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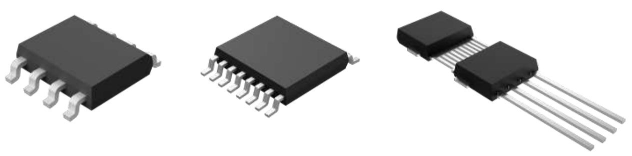
MLX90372 - Triaxis® Position Processor

Datasheet

Features and Benefits

- Triaxis® Hall Technology
- On Chip Signal Processing for Robust Absolute Position Sensing
- ISO26262 ASIL-C capable, Safety Element out of Context (SEooC)
- Programmable Measurement Range
- Programmable Linear Transfer Characteristic (4 or 8 Multi-points or 16 or 32 Piece-Wise-Linear)
- Selectable (fast) SENT or PWM Output
- SAE J2716 APR2016 SENT
- Enhanced serial data communication
- 48 bit ID Number option
- Single Die - SOIC-8 Package RoHS Compliant
- Dual Die (Full Redundant) - TSSOP-16 Package RoHS Compliant
- DMP-4 RoHS Compliant
- Robustness against stray-field



SOIC-8 *TSSOP-16* *DMP-4*

Application Examples

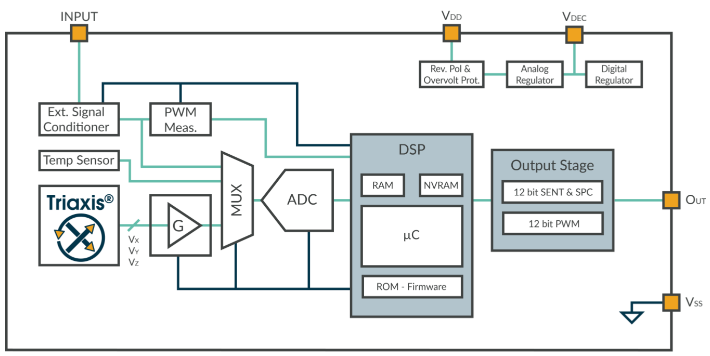
- Absolute Rotary Position Sensor
- Pedal Position Sensor
- Throttle Position Sensor
- Ride Height Position Sensor
- Absolute Linear Position Sensor
- Steering Wheel Position Sensor
- Float-Level Sensor
- Non-Contacting Potentiometer

Description

The MLX90372 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 an output stage driver.

The MLX90372 is sensitive to the three components of the magnetic flux density applied to the IC (i.e. Bx, By and Bz). This allows the MLX90372 with the correct magnetic circuit to decode the absolute position of any moving magnet (e.g. rotary position from 0 to 360 Degrees or linear displacement, see fig. 2). It enables the design of non-contacting position sensors that are frequently required for both automotive and industrial applications.

The MLX90372 provides SENT frames encoded according to a Secure Sensor format. The circuit delivers enhanced serial messages providing error codes, and user-defined values. Through programming, the MLX90372 can also be configured to output a PWM (Pulse Width Modulated) signal.



REVISION 7 - March 23, 2018
3901090372

Ordering Information

Product	Temp.	Package	Option Code	Packing Form	Definition
MLX90372	G	DC	ACC-100	RE	Angular Rotary Strayfield Immune
MLX90372	G	DC	ACC-200	RE	Linear position Strayfield Immune
MLX90372	G	DC	ACC-300	RE	Angular Rotary / Linear position
MLX90372	G	GO	ACC-100	RE	Angular Rotary Strayfield Immune
MLX90372	G	GO	ACC-200	RE	Linear position Strayfield Immune
MLX90372	G	GO	ACC-300	RE	Angular Rotary / Linear position
MLX90372	G	GO	ACC-500	RE	Angular Rotary Strayfield Immune
MLX90372	G	VS	ACC-300	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACC-301	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACC-303	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACC-308	RE/RX	Angular Rotary / Linear position
MLX90372	G	DC	ACE-100	RE	Angular Rotary Strayfield Immune
MLX90372	G	DC	ACE-200	RE	Linear position Strayfield Immune
MLX90372	G	DC	ACE-300	RE	Angular Rotary / Linear position
MLX90372	G	GO	ACE-100	RE	Angular Rotary Strayfield Immune
MLX90372	G	GO	ACE-200	RE	Linear position Strayfield Immune
MLX90372	G	GO	ACE-300	RE	Angular Rotary / Linear position
MLX90372	G	VS	ACE-100	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-101	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-103	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-108	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-200	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-201	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-203	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-208	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-300	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-301	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-303	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-308	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-350	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ACE-357	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ADE-310	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ADE-311	RE/RX	Angular Rotary / Linear position

Product	Temp.	Package	Option Code	Packing Form	Definition
MLX90372	G	VS	ADE-313	RE/RX	Angular Rotary / Linear position
MLX90372	G	VS	ADE-318	RE/RX	Angular Rotary / Linear position

Table 1 - Ordering Codes

Temperature Code:	**G: from -40°C to 160°C**
Package Code:	DC : SOIC-8 package (see 18.1) GO : TSSOP-16 package (full redundancy dual die, see 18.5) VS : DMP-4 package (PCB-less dual mold, see 18.12)
Option Code - Chip revision	**ACC-123 : Chip Revision** ▪ ACC : Not recommended for new designs [1] ▪ ACE : Standard preferred revision [1] ▪ ADE : DMP “low emissions” version
Option Code - Application	ACE-123 : **1-Application - Magnetic configuration** ▪ 1: Angular Rotary Strayfield Immune - Low field Variant ▪ 2: Linear position Strayfield Immune ▪ 3: Legacy / Angular Rotary / Linear position ▪ 5: Angular Rotary Strayfield Immune - High field Variant
Option Code - SW & DMP-4 configuration	ACE-123 : **2-SW and DMP-4 package configuration** For SOIC-8 (code DC) and TSSOP-16 (code GO) packages ▪ 0: SENT 3µs mode For DMP-4 (code VS) package with Pinout-A (see section 3.3) ▪ 0: SENT 3µs mode, standard capacitor configuration [2] ▪ 1: SENT 3µs mode, capacitor configuration no 2 [2] For DMP-4 (code VS) package with Pinout-B (see section 3.4) ▪ 5: SENT 3µs mode
Option Code - Trim & Form	ACE-123 : **3-DMP-4 Trim & Form configuration** ▪ 0: Standard straight leads. See section 18.9 ▪ 1: Trim and Form STD1 2.54. See section 18.10 (not recommended for new designs, prefer STD4 2.54) ▪ 3: Trim and Form STD2 2.54. See section 18.11 ▪ 7: Trim and Form STD3 2.00. See section 18.12 ▪ 8: Trim and Form STD4 2.54. See section 18.13

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[1] ACE is preferred product revision to be selected for new designs. ACC remains in production during the entire product lifecyc le.
[2] See section 15.3 Wiring with the MLX90372 in DMP-4 Package (built-in capacitors)

Packing Form:	-RE : Tape & Reel ▪ VS:2500 pcs/reel ▪ DC:3000 pcs/reel ▪ GO:4500 pcs/reel -RX : Tape & Reel, similar to RE with parts face-down (VS package only)
Ordering Example:	MLX90372GDC-ACE-300-RE For a legacy version in SOIC-8 package, delivered in Reel of 3000pcs.

Table 2 - Ordering Codes Information

Contents

1. Functional Diagram and Application Modes

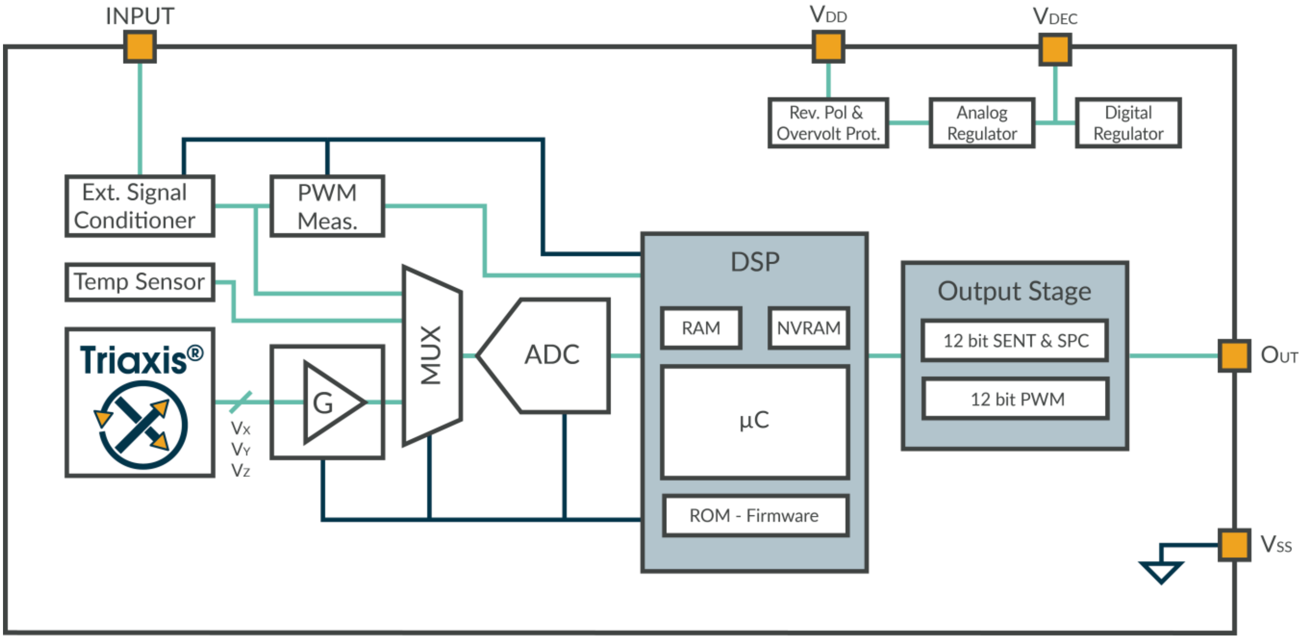

fig. 1 - MLX90372 Block diagram

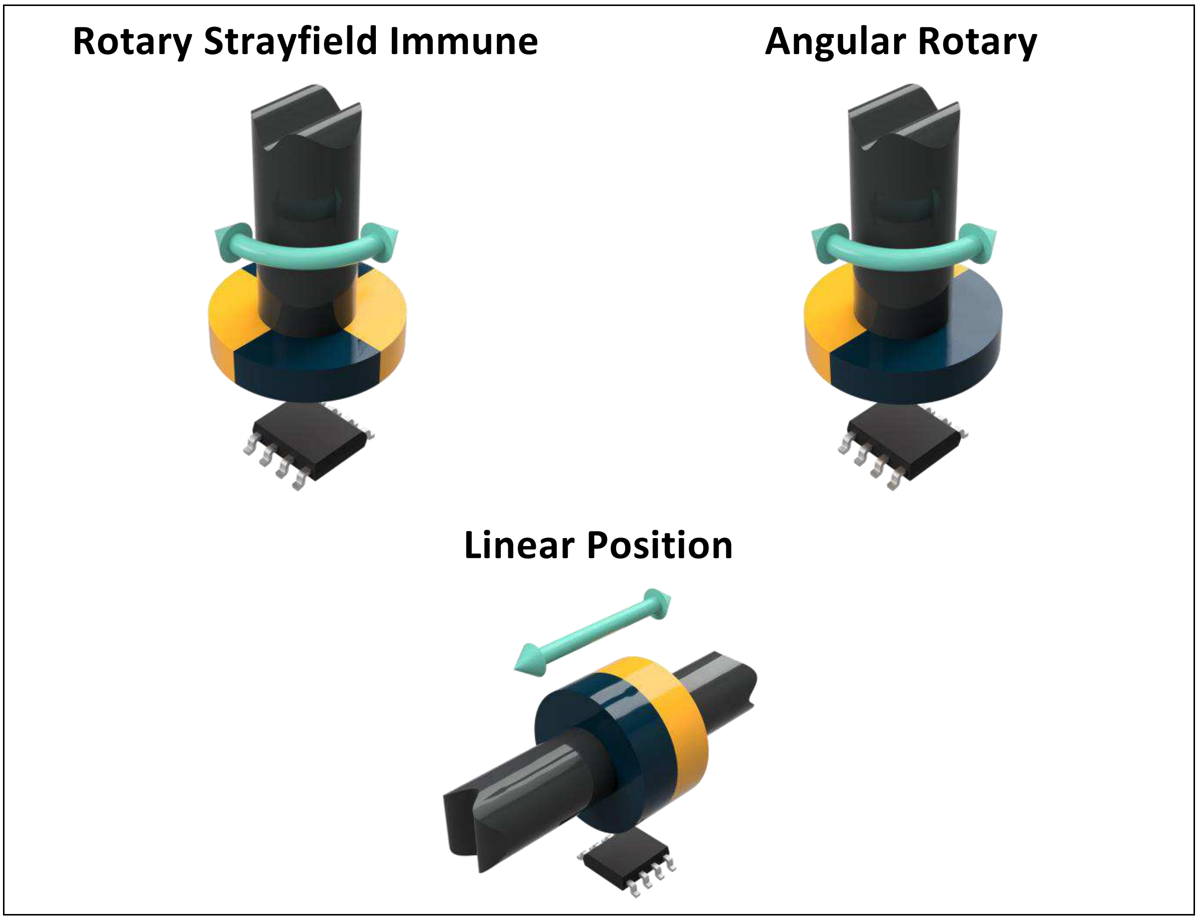

fig. 2 - Application Modes

2. Glossary of Terms

Name	Description
ADC	Analog-to-Digital Converter
AoU	Assumption of Use
ASP	Analog Signal Processing
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})
DMP	Dual Mould Package
DP	Discontinuity Point
DCT	Diagnostic Cycle Time
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
LSB/MSB	Least Significant Bit / Most Significant Bit
NC	Not Connected
NVRAM	Non Volatile RAM
POR	Power On Reset
PSF	Product Specific Functions
PWL	Piecewise Linear
PWM	Pulse Width Modulation
RAM	Random Access Memory
ROM	Read-Only Memory
SEooC	Safety Element out of Context
TC	Temperature Coefficient (in ppm/°C)
Tesla (T)	SI derived unit for the magnetic flux density (Vs/m2)

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	Input	For test or Application
3	Test	For test or Application
4	N.C.	Not connected
5	OUT	Output
6	V_{SS}	Digital ground
7	V_{DEC}	Decoupling pin
8	V_{SS}	Analog ground

Table 4 - SOIC-8 Pins definition and description

Pins Input and Test are internally grounded in application. For optimal EMC behaviour always connect the unused 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}	Analog ground die1
3	V_{DD1}	Supply die1
4	$Input_1$	For test or Application
5	$Test_2$	For test or Application
6	OUT_2	Output die2
7	N.C.	Not connected
8	V_{SS2}	Digital ground die2
9	V_{DEC2}	Decoupling pin die2
10	V_{SS2}	Analog ground die2
11	V_{DD2}	Supply die2
12	$Input_2$	For test or Application
13	$Test_1$	For test or Application
14	N.C.	Not connected
15	OUT_1	Output die1
16	V_{SS1}	Digital ground die1

Table 5 - TSSOP-16 Pins definition and description

Pins Input and Test are internally grounded in application. For optimal EMC behaviour always connect the unused pins to the ground of the PCB.

3.3. Pin Definition for DMP#1 - Pinout A

DMP-4 package pinout A 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 (pinout A)

3.4. Pin Definition for DMP#2 - Pinout B

DMP-4 package configuration pinout B offers full benefit of the applications of Input pin (NTC, digital or analog gateway).

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

Table 7 - DMP-4 Pins definition and description (pinout B)

4. Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit	Condition
Supply Voltage	V_{DD}		28	V	< 48h ; T_j < 175°C
	V_{DD}		37	V	< 60s ; $T_{AMB} \leq 35$°C
Reverse Voltage Protection	$V_{DD\text{-}rev}$	-14		V	< 48h
	$V_{DD\text{-}rev}$	-20		V	< 1h
Positive Output Voltage	V_{OUT}		28	V	< 48h
Reverse Output Voltage	$V_{OUT\text{-}rev}$	-14		V	< 48h
Internal Voltage	V_{DEC}		3.6	V	
	$V_{DEC\text{-}rev}$	-0.3		V	
Positive Input pin Voltage	V_{Input}		6	V	
Reverse Input pin Voltage	$V_{Input\text{-}rev}$	-3		V	
Operating Temperature	T_{AMB}	-40	+160	°C	
Junction Temperature	T_J		+175	°C	see 18.17 for package thermal dissipation values
Storage Temperature	T_{ST}	-55	+170	°C	
Magnetic Flux Density	B_{max}	-1	1	T	

Table 8 - 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.

5. Isolation Specification

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

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 9 - 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	V_{DD}	4.5	5	5.5	V	For voltage regulated mode
Supply Voltage Battery	V_{DD}	6	12	18	V	For Battery usage [(4)]
Supply Current[(3)]	I_{DD}	9.0	10.5	12.6	mA	Rotary and linear stray field applications (option code -100, -200, -500)
Supply Current[(3)]	I_{DD}	8.0	9.0	10.5	mA	Legacy applications (option code -300)
Surge Current	I_{surge}	-	30	40	mA	Startup current (without capacitor charge transient, $t_{startup}$ < 40µs)
Start-up Level (rising)	$V_{DDstartH}$	3.95	4.1	4.25	V	
Start-up Hysteresis	$V_{DDstartHyst}$	150	200	250	mV	
PTC Entry Level (rising)	V_{PROV0}	7.10	7.35	7.60	V	Supply overvoltage detection in 5V applications [(4)]
PTC Entry Level Hysteresis	$V_{PROV0Hyst}$	400	500	600	mV	
PTC Entry Level (rising)	V_{PROV1}	21.5	22.5	23.5	V	For Battery usage [(4)]
Under voltage detection	V_{DDUVL}	3.75	3.90	4.05	V	Supply voltage low threshold
Under voltage detection hysteresis	$V_{DDUVHyst}$	150	200	250	mV	
Regulated Voltage	V_{DEC}	3.2	3.3	3.4	V	Internal analog voltage
Regulated Voltage over voltage detection	V_{DECOVH}	3.65	3.75	3.85	V	High threshold
Regulated Voltage under voltage detection	V_{DECUVL}	2.70	2.85	2.92	V	Low threshold
Regulated Voltage UV / OV detection hysteresis	$V_{DECOVHyst}$ $V_{DECUVHyst}$	100	150	200	mV	
Power-On reset (rising)	V_{POR}	1.585	1.680	1.735	V	Refers to internal digital regulator voltage
Power-On reset Hysteresis	$V_{PORHyst}$	30	100	200	mV	

Table 10 - Supply System Electrical Specifications

[3] *For the dual die version, the supply current is multiplied by 2.*
[4] *Selection between 5V or battery applications is done using WARM_ACT_HIGH parameter. See chap. 12*

Electrical Parameter	Symbol	Min	Typ	Max	Unit	Condition
Output Short Circuit Current[5]	$I_{OUTshortPp}$	-25 10		-10 25	mA mA	Push-pull mode V_{OUT} = 0 V V_{OUT} = 5 V / 18V
Output Short Circuit Current	$I_{OUTshortOd}$	25		90	mA	PWM mode Open Drain only (see 13.1.1)
Output Load	R_L	3			kΩ	PWM pull-up to 5V, PWM pull-down to 0V
	R_L	10	-	55	kΩ	SENT pull-up
	R_L	1	-	100	kΩ	Open drain pull-up
Digital push-pull output level	$V_{satLoPp}$	0	1	2	$\%V_{DD}$	$R_L \geq 10k\Omega$
	$V_{satLoPp}$			5	$\%V_{DD}$	$R_L \geq 3k\Omega$, pull-up to 5V
	$V_{satHiPp}$	98	99	100	$\%V_{DD}$	$R_L \geq 10k\Omega$
	$V_{satHiPp}$	95			$\%V_{DD}$	$R_L \geq 3k\Omega$, pull-down
Digital open drain output level	$V_{satLoOd}$	0		10	$\%V_{ext}$	Pull-up to any external voltage $V_{ext} \leq 18V$, $I_L \leq 3.4mA$
	$V_{satHiOd}$	90		100	$\%V_{DD}$	Pull-down to GND with any supply voltage $V_{DD} \leq 18V$, $I_L \leq 3.4mA$
Digital output Ron	R_{on}	27	50	100	Ω	ACC and ACE chip revision. Push-pull mode
	R_{on}	50	100	215	Ω	ADE chip revision. Push-pull mode

Table 11 - Output Electrical specifications

[5] *Output current limitation triggers after a typical delay of 3µs.*

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	Including thermal and lifetime drift
		-5		5	$\%F_{ck}$	Relative tolerances, including thermal and lifetime drift
Main Clock initial tolerances	$\Delta F_{CK,0}$	23.75	24	24.25	MHz	T=35°C
Main Clock Frequency Thermal Drift	$\Delta F_{CK,T}$	-2	-	2	$\%F_{ck}$	Relative to clock frequency at 35°C. No ageing effect.
1MHz Clock Frequency	F_{1M}		1		MHz	
Intelligent Watchdog Timeout	T_{IWD}	19	20	21	ms	F_{CK} = 24MHz
Absolute Watchdog Timeout	T_{AWD}	19	20	21	ms	F_{1M} = 1MHz
Analog Diagnostics DCT	DCT_{ANA}	34		34	$T_{angleMeas}$	Asynchronous mode (7.2.1)
		17		17	T_{frame}	Sync. Mode, $N_{angFram}$=2
		34		34	T_{frame}	Sync. Mode, $N_{angFram}$=1
Digital Diagnostics DCT	DCT_{DIG}			20	ms	see Table 70, section 14.2
Fail Safe state duration	T_{FSS}	28.4	32.0	34.6	ms	For digital single-event faults
Safe startup Time	$T_{SafeStup}$		$T_{init} + DCT_{ANA}$		ms	see Table 15 for T_{init}

Table 12 - General Timing Specifications

7.2. Timing Modes

The MLX90372 can be configured in two continuous angle acquisition modes described in the following sections.

7.2.1. Continuous Asynchronous Acquisition Mode

In this mode, the sensor continuously acquire angle at a fixed rate that is asynchronous with regards to the output. The acquisition rate is defined by the T_ADC_SEQ parameter which defines the angle measurement period $T_{angleMeas}$. This mode is used in SENT without pause and PWM. Despite that PWM is periodic, asynchronous mode is better suited and enable complete filtering options for PWM signals that are often slow compared to the measurement sequence.

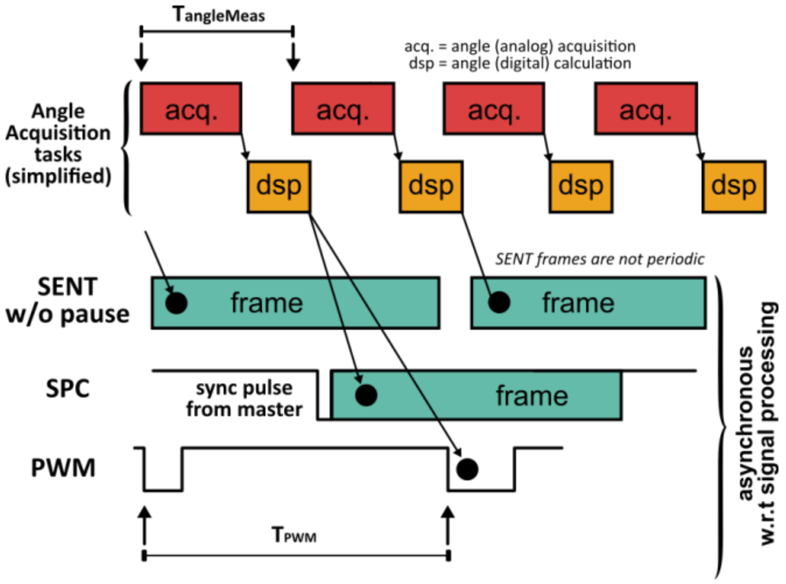

fig. 3 - Continuous Asynchronous Timing Mode

Parameter	Symbol	Min.	Typ	Max.	Unit	Condition
Angle acquisition time	$T_{angleAcq}$		330		µs	
Internal Angle Measurement Period	$T_{angleMeas}$	528	588	-	µs	Typical is default factory settings (no user control)
SENT Frame Tick Count	N_{Tframe}	282	-	-	ticks	**Do not change** for asynchronous mode (see chap.12, T_FRAME)

Table 13 - 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 makes sense only with constant SENT frame length (SENT with pause). The length of the SENT frame is defined by the parameter T_FRAME in number of ticks. The user has the choice to select either one or two angle acquisitions and DSP calculations per frame.

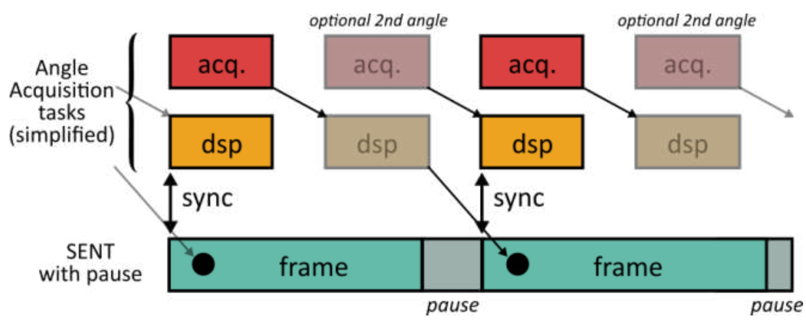

fig. 4 - Continuous Synchronous Timing Mode

Following table describes the frame length of synchronous acquisition mode with regards to T_FRAME parameter value (see chap. 12). Minimal values represent MLX90372 best achievable performance. Typical values are default or recommended values. Maximal values are limited by the SAE J2716 standard and not displayed in this table. For a chosen timing configuration, one has to take into account the main clock relative tolerances listed in Table 12 to get a tolerance on the frame length.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
SENT Frame Tick Count (Normal SENT)	N_{Tframe}	310[6]	320	-	ticks	For tick time of 3µs (Normal SENT) and two angles per frame
SENT Frame Tick Count (Normal SENT)	N_{Tframe}	282[6]	304[7]	-	ticks	For tick time of 3µs (Normal SENT) and one angle per frame
SENT Frame Tick Count (Fast SENT)	N_{Tframe}	320[6]	330	-	ticks	For tick time of 1.5µs (Fast SENT) and one angle per frame
SENT Frame Period (Normal)	T_{frame}	930[6]	960	-	µs	3µs tick time with pause and two angles per frame (F_{CK} = 24MHz)
SENT Frame Period (Fast)	T_{frame}	480[6]	495	-	µs	1.5µs tick time with pause, one angle per frame (F_{CK} = 24MHz)
Number of angles per frame	$N_{angFram}$	1	2	2		set by TWO_ANGLES_FRAME parameter

Table 14 - SENT Synchronous Timing Mode Configurations

7.3. Timing Definitions

7.3.1. Startup Time

SENT 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. At that time, the IC starts transmitting initialisation frames. The second value, T_{stup}, is the time when the first valid angle is transmitted.

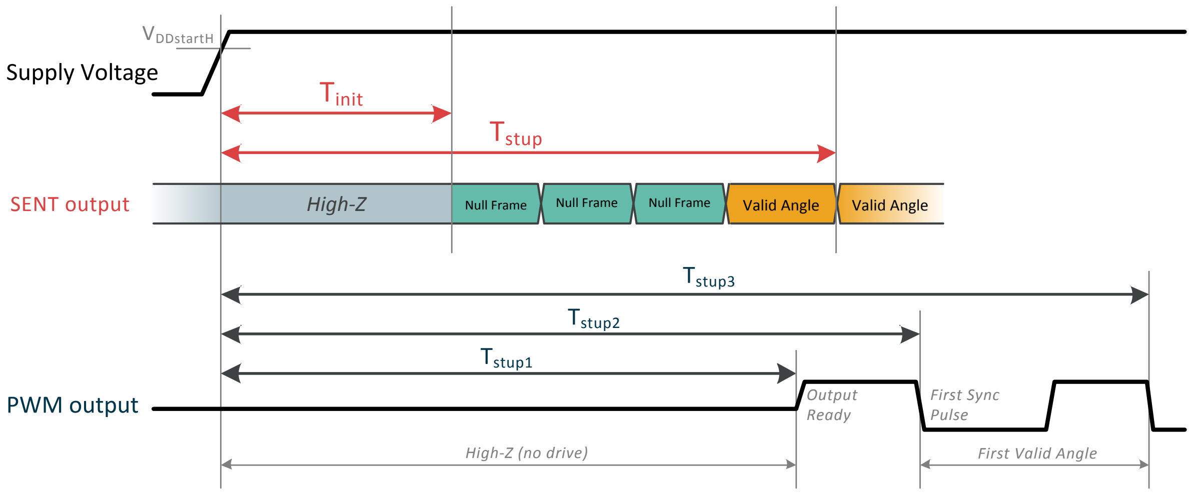

fig. 5 - Startup Time Definition

[6] *Minimal timings are only confirmed to work in a specific configuration and may lead to noise degradation. Melexis recommends typical configuration (factory settings) for safe operation with any end user configuration.*

[7] *This timing optimizes the startup time (see Table 16)*

In PWM mode, startup is defined by three values, $T_{stup[1..3]}$. The first value is reached when the output is ready and starts to drive a voltage. The second value T_2 is the start of the first value angle transmission and the third one T_3 the moment the first angle has been transmitted.

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.

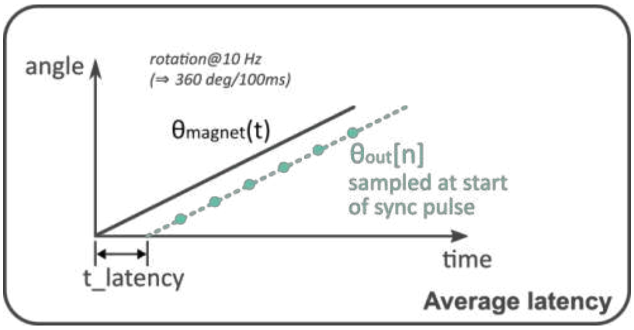

fig. 6 - Definition of Latency

7.3.3. 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. Worst case is happening when the movement of the magnet occurs just after a measurement sequence has begun. Step response therefore consists of the sum of:

- $\delta_{mag,measSeq}$, the delay between magnetic change and start of next measurement sequence
- $T_{measSeq}$, the measurement sequence length
- $\delta_{measSeq,frameStart}$, the delay between end of measurement sequence and start of next frame
- T_{frame}, the frame length

Worst case happens when $\delta_{mag,measSeq} = T_{measSeq}$, therefore this gives:

$$T_{wcStep} = 2T_{measSeq} + \delta_{measSeq,frameStart} + T_{frame}$$

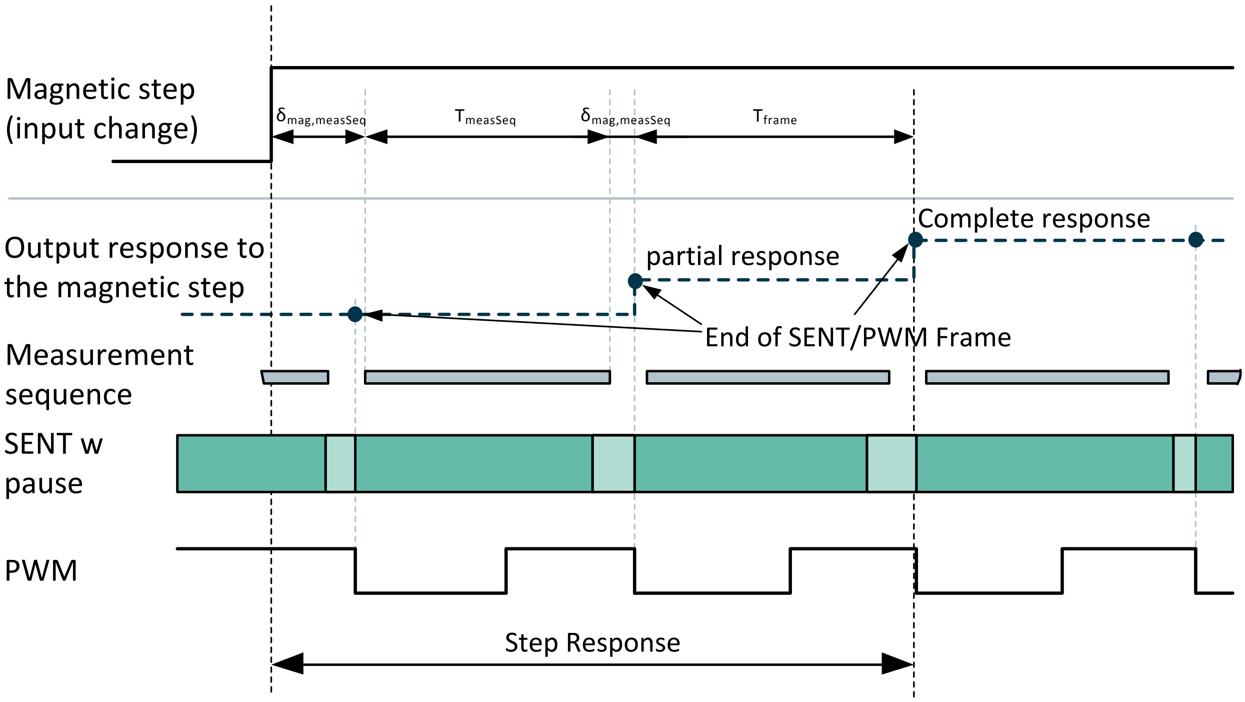

fig. 7 - Step Response Definition

7.4. SENT timing specifications

7.4.1. MLX90372 ACE/ADE SENT Timing Specifications

For the SENT configurations, specifications are valid under the corresponding minimum and typical conditions defined in Table 14.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Tick time		1.5	3	6	µs	1.5µs = Fast SENT 3µs = Normal SENT (default) 6µs = Slow SENT
SENT startup time (up to first sync pulse)	T_{init}	-	2.95	3.10	ms	Until initialisation frame start
SENT edge rise Time		4.5	6.2	7.5	µs	for SENT_SEL_SR_RISE/FALL = 4 (see 11.1.6)
SENT edge fall Time		3.9	4.8	5.2	µs	
Slow Message cycle length			791 475		ms	Extended sequence (40 frames) Short sequence (24 frames)

Table 15 - SENT General Timing Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT with pause (synchronous), 3µs tick time, 2 angles per SENT frame						
SENT startup time	T_{stup}	6.48	6.60	-	ms	Until first valid angle received
Average Latency	T_{latcy}	1.73 2.19	1.77 2.25	-	ms	Filter = 1 (FIR11) Filter = 2 (FIR1111) [8]
Step Response (worst case)	T_{wcStep}	2.98 3.91	3.12 4.08	-	ms	Filter = 1 (FIR11) Filter = 2 (FIR1111)
For SENT with pause (synchronous), 3µs tick time, 1 angle per SENT frame						
SENT startup time	T_{stup}	6.99	6.48	-	ms	Until first valid angle received
Average Latency	T_{latcy}	1.33	1.54	-	ms	Filter = 0 (no filter)
Step Response (worst case)	T_{wcStep}	2.32	2.60	-	ms	Filter = 0 (no filter)
For SENT with pause (synchronous), 1.5µs tick time, 1 angle per SENT frame						
SENT startup time	T_{stup}	6.12	6.23	-	ms	Until first valid angle received
Average Latency	T_{latcy}	0.98 1.15 1.31	1.05 1.21 1.37	-	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) [8]
Step Response (worst case)	T_{wcStep}	1.58 1.89 2.20	1.63 1.95 2.27	-	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) [8]

Table 16 - Synchronous SENT Mode Timing Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT without pause (asynchronous), 3µs tick time[9]						
SENT startup time	T_{stup}	6.25 6.42	6.39 6.56	6.51 6.68	ms	Until first valid angle received with SENT_INIT_GM = 1
Average Latency[9]	T_{latcy}	1.40 1.67 2.20	1.40 1.70 2.29	-	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) [8]
Step Response (worst case)	T_{wcStep}	-	2.41 2.94 4.00	2.72 3.32 4.50	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) [8]

[8] *See section 13.4 for details concerning Filter parameter*

[9] *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*

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT without pause (asynchronous), 1.5µs tick time(9)						
SENT startup time	T_{stup}	6.42	6.50	6.56	ms	Until first valid angle received
Average Latency(9)	T_{latcy}	0.91 1.17 1.70	0.91 1.21 1.80	-	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) (8)
Step Response (worst case)	T_{wcStep}	-	1.76 2.29 3.34	1.94 2.54 3.72	ms	Filter = 0 (no filter) Filter = 1 (FIR11) Filter = 2 (FIR1111) (8)

Table 17 - Asynchronous SENT Mode Timing Specifications

7.4.2. MLX90372 ACC Default SENT Timing specifications

MLX90372 ACC versions come with the following typical default programming that differs from ACE/ADE version (see chapter 12, item no 134, T_FRAME).

Parameter	Symbol	Min	Typ	Max	Unit	Condition
SENT Frame Tick Count (Normal SENT)	N_{Tframe}	-	366	-	ticks	For tick time of 3µs (Normal SENT) and two angles per frame

Table 18 - Default ACC Synchronous SENT frame length

For this typical value, the timing performances are described in the next table (Table 19 - Synchronous SENT mode ACC default timing specificationsTable 19). ACC has the same timing capabilities than the ACE and can be programmed in a similar way. When the ACC default programming is changed to match the one of ACE/ADE, timing performances are equivalent. For timing performances not described in this section, refer to the Table 14 and section 7.4.1.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT with pause (synchronous), 3µs tick time, 2 angles per SENT frame						
SENT startup time	T_{stup}	-	7.18	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	1.79 2.33	-	ms	Filter = 1 (FIR11) Filter = 2 (FIR1111) (10)
Step Response (worst case)	T_{wcStep}	-	3.28 4.38	-	ms	Filter = 1 (FIR11) Filter = 2 (FIR1111) (8)
For SENT with pause (synchronous), 3µs tick time, 1 angle per SENT frame(11)						

[10] *See section 13.4 for details concerning Filter parameter*

[11] *Need experimental/formal confirmation, data based on simulation*

Parameter	Symbol	Min	Typ	Max	Unit	Condition
SENT startup time	T_{stup}	-	6.60	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	1.49	-	ms	Filter = 0 (no filter)
Step Response (worst case)	T_{wcStep}	-	2.61		ms	Filter = 0 (no filter)

Table 19 - Synchronous SENT mode ACC default timing specifications

7.5. PWM 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 Initial Tolerances	$\Delta F_{PWM,0}$	-1.5		1.5	$\%F_{PWM}$	T=35°C, can be trimmed at EOL
PWM Frequency Thermal Drift	$\Delta F_{PWM,T}$	-2.0		2.0	$\%F_{PWM}$	
PWM Frequency Drift	ΔF_{PWM}	-5.0		5.0	$\%F_{PWM}$	Over temperature and lifetime
PWM startup Time (up to output ready)	T_{stup1}		6.60		ms	
PWM startup Time (up to first sync. Edge)	T_{stup2}	7.10	7.60	16.6	ms	$T_{stup1} + T_{PWM}$
PWM startup Time (up to first data received)	T_{stup3}	7.60	8.60	26.6	ms	$T_{stup1} + 2^* T_{PWM}$ [12]
Rise Time PWM		1.0	4.8	12.0	µs	typ. for SENT_SEL_SR_RISE/FALL = 4 (see 11.1.6). Measured between 1.1V and 3.8V
Fall Time PWM		1.0	4.8	12.0	µs	

Table 20 - PWM timing specifications

[12] *First frame transmitted has no synchronization edge; therefore the second frame transmitted is the first complete one.*

8. Magnetic Field Specifications

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

8.1. Rotary Stray-field Immune Mode - Low Field Variant (-100 code)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Number of magnetic poles	N_P	4[13]	-	-		
Magnetic Flux Density in X-Y plane	B_X, B_Y[14]			25[15]	mT	$\sqrt{B_X^2 + B_Y^2}$ (this is not the useful signal)
Magnetic Flux Density in Z	B_Z			100	mT	(this is not the useful signal)
Magnetic in-plane gradient of in-plane field component	$\frac{\Delta B_{XY}}{\Delta XY}$	3.8	10		$\frac{mT}{mm}$	$\frac{1}{2}\sqrt{\left(\frac{dB_X}{dX} - \frac{dB_Y}{dY}\right)^2 + \left(\frac{dB_X}{dY} + \frac{dB_Y}{dX}\right)^2}$ this is the useful signal (see fig. 8)
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{ppm}{°C}$	
Field Strength Resolution[16]	$\frac{\Delta B_{XY}}{\Delta XY}$	0.075	0.100	0.125	$\frac{mT}{mm\ LSB}$	Magnetic field gradient norm (12bits data)
Field too Low Threshold[17]	B_{TH_LOW}	0.8	1.2	[18]	$\frac{mT}{mm}$	Typ is recommended value to be set by user (see 13.5.4)
Field too High Threshold[17]	B_{TH_HIGH}	70	100[19]	102[19]	$\frac{mT}{mm}$	
Field too low Threshold code [17]	DIAG_ FIELDTOOLOW THRES		3		LSB	decimal value
Field too high Threshold code [17]	DIAG_ FIELDTOOHIGH THRES		250		LSB	decimal value

Table 21 - Magnetic specification for rotary stray-field immune- low field variant

Nominal performances apply when the useful signal $\Delta B_{XY}/\Delta XY$ is above the typical specified limit. Under this value, limited performances apply. See 8.1 for accuracy specifications. Stray-field immunity is tested according to ISO 11452-8:2015.

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[13] *Due to 4 poles magnet usage, maximum angle measurement range is limited to 180°*

[14] *The condition must be fulfilled for all combinations of B_X and B_Y.*

[15] *Above this limit, the IMC® starts to saturate, yielding to an increase of the linearity error.*

[16] *Only valid with default MAGNET_SREL_T[1..7] configuration*

[17] *Typ. value is set by default for NVRAM rev.9 and shall be set by user for rev.8 (see Table 49, USER_ID3 and 13.5.4)*

[18] *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.*

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

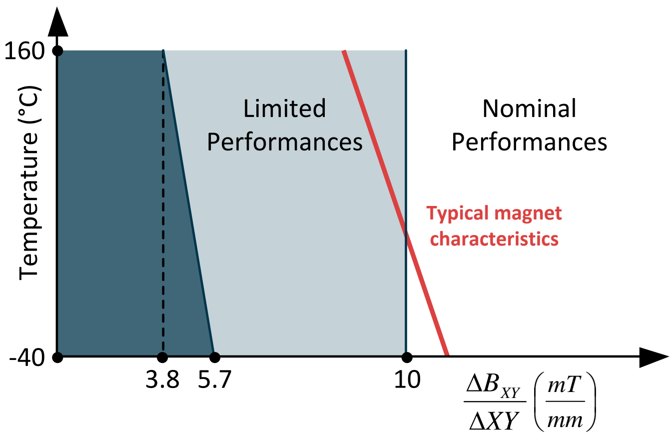

fig. 8 - Minimum useful signal definition for rotary stray-field immune application-low field variant

8.2. Rotary Stray-field Immune Mode - High Field Variant (-500 code)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Number of magnetic poles	N_P	4(13)	-	-		
Magnetic Flux Density in X-Y plane	B_X, B_Y (14)			67(15)	mT	$\sqrt{B_X^2 + B_Y^2}$ (this is not the useful signal)
Magnetic Flux Density in Z	B_Z			100	mT	(this is not the useful signal)
Magnetic in-plane gradient of in-plane field component	$\frac{\Delta B_{XY}}{\Delta XY}$	8.25			$\frac{mT}{mm}$	$\frac{1}{2}\sqrt{\left(\frac{dB_X}{dX}-\frac{dB_Y}{dY}\right)^2+\left(\frac{dB_X}{dY}+\frac{dB_Y}{dX}\right)^2}$ this is the useful signal.
Magnet Temperature Coefficient	TC_m			0	$\frac{ppm}{°C}$	
Field Strength Resolution(16)	$\frac{\Delta B_{XY}}{\Delta XY}$	0.075	0.100	0.125	$\frac{mT}{mm\ LSB}$	Magnetic field gradient norm (12bits data)
Field too Low Threshold(17)	B_{TH_LOW}	1.2	2	(18)	$\frac{mT}{mm}$	Typ is recommended value to be set by user (see 13.5.4)
Field too High Threshold(17)	B_{TH_HIGH}	80	100(19)	102(19)	$\frac{mT}{mm}$	
Field too low Threshold code (17)	DIAG_ FIELDTOOLOW THRES		5		LSB	decimal value
Field too high Threshold code (17)	DIAG_ FIELDTOOHIGH THRES		250		LSB	decimal value

Table 22 - Magnetic specification for rotary stray-field immune

See 8.2 for accuracy specifications. Stray-field immunity is tested according to ISO 11452-8:2015.

8.3. Linear Stray-field Immune Mode (-200 code)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Number of magnetic poles	N_P		2	-		Linear movement
Magnetic Flux Density in X	B_X			80[20]	mT	$B_Y \leq 20mT$
Magnetic Flux Density in X-Y	B_X, B_Y[21]			70[22]	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[23]		$\frac{mT}{mm}$	$\sqrt{\left(\frac{\Delta B_X}{\Delta X}\right)^2 + \left(\frac{1}{G_{IMC}}\frac{\Delta B_Z}{\Delta X}\right)^2}$ [24]
Distance between the two IMC®	ΔX		1.91			see chapter 18 for magnetic center definitions
IMC gain	G_{IMC}		1.19			see [24]
Magnet Temperature Coefficient	TC_m	-2400		0	$\frac{ppm}{°C}$	
Field Strength Resolution[16]	$\frac{\Delta B_{XZ}}{\Delta X}$	0.037	0.05	0.063	$\frac{mT}{mm\ LSB}$	Magnetic field gradient norm expressed in 12bits words
Field too Low Threshold[17]	B_{TH_LOW}	0.2	1.2	[25]	$\frac{mT}{mm}$	Typ is recommended value to be set by user (see 13.5.4)
Field too High Threshold[17]	B_{TH_HIGH}	35	50	51	$\frac{mT}{mm}$	
Field too low Threshold code [17]	DIAG_ FIELDTOOLOW THRES		6		LSB	decimal value
Field too high Threshold code [17]	DIAG_ FIELDTOOHIGH THRES		250		LSB	decimal value

Table 23 - Magnetic specifications for linear stray-field application

Nominal performances apply when the useful signal ΔBxz/Δx and temperature ranges are inside the values defined in the following figure (fig. 9). At higher temperature or lower field gradients, the accuracy of MLX90372 is degraded and Limited Performances, described in section 9.4.2, apply. Stray-field immunity is tested according to ISO 11452-8:2015.

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[20] Above 80 mT, with B_Y field in the mentioned limits, the IMC® starts saturating yielding to an increase of the linearity error.

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

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

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

[24] 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.

[25] 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.