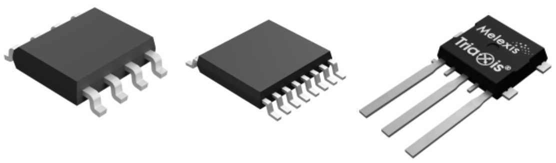
MLX90423

Triaxis® Position Sensor IC
Datasheet

Features and Benefits

- Triaxis® Hall Technology
- On Chip Signal Processing for Robust Absolute Position Sensing
- Programmable Measurement Range
- Programmable Linear Transfer Characteristic (12 to 16 Multi-points)
- Selectable output modes
  - SENT (SAE J2716 APR2016)
  - PWM (Pulse Width Modulation)
  - Ratiometric analog
- ISO26262 SEooC ASIL READY BY MELEXIS
  - ASIL-C for SENT and PWM Output
  - ASIL-B for analog
- AEC-Q100 Qualified (Grade 0)
- Robustness against stray magnetic field up to 5mT (4kA/m) as per ISO 11452-8. Stray field immune angle sensing up to 360°
- 48 bit ID Number option
- Packages, ROHS compliant
  - Single Die - SOIC-8
  - Dual Die (Full Redundant) - TSSOP-16
  - PCB-less SMP-3



SOIC-8 *TSSOP-16* *SMP-3*

Application Examples

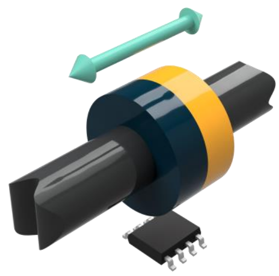
- Absolute Rotary Position Sensor
- Pedal Position Sensor
- Throttle Position Sensor
- Ride Height Position Sensor
- Absolute Linear Position Sensor
- Steering Wheel Position Sensor
- Float-Level Sensor
- Non-Contacting Potentiometer

Description

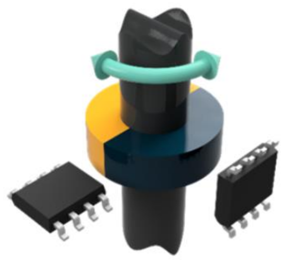
The MLX90423 is a monolithic magnetic position processor IC. It consists of a Triaxis® Hall magnetic front end, an analog to digital signal conditioner, a DSP for advanced signal processing and a programmable output stage driver.

The MLX90423 is sensitive to the three components of the magnetic flux density applied to the ICs (i.e. Bx, By and Bz). This allows the MLX90423 with the correct magnetic circuit to decode the absolute position of any moving magnet (linear displacement + 360° trough shaft, see Figure 1). It enables the design of non-contacting position sensors that are frequently required for both automotive and industrial applications.

The MLX90423 provides ratiometric analog, PWM output or SENT frames encoded according to a Secure Sensor format. The circuit delivers enhanced serial messages providing error codes, and user-defined values.



Linear
(Stray field robust)



360° trough shaft
Stray field robust

Figure 1 MLX90423 application modes

Ordering Information

Product	Temp. Code	Package Code	Option Code	Packing Form	Definition
MLX90423	G	DC	ACA-230	RE	Linear stray field robust
MLX90423	G	GO	ACA-230	RE	Linear stray field robust
MLX90423	G	VE	ACA-230	RE/RX	Linear stray field robust
MLX90423	G	GO	ACA-430	RE	Linear Legacy

Table 1 Ordering Codes

Temperature Code	G: from -40°C to 160°C
Package Code	DC: SOIC-8 package (see 19.1) GO: TSSOP-16 package (full redundancy dual die, see 19.2) VE: SMP-3 package (PCB-less single mold, see 19.3)
Option Code - Chip revision	**ACA-123: Chip Revision** ▪ ACA: MLX90423 production version
Option Code - Application	**ACA-123: 1-Application - Magnetic configuration** ▪ 2: Pre-programmed linear stray field robust (programmable to 360° trough shaft) ▪ 4: Linear legacy
Option Code - SW configuration	**ACA-123: 2-SW configuration** ▪ 3: Pre-programmed SENT version (programmable to PWM or Analog)
Option Code – Trim & Form	**ACA-123: 3- Trim & Form configuration** ▪ 0: Standard straight leads.
Packing Form	RE: Tape & Reel ▪ DC: 3000 pcs/reel ▪ GO: 4500 pcs/reel ▪ VE: 2500 pcs/reel RX: Tape & Reel, similar to RE with parts face-down (VE package only)
Ordering Example:	MLX90423GDC-ACA-230-RE For a Linear stray field robust SENT version in SOIC-8 package, delivered in Reel of 3000pcs.

Table 2 Ordering Codes Information

Contents

1. Functional Diagram and Application Modes

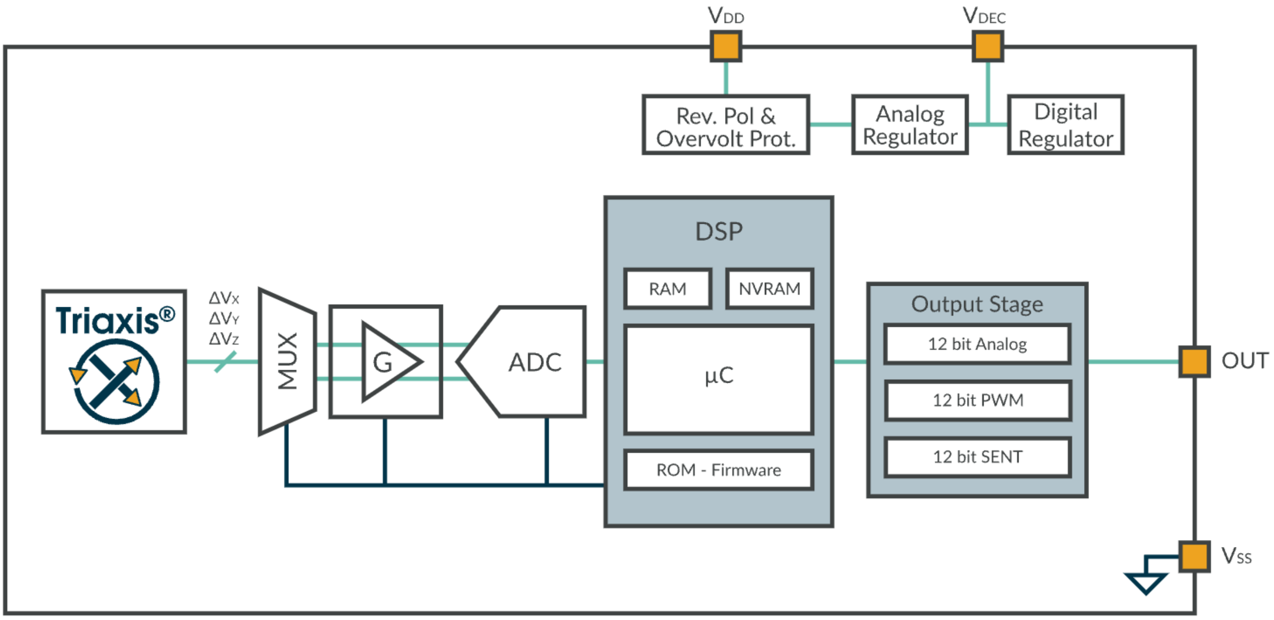


Figure 2 MLX90423 Block diagram

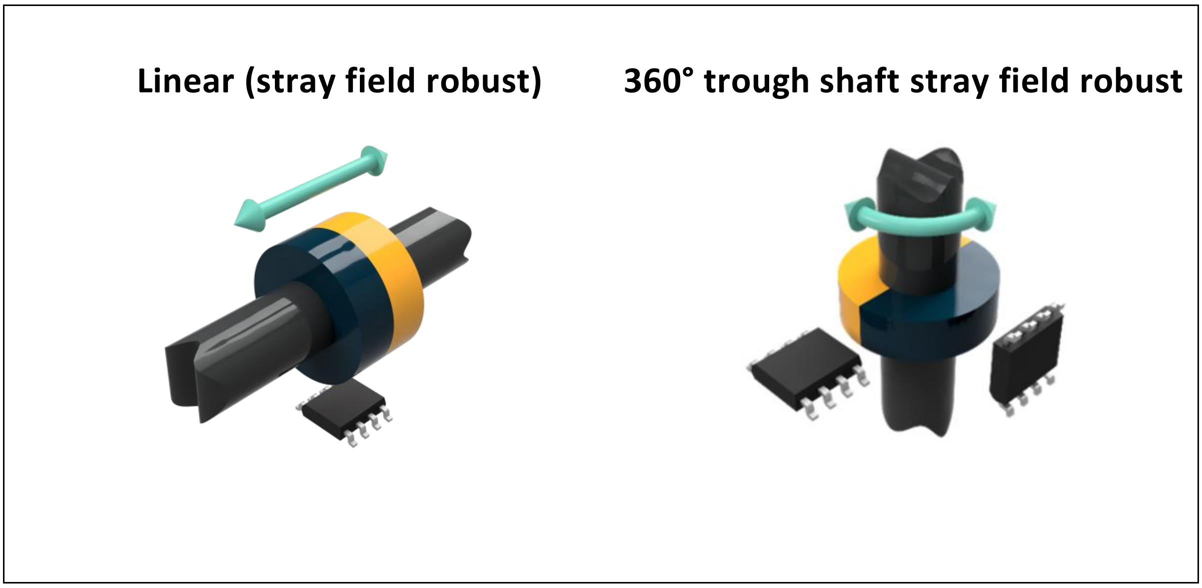


Figure 3 Application Modes

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})
DAC	Digital-to-Analog Converter
DCT	Diagnostic Time Interval: worst-case time between 2 consecutive runs of a specific diagnostic
DCT_ana	Max value of individual DCT of analog safety mechanisms (programmable value)
DCT_dig	Max value of individual DCT of digital safety mechanisms (programmable value)
DP	Discontinuity Point
DSP	Digital Signal Processing
ECC	Error Correcting Code
EMA	Exponential Moving Average
EMC	Electro-Magnetic Compatibility
EoL	End of Line
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
POR	Power-On Reset
PSF	Product Specific Functions
PWM	Pulse Width Modulation
RAM	Random Access Memory
ROM	Read-Only Memory
SENT	Single Edge Nibble Transmission
SEooC	Safety Element out of Context
SMP	Single mold package
T_{FRAME}	Communication frame period
TC	Temperature Coefficient (in ppm/°C)
T_{FSS}	Fail Safe state duration
Tesla (T)	SI derived unit for the magnetic flux density (Vs/m2)
V_{DD}	Supply Voltage
V_{DEC}	Analog regulator supply
V_{DIG}	Digital regulator supply
V_{ext}	External pull-up voltage (related to Output)

Table 3 Glossary of Terms

3. Pin Definitions and Descriptions

3.1. Pin Definition for SOIC-8 package

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 optimal EMC behaviour connect the Test and N.C. pins to the ground of the PCB.

3.2. Pin Definition for TSSOP-16 package

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 die1
5	$Test_{22}$	For Melexis factory test die2
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 die2
13	$Test_{21}$	For Melexis factory test die1
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 optimal EMC behaviour connect the Test and N.C. pins to the ground of the PCB.

3.3. Pin Definition for SMP-3 package

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 6 SMP-3 Pins definition and description

4. Absolute Maximum Ratings

Parameter		Symbol	Min	Max	Unit	Condition
Supply Voltage [(1)]	Positive	V_{DD}		28 37	V	< 48h, T_J < 175°C < 60s, T_{AMB} ≤ 35°C
	Reverse	$V_{DD\ -rev}$	-14 -18		V	< 48h < 1h
Output Voltage [(1)]	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			< 1h
Test1 pin Voltage	Positive	V_{TEST1}		6	V	< 1h
	Reverse	$V_{TEST1-rev}$	-3			< 1h
Test2 pin Voltage	Positive	V_{Test2}		3.6	V	< 1h
	Reverse	$V_{Test2-rev}$	-0.3			< 1h
Operating Temperature		T_{AMB}	-40	+160	°C	
Junction Temperature		T_J		+175 +190	°C	See 19.4 for package thermal dissipation values < 100h
Storage Temperature		T_{ST}	-55	+170	°C	
Magnetic Flux Density		B_{max}	-1	1	T	

Table 7 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.

[1] *Valid for full operating temperature range.*

5. Isolation Specification

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 8 Isolation specification

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 [2]	V_{DD}	4.5 6	5 12	5.5 18	V	For voltage regulated mode For Battery usage (PWM and SENT only)
Supply Current [3][4]	I_{DD}			12	mA	
Start-up Level rising	$V_{DDstartH}$ $V_{DDstartHyst}$	3.85	4.00 0.10	4.15	V	
PTC Entry Level	V_{PROV0} $V_{PROV0Hyst}$	5.85 0.10	6.05 0.18	6.25 0.25	V	For voltage regulated mode
PTC Entry Level	V_{PROV1} $V_{PROV1Hyst}$	21.0 1.0	22.5 1.5	23.5 2.0	V	For Battery usage
Under voltage detection	V_{DDUVL} $V_{DDUVHyst}$	3.75	3.90 0.10	4.05	V	
Regulated Voltage	V_{DEC}	3.2	3.3	3.4	V	Internal analog voltage
External Voltage	V_{ext}			18 V_{DD} 18	V	Analog output Digital output Push-Pull Digital output with open-drain NMOS

Table 9 Supply System Electrical Specifications

[2] *See WARM_ACT_HIGHV parameter in section 12 for the supply voltage mode selection.*
[3] *For the dual die version, the supply current is multiplied by 2.*
[4] *See POWER_MODE_LOW parameter in section 12 for the power mode selection.*

Electrical Parameter	Symbol	Min	Typ	Max	Unit	Condition
Output Short Circuit Current	$I_{OUTshort}$	10		35	mA	
Output Load	R_L	5	10		kΩ	**Analog &** Pull-up to V_{ext} Pull-down to 0V
		5		100	kΩ	**PWM, push-pull &** Pull-up to $V_{ext} = V_{DD}$ Pull-down to 0V
		10		55	kΩ	**SENT, push-pull &** Pull-up to $V_{ext} = V_{DD}$ Pull-down to 0V
		1.5		25	kΩ	**Digital, Open drain PMOS &** Pull-down to 0V
		5 1.5		18 25	kΩ kΩ	**Digital, Open drain NMOS &** Pull-up to $V_{ext} \leq 18V$ Pull-up to $V_{ext}=V_{DD}$
Analog Output Saturation Level	V_{satA_lo}		0.5 [5] 3.3 [5]	1.2 [6] 7.4 [6]	% V_{DD} % V_{DD}	Pull-up $R_L \geq 10$ kΩ to $V_{ext} = V_{DD}$ Pull-up $R_L \geq 5$ kΩ to $V_{ext} \leq 18V$
	V_{satA_hi}	97.0 [6] 95.0 [6]	99 [5] 98 [5]		% V_{DD} % V_{DD}	Pull-down $R_L \geq 10$ kΩ Pull-down $R_L \geq 5$ kΩ
Digital Output Push-pull level	V_{satD_lopp}			1.2 [6] 5.0 [6]	% V_{DD} % V_{DD}	Pull-up $R_L \geq 10$ kΩ to $V_{ext} = V_{DD}$ Pull-up $R_L \geq 5$ kΩ to $V_{ext} = V_{DD}$
	V_{satD_hipp}	97 [6] 95 [6]			% V_{DD} % V_{DD}	Pull-down $R_L \geq 10$ kΩ Pull-down $R_L \geq 5$ kΩ
Digital Output Open Drain Level	V_{satD_lood} V_{satD_hiod}	0 90		10 100	% V_{ext} % V_{DD}	Pull-up to $V_{ext} \leq 18V$, $I_L \leq 3.4mA$ Pull-down to 0V with $V_{DD} \leq 18V$, $I_L \leq 3.4mA$
Output leakage in Digital Open drain & Hi-Z modes [7]	$I_{leakpuOd}$ I_{leakpu} I_{leakpd}			100 20 20	µA µA µA	Pull-up to $V_{ext} > V_{DD}$ Pull-up to $V_{ext} = V_{DD}$ Pull-down to 0V
Digital output R_{on}	R_{on}	27	50	130	Ω	Push-pull mode (out of clamping bands)
Passive Diagnostic Output Level Broken-Wire Detection [8]	BV_{SS}	 99.5	1.2 0.5 100	4.0 1.6	% V_{DD} % V_{DD} % V_{DD}	**Broken V_{SS} &** Pull-down $R_L < 25$ kΩ Pull-down $R_L < 10$ kΩ Pull-up $R_L > 1$ kΩ to V_{ext}
	BV_{DD}	 92.5 97	0 98.7 99.5	0.5	% V_{DD} % V_{DD} % V_{DD}	**Broken V_{DD} &** Pull-down $R_L > 1$ kΩ Pull-up $R_L < 25$ kΩ to V_{ext} Pull-up $R_L < 10$ kΩ to V_{ext}

Table 10 Output Electrical specifications

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[5] At 35°C and 5V supply voltage with typical process parameters
[6] At 160°C and ≥4.5V supply voltage
[7] The digital output level is thereby defined by the external voltage and pull-up or pull-down resistor.
[8] Valid for dual-die configurations as well where the two dies have the same supply and ground level, while the output of one die is connected with PU and the output of the other one is connected with PD. For detailed information.

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	24	25.2	MHz	Over temperature and lifetime
	ΔF_{CK}	-5		5	$\%F_{ck}$	
Main clock relative tolerances	$\Delta F_{CK,0}$	-1.0		1.0	$\%F_{ck}$	T=35°C, trimmed
	$\Delta F_{CK,T}$	-3.5		3.5		Thermal drift relative to 35°C
1MHz Clock Frequency	F_{1M}	0.95	1.00	1.05	MHz	Over temperature and lifetime
	ΔF_{1M}	-5		5	$\%F_{1M}$	
Digital Diagnostics Cycle	DCT_dig			20	ms	
Fail Safe state duration	T_{FSS}	5		33	ms	For digital single-event faults [9]

Table 11 General Timing Specifications

7.2. Timing Modes

The MLX90423 can be configured in two continuous acquisition modes described in the following sections.

7.2.1. Continuous Asynchronous Acquisition Mode

In this mode, the sensor continuously acquires angle at a fixed rate and updates its output when the information is ready. The acquisition rate is defined by the angle measurement period $T_{angleMeas}$. PWM output frequency is asynchronous with regards to the angle measurement sequence and controlled by T_FRAME_PWM parameter.

With PWM frequency configured higher than 2kHz, the $T_{angleMeas}$ can be higher than the actual PWM period, resulting in the PWM data not updated between two consecutive periods.

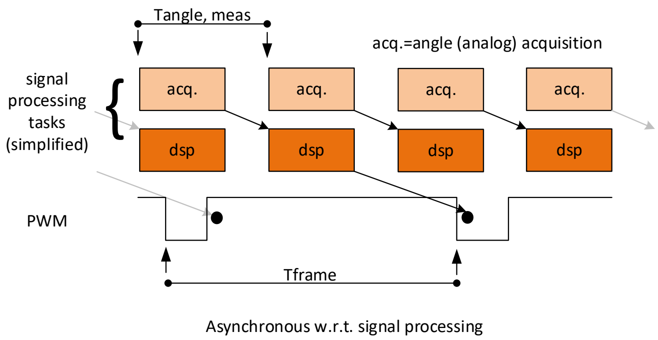

Figure 4 Continuous Asynchronous Timing Mode for PWM mode

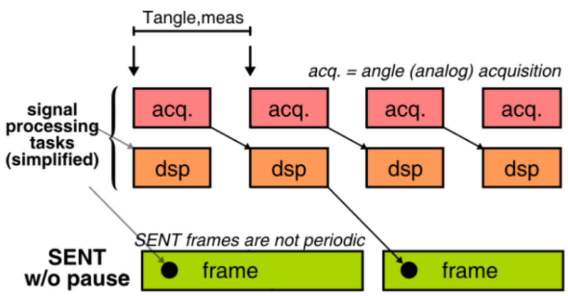

Figure 5 Continuous Asynchronous Timing Mode for SENT mode

[9] *Fully programmable. Time between reset due to digital fault to first valid data transmission.*

Parameter	Symbol	Min.	Typ	Max.	Unit	Condition
Angle acquisition time	$T_{angleAcq}$		130		µs	
Internal Angle Measurement Period	$T_{angleMeas}$	204	210		µs	Typical is default factory settings

Table 12 Continuous Asynchronous Timing Mode

7.2.2. Continuous Synchronous Acquisition Mode

In continuous synchronous timing mode, the sensor acquires angles based on the output frequency. As a consequence, the output should have a fixed frame frequency. This mode is used only with constant SENT frame length (SENT with pause). The length of the SENT frame is defined by the parameter T_FRAME_SENT in number of ticks. The user has the choice to select either one or two angle acquisitions and DSP calculations per frame [10].

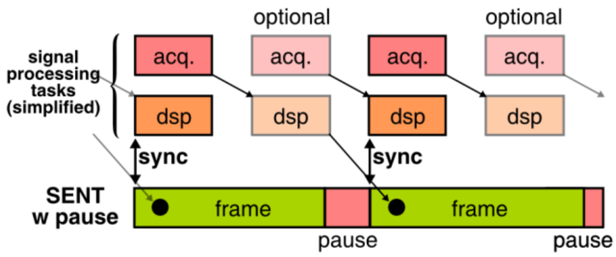

Figure 6 Continuous Synchronous Timing Mode for SENT mode

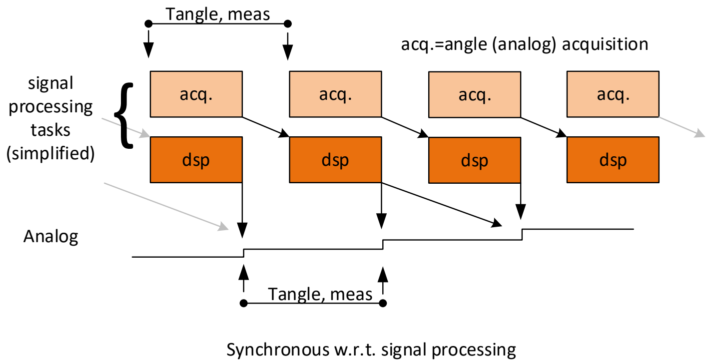

Figure 7 Continuous synchronous Timing Mode for Analog mode

7.3. Timing Definitions

7.3.1. Startup Time

7.3.1.1. Startup Time in Analog mode

In analog mode, the start-up time τ_{SU} is defined by the duration between the supply voltage is raised and the output is set to the voltage level of the measured angle. During the start-up phase, the sensor output remains in a high impedance state. The output driver is enabled only when the sensor is able to transmit a valid angle.

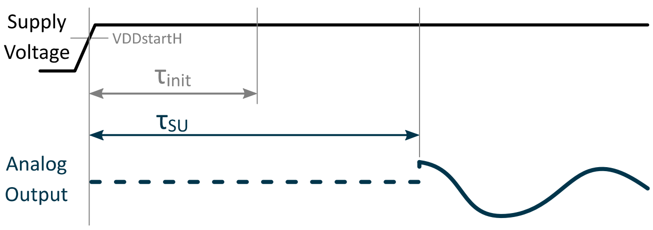

Figure 8 Startup Time Definition in Analog mode

[10] See TWO_ANGLES_FRAME parameter in section 12 for the number of angle acquisitions per frame selection.

7.3.1.2. Startup Time in PWM mode

In PWM mode, the start-up phase consists of three phases of durations $T_{stup[1..3]}$.

- The first phase T_{stup1} ends when the sensor output leaves high impedance state and starts to drive a voltage.
- The second phase T_{stup2} ends when an angle is ready to be transmitted and indicated by the first synchronization edge of the PWM signal.
- The start-up phase is considered complete after T_{stup3} when the first angle has been transmitted, which happens one PWM period after T_{stup2}.

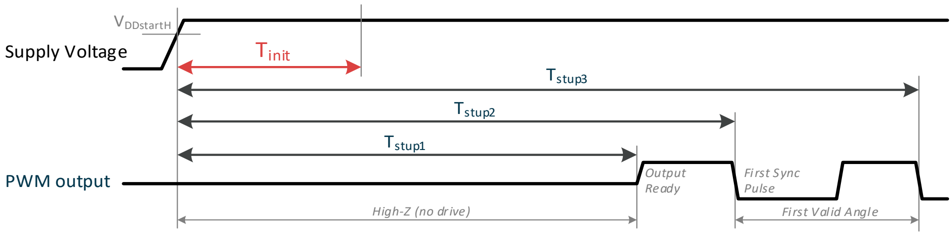

Figure 9 Startup Time Definition in PWM mode

7.3.1.3. Startup Time in SENT mode

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.

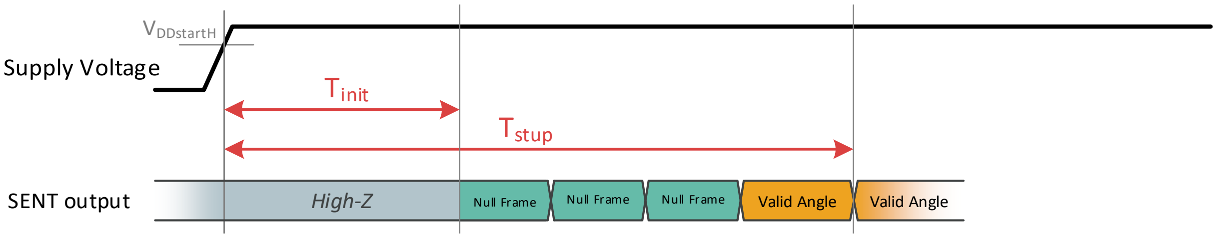

Figure 10 Startup Time Definition in SENT mode

7.3.2. 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 system for regulation calculations.

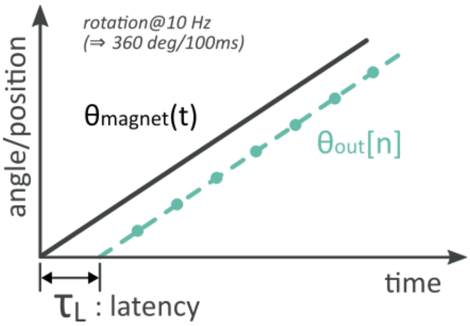

Figure 11 Definition of Latency

7.3.3. Step Response (worst case)

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 illustrated in Figure 12.

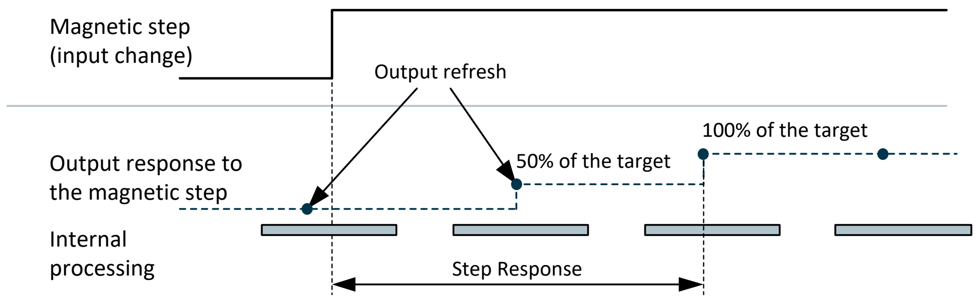

Figure 12 Step Response Definition

7.4. Analog output timing specifications

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Output refresh period	τ_R		512		µs	
Latency	τ_L		302		µs	
Step response	τ_S			925	µs	Filter 0
Start-up time	τ_{SU}			5.0	ms	
Safe startup Time [11]	$T_{SafeStup}$			25.9	ms	Including full diagnostic cycle and start-up time
Slew-rate	S_R	90			V/ms	C_{out} = 100nF
Analog Diagnostics Cycle	DCT_ana			15.4	ms	

Table 13 Analog output timing specifications

7.5. PWM output timing specifications

For the parameters in below table, maximum timings correspond to minimal frequency and vice versa.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
PWM Frequency	F_{PWM}	100	1000	2000	Hz	
PWM Frequency Tolerances	ΔF_{PWM}	-5		5	$\%F_{PWM}$	Over temperature and lifetime
	$\Delta F_{PWM,0}$	-1.0		1.0		T=35°C, trimmed
	$\Delta F_{PWM,T}$	-3.5		3.5		Thermal drift relative to 35°C
PWM startup Time	T_{stup1}		4.1		ms	up to output ready
	T_{stup2}		5.2		ms	up to first sync. Edge
	T_{stup3}		6.3		ms	up to first data received
PWM Safe startup time	$T_{SafeStup}$			25.9	ms	up to first sync. Edge
Analog Diagnostics Cycle	DCT_ana			15.4	ms	

Table 14 PWM timing specifications

[11] *Time between reset due to digital fault to first valid data transmission. Min. value defined by OUT_DIAG_HIZ_TIME.*

7.6. SENT output timing specifications

Timing specifications are valid for a given configuration of the SENT frame.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Tick time			3		µs	
SENT edge rise Time	T_{RISE}			18	µs	between 1.1V and 3.8V
SENT edge fall Time	T_{FALL}			6.5	µs	
Serial Message cycle length [12]			432 612		frames	Standard sequence (24 frames) Extended sequence (34 frames)
SENT startup time (up to first sync pulse)	T_{init}	-	3.5	4.5	ms	Until initialisation frame start
For SENT with pause (synchronous), 1 angle acquisition per SENT frame, T_FRAME_SENT = 282						
Output refresh period		846			µs	
SENT startup time	T_{stup}	-	6.6	-	ms	Until first valid angle received
Average Latency	T_{latcy}	- - -	1.33 1.6 2.5	- - -	ms	Filter = 0 Filter = 1 Filter = 2
Step Response (worst case)	T_{wcStep}	- - -	- - -	2.2 3.05 4.8	ms	Filter = 0 Filter = 1 Filter = 2
Analog Diagnostics Cycle	DCT_ana			10.64	ms	
For SENT with pause (synchronous), 2 angle acquisitions per SENT frame, T_FRAME_SENT = 310						
Output refresh period		930			µs	
SENT startup time	T_{stup}	-	-	6.26	ms	Until first valid angle received
Average Latency	T_{latcy}	- - -	- - -	1.3 1.5 2.0	ms	Filter = 0 Filter = 1 Filter = 2
Step Response (worst case)	T_{wcStep}	- - -	- - -	2.4 2.9 3.8	ms	Filter = 0 Filter = 1 Filter = 2
Analog Diagnostics Cycle	DCT_ana			11.3	ms	
For SENT without pause (asynchronous) [13], 1 angle acquisition per SENT frame						
Internal measurement period		486	512	538	µs	
SENT startup time	T_{stup}	-	-	6.26	ms	Until first valid angle received
Average Latency	T_{latcy}	- - -	- - -	2.0 2.3 2.8	ms	Filter = 0 Filter = 1 Filter = 2
Step Response (worst case)	T_{wcStep}	- - -	- - -	2.7 3.2 4.3	ms	Filter = 0 Filter = 1 Filter = 2
Analog Diagnostics Cycle	DCT_ana			12.4	ms	

Table 15 SENT Mode Timing Specifications

[12] See section 11.3.7 for details concerning Serial Message
[13] In asynchronous mode, the latency is defined as an average delay with regards to all possible variations. For worst case, refer to step response (worst case) values.

8. Magnetic Field Specifications

8.1. Definitions

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

8.1.1. Practical magnetic fields and B/dB ratio

The B/dB ratio represents the ratio of the flux density norm divided by the flux density gradient norm along a specified axis. This ratio is computed for all the positions of the magnet used in the application. B represents the flux density norm and is seen as a common mode signal by a stray field immune sensor. dB, or more formally $\|\partial \boldsymbol{B}/\partial X\|$, is the differential flux density norm. A stray field immune sensor uses the differential signal to compute the angle; the smaller the B/dB ratio, the more accurate the sensor.

Here is the formula to compute the B/dB ratio for a linear stray field immune mode:

$$B/dB = \frac{\sqrt{B_X^2 + B_Z^2}}{\sqrt{\left(\frac{\delta B_X}{\delta X}\right)^2 + \left(\frac{\delta B_Z}{\delta X}\right)^2} \cdot 1mm}$$

Here is the formula to compute the B/dB ratio for a 360° through shaft stray field immune mode:

$$B/dB = \frac{\sqrt{B_X^2 + B_Y^2}}{\sqrt{\left(\frac{\delta B_X}{\delta X}\right)^2 + \left(\frac{\delta B_Y}{\delta X}\right)^2} \cdot 1mm}$$

For practical reasons, the B/dB component is normalized to one millimeter. When calculating the B/dB ratio, the exact location of the magnetic sensing elements and their relative distance should be taken into account (see Table 16 and Table 17, distance between the two IMC).

8.1.2. Ideal magnetic field

The “ideal magnetic field" refers to a rotating differential magnetic field where the chip is at the center of a quadripolar field. As the common mode is always null, the IC sees only a differential mode field.

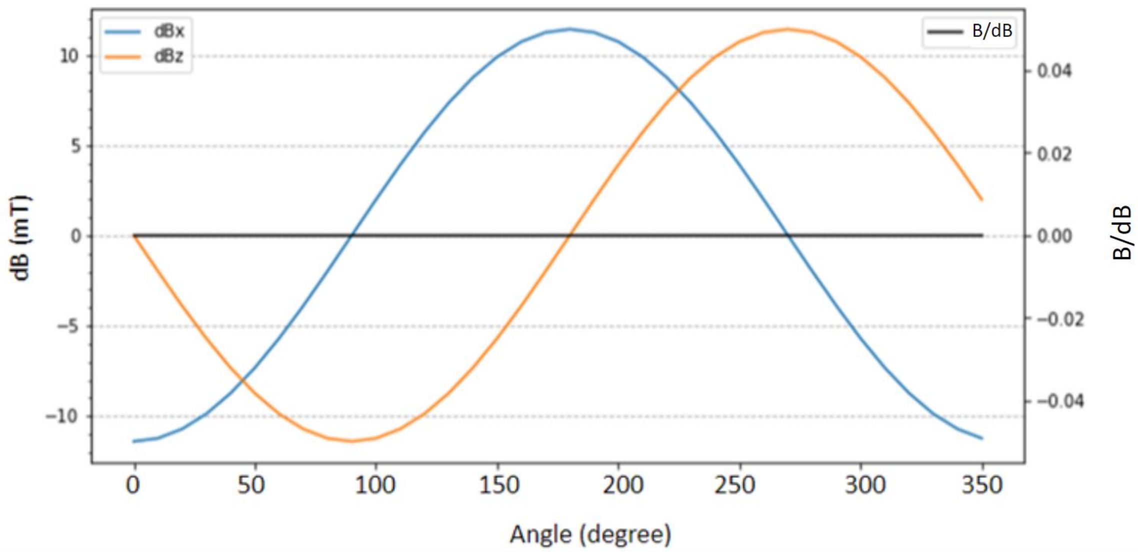

Figure 13 Ideal gradient magnetic field

8.2. Linear stray field robust (-2xx order code)

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	-		Linear movement
Magnetic Flux Density in X	B_X			80 [14]	mT	$B_Y \leq 20mT$
Magnetic Flux Density in X-Y	B_X, B_Y [15]			70 [16]	mT	$\sqrt{B_X^2 + B_Y^2}$, B_Y >20mT
Magnetic Flux Density in Z	B_Z			100	mT	
Magnetic gradient of X-Z field components	$\frac{\Delta B_{XZ}}{\Delta X}$	3	6 [17]		$\frac{mT}{mm}$	$\sqrt{\left(\frac{\Delta B_X}{\Delta X}\right)^2 + \left(\frac{1}{G_{IMC}}\frac{\Delta B_Z}{\Delta X}\right)^2}$ [18]
Distance between the two IMC	ΔX		1.91		mm	see section 19 for magnetic center definitions
IMC gain	G_{IMC}		1.19			See [18]
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{ppm}{°C}$	
Field Strength Resolution	$\frac{\Delta B_{XZ}}{\Delta X}$	0.074	0.1	0.126	$\frac{mT}{mm\ LSB}$	Magnetic field gradient norm expressed in 12bits words
Field too Low Threshold [19]	B_{TH_LOW}	0.5	1.5	7.5 [20]	$\frac{mT}{mm}$	
Field too High Threshold [19]	B_{TH_HIGH}	0	28	28 [21]	$\frac{mT}{mm}$	

Table 16 Magnetic specifications for linear stray field robust application

Nominal performances apply when the useful signal ΔBxz/ΔX and temperature range are inside the values defined in the following Figure 14. At higher temperature or lower field gradients, the accuracy of the MLX90423 is degraded.

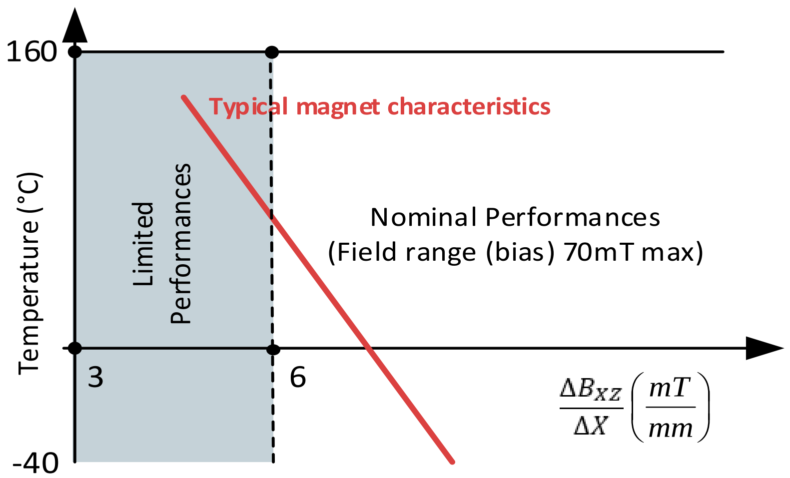

Figure 14 Minimum useful signal definition for linear stray field robust application

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[14] Above 80 mT, with BY field in the mentioned limits, the IMC starts saturating yielding to an increase of the linearity error.
[15] The condition must be fulfilled for all combinations of Bx and By.
[16] Above 70 mT, the IMC starts saturating yielding to an increase of the linearity error.
[17] Below 6 mT/mm, the performances are degraded due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.
[18] IMC has better performance for concentrating in-plane (X-Y) field components, resulting in a better magnetic sensitivity. A correction factor, called IMC gain has to be applied to the Z field component to account for this difference.
[19] Typ. value is set by default
[20] Higher values of Field too Low threshold are not recommended by Melexis and shall only been set in accordance with the magnetic design and taking a sufficient safety margin to prevent false positive.
[21] Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensor.

8.3. 360° trough shaft stray field robust (-2xx order code)

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	-		Linear movement
Magnetic Flux Density in X	B_X			80 (14)	mT	$B_Y \leq 20mT$
Magnetic Flux Density in X-Y	B_X, B_Y (15)			70 (16)	mT	$\sqrt{B_X^2 + B_Y^2}$, B_Y >20mT
Magnetic Flux Density in Z	B_Z			100	mT	
Magnetic gradient of X-Y field components	$\frac{\Delta B_{XY}}{\Delta X}$	3	6(17)	30	$\frac{mT}{mm}$	$\sqrt{\left(\frac{\Delta B_X}{\Delta X}\right)^2 + \left(\frac{1}{G_{IMC}}\frac{\Delta B_Y}{\Delta X}\right)^2}$ (18)
Distance between the two IMC	ΔX		1.91		mm	see section 19 for magnetic center definitions
IMC gain	G_{IMC}		1.19			See (18)
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{ppm}{°C}$	
Field Strength Resolution	$\frac{\Delta B_{XY}}{\Delta X}$	0.074	0.1	0.126	$\frac{mT}{mm\ LSB}$	Magnetic field gradient norm expressed in 12bits words
Field too Low Threshold (19)	B_{TH_LOW}	0.5	1.5	7.5 (20)	$\frac{mT}{mm}$	
Field too High Threshold (19)	B_{TH_HIGH}	0	28	28 (21)	$\frac{mT}{mm}$	

Table 17 Magnetic specifications for 360° trough shaft stray field robust application

Nominal performances apply when the useful signal ΔBxy/ΔX and temperature range are inside the values defined in the following Figure 15. At higher temperature or lower field gradients, the accuracy of the MLX90423 is degraded.

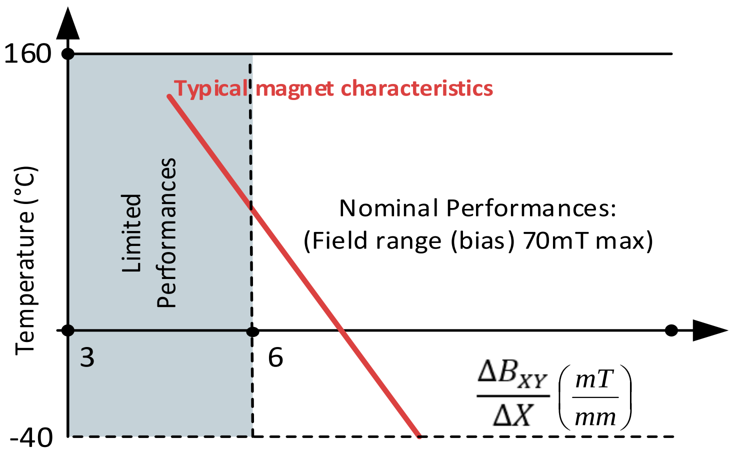


Figure 15 Minimum useful signal definition for 360° trough shaft stray field robust application

8.4. Linear legacy (-4xx order code)

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 [15]			70 [16]	mT	$\sqrt{B_X^2 + B_Y^2}$
Magnetic Flux Density in Z	B_z			100	mT	in absolute value
Useful Magnetic Flux Density Norm	B_{Norm}	10[22]	20		mT	$\sqrt{B_X^2 + \left(\frac{1}{G_{IMC}} B_Z\right)^2}$ (X-Z mode)
Distance between the two IMC	ΔX		1.91		mm	see section 19 for magnetic center definitions
IMC gain	G_{IMC}		1.19			See [18]
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{\text{ppm}}{°\text{C}}$	
Field Too Low Threshold [19]	B_{TH_LOW}	1	3	15[20]	mT	
Field Too High Threshold [19]	B_{TH_HIGH}	0	56	56 [21]	mT	

Table 18 Magnetic specifications for standard application

Nominal performances apply when the useful signal B_{Norm} and temperature range are inside the values defined in the following Figure 16 Figure 14. At higher temperature or lower field, the accuracy of the MLX90423 is degraded.

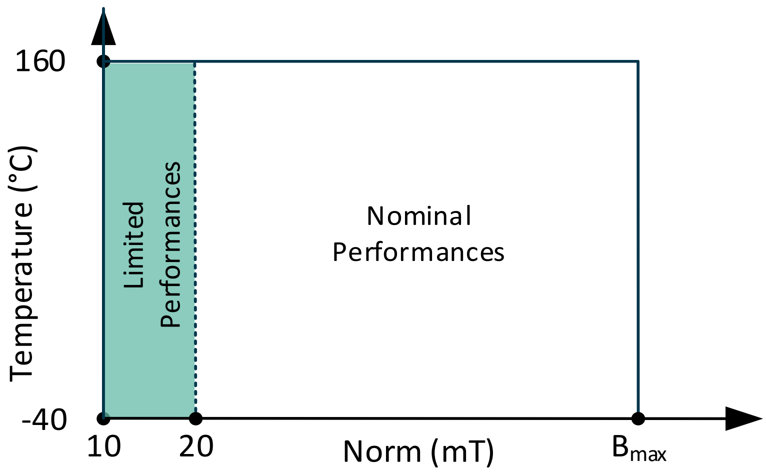


Figure 16 Minimum useful signal definition for linear legacy application

[22] *Only valid under the conditions of Figure 16. 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.*

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

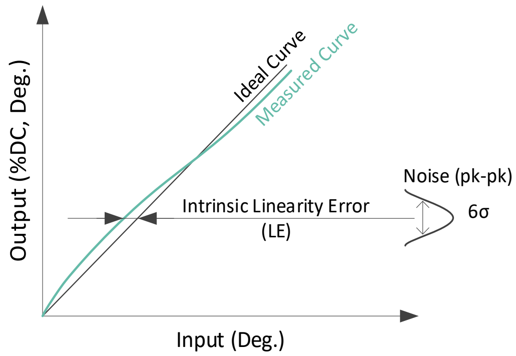


Figure 17 Sensor accuracy definition

Illustration of Figure 17 depicts the intrinsic linearity error in new parts. The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) considering an ideal magnetic field. Once associated to a practical magnetic construction and the associated mechanical and magnetic tolerances, the output linearity error increases. However, it can be improved with the multi-point end-user calibration (see 14.2.3). As a consequence, this error is not critical in application because 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, aging, etc... This 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 status at the start of the operating life. Note the total drift $\partial\theta_{TT}$ is always defined with respect to 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.

9.2. Linear stray field robust – performances (-2xx order code)

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

Parameter	Symbol	Min	Typ	Max	Unit	Condition		
XZ - Intrinsic Linearity Error	L_{E_XZ}	-1.5		1.5	Deg.			
Angular Noise [23]				0.65 0.75	Deg.	6mT/mm	125°C 160°C	Filter = 0 Filter = 0
				1.2 1.4 1.0	Deg.	3mT/mm	125°C 160°C 160°C	Filter = 0 Filter = 0 Filter = 1
XZ – Angular Thermal Drift	$\partial\theta_{TT\_XZ}$			0.65 0.8	Deg.	3mT/mm	125°C 160°C	B/dB=0 [24]
				0.48 0.6	Deg.	6mT/mm	125°C 160°C	
				0.8	Deg.	6mT/mm	160°C	B/dB=3 [25]
				1.2	Deg.	6mT/mm	160°C	B/dB=5 [26]
Stray field Immunity	$\partial\theta_{FF}$			0.4	Deg.	6mT/mm	In accordance of ISO 11452-8: 2015, at 30°C, with magnetic In-plane gradient of In-plane field component, and stray field strength of 4000A/m from any direction	
Hysteresis				0.1	Deg.	6mT/mm		

Table 19 Linear stray field robust- Magnetic Performance

[23] *6σ*

[24] *Verification done on new and aged devices in an ideal magnetic field gradient (Bd/B=0). Relative to 35°C. An additional application-specific error arises from the non-ideal magnet and mechanical tolerance drift.*

[25] *Verification done on new and aged devices for B/dB = 3. Relative to 35°C.*

[26] *Verification done on new and aged devices for B/dB = 5. Relative to 35°C.*

9.3. 360° trough shaft stray field robust – performances (-2xx order code)

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

Parameter	Symbol	Min	Typ	Max	Unit	Condition		
XY - Intrinsic Linearity Error	L_{E_XY}	-1.5		1.5	Deg.			
Angular Noise [23]				0.65 0.75	Deg.	6mT/mm	125°C 160°C	Filter = 0 Filter = 0
				1.2 1.4 1.0	Deg.	3mT/mm	125°C 160°C 160°C	Filter = 0 Filter = 0 Filter = 1
XY – Angular Thermal Drift	$\partial\theta_{TT\_XY}$			0.65 0.8	Deg.	3mT/mm	125°C 160°C	B/dB=0 [24]
				0.48 0.6	Deg.	6mT/mm	125°C 160°C	
Stray field Immunity	$\partial\theta_{FF}$			0.4	Deg.	6mT/mm	In accordance of ISO 11452-8: 2015, at 30°C, with magnetic In-plane gradient of In-plane field component, and stray field strength of 4000A/m from any direction	
Hysteresis				0.1	Deg.	6mT/mm		

Table 20 360° trough shaft stray field robust mode - Magnetic Performance

9.4. Linear legacy– performances (-4xx order code)

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

Parameter	Symbol	Min	Typ	Max	Unit	Condition	
XZ - Intrinsic Linearity Error	L_{E_Xz}	-1.0		1.0	Deg.		
Noise [23]				0.22 0.28 0.11 0.14	Deg.	20mT	125°C; Filter = 0 160°C; Filter = 0 125°C; Filter = 2 160°C; Filter = 2
				0.42 0.56	Deg.	10mT	125°C; Filter = 0 160°C; Filter = 0
XZ - Thermal Drift [24]	$\partial\theta_{TT\_XZ}$	-0.25 -0.4		0.25 0.4	Deg.	20mT	125°C 160°C
		-0.4 -0.55		0.4 0.55	Deg.	10mT	125°C 160°C
Hysteresis				0.1 0.2	Deg.	20mT 10mT	

Table 21 Linear legacy mode - Magnetic Performance

10. Memory Specifications

Parameter	Symbol	Value	Unit	Note
ROM	ROMsize	19	kB	1-bit parity check per 32bits word (single error detection)
RAM	RAMsize	576	B	1-bit parity check per 16bits word (single error detection)
NVRAM	NVRAMsize	192	B	6-bit ECC per word 16b (single error correction, double error detection)

Table 22 Memory Specifications

11. Output Protocol Description

Output protocol description is valid for temperature range [-40, 160] °C and supply voltage range [4.5, 5.5] V unless otherwise noted.

11.1. Analog Output Description

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Thermal analog output Drift				0.2	% V_{DD}	
Analog Output Resolution	R_{DAC}		12		bit	12bit DAC (Theoretical)
		-4		+4	LSB_{12}	INL (before EoL calibration), output clamped between 3-97% V_{DD}
		-1.0		1.5	LSB_{12}	DNL
Ratiometric Error		-0.05		0.05	% V_{DD}	

Table 23 Analog Output Description

11.2. PWM (pulse width modulation)

11.2.1. Definition

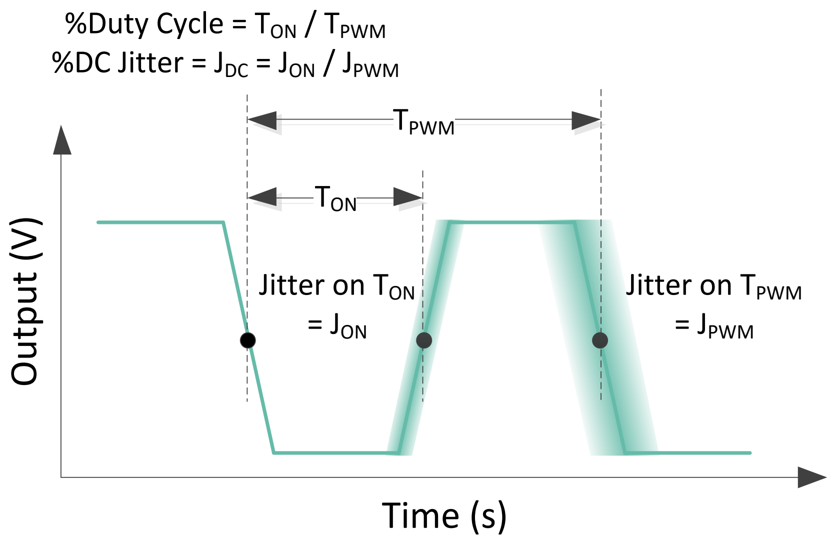


Figure 18 PWM Signal definition

Parameter	Symbol	Test Conditions
PWM period	T_{PWM}	Trigger level = 50% V_{DD}
Rise time, Fall time	t_{rise}, t_{fall}	Between 10% and 90% of V_{DD}
Jitter	J_{on} J_{PWM}	±3σ for 1000 successive acquisitions with clamped output
Duty Cycle	DC	100*T_{ON} / T_{PWM}

Table 24 PWM Signal definition

11.2.2. PWM performances

Parameter	Symbol	Min	Typ	Max	Unit	Condition
PWM Output Resolution	R_{pwm}		0.024		%DC/LSB12	
PWM %DC Jitter	J_{DC}			0.03	%DC	Push-pull, 2kHz C_{OUT} = 10nF, R_L = 10kΩ
PWM Period Jitter	J_{pwm}	-	-	500	ns	2kHz
PWM %DC thermal drift			0.02	0.05	%DC	Push-pull, 2kHz C_{OUT} = 10nF, R_L = 10kΩ
Rise/Fall Time PWM	T_{rise_fall}	2.5	5.0	7.5	µs	Push-pull C_{OUT} ≤ 15nF [27] [28]
Rise/Fall Active Slope PWM[29]	S_{rise_fall}	0.5	0.8	1.6	V/µs	Push-pull or open-drain C_{OUT} ≤ 15nF [27][28]

Table 25 PWM Signal Specifications

11.3. Single Edge Nibble Transmission (SENT) SAE J2716

The MLX90423 provides a digital output signal compliant with SAE J2716 Revised APR2016.

11.3.1. Sensor message definition

The MLX90423 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 [30] and Serial Communication [31] nibble pulse.
- A sequence of six 4-bit data nibbles pulses representing the values of the signal(s) to be transmitted.
- One 4-bit Checksum nibble pulse.
- One optional pause pulse.

See also SAE J2716 APR2016 for general SENT specification.

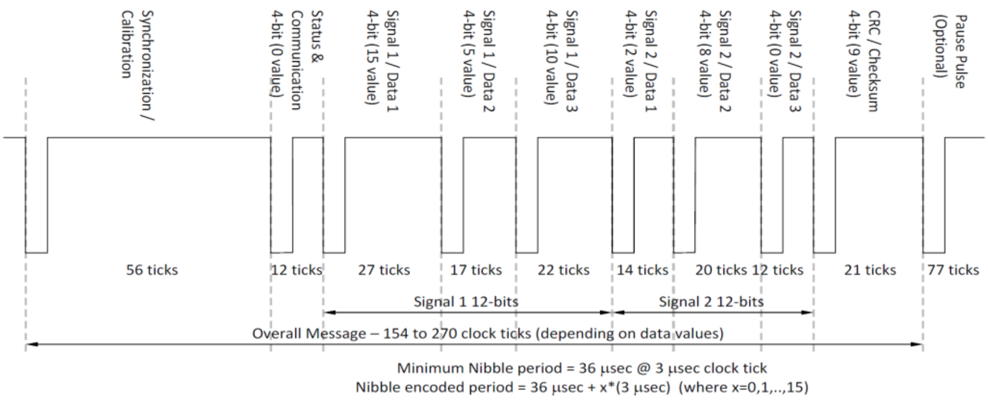


Figure 19 SENT message encoding example for two 12bits signals

[27] The 10nF output capacitor included in the SMP-3 package needs to be taken into account in the capacitance limit.
[28] If the total load current at the output is high enough to trigger the current limit protection, then the slopes will be determined by the maximum output current drive of around 15mA (typical value).
[29] For voltage regulated mode [4.5, 5.5] V and for Battery usage [6, 18] V
[30] See SENT_REPORT_MODE_ANA parameter in in section 12.
[31] See section 11.3.7

11.3.2. Sensor message frame contents

The SENT output of MLX90423 transmits a sequence of data nibbles, according to the Table 26.

Description	Symbol	Min	Typ	Max	Unit	Description
Clock tick time	Tick Time	-	3	-	µs	Normal SENT
Number of data nibbles	Xdn	-	6	-		
Frame duration	Npp	154		270	ticks	No pause pulse [32]; 1 angle per frame
	Ppc	282 310		[33]	ticks	With pause pulse [32]; 1 angle per frame With pause pulse [32]; 2 angles per frame
Sensor type [34]			A.1 A.3			Dual Throttle Position sensors Single Secure sensors

Table 26 SENT Protocol Frame Configuration

11.3.3. SENT Format Option

11.3.3.1. H.4 Single Secure Sensor Frame Format

The default SENT format option of MLX90423 is followed by Single Secure Sensor. The MLX90423 SENT transmits a sequence of data nibbles; according the format defined in SAE J2716 appendix H.4. The frame contains 12-bit angular value, an 8-bit rolling counter and an inverted copy of the most significant nibble of angular value.

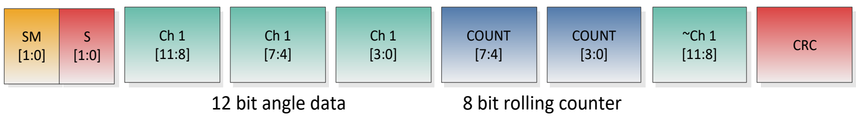


Figure 20 H.4 Single Secure Sensor Frame Format

11.3.3.2. H.1 Dual Throttle Position Sensor Frame Format

The optional SENT format option of MLX90423 is followed by Dual Throttle Position Sensor. The MLX90423 SENT transmits a sequence of data nibbles; according the format defined in SAE J2716 appendix H.1. The frame contains 12-bit angular value and a configurable 12-bit data channel [35].

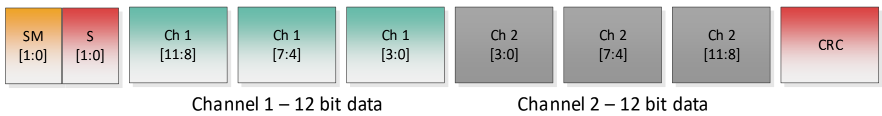


Figure 21 H.1 Dual Throttle Position Sensor Frame Format

11.3.4. Start-up behaviour

The circuit will send initialisation frames once digital start-up is done but angle measurement initialisation sequence is not yet complete. These initialisation frames content can be chosen by user with the following option:

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

Table 27 Initialization Frame Content Definition

[32] *See PROTOCOL parameter in section 12.*
[33] *Maximal values are limited by the SAE J2716 standard and not displayed in this table.*
[34] *See SENT_FC_FORMAT parameter in section 12.*
[35] *See SENT_FAST_CHANNEL_2 parameter in section 12 for the configuration of the 12-bit data channel 2*

11.3.5. Output configuration

In SENT mode, the MLX90423 can be configured in open drain mode, normal push-pull mode or 6-bit DAC mode [36].

The output resistive load, e.g. the external pull-up or pull-down resistor should be carefully selected [37], because the MLX90423 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, e.g. parameters $V_{satD\_lopp}/V_{satD\_hipp}$ in Table 10. In principle, the values in Table 10 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. The maximum output resistive load value should be less than 55kΩ to avoid unexpected impact from leakage current.
- Furthermore, the output capacitance should also be properly chosen, together with the output resistive load to correspondingly match the application, to allow appropriate time constant for the transmission of the SENT signal.

11.3.6. SENT Output Nibble configuration

The SENT protocol allows to either fix the number of ticks for the high time or 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	High/low time configuration
0	Fixed high time (7 ticks)
1	Fixed low time (5 ticks)

Table 28 SENT Nibble configuration (high/low times)

11.3.7. Serial Message (Slow Channel)

Serial Message is transmitted sequentially in bit number 3 and 2 of Status and Serial Communication nibble pulse (see Figure 22).

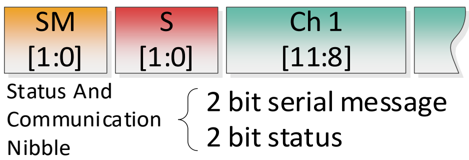


Figure 22 SENT Status and Serial Message Nibble

SERIAL_CONFIG parameter allows to enable/disabled the Serial Message (see Table 29)

SERIAL_CONFIG	Descriptions
0	Serial Message is disabled
1	Serial Message is enabled

Table 29 Serial Message configuration

According to the standard: SM[0] contains a 6bits CRC followed by a 12-bits data and SM[1] contains a 8-bit ID. 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.

---

[36] *See ABE_OUT_MODE parameter in section 12 and section 14.1 for the HW backend-output-amplifier mode selection.*
[37] *See section 16.*

Enhanced serial message with 12-bit data and 8-bit ID is used (SAE J2716 APR2016 5.2.4.2, Figure 5.2.4.2-2).

11.3.7.1. Serial Message data sequence

Correspondence between 8-bit ID and message content is defined in Table 30. By default, an Enhanced Standard sequence consisting of a cycle of 24 data is transmitted. Enhanced Extended sequences can be enabled.

#	8-bit ID	Item	Source data
		Standard Sequence	
1	0x01	Diagnostic error code	Current status code from RAM
2	0x06	SENT standard revision	SENT_REV from the ROM (default value=0x4)
3	0x01	Diagnostic error code	Current status code from RAM
4	0x05	Manufacturer code	SENT_MAN_CODE from the ROM (default value=0x006)
5	0x01	Diagnostic error code	Current status code from RAM
6	0x03	Channel 1 / 2 Sensor type	SENT_SENSOR_TYPE from the ROM (default value=0x050)
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 [38]	
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
		Extended Data Sequence Field Norm ID and position [39]	
25, 33	0x01	Diagnostic error code	Current status code from RAM
26, 34	0x80	Field Strength	
		Extended Data Sequence Ramprobe ID and position [40]	

[38] *See SENT_SLOW_EXTENDED parameter in section 12.*
[39] *See SENT_SLOW_EXTENDED_FIELD parameter in section 12.*
[40] *See SENT_SLOW_EXTENDED_ RAMPROBE parameter in section 12.*

#	8-bit ID	Item	Source data
25, 27, 33	0x01	Diagnostic error code	Current status code from RAM
26, 28, 34	0x80	Ramprobe	

Table 30 SENT Enhanced Serial Message Standard and Extended Data Sequence

11.3.7.2. Diagnostic Error Code

The list of error and status messages transmitted in the Serial Message 12-bit data field when 8-bit ID is 0x01, is given in the Table 31.

- The error is one-hot encoded and therefore each bit is linked to one or several diagnostics. Only the first error detected is reported and serial message error code will not be updated until all the errors have disappeared. This mechanism ensures only one error at a time takes control of the error debouncing counter (see 14.5.2).
- The MSB acts as an error Flag when SENT_DIAG_STRICT is set. This bit will be high only when an error is present. This bit can be kept high even if no error is present (SENT_DIAG_STRICT = 0).
- SLOW_ERROR_REPORT_DISABLE parameter allows to disable the 12-bit diagnostic error code reporting, regardless of an error.

Bit Nb	12 Bit Data (hex)	Diagnostic	Comments [41]
0	0x801	GAINOOS	Magnetic Signal Conditioning Gain Clamping
1	0x802	FIELDTOOLOW	Fieldstrength is below defined low threshold [42]
2	0x804	FIELDTOOHIGH	Fieldstrength is above defined high threshold [43]
3	0x808	ADCCLIP	ADC Overflow Errors
4	0x810	ADC_test	ADC Conversion errors
5	0x820	SUP_UV_VDDA || SUP_OV_VDDA || SUP_UV_VS || SUP_OV_VS	Aggregation [44] Supply Voltage Monitors (V_{DEC} under voltage) Supply Voltage Monitors (V_{DEC} over voltage) Supply Voltage Monitors (V_{DD} under voltage) Supply Voltage Monitors (V_{DD} over voltage)
6	0x840	SUP_OV_V1V8	Supply Voltage Monitors (V_{DIG} over voltage)
7	0x880	ROCLIP	Magnetic Signal Conditioning Rough Offset Clipping check
8	0x900	OVERTEMP || ADCDROP	Aggregation [44] Overheating monitor Logical Monitoring of program sequence
9	0xA00	DSPOVERFLOW || HEBIAS || AFESELFTEST	Aggregation [44] DSP Overflow HE Bias Current Supply Monitor Magnetic Signal Conditioning Voltage Test Pattern
10	0xC00	N/A	
11	0x800	Extra Error Flag	Set to one if any error present (only when SENT_DIAG_STRICT = 1). Otherwise, always high.

Table 31 Diagnostic Error Code in Serial Message

[41] *See safety mechanism in section 15.2*
[42] *See DIAG_FIELDTOOLOWTHRES parameter in section 12 and section 14.5.4*
[43] *See DIAG_FIELDTOOHIGHTHRES parameter in section 12 and section 14.5.4*
[44] *With OR function*

12. End-User Programmable Items

Parameter	PSF values	Description	Default Values	#bits
GENERAL CONFIGURATION				
USER_ID[0..5]	2..10	User Id. Reference, see section 13	- [45]	8
MEMLOCK	70	Enable NVRAM write protection 0: Disabled 3: Enabled	0	2
SENSOR FRONT END				
GAINSATURATION	15	Gain saturation enable 0: No gain saturation 1: Gain clipped between GAINMIN and GAINMAX	0	1
GAINMIN	13	Virtual gain min	0	6
GAINMAX	14	Virtual gain max	64	7
SENSING_MODE	29	Sensing mode selection 0: (dBx/dBz), Linear w/stray field robustness 1: (dBx/dBy), 360° through shaft 3: (Bx/Bz), Linear Legacy	0	2
DIGITAL SIGNAL PROCESS				
DP	57	DSP discontinuity point New Angle = Angle - DP	0	13
CW	23	Magnet rotation direction, see section 14.2.1 0: Counter-Clockwise 1: Enable Clockwise	0	1
FILTER	30	FIR filter bandwidth selection, see 14.4 00: No filter 01: FIR11 10: FIR1111 11: Do not use	0	2
WORK_RANGE_GAIN	19	Post DSP Gain stage applied just before linearization	16	8
LNR_X[0..15]	32..43 136 138 140 142	X coordinate for 16 pts linearization	-	16
LNR_Y[0..15]	44..55 137 139 141 143	Y coordinate for 16 pts linearization Default SENT output = [1..4088] LSB_{12}	-	16
USEROPTION _SCALING	24	Enables the output scaling x2 after linearization 0: [0..100%] 1: [-50%..150%]	0	1
OUTSLOPE_HOTCOLD _EN	124	Enable OUTSLOPE_[HOT, COLD] instead of USER_ID[4,5]	0	1
OUTSLOPE_COLD	9	Slope coefficient at cold of the programmable temperature-dependent offset	0	8
OUTSLOPE_HOT	11	Slope coefficient at hot of the programmable temperature-dependent offset	0	8
CLAMPLOW	22	Low clamping value of angle output data	1	12

[45] *See section 13*

Parameter	PSF values	Description	Default Values	#bits
CLAMPHIGH	28	High clamping value of angle output data	4088	12
DIAGNOSTICS				
DIAG_GLOBAL_EN	74	Diagnostics global enable. **Do not modify!**	1	1
DIAG_FIELDTOOLOW THRES	62	Diagnostic threshold for too-low field detection	3	4
DIAG_FIELDTOOHIGH THRES	63	Diagnostic threshold for too-high field detection	14	4
EXTENDED_RANGE_T HRESHOLD	64	Extended range threshold for clamping the output signal Output =CLAMPHIGH, if the DIAG_FIELDTOOLOWTHRES < Field strength < EXTENDED_RANGE_THRESHOLD	0	4
DIAG_DEBOUNCE_ST EPDOWN	71	Diagnostic debouncing step-down time used for recovery time setting (cannot be higher than DIAG_DEBOUNCE_THRESH)	1	2
DIAG_DEBOUNCE_ST EPUP	72	Diagnostic debouncing step-up time used for hold time setting	1	2
DIAG_DEBOUNCE_TH RESH	73	Diagnostic debouncing threshold	1	3
OUT_DIAG_HIZ_TIME	106	Transient failure recovery time when a transient digital failure is detected. Timeout = (5 + OUT_DIAG_HIZ_TIME) * 1ms	10	5
COLD_SAFE_STARTUP _EN	68	0: Normal start-up after power-on reset 1: Safe start-up after power-on reset: all diagnostics are run once before starting transmission	0	1
OUT_ALWAYS_HIGHZ	69	Forces the OUT pin in high-Z mode 0: OUT will transmit data 1: OUT will permanently forced to high-Z mode.	0	1
		ANALOG Diagnostics		
DAC_REPORT_MODE _ANA	113	Defines the DAC state in analog-fault report mode: 0x0: Output = high-Z 0x2: Output = 0 constant 0x3: Output = V_{DD} constant	2	2
		PWM Diagnostics		
PWM_REPORT_MOD E_ANA	117	Defines the error code within PWM frame in analog fault report mode, see section 14.5.5 0: PWM %DC value 1: HiZ	0	1
PWM_DC_FIELDTOOL OW_BAND	17	PWM diagnostic band for analog fault reporting (FIELDTOOLOW) see section 14.5.5 0: Lower band (below CLAMPLOW) 1: Upper band (above CLAMPHIGH)	0	1
PWM_DC_FAULT_BA ND	123	PWM diagnostic band for analog fault reporting (<>FIELDTOOLOW) see section 14.5.5 0: Lower band (below CLAMPLOW) 1: Upper band (above CLAMPHIGH)	0	1
PWM_DC_FIELDTOOL OW_VAL	65	PWM % DC fault value for analog fault reporting (FIELDTOOLOW) see section 14.5.5	2	3
PWM_DC_FAULT_VA L	115	PWM % DC fault value for analog fault reporting (<>FIELDTOOLOW) see section 14.5.5	0	3
		SENT Diagnostics		
SENT_REPORT_MODE _ANA	112	Defines the error message within SENT frame in diagnostic mode, see section 14.5.6	0	2

Parameter	PSF values	Description	Default Values	#bits
		0x0: Status bit S0 is set 0x1: SENT status bit S0 is set and the output signal is set to the error code 0xFFF (d4095) 0x2: Status bit S0 is set and the redundant nibble is invalid Refer to the Safety Manual		
SLOW_ERROR_REPORT_DISABLE	121	Disable Diagnostic error code in Serial Message data 0: Enabled 1: Disabled	0	1
OUTPUT CONFIGURATIONS				
PROTOCOL	108	Selection of the output protocol, see section 14.1.1 0: Analog output 1: PWM 2: SENT without pause 3: SENT with pause	3	2
ABE_OUT_MODE	89	HW backend-output-amplifier mode selection in normal mode (outside diagnostic report mode), see section 14.1.1 0: 12-bit DAC (Analog) 1: Open-drain-Nmos (PWM/SENT) 2: Open-drain-Pmos (PWM/SENT) 3: Push-Pull (PWM/SENT) 4: 6-bit DAC (PWM/SENT w/ pulse shaping) (non-ratiometric output at 5V)	4	3
RAMPROBE_EN	110	RAM-probe enable in Analog/PWM. 0: Disabled 1: Enables Ram Probe on output.	0	1
RAMPROBE_PTR	128	Address of the RAM field to be probed See SENT_FAST_CHANNEL_2 for SENT protocol or RAMPROBE_EN for PWM/Analog protocols	0	16
RAMPROBE_ROTATE	109	Right-shifting the RAM field in RAM-probe mode 0: LSB 12 1: MSB12	0	1
PTC COMMUNICATION				
WARM_TRIGGER_LONG	125	Add delay for PTC entry level	0	1
WARM_ACT_HIGHV	26	Supply voltage mode selection 0: Voltage regulated mode 1: Battery usage	0	1
ROUT_LOW	107	Select output impedance for PTC Communication	1	1
MUPET_ADDRESS	111	PTC address for which the slave will answer	0	2
PWM PROTOCOL OPTIONS				
T_FRAME_PWM	82	(Output frame period +50) x 4 us, see section 14.1.3	N/A	12
PWM_POL	60	Invert the PWM waveforms, see section 14.1.3 0: The low-state duration is proportional to the data to transmit 1: The high-state duration is proportional to the data to transmit	0	1
SENT PROTOCOL OPTIONS				
		SENT general configuration		
SENT_FC_FORMAT	90	SENT frame format option 0: Format H.1 (A.1, Two 12-bit Fast Channels)	1	1

Parameter	PSF values	Description	Default Values	#bits
		1: Format H.4 (A.3, Single secure sensor)		
NIBBLE_PULSE_CONFIG	59	Sets the SENT nibble high/low-time configuration: 0: 7 fixed ticks high time 1: 5 fixed ticks low time	1	1
SENT_LEGACY_CRC	75	Enable legacy CRC calculation 0: The CRC recommended by SAE J2716 is calculated	0	1
SENT_INIT_GM	76	Initialization frame data until first valid data 0: 0x000 1: 0xFFF(d4095) error code	0	1
		SENT with pause		
T_FRAME_SENT	85	SENT with pause pulse period in ticks of 3us (SENT frame period= T_FRAME_SENT +155 ticks)	155	11
TWO_ANGLES_FRAME	16	Enable 2 angle measurements per SENT frame (SENT with pause pulse only)	1	1
T_SYNC_DELAY	20	SENT - ADC synchronization delay (SENT with pause pulse only)	150	8
		H.1 Dual Throttle Position Sensor Frame Format		
SENT_FAST_CHANNEL_2	77	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	0	2
		SENT Serial Message		
SERIAL_CONFIG	66	Serial Message configuration 0: Serial Message is disabled 1: Serial Message is enabled	1	1
SENT_SLOW_EXTENDED	116	Serial Message Sequence definition 0: Standard Serial Message 1: Extended Serial Message	0	1
SENT_CHANNEL_X[1..2]	92; 93	Part of the Standard Serial Message: Fast-channel 1 – X[1..2]	0	12
SENT_CHANNEL_Y[1..2]	95; 99	Part of the St``andard Serial Message: Fast-channel 1 – Y[1..2]	0	12
SENT_SENSOR_[1..4]	97..104	Part of the Standard Serial Message: Sensor ID[1..4]	0	12
SENT_OEM_[1..4]	79..88	Part of the Extended Serial Message: OEM code[1..4]	0	12
SENT_SLOW_EXTENDED_FIELD	119	Enable field norm the Extended Serial Message 0: disable 1: enable	0	1
SENT_SLOW_EXTENDED_RAMPROBE	120	Enable ramprobe in the Extended Serial Message 0: disable 1: enable	0	1
SENT_DIAG_STRICT	58	Option of Error Code reporting in the SENT slow message, see 14.5.6	0	1

Table 32 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.

13. End-User Identification Items

Parameter	Description	Default	
		Values	#bits
USER_ID0	Bin1 from production test Can be used by end-user to program information to keep traceability	1	8
USER_ID1	Reserve for end-user to program information to keep traceability	0	8
USER_ID2		5	8
USER_ID3		1	8
USER_ID4		N/A	8
USER_ID5		0	8
MLX_ TEST_STATUS	Bin 1 verification bit	1	1
MLX_ID0	X-Y position on the wafer (8 bit each)	MLX	16
MLX_ID1	Wafer ID [15:11] Lot ID [10: 0]	MLX	16
MLX_ID2	Lot id code [16:11] Fab ID (4 bits) Test Database ID (6 bits)	MLX	16

Table 33 Melexis and Customer ID fields description

User identification numbers (48 bits) are freely usable by customers for traceability purpose. Other IDs are read only.

14. Description of End-User Programmable Items

14.1. Output modes

14.1.1. Protocol

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

PROTOCOL	Description
0	Continuous synchronous angle acquisition, analog output (DAC)
1	Continuous asynchronous angle acquisition, PWM
2	Continuous asynchronous angle acquisition, SENT without pause
3	Continuous synchronous angle acquisition, SENT with pause

Table 34 Protocol selection

14.1.2. Output stage mode

The parameter ABE_OUT_MODE defines the output stage mode (outside of fail-safe state) in application.

ABE_OUT_MODE	Description	Comments
0	12-bit DAC (Analog)	Ratiometric output
1	Open-drain NMOS (PWM/SENT)	Requires to connect a pull-up resistor on the OUT line
2	Open-drain PMOS (PWM/SENT)	Requires to connect a pull-down resistor on the OUT line
3	Push-Pull (PWM/SENT)	
4 [46]	6-bit DAC (PWM/SENT w/ pulse shaping)	Non-ratiometric output; 5V To be preferred for EMC performance

Table 35 Output stage mode selection

14.1.3. PWM Protocol

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

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

The PWM frequency is selected in the range [100, 5000] Hz by the T_FRAME_PWM parameter (12bits), defining the period time in the range [0.20, 16.38] ms.

$$T_{PWM} = \frac{4}{10^6} \times (T\_FRAME\_\text{PWM} + 50)$$

The PWM period is subject to the same tolerances as the main clock (see Table 11).

14.2. Output Transfer Characteristic

Figure 23 gives the simplified digital signal processing chain from the position after ADC to the output. This section explains the compensation capability of the IC. The remainder of this chapter explains every parameter in more detail.

[46] *In case the 6-bit DAC output stage mode is used when the protocol selected is PWM, then NV_NIBBLE_PULSE_CONFIG shall be set to 0x0.*

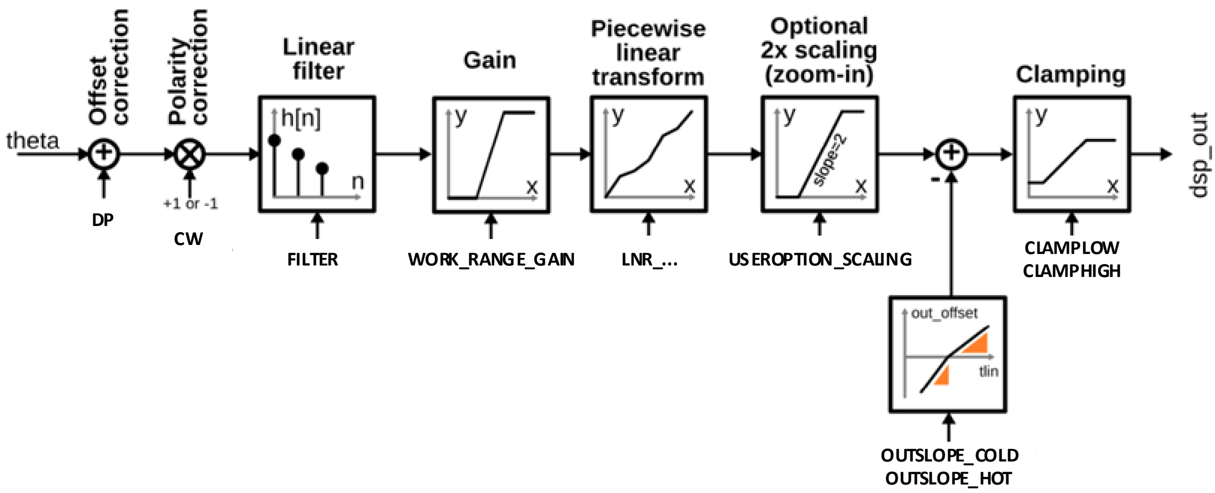


Figure 23 Simplified Digital Signal Process Chain from ADC to the Output of MLX90423

Parameter	Value	Unit
DP	0 to 359.9999	deg.
CW	0 → counter clockwise 1 → clockwise	LSB
LNR_Xx With x= 0 to 15	0 to 100	%
LNR_Yx With x= 0 to 15	-50 to 150	%
CLAMPLOW	0 … 100	%
CLAMPHIGH	0 … 100	%

Table 36 Output linearization and clamping parameters

14.2.1. 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 parameter is used as reference for all the angular measurements.

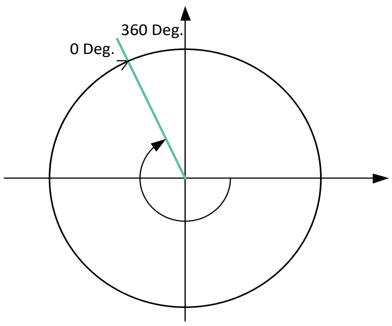


Figure 24 Discontinuity Point Positioning

14.2.2. CW (Clockwise)

The CW parameter defines the magnet rotation direction.

CW	Value
Clockwise	1
Counter Clockwise	0

Table 37 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 pin order direction for the SMP-3 package

Clockwise if defined by the reverse pin order. Refer to the package's drawings in section 19.

14.2.3. 16-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 MLX90423 16-pts transfer function from the digital angle value to the output voltage is described in Figure 25.

Beyond the start and end points, the slope shall be extrapolated based on the last and last-before-one point. Sixteen [47] calibration points [LNR_X0 to 15, LNR_Y0 to 15] divide the transfer curve into 17 segments. Each segment is defined by 2 points and the values in between is calculated by linear interpolation.

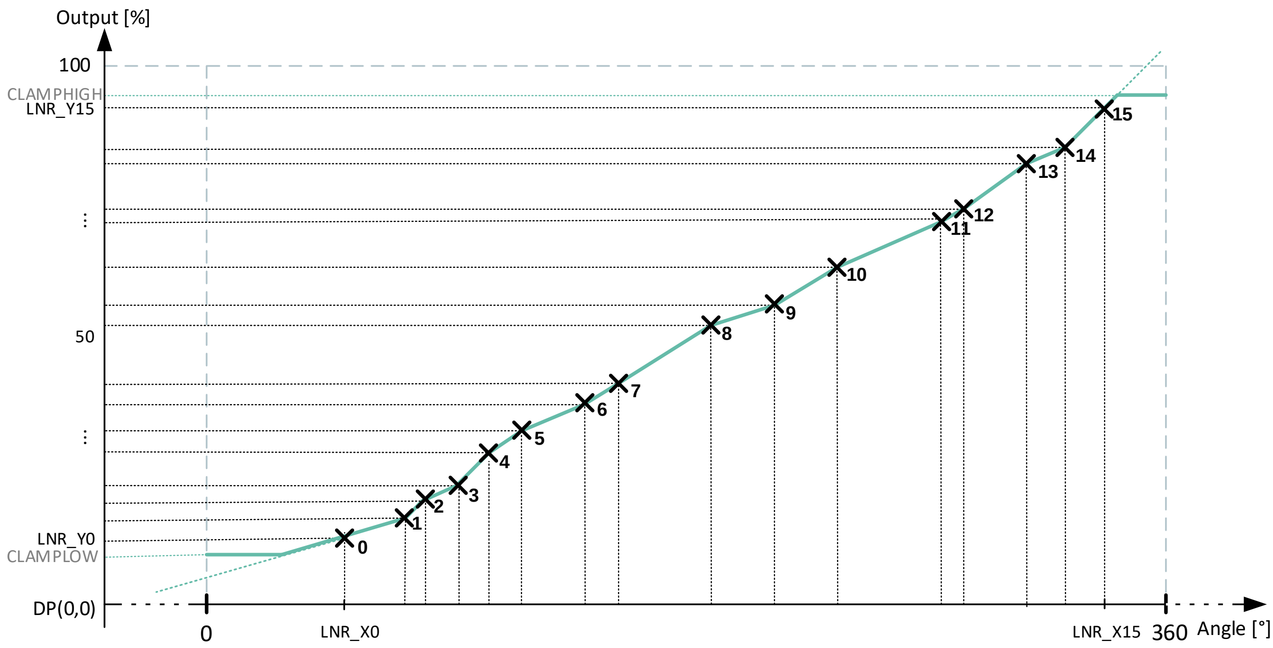


Figure 25 16-pts Linearization Parameters Description

14.2.4. 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 defines 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:

[47] *The number of linearization points is reduced in case the patch area is needed.*

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

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.

Following tables give some values as example:

WORK_RANGE_GAIN	Factor	Range (w)	θmin	θmax
0x10	1	360°	0°	360°
0x20	2	180°	90°	270°
0x40	4	90°	135°	225°
0xFF	15.94	22.6°	168.7°	191.3°

Table 38 Working range defined by WORK_RANGE_GAIN parameter

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

14.2.5. Enable scaling Parameter

This parameter enables to double the scale of Y coordinates linearization parameters, see the Table 39.

USEROPTION_SCALING	LNR_Y min value	LNR_Y max value
0	0%	100%
1	-50%	150%

Table 39 USEROPTION_SCALING parameter

14.2.6. Thermal OUTSLOPE offset correction

Two parameters, OUTSLOPE_HOT and OUTSLOPE_COLD, are used to add a temperature dependent offset. This feature is enabled by the parameter OUTSLOPE_HOTCOLD_EN.

The MLX90423 uses its internal linearized temperature to compute the offset shift as depicted in the Figure 26.

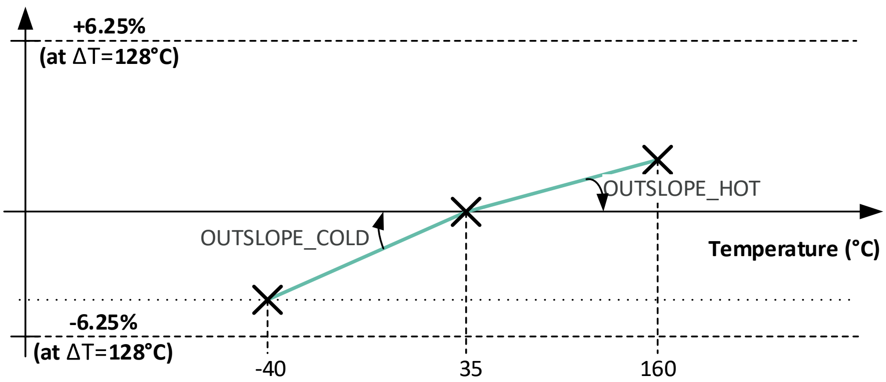


Figure 26 Temperature compensated offset

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 12bit output scale for a temperature difference of 128°C. The added thermal offset varies with temperature following the equations below.

The two thermal coefficients are encoded in signed two's complement 8bit format (-128 to 127) and defined separately below 35°C (OUTSLOPE_COLD) and above 35°C (OUTSLOPE_HOT).

If IC internal temperature is higher than 35°C then:

$$\theta_{Tcomp} = \theta_{out} - \Delta T \cdot \mathrm{OUTSLOPE\_HOT}$$

If IC internal temperature is lower than 35°C then:

$$\theta_{Tcomp} = \theta_{out} - \Delta T \cdot \mathrm{OUTSLOPE\_COLD}$$

14.2.7. CLAMPING Parameters

The clamping levels are two independent values to limit the output voltage range.

- The CLAMPLOW parameter adjusts the minimum output level.
- The CLAMPHIGH parameter sets the maximum output.

Both parameters have 12 bits of adjustment. The values are encoded in fractional code, from 0% to 100%.

14.3. Sensor Front-End

Parameter	Value
SENSING_MODE	[0, 3]
GAINMIN	[0 to 63]
GAINMAX	[0 to 127]
GAINSATURATION	[0, 1]

Table 40 Sensing Mode and Front-End Configuration

14.3.1. 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 table below. This 2-bit value selects the first (B1) and second (B2) field components according to the Table 41 content.

SENSING_MODE	B1	B2	Angular
0	X	Z	Linear w/stray field robustness (dual-disk IMC) (dBx/dBz)
1	X	Y	360° through shaft (dual-disk IMC) (dBx/dBy)
2			Reserved, do not use
3	X	Z	Linear legacy (dual-disk IMC) (Bx/Bz)

Table 41 Sensing Mode Description

14.3.2. GAINMIN and GAINMAX Parameters

GAINMIN and GAINMAX define the thresholds on the gain code outside which the fault “GAIN out of Spec.” is reported. If GAINSATURATION is set, then the virtual gain code is saturated at GAINMIN and GAINMAX, and no Diagnostic fault is set since the saturations applies before the diagnostic is checked.

14.4. Filtering

The MLX90423 features a FIR filter mode controlled with DSP_FILTER parameter.

DSP_FILTER = 0 corresponds to no filtering. The transfer function is described by:

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

This filter characteristic is given in the Table 42.

DSP_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

DSP_FILTER	0	1	2
Efficiency RMS (dB)	0	3.0	6.0

Table 42 FIR Filter Characteristics

14.5. Programmable Diagnostics Settings

14.5.1. Diagnostics Global Enable

DIAG_GLOBAL_EN should be kept to its default value (1) to retain all functional safety abilities of the MLX90423. This feature shall not be disabled.

14.5.2. 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 section 12 should be used.

Parameter	Description
DIAG_DEBOUNCE_STEPDOWN	Decrement values for debouncer counter. The counter is decremented once per evaluation cycle when no analog fault is detected.
DIAG_DEBOUNCE_STEPUP	Increment value for debouncer counter. The counter is incremented once per evaluation cycle when an analog fault is detected.
DIAG_DEBOUNCE_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 43 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 14.5.6 for SENT error message codes and see section 14.5.5 for PWM error reporting). 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 section 15.3. The reporting and recovery time are defined in the Table 44 (valid for DIAGDEBOUNCE_THRESH ≠ 0).

Parameter	Min	Max
Reporting Time	$DCT \cdot \left(\left\lceil \frac{\mathrm{THRESH}}{\mathrm{STEPUP}} \right\rceil - 1\right)$	$DCT \cdot \left(\left\lceil \frac{\mathrm{THRESH}}{\mathrm{STEPUP}} \right\rceil\right)$
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 44 Diagnostic Reporting and Recovery times

14.5.3. Over/Under Temperature Diagnostic

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

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

ROM_DIAG_TEMP_THR_LOW/HIGH are encoded on 8-bit unsigned values with the following relationship towards T_{LIN}.

$$ROM\_DIAG\_TEMP\_THR\_(LOW/HIGH) = \frac{T_{LIN}}{16}$$

T_{LIN} is encoded using the SENT standard for temperature sensor. One can get the physical temperature of the die using following formula:

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

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	T_{LinErr}	-8	-	8	°C	from -40 to 160°C
T_{LIN} linearity error	T_{LinErr}	-2	-	6	°C	from 35 to 125°C
Low temperature threshold	ROM_DIAG_TEMP_THR_LOW	-	8	-	LSB8	Fixed value, corresponds to -57°C
High temperature threshold	ROM_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 45 Linearized Temperature Sensor characteristics

14.5.4. 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. Field strength value is optionally available in SENT fast channel 2.

14.5.5. PWM diagnostic reporting

PWM diagnostic reporting can be configure separately in case of Analog fault or Field strength too low.

14.5.5.1. Analog fault

- The parameter PWM_REPORT_MODE_ANA defines how the fault is reported

PWM_REPORT_MODE_ANA	Description
0	PWM - config 2 (PWM signal in fault band) (default) See PWM_DC_XXX parameters for the fault band definition
1	PWM - config 1 (HiZ)

Table 46 Linearized Temperature Sensor characteristics

When reporting an analog fault, the parameter PWM_DC_FAULT_BAND and PWM_DC_FAULT_VAL can be used to specify the 12-bits output level:

- The parameter PWM_DC_FAULT_BAND defines the BAND within which the output level is.

PWM_DC_FAULT_BAND	Description
0	The Low band [0 to CLAMPLOW] is selected
1	The High band [CLAMPHIGH to 4095] is selected

Table 47 Output level band selection in case of an analog fault

- The parameter PWM_DC_FAULT_VAL selects a value in the specified band

$$\text{Low band output level} = PWM\_DC\_FAULT\_VAL \cdot \left(\frac{CLAMPLOW}{8}\right)$$

$$\text{High band output level} = 4095 - PWM\_DC\_FAULT\_VAL \cdot \left(\frac{CLAMPHIGH}{8}\right)$$

14.5.5.2. Field strength too low

Correspondingly, the parameters PWM_DC_FIELDTOOLOW_BAND and PWM_DC_FIELDTOOLOW_VAL can be used to specify the 12-bits output level in case of a field strength too low event.

14.5.6. SENT diagnostic reporting

- The parameter SENT_REPORT_MODE_ANA defines how the fault is reported.

SENT_REPORT_MODE_ANA	Description
0	Status bit S0 is set
1	Status bit S0 is set and the output signal is in a fault band (default). SENT fault value is generated by SW and is: Fault_code = 0xFF9 + ROM_DIAG_FAULT_CODE.
2	Status bit S0 is set and the redundant nibble is inverted

Table 48 SENT diagnostic reporting

- The parameter SENT_DIAG_STRICT defines the option of analog fault reporting in the SENT slow message.

SENT_DIAG_STRICT	Description
0	bit 11 of the diagnostic SENT serial field is always set to '1' (default).
1	bit 11 of the diagnostic SENT serial field is set to '1' only when a fault is reported.

Table 49 SENT option of analog fault reporting

15. Functional Safety

15.1. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90423 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.

15.2. Safety Mechanisms

The MLX90423 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_GLOBAL_EN = 0 (see section 14.5.1. This option should not be used in application mode!

Table 50 Self Diagnostic Legend

Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Support. Func.	Module & Package	Reporting mode	At startup	DIAG EN
Signal-conditioning (AFE, External Sensor) Diagnostic	●	●				●			
Magnetic Signal Conditioning Voltage Test Pattern	●	○	○				ANA	NO	●
Magnetic Signal Conditioning Rough Offset Clipping check	●		○				ANA	NO	●
Magnetic Signal Conditioning Gain Monitor	●		○			●	ANA	YES	●
Magnetic Signal Conditioning Gain Clamping	●		○			●	ANA	YES	●
Mag. Sig. Cond. Failure control by the chopping technique	●						n/a	YES	
A/D Converter Test Pattern		●					ANA	NO	●
ADC Conversion errors & Overflow Errors		●					ANA	YES	●
ADC Common Mode monitor		●					ANA	YES	
Flux Monitor (Rotary mode)	●	○				●	ANA	NO	●
HE Bias Current Supply Monitor	●						ANA	NO	●
Digital-circuit Diagnostic		○	●		○				
RAM Parity, 1 bit per 16 bits word, ISO D.2.5.2			●				DIG	YES	●
ROM Parity, 1 bit per 32 bits word, ISO D.2.5.2			●				DIG	YES	●
NVRAM 16 bits 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	●
DSP Test Pattern (atan2)			●		○		DIG	NO	●
Critical ports monitoring			●				DIG	NO	●
ADC data adder test – range check		○					DIG	YES	●
SENT Fall Collision detection (SENT pulse generator)			●				DIG	NO	●
DSP Overflow	○	○	●				ANA	n/a	●

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 [48]				●			n/a	n/a	
System-level diagnostic					●	●			
Supply Voltage Monitors (V_{DEC} under and over voltage, V_{DD} under voltage, V_{DIG} over voltage)					●	●	ANA	YES	●
External Supply Overvoltage Monitor (V_{DD} over voltage)					●	●	High-Z	YES	
Digital Supply under-voltage monitor					●	●	DIG	YES	
Overheating monitor	○	○	○	○	○	●	ANA	YES	●
Warning/Reporting Mechanisms									
HW Error Controller			●	●	●		DIG	YES	
HW Fail-safe mode with timeout			●	●	●		DIG	YES	
Analog-type Error management	●	●			●		ANA	NO	●
Safe start-up mode			●		●		DIG	n/a	
Mechanisms executed at start-up only									
RAM March-C HW Test at start-up			●		●		DIG	YES	

Table 51 MLX90423 List of Self Diagnostics with Characteristics

[48] *Only for SENT H.4 format*

15.3. Fault Handling Time Interval

The Fault Handling Time Interval (FHTI) is the time interval between the occurrence of a fault causing a malfunction in the MLX90423 and the end of the last frame preceding the transition into the defined fail-safe state. The following equation is valid for any diagnostic:

$$FHTI \ = max[(DCT\_ana + 2 \times T_{FRAME}), (DC\mathrm{T\_dig})]$$

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 MLX90423, including cycle times, execution times and reporting times for every implemented safety mechanism.

16. Recommended Application Diagrams

16.1. Wiring in SOIC-8 Package

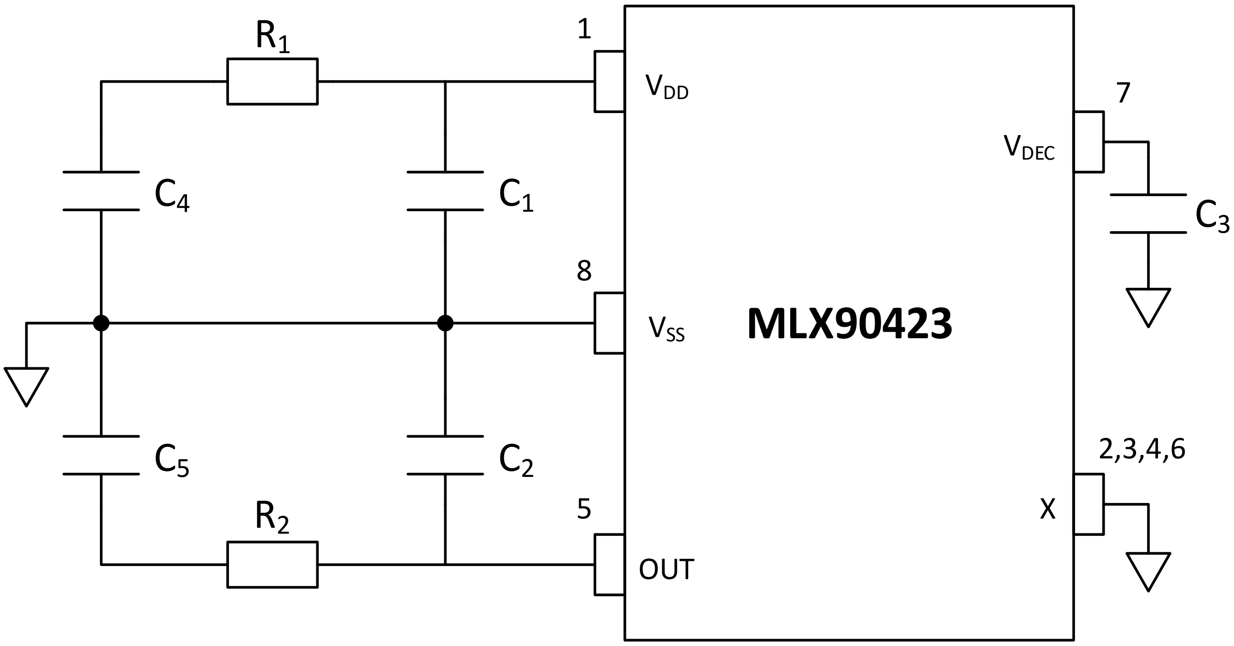


Figure 27 Recommended wiring for SOIC-8 package

Component	min	Typ	Max	Unit	Remark
C_1	100	220	-	nF	Close to the IC pin
$C_2(C_L)$	-	10	100	nF	Analog
	-	10	22		PWM
	-	10	22		SENT
C_3	100	100	220	nF	Close to the IC pin
C_4	-	-	1	nF	Close to the connector
C_5	-	-	1	nF	Close to the connector
R_1	-	0	10	Ω	
R_2	-	0 [49]	-	Ω	

Table 52 Recommended Values for SOIC-8 Package

[49] *Normally external PI filters to improve EMC as recommended by the SENT standard are not needed. As the SENT product includes sophisticated SENT signal shaping. Extra PI filtering may bring the signal slopes out of the SENT specified range.*

16.2. Wiring in TSSOP-16 Package

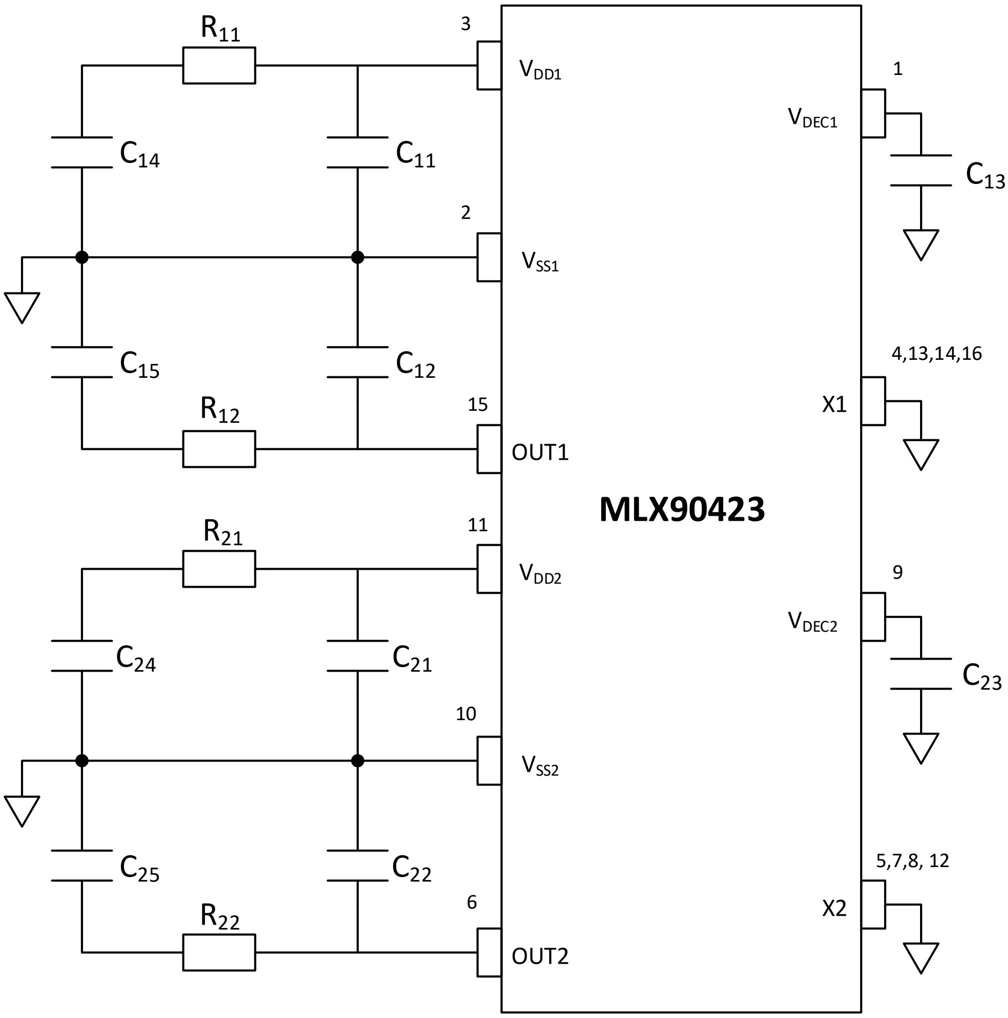


Figure 28 Recommended wiring for TSSOP-16 package (dual die)

Component	min	Typ	Max	Unit	Remark
C_{x1}	100	220	-	nF	Close to the IC
$C_{x2}(C_L)$	-	10	100	nF	Analog
	-	10	22		PWM
	-	10	22		SENT
C_{x3}	100	100	220	nF	Close to the IC
C_{x4}	-	-	1	nF	Close to the connector
C_{x5}	-	-	1	nF	Close to the connector
R_{x1}	-	0	10	Ω	
R_{x2}	-	0 (49)	-	Ω	

Table 53 Recommended Values for TSSOP-16 Package

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

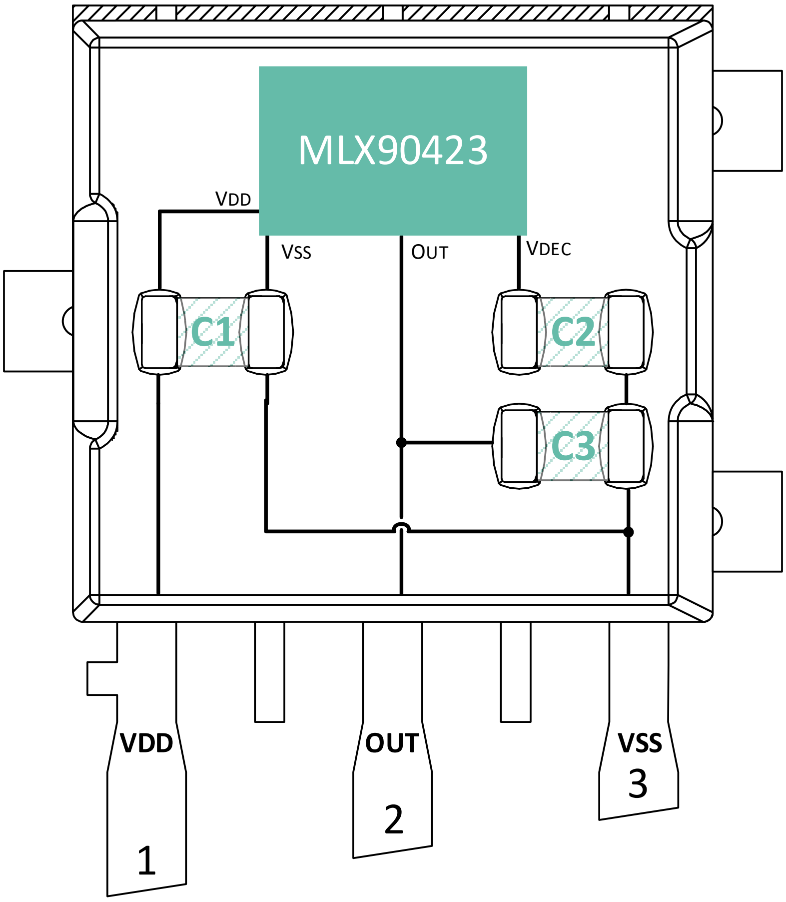


Figure 29 Internal wiring of the MLX90423 in SMP-3

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

Table 54 SMP-3 capacitors configuration

17. Standard information regarding manufacturability of Melexis products with different soldering processes

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to 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.

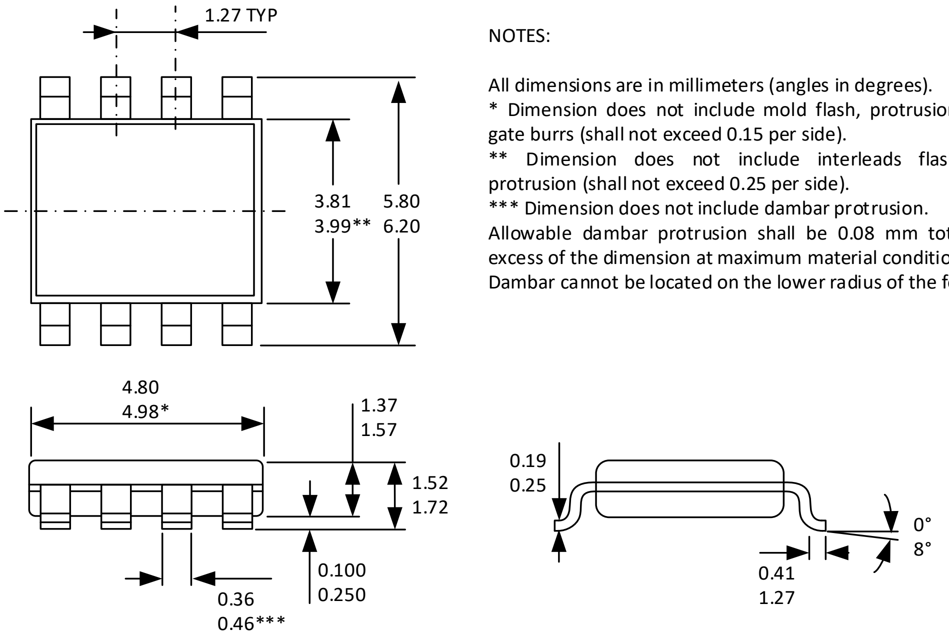
18. ESD Precautions

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

19. Package Information

19.1. SOIC-8- Package

19.1.1. SOIC-8- 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.

Figure 30 SOIC-8 Package Outline Dimensions

19.1.2. SOIC-8- Pinout and Marking

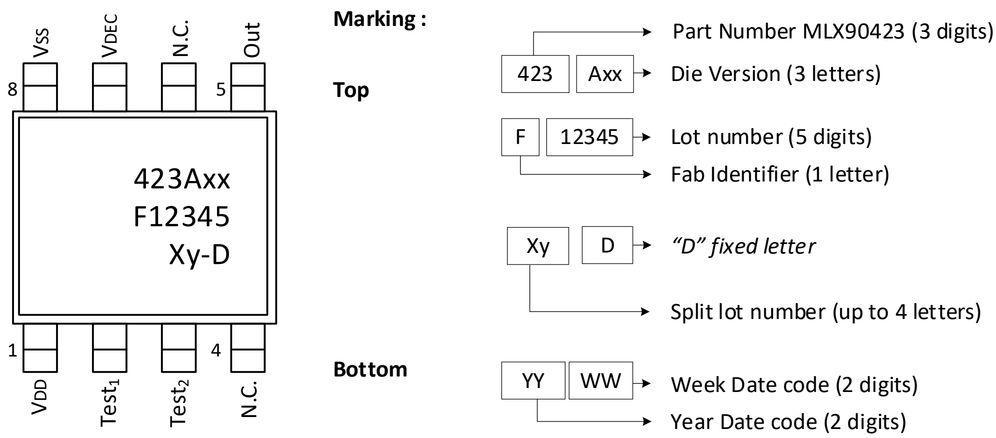


Figure 31 SOIC-8 Package Pinout and Marking

19.1.3. SOIC-8- Sensitive spot positioning

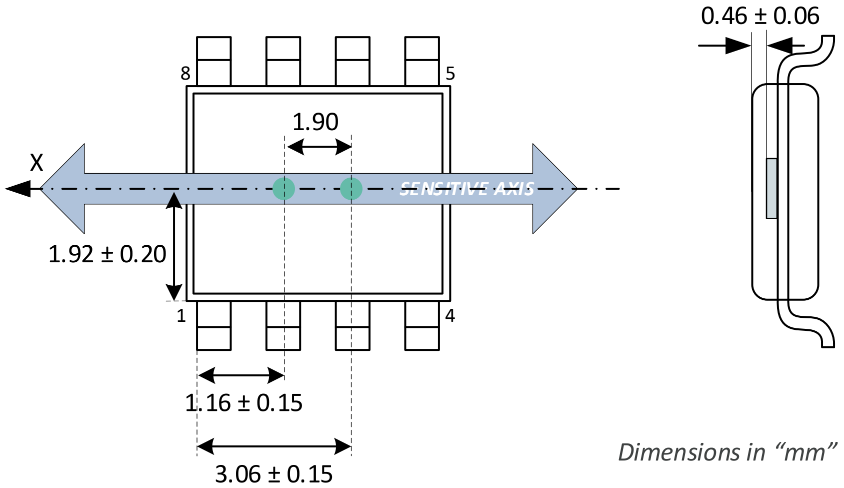


Figure 32 SOIC-8 Package Sensitive Spot Position

19.1.4. SOIC-8- Angle detection

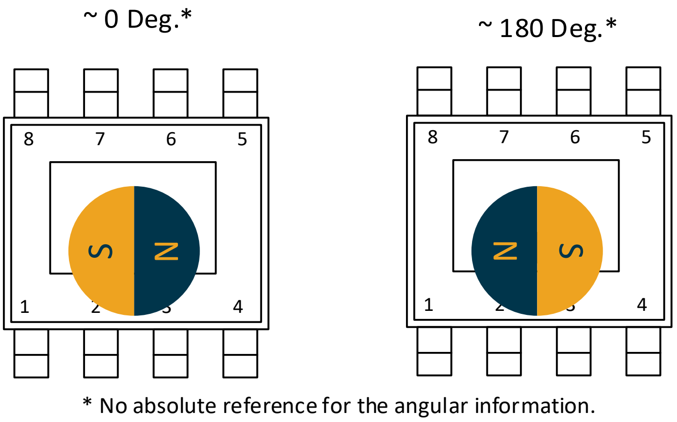
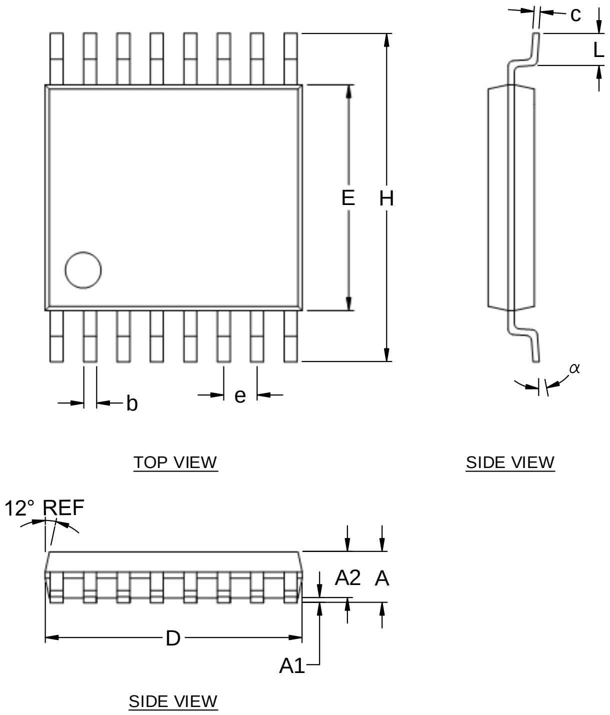


Figure 33 SOIC-8 Package Angle Detection

The MLX90423 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. (which can be fixed in the application through the discontinuity point).

19.2. TSSOP-16- Package

19.2.1. TSSOP-16- Package Dimensions



SYMBOL	MINIMUM	MAXIMUM
A	– – –	1.10
A1	0.05	0.15
A2	0.85	0.95
D	4.90	5.10
E	4.30	4.50
H	6.40 REF	
L	0.50	0.75
b	0.19	0.30
c	0.09	0.20
e	0.65 BSC	
α	0°	8°

NOTE :

1. ALL DIMENSIONS IN MILLIMETERS (mm) UNLESS OTHERWISE STATED.
2. DIMENSION D DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS OF MAX 0.15 mm PER SIDE.
3. DIMENSION E DOES NOT INCLUDE INTERLEADS FLASH OR PROTRUSIONS OF MAX 0.25 mm PER SIDE.
4. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION OF MAX 0.08 mm.

Figure 34 TSSOP-16 Package Outline Dimensions

19.2.2. TSSOP-16- Pinout and Marking

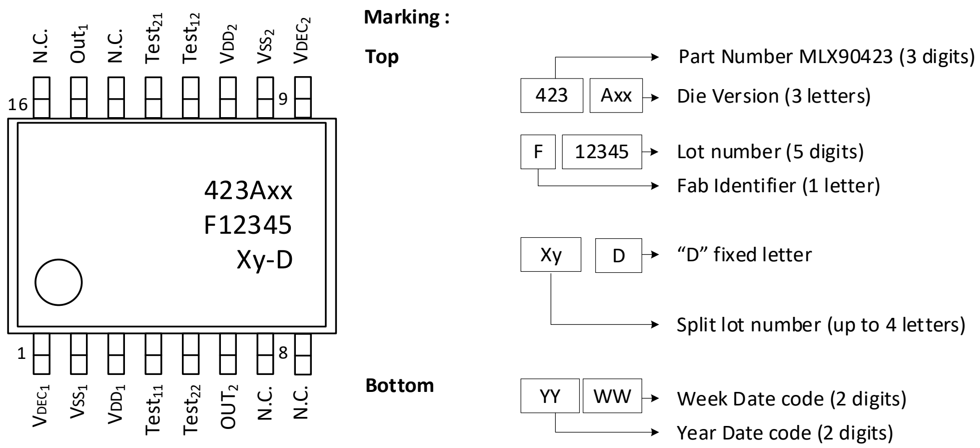


Figure 35 TSSOP-16 Package Pinout and Marking

19.2.3. TSSOP-16- Sensitive spot positioning

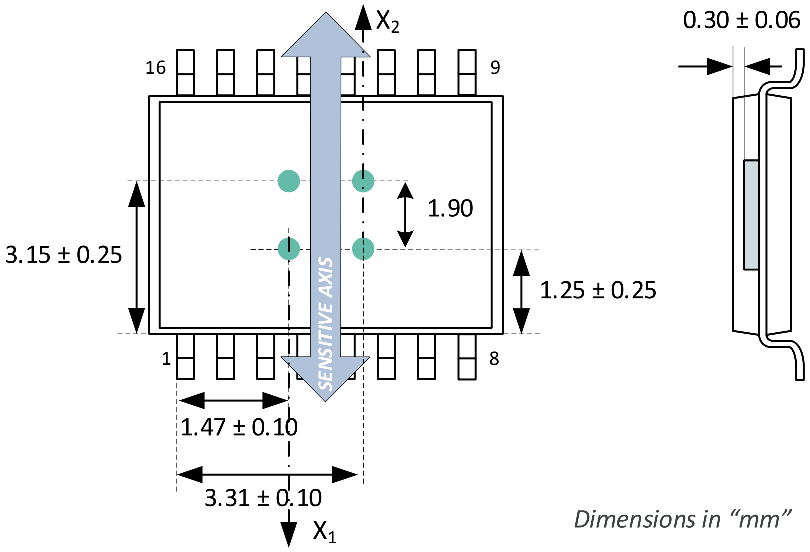


Figure 36 TSSOP-16 Package Sensitive Spot Position

19.2.4. TSSOP-16- Angle Detection

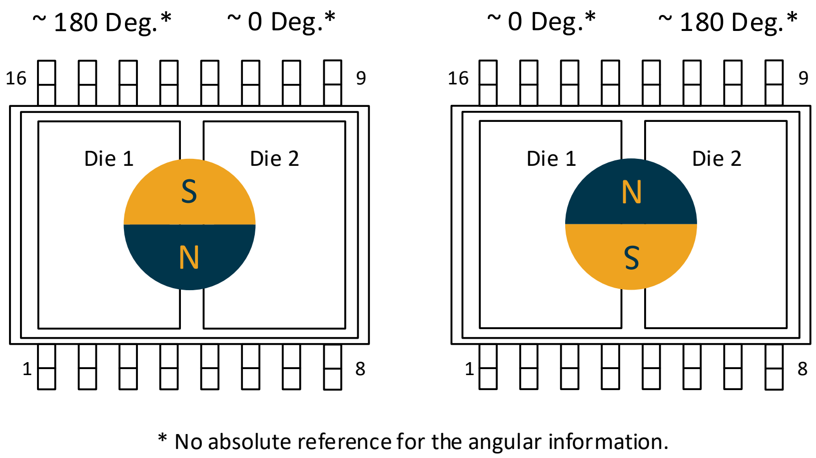
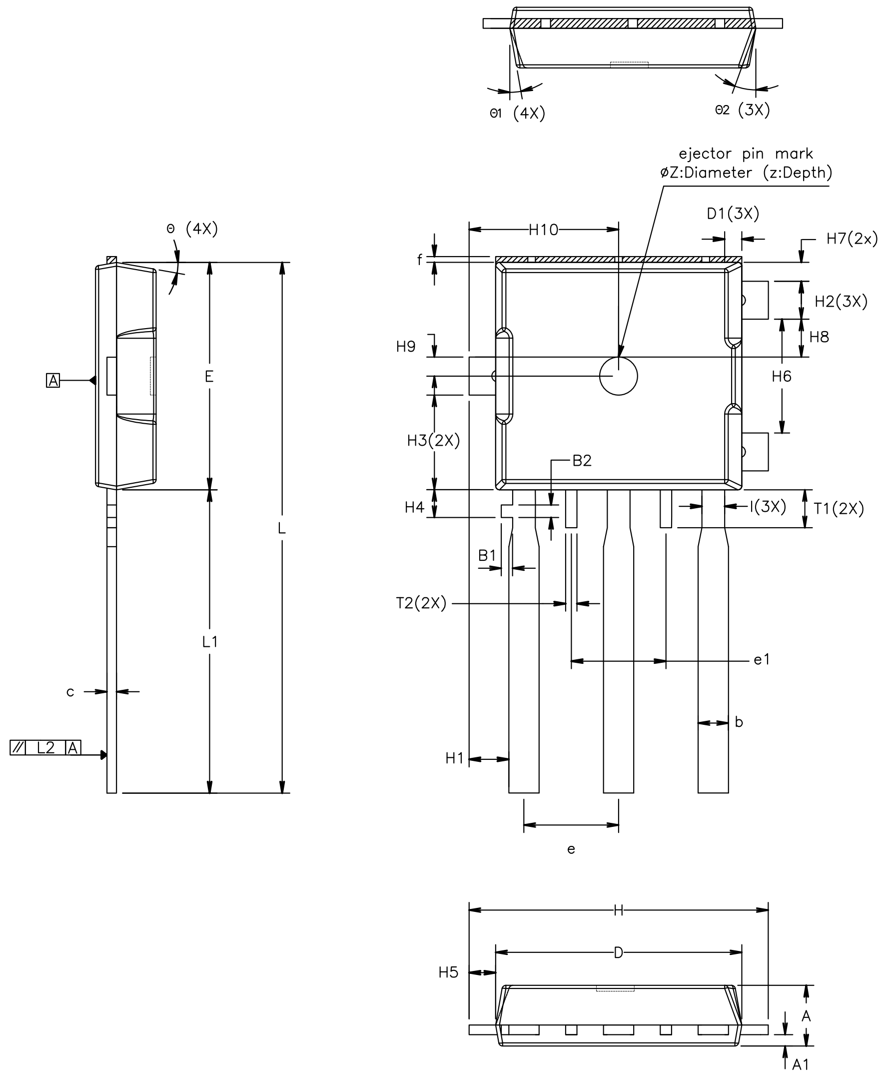


Figure 37 TSSOP-16 Package Angle Detection

The MLX90423 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. (which can be fixed in the application through the discontinuity point).

19.3. SMP-3- Package

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



Dimension	MIN.	NOM.	MAX.
A	1.550	1.600	1.650
A1	0.235	0.300	0.365
B1	0.235	0.300	0.365
B2		0.33 REF	
c	0.179	0.254	0.329
D	6.420	6.500	6.580
D1		0.450 REF	
E	5.920	6.000	6.080
f	0.000	- - -	0.152
H	7.75	7.900	8.050
H1	0.850	1.050	1.250
H2	0.925	1.000	1.075
H3	2.405	2.500	2.595
H4	0.635	0.730	0.825
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	3.800	3.950	4.100

Dimension	MIN.	NOM.	MAX.
L	13.800	14.000	14.200
L1	7.870	8.000	8.130
L2	-0.325	0.000	0.325
I	0.525	0.600	0.675
b	0.725	0.800	0.875
e1	2.400	2.500	2.600
e	2.400	2.500	2.600
θ	8°	10°	12°
θ1	8°	10°	12°
θ2	18°	20°	22°
øZ	0.900	1.000	1.100
z	0.000	- - -	0.152
T1	0.870	1.000	1.130
T2	0.225	0.300	0.375

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 38 SMP-3 Package Outline Dimensions

19.3.2. SMP-3- Pinout and Marking

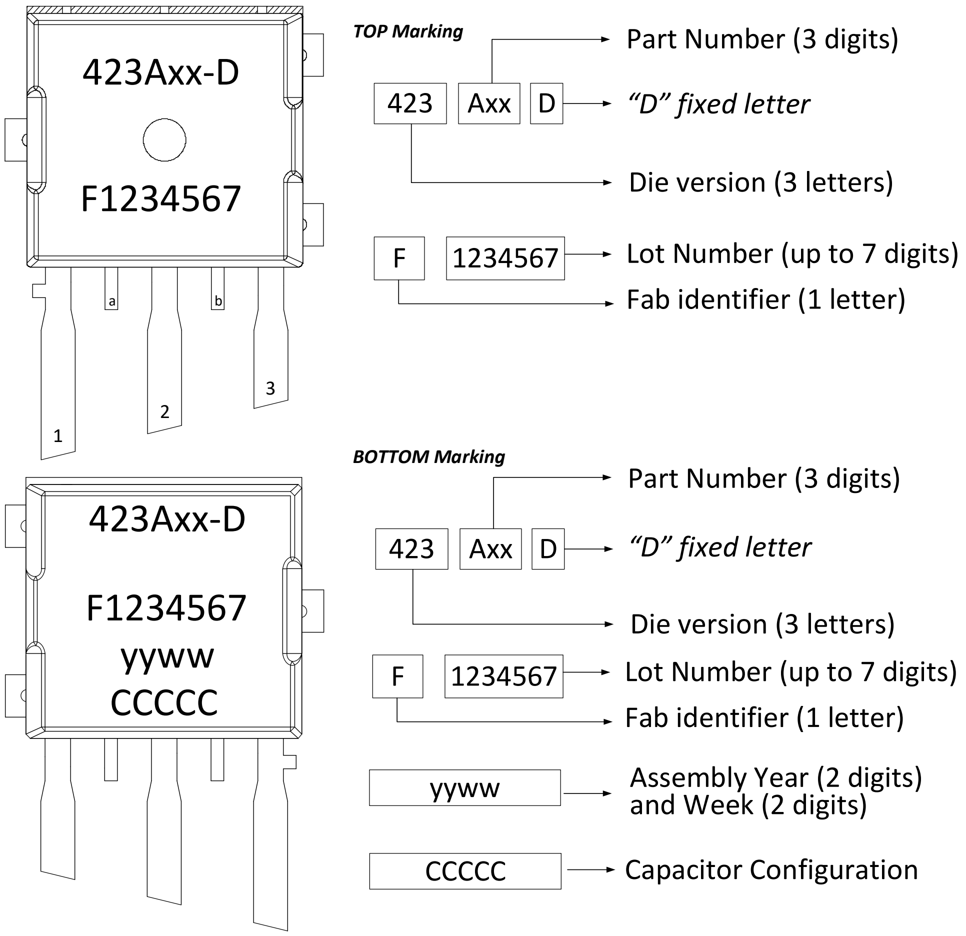


Figure 39 SMP-3 Package Pinout and Marking

19.3.3. SMP-3 – Sensitive spot positioning

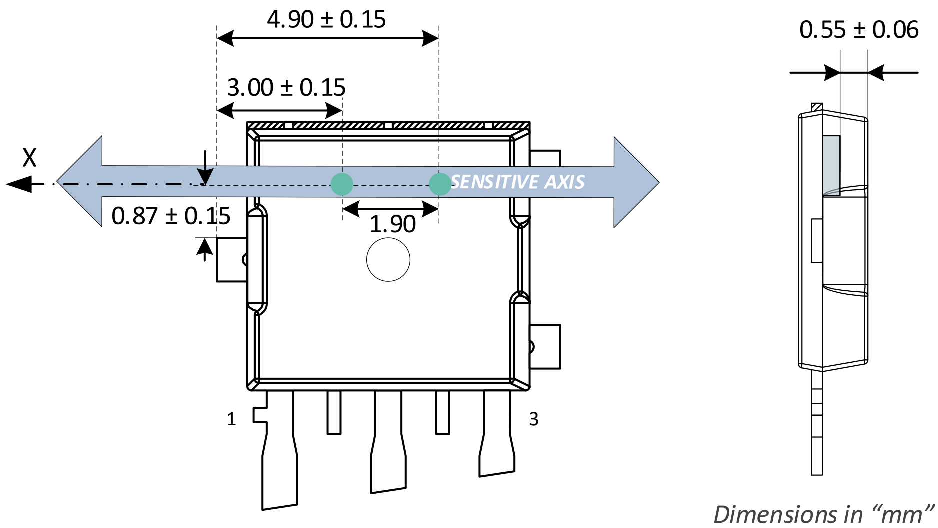


Figure 40 SMP-3 Package Sensitive Spot Position

19.3.4. SMP-3- Angle Detection

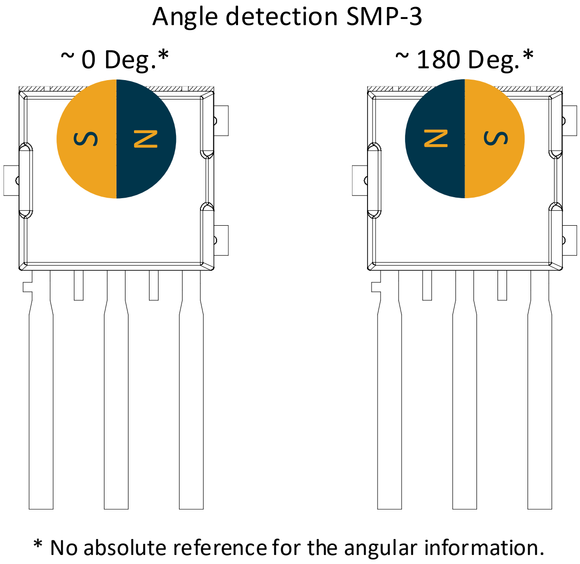


Figure 41 SMP-3 Package Angle Detection

The MLX90423 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. (which can be fixed in the application through the discontinuity point).

19.4. Packages Thermal Performances

The Table 55 below describe the thermal behaviour 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
SMP-3	34.4 K/W	-	206 K/W

Table 55 Standard Packages Thermal Performances

20. 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:

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

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