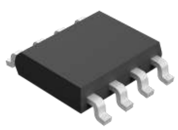
MLX90378 - Triaxis® Position Processor

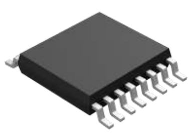
Datasheet

Features and Benefits

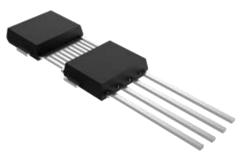
- Triaxis® Hall Technology
- On Chip Signal Processing for Robust Absolute Position Sensing
- ISO26262 ASIL-C Safety Element out of Context
- Input / Gateway Pin for External Measurement
- Programmable Measurement Range
- Programmable Linear Transfer Characteristic (4 Multi-points per axis)
- Dual PWM Output
- Selectable PWM or (fast) SENT Outputs
- SAE J2716 APR2016 SENT
- Enhanced serial data communication
- 48bit ID Number option
- Single Die - SOIC-8 Package RoHS Compliant
- Dual Die – TSSOP-16 Package RoHS Compliant
- PCB-less DMP-4 Package (RoHS)



SOIC-8



TSSOP-16



DMP-4

Application Examples

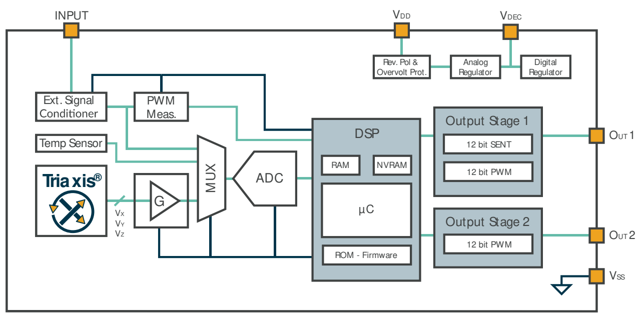
- Automotive Shift Levers
- Industrial Joysticks
- Transmission Position Sensors

Description

The MLX90378 is a monolithic magnetic position processor IC designed for 3D motion applications (e.g. joysticks). It consists of a Triaxis® Hall magnetic front end, an analog to digital signal conditioner, a DSP for advanced signal processing and a dual output stage driver capable of providing two PWM outputs or a single SENT output with two channels.

The MLX90378 is sensitive to the three components of the magnetic flux density applied to the IC (i.e. Bx, By and Bz). This allows the MLX90378 with the correct magnetic circuit to decode the absolute position of any moving magnet. It enables the design of non-contacting 3D position sensors that are frequently required for both automotive and industrial applications.

The MLX90378 provides output data according to the SENT protocol or via two PWM signals. The SENT frames can be encoded in a variety of formats (e.g. H.1 format). Additionally, the SENT protocol allows for external measurements, error codes, and user defined values. The two PWM (Pulse Width Modulated) signals correspond to the joystick angle.



Ordering Information

Product	Temp.	Package	Option Code	Packing Form	Definition
MLX90378	G	DC	ABJ-300	RE	3D / Joystick position
MLX90378	G	GO	ABJ-300	RE	3D / Joystick position
MLX90378	G	VS	ABJ-300	RE/RX	3D / Joystick position
MLX90378	G	VS	ABJ-307	RE/RX	3D / Joystick 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 (redundant dual die, see 18.4) VS: DMP-4 package (PCB-less dual mold, see 18.7)
Option Code:	ABJ-123 1: **Application - Magnetic configuration** ▪ 3: 3D / Joystick position
	2: **SW configuration** For SOIC-8 (code DC) and TSSOP-16 (code GO) packages ▪ 0: SENT 3µs mode For DMP-4 (code VS) package (see section 15.4) ▪ 0: SENT 3µs mode (C1=10nF; C2=100nF; C3=220nF; C4=10nF)
	3: **Trim & Form configuration** For SOIC-8 (code DC) and TSSOP-16 (code GO) packages ▪ 0: Default For DMP-4 (code VS) package (see section 18.7) ▪ 0: Standard straight leads (see section 18.7.1) ▪ 7: Trim and Form STD3 2.00 (see section 18.7.2)
Packing Form:	-RE: Tape & Reel ▪ DC: 3000 pcs / reel ▪ GO: 4500 pcs / reel ▪ VS: 2500 pcs/reel -RX: Tape & Reel, similar to RE with parts face-down (VS package only)
Ordering Example:	MLX90378GGO-ABJ-300-RE For a dual die standard version delivered in tape and reel packaging.

Table 2 - Ordering Codes Information

Contents

1. Functional Diagram and Application Modes

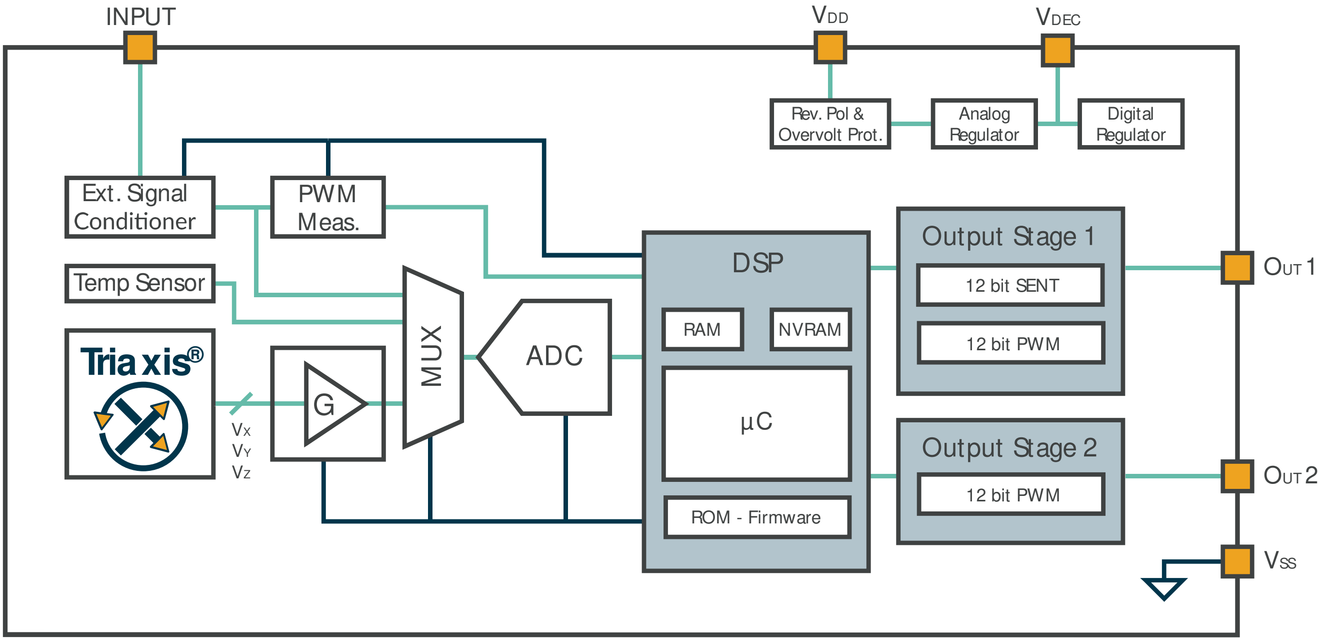


Figure 1 – MLX90378 Block Diagram

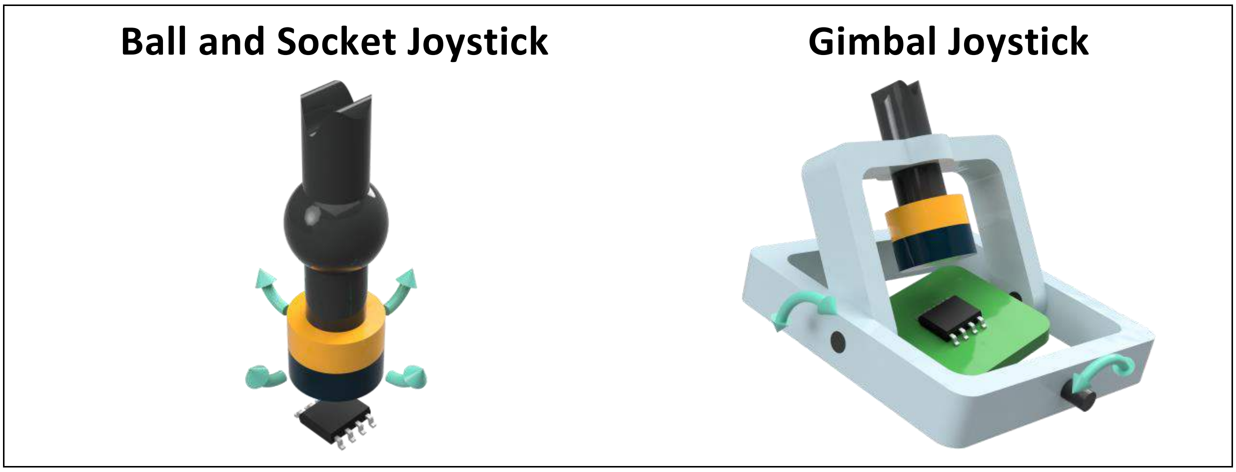


Figure 2 – Application Modes

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})
DCC	Data Consistency Check
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
FC	Frame Control
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
(NV)RAM	(Non-Volatile) Random Access Memory
POR	Power On Reset
PSF	Product Specific Functions
PWL	Piecewise Linear
PWM	Pulse Width Modulation
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	OUT_2	Second output
4	Test	For test or application
5	OUT_1	First 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 but for optimal EMC behaviour always connect the unused pins to the ground of the PCB.

3.2. Pin Definition for TSSOP-16 package

Pin #	Die	Name	Description
1	1	V_{DEC}	Decoupling pin
2	1	V_{SS}	Analog ground
3	1	V_{DD}	Supply
4	1	Input	For test or application
5	1	OUT_2	Second output
6	2	Test	For test or application
7	2	OUT_1	First output
8	2	V_{SS}	Digital ground
9	2	V_{DEC}	Decoupling pin
10	2	V_{SS}	Analog ground
11	2	V_{DD}	Supply
12	2	Input	For test or application
13	2	OUT_2	Second output
14	1	Test	For test or application
15	1	OUT_1	First output
16	1	V_{SS}	Digital ground

Table 5 - TSSOP-16 Pins definition and description

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

3.3. Pin Definition for DMP-4 package

DMP-4 package adds a dual output PCB-less solution to the Triaxis® product family.

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

Table 6 - DMP-4 Pins definition and description

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} < 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	
Test pin Voltage	V_{TEST}		3.6	V	
	$V_{TEST\text{-}rev}$	-0.3		V	
Operating Temperature	T_{AMB}	-40	+160	°C	
Junction Temperature	T_J		+175	°C	see 18.10 for package thermal dissipation values
Storage Temperature	T_{ST}	-55	+170	°C	
Magnetic Flux Density	B_{max}	-1	1	T	

Table 7 - Absolute maximum ratings

Exceeding 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 8 – Isolation specification

6. General Electrical Specifications

General electrical specifications are valid for temperature range -40°C to 160°C and supply voltage range 4.5V to 5.5V unless otherwise specified.

6.1. Supply System Electrical Specifications

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[2]
Supply Current[1]	I_{DD}	8.0	9.0	10.5 12.0	mA	SENT with Pause SENT without Pause, switch button enabled
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	First valid SENT w/o diag bit (supply monitor)
Start-up Hysteresis	$V_{DDstartHyst}$	150	200	250	mV	Last valid SENT w/o diag bit (supply monitor)
PTC Entry Level (rising)	V_{PROV0}	7.10	7.35	7.60	V	Supply overvoltage detection in 5V applications[2]
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[2]
Under voltage detection	V_{DDUVL}	3.75	3.90	4.05	V	Supply voltage low threshold First SENT frame
Under voltage detection hysteresis	$V_{DDUVHyst}$	150	200	250	mV	Supply voltage low threshold Last SENT frame
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 voltage V_{dig}
Power-On reset Hysteresis	$V_{PORHyst}$	30	100	200	mV	

Table 9 - Supply System Electrical Specifications

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

[2] *Selection between 5V or battery applications is done using WARM_ACT_HIGH parameter. See chapter. 12*

6.2. Output Electrical Specifications

Electrical Parameter	Symbol	Min	Typ	Max	Unit	Condition
Output Short-Circuit Current Limit in Push-Pull mode	$I_{OUTshortPp}$	 6 -28 0.1 8.5 -28 0.1		 25 -8 2 35 -8 2	mA	SENT Out=low, 0V ≤ V_{OUT} ≤ 18V, (3) Out=high, 0V ≤ V_{OUT} ≤ V_{DD} Out=high, 12V ≤ V_{OUT} ≤ 18V PWM Out=low, 0V ≤ V_{OUT} ≤ 18V, (3) Out=high, 0V ≤ V_{OUT} ≤ V_{DD} Out=high, 12V ≤ V_{OUT} ≤ 18V
Output Short-Circuit Current Limit in Open-Drain Mode	$I_{OUTshortOd}$	6 35		25 100	mA	SENT Out=low, 0V ≤ V_{OUT} ≤ 18V, (3) PWM Out=low, 0V ≤ V_{OUT} ≤ 18V
Output Load	R_L	3			kΩ	PWM pull-up to 5V, PWM pull-down to 0V
	R_L	10	-	55	kΩ	SENT pull-up
Digital push-pull output level	$V_{satLoPp}$	0	1	2	$\%V_{DD}$	R_L ≥ 10kΩ
	$V_{satLoPp}$			5	$\%V_{DD}$	R_L ≥ 3kΩ, pull-up to 5V
	$V_{satHiPp}$	98	99	100	$\%V_{DD}$	R_L ≥ 10kΩ
	$V_{satHiPp}$	95			$\%V_{DD}$	R_L ≥ 3kΩ, pull-down
Digital open drain output level	$V_{satLoOd}$	0		10	$\%V_{ext}$	Pull-up to any external voltage V_{ext} ≤ 18V, I_L ≤ 3.4mA
	$V_{satHiOd}$	90		100	$\%V_{DD}$	Pull-down to GND with any supply voltage V_{DD} ≤ 18V, I_L ≤ 3.4mA
Digital output Ron	R_{on}	27	50	100	Ω	Push-pull mode

Table 10 - Output Electrical Specifications

6.3. Input Electrical Specifications

Electrical Parameter	Symbol	Min	Typ	Max	Unit	Condition
Input Voltage range		-1.5		5.0	V	

Table 11 – Input Electrical Specifications

[3] *The current limitation triggers after a typical delay of 3µs if the short circuit impedance is smaller than 20 Ohms*

7. Timing Specification

Timing specifications are valid for temperature range -40°C to 160°C and supply voltage range 4.5V to 5.5V unless otherwise specified.

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
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 35°C
1MHz Clock Frequency	F_{1M}	0.95	1	1.05	MHz	
Intelligent Watchdog Timeout	T_{IWD}	19	20	21	ms	F_{CK} = 24MHz
Absolute Watchdog Timeout	T_{AWD}	19		21	ms	F_{1M} = 1MHz
Analog Diagnostics DCT	DCT_Ana		34		$T_{angle\text{-}Meas}$	Asynchronous mode (7.2.1)
			17		T_{frame}	Sync. Mode, $N_{angFram}$=2
			34		T_{frame}	Sync. Mode, $N_{angFram}$=1
Digital Diagnostics DCT	DCT_Dig			22	ms	see Functional Safety, section 14.2
Fail Safe state duration	T_{FSS}	28.4	32	34.6	ms	For digital single-event faults
NVRAM BIST Diagnostic DCT	DCT_nvram_bist	32	48	64	ms	

Table 12 - General Timing Specifications

7.2. Timing Modes

The MLX90378 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 acquires angles at a fixed rate that is asynchronous with regards to the output. The acquisition rate is defined by the variable T_ADC_SEQ and defines the angle measurement period $T_{angleMeas}$. This mode is used in PWM and SENT without a pause pulse. Even though PWM is periodic, asynchronous mode is better suited and enables complete filtering options for PWM signals that are often slow compared to the measurement sequence.

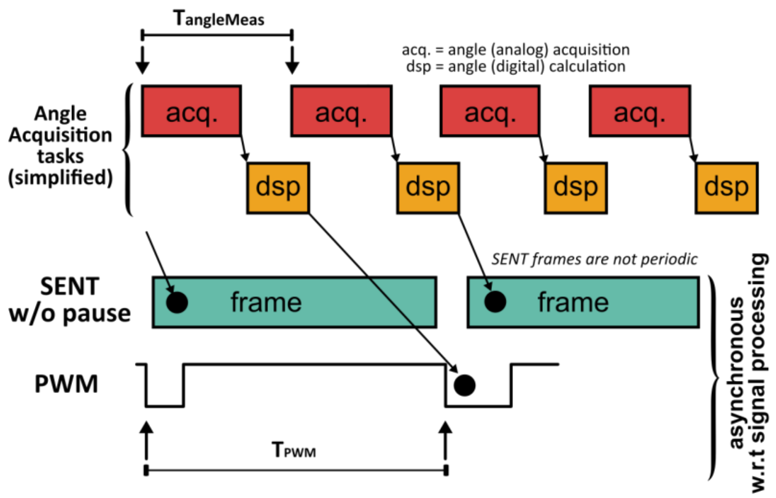

Figure 3 – Continuous Asynchronous Timing Mode

Parameter	Symbol	Min.	Typ	Max.	Unit	Condition
Angle acquisition time	$T_{angleAcq}$		388		µs	
Internal Angle Measurement Period	$T_{angleMeas}$	600	846	-	µs	Typical is default factory settings (no user control)
SENT Frame Tick Count	N_{Tframe}	282	-	-	ticks	Do not modify even for asynchronous mode

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. Therefore, the output should have a fixed frame frequency. This mode is used only with constant SENT frame length (SENT with a pause pulse). The length of the SENT frame is defined by the parameter T_FRAME, expressed in number of ticks. The user has the choice to select either one or two angle acquisitions and DSP calculations per frame.

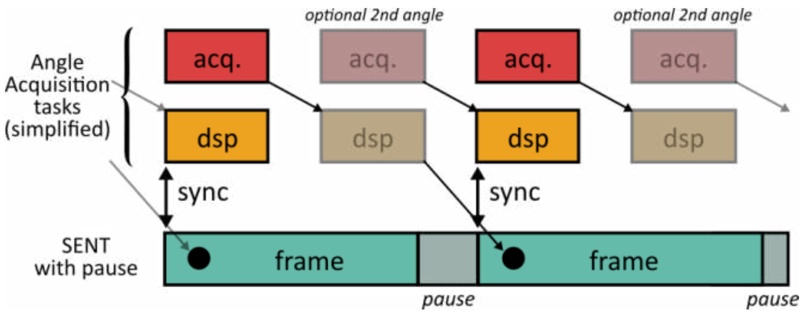

Figure 4 – Continuous Synchronous Timing Mode

Parameter	Symbol	Min	Typ	Max	Unit	Condition
SENT Frame Tick Count (Normal SENT)	N_{Tframe}	370[4]	-	-	ticks	For tick time of 3µs (Normal SENT) and two angles per frame
SENT Frame Tick Count (Normal SENT)	N_{Tframe}	282[4]	-	-	ticks	For tick time of 3µs (Normal SENT) and one angle per frame
SENT Frame Tick Count (Fast SENT)	N_{Tframe}	380[4]	-	-	ticks	For tick time of 1.5µs (Fast SENT) and one angle per frame
SENT Frame Period (Normal)	T_{frame}	1110[4]	-	-	µs	3µs tick time with pause and two angles per frame (F_{CK} = 24MHz)
SENT Frame Period (Normal)	T_{frame}	846[4]	-	-	µs	3µs tick time with pause and one angle per frame (F_{CK} = 24MHz)
SENT Frame Period (Fast)	T_{frame}	570[4]	-	-	µs	1.5µs tick time with pause, one angle per frame (F_{CK} = 24MHz)
Number of angles per frame	$N_{angFram}$	1	1	2	-	set by TWO_ANGLE_FRAME parameter

Table 14 - SENT Synchronous Timing Mode Configuration

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.

For PWM, startup is defined by three values, $T_{stup[1..3]}$. The first value is reached when the output is ready. The second one is the start of the first value angle transmission and the third one the moment the first angle has been transmitted.

[4] 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.

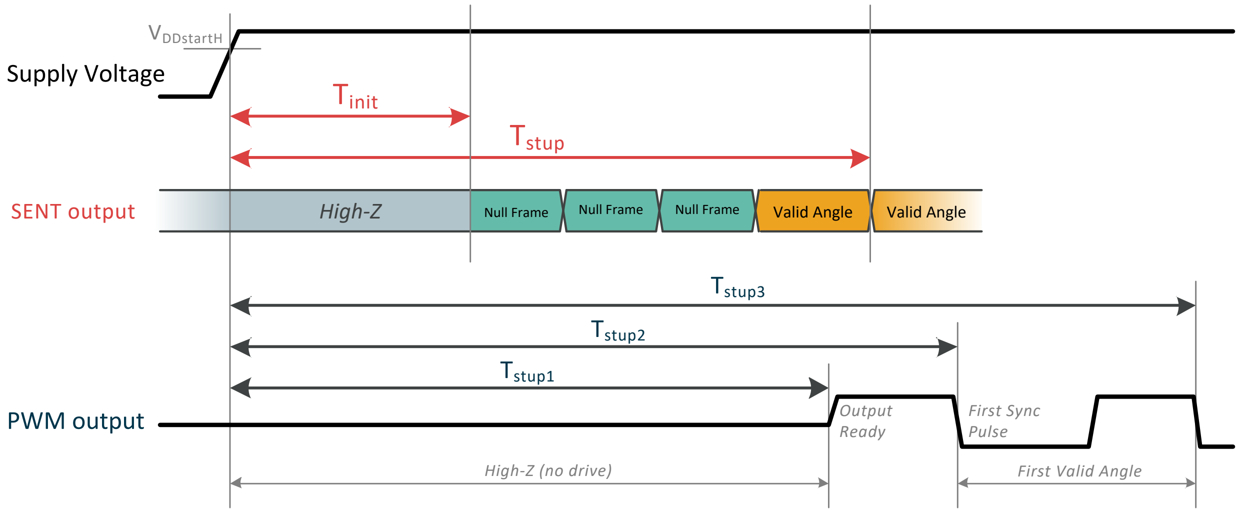

Figure 5 – Start-up Time Definition

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.

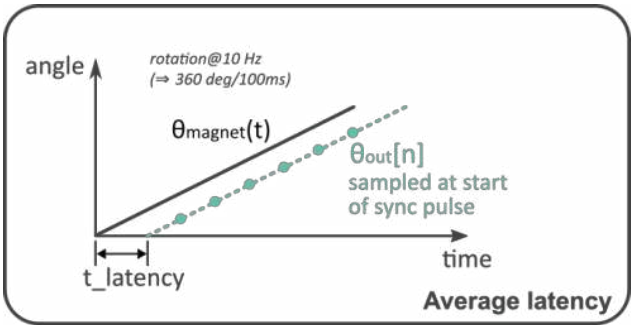

Figure 6 – Definition of Latency

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

For worst case, the measurement sequence length is considered for $\delta_{mag,measSeq}$. This gives:

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

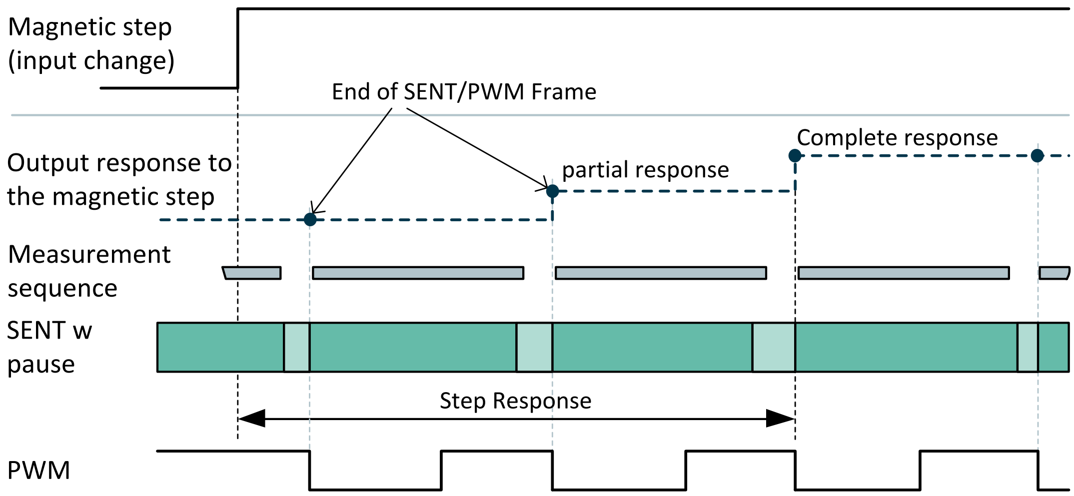

Figure 7 – Step Response Definition

7.4. PWM timing specifications

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}		6.90		ms	
PWM startup Time (up to first sync. Edge)	T_{stup2}	7.40	7.90	16.9	ms	$T_{stup1} + T_{PWM}$
PWM startup Time (up to first data received)	T_{stup3}	7.90	8.90	26.9	ms	$T_{stup1} + 2^{*} T_{PWM}$ [5]
Rise Time PWM		1.0	4.8	12.0	µs	Typ. with SENT_SLOPE_TRIM=4. Measured between 1.1V and 3.8V
Fall Time PWM		1.0	4.8	12.0	µs	

Table 15 - PWM timing specifications

7.5. SENT timing specifications

For different SENT configurations, specifications are valid under the corresponding minimum and typical conditions of 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}	-	2.80	-	ms	Until initialisation frame start
SENT edge rise Time		4.5	6.4	7.7	µs	for SENT_SLOPE_TRIM=0x24 (see 0)
SENT edge fall Time		3.9	4.8	5.2	µs	
Slow Message cycle length (enhanced serial 18-bit)			360		T_{frame}	Standard sequence (20 frames), no Bfield

Table 16 - SENT General Timing Specifications

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

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT with pause (synchronous), 3µs tick time, 2 angles per SENT frame H.1 format						
SENT startup time	T_{stup}	-	7.50	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	2.02	-	ms	Filter = 1 (FIR11)
Step Response (worst case)	T_{wcStep}	-	-	3.31	ms	Filter = 1 (FIR11)
For SENT with pause (synchronous), 3µs tick time, 1 angle per SENT frame H.1 format(6)						
SENT startup time	T_{stup}	-	6.90	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	1.90	-	ms	Filter = 1 (FIR11)
Step Response (worst case)	T_{wcStep}	-	-	2.48	ms	Filter = 1 (FIR11)
For SENT with pause (synchronous), 1.5µs tick time, 1 angle per SENT frame H.1 format						
SENT startup time	T_{stup}	-	6.70	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	1.48	-	ms	Filter = 1 (FIR11)
Step Response (worst case)	T_{wcStep}	-		2.49	ms	Filter = 1 (FIR11)

Table 17 - Synchronous SENT Mode Timing Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT without pause (asynchronous), 3µs tick time, H.1 format(7)						
SENT startup time	T_{stup}	-	7.10	-	ms	Until first valid angle received
Average Latency	T_{latcy}	-	2.23	-	ms	Filter = 0 (no filter)
Step Response (worst case)	T_{wcStep}	-	-	3.00	ms	Filter = 0 (no filter)

Table 18 - Asynchronous SENT Mode Timing Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Condition
For SENT with pause (synchronous), 3µs tick time, 1 angle per SENT frame(6)						
Input pin for external measurement Step Response (worst case)	T_{wcStep_SB}			11	ms	Filter = 0 (no filter)

Table 19 – Input Pin for External Measurement Timing Specification

6 Data based on simulation

7 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

Magnetic Field specifications are valid for temperature range -40°C to 160°C unless otherwise specified.

8.1. Standard Joystick Mode

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Number of magnetic poles	N_P	-	2	-		
Magnetic Flux Density in XY	B_x, B_y			70	mT	$\sqrt{B_x{}^2 + B_y{}^2}$
Magnetic Flux Density in Z	B_z			100	mT	
Useful Magnetic Flux Density Norm projection per magnetic component	B_{Norm}	10[8]			mT	$\sqrt{B_x{}^2 + (B_z / G_{IMC})^2}$ $\sqrt{B_y{}^2 + (B_z / G_{IMC})^2}$ Joystick mode (see 13.4.1 for sensing mode description)
IMC gain[9]	G_{IMC}		1.19			
Field Too Low Threshold[10]	B_{TH_LOW}	0.4	4.8	7	mT	Typ is recommended value to be set by user (see 13.7.4)
Field Too High Threshold[10]	B_{TH_HIGH}	70	100[11]	100[11]	mT	
Field too low Threshold code[10]	DIAG_FIELDTOOLOW THRES		12		LSB	decimal value
Field too high Threshold code[10]	DIAG_FIELDTOOHIGH THRES		250		LSB	decimal value

Table 20 - Magnetic specifications for Standard application

Nominal performances apply when the useful signal B_{Norm} is above the typical specified limit. Under this value, limited performances apply. See 9.2 for accuracy specifications.

[8] Below 10 mT the performances are degraded due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.

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

[10] Typ. value is recommended by Melexis and shall be set by user, see 13.7.4 for further explanation.

[11] Due to the saturation effect of the IMC, the FieldTooHigh monitor detects only defects in the sensors.

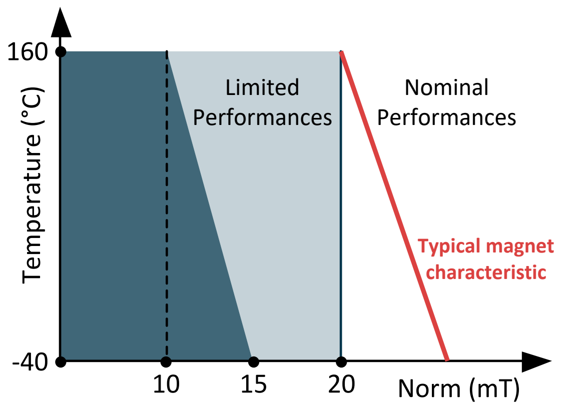

Figure 8 – Minimum useful signal definition for Standard/Legacy application

9. Accuracy Specifications

Accuracy specifications are valid for temperature range -40°C to 160°C and supply voltage range 4.5V to 5.5V unless otherwise specified.

9.1. Definition

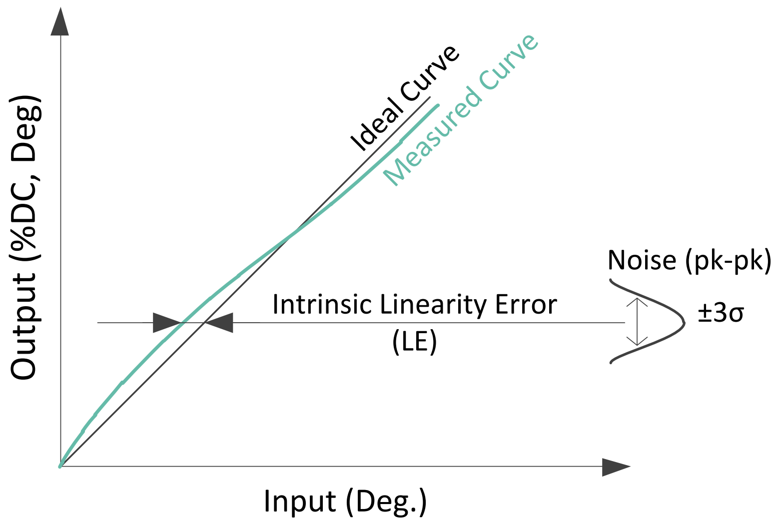

Figure 9 – Sensor accuracy definition

9.2. Standard Mode Nominal Performances

Valid before EoL calibration and for all applications under nominal conditions described in section 8.1 (Figure 8) and chapter 6.

The magnetic field definition is the following:

Bx=B*Cos(Alpha)*Sin(Beta)

By=B*Cos(Beta)*Sin(Alpha)

Bz=B*Sin(Beta)*Sin(Alpha)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Alpha - Intrinsic Linearity Error[12]	L_E	-2.5		2.5	Deg.	
Beta - Intrinsic Linearity Error[12]	L_E	-2.5		2.5	Deg.	
Noise[13]			0.05 0.1 0.05	0.1 0.2 0.1	Deg.	Filter = 0, 40mT Filter = 0, 20mT Filter = 2
Alpha - Thermal Drift[13]		-0.6		0.6	Deg.	Relative to 35°C (under the condition of norm projection)
Beta - Thermal Drift[13]		-0.6		0.6	Deg.	Relative to 35°C (under the condition of norm projection)
Hysteresis				0.1	Deg.	20mT

Table 21 - Standard Mode Nominal Magnetic Performances

9.3. Standard Mode Limited Performances

Valid before EoL calibration and for all applications under limited performances conditions described in section 8.1 (Figure 8) and chapter 6.

Parameter	Symbol	Min	Typ	Max	Unit	Condition
Alpha - Intrinsic Linearity Error[12]	L_E	-2.5		2.5	Deg.	
Beta - Intrinsic Linearity Error [12]	L_E	-2.5		2.5	Deg.	
Noise [13]			0.2 0.14 0.1	0.4 0.28 0.2	Deg.	Filter = 0 Filter = 1 Filter = 2
Alpha - Thermal Drift [13]		-0.8		0.8	Deg.	Relative to 35°C
Beta - Thermal Drift [13]		-0.8		0.8	Deg.	Relative to 35°C
Hysteresis			0.1	0.2	Deg.	10mT

Table 22 - Standard Mode Limited Magnetic Performances

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[12] The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating field for Bx and By and B_z. 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.

[13] $\pm 3\sigma$

10. Memory Specifications

Parameter	Symbol	Min	Typ	Max	Unit	Note
ROM	ROM_{size}		32		kB	1-bit parity check (single error detection)
RAM	RAM_{size}		1024		B	1-bit parity check (single error detection)
NVRAM	$NVRAM_{size}$		256		B	6 bits ECC (single error correction, double error detection)

Table 23 - Memory Specifications

11. Digital output protocol

11.1. PWM (pulse width modulation)

11.1.1. Definition

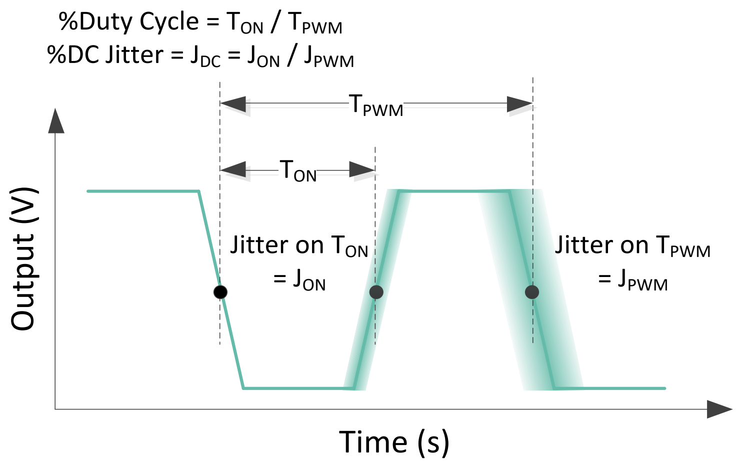


Figure 10 – PWM Signal definition

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	T_{ON} / T_{PWM}

Table 24 - PWM Signal definition

11.1.2. PWM performances

Parameter	Symbol	Min	Typ	Max	Unit	Condition
PWM Output Resolution	R_{pwm}		0.024	0.051	%DC/LSB	2kHz. Worst case error for 160°C
PWM %DC Jitter	J_{DC}			0.03	%DC	Push-Pull, 2kHz, C_L=4.7nF, R_{LPU} =4.7kΩ
PWM Period Jitter	J_{pwm}	-	-	300	ns	Push-Pull, 2kHz, C_L=4.7nF, R_{LPU}=4.7kΩ
PWM %DC thermal drift			0.02	0.05	%DC	Push-Pull, 2kHz, C_L=4.7nF, R_{LPU}=4.7kΩ

Table 25 - PWM Signal Specifications

11.2. Single Edge Nibble Transmission (SENT) SAE J2716

The MLX90378 provides a digital output signal compliant with SAE J2716 Revised APR2016.

11.2.1. Sensor message definition

The MLX90378 repeatedly transmits a sequence of pulses, corresponding with a sequence of nibbles (4 bits), with the following sequence:

- Calibration/Synchronization pulse period 56 clock ticks to determine the time base of the SENT frame
- One 4-bit Status and Serial Communication nibble pulse
- A sequence of one up to six 4-bits data nibble pulses representing the values of the signal(s) to be transmitted. The number of nibbles will be fixed for each application of the encoding scheme (i.e. Two 12-bit fast channels – H.1)
- One 4-bits Checksum nibble pulse
- One optional pause pulse

See also SAE J2716 APR2016 for general SENT specification.

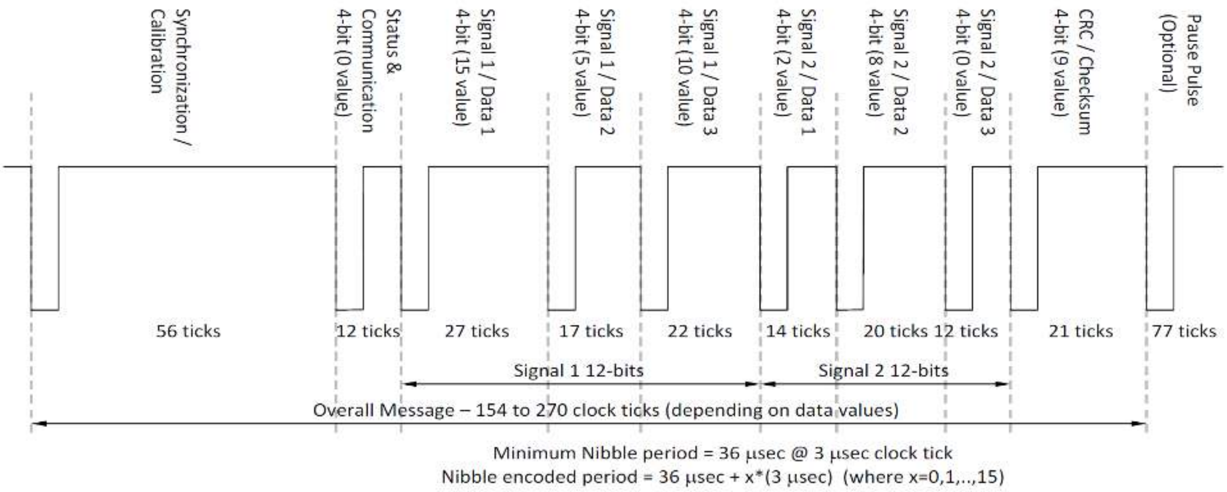


Figure 11 – SENT message encoding example for two 12bits signals

11.2.2. Sensor message frame contents

The MLX90378 SENT transmits a sequence of data nibbles, according to the following configurations:

Description	Symbol	Min	Typ	Max	Unit	Description
SENT	SENTrev		2010	2016		SENT revision. Supports enhanced serial channel messages (2016)
Clock tick time	tickTime	1	3	12	µs	Main use cases : Fast SENT, 1.5µs tick time Normal SENT, 3µs tick time Slow SENT, 6µs tick time (see section 7.5)
Number of data nibbles	Xdn	4	6	6		
Frame duration (no pause pulse)	Npp	154		270	ticks	6 data nibbles
Frame duration with pause pulse	Ppc	304	366	922	ticks	Valid for 3µs tick time
Sensor type	A.7					Position sensors and Ratio sensors

Table 26 - SENT Protocol Frame Definition

11.2.3. SENT message format for dual angle output (standard Joystick mode)

The MLX90378 SENT transmits a sequence of data nibbles; according to the H.1 format defined in SAE J2716 appendix A.7. The frame contains two 12-bit data values; typ. one for alpha angle, one for beta angle.

Figure 12 – A.7 Position Sensor Frame Format

Alpha and beta angles can be swapped between Channel 1 and Channel 2 depending on the system requirements.

11.2.4. SENT message format for XYZ output (magnetometer mode)

The MLX90378 SENT transmits a sequence of data nibbles; according to the F2.4 format defined in SAE J2716 appendix A.3. As there are three axes to be measured and transmitted the fast channel multiplexing is utilized to transmit the X, Y, and Z axis information in sequence.

Each frame consists of six data nibbles as shown below. The data is transmitted as a 16-bit value while the first two nibbles are the frame counter and data consistency counter.

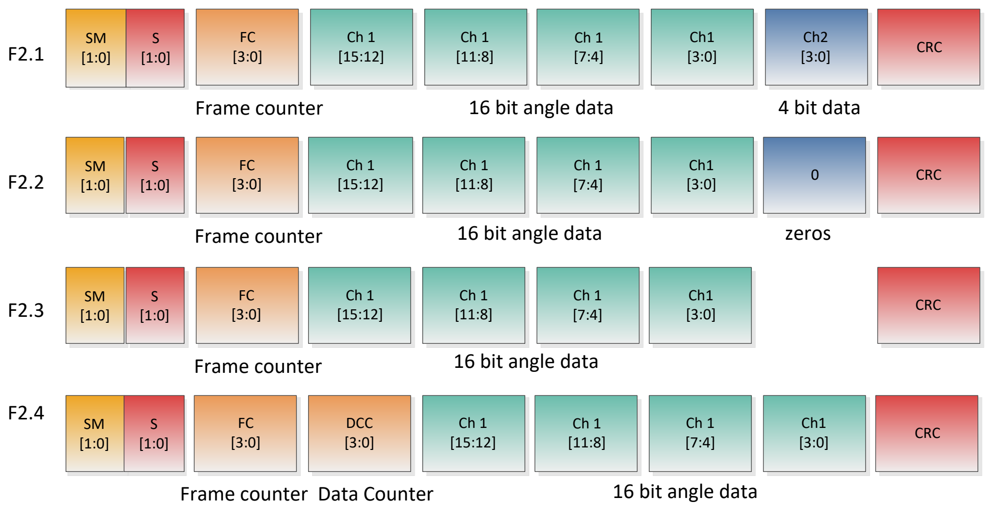


Figure 13 – F2.x – Multiplexing Frame Formats

11.2.4.1. Fast Channel Multiplexing

The pattern above is repeated three times until all three axes are transmitted with the FC indicating which axis is being transmitted (0=B1, 1=B2, 2=B3), where B1,2,3 are defined by DSP_CHANNEL_MAPXYZ. This pattern repeats sequentially (0, 1, 2, 0, 1, 2..). After each loop of the frame control the DCC is incremented and data from next ADC-measurement is used.

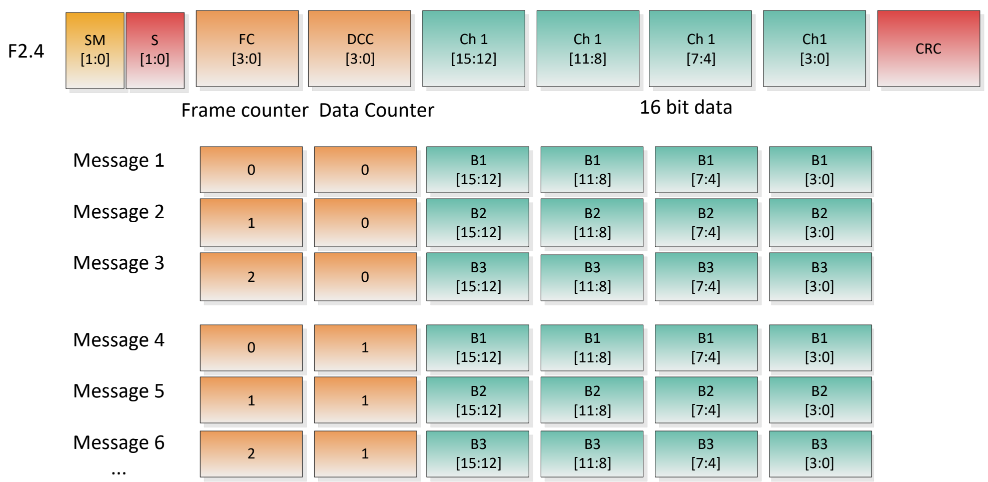


Figure 14 – Example of Fast Channel Multiplexing with DCC

11.2.5. SENT message format for angle and input/gateway measurement

The MLX90378 SENT transmits a sequence of data nibbles; according to the F1.1 format defined in SAE J2716 appendix A.3.The frame contains 12-bit angular value and 8 bit of gateway measurement.

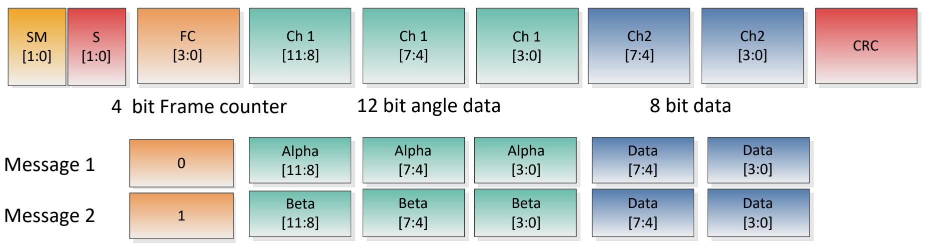


Figure 15 – Example of Fast Channel Multiplexing with Gateway

11.2.5.1. Fast Channel Multiplexing

The MLX90378 SENT transmits a sequence of data nibbles; according to the F1.3 format defined in SAE J2716. The fast channel multiplexing transmits 12-bit angular value and the FC identifies the corresponding angle.

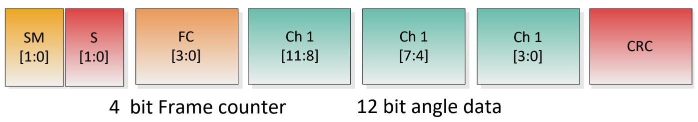


Figure 16 – Fast Multiplexing Frame Format

11.2.6. Start-up behaviour

The circuit will start to 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 the user with the following option:

SENT_INIT_GM	Initialisation frame value	Comments
0	0x000	SAE compliant
1	0xFF9 + NV_DIAG_FAULT_CODE	OEM requirement

Table 27 - Initialisation Frame Content Definition

11.2.7. SENT Timing configuration

SENT_TICK_TIME	Tick time configuration	Description
0	3 µs	Standard SENT
1	0.5 µs	Not recommended
2	1 µs	Not recommended
3	1.5 µs	Fast SENT
4	2.0 µs	Not recommended
5	2.5 µs	Not recommended
6	6 µs	Slow SENT
7	12 µs	Not recommended

Table 28 - SENT Tick Time Configuration

SENT_SEL_SR_FALL SENT_SEL_SR_RISE	Fall time (T_{fall}) configuration	Rise Time (T_{rise})
0	No slew rate control	No slew rate control
1	0.7 µs	1.0 µs
2	1.4 µs	2.0 µs
3	1.9 µs	3.0 µs
4	4.8 µs	6.0 µs
5	9.6 µs	12 µs
6	19 µs	24 µs
7	24 µs	30 µs

Table 29 - SENT Rise and Fall Times Configuration

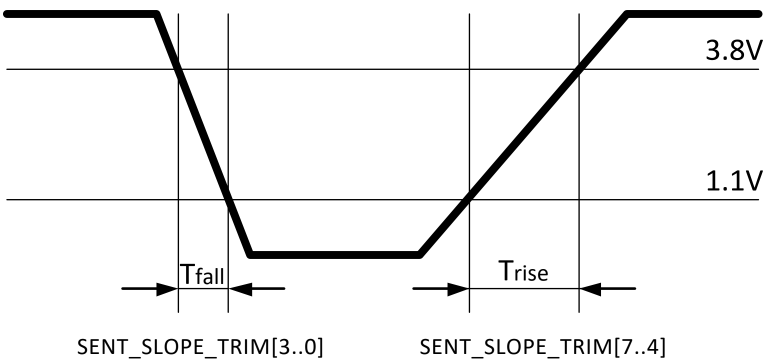


Figure 17 – SENT Rise and Fall Times Configuration

NIBBLE_PULSE_CONFIG	High/low time configuration
2	Fixed low time (5 ticks)
3	Fixed high time (6 ticks)

Table 30 - SENT Nibble configuration (high/low times)

11.2.8. Serial message channel (slow channel)

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

Enhanced format with 12-bits data and 8-bits message ID is used (SAE J2716 APR2016 5.2.4.2, fig. 5.2.4.2-2). According to the standard, SM[0] contains a 6bits CRC followed by a 12-bits data. Message content is defined by a 8-bit message ID transmitted in the SM[1] channel. Correspondence between ID and message content is defined in the table below (Table 31).

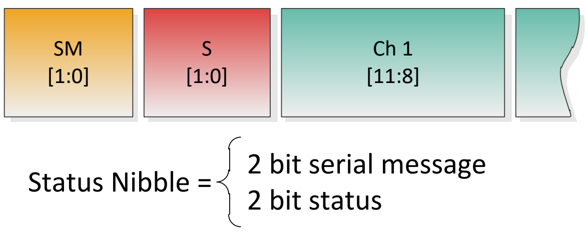


Figure 18 – SENT Status Nibble and Serial Message

By default, the short sequence consisting of a cycle of 24 data is transmitted (Table 31). An extended sequence can be used through configuration of SENT_SLOW_EXTENDED. Additionally, the norm of the B field detected by the sensor can be returned at the end of the sequence by setting SENT_SLOW_BFIELD.

#	8bit ID	Item	Source data
1	0x01	Diagnostic error code	Current status code from RAM
2	0x06	SENT standard revision	SENT_REV from NVRAM
3	0x01	Diagnostic error code	Current status code from RAM
4	0x05	Manufacturer code	SENT_MAN_CODE from NVRAM
5	0x01	Diagnostic error code	Current status code from RAM
6	0x03	Channel 1 / 2 Sensor type	SENT_SENSOR_TYPE from NVRAM
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	0x81	Switch Button	Switch Button Status
19	0x01	Diagnostic error code	Current status code from RAM
20	0x82	Gateway measurement	Gateway ADC
21	0x01	Diagnostic error code	Current status code from RAM
22	0x80	Magnetic Field Magnitude	B Field Magnitude from RAM. Slope 0.1mT / LSB

Table 31 - SENT Slow Channel Standard Data Sequence

For Field Strength encoding, see chapter 8, Magnetic Field Specifications, under the section corresponding to the selected application.

11.2.9. Serial Message Error Code

The list of error and status messages transmitted in the 12-bit Serial Message data field when Serial Message 8-bit ID is 0x01, is given in the Table 32.

Bit Nb	12 Bit Data (hex)	Diagnostic	Comments
-	0x000 / 0x800	No error	Programmable (SENT_DIAG_STRICT, see chap.12, Table 34, #151)
0	0x801	GainOOS	Gain out of spec (see GAIN_MIN, GAIN_MAX)
1	0x802	FieldTooLow	Fieldstrength below defined low threshold (see 13.7.4)
2	0x804	FieldTooHigh	Fieldstrength above defined high threshold (see 13.7.4)
3	0x808	ADCclip	ADC is saturated, either low or high
4	0x810	ADC_test / ADC drop	ADC wrong conversion
5	0x820	Analog Supply Monitors	Detects VDDA (VDEC) over and under voltage or VDD under voltage
6	0x840	Digital Supply Monitors	Detects VDDD (1.8V internal digital supply) overvoltage
7	0x880	RoughOffset	Hall Element offset monitor
8	0x900	Over/Under Temp	Temperature sensor monitor (see 13.7.3)
9	0xA00	DSPoverflow	Overflow in digital signal conditioning
10	0xC00	Biaising current monitor	Biaising current is out of range
11	0x800	Extra Error Flag	set to one if any error present (only when SENT_DIAG_STRICT = 1). Otherwise, always high.

Table 32 - SENT Serial Message Error Code

In case multiple errors occur, the first detected error will be reported until all errors are cleared out.

11.2.10. SENT configuration shorthand definition

Shorthand description	Format	Req	90372 programmable setting
SENT SAE J2716 Rev	SENT xxxx	2007 2008 2010 2016	**CRC_2007** 0 > 2007 1 2007
Clock Tick length [µs]	XX.X µs	0.5<xx<12	**SENT_TICK_TIME** 0 SENT 3.0µs 1 SENT 0.5µs 2 SENT 1µs 3 SENT 1.5µs 4 SENT 2.0µs 5 SENT 2.5µs 6 SENT 6.0µs 7 SENT 12.0µs
Number of data Nibbles	X dn	4 ≤ x ≤ 6	6 Data nibbles
Pause Pulse Option	npp ppc (xxx.0) xxx	No pause Pulse Pause Pulse with const. frame length Frame Length (in clock ticks)	**PROTOCOL** 0 = npp 2 = ppc **T_FRAME** xxx > 304…4095
Use of Serial protocol	nsp ssp esp	No serial protocol Short serial protocol Enhanced serial protocol	**SERIAL_CONFIG** 1 nsp 2 ssp (not compliant) 3 esp
Sensor type	H.1	Sensor 12-Bit CH1 & CH2	H.1

Table 33 - SENT Shorthand Description

12. End-User Programmable Items

Parameter	PSF value	Description	Default Values Standard	#bits
USER_ID[0..5]	1..6	User Id. Reference. Reserved for customer traceability	see 12.1	8
SENSING_MODE	8	Mapping fields for output angle 3D position / Joystick - order code 300	4	4
DSP_NB_CONV	9	Number of phase spinning within ADC sequence 3: 4 phase spinning	3	3
CW_Alpha	10	Set rotation to clockwise for Alpha	0	1
CW_Beta	11	Set rotation to clockwise for Beta	0	1
FILTER	12	Filter mode selection	1	2
DSP_CHANNEL_MAPXYZ	13	DSP Channel mapping 0 : B1 = X, B2 = Y , B3 = Z	0	3
FMC_DATA	14	Data fast channel multiplexing 0: Bx, By, Bz field components Note: output Bx, By, Bz components are not compensated over temperature	0	1
GAINSATURATION	15	Gain Saturates on GAINMIX and GAINMAX	0	1
ENHORTH	17	Enable enhanced Orthogonality correction	1	1
DENOISING_FILTER_SEL	18	Select the alpha parameter of the EMA (IIR) filter	0	1
ENHFORM	19	Enable enhanced Front-end "Joystick" angle correction	1	1
GAINMIN	23	Low threshold for virtual gain	1	8
GAINMAX	24	High threshold for virtual gain	63	8
HYST	25	Hysteresis threshold for EMA filter	0	1
DP_ALPHA	26	Discontinuity point for Alpha	0	16
DP_BETA	27	Discontinuity point for beta	0	16
LNRS0_Alpha LNR_A_S_ALPHA LNR_B_S_ALPHA LNR_C_S_ALPHA LNR_D_S_ALPHA	28 31 34 37 40	4pts – Slope for reference points A,B,C,D for Alpha	4000h 4000h N/A N/A N/A	16
LNR_A_X_ALPHA, LNR_B_X_ALPHA LNR_C_X_ALPHA LNR_D_X_ALPHA	29 32 35 38	4pts - X Coordinate for reference points A,B,C,D for Alpha	4000h N/A N/A N/A	16
LNR_A_Y_ALPHA, LNR_B_Y_ALPHA LNR_C_Y_ALPHA LNR_D_Y_ALPHA	30 33 36 39	4pts - Y Coordinate for reference points A,B,C,D for Alpha	8000h N/A N/A N/A	16
LNRS0_ BETA LNR_A_S_ BETA	41 44	4pts – Slope for reference points A,B,C,D for Beta	4000h 4000h	16

Parameter	PSF value	Description	Default Values Standard	#bits
LNR_B_S_ BETA LNR_C_S_ BETA LNR_D_S_ BETA	47 50 53		N/A N/A N/A	
LNR_A_X_ BETA LNR_B_X_BETA LNR_C_X_ BETA LNR_D_X_ BETA	42 45 48 51	4pts - X Coordinate for reference points A,B,C,D for Beta	4000h N/A N/A N/A	16
LNR_A_Y_ BETA LNR_B_Y_ BETA LNR_C_Y_ BETA LNR_D_Y_ BETA	43 46 49 52	4pts - Y Coordinate for reference points A,B,C,D for Beta	8000h N/A N/A N/A	16
CLAMPLOW	54	Low clamping value of output data	10	16
CLAMPHIGH	55	High clamping value of output data	FF80	16
PUSHBUTTON_THRESHOLD	56	High Threshold for the pushbutton functionality	0	16
KT_ALPHA	57	“Joystick” ALPHA angle correction parameter	0x8000	16
KT_BETA	58	“Joystick” BETA angle correction parameter	0x8000	16
S_KZ	59	Sensitivity correction Z vs XY	0x7F	8
K_ORTH_ZX_ALPHA	60	Front-end “Joystick” angle correction parameter	0	8
K_ORTH_ZY_ALPHA	61	Front-end “Joystick” angle correction parameter	0	8
K_ORTH_ZX_BETA	62	Front-end “Joystick” angle correction parameter	0	8
K_ORTH_ZY_BETA	63	Front-end “Joystick” angle correction parameter	0	8
DIAG_TEMP_THR_LOW	64	Threshold for low temperature diagnostic	8h	8
DIAG_TEMP_THR_HIGH	65	Threshold for high temperature diagnostic	88h	8
DIAG_FIELDTOOLOWTHRES	66	Field limit under which a fault is reported	0	8
DIAG_FIELDTOOHIGHTHRES	67	Field limit over which a fault is reported	0xFFh	8
ABE_INPUT_MODE	69	External input configuration 0: disabled	0	3
PUSHBUTTON_ENABLE	70	Enable Pushbutton feature	0	1
PUSHBUTTON_POL	71	Invert the pushbutton polarity	N/A	1
PUSHBUTTON_THRESHOLD_HYST	72	Low Threshold for the pushbutton functionality	N/A	3
DIAG_DEBOUNCE_STEPDOWN	74	Diagnostic debouncing stepdown time	1	4
DIAG_DEBOUNCE_STEPUP	75	Diagnostic debouncing stepup time	2	4
DIAG_DEBOUNCE_THRESH	77	Diagnostic debouncing threshold	2	4
DIAG_GLOBAL_EN	78	Diagnostics global enable. **Do not modify!** (see Safety Manual)	1	1
COLD_SAFE_STARTUP_EN	79	Normal (0) or full safe (1) start-up after power-on reset	0	1
PROTOCOL	81	Select digital output communication mode 2 = SENT with pause (default)	2	2
PWM2_EN	82	Enables the second PWM Output	0	1
PWM_POL	83	Invert the PWM polarity	N/A	1

Parameter	PSF value	Description	Default Values Standard	#bits
PWM_SWAP	84	Swap PWM channels	N/A	1
PWM_REPORT_MODE_ANA	85	Error message within PWM frame	0	1
PWM_DC_FAULT	87	PWM Duty cycle in case of fault	4	8
RAMPROBE_OFFSET	88	Signed offset to be added to the RAM-probed data	N/A	16
SENT_SEL_SR_FALL	90	SENT slope Fall time configuration	4	3
SENT_SEL_SR_RISE	91	SENT slope Rise time configuration	4	1
SENT_REPORT_MODE_ANA	92	Error message within SENT frame in diagnostic mode: 0 : SENT – status bit S0 is set 1: SENT – status bit S0 is set and data = FF9 + DIAG_FAULT_CODE	0	1
STATUS_IN_CRC	94	Add first nibble in SENT CRC calculation	0	1
FAST_CHANNEL_SWAP	95	Enable swap Ch1 & Sh 2	0	1
SENT_FAST_CHANNEL_1	96	Select data for Channel 1 0 = Alpha	0	2
RAMPROBE_ROTATE	97	Right-shifting N times the RAM-probed data	N/A	4
RAMPROBE_PTR	98	Ramprobe Address	N/A	16
RAMPROBE_MASK	99	" AND" Mask of the RAM-probed data	N/A	16
SENT_MAN_CODE	101	Serial data message Manufacturer code	6	12
SENT_REV	102	Serial data message SENT rev	4	12
SENT_SENSOR_TYPE	104	Serial data message SENSOR_TYPE	0x50h	12
DIAG_FAULT_CODE	106	Option for fault code building in SENT mode: Fault_code = 0xFF9 + NV_DIAG_FAULT_CODE (only applicable for joystick angle configured channels)	6	3
SENT_TICK_TIME	108	Sent tick time. 0 : 3 usec	0	3
TWO_ANGLES_FRAME	109	Enable 2 angle measurements SENT period w/ pause pulse	1	1
NIBBLE_PULSE_CONFIG	110	SENT nibble high/low-time configuration 2 : Fixed 5 ticks low	2	2
SENT_FAST_CHANNEL_2	111	Select data for Channel 2 0 : Beta	0	2
SENT_LEGACY_CRC	112	Enable SENT2007 CRC calculation	0	1
SENT_SLOW_BFIELD	113	Enable enhanced serial message ID 80	0	1
SENT_FC_FORMAT	114	SENT Fast Channel format configuration 0: format H.1 1: format H.6 2: format H.7 3: format F1.1 4: format F1.2 5: format F1.3	0	4

Parameter	PSF value	Description	Default Values Standard	#bits
		6: format F1.4 7: format F1.5 8: format F1.6 9: format F2.1 10: format F2.2 11: format F2.3 12: format F2.4		
T_FRAME	117	SENT Frame Tick Count or PWM period in 4µs/LSB	370	12
DIAG_GATEWAY	105	Enable status check external input	0	1
DIAG_GTW_MIN	131	Min Threshold for external input "Switch Button diagnostic"	N/A	4
DIAG_GTW_MAX	118	Max Threshold for external input "Switch Button diagnostic"	N/A	4
SWITCHBUTTON_THRESHOLD	129	Threshold " Switch Button" on condition	0x3Fh	8
SWITCHBUTTON_HYST	130	Threshold "Switch Button" off condition	0	4
T_SYNC_DELAY	120	SENT - ADC synchronization delay	95	12
SENT_DIAG_STRICT	121	Enhanced serial error reporting option : Disable Bit 11 when no error is present.	1	1
SERIAL_CONFIG	122	Serial data protocol configuration 1: No serial protocl (nsp) 3: enhanced serial protocol (esp)	3	2
SENT_INIT_GM	123	SENT initialization configuration 0 : transmitting 0 as initialization data 1 : transmitting 0xFF9 + NV_DIAG_FAULT_CODE as initialization data	0	1
SENT_CHANNEL_X1	124	Serial data message X1	0	12
SENT_CHANNEL_X2	125	Serial data message X2	0	12
SENT_CHANNEL_Y1	126	Serial data message Y1	0	12
SENT_CHANNEL_Y2	127	Serial data message Y2	0	12
WARM_TRIGGER_LONG	133	Add delay to enter PTC mode	0	1
ABE_OUT_MODE	134	Output mode in normal condition 00: SENT mode = digital push-pull 01: SENT mode = open-drain 10: PWM mode = digital fast push-pull 11: PWM open-drain	0	2
ABE_OUT_CFG	135	Output pin	6	5
OUT_DIAG_HIZ_TIME	136	"Transient failure reporting time. When a transient digital failure is detected, the output is in high-Z mode Timeout = ((NV_OUT_DIAG_HIZ_TIME+1) * 4 -1) * 1ms.	7	3

Parameter	PSF value	Description	Default Values Standard	#bits
ROUT_LOW	137	Sensor output impedance in PTC mode Option for output pull-up resistor 0: > 200 Ohms 1: < 200 Ohms	1	1
MEMLOCK	138	Enable NVRAM write LOCK	0	2
WARM_ACT_HIGHV	139	Activate V_{DD} > 5 V application	0	1

Table 34 - MLX90378 End-User Programmable Items Table

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

12.1. End User Identification Items

Parameter	PSF value	Description	Default Values Standard	#bits
USER_ID[0..5]	1,2,5,6	User Id. References	-	8
USER_ID2	3	Product Number for 90378ABJ	17	8
USER_ID3	4	NVRAM default content revision • 300 standard Legacy (Warning! if used overwrites NVRAM rev. information)	1	8
TEST_STATUS	690	Final test status 1: Bin 1	1	1
IMC_VERSION	689	1: clover IMC	1	7
MLX_ID0	691	X-Y position on the wafer (8 bit each)	-	16
MLX_ID1	694	Wafer ID (5 bits) Lot ID [10...0]	-	16
MLX_ID2	697	Lot ID [16...11] Fab ID (4 bits) Test Database ID (6 bits)	-	16

Table 35 - Melexis and Customer ID fields description

User identification numbers (96 bits, 6 words) are freely useable by customers for traceability purpose. Other IDs are read only.

13. Description of End-User Programmable Items

13.1. Output Configuration

The MLX90378 can operate as a joystick sensor or a 3D magnetometer. In joystick mode the MLX90378 computes two angular values, Alpha and Beta, based on the magnetic field. The output values are then computed based on the end of line calibration performed which defines a transfer function mapping the angle value to a PWM duty cycle or a SENT value.

In magnetometer mode the MLX90378 multiplexes the X, Y, and Z axis values onto the SENT bus via fast channel multiplexing and are transmitted as 16-bit 2's complement encoded values or signed 12-bit values.

13.1.1. Channel Selection

The MLX90378 provides the ability to define the data that will be transmitted in the SENT channels and swap the Alpha and Beta angles between the two available channels. This is particularly useful in the event the IC is rotated 90 degrees (e.g. for PCB layout purposes).

SENT_FAST_CHANNEL_1/2	Channel 1	Channel 2
0	Alpha	Beta
1	Internal temperature	Internal temperature
2	Field norm	Field norm
3	Ramprobe	Ramprobe

Table 36 – SENT Channel selection

NV_FAST_CHANNEL_SWAP	Angle to Channel Assignment
0	Channel 1 = Alpha Angle Channel 2 = Beta Angle
1	Channel 1 = Beta Angle Channel 2 = Alpha Angle

Table 37 – NV Channel selection

13.1.2. OUT mode (ABE_OUT_MODE)

Defines the Output Stage mode (SENT, PWM) in application.

ABE_OUT_MODE	Type	Description	Comments
0	SENT	Push-Pull	
1	SENT	Open Drain	requires a pull-up resistor
2	PWM	Push-Pull	
3	PWM	Open Drain	requires a pull-up resistor

Table 38 - Output Mode Selection

13.1.3. Digital OUT protocol (PROTOCOL)

Selection of the measurement timing mode and the corresponding output protocol

PROTOCOL	Type	Descriptions
0	SENT	Continuous asynchronous angle acquisition, SENT without pause pulse
1	PWM	Continuos asynchronous angle acquisition, PWM
2	SENT	Continuous synchronous angle acquisition, SENT with pause
3	Not used	Not used

Table 39 - Protocol Selection

13.1.4. Serial Channel Configuration- Status and Communication Nibble

SERIAL_CONFIG	Type	Descriptions
0	-	Status and Communication nibble is not present. This configuration is not compliant with SENT. Do Not Use!
1	nsp	Status nibble will report an error. Data sent along the serial channel is taken from RAM.
2	esp	Status nibble reports errors and serial channel reports sequence defined in 11.2.8
3	not used	Not used

Table 40 - SENT Serial Channel Configuration

13.1.5. Pushbutton Output

The MLX90378 includes the ability to determine if the magnet is suddenly moved towards the sensor. This enables detection of a push movement of the joystick. The push detection behaviour is set by three parameters. This function is only available when configured to use SENT output as the pushbutton state is indicated by output 2.

In normal operation the MLX90378 continuously computes the magnetic norm or magnitude. When the norm exceeds the value specified in NV_PUSHBUTTON_THRESHOLD output 2 will go to the pushed state defined by NV_PUSHBUTON_POL. When the norm is less than NV_PUSHBUTTON_THRESHOLD_HYST output 2 will go to the released state defined by NV_PUSHBUTTON_POL.

NV_PUSHBUTTON_POL	Output 2 State
0x0	Pushed: High Released: Low
0x1	Pushed: Low Released: High

Table 41 – Pushbutton Output Selection

13.1.6. PWM Output Mode

If PWM output mode is selected, the output signal is a digital signal with two Pulse Width Modulation (PWM) channels; one for Alpha angle and one for Beta angle.

The PWM polarity is selected by the PWMPOL 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, 2000] Hz by the T_FRAME parameter (12bits), defining the period time in the range [0.5; 10] ms. Minimum allowed value for T_FRAME is therefore 125 (0x7d).

$$T_{PWM} = \frac{4}{10^6} \times T\_FRAME$$

- PWM period is subject to the same tolerances as the main clock (see ΔT_{ck}).

13.2. Angular Calculation Formula

The angle may be computed by two methods: the standard joystick formula or the enhanced formula which allows for improved performance.

13.2.1. Standard Formula (NV_ENHFORM)

The standard formulas for Alpha and Beta angle are shown below. These are used when the enhanced formula is not selected (NV_ENHFORM=0).

Angle	Formula
Alpha	$\alpha = ATAN2(K_Z * B_Z, B_X)$
Beta	$\beta = ATAN2(K_Z * B_Z, B_Y)$

Table 42 – Standard Joystick Angular Calculation Formula

13.2.2. Enhanced Formula

When selected the enhanced formulas for Alpha and Beta are enabled (NV_ENHFORM=1).

Angle	Formula
Alpha	$\alpha = ATAN2\left(\sqrt{(K_Z * B_Z)^2 + \left(K_{T-Alpha} * B_Y\right)^2}, B_X\right)$
Beta	$\beta = ATAN2\left(\sqrt{(K_Z * B_Z)^2 + (K_{T-Beta} * B_X)^2}, B_Y\right)$

Table 43 – Enhanced Angular Calculation Formula

13.3. Output Transfer Characteristic

The output behaviour is defined by a four-point transfer function. Each axis can be programmed with an independent transfer function.

Output Transfer Characteristic	4POINTS	DSP_LNR_RESX2
4 Arbitrary Points	1	0

Table 44 - Output Transfer Characteristic Selection Table

Parameter	LNR type	Value	Unit
CW	All	0 → counter clockwise 1 → clockwise	LSB
DP	All	0 … 359.9999	deg
LNRAX LNRBX LNRCX LNRDX	4 pts, X coordinates	0 … 359.9999	deg
LNRAY LNRBY LNRCY LNRDY	4 pts, Y coordinates	0 … 100 -50 … + 150 0..4095 -2048..6142	% LSB_{12}
LNRS0 LNRAS LNRBS LNRCS LNRDS	4 pts, slopes	-17 … 0 … 17 -700..700	%/deg LSB_{12}
CLAMP_LOW	All	0 … 100 0..4095	% LSB_{12}
CLAMP_HIGH	All	0 … 100 0 … 4095	% LSB_{12}

Table 45 - Output linearization and clamping parameters

13.3.1. CW (Clockwise) Parameter

The CW parameter defines the magnet rotation direction.

- 0 or counter clockwise is defined by the 1-4-5-8 pin order direction for the SOIC-8 package and 1-8-9-16 pin order direction for the TSSOP-16 package.
- 1 or clockwise is defined by the reverse direction: 8-5-4-1 pin order direction for the SOIC-8 and 16-9-8-1 pin order direction for the TSSOP-16 package.

Refer to the drawing in the sensitive spot positioning section (18.3, 18.6).

13.3.2. Discontinuity Point (or Zero Degree Point)

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

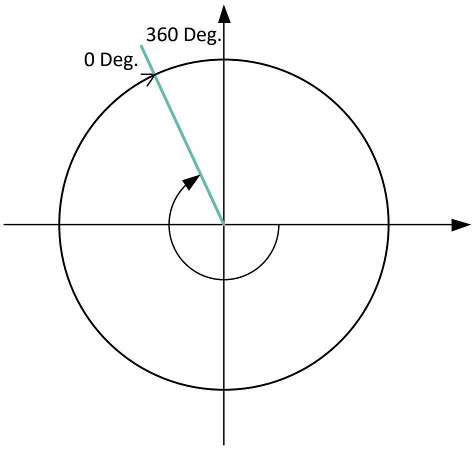


Figure 19 – Discontinuity Point Positioning

13.3.3. 4-Pts LNR Parameters

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

The shape of the MLX90378 four points transfer function from the digital angle value to the digital output is described in the following figure (Figure 20).

Three calibration points are typically used for each axis (e.g. left position, middle position, right position). The fourth point allows for dead zones to be added in case the application wants decreased sensitivity around a specific angle of rotation (typically the middle position).

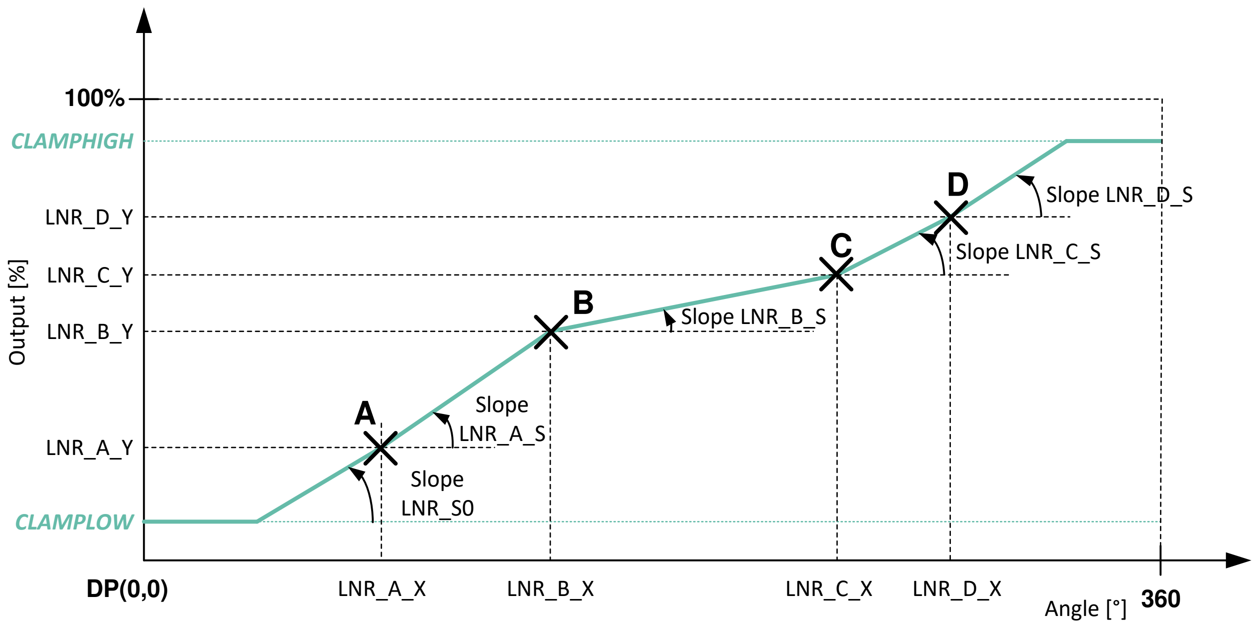


Figure 20 – 4pts Linearization Parameters Description

13.3.4. 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 16-bits of adjustment and are available for all four LNR modes. As output data resolution is limited to 12-bits, both in SENT and in PWM, the 4 LSB of this parameter will have no significant effect on the output. The value is encoded in fractional code, from 0% to 100%

13.4. Sensor Front-End

Parameter	Value
SENSING MODE	[4,5]
GAINMIN	[0..63]
GAINMAX	[0..63]
GAINSATURATION	[0, 1]

Table 46 - Sensing Mode and Front-End Configuration

13.4.1. SENSING MODE (NV_DSP_CHANNEL_MAPXYZ)

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

This 3-bit value selects the first (B1), second (B2), and third (B3) field components according to the Table 47 content.

MAPXYZ	B1	B2	B3
0	X	Y	Z
1	X	Z	Y
2	Y	Z	X
3	Y	X	Z
4	Z	X	Y
5	Z	Y	X
6-7		Invalid	

Table 47 - Sensing Mode Description

13.4.2. 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.

13.5. External input and switch

The MLX90378 provides the ability to measure an external analog or PWM signal and transmit the raw data in the SENT channel and/or Serial message channel.

When the signal exceeds the value specified in SWITCHBUTTON_THRESHOLD, "Switch Button" will go to the high state. When the signal is less than SWITCHBUTTON_HYST, "Switch Button" will go to the low state. This is reported as the "Switch Button Status" in the SENT Slow Channel Standard Data Sequence.

ABE_INPUT_MODE	External input configuration
0	Disabled
2	Analog mode
3	Inverted Analog mode
5	PWM mode

Table 48 – External input and switch configuration

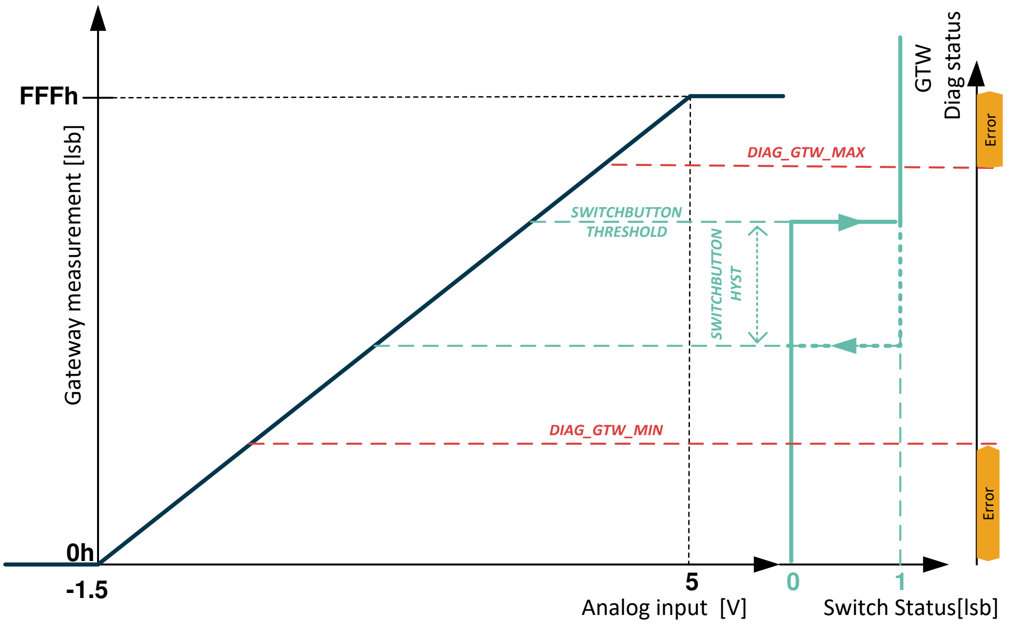


Figure 21 – External input and switch behaviour

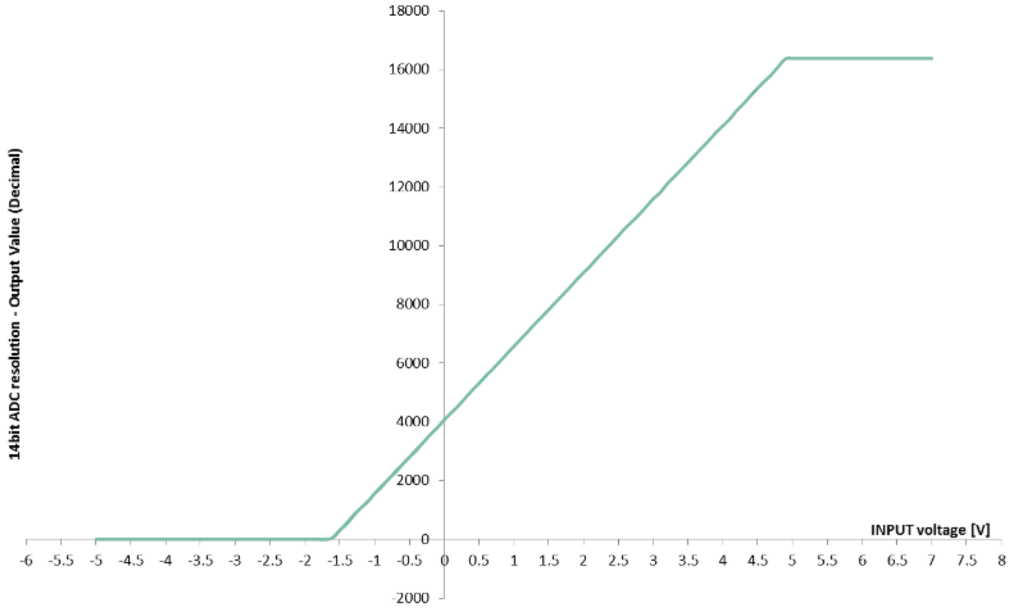


Figure 22 – ADC range for Switch Button Input Pin

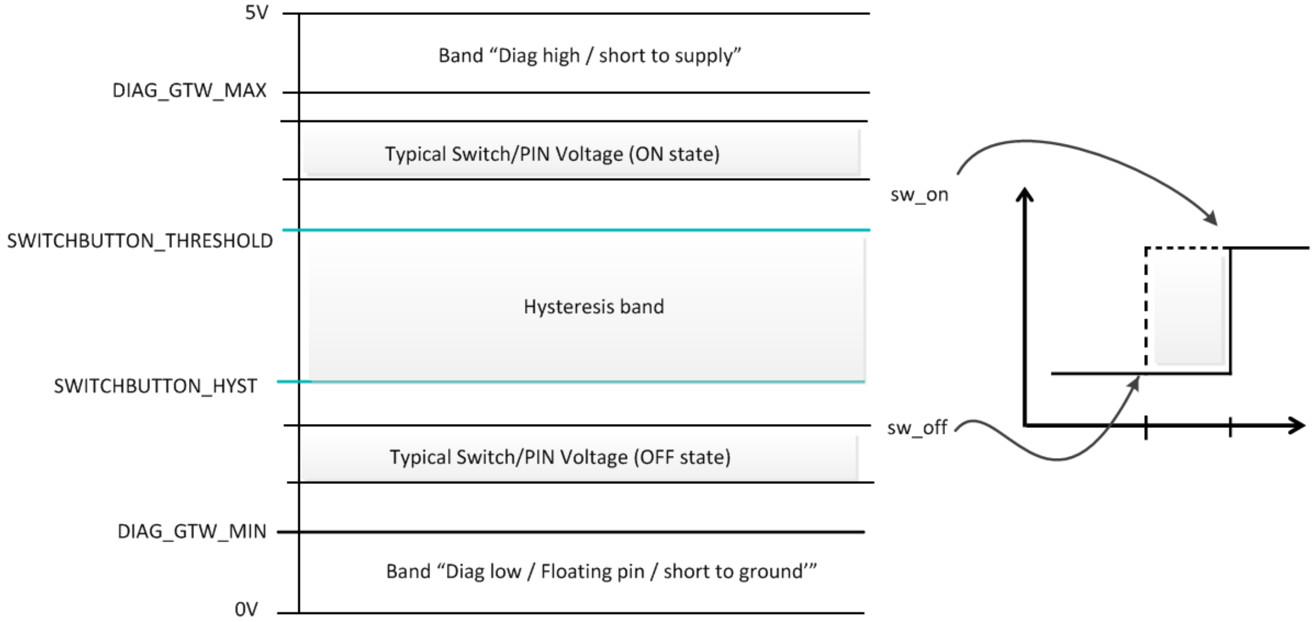


Figure 23 - Illustration of Switch Button states

13.6. Filter

Parameter	Value
FILTER	0 … 2
HYST	0 … 255

Table 49 - Filter configuration

The MLX90378 includes 2 types of filters:

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

13.6.1. Exponential Moving Average (IIR) Filter

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

$$y_n = a * x_n + (1-a) * y_{n-i} \qquad x_n = Angle \quad y_n = Output$$

The filters characteristic is given in the following table (Table 50):

DENOISING_FILTER_ALPHA_SEL	0	1	2	3
Coefficients a	0.75	0.5	0.25	0.125
Efficiency RMS (dB)		2.4	4.2	

Table 50 - IIR Filter characteristics

13.6.2. FIR Filters

The MLX90378 features 2 FIR filter modes controlled with Filter = 1…2. Filter = 0 corresponds to no filtering. The transfer function is described by:

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

This filter characteristic is given in Table 51.

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

Table 51 - FIR Filter Characteristics

13.7. Programmable Diagnostics Settings

13.7.1. Diagnostics Global Enable

DIAG_EN should be kept to its default value (1) to retain all functional safety abilities of the MLX90378. It is not recommended to disable this feature.

13.7.2. Diagnostic Debouncer

A debouncing algorithm is available for analog diagnostic reporting (see chapter 14, Functional Safety). However, enabling this debouncer increases the DCT of the device. Therefore, Melexis recommends keeping the debouncing of analog faults off by not modifying debouncer values (see Table 34 for default values)

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

Table 52 - Diagnostic debouncing parameters

The debouncing algorithm will increment the debouncing counter by STEPUP value in case of an analog error, and decrement this same counter by STEPDOWN when the system is free of analog diagnostic error. When the debouncing counter reaches a value defined by DEBOUNCE THRESHOLD, an error is reported and the debouncing counter stays clamped to this DEBOUNCE THRESHOLD value. The recovery happens when this counter reaches zero. To implement proper reporting times, one should refer to the DCT defined in the Table 12.

The reporting and recovery time are therefore defined as

Parameter	Min	Max
Reporting Time	$DTI \cdot \left(\left\lceil \frac{THRESH}{STEPUP} \right\rceil - 1\right)$	$DTI \cdot \left(\left\lceil \frac{THRESH}{STEPUP} \right\rceil\right)$
Recovery Time	$DTI \cdot \left(\left\lceil \frac{THRESH}{STEPDOWN} \right\rceil + 1\right)$	$DTI \cdot \left(\left\lceil \frac{THRESH}{STEPDOWN} \right\rceil + 2\right)$
	$\left\lceil \frac{x}{y} \right\rceil$	is the ceiling function of x divided by y

Table 53 - Diagnostic Reporting and Recovery times

13.7.3. Over/Under Temperature Diagnostic

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

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

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

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

DIAG_TEMP_THR_LOW/HIGH are encoded on 8-bit unsigned values with the following relationship towards T_{Lin}

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

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/LSB	
T_{LIN} refresh rate	$F_{S,TLIN}$	-	200	-	Hz	
T_{LIN} linearity error	T_{LinErr}	-8	-	8	°C	from -40 to 160°C
High temperature threshold	DIAG_TEMP_THR_HIGH	-	8	-	LSB	Recommended value, corresponds to -57°C
Low temperature threshold	DIAG_TEMP_THR_LOW	-	136	-	LSB	Recommended value, corresponds to 199°C
High/low temperature threshold resolution	Res_{Tthr}		2		°C/LSB	

Table 54 - Linearized Temperature Sensor characteristics

13.7.4. Field Strength

Field strength is a value computed by the IC using the same field components used to compute the angle. Therefore, this value represents the norm of the flux density, or of the flux density gradient, in the plane defined by the selected application. Field Strength is compensated over the circuit operating temperature range and therefore represents a reliable image of the field intensity generated by the magnet.

Field Strength value is available either in SENT slow channel or in SENT secondary channel. The encoding of this value is specified in chapter 8, Magnetic Field Specifications, and depends on the selected application.

13.7.5. PWM Diagnostic

DC_FAULT

This parameter defines the duty-cycle that is present on PWM output in case of diagnostic reporting.

14. Functional Safety

14.1. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90378 component in a safety related item, as Safety Element Out-of-Context (SEooC).

In particular it includes:

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

14.2. Safety Mechanisms

The MLX90378 provides numerous self-diagnostic features (safety mechanisms). Those features increase the robustness of the IC functionality by either preventing the IC to provide an erroneous output signal or reporting the failure according to the SENT protocol definition.

Legend
● High coverage
○ Medium coverage
ANA : Analog hardware failure reporting, described in the safety manual
High-Z : Special reporting, output is set in high impedance mode (no HW fail-safe mode/timeout, no SW safe startup)
DIG : Digital hardware failure reporting, described in the safety manual
* : Diagnostic Cycle Time (see 7.1 for values)
At Startup : HW fault present at time zero is detected before a first frame is transmitted.
DIAG_EN : This safety mechanism can be disabled by setting DIAG_EN = 0 (see 12 End-User Programmable Items). This option should not be used in application mode!

Table 55 - Self Diagnostic Legend

Category and safety mechanism name	Front - end	ADC	DSP	Back-end	Sup port. Func.	Module & Packag e	DCT*	Reportin g mode	At startu p	DIA G EN
Signal-conditioning (AFE, External Sensor) Diagnostic	●	●				●		ANA		
Magnetic Signal Conditioning Voltage Test Pattern	●	○	○				DCT_Ana	ANA		●
Magnetic Signal Conditioning Rough Offset Clipping check	●		○				DCT_Ana	ANA	NO	●
Magnetic Signal Conditioning Gain Monitor	●		○			●	DCT_Ana	ANA	YES	●
Magnetic Signal Conditioning Gain Clamping	●		○			●	DCT_Ana	ANA	YES	
Mag. Sig. Cond. Failure control by the chopping technique	●						n/a	n/a	YES	
External Sensor Sig. Cond. Voltage Valid Range Check	●					●	DCT_Ana	ANA	YES	●
External Sensor Sig. Cond. Frequency Valid Range Check	●					●	DCT_Ana	ANA	YES	●
A/D Converter Test Pattern		●					DCT_Ana	ANA		●
ADC Conversion errors & Overflow Errors		●					DCT_Ana	ANA	YES	●
Flux Monitor (Specific to Rotary mode)	●	○				●	DCT_Ana	ANA	YES	●
Digital-circuit Diagnostic			●					DIG		
RAM Parity, 1 bit per 16 bits word, ISO D.2.5.2			●				<10µs	DIG	YES	●
ROM Parity, 1 bit per 16 bits word, ISO D.2.5.2			●				<10µs	DIG	YES	●
NVRAM 16 bits signature (run-time) ISO D.2.4.3			●				DCT_nvram_bis t	DIG		
NVRAM Single Error Correction ECC			●				n/a	n/a	YES	
NVRAM Double Error Detection ECC ISO			●				DCT_Dig	DIG	YES	

Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Sup port. Func.	Module & Package	DCT*	Reporting mode	At startup	DIAG EN
Logical Monitoring of program sequence ISO D.2.9.3 via Watchdog "IWD" (cpu clock) ISO D2.9.2			●		○		Tiwd	DIG		●
Watchdog "AWD" (separate clock) ISO D2.9.1			●		○		Tawd	DIG		
CPU Errors "Invalid Address", "Wrong opcode"			●		○		<10µs	DIG	YES	
ADC Interface Checksum		●					DCT_Dig	DIG	NO	●
DSP Test Pattern (atan2)			●		○		DCT_Dig	DIG		●
Critical ports monitoring			●				DCT_Dig	DIG	NO	●
SENT H/W Interface Diagnostic				●				DIG		
SENT parity check over Configuration registers				●			<10µs	DIG	NO	●
SENT block: Protection against re-configuration at run-time				●			<10µs	DIG	NO	●
SENT Frame Counter & Redundant Nibble				●			n/a	n/a	n/a	
System-level diagnostic					●	●		ANA		
Supply Voltage Monitors (all supply domains) except VS_OV & POR					●	●	DCT_Ana	ANA	NO	●
External Supply Overvoltage Monitor VS_OV					●	●	2.1ms	High-Z	YES	
Digital Supply under-voltage monitor (Power-on reset)					●	●	<10µs	High-Z	YES	
Supply Bias Current Monitor					●		DCT_Ana	ANA		●
Overheating monitor	○	○	○	○	○	●	DCT_Ana	ANA	YES	●
Warning/Reporting Mechanisms							n/a	n/a		

Category and safety mechanism name	Front-end	ADC	DSP	Back-end	Support. Func.	Module & Package	DCT*	Reporting mode	At startup	DIAG EN
HW Error Controller			●	●	●		n/a	DIG	YES	
HW Fail-safe mode with timeout			●	●	●		n/a	DIG	YES	
Analog-type Error management	●	●			●		n/a	ANA		
Safe start-up mode			●		●		n/a	DIG	n/a	
Mechanisms executed at start-up only										
RAM March-C HW Test at start-up			●		●		n/a	DIG	YES	

Table 56 - MLX90378 List of Self Diagnostics with Characteristics

15. Recommended Application Diagrams

15.1. Wiring with the MLX90378 in SOIC-8 Package

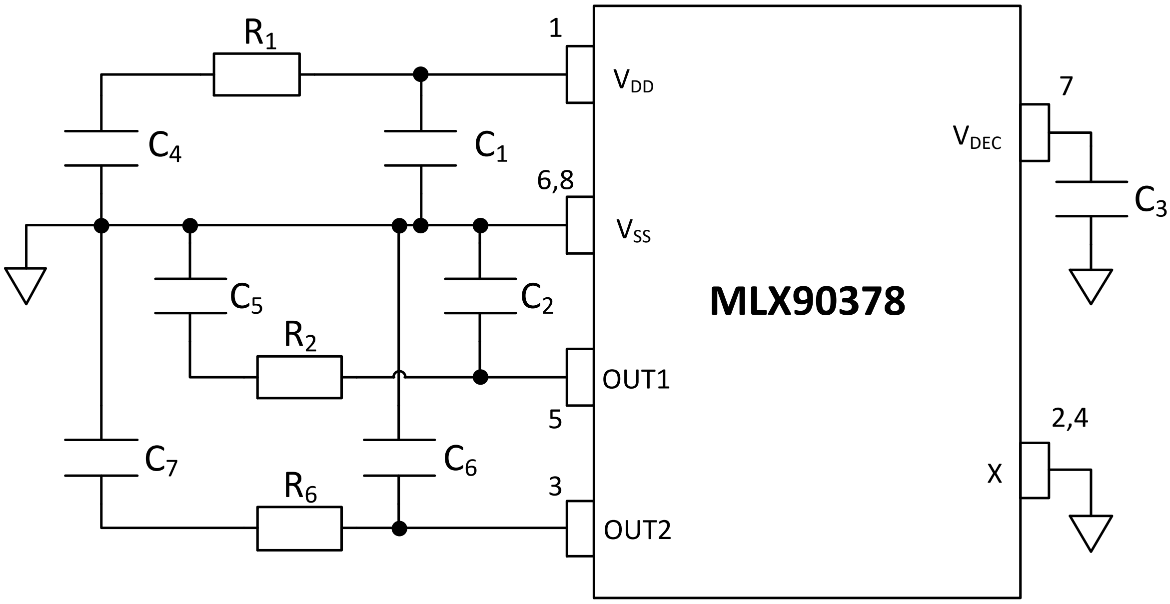


Figure 24 – Recommended wiring for the MLX90378 in SOIC-8 package

Component	min	Typ	Max	Remark
C_1	100 nF	220 nF	-	Close to the IC pin
C_2,C_6 (C_L)	-	4.7nF 2.2nF	10nF 4.7nF	normal SENT / PWM fast SENT
C_3	100 nF	100 nF	-	Close to the IC pin
C_4	-	1nF	-	Close to the connector
C_5,C_7	-	1nF	15nF	Close to the connector
R_1	-	10 Ω	-	Recommended value
R_2,R_6	-	120 Ω	220 Ω	Recommended value

Table 57 - Recommended Values for the MLX90378 in SOIC-8 Package

15.2. Wiring with the MLX90378 in TSSOP-16 Package

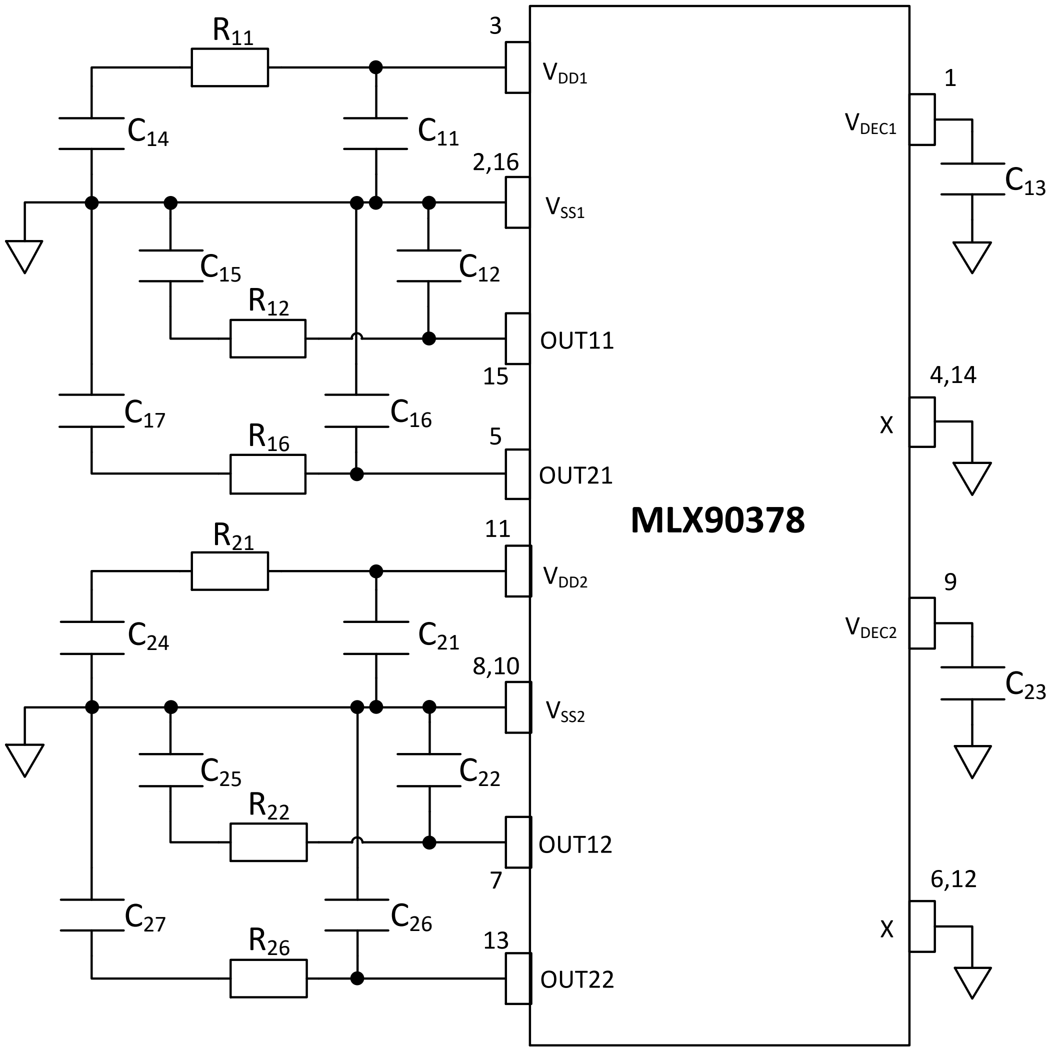


Figure 25 – Recommended wiring for the MLX90378 in TSSOP-16 package

Component	min	Typ	Max	Remark
C_{x1}	100 nF	220 nF	-	Close to the IC pin
C_{x2},C_{x6} (C_L)	-	4.7nF 2.2nF	10nF 4.7nF	normal SENT / PWM fast SENT
C_{x3}	47 nF	100 nF	-	Close to the IC pin
C_{x4}	0	1nF	-	Close to the connector
C_{x5},C_{x7}	0	1nF	15nF	Close to the connector
R_{x1}	0	10 Ω	-	Recommended value
R_{x2},R_{x6}	0	120 Ω	220 Ω	Recommended value

Table 58 - Recommended Values for the MLX90378 in TSSOP-16 Package

15.3. Wiring for Switch Button function (For SOIC-8 (code DC) and TSSOP-16 (code GO) packages)

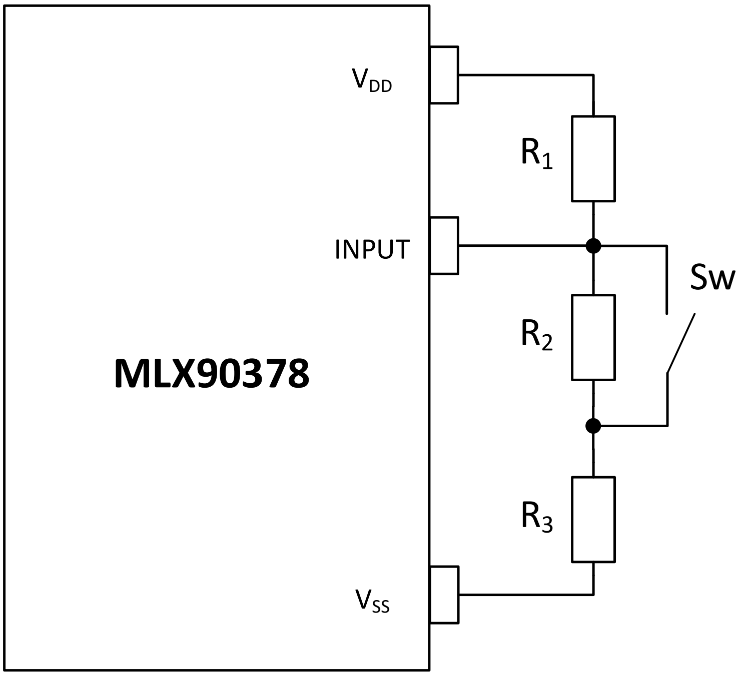
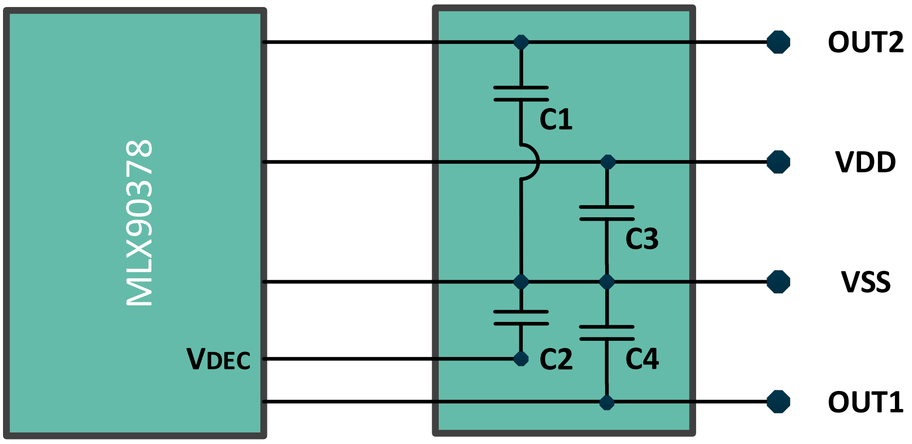


Figure 26 – Recommended Wiring for Switch Button function

Component	min	Typ	Max	Remark
R_1		1.3 kΩ		Max tolerance : 5%
R_2		2.2 kΩ		Max tolerance : 5%
R_3		1.2 kΩ		Max tolerance : 5%
$R_{ON\ SW}$			20 Ω	

Table 59 - Recommended Values for Switch Button function

15.4. Wiring with the MLX90378 in DMP-4 Package (built-in capacitors)



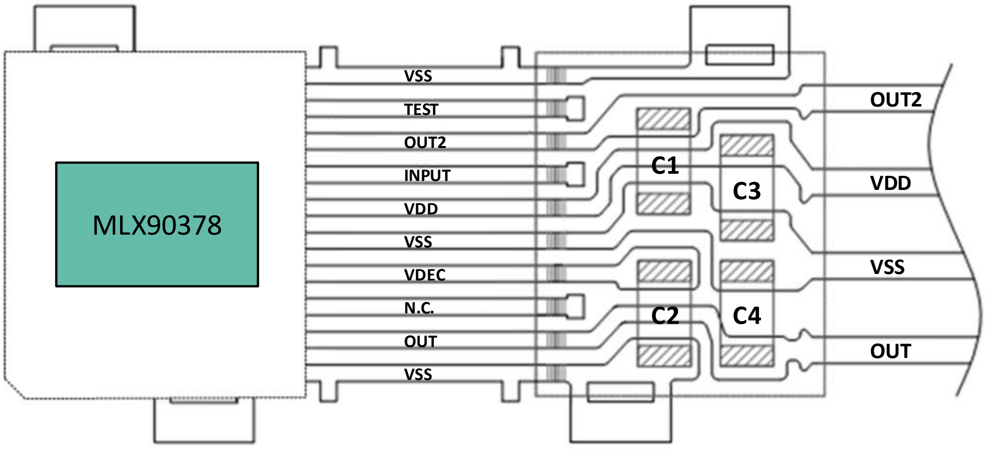


Table 60 - Internal wiring of the MLX90374 in DMP-4

Component	Value	Remark
C1,C4	10.0 nF	Ordering code -30x
C2	220 nF	Ordering code -30x
C3	100 nF	Ordering code -30x

Table 61 - DMP-4 capacitors configuration

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

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

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

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

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

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

17. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).

Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

18. Package Information

18.1. SOIC-8- Package Dimensions

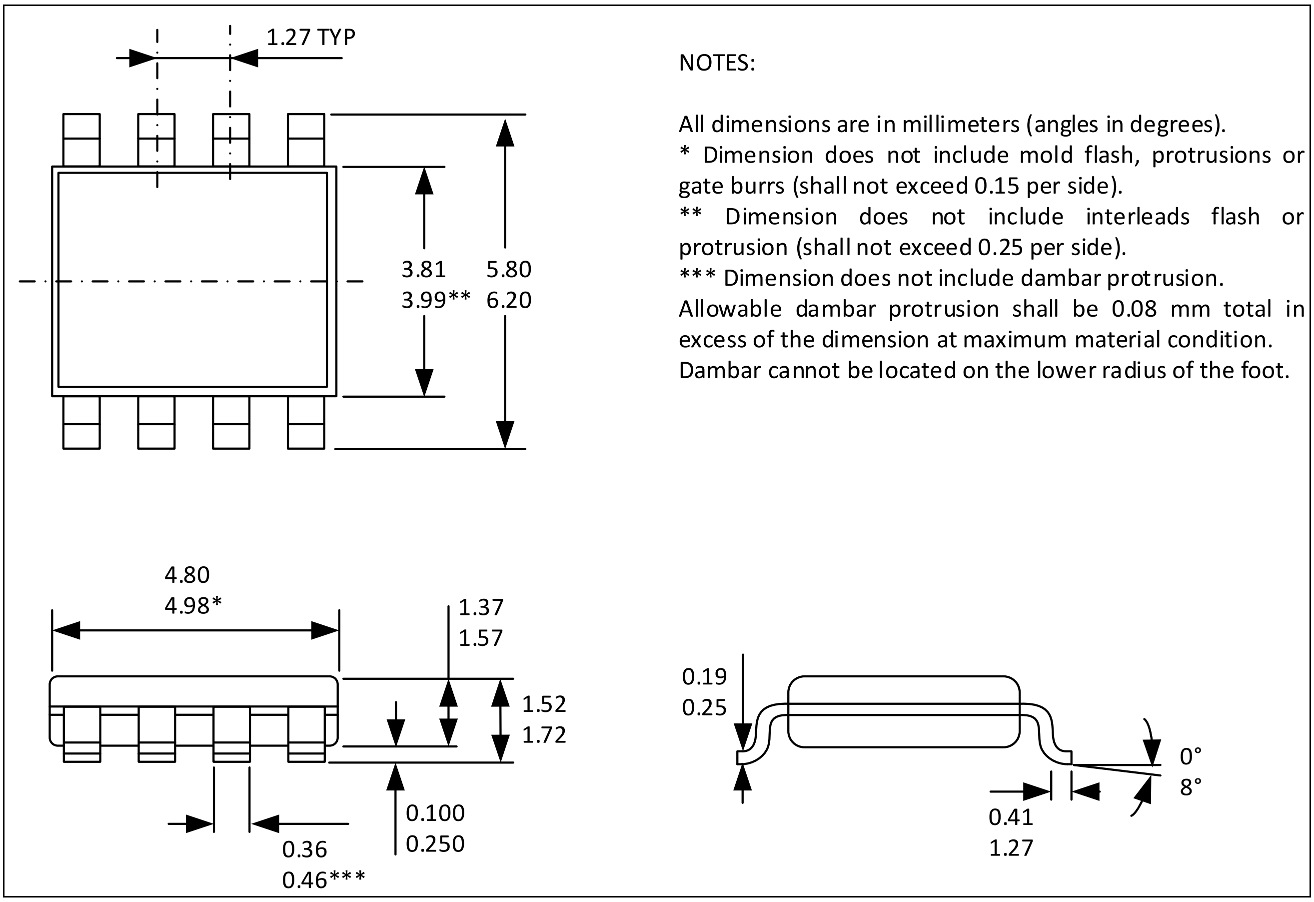


Figure 27 – SOIC-8 Package Outline Dimensions

18.2. SOIC-8- Pinout and Marking

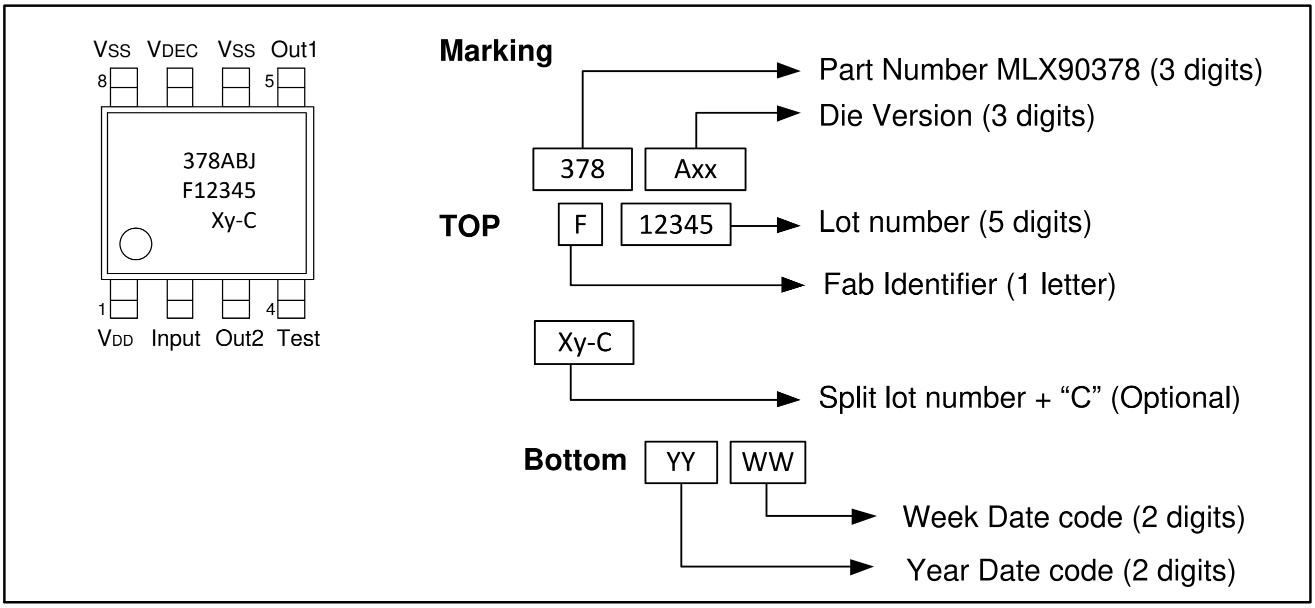


Figure 28 – SOIC-8 Pinout and Marking

18.3. SOIC-8 – Sensitive spot positioning

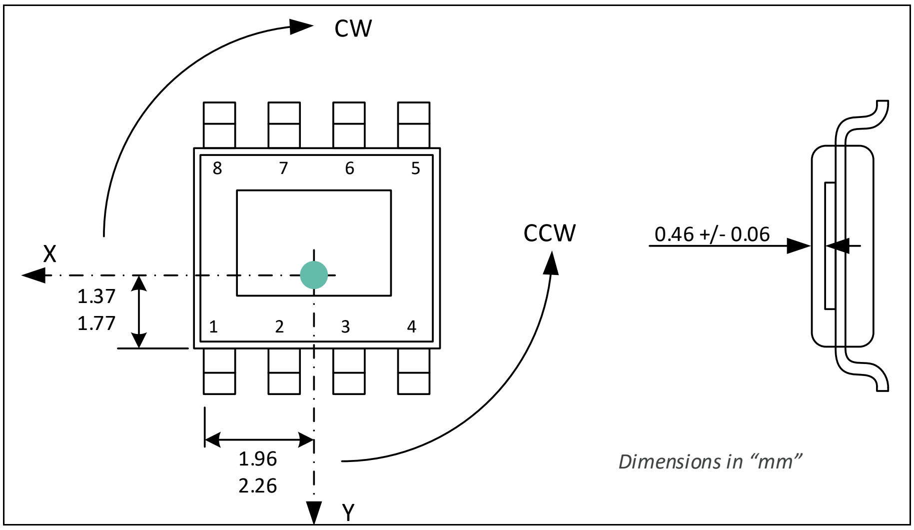
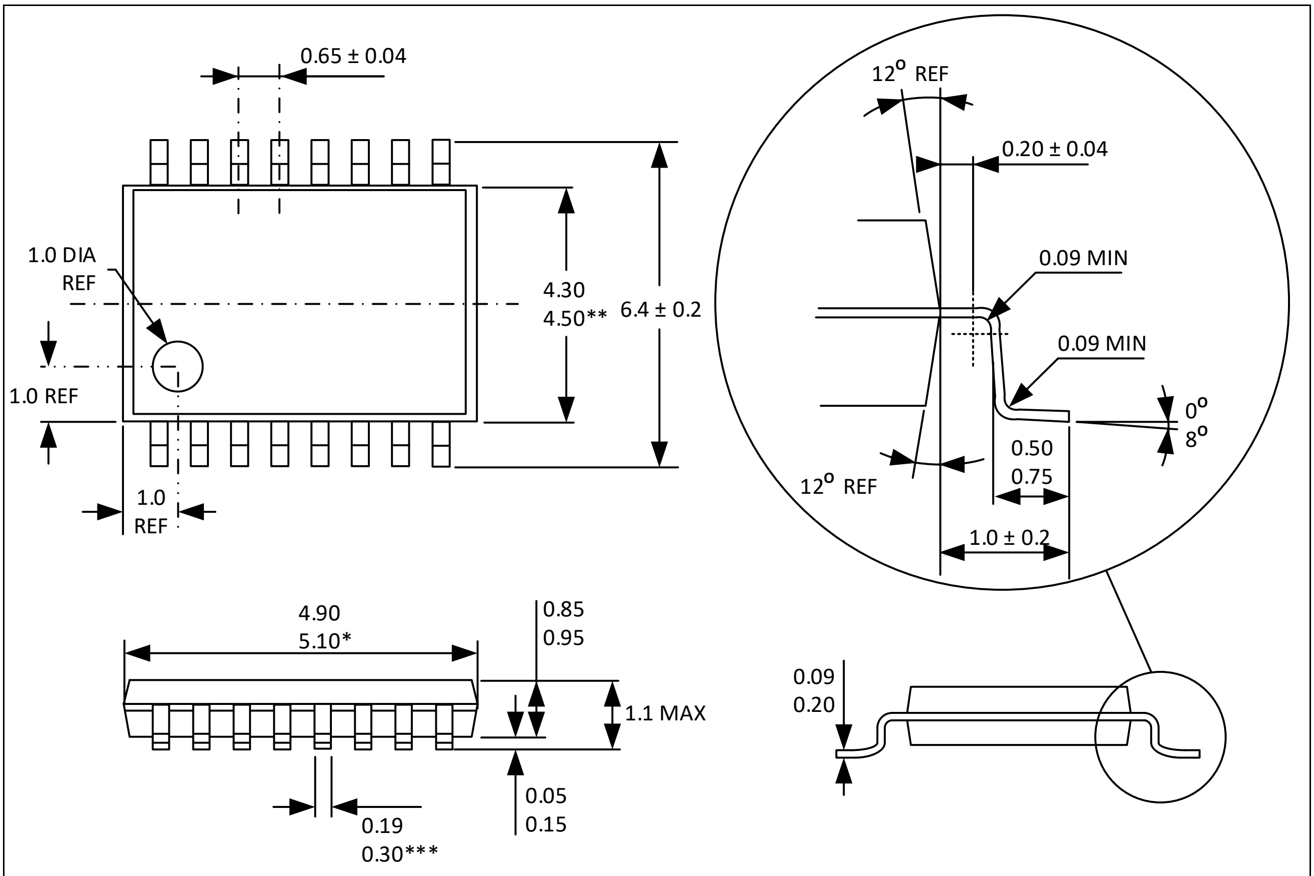


Figure 29 – SOIC-8 Sensitive Spot Position

18.4. TSSOP-16- Package Dimensions



NOTES:

All dimensions are in millimeters (angles in degrees).
* Dimension does not include mold flash, protrusions or gate burrs (shall not exceed 0.15 per side).
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side).
*** Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot.
REF: Reference dimensions as stated in packaging supplier POD, based on JEDEC.

Figure 30 – TSSOP-16 Package Outline Dimensions

18.5. TSSOP-16- Pinout and Marking

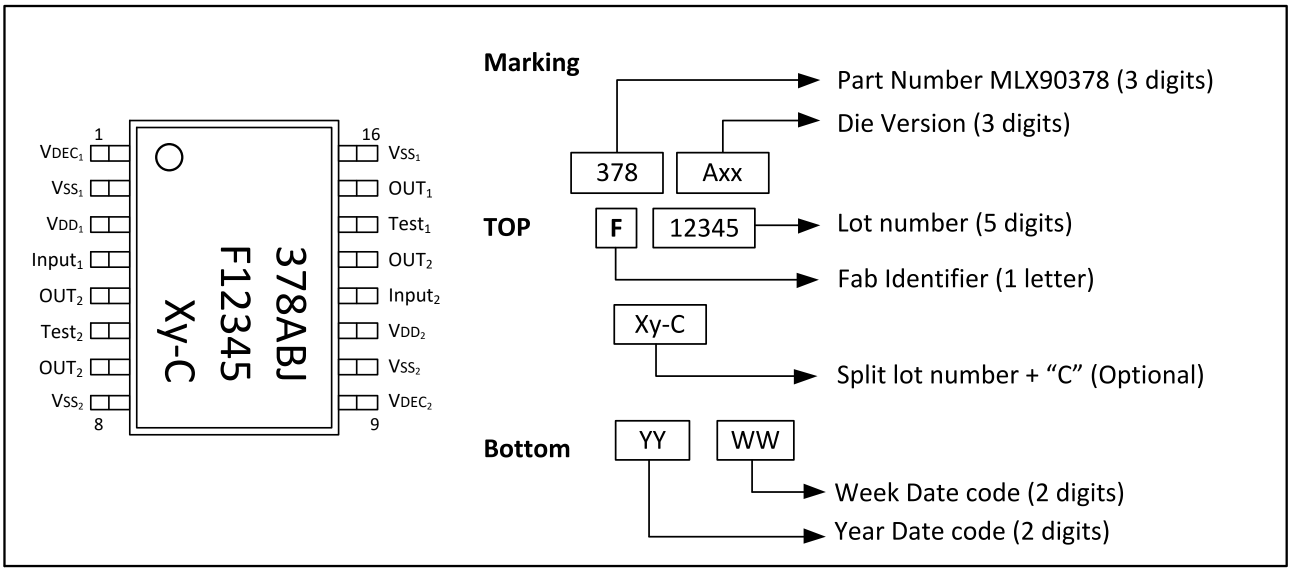


Figure 31 – TSSOP-16 Pinout and Marking

18.6. TSSOP-16 – Sensitive spot positioning

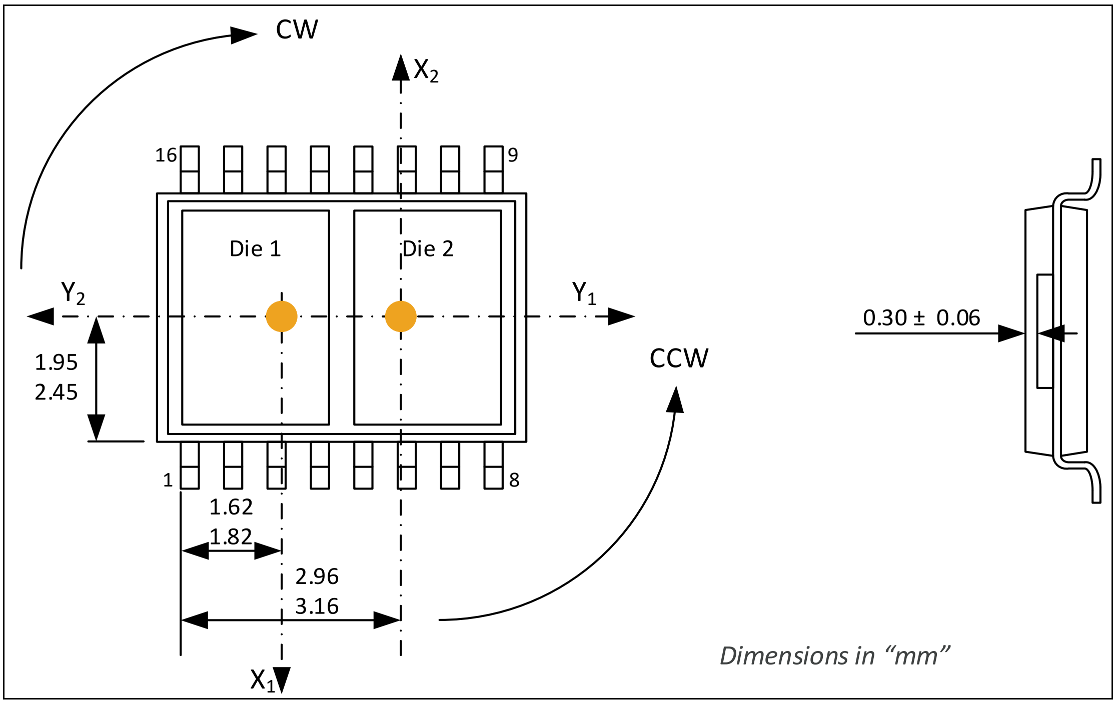
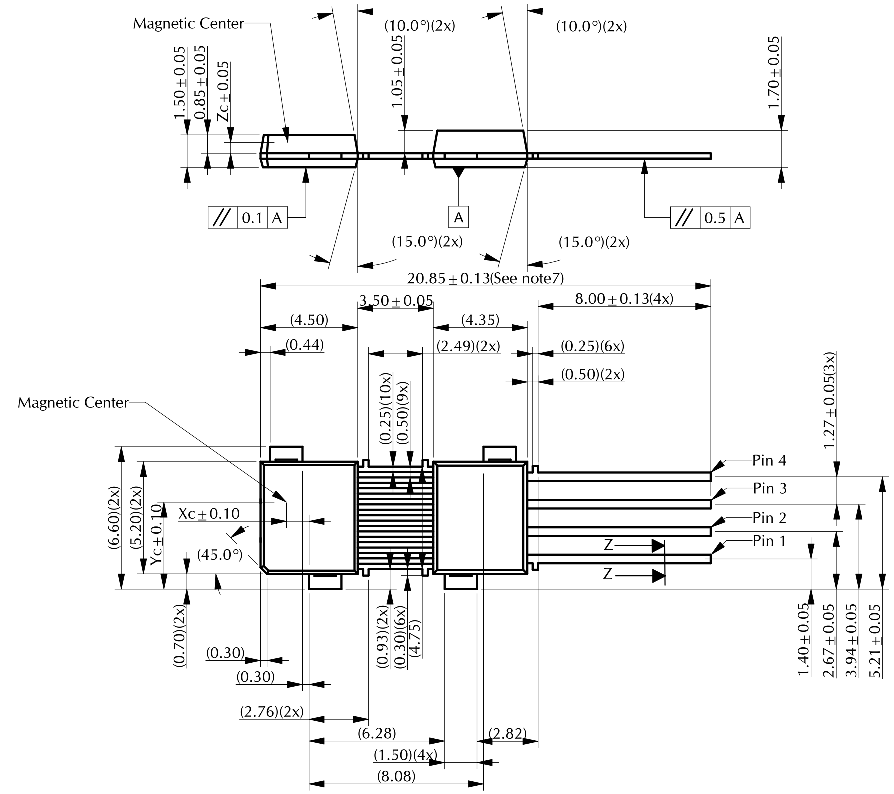


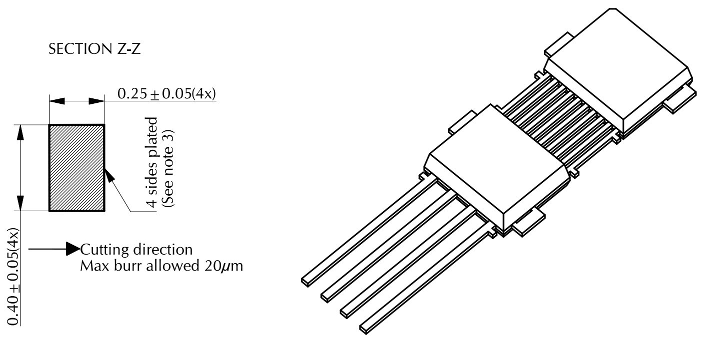
Figure 32 – TSSOP-16 Sensitive Spot Position

18.7. DMP-4- Package Dimensions

18.7.1. DMP-4- Package Outline Dimensions (POD) STD1 1.27

Rev.	Description	Date	Trigram
1.0	Initial creation	2011-06	VLV
2.0	Template update	2017-08-09	EVA



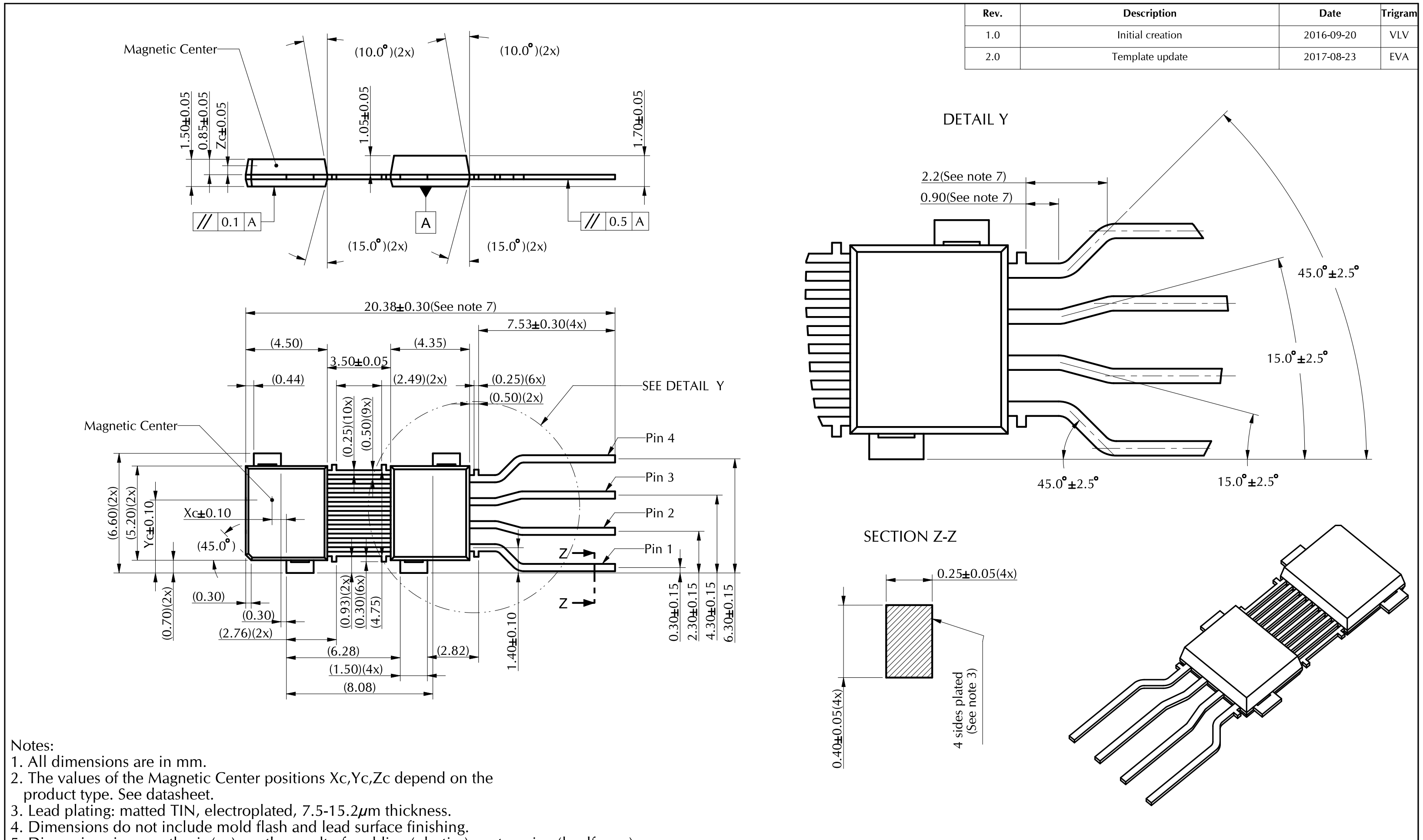


Notes:
1. All dimensions are in mm.
2. The values of the Magnetic Center positions Xc,Yc,Zc depend on the product type. See datasheet.
3. Lead plating: matted TIN, electroplated, 7.5-15.2μm thickness.
4. Dimensions do not include mold flash and lead surface finishing.
5. Dimensions in parenthesis (xx)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

Melexis INSPIRED ENGINEERING		Name	Date	DMP STD1 1.27			
	Created	VLV	2011-06				
	Modified	EVA	2017-08-09				
	Approved	HHA / DFI	2017-08-10	Gen. tolerance: Lin.: ±0.3 mm, Ang.: ±2°			
File dmp_STD1_1-27	Scale	5:1		Sheet 1 of 1	Rev.	2.0	A4

Figure 33 – DMP-4 Straight Leads Package Outline Drawing

18.7.2. DMP-4- Package Outline Dimensions (POD) STD3 2.00



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

		Name	Date	
Melexis INSPIRED ENGINEERING	Created	VLV	2016-09-20	DMP STD3 2.00
	Modified	EVA	2017-08-23	
	Approved	HHA / DFI	2017-11-29	Gen. tolerance: Lin.: ±0.3 mm, Ang.: ±2°
File dmp_std3_2-00	Scale	5:1		Sheet 1 of 1 · Rev. 2.0 · A4

Figure 34 – DMP-4 STD3 2.00 Package Outline Drawing

18.8. DMP-4- Marking

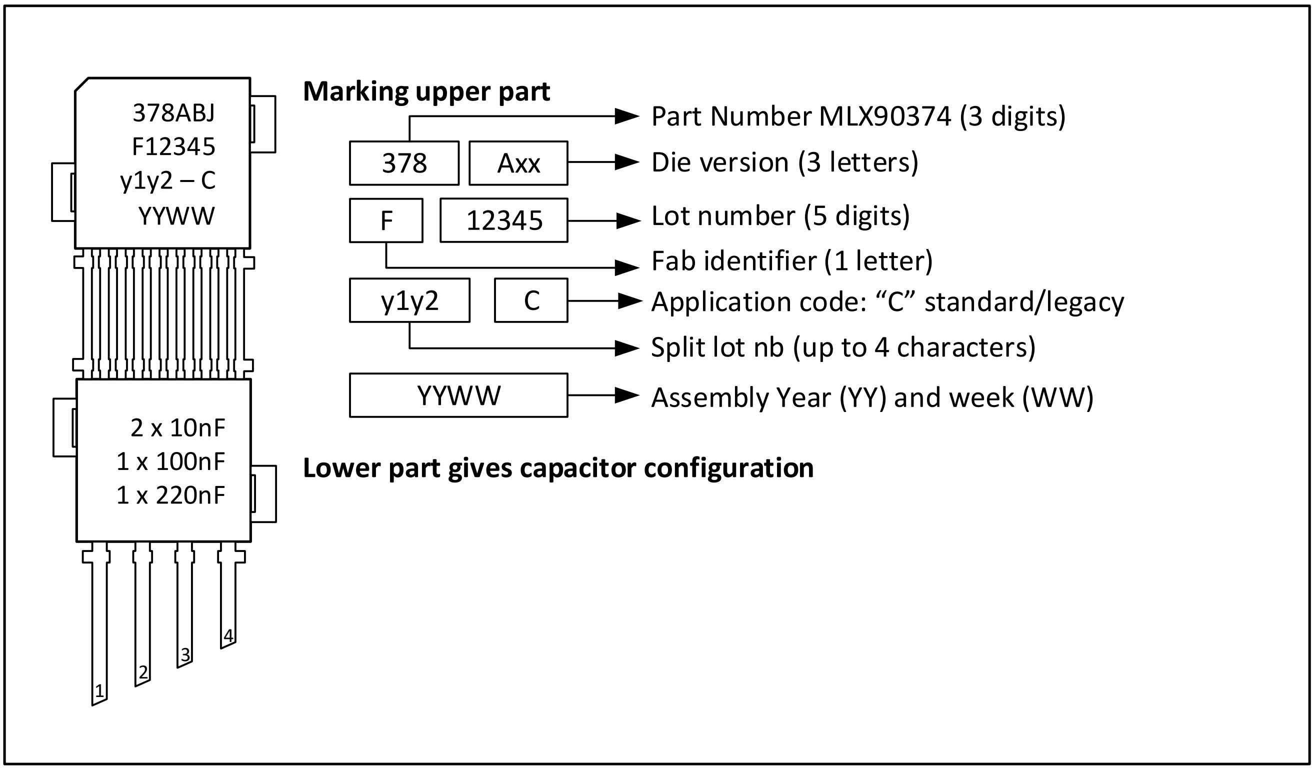


Figure 35 – DMP-4 Marking

18.9. DMP-4 – Sensitive spot positioning

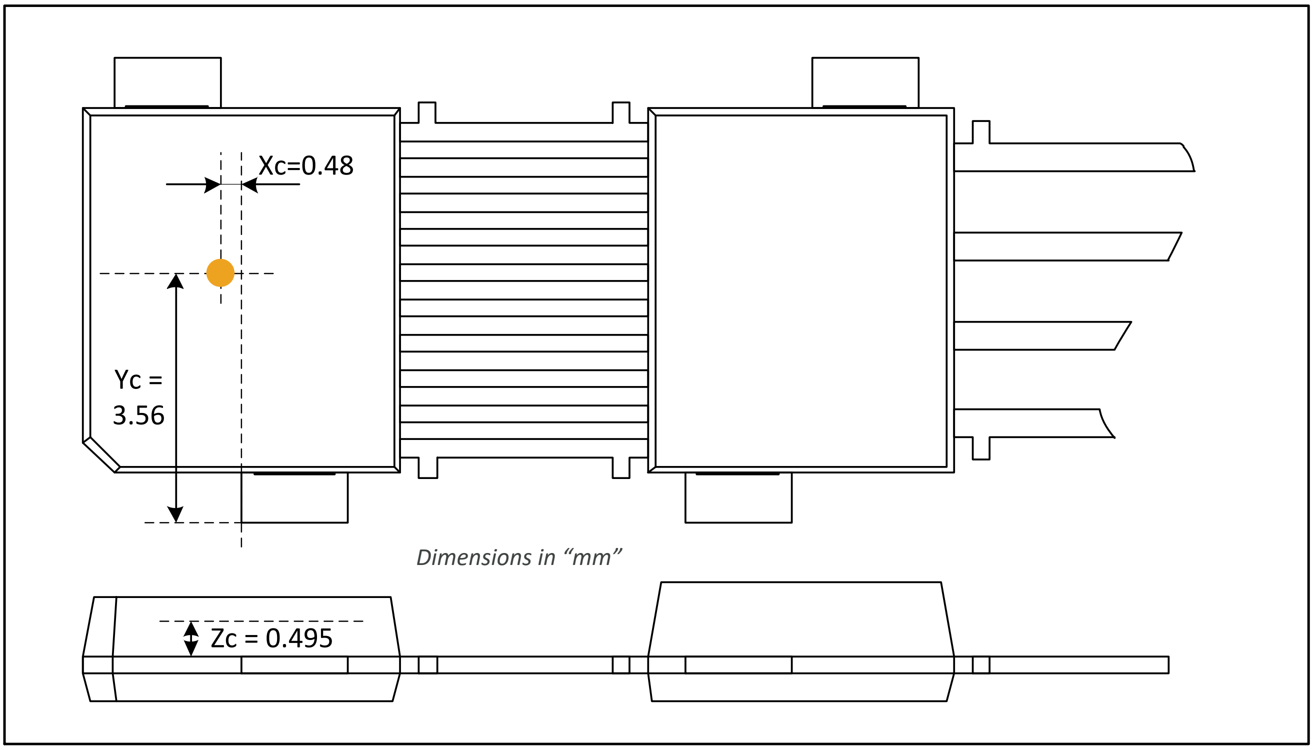


Figure 36 – DMP-4 Linear Stray-field Sensitive Spots Position

18.10. Packages Thermal Performances

The table 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
DMP-4	32.2 K/W	88.7 K/W	done without PCB [14]

Table 62 - Standard Packages Thermal Performances

14 DMP-4 as PCB-less solution has been evaluated in a typical application case. Values for this package are given as informative.

19. Contact

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

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

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	Email : sales_europe@melexis.com
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	Email : sales_usa@melexis.com
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