Outside of the "Limited Performances" zone, the performances are further degraded due to a reduction of the signal-to-noise ratio and signal-to-offset ratio.*

[15] *The IMC has a better performance for concentrating in-plane (X-Y) field components, resulting in a better overall magnetic sensitivity. A correction factor, called IMC gain has to be applied to the z field component to account for this difference.*

[16] *Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensor*

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9. Accuracy Specifications

Accuracy specifications are valid for temperature range [-40, 160] °C and supply voltage range [4.5, 5.5] V unless otherwise noted.

9.1. Definitions

This section defines several parameters, which will be used for the magnetic specifications.

9.1.1. Intrinsic Linearity Error

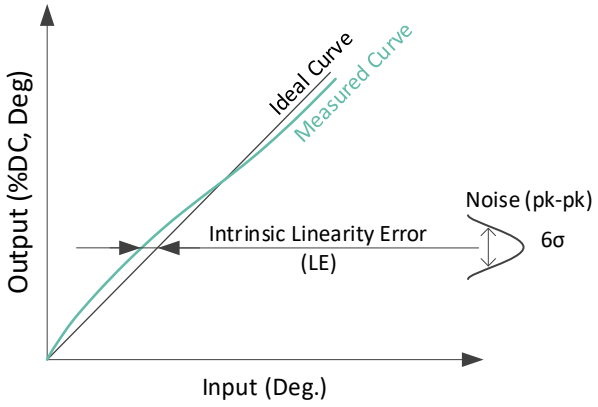


Figure 9 - Sensor accuracy definition

The illustration of Figure 9 depicts the intrinsic linearity error in new parts. The Intrinsic Linearity Error refers to the error sources of the IC (offset, sensitivity mismatch, orthogonality error) taking into account an ideal magnetic field. Once associated to a practical magnetic construction and its respective mechanical and magnetic tolerances, the output linearity error increases. The linearity error can be improved with the multi-point end-user calibration (see 13.2). As a consequence, this error is not the critical factor in application when it is calibrated away.

9.1.2. Total Angle Drift

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

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

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

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9.2. Performances

9.2.1. Nominal Performances

Valid before EoL calibration and for all applications under nominal performances conditions described in chapter 6 and chapter 8.

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
XY - Intrinsic Linearity Error	L_{E_XY}	-1		1	Deg.	
XZ - Intrinsic Linearity Error	L_{E_XZ}	-2.5		2.5	Deg.	
YZ - Intrinsic Linearity Error	L_{E_YZ}	-2.5		2.5	Deg.	
Noise (17)			0.1 0.15 0.1	0.2 0.35 0.2	Deg.	Filter = 0, B_{Norm} ≥ 40mT Filter = 0, B_{Norm} ≥ 20mT Filter = 2, B_{Norm} ≥ 20mT
XY - Total Drift (18)	$\partial\theta_{TT_XY}$	-0.6		0.6	Deg.	Relative to 35°C.
XZ - Total Drift (18)	$\partial\theta_{TT_XZ}$	-0.8		0.8	Deg.	
YZ - Total Drift (18)	$\partial\theta_{TT_YZ}$	-0.8		0.8	Deg.	
Hysteresis				0.1	Deg.	B_{Norm} ≥ 20mT

Table 19 - Nominal magnetic performances

9.2.2. Limited Performances

Valid before EoL calibration and for all applications under limited performances conditions described in chapter 6 and chapter 8.

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
XY - Intrinsic Linearity Error	L_{E_XY}	-1		1	Deg.	
XZ - Intrinsic Linearity Error	L_{E_XZ}	-2.5		2.5	Deg.	
YZ - Intrinsic Linearity Error	L_{E_YZ}	-2.5		2.5	Deg.	
Noise (17)			0.15 0.3 0.55 0.15	0.25 0.45 0.8 0.25	Deg.	Filter = 0, B_{Norm} ≥ 40mT Filter = 0, B_{Norm} ≥ 20mT Filter = 0, B_{Norm} ≥ 10mT Filter = 2, B_{Norm} ≥ 20mT
XY - Total Drift (18)	$\partial\theta_{TT_XY}$	-0.8		0.8	Deg.	Relative to 35°C.
XZ - Total Drift (18)	$\partial\theta_{TT_XZ}$	-1.0		1.0	Deg.	
YZ - Total Drift (18)	$\partial\theta_{TT_YZ}$	-1.0		1.0	Deg.	
Hysteresis				0.2	Deg.	B_{Norm} ≥ 10mT

Table 20 - Limited magnetic performances

17 ±3σ

18 Verification done on new and aged devices in an ideal magnetic field. An additional application-specific error arises from the non-ideal magnet and mechanical tolerance drift.

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9.2.3. High-Temperature Extension Performances

When the MLX90422 is exposed to high-temperatures within the range [160, 180] °C and the supply voltage remains in the range [4.5, 5.5] V, the following magnetic performances apply.

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
XY - Intrinsic Linearity Error	L_{E_XY}	-1.2		1.2	Deg.	
XZ - Intrinsic Linearity Error	L_{E_XZ}	-2.5		2.5	Deg.	
YZ - Intrinsic Linearity Error	L_{E_YZ}	-2.5		2.5	Deg.	
Noise (17)			0.20 0.40 0.80 0.20	0.30 0.55 1.0 0.30	Deg.	Filter = 0, B_{Norm} ≥ 40mT Filter = 0, B_{Norm} ≥ 20mT Filter = 0, B_{Norm} ≥ 10mT Filter = 2, B_{Norm} ≥ 20mT
XY - Total Drift (18)	$\partial\theta_{TT_XY}$	-1.0		1.0	Deg.	Relative to 35°C, B_{Norm} ≥ 10mT
		-0.75		0.75	Deg.	Relative to 35°C, B_{Norm} ≥ 20mT
XZ - Total Drift (18)	$\partial\theta_{TT_XZ}$	-1.2		1.2	Deg.	Relative to 35°C, B_{Norm} ≥ 10mT
	$\partial\theta_{TT_XZ}$	-1.0		1.0	Deg.	Relative to 35°C, B_{Norm} ≥ 20mT
YZ - Total Drift (18)	$\partial\theta_{TT_YZ}$	-1.2		1.2	Deg.	Relative to 35°C, B_{Norm} ≥ 10mT
	$\partial\theta_{TT_YZ}$	-1.0		1.0	Deg.	Relative to 35°C, B_{Norm} ≥ 20mT
Hysteresis				0.2	Deg.	B_{Norm} ≥ 10mT

Table 21 - High-Temperature Magnetic Performances

10. Memory Specifications

Parameter	Symbol	Value	Unit	Note
ROM	ROM_{size}	16	kB	1-bit parity check per 32-bit word (single error detection)
RAM	RAM_{size}	512	B	1-bit parity check per 16-bit word (single error detection)
NVRAM	$NVRAM_{size}$	128	B	6-bit ECC per word 16b (single error correction, double error detection)

Table 22 - Memory specifications

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11. Output Protocol Description

11.1. Single Edge Nibble Transmission (SENT) SAE J2716

The MLX90422 provides a digital output signal compliant with SAE J2716 Revised APR2016.

11.1.1. Sensor Message Definition

The MLX90422 repeatedly transmits a sequence of pulses, corresponding to a sequence of nibbles (4 bits), with the following sequence:

- Calibration/Synchronization pulse period 56 clock ticks to determine the time base of the SENT frame
- One 4-bit Status and Serial Communication nibble pulse
- A sequence six 4-bit data nibbles pulses representing the values of the signal(s) to be transmitted. The number of nibbles will be fixed for each application of the encoding scheme (i.e. Single Secure sensor format A.3, Throttle position sensor A.1)
- One 4-bit Checksum nibble pulse
- One optional pause pulse

See also SAE J2716 APR2016 for general SENT specification.

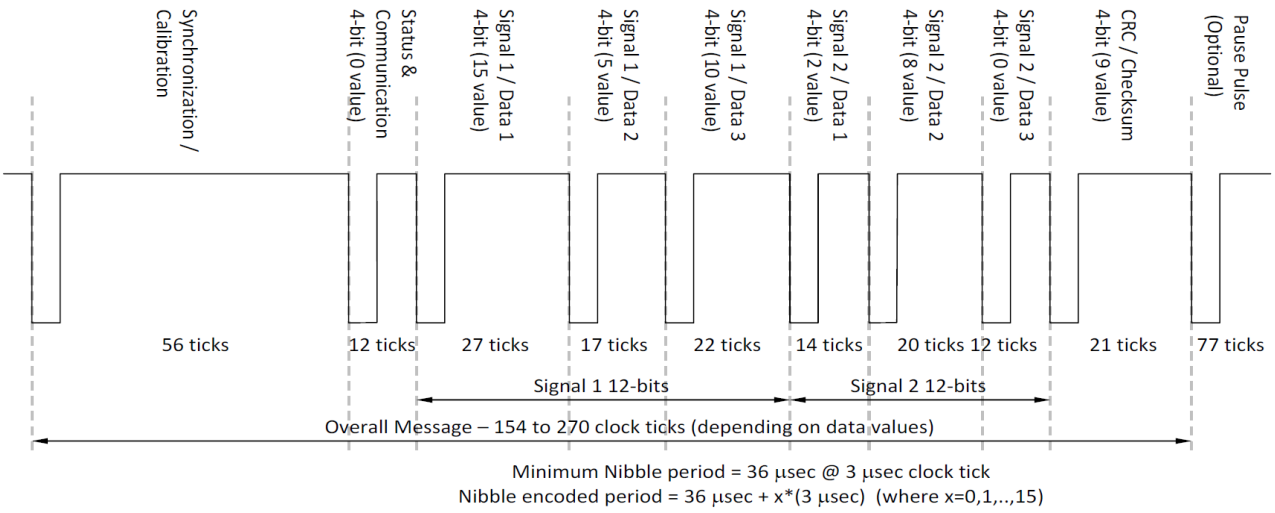


Figure 10 - SENT message encoding example for two 12-bit signals

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11.1.2. Sensor Message Frame Contents

The SENT output of the MLX90422 transmits a sequence of data nibbles, according to the following configurations:

Description	Symbol	Min	Typ.	Max	Unit	Description
Clock tick time	Tick Time		3		µs	Normal SENT, 3µs tick time
Number of data nibbles	Xdn		6			
Frame duration w/o pause	Npp	154		270	ticks	6 data nibbles
Frame duration w/ pause	Ppc	287	287	922	ticks	6 data nibbles
Sensor type			A.1 A.3			Dual Throttle Position sensor Single Secure sensor

Table 23 - SENT protocol frame definition

11.1.3. SENT Format Option

The default SENT format option of MLX90422 is Single Secure Sensor A.3 (H.4). The MLX90422 SENT transmits a sequence of data nibbles; according single secure sensor format defined in SAE J2716 appendix H.4 [19]. The frame contains 12-bit angular value, an 8-bit rolling counter and an inverted copy of the most significant nibble of angular value.

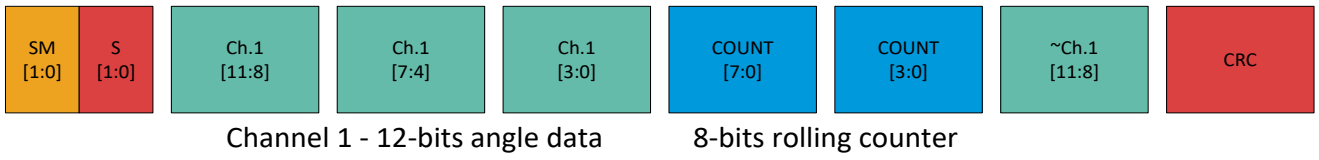


Figure 11 - H.4 frame format

Optionally, the SENT format option of MLX90422 can be changed to Dual Throttle Position Sensor A.1 (H.1). The MLX90422 SENT transmits a sequence of data nibbles; according single secure sensor format defined in SAE J2716 appendix H.1 [20]. The frame contains 12-bit magnetic measurement value and a configurable 12-bit data which can contain either the internal sensor temperature or an inverted value of the magnetic measurement.

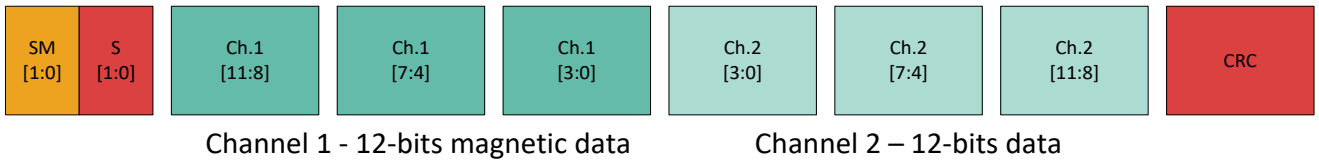


Figure 12 - H.1 frame format

[19] *As referenced from section A.3 Single Secure Sensor of the standard.*

[20] *As referenced from section A.1 Single Secure Sensor of the standard.*

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11.1.4. Start-up Behavior

The circuit will send initialisation frames once digital start-up is done but angle measurement initialisation sequence is not yet complete (see section 7.2.1). These initialisation frames content can be chosen by user with SENT_INT_GM parameter.

SENT_INIT_GM	Initialisation frame value	Comments
0	0x000	SAE compliant, default
1	0xFFF	OEM requirement

Table 24 - Initialization frame content definition

11.1.5. Output Configuration

The output resistive load, e.g. the external pull-up resistor should be carefully selected, because the MLX90422 has a built-in high order low pass filter. A large resistive load will deteriorate the generated SENT signal, and could make the output signal not comply to the SENT specifications, such as the fall times and the minimum output voltages. In principle, the values in Table 13 should be considered, which means it is not recommended to have a resistive load value smaller than 10kΩ, and a resistive load value smaller than 3kΩ should be avoided.

Furthermore, the output capacitance should also be properly chosen, together with the output resistive load to correspondingly match the application, e.g. tick time, to allow appropriate time constant for the transmission of the SENT signal. Details can be seen in sections 15.1 and 15.2.

11.1.6. Enhanced Serial Message (ESM) channel

Serial data is transmitted sequentially in bit number 3 and 2 of the status and communication nibble. A serial message frame stretches over 18 consecutive SENT data messages from the transmitter. All 18 frames must be successfully received (no errors, calibration pulse variation, data nibble CRC error, etc.) for the serial value to be received.

Enhanced serial message with 12-bit data and 8-bit message ID is used (SAE J2716 APR2016 5.2.4.2, Figure 5.2.4.2-2). According to the standard, SM[0] contains a 6-bit CRC followed by a 12-bit data. Message content is defined by a 8-bit message ID transmitted in the SM[1] channel. Correspondence between ID and message content is defined in the tables below (Table 25).

By default, the short sequence consisting of a cycle of 24 data is transmitted. An extended sequence can optionally be used leading to a cycle with 32 data being transmitted.

Additionally, the norm of the B field detected by the sensor can optionally be returned at the end of the sequence (short or extended).

#	8-bit ID	Item	Source data
		Short Sequence	
1	0x01	Diagnostic error code	Current status code from RAM
2	0x06	SENT standard revision	0x004 from ROM
3	0x01	Diagnostic error code	Current status code from RAM
4	0x05	Manufacturer code	0x006 from ROM
5	0x01	Diagnostic error code	Current status code from RAM
6	0x03	Channel 1 / 2 Sensor type	0x050 from ROM

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#	8-bit ID	Item	Source data
7	0x01	Diagnostic error code	Current status code from RAM
8	0x07	Fast channel 1: X1	SENT_CHANNEL_X1 from NVRAM
9	0x01	Diagnostic error code	Current status code from RAM
10	0x08	Fast channel 1: X2	SENT_CHANNEL_X2 from NVRAM
11	0x01	Diagnostic error code	Current status code from RAM
12	0x09	Fast channel 1: Y1	SENT_CHANNEL_Y1 from NVRAM
13	0x01	Diagnostic error code	Current status code from RAM
14	0x0A	Fast channel 1: Y2	SENT_CHANNEL_Y2 from NVRAM
15	0x01	Diagnostic error code	Current status code from RAM
16	0x23	(Internal) temperature	Current temperature from RAM
17	0x01	Diagnostic error code	Current status code from RAM
18	0x29	Sensor ID #1	SENT_SENSOR_ID1 from NVRAM
19	0x01	Diagnostic error code	Current status code from RAM
20	0x2A	Sensor ID #2	SENT_SENSOR_ID2 from NVRAM
21	0x01	Diagnostic error code	Current status code from RAM
22	0x2B	Sensor ID #3	SENT_SENSOR_ID3 from NVRAM
23	0x01	Diagnostic error code	Current status code from RAM
24	0x2C	Sensor ID #4	SENT_SENSOR_ID4 from NVRAM
Extended Sequence			
25	0x01	Diagnostic error code	Current status code from RAM
26	0x90	OEM Code #1	SENT_OEM_CODE1 from NVRAM
27	0x01	Diagnostic error code	Current status code from RAM
28	0x91	OEM Code #2	SENT_OEM_CODE2 from NVRAM
29	0x01	Diagnostic error code	Current status code from RAM
30	0x92	OEM Code #3	SENT_OEM_CODE3 from NVRAM
31	0x01	Diagnostic error code	Current status code from RAM
32	0x93	OEM Code #4	SENT_OEM_CODE4 from NVRAM
Field Norm Extension			
25 or 33	0x01	Diagnostic error code	Current status code from RAM
26 or 35	0x80	Magnetic field Norm	Field Strength corrected from RAM

Table 25 - SENT slow channel data sequence

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11.1.7. Enhanced Serial Message Error Code

The list of error and status messages transmitted in the 12-bit Serial Message data field when Serial Message 8-bit ID is 0x01, is given in the Table 26. The error is one-hot encoded and therefore each bit is linked to one or several diagnostics. Only the first error detected during a diagnostics cycle is reported, and the serial message error code will be updated at every diagnostics cycle. The serial message error code will only be cleared out once all the errors have disappeared. This mechanism ensures only one error at a time takes control of the error debouncing counter (see 13.5.2).

The MSB acts either as an error flag or can be kept high regardless of the error status. See section 13.5.6.

Bit Nb	12 Bit Data (hex)	Diagnostic	Comments
-	0x000 / 0x800	No error	Programmable (See section 13.5.6)
0	0x801	GAINOOS	Magnetic Signal Conditioning Gain Clamping
1	0x802	FieldTooLow	Fieldstrength is below defined low threshold (see section 13.5.3)
2	0x804	FieldTooHigh	Fieldstrength is above defined high threshold (see section 13.5.3)
3	0x808	ADCclip	ADC is saturated, either low or high
4	0x810	ADC_test	ADC made wrong conversion
5	0x820	Analog Supply Monitors	Detects VDDA (VDEC) over and under voltage or VDD under voltage
6	0x840	Digital Supply Monitors	Detects VDDD (1.8V internal digital supply) overvoltage
7	0x880	RoughOffset	Hall Element offset monitor
8	0x900	Over/Under Temp / ADCdrop	Temperature sensor monitor (see 13.5.3) / ADC conversion interruption
9	0xA00	DSP overflow / HE_Bias / Analog Front End	DSP overflow / Hall Element biasing issue / Analog front end self-test
10	0xC00	Supply Bias Current / Stress Range	Current biasing system monitor / Stress Sensor Readout
11	0x800	Extra Error Flag	set to one if any error present (only when SENT_DIAG_STRICT = 1). Otherwise, always high.

Table 26 - SENT serial message error code for enhanced serial message

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12. End-User Programmable Items

Parameter	PSF value	Description	Default Values	# bits
GENERAL CONFIGURATION				
USER_ID[0:5]	94 .. 101	Reserve for end-user to program information to keep traceability, unless the patch area is used.	-	8
WARM_TRIGGER_LONG	120	Add delay for PTC entry level	0	1
MUPET_ADDRESS	124	PTC address for which the slave will communicate	0/1	2
SENSOR FRONT-END				
GAINMIN	2	Virtual Gain min	0	6
GAINMAX	3	Virtual Gain max	47	7
GAINSATURATION	4	Gain saturation enable	0	1
SENSING_MODE	22	0: X-Y Angular Rotary 1: Y-Z Angular Rotary / Y Linear Position 2: X-Z Angular Rotary / X Linear Position 3: Do not use	0	2
FILTERING				
FILTER	23	FIR filter bandwidth selection 0: no filter 1: FIR11 (default) 2: FIR1111 3: Do not use	1	2
LINEAR TRANSFER CHARACTERISTIC				
4POINTS	17	Enable 4 points linearization	0	1
CLAMPHIGH	21	High clamping value of angle output data	4088	12
CLAMPLOW	15	Low clamping value of angle output data	1	12
CW	16	Magnet rotation direction.	0	1
DP	10	DSP discontinuity point	0	13
LNRS0	24	4-pts - Slope coefficient before reference point A	-	16
LNRAX LNRBX LNRCX LNRDX	27 37 48 60	4-pts - X Coordinate for reference points A,B,C,D	-	16
LNRAY LNRBY LNRCY LNRDY	32 43 55 67	4-pts - Y Coordinate for reference points A,B,C,D	-	16

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Parameter	PSF value	Description	Default Values	# bits
LNRAS LNRBS LNRCS LNRDS	34 45 57 69	4-pts - Slope coefficient for reference points A,B,C,D	-	16
LNRY0 LNRY1 LNRY2 LNRY3 LNRY4 LNRY5 LNRY6 LNRY7 LNRY8 LNRY9 LNRY10 LNRY11 LNRY12 LNRY13 LNRY14 LNRY15 LNRY16	26 28 33 36 39 44 47 50 56 59 62 68 71 74 77 80 83	17-pts / 16 segments - Y coordinate point [0:16]	1 256 512 767 1023 1278 1534 1789 2045 2300 2555 2811 3066 3322 3577 3833 4089	12
OUTSLOPE_COLD	85	Slope coefficient at cold of the programmable temperature-dependent offset.	0	8
OUTSLOPE_HOT	86	Slope coefficient at hot of the programmable temperature-dependent offset.	0	8
T_SYNC_DELAY	8	SENT - ADC synchronization delay (SENT with PAUSE only)	130	8
TWO_ANGLES_FRAME	127	Enable 2 fields measure per output frame (SENT with PAUSE only)	1	1
USEROPTION_SCALING	18	Enable output scaling 2x after linearization	0	1
WORK_RANGE	128	Working Range 17 points.	0	4
WORK_RANGE_GAIN	7	Post DSP Gain Stage.	16	8
		DIAGNOSTICS		
COLD_SAFE_STARTUP_EN	52	Normal (0) or safe start-up (1) after power-on reset	0	1
DIAG_EN	42	Diagnostics global enable. **Do not modify!**	1	1
DIAG_FIELDTOOHIGHTHRES	132	Field strength limit over which a fault is reported.	14	4
DIAG_FIELDTOOLOWTHRES	133	Field strength limit under which a fault is reported.	3	4

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Parameter	PSF value	Description	Default Values	# bits
DIAGDEBOUNCE_STEPDOWN	30	Diagnostic debouncing step-down time used for recovery time setting	1	2
DIAGDEBOUNCE_STEPUP	31	Diagnostic debouncing step-up time used for hold time setting	1	2
DIAGDEBOUNCE_THRESH	41	Diagnostic debouncing threshold	1	3
MEMLOCK	54	Enable NVRAM write protection	0	2
OUT_DIAG_HIZ_TIME	118	Recovery time when a transient digital fault is detected	15	5
ROUT_LOW	119	Select output impedance for PTC communication	1	1
SENT_DIAG_STRICT	11	Option of analog fault reporting in the SENT slow message	0	1
SENT_REPORT_MODE_ANA	125	Defines the error message within SENT frame in diagnostic mode Refer to the Safety Manual	0	2
OUTPUT CONFIGURATION				
NIBBLE_PULSE_CONFIG	12	Sets the SENT nibble high/low-time configuration: 0: 7 fixed ticks high time 1: 5 fixed ticks low time	1	1
PROTOCOL	121	Selection of the measurement timing mode and the corresponding output protocol 0: continuous asynchronous angle acquisition, SENT without PAUSE 1: continuous synchronous angle acquisition, SENT with PAUSE	1	1
T_FRAME	88	SENT period in ticks of 3us	287	12
SENT PROTOCOL OPTIONS				
SENT_FAST_CHANNEL_2	66	Definition of data transmitted in the SENT fast channel 2 in case SENT_FC_FORMAT=0 0: Temperature sensor (SP ID 0x23) 1: 0xFF9(d4089) - CH1 2: RAM data (RAMPROBE_PTR) 3: 0xFFF(d4095) - CH1	3	2
SENT_FC_FORMAT	90	SENT frame format option 0: Format H.1 (A.1, Two 12-bit Fast Channels) 1: Format H.4 (A.3, 12-bit Fast Channel & Single secure)	1	1

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Parameter	PSF value	Description	Default Values	# bits
SENT_INIT_GM	65	Initialization frame definition until first valid data 0: 0x000 1: 0xFFF(d4095) error code	0	1
SENT_LEGACY_CRC	64	Enable legacy CRC calculation 0: The SAE J2716 recommended CRC is calculated	0	1
SERIAL_CONFIG	91	Serial Message configuration 0: Serial Message is disabled 1: Serial Message is enabled	1	1
SENT_SLOW_EXTENDED	126	Serial Message Sequence definition 0: Short Sequence Serial Message 1: Extended Sequence Serial Message	0	1
SENT_SLOW_EXTENSION	129	Extended sequence configuration 0: without field norm extension 1: with field norm extension	1	1
SENT_CHANNEL_X1	103	Part of ESM: Fast-channel 1 - X1	0	12
SENT_CHANNEL_X2	104	Part of ESM: Fast-channel 1 - X2	0	12
SENT_CHANNEL_Y1	106	Part of ESM: Fast-channel 1 - Y1	0	12
SENT_CHANNEL_Y2	108	Part of ESM: Fast-channel 1 - Y2	0	12
SENT_OEM_CODE1 SENT_OEM_CODE2 SENT_OEM_CODE3 SENT_OEM_CODE4	73 75 78 81	Part of ESM: OEM code [1:4] (only if 4POINTS = 1)	-	12
SENT_SENSOR_ID1 SENT_SENSOR_ID2 SENT_SENSOR_ID3 SENT_SENSOR_ID4	110 111 113 115	Part of SSM/ESM: Sensor ID-[1:4]	-	12

Table 27 - MLX90422 end-user programmable items table

Performances described in this document are only achieved by adequate programming of the device. To ensure desired functionality, Melexis recommends to follow its programming guide and to contact its technical or application service.

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13. Description of End-User Programmable Items

13.1. SENT Output Mode Options

The parameter PROTOCOL defined the measurement timings mode and the corresponding output protocol.

PROTOCOL	Description
0	Continuous asynchronous angle acquisition, SENT without pause
1	Continuous synchronous angle acquisition, SENT with pause

Table 28 - MLX90422 protocol selection

When using the SENT with pause protocol, the parameter T_FRAME can be used to control the SENT frame period. By default, the period is 287 ticks. While this parameter is encoded on 12 bits, it is recommended that its value fits within the range specified in section 11.1.

The frame format, and therefore the data available through the fast channels, is selected using the SENT_FC_FORMAT parameter. Refer to section 11.1.3 for a description of these SENT frame format.

SENT_FC_FORMAT	Description
0	Dual Throttle Position Sensor A.1 (H.1)
1	Single Secure Sensor A.3 (H.4), default

Table 29 - MLX90422 frame format selection

When using the H.1 format, the parameter SENT_FAST_CHANNEL_2 can be used to control what data will be output on the 2nd fast channel

SENT_FAST_CHANNEL_2	Description
0	Internal temperature sensor (SP ID 0x23)
1	0xFF9(d4089) - CH1
2	RAM data (RAMPROBE_PTR)
3	0xFFF(d4095) - CH1

Table 30 - MLX90422 fast channel 2 data selection

The SENT protocol allows to either fix the number of ticks for the high time of fix the number of ticks for the low time in the SENT nibble pulses. This can be done using NIBBLE_PULSE_CONFIG parameter.

NIBBLE_PULSE_CONFIG	Description
0	Fixed high time (7 ticks)
1	Fixed low time (5 ticks), default

Table 31 - MLX90422 nibble pulses configuration

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The enhanced serial message channel can be enabled or disabled using the SERIAL_CONFIG parameter.

SERIAL_CONFIG	Description
0	Serial Message is disabled
1	Serial Message is enabled, default

Table 32 - MLX90422 enhanced serial message configuration

When the enhanced serial message is enabled, it is possible to control whether the short sequence of the extended sequence is used (see section 11.1.6) using the SENT_SLOW_EXTENDED parameter

SENT_SLOW_EXTENDED	Description
0	Short Sequence Serial Message, default
1	Extended Sequence Serial Message

Table 33 - MLX90422 serial sequence message definition

Furthermore, when the extended sequence is enabled, it is possible to configure whether or not the field norm extension is used (see section 11.1.6) using the SENT_SLOW_EXTENSION parameter

SENT_SLOW_EXTENSION	Description
0	without field norm extension
1	with field norm extension, default

Table 34 - MLX90422 extended sequence definition

13.2. Output Transfer Characteristic

There are 2 different possibilities to define the transfer function (LNR) as specified in Table 35.

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

Output Transfer Characteristic	4POINTS
4 Arbitrary Points	1
17 Equidistant Points	0

Table 35 - Output transfer characteristic selection table

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13.2.1. Clockwise Parameter

The CW parameter defines the magnet rotation direction.

Rotation Direction	CW
Clockwise	1
Counter Clockwise	0

Table 36 - Magnet rotation selection table

Counter clockwise is the defined by

- the 1-4-5-8 pin order direction for the SOIC-8 package
- the 1-8-9-16 pin order direction for the TSSOP-16 package
- the 1-2-3-4 pin order direction for the DMP-4 package
- the 1-2-3 pin order direction for the SMP-3 package
- the 1-2-3-4 pin order direction for the SMP-4 package

Clockwise if defined by the reverse pin order. Refer to the package drawings in chapter 18.

13.2.2. Discontinuity Point (or Zero Degree Point)

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

$$\text{New Angle} = \text{Angle} - \text{DP}$$

The DP parameter is encoded using a 13-bit two's complement signed format. The new angle and the input angle are expressed in LSB12.

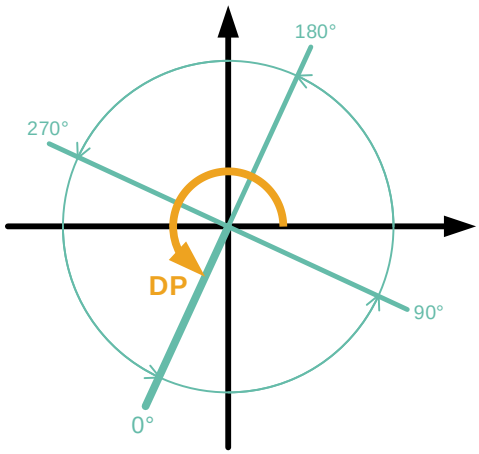


Figure 13 - Discontinuity point positioning (for CW=0)

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13.2.3. 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 MLX90422 four points transfer function from the digital angle value to the digital output is described in the following figure (Figure 14). Seven segments can be programmed but the clamping levels are necessarily flat.

Two, three, or even six calibration points are then available, reducing the overall non-linearity of the IC by almost an order of magnitude each time. Three or six calibration point will be preferred by customers looking for excellent non-linearity figures. Two-point calibrations will be preferred by customers looking for a cheaper calibration set-up and shorter calibration time.

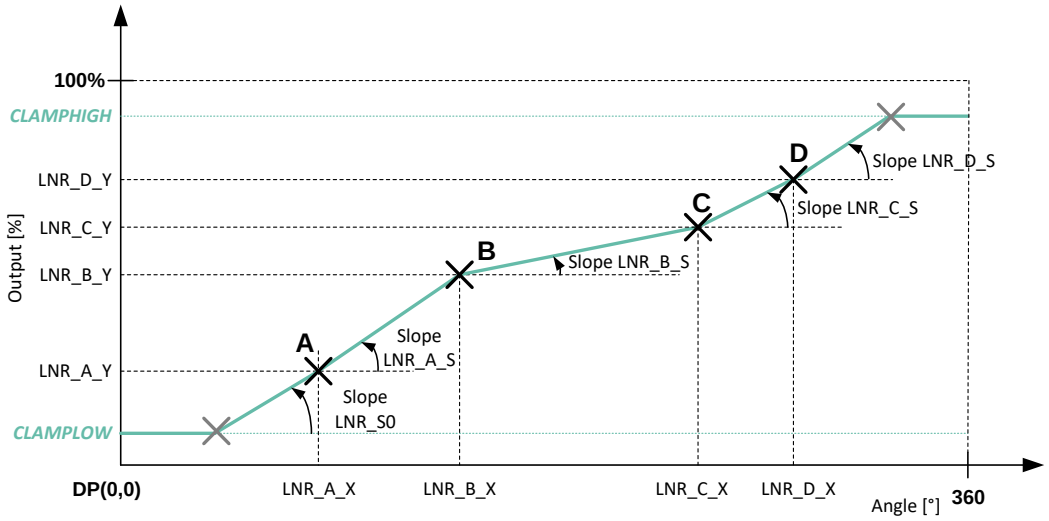


Figure 14 - 4pts linearization parameters description

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13.2.4. 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 MLX90422 seventeen points transfer function from the digital angle value to the output voltage is described in the Figure 15.

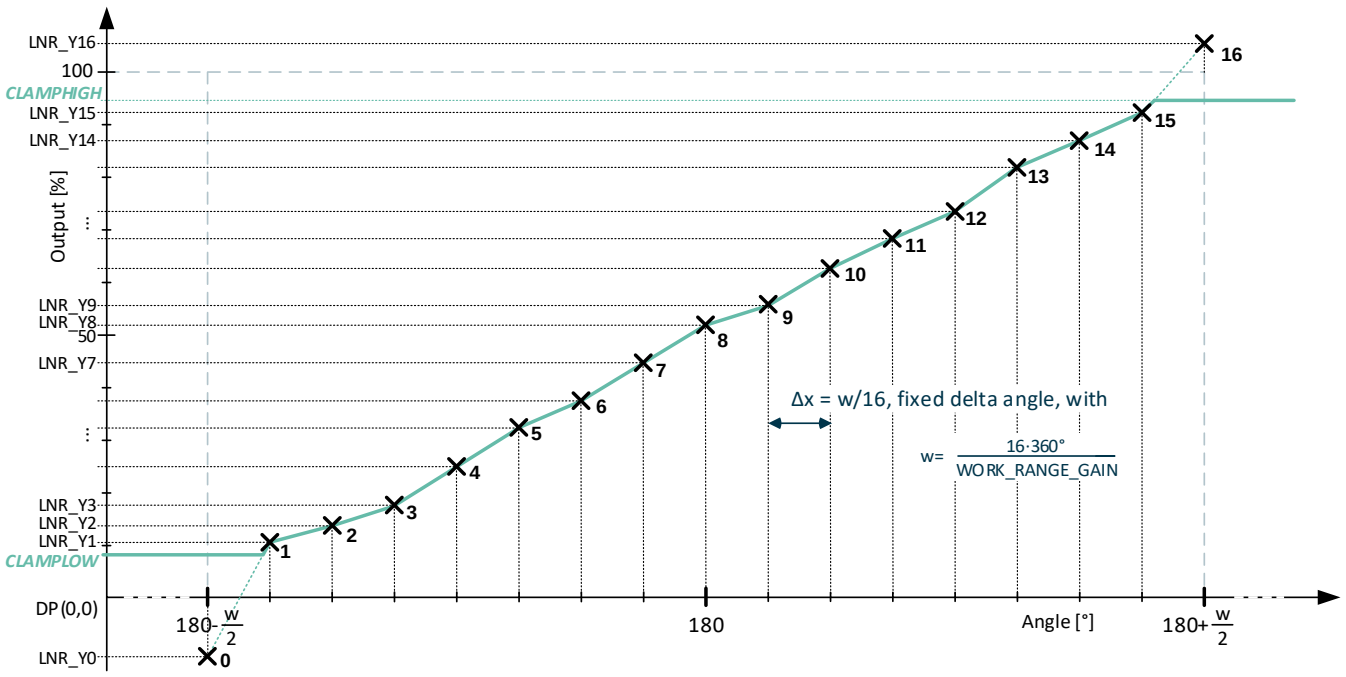


Figure 15 - 17pts linearization parameters description

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 linearly interpolated.

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13.2.5. WORK_RANGE Parameter for Angle Range Selection

The parameter WORK_RANGE determines the input range on which the 16 segments are uniformly spread. This parameter is provided for compatibility with former versions of Melexis Triaxis® sensors.

For full featured working range selection, see section 13.2.6. For WORK_RANGE parameter, following table applies.

WORK_RANGE	Range	Δx 17pts	WORK_RANGE	Range	Δx 17pts
0	360.0°	22.5°	8	180.0°	11.3°
1	320.0°	20.0°	9	144.0°	9.0°
2	288.0°	18.0°	10	120.0°	7.5°
3	261.8°	16.4°	11	102.9°	6.4°
4	240.0°	15.0°	12	90.0°	5.6°
5	221.5°	13.8°	13	80.0°	5.0°
6	205.7°	12.9°	14	72.0°	4.5°
7	192.0°	12.0°	15	65.5°	4.1°

Table 37 - Work range for 360° periodicity

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

13.2.6. WORK_RANGE_GAIN Parameter for Angle Range Selection

Alternatively, the range for the angle can be selected using the WORK_RANGE_GAIN parameter, which applies a fixed gain to the transfer characteristics. WORK_RANGE_GAIN is coded on 8 bits where the 4 MSB define the integer part and the 4 LSB the fractional part (in power of twos). Therefore, the following equation applies to define the angle range *w*:

$$w = \frac{16 * 360}{WORK_RANGE_GAIN}$$

Both minimal and maximal angles are then defined by:

$$\theta_{min} = \frac{360 - w}{2} \; ; \; \theta_{max} = \frac{360 + w}{2}$$

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

Using WORK_RANGE_GAIN parameter, the anchor point is kept at *180* and the range is symmetrically set around this value. It creates a zoom-in of the angle around this point.

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Following tables give some values as an example:

WORK_RANGE_GAIN	Factor	Range (w)	θmin	θmax	Δx 17pts
0x10	1	360°	0°	360°	22.5°
0x20	2	180°	90°	270°	11.3°
0x40	4	90°	135°	225°	5.6°
0xFF	15.94	22.6°	168.7°	191.3°	1.41°

Table 38 - Working range defined by WORK_RANGE_GAIN parameter

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

13.2.7. Thermal OUTSLOPE Offset Correction

Two parameters, OUTSLOPE_HOT and OUTSLOPE_COLD, are used to add a temperature dependent offset. In the MLX90422, this offset is applied to the angle just before the clamping function.

The offset shift is computed using the device internal linearized temperature as depicted in the figure below (Figure 16).

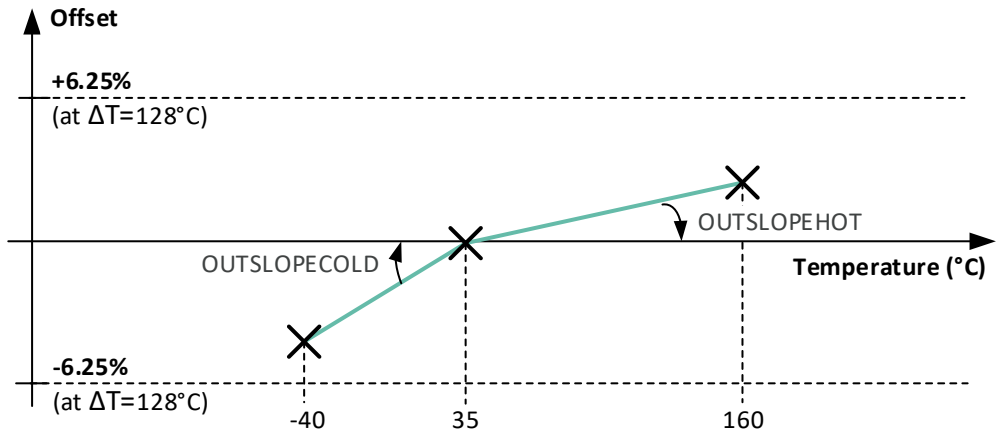


Figure 16 - Temperature compensated offset

The thermal offset can be added or subtracted to the output, before the clamping. The span of this offset is ±6.25% of the full output scale for a temperature difference of 128°C. Two thermal coefficients are defined depending on whether the linearized temperature is below (OUTSLOPE_COLD) or above (OUTSLOPE_HOT) the 35°C anchor point.

If the device internal temperature is higher than 35°C then:

$$\text{Compensated Angle} = \text{Angle} - \Delta T \cdot \frac{\text{OUTSLOPE_HOT}}{64}$$

If the device internal temperature is lower than 35°C then:

$$\text{Compensated Angle} = \text{Angle} - \Delta T \cdot \frac{\text{OUTSLOPE_COLD}}{64}$$

Each of the two thermal coefficients is encoded using an 8-bit two's complement signed format. The thermally compensated angle and the input angle are expressed in LSB12, while the linearized temperature difference ΔT is expressed in °C.

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13.2.8. Clamping Parameters

The clamping levels are two independent values to limit the output voltage range in normal operation. The CLAMPLOW parameter adjusts the minimum output level. The CLAMPHIGH parameter sets the maximum output level. Both parameters have 12 bits of adjustment and are available for all four LNR modes. The values are encoded in fractional code, from 0% to 100%

13.3. Sensor Front-End

Parameter	Value
SENSING_MODE	[0:2]
GAINMIN	[0:47]
GAINMAX [21]	[0:48]
GAINSATURATION	[0:1]

Table 39 - Sensing mode and front-end configuration

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-bit value selects the first (B1) and second (B2) field components according to the Table 40 content.

SENSING_MODE	B1	B2	Motion
0	X	Y	X-Y Angular Rotary
1	Y	Z	Y-Z Angular Rotary / Y Linear Position
2	X	Z	X-Z Angular Rotary / X Linear Position

Table 40 - Sensing mode description

GAINMIN and GAINMAX define the thresholds of the gain monitor diagnostic. Whenever the virtual gain is strictly outside of these limits, the diagnostic reports a fault. When GAINMIN = 0 or GAINMAX > 47, the corresponding fault reporting is disabled.

If GAINSATURATION is set, then the virtual gain is held between GAINMIN and GAINMAX values. The saturation of the gain applies before the diagnostic is checked. Therefore, the gain monitor diagnostic can be considered inactive.

13.4. Filtering

The MLX90422 features 2 low-pass FIR filter modes controlled with FILTER = 1…2. FILTER = 0 corresponds to no filtering. The transfer function is described by:

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

[21] *A value of 48 (0x30) or above disables the diagnostic.*

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This filter characteristic is given in the Table 41.

FILTER	0	1	2
Type	Disable	Finite Impulse Response (FIR)	
Coefficients a_i	1	11	1111
Title	No filter	ExtraLight	Light
DSP cycles (j= nb of taps)	1	2	4
Efficiency RMS (dB)	0	3.0	6.0

Table 41 - FIR filter characteristics

13.5. Programmable Diagnostics Settings

13.5.1. Diagnostics Global Enable

DIAG_EN should be kept to its default value (1) to retain all functional safety abilities of the MLX90422. This feature shall not be disabled.

13.5.2. Diagnostic Debouncer

A debouncing algorithm is available for analog diagnostic reporting. Enabling this debouncer will increase the FHTI of the device. Therefore, Melexis recommends keeping the debouncing of analog faults off, by not modifying below described values. The factory default settings mentioned in chapter 12 should be used.

Parameter	Description
DIAGDEBOUNCE_STEPDOWN	Decrement values for debouncer counter. The counter is decremented once per evaluation cycle when no analog fault is detected.
DIAGDEBOUNCE_STEPUP	Increment value for debouncer counter. The counter is incremented once per evaluation cycle when an analog fault is detected.
DIAGDEBOUNCE_THRESH	Threshold for debouncer counter to enter diagnostic mode. When set to 0, debouncing is off and analog faults are reported immediately after detection.

Table 42 - Diagnostic debouncing parameters

Once an analog monitor detects an error, it takes control of the debouncing counter. This counter will be incremented by DIAGDEBOUNCE_STEPUP value each time this specific monitor is evaluated and the error is still present. When the debouncing counter reaches the value defined by DIAGDEBOUNCE_THRESH, an error is reported on the error channel, and the debouncing counter stays clamped to this DEBOUNCE_THRESH value (see section 13.5.6 for SENT error message codes). Once the error disappears, each time its monitor is evaluated, the debouncing counter is decremented by DIAGDEBOUNCE_STEPDOWN value. When the debouncing counter reaches zero, the error disappears from the reporting channel and the debouncing counter is released. To implement proper reporting times, one should refer to the FHTI, see chapter 14.3. The reporting and recovery time are defined in the table below (valid for DIAGDEBOUNCE_THRESH > 0).

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Parameter	Min	Max
Reporting Time	$DCT \cdot \left(\left\lceil \frac{THRESH}{STEPUP} \right\rceil - 1\right)$	$DCT \cdot \left(\left\lceil \frac{THRESH}{STEPUP} \right\rceil\right)$
Recovery Time	$DCT \cdot \left(\left\lceil \frac{THRESH}{STEPDOWN} \right\rceil\right)$	$DCT \cdot \left(\left\lceil \frac{THRESH}{STEPDOWN} \right\rceil + 1\right)$
	$\left\lceil \frac{x}{y} \right\rceil$	is the ceiling function of x divided by y

Table 43 - Diagnostic reporting and recovery times

13.5.3. Over/Under Temperature Diagnostic

DIAG_TEMP_THR_HIGH defines the threshold for over temperature detection and is compared to the linearized value of the temperature sensor T_{LIN}. DIAG_TEMP_THR_LOW defines the threshold for under temperature detection and is compared to the linearized value of the temperature sensor T_{LIN}.

T_{LIN} is a measurement of the die temperature, not of the ambient temperature. T_{LIN} is encoded using the SENT standard for temperature sensor. One can get a measurement the physical temperature T_{PHY} of the die from T_{LIN} using following formula

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

Unlike T_{LIN}, DIAG_TEMP_THR_LOW and DIAG_TEMP_THR_HIGH are encoded using 8-bit unsigned values. Therefore, a factor of 16 must be considered when comparing either threshold to T_{LIN}.

$$DIAG_TEMP_THR_(LOW/HIGH) = \frac{T_{LIN}}{16}$$

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

Parameter	Symbol	Min	Typ.	Max	Unit	Condition
T_{LIN} resolution	Res_{TLIN}	-	0.125	-	°C	12-bit range
T_{LIN} refresh rate	$F_{S,TLIN}$	-	200	-	Hz	
T_{LIN} linearity error [22]	T_{LinErr}	-8 -2	- -	8 6	°C °C	from -40 to 160°C from 35 to 125°C
Low temperature threshold	DIAG_TEMP_THR_LOW	-	8	-	LSB8	Fixed value, corresponds to -57°C
High temperature threshold	DIAG_TEMP_THR_HIGH	-	136	-	LSB8	Fixed value, corresponds to 199°C
High/low temperature threshold resolution	Res_{Tthr}	-	2	-	°C	8-bit range

Table 44 - Linearized temperature sensor characteristics

[22] The linearity error T_{LinErr} is the maximum deviation of the measured die T_{PHY} compared to the real die temperature T_{die} over a range of temperature. At a specific die temperature, it is computed using $T_{LinErr} = T_{PHY} - T_{die}$

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13.5.4. High-Temperature Extension Over-Temperature Diagnostic

When operating at a junction temperature up to 175°C, the MLX90422 retains all its diagnostic features. There's no risk of false-positive. Above this temperature, the overheating monitor enters its detection range. The default configuration of this monitor reports a typical junction temperature of 199°C. Due to temperature sensor tolerances and noise at high temperatures, Melexis recommends a safety margin greater than 15°C. Consequently, if the sensor operates up to 190°C of junction temperature, Melexis cannot guarantee that the overheating monitor will not report an error and recommends to adapt the overheating monitor threshold to 207°C. This can be done by reprogramming a custom device configuration (patch) shown in Table 14 below. Contact a Melexis representative for further information.

Parameter	Patch Content
PATCH2_ADDRESS	0x3B0F
PATCH2_INSTRUCTION	0x008C

Table 45 - High-temperature extension patch to prevent false-positive on overheating monitor

13.5.5. Field Strength and Field Monitoring Diagnostics

Field Strength is compensated over the circuit operating temperature range and represents a reliable image of the field intensity generated by the magnet.

13.5.6. SENT Mode Diagnostic Reporting

In case of a digital fault, the OUT pin is configured in high-impedance. Conversely, an analog fault is reported by setting the SENT status bit S0 (refer to section 11.1.3).

The parameter SENT_DIAG_STRICT controls the behavior of the MSB in the ESM error code (see bit 11 in Table 26).

SENT_DIAG_STRICT	Description
0	The MSB (in 11 in Table 26) in the ESM error reporting is fixed high, even if no error needs to be reported.
1	The MSB in the ESM error reporting acts as an error reporting flag.

Table 46 - ESM error code MSB behavior selection

This reporting behavior is only valid for the factory default settings, with the exception of the aforementioned parameters in this section. Other reporting behaviors and further information on the safe-states are available in the safety manual of the MLX90422.

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14. Functional Safety

14.1. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90422 component in a safety related item, as a 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:
  - assumptions 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, to be used for the system integration), HW architectural metrics and description of dependent failures initiators.
- The description and the result of the functional safety assessment process; list of confirmation measures and description of the independency level.

14.2. Safety Mechanisms

The MLX90422 provides numerous self-diagnostic features (safety mechanisms). Those features increase the robustness of the IC functionality either by preventing the IC from providing an erroneous output signal or by reporting the failure according to the SENT protocol definition.

Legend
● High coverage
○ Medium coverage
ANA: Analog hardware failure reporting mode, described in the safety manual
High-Z: A special failure reporting mode where the output is set in high-impedance mode (no HW fail-safe mode/timeout, no SW safe startup)
DIG: Digital hardware failure reporting mode, described in the safety manual
At Startup: A HW fault present at time zero is detected before the first frame is transmitted.
DIAG_EN: This safety mechanism can be disabled by setting DIAG_EN = 0 (see chapter 13.5.1). This option should not be used in application mode!

Table 47 - Self diagnostic legend

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Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Support. Func.	Module & Package	Reporting mode	At startup	DIAG EN
Signal-conditioning Diagnostic	●	●	○			●			
Magnetic Signal Conditioning Voltage Test Pattern	●	○	○				ANA	NO	●
Magnetic Signal Conditioning Rough Offset Clipping check	●		○				ANA	NO	●
Magnetic Signal Conditioning Gain Monitor & Clamping	●		○			●	ANA	YES	●
Mag. Sig. Cond. Failure Control by the Chopping Technique	●						n/a	n/a	
ADC Test Pattern		●					ANA	NO	●
ADC Conversion Errors & Overflow Errors		●					ANA	YES	●
ADC Common Mode Monitor		●					n/a	YES	
Flux Monitor (Rotary mode)	●	○				●	ANA	NO	●

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Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Support. Func.	Module & Package	Reporting mode	At startup	DIAG EN
Digital-circuit Diagnostic		●	●		○				
RAM Parity, 1-bit per 16-bit word, ISO D.2.5.2			●				DIG	YES	
ROM Parity, 1-bit per 32-bit word, ISO D.2.5.2			●				DIG	YES	
NVRAM 16-bit signature (run-time) ISO D.2.4.3, by means of SW CRC-CCITT16			●				DIG	NO	
NVRAM Double Error Detection ECC ISO D.2.4.1			●				DIG	YES	
Logical Monitoring of Program Sequence ISO D.2.9.3 via Watchdog "IWD" (CPU clock) ISO D.2.9.2			●		○		DIG	NO	●
Watchdog "AWD" (separate clock) ISO D2.9.1			●		○		DIG	YES	
CPU Errors "Invalid Address", "Wrong opcode"			●		○		DIG	YES	
ADC Interface Checksum		●					DIG	NO	●
ADC Internal Errors		○					DIG	YES	
DSP Test Pattern (atan2)			●		○		DIG	NO	●
Critical Ports Monitoring			●				DIG	NO	●
ADC Data Adder Test - Range Check and Buffer alignment		○					DIG	YES	●
ADC Data Adder Error		○					DIG	YES	
DSP Overflow	○	○	●				ANA	NO	●
SENT Fall Collision detection (SENT pulse generator)			●				DIG	NO	●

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Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Support. Func.	Module & Package	Reporting mode	At startup	DIAG EN
Communication Interface Diagnostic				●					
SENT Protection Against Re-configuration at Run-time				●			DIG	NO	●
SENT Frame Counter & Redundant Nibble				●			n/a	n/a	
System-level Diagnostic					●	●			
Supply Voltage Monitors (all supply domains except VDD_OV & POR)					●	●	ANA	YES	●
External Supply Over-voltage Monitor					●	●	High-Z	YES	
Digital Supply Under-voltage Monitor (Power-on Reset)					●	●	High-Z	YES	
Overheating Monitor	○	○	○	○	○	●	ANA	YES	●
Warning/Reporting Mechanisms									
HW Error Controller			●	●	●		DIG	n/a	
HW Fail-safe mode with timeout			●	●	●		High-Z	n/a	
Analog-type Error management	●	●			●		ANA	n/a	
Safe start-up mode			●		●		DIG	n/a	
Mechanisms executed at start-up only									
RAM March-C HW Test at start-up			●		●		DIG	YES	

Table 48 - MLX90422 list of self-diagnostics with characteristics

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14.3. Fault Handling Time Interval

The Fault handling Time Interval (FHTI) is the time interval between the start of the first frame with invalid position value without notice, and the end of the last frame preceding a fail-safe state of the IC.

The following table provides the worst-case FHTI for both an analog fault and a digital fault in MLX90422.

Case	FHTI	Comment
Analog Fault	DCT_{ANA} + 2 T_{frame}	Refer to section 7.3 for the DCT_{ANA} and T_{frame} values
Digital Fault	DCT_{DIG}	Refer to section 7.3 for the DCT_{DIG} value

Table 49 - Worst-case FHTI

The FHTI values provided here are valid only for the default factory settings. A full list of timings is available in the safety manual of the MLX90422, including cycle times, execution times and reporting times for every implemented safety mechanism.

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15. Recommended Application Diagrams

15.1. Wiring with the MLX90422 in SOIC-8 Package

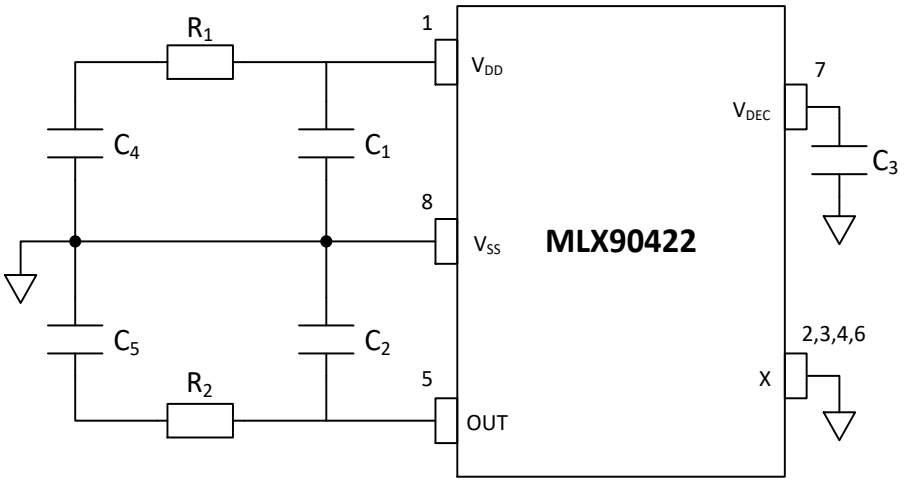


Figure 17 - Recommended wiring for the MLX90422 in SOIC-8 package

Component	Min	Typ.	Max	Remark
C_1	100nF	220 nF	-	
$C_2(C_L)$	1 nF	10 nF	22 nF	
C_3	100nF	100 nF	220 nF	
C_4	-	-	1 nF	Optional, for improved EMC robustness
C_5	-	-	1 nF	
R_1	-	-	10 Ω	
R_2	-	-	-	

Table 50 - Recommended values for the MLX90422 in SOIC-8 Package

For best EMC performance, C_1, C_2 and C_3 with typical values need to be placed as close as possible to the IC. To further improve EMC robustness, a 1nF capacitor can be placed close to the connector (C_4, C_5) and a 10 Ohm resistor added in series with the supply line (R_1).

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15.2. Wiring with the MLX90422 in TSSOP-16 Package

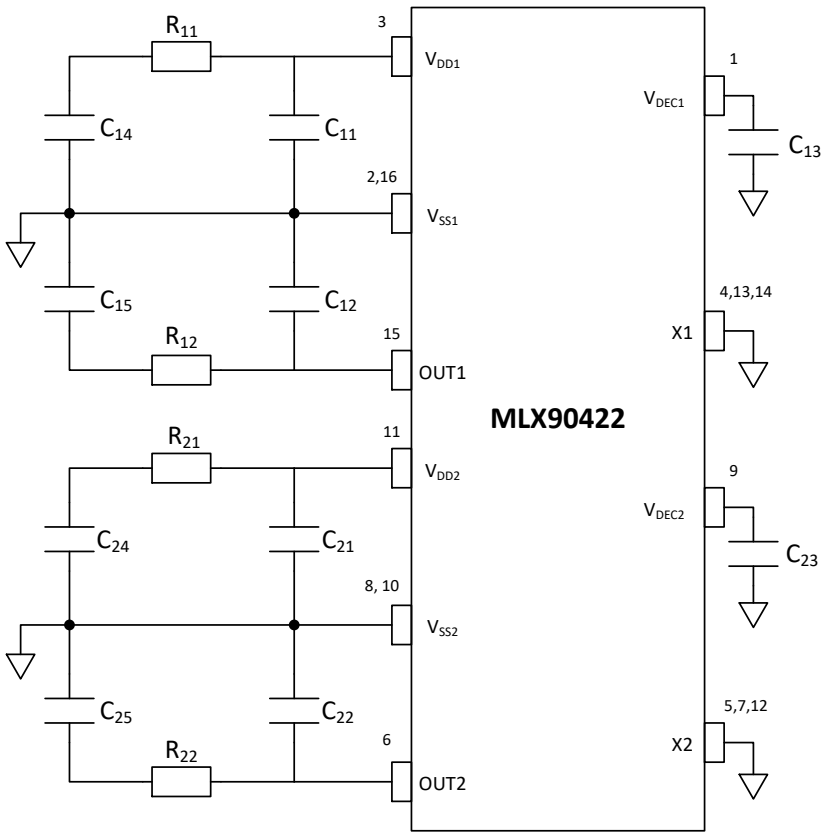


Figure 18 - Recommended wiring for the MLX90422 in TSSOP-16 package (dual die)

Component	Min	Typ.	Max	Remark
C_{x1}	100nF	220 nF	-	
$C_{x2}(C_L)$	1 nF	10 nF	22 nF	
C_{x3}	100nF	100 nF	220 nF	
C_{x4}	-	-	1 nF	Optional, for improved EMC robustness
C_{x5}	-	-	1 nF	
R_{x1}	-	-	10 Ω	
R_{x2}	-	-	-	

Table 51 - Recommended values for the MLX90422 in TSSOP-16 Package

For best EMC performance, C_{x1}, C_{x2} and C_{x3} with typical values need to be placed as close as possible to the IC. To further improve EMC robustness, a 1nF capacitor can be placed close to the connector (C_{x4}, C_{x5}) and a 10 Ohm resistor added in series with the supply line (R_{x1}).

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15.3. Wiring with the MLX90422 in DMP-4 Package (built-in capacitors)

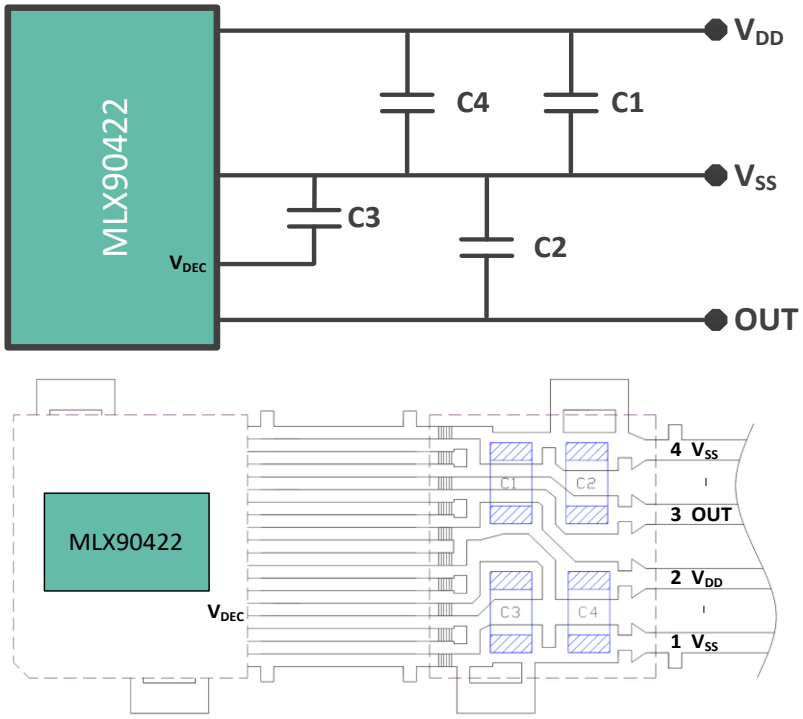


Figure 19 - Internal wiring of the MLX90422 in DMP-4

Component	Value	Remark
C1	220 nF	Supply capacitor
C2	10 nF	Output capacitor
C3	100 nF	Decoupling capacitor
C4	-	Not mounted

Table 52 - DMP-4 capacitors configuration

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15.4. Wiring with the MLX90422 in SMP-3 Package (built-in capacitors)

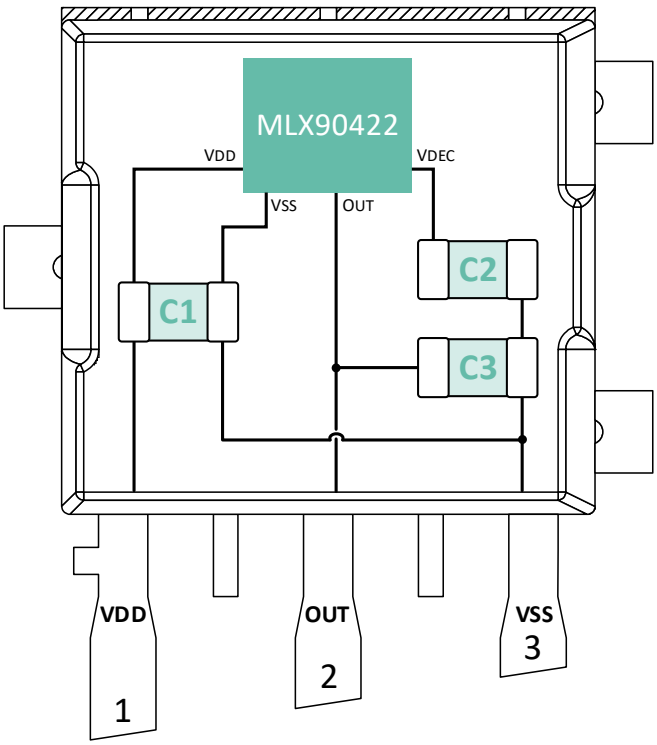


Figure 20 - Internal wiring of the MLX90422 in SMP-3

Component	Value	Remark
C1	220nF	Supply capacitor
C2	100nF	Decoupling capacitor
C3	10nF	Output capacitor

Table 53 - SMP-3 capacitors configuration

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15.5. Wiring with the MLX90422 in SMP-4 Package (built-in capacitors)

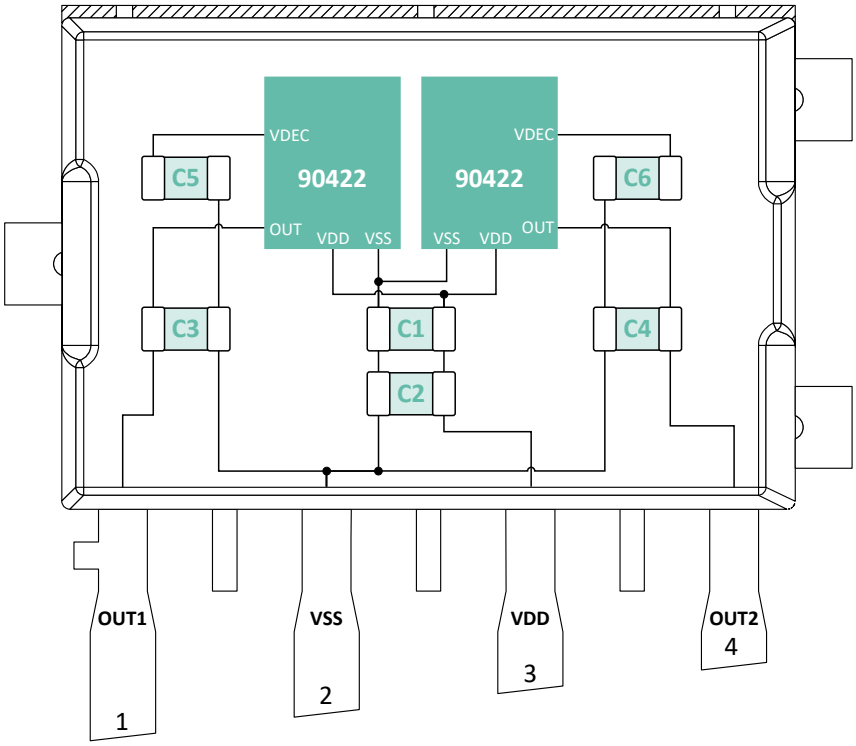


Figure 21 - Internal wiring of the MLX90422 in SMP-4

Component	Value	Remark
C1 C2	220nF	Supply capacitor
C3 C4	10nF	Output capacitor
C5 C6	100nF	Decoupling capacitor

Table 54 - SMP-4 capacitors configuration

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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 & form 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.

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18. Package Information

18.1. SOIC-8 - Package Information

18.1.1. SOIC-8 - Package Dimensions

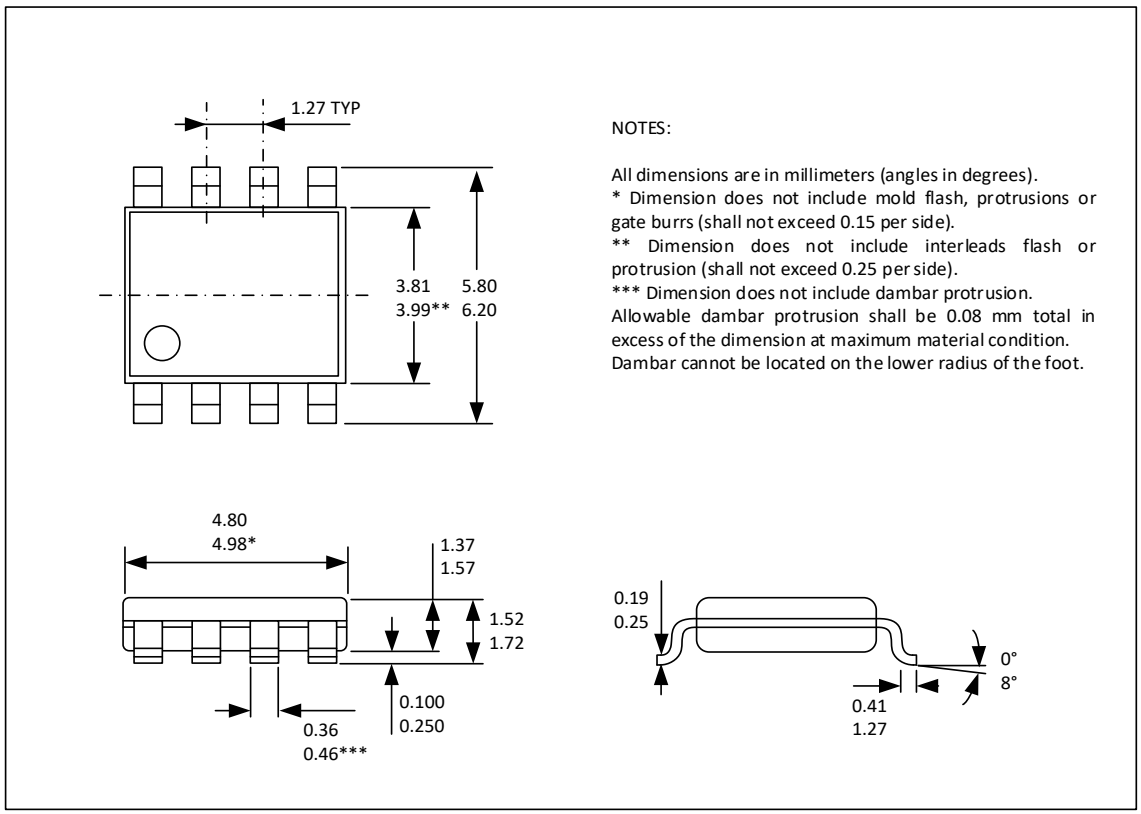


Figure 22 - SOIC-8 package outline drawing

18.1.2. SOIC-8 - Pinout and Marking

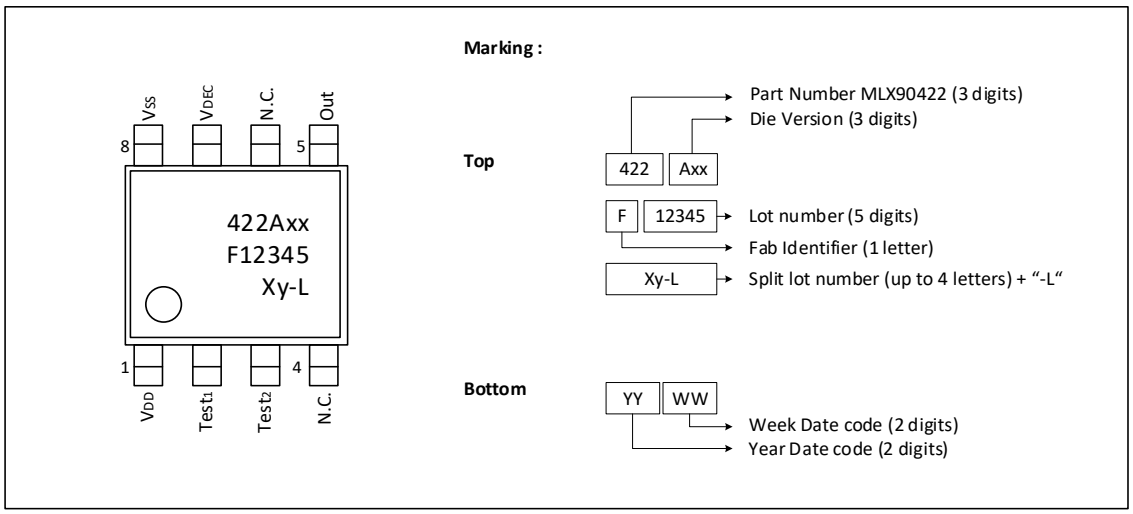


Figure 23 - SOIC-8 pinout and marking

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18.1.3. SOIC-8 - Sensitive Spot Positioning

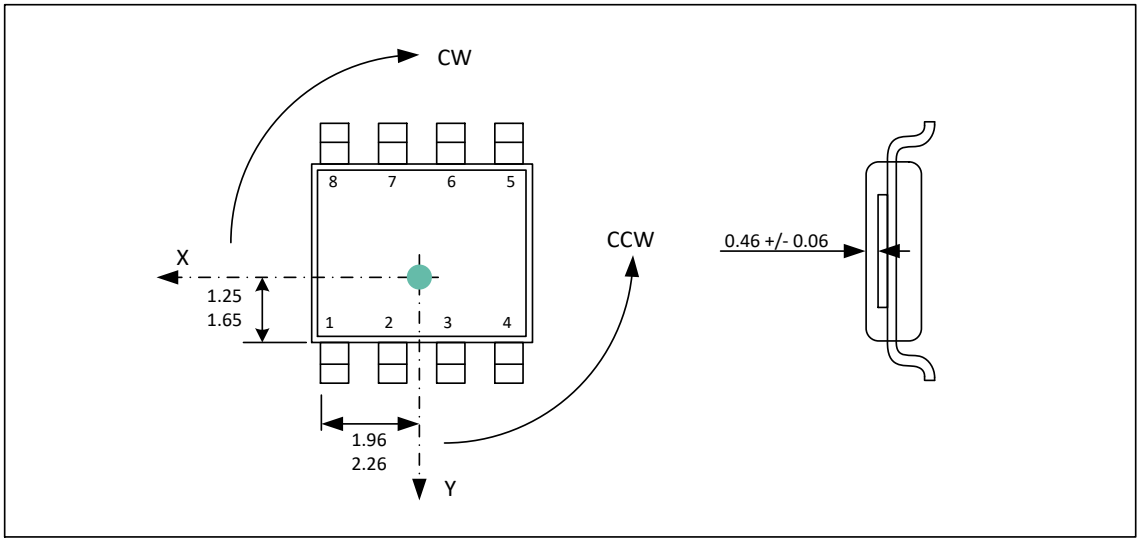


Figure 24 - SOIC-8 sensitive spot position

18.1.4. SOIC-8 - Angle Detection

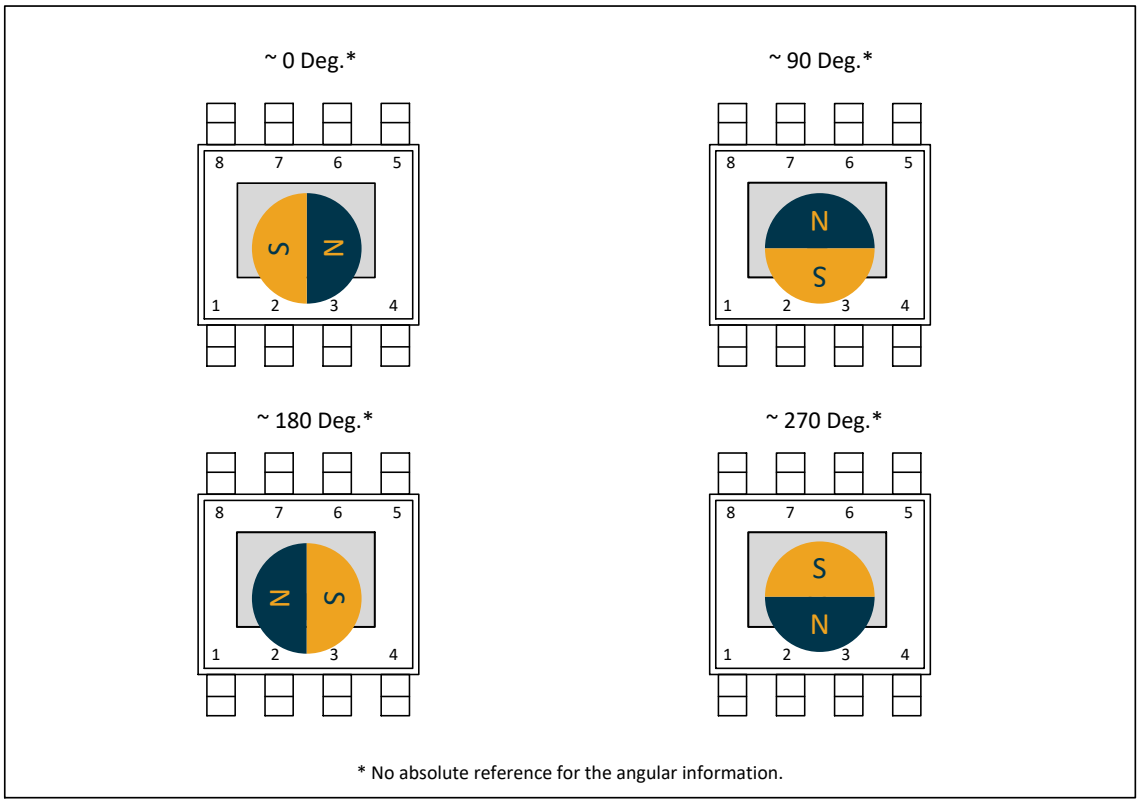


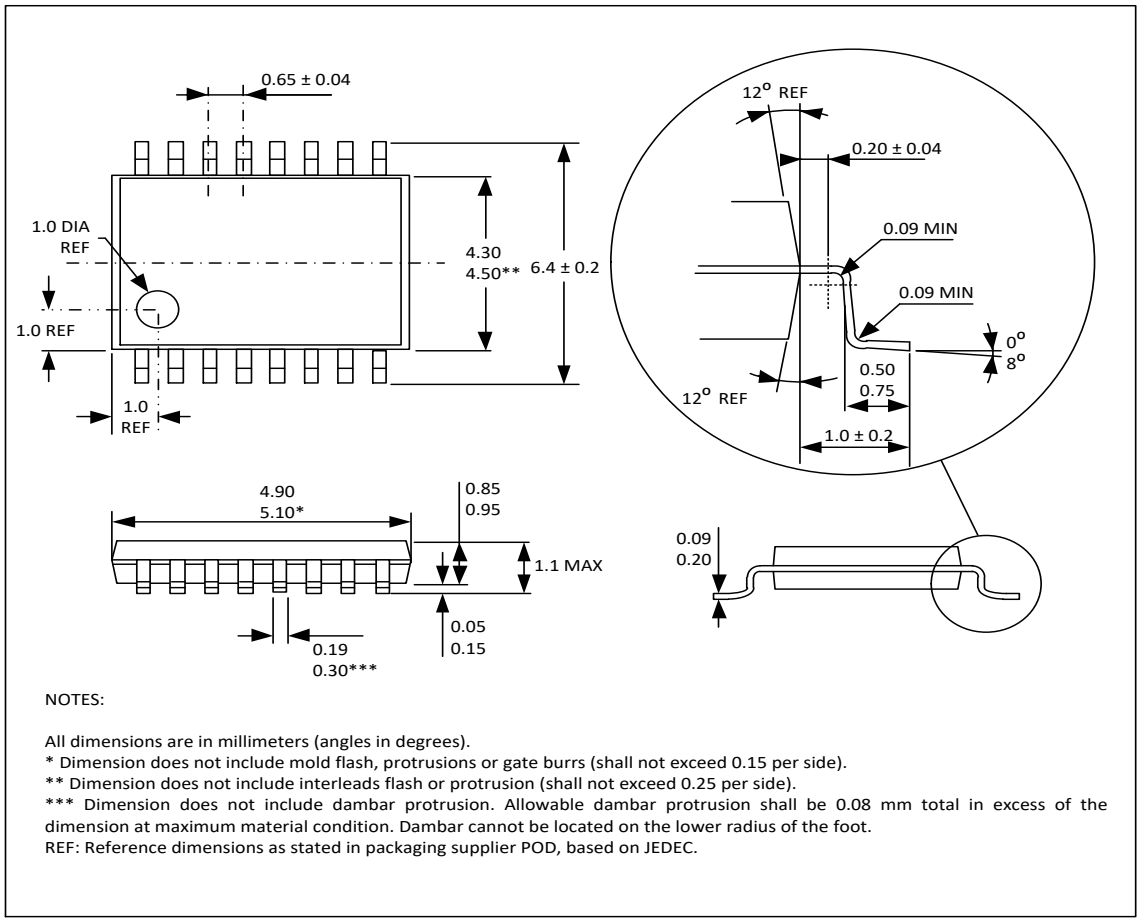
Figure 25 - SOIC-8 angle detection

The MLX90422 is an absolute angular position sensor but the linearity error (See section 9) does not include the error linked to the absolute reference 0 Deg. This reference can be fixed in the application through the discontinuity point.

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18.2. TSSOP-16 - Package Information

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 26 - TSSOP-16 package outline drawing

18.2.2. TSSOP-16 - Pinout and Marking

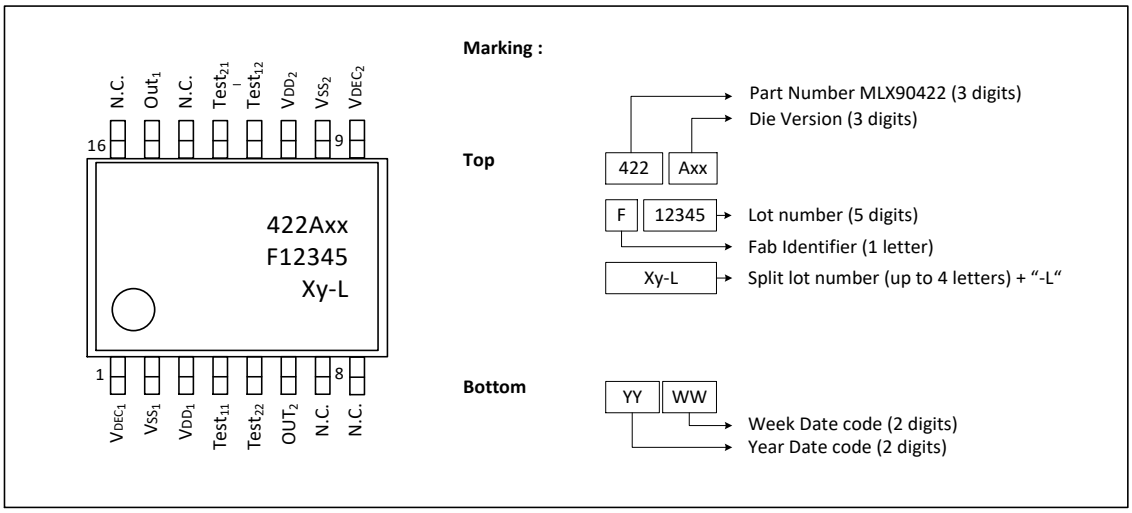


Figure 27 - TSSOP-16 pinout and marking

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18.2.3. TSSOP-16 - Sensitive Spot Positioning

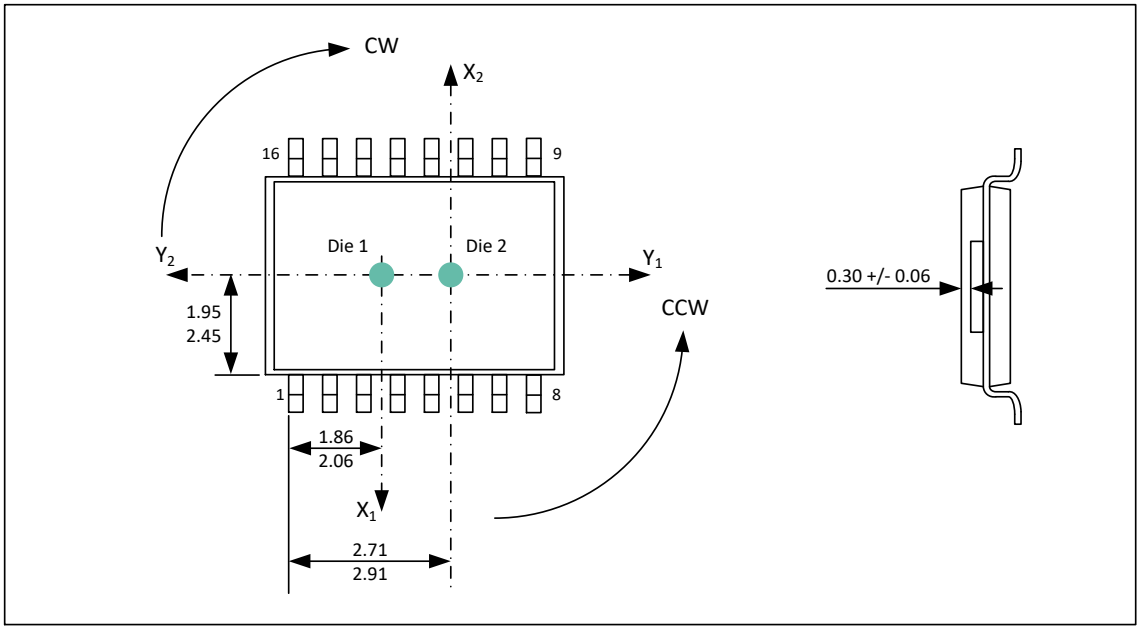


Figure 28 - TSSOP-16 sensitive spot position

18.2.4. TSSOP-16 - Angle Detection

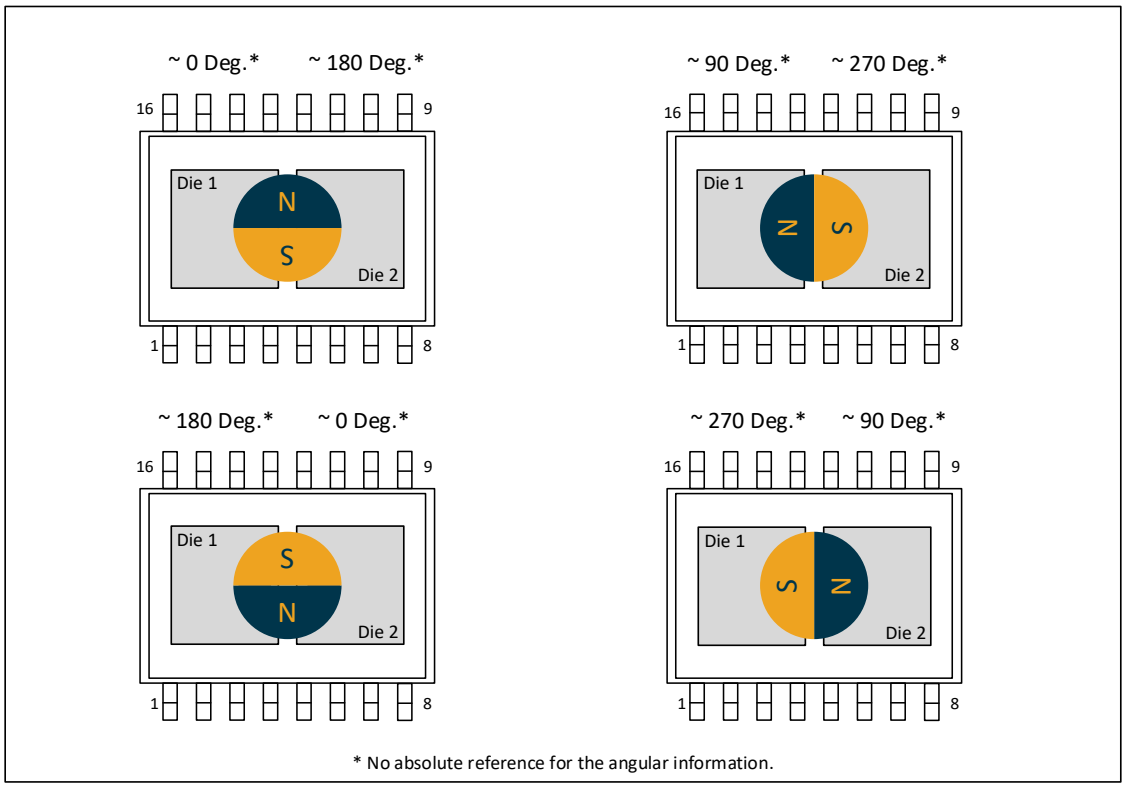


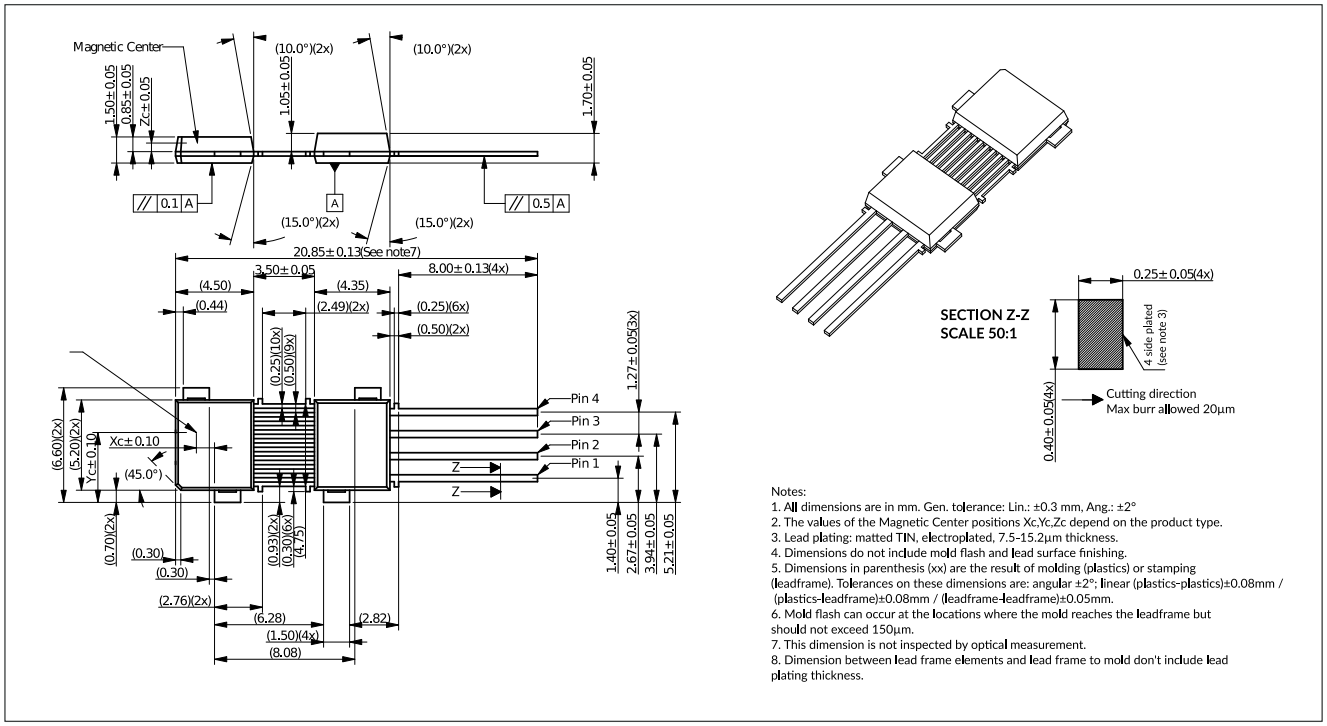
Figure 29 - TSSOP-16 angle detection

The MLX90422 is an absolute angular position sensor but the linearity error (See section 9) does not include the error linked to the absolute reference 0 Deg. This reference can be fixed in the application through the discontinuity point.

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18.3. DMP-4 - Package Information

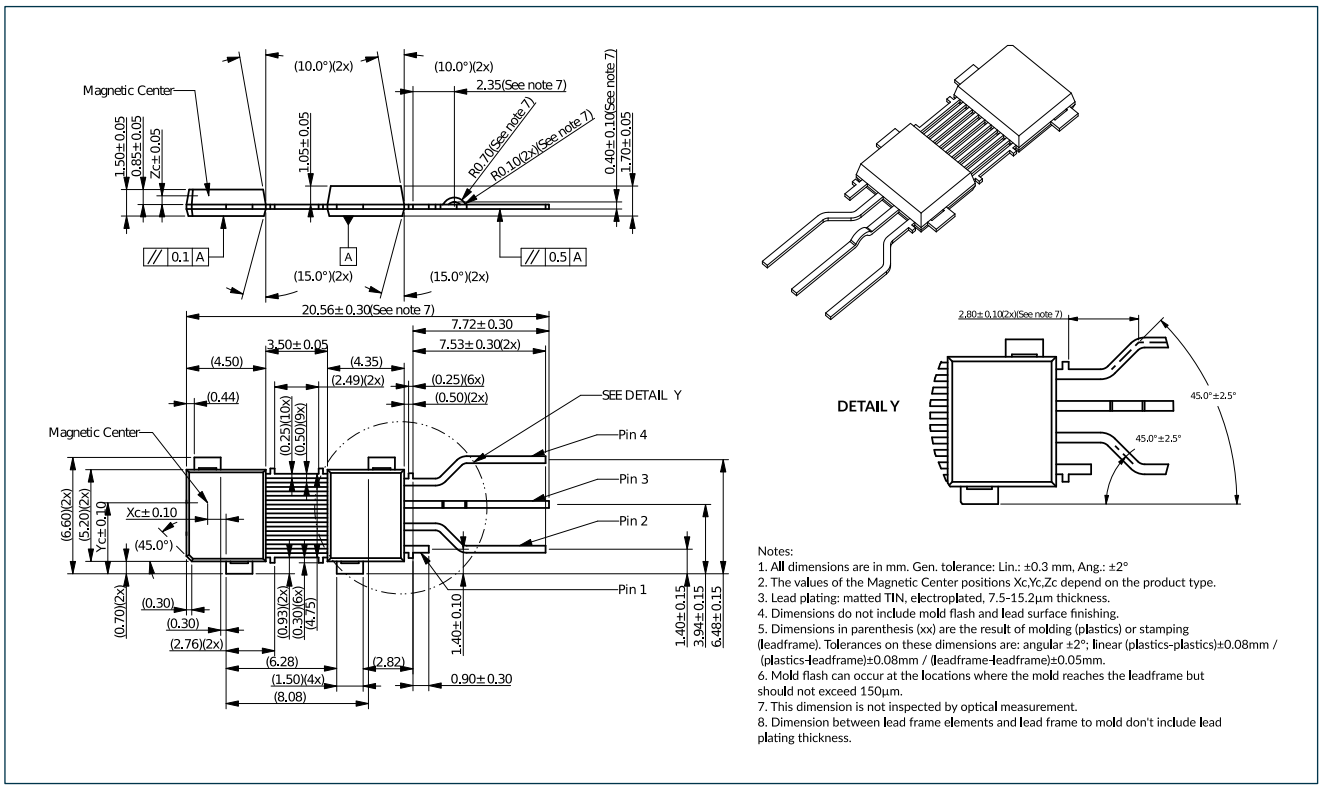
18.3.1. DMP-4 - Package Outline Dimensions (POD) - Straight Leads



Notes:
1. All dimensions are in mm. Gen. tolerance: Lin.: ±0.3 mm, Ang.: ±2°
2. The values of the Magnetic Center positions Xc,Yc,Zc depend on the product type.
3. Lead plating: matted TIN, electroplated, 7.5-15.2µm thickness.
4. Dimensions do not include mold flash and lead surface finishing.
5. Dimensions in parenthesis (xx) are the result of molding (plastics) or stamping (leadframe). Tolerances on these dimensions are: angular ±2°; linear (plastics-plastics)±0.08mm / (plastics-leadframe)±0.08mm / (leadframe-leadframe)±0.05mm.
6. Mold flash can occur at the locations where the mold reaches the leadframe but should not exceed 150µm.
7. This dimension is not inspected by optical measurement.
8. Dimension between lead frame elements and lead frame to mold don't include lead plating thickness.

Figure 30 - DMP-4 straight leads package outline drawing

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



Notes:
1. All dimensions are in mm. Gen. tolerance: Lin.: ±0.3 mm, Ang.: ±2°
2. The values of the Magnetic Center positions Xc,Yc,Zc depend on the product type.
3. Lead plating: matted TIN, electroplated, 7.5-15.2µm thickness.
4. Dimensions do not include mold flash and lead surface finishing.
5. Dimensions in parenthesis (xx) are the result of molding (plastics) or stamping (leadframe). Tolerances on these dimensions are: angular ±2°; linear (plastics-plastics)±0.08mm / (plastics-leadframe)±0.08mm / (leadframe-leadframe)±0.05mm.
6. Mold flash can occur at the locations where the mold reaches the leadframe but should not exceed 150µm.
7. This dimension is not inspected by optical measurement.
8. Dimension between lead frame elements and lead frame to mold don't include lead plating thickness.

Figure 31 - DMP-4 STD2 2.54 package outline drawing

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

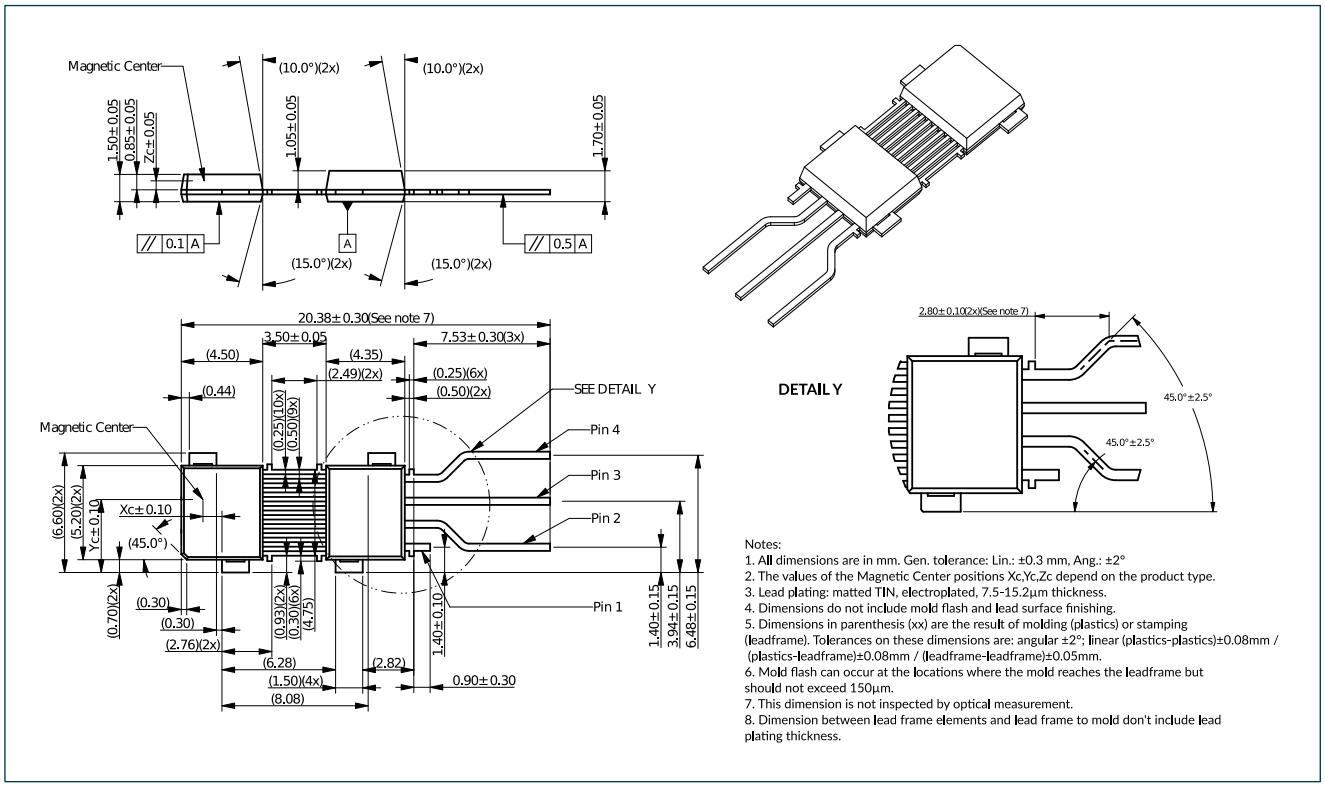


Figure 32 - DMP-4 STD4 2.54 package outline drawing

18.3.4. DMP-4 - Marking

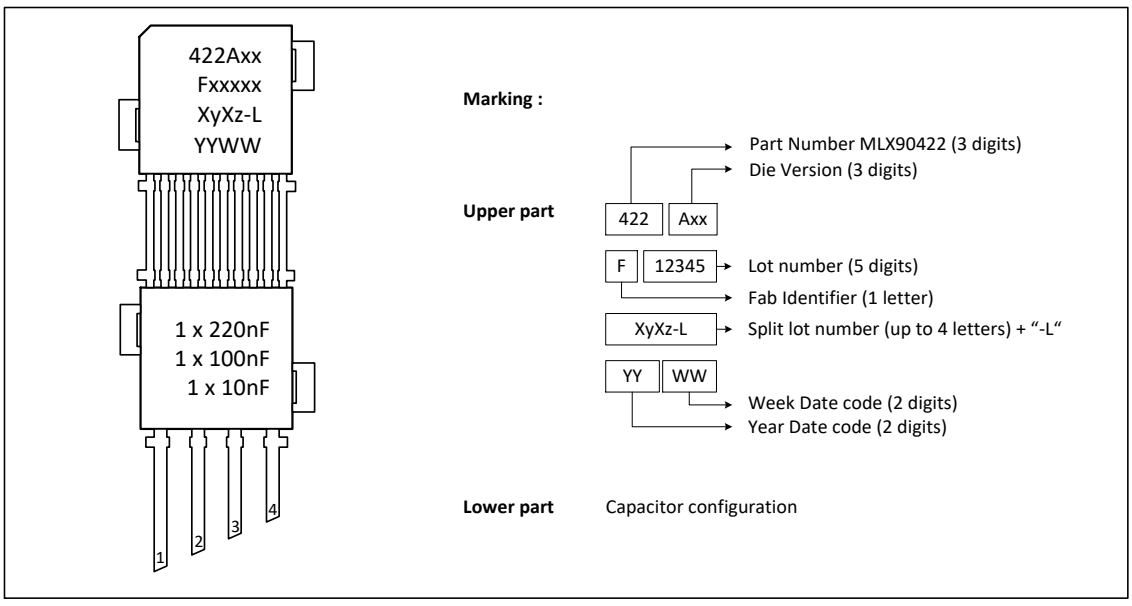


Figure 33 - DMP-4 Marking

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18.3.5. DMP-4 - Sensitive Spot Positioning

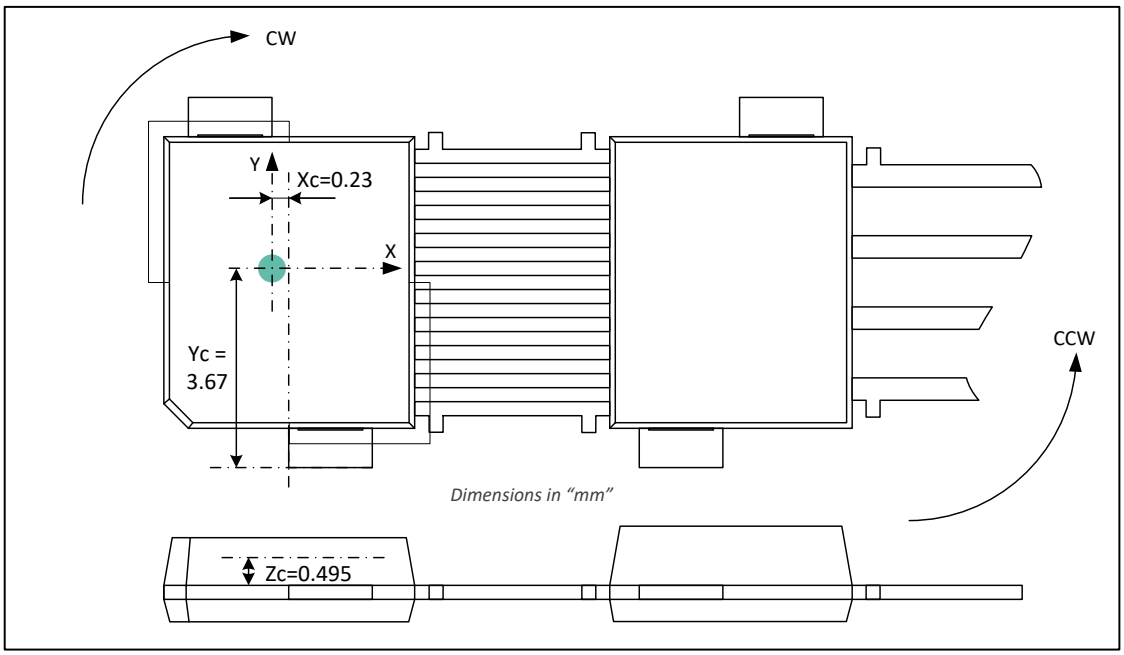


Figure 34 - DMP-4 sensitive spot position

18.3.6. DMP-4 - Angle Detection

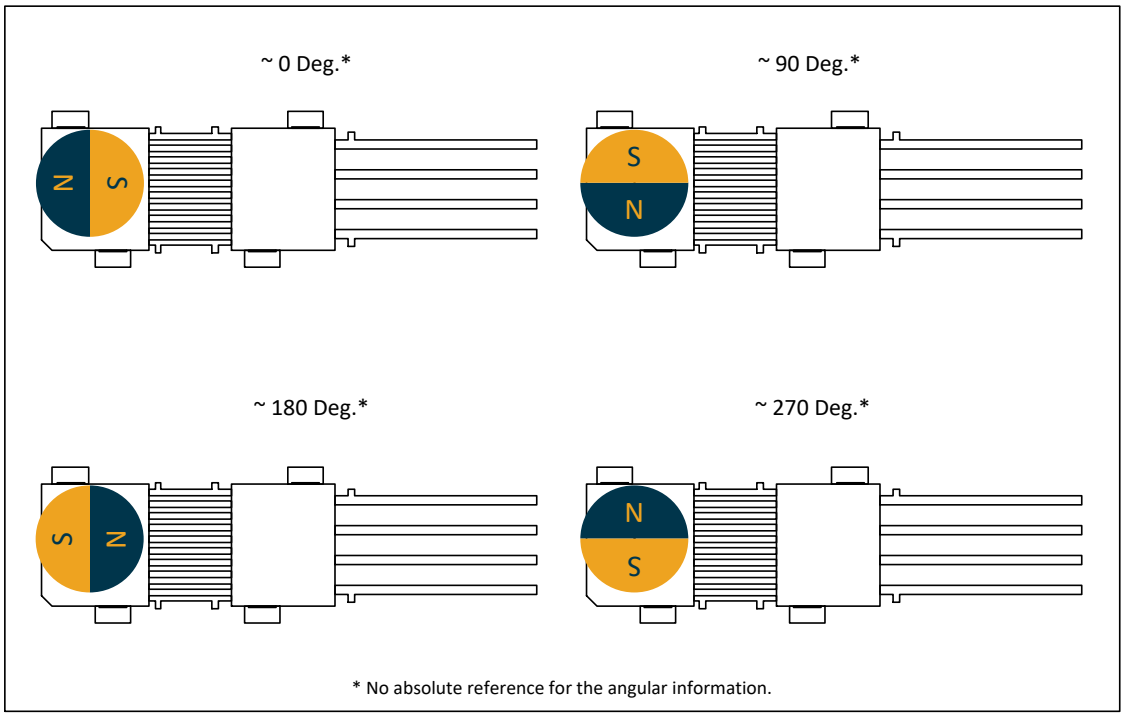


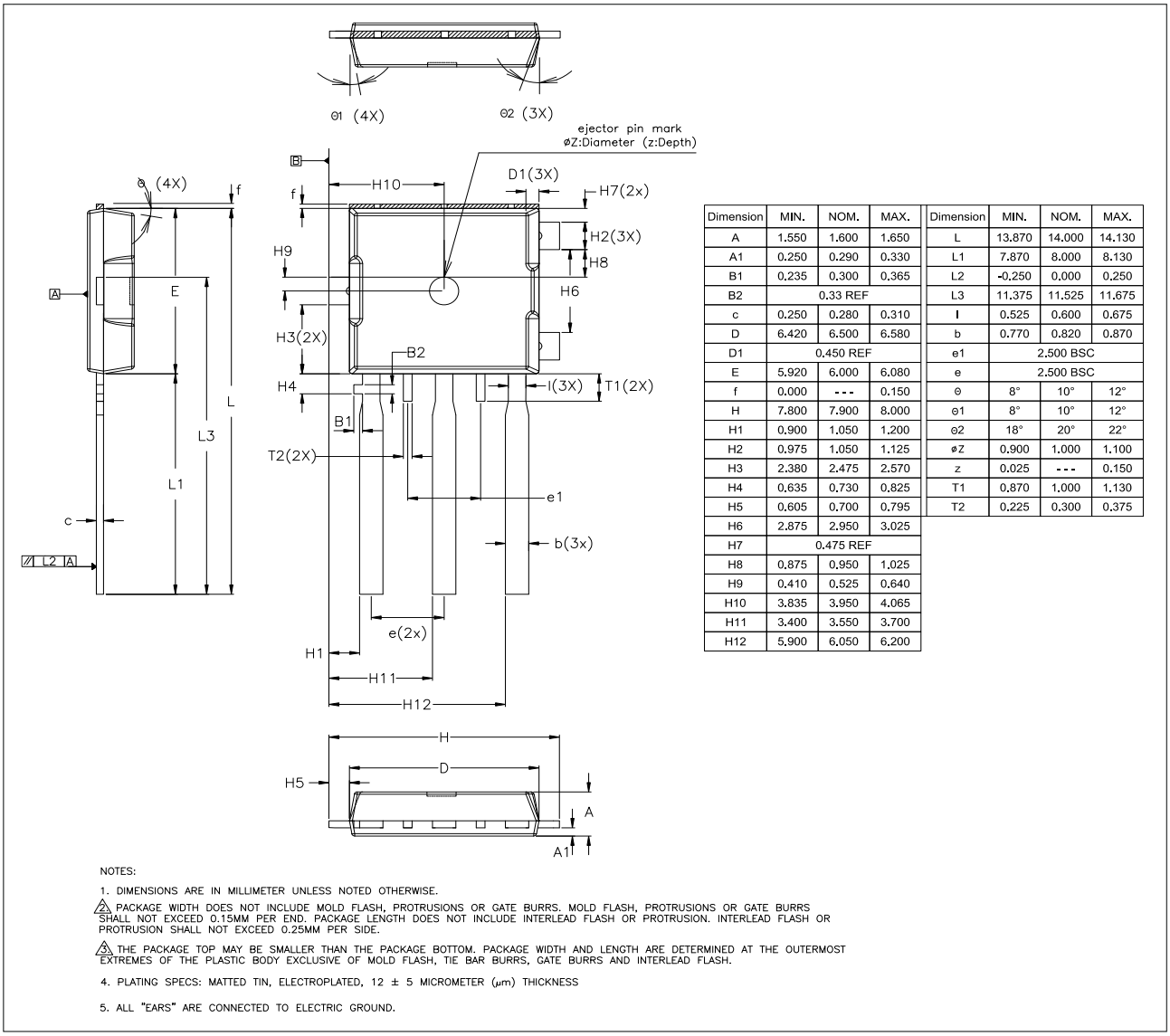
Figure 35 - DMP-4 angle detection

The MLX90422 is an absolute angular position sensor but the linearity error (See section 9) does not include the error linked to the absolute reference 0 Deg. This reference can be fixed in the application through the discontinuity point.

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18.4. SMP-3 - Package Information

18.4.1. SMP-3 - Package Outline Dimension (POD)



Dimension	MIN.	NOM.	MAX.
A	1.550	1.600	1.650
A1	0.250	0.290	0.330
B1	0.235	0.300	0.365
B2		0.33 REF	
c	0.250	0.280	0.310
D	6.420	6.500	6.580
D1		0.450 REF	
E	5.920	6.000	6.080
f	0.000	---	0.150
H	7.800	7.900	8.000
H1	0.900	1.050	1.200
H2	0.975	1.050	1.125
H3	2.380	2.475	2.570
H4	0.635	0.730	0.825
H5	0.605	0.700	0.795
H6	2.875	2.950	3.025
H7		0.475 REF	
H8	0.875	0.950	1.025
H9	0.410	0.525	0.640
H10	3.835	3.950	4.065
H11	3.400	3.550	3.700
H12	5.900	6.050	6.200

Dimension	MIN.	NOM.	MAX.
L	13.870	14.000	14.130
L1	7.870	8.000	8.130
L2	-0.250	0.000	0.250
L3	11.375	11.525	11.675
l	0.525	0.600	0.675
b	0.770	0.820	0.870
e1		2.500 BSC	
e		2.500 BSC	
θ	8°	10°	12°
θ1	8°	10°	12°
θ2	18°	20°	22°
øZ	0.900	1.000	1.100
z	0.025	---	0.150
T1	0.870	1.000	1.130
T2	0.225	0.300	0.375

NOTES:

1. DIMENSIONS ARE IN MILLIMETER UNLESS NOTED OTHERWISE.
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. PLATING SPECS: MATTED TIN, ELECTROPLATED, 12 ± 5 MICROMETER (μm) THICKNESS
5. ALL "EARS" ARE CONNECTED TO ELECTRIC GROUND.

Figure 36 - SMP-3 package outline drawing

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18.4.2. SMP-3 - Marking

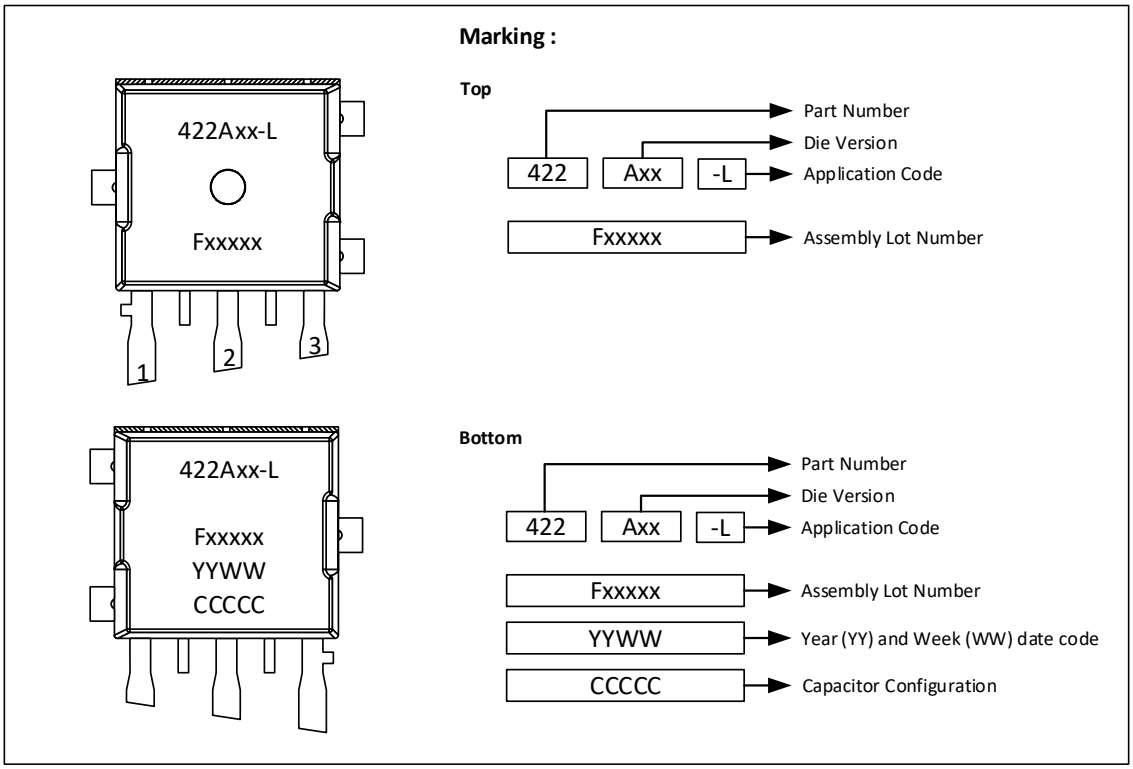


Figure 37 - SMP-3 marking

18.4.3. SMP-3 - Sensitive Spot Positioning

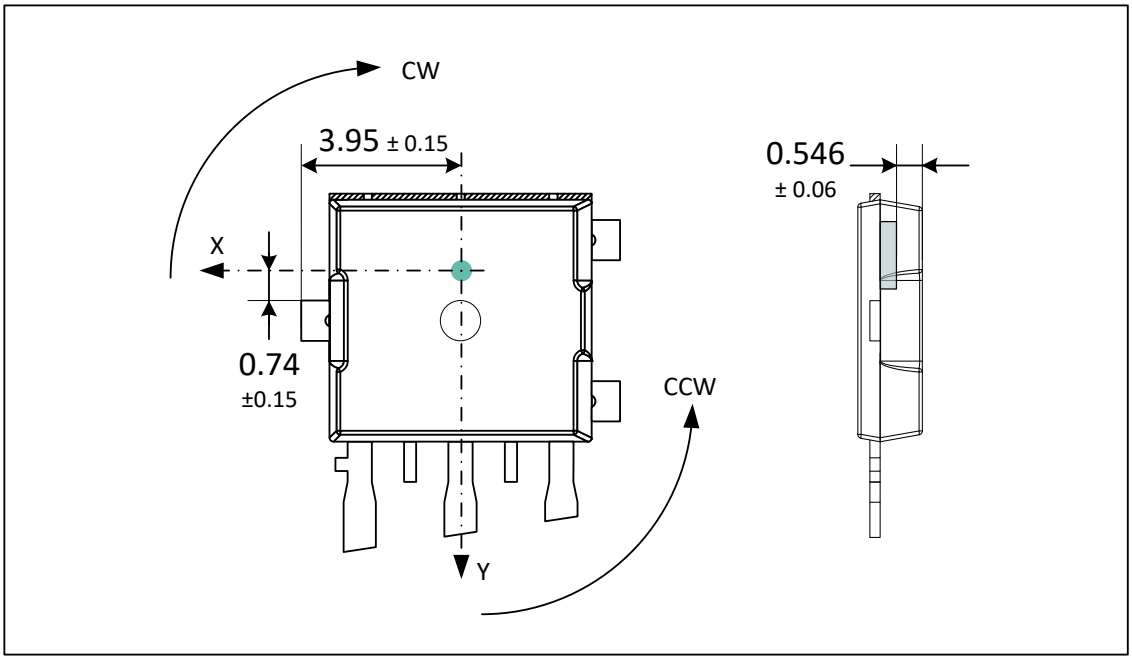


Figure 38 - SMP-3 sensitive spot position

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18.4.4. SMP-3 - Angle Detection

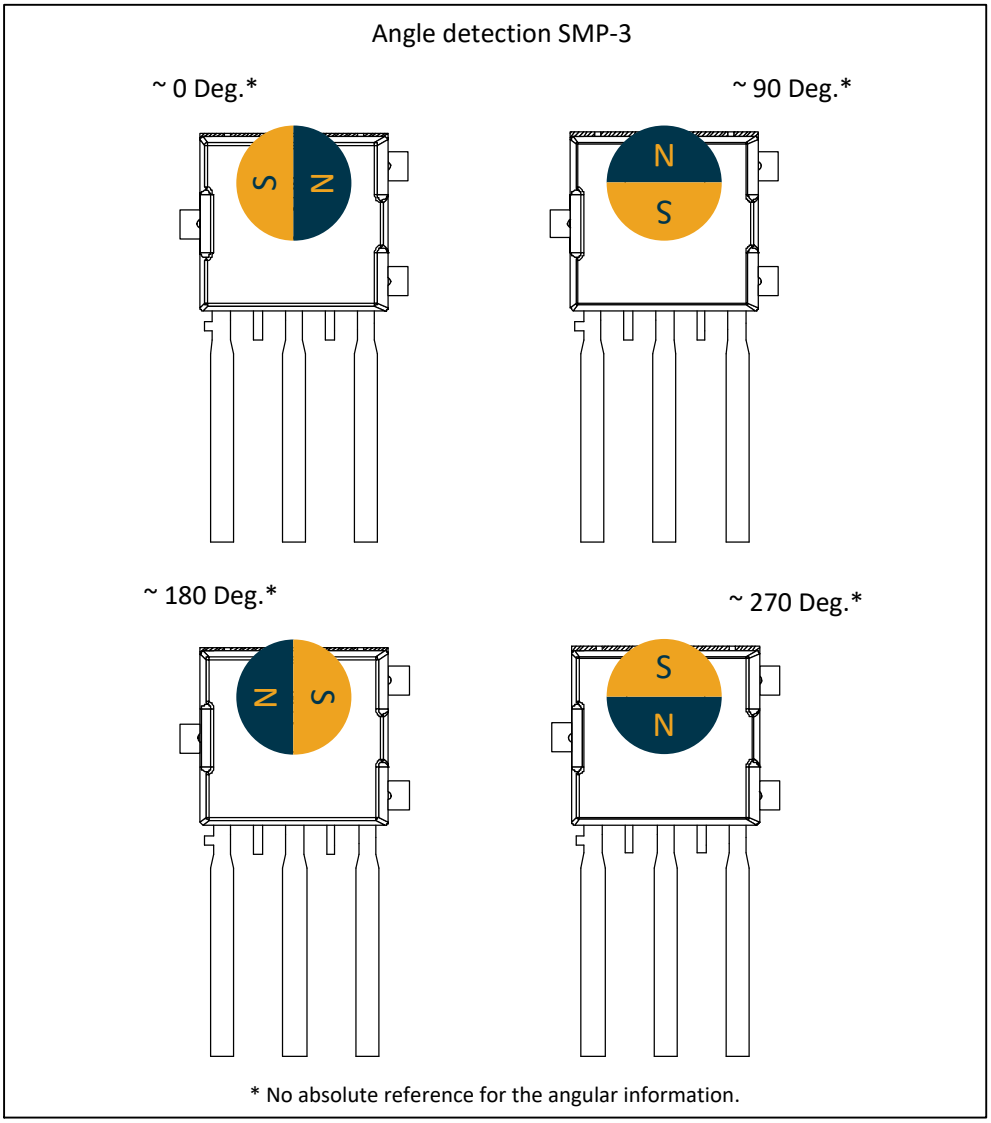
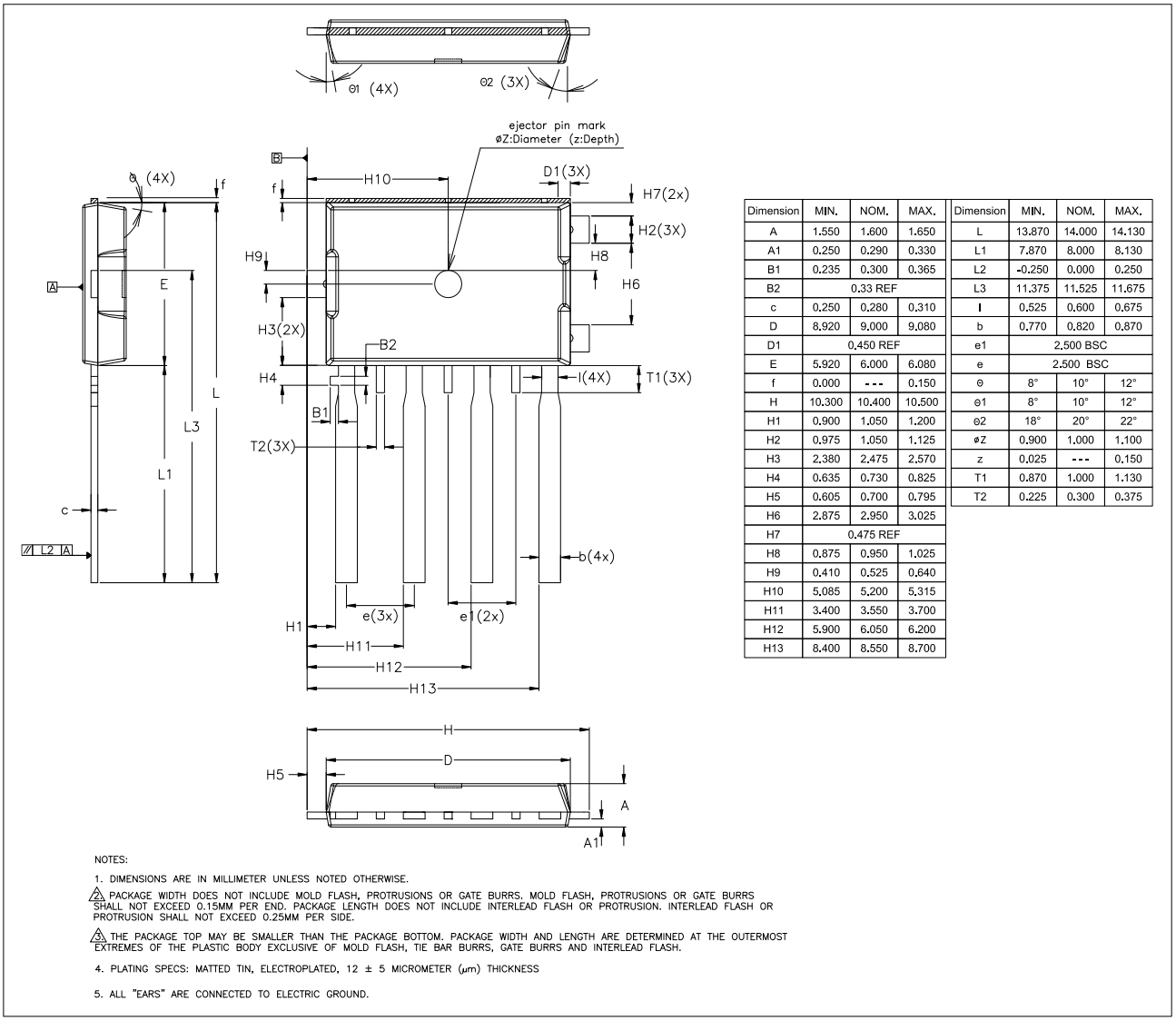


Figure 39 - SMP-3 angle detection

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18.5. SMP-4 - Package Information

18.5.1. SMP-4 - Package Outline Dimension (POD)



Dimension	MIN.	NOM.	MAX.
A	1.550	1.600	1.650
A1	0.250	0.290	0.330
B1	0.235	0.300	0.365
B2		0.33 REF	
c	0.250	0.280	0.310
D	8.920	9.000	9.080
D1		0.450 REF	
E	5.920	6.000	6.080
f	0.000	---	0.150
H	10.300	10.400	10.500
H1	0.900	1.050	1.200
H2	0.975	1.050	1.125
H3	2.380	2.475	2.570
H4	0.635	0.730	0.825
H5	0.605	0.700	0.795
H6	2.875	2.950	3.025
H7		0.475 REF	
H8	0.875	0.950	1.025
H9	0.410	0.525	0.640
H10	5.085	5.200	5.315
H11	3.400	3.550	3.700
H12	5.900	6.050	6.200
H13	8.400	8.550	8.700

Dimension	MIN.	NOM.	MAX.
L	13.870	14.000	14.130
L1	7.870	8.000	8.130
L2	-0.250	0.000	0.250
L3	11.375	11.525	11.675
l	0.525	0.600	0.675
b	0.770	0.820	0.870
e1		2.500 BSC	
e		2.500 BSC	
θ	8°	10°	12°
θ1	8°	10°	12°
θ2	18°	20°	22°
øZ	0.900	1.000	1.100
z	0.025	---	0.150
T1	0.870	1.000	1.130
T2	0.225	0.300	0.375

NOTES:

1. DIMENSIONS ARE IN MILLIMETER UNLESS NOTED OTHERWISE.
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. PLATING SPECS: MATTED TIN, ELECTROPLATED, 12 ± 5 MICROMETER (μm) THICKNESS
5. ALL "EARS" ARE CONNECTED TO ELECTRIC GROUND.

Figure 40 - SMP-4 package outline drawing

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18.5.2. SMP-4 - Marking

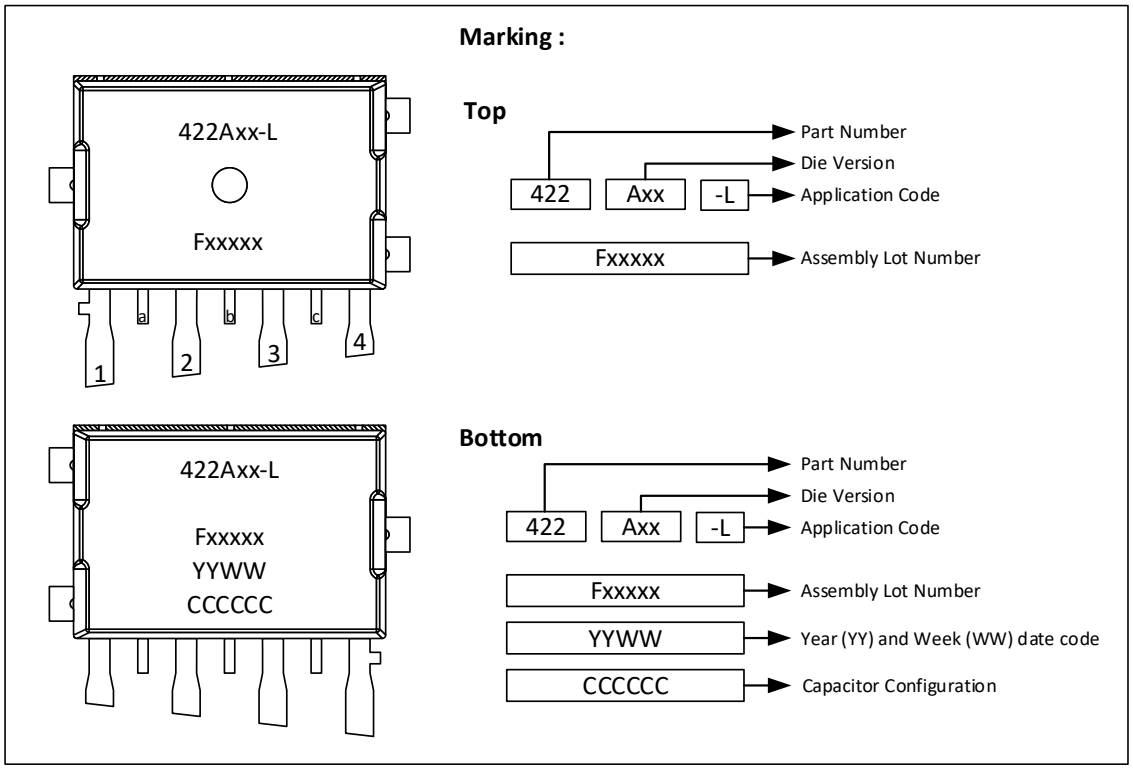


Figure 41 - SMP-4 marking

18.5.3. SMP-4 - Sensitive Spot Positioning

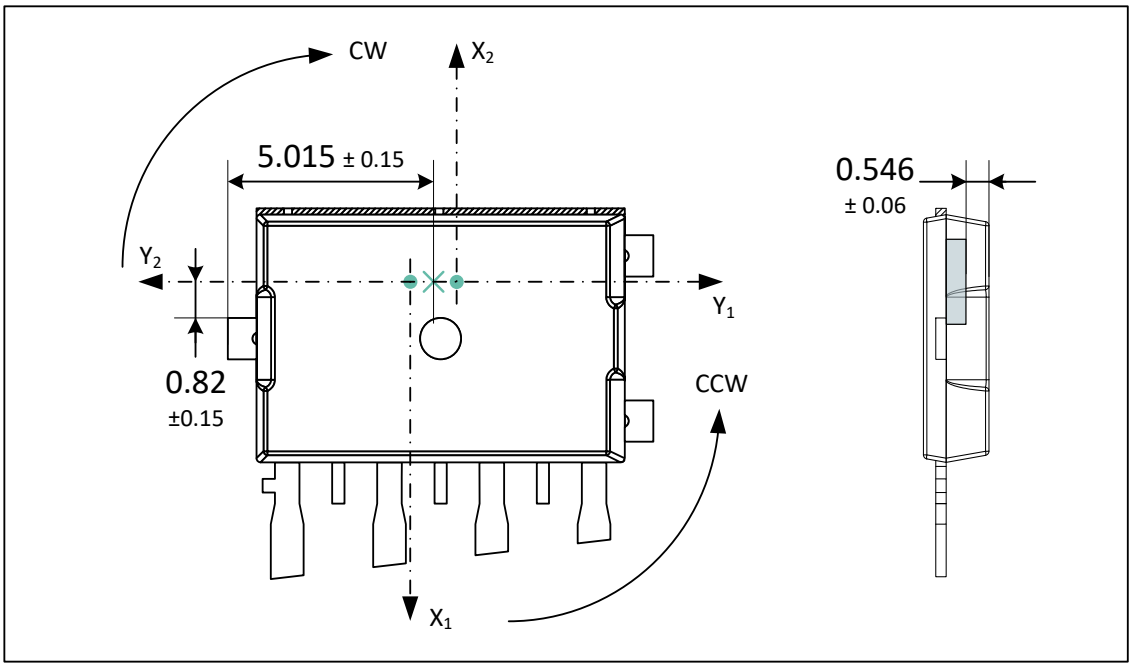


Figure 42 - SMP-4 sensitive spot position

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18.5.4. SMP-4 - Angle Detection

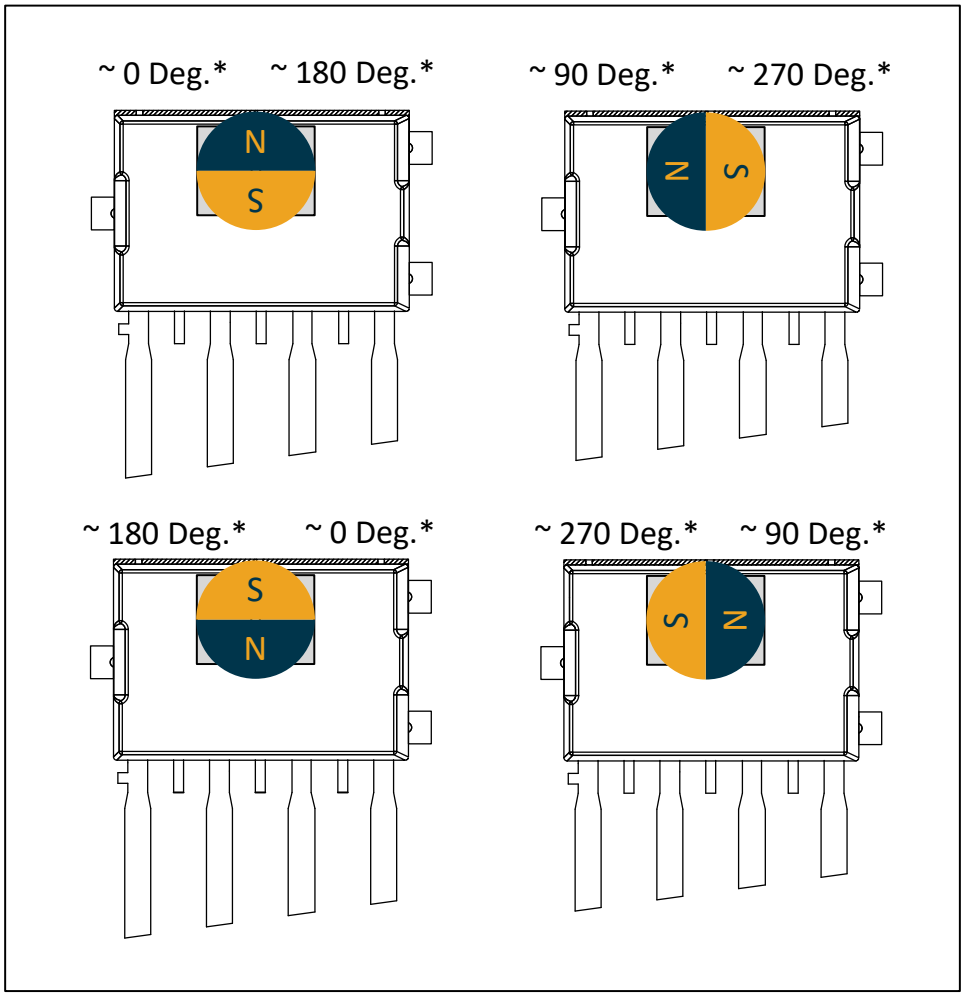


Figure 43 - SMP-4 angle detection

18.6. Packages Thermal Performances

The table below describes the thermal behavior of available packages 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)
SOIC-8	38.8 K/W	112 K/W	153 K/W
TSSOP-16	27.6 K/W	99.1 K/W	137 K/W
DMP-4	32.2 K/W	-	88.7 K/W [23]
SMP-3	34.4 K/W	-	206 K/W [23]
SMP-4	20.8 K/W	-	140 K/W [23]

Table 55 - Standard packages thermal performances

[23] *PCB-less solutions have been evaluated in a typical application case. Values for these packages are given as informative.*

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