MLX90510

Datasheet

1. Features and Benefits

- High Speed Inductive Position Sensing Technology for speeds up to 660 000 e-rpm

- High accuracy: Maximum ±0.36° electrical up to 240 000 e-rpm, ±0.66° electrical up to 660 000 e-rpm

- Differential Sine and Cosine analog outputs

- System propagation delay variation less than ±120 ns

- Programmable on-chip input signal offset compensation and zero output-angle position adjustment

- Programmable linear transfer characteristic (16 points)

- Immune to magnetic stray fields (ISO 11452-8)

- Wide operating supply voltage range

- Overvoltage and reverse-polarity protection: -24 V to +24 V maximum

- Ambient operating temperature range from -40°C to 160°C

- Through-Shaft, End-of-Shaft and Side-of-Shaft operation

- ISO 26262 ASIL C SEooC (Safety Element out of Context)

- TSSOP-16 Package RoHS Compliant

TSSOP-16

2. Application Examples

- High speed absolute rotary position sensor

- Motor position sensing (BLDC, PMSM, PMSR)

- Traction motor

- e-brake booster

- Electric Power Steering (EPS)

3. Description

An inductive position sensor is used for absolute rotary motion/position sensing in automotive and industrial applications.

The MLX90510 is designed to interface an inductive transducer, process the captured signals and provide differential Sine & Cosine outputs, see Figure 3.

The inductive sensor operation is based on the inductive coupling between a transmitting coil, the target and three receiving coils.

The on-chip LC oscillator generates an electromagnetic field together with the transmitting coil. This electromagnetic field induces a target (rotor) angle dependent voltage in the three receiving coils. These three signals are captured and processed by the MLX90510 internal signal processing units. The receiving coils are arranged in a fixed staggered position to each other depending on the number of poles of the metallic target (rotor) above the coils. Typically, the coils are realized as printed circuit board tracks.
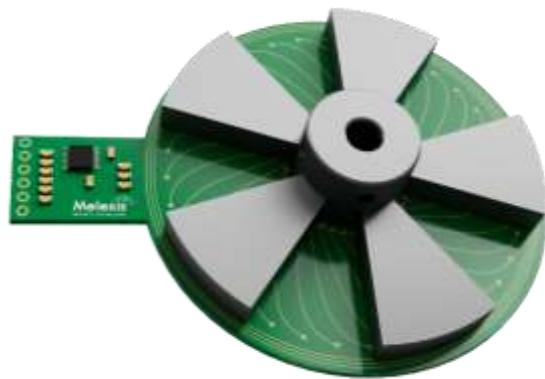
Figure 1 – Example of application

REVISION 003 – JULY 15, 2022

3901090510

Contents

4. Ordering Information

Ordering Code	Temperature	Package	Definition	Packing
MLX90510GGO-BBA-100-RE	-40°C to 160°C	TSSOP-16	Angular rotary SIN/COS, normal acceleration capability	Reel
MLX90510GGO-BBA-101-RE	-40°C to 160°C	TSSOP-16	Angular rotary SIN/COS, medium acceleration capability	Reel
MLX90510GGO-BBA-102-RE	-40°C to 160°C	TSSOP-16	Angular rotary SIN/COS, high acceleration capability	Reel

Table 1 – Ordering codes

MLX90510GGO-BBA-100-RE

Packing delivery form
Option code for variant
Silicon version
Package code
Temperature code
Product name
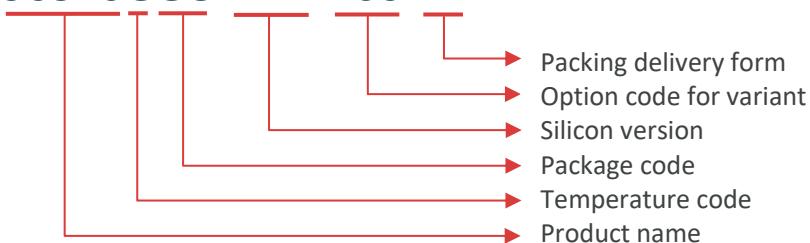
5. Glossary of Terms

Term	Description
° el	Electrical degree
ABE	Analog Back-End
ADC	Analog-to-Digital Converter
AGC	Automatic Gain Control
AFE	Analog Front-End
AoU	Assumptions-of-Use
ASIL	Automotive Safety Integrity Level
DAC	Digital-to-Analog Converter
DC	Direct Current
DSP	Digital Signal Processing
EEPROM	Electrically Erasable Programmable Read Only Memory
ECU	Electronic Control Unit
EMC	Electro-Magnetic Compatibility
ESD	Electro-Static Discharge
e-rpm	Electrical rotation per minute
FBH	Fault Band High
FBL	Fault Band Low
FDTI	Fault Detection Tolerance Interval
FTTI	Fault Tolerant Time Interval
GND	Ground
HBM	Human Body Model
ISO	International Standardization Organization
I/Q	In-phase and Quadrature
LC	Inductor-Capacitor
LCO	LC Oscillator
PCB	Printed Circuit Board
PGA	Programmable Gain Amplifier
PGI	Program Interface
POR	Power-On Reset
RCO	RC Oscillator
Rx	Receiving
SAD	Set Circuit Address
SEooC	Safety Element out-of-Context
TSSOP	Thin-Shrink Small-Outline Package
Tx	Transmitting
V_P	Peak Voltage
V_{PP}	Peak to Peak Voltage

Table 2 – Glossary of terms

6. Marking, Pin Definitions and Descriptions

For more information see application diagrams in Chapter 13.
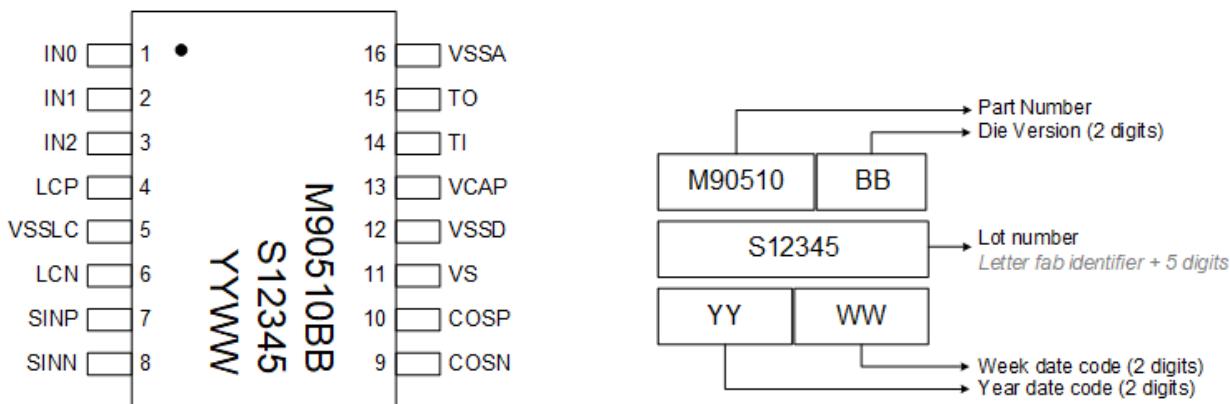
Figure 2 – TSSOP16 pin names and marking

6.1. Pin Definition

Pin #	Name	Description
1	IN0	Sensor Rx coil input 0
2	IN1	Sensor Rx coil input 1
3	IN2	Sensor Rx coil input 2
4	LCP	Tx coil, positive connection
5	VSSLC	LCO ground (connect to GND, see Figure 15)
6	LCN	Tx coil, negative connection
7	SINP	Sine positive differential output
8	SINN	Sine negative differential output
9	COSN	Cosine negative differential output
10	COSP	Cosine positive differential output
11	VS	Supply voltage
12	VSSD	Digital ground (connect to GND, see Figure 15)
13	VCAP	External supply buffer capacitor connection
14	TI	Test input (connect to GND, see Figure 15) [1]
15	TO	Test output (connect to GND, see Figure 15)
16	VSSA	Analog ground (connect to GND, see Figure 15)

Table 3 – TSSOP-16 Pins definition and description

[1]   For multi-sensor applications, TI can be connected to VCAP with a 1 kΩ resistor, refer to Chapter 13

7. Absolute Maximum Ratings

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

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply Voltage	VS	-18		18	V	Continuous
	VS	-24		24	V	For < 1 h
Output current limit	I_{SINP}, I_{SINN}, I_{COSP}, I_{COSN}	-10		10	mA	Continuous
Voltage on output pins SINP, SINN, COSP, COSN	V_{SINP}, V_{SINN}, V_{COSP}, V_{COSN}	-18		18	V	
Voltage on pins LCP, LCN	V_{LCN}, V_{LCP}	-2 -0.3		5.5 5.5	V	VS floating VS connected
Voltage on pins INx, VCAP, TI, TO	V_{INx}, V_{VCAP}, V_{TI}, V_{TO}	-0.3		5.5	V	INx: IN0, IN1, IN2
ESD CDM robustness	V_{CDM}			±750	V	IN0, SINN, COSN, VSSA pins
ESD CDM robustness	V_{CDM}			±500	V	All the other pins
ESD HBM				±4	kV	According AEC-Q100-002 Global pins: VS, VSSA, VSSD, VSSLC, SINP, SINN, COSP, COSN
ESD HBM				±2	kV	According AEC-Q100-002 Local pins: INx, LCP, LCN, VCAP, TI, TO
Ambient Temperature	T_A	-40		160	°C	
Junction Temperature	T_{JUNC}			175	°C	
Storage Temperature	$T_{storage}$	-55		175	°C	
Thermal resistance junction to ambient	R_{thja}			137	K/W	
Thermal resistance junction to case	R_{thjc}			27.6	K/W	
EEPROM programming temperature	T_{EEPROM}	-40		125	°C	
EEPROM number of erase/write cycles				2000		per row and column

Table 4 – Absolute maximum ratings

8. Electrical and System Level Performance Specifications

MLX90510 Electrical and system level performance specifications are given in Table 5.

T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply voltage	VS	4.5	5	5.5	V	
Regulated voltage supply	V_{CAP}		4.9	5.29	V	C_2 = 0.47 µF, typical value for VS ≥ 5 V, max value for VS = 5.5 V
Operating current	I_{VS}		16[1]	20[2]	mA	Assuming the use of components according to Table 22 and speed < 240 000 e-rpm
Operating current (low power mode)	I_{VS_LP}			2.3	mA	For VS > $V_{ov\_vs\_lh}$, see Section 11.3.2, Figure 12
RC oscillator frequency	f_{RCO}		20		MHz	
Power-on reset voltage	V_{POR_hl}	2	2.5	3.1	V	VS rising up, see Figure 12
Start-up time[3]	T_{STUP}		1	3	ms	C_2 = 0.47 µF
Inrush current[4]	$I_{VS\_startup}$		25	35	mA	C_{VS} = 0.47 µF
Differential Sine and Cosine analog signals resolution			12		bit	
System propagation delay	T_{delay}	-0.12	0	0.12	µs	
Position signal rms noise	Acc_{noise}		0.055		° el	
Position signal accuracy[5]	$Acc_{position}$	-0.36		0.36	° el	

Table 5 – Electrical and system level performance specifications

[1]   Assuming a typical oscillator current consumption I_{VS_LCO} = 3 mA (see Figure 5)
[2]   Including a maximum oscillator current consumption I_{VS_LCO} = 6 mA (see Figure 5)
[3]   VS rise time from 0 V to 5 V ≥ 25 µs
[4]   VS rise time from 0 V to 5 V ≥ 100 µs
[5]   This error includes noise, ABE offset and gain mismatch, and system propagation delay as main contributors, but also other effects. The value reported is a ±3σ value. The error caused by noise can be decreased by higher input signal strength. The error caused by ABE offset and gain mismatch and system propagation delay can be reduced by means of ECU based compensations. For more details see Section 9.4.1. This error specification is valid within the standard speed and acceleration ranges, see Section 9.4.1, and with ideal, offset free input signals.

9. Detailed Description

9.1. Block Diagram

The MLX90510 is an inductive position sensor which is used for absolute rotary motion/position sensing. The block diagram is given in Figure 3.
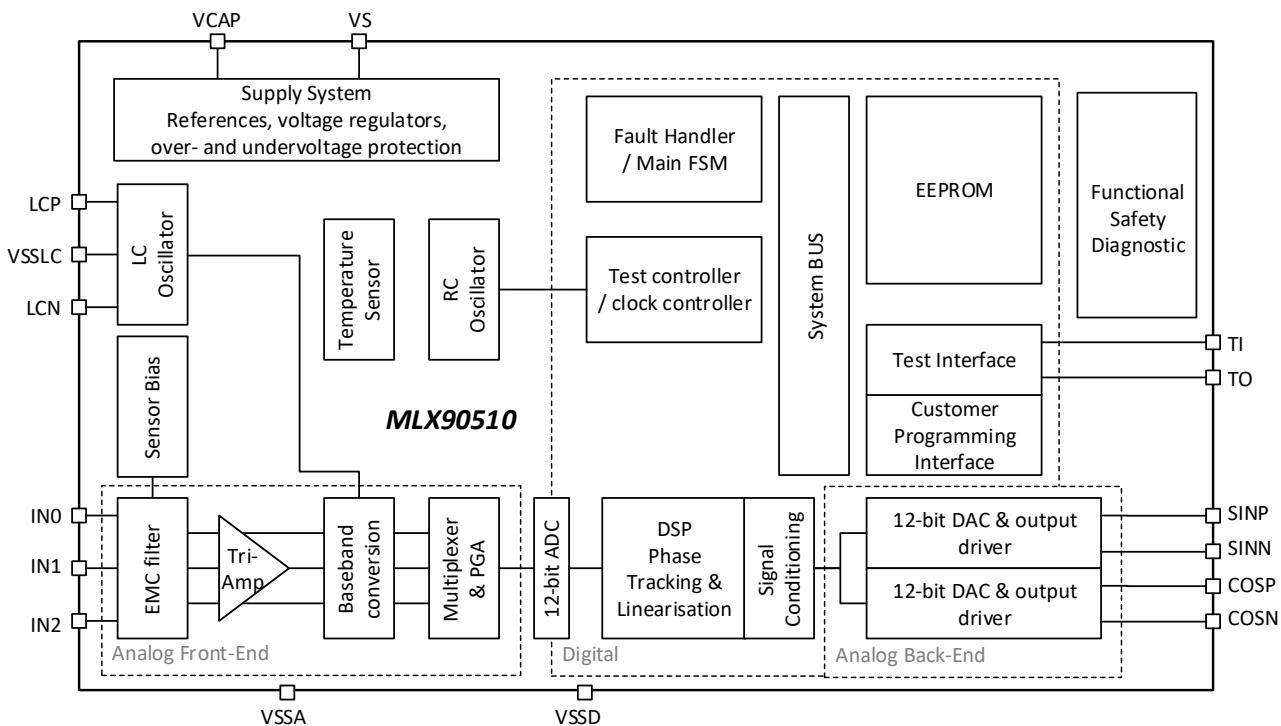

Figure 3 – Block diagram

The main position sensor signal processing blocks consist of: sensor excitation with an LC Oscillator (LCO), Sensor Bias unit, the Analog Front-End (AFE) performing the sensor position signal analog pre-processing, the Analog-To-Digital Conversion (ADC) followed by the Digital Signal Processing (DSP) and an Analog Back-End (ABE) providing the output signals.

The AFE consists of an EMC filter, Tri-Amplifier, Baseband conversion, Multiplexer and Programmable Gain Amplifier (PGA). The digital core provides the signal processing for angular computation and system control. The ABE consists of two 12-bit Digital-to-Analog Converters (DAC) and the differential output driver generates the Sine/Cosine output signals. The main supporting functionalities are the supply system, functional safety diagnostics, a Customer Programming Interface (PGI) and an EEPROM for the system configuration data storage.

The Functional Safety Diagnostic provides numerous self-diagnostic features to check the integrity of the sensor coil system, the integrity of the input and output signals, various PCB interfaces, and the IC itself.

9.2. Sensor Coil System

The MLX90510 is designed for an external sensor coil system consisting of one transmitting (Tx) coil and three star-connected receiving (Rx) coils, see application diagrams in Chapter 13. The Rx coils specification is provided in Table 6, while the Tx coil, being part of the LC oscillator, is specified in Section 9.3. For details and support regarding sensor coil system designs please contact the Melexis sales office.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Rx coil inductances	L_{Rx}	40		500	nH	

Table 6 – Sensor coil system parameters

9.3. LC Oscillator

The LCO drives the Tx coil of the sensor coil system. The LCO frequency (f_{LCO}) is defined by the external inductance (L_{Tx}) and the two external capacitors C_{LCO} (see Figure 4). The R_{Tx} represents the resistance of the Tx coil. A customization of the frequency is possible by variation of L_{Tx} and C_{LCO}.
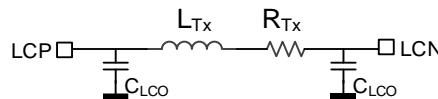
Figure 4 – LCO Tx coil model

The LCO frequency can be calculated using the following formula:

$$f_{LCO} = \frac{1}{2\pi}\sqrt{\frac{2}{C_{LCO}L_{Tx}} - \left(\frac{R_{Tx}}{L_{Tx}}\right)^2}$$

The LCO amplitude and operating point are trimmed and regulated and both, frequency and amplitude, are monitored. The LCO frequency monitor is set to the minimum and maximum of the LCO frequency range given in Table 7. The LCO is by default enabled and can be disabled by setting the LC_OSC_EN field to 0 in the EEPROM, see Chapter 12.

The LCO amplitude can be reduced by setting LC_OSC_AMP to 1. A reduced LCO amplitude is used for cases for which the maximum input signal amplitude (A_{Rotor}) is exceeded, refer to Section 9.4.1, or to reduce emissions.

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
LCO frequency range	f_{LCO}	2.0	3.5[1]	5.0	MHz	
LCO common mode voltage	V_{CM}		1.68		V	
LCO amplitude	A_{LCO}		2.4 (1.4)[2][3]		V_{PP}	LC_OSC_AMP = 0 (1)
Tx coil inductance	L_{Tx}	1	4	10	µH	
Tx coil internal resistance	R_{Tx}		5		Ω	
Tx quality factor	Q_{Tx}		18[4][5]			
LCO current consumption	I_{VS_LCO}		3[4][6]	6	mA	
LCO startup time	$T_{startup\_LCO}$		200		µs	

Table 7 – LCO electrical parameters

[1]   The typical LCO frequency (f_{LCO}) is defined by the Tx coil inductance (L_{Tx}) and the external capacitors (C_{LCO}). A customization of the frequency is possible by variation of L_{Tx} and C_{LCO}. As an example, for a typical value of f_{LCO} = 3.5 MHz, the external components can be set as L_{Tx} = 4 µH and C_{LCO} = 1 nF. However, other component value combinations within the specification range are applicable.
[2]   The LCO amplitude is measured from LCN or LCP to GND (See Figure 15).
[3]   The LCO amplitude shall be reduced in case the input signal amplitude (A_{Rotor}) is exceeded or to reduce emissions.
[4]   Typical value consistent with f_{LCO} = 3.5 MHz, L_{Tx} = 4 µH. This corresponds to a R_{Tx} = 5 Ω and C_{LCO} equivalent series resistance within 1 Ω.
[5]   Tx quality factor can be calculated with $Q_{Tx} = 2\pi \cdot f_{LCO} \cdot L_{Tx} / R_{Tx}$.
[6]   See Figure 5 for relation between Q_{Tx} and I_{VS_LCO} (typical conditions).
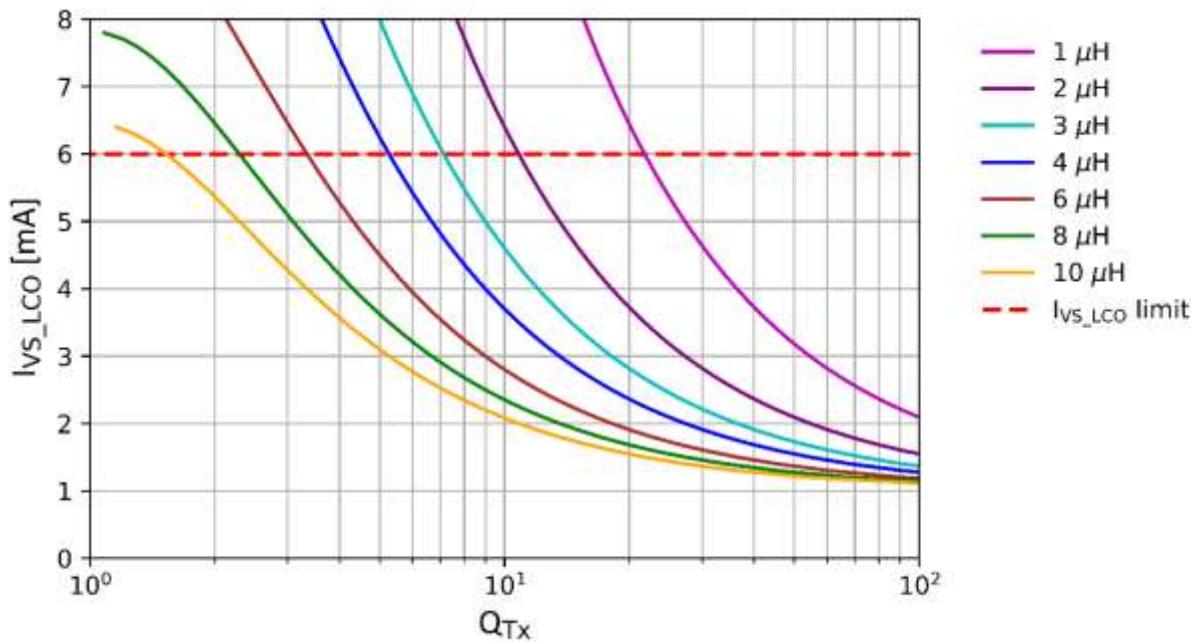
Figure 5 – I_{VS_LCO} as function of Q_{Tx} for LCO frequency of 3.5 MHz

9.4. Analog Signal Processing

The sensor coil system is connected to the MLX90510 and the signals from the Rx coils are processed by the AFE.

The input signals INx are filtered through the EMC filter to suppress high frequency noise. The common mode of the input signals, caused by symmetrical coupling from the Tx coil, is suppressed by the Tri-Amplifier.

The AFE converts the Tri-Amplifier output signals into baseband signals. The latter are multiplexed and an AGC is implemented to control the PGA and reach a large input voltage range. The signals are converted into digital signals with the ADC.

9.4.1. Input Signal Specification

The three input signal envelopes (INx) from the sensor coil system are composed of an angular signal A_{Rotor} with phase φ following the rotor electrical angle, a common mode signal A_{Common} and an asymmetry signal A_{Asym} according to the formulas below.

$$IN0 = A_{\text{Rotor}}\sin\left(\phi - \frac{1}{6}\pi\right) + A_{\text{Common}} + A_{\text{Asym0}}$$
$$IN1 = A_{\text{Rotor}}\sin\left(\phi - \frac{5}{6}\pi\right) + A_{\text{Common}} + A_{\text{Asym1}}$$
$$IN2 = A_{\text{Rotor}}\sin\left(\phi - \frac{9}{6}\pi\right) + A_{\text{Common}} + A_{\text{Asym2}}$$

A_{Common} is caused by a coupling from the Tx coil into the Rx coils that is equal on all three inputs. The common mode voltage is suppressed by the MLX90510.

The asymmetry signals A_{Asym0}, A_{Asym1} and A_{Asym2} are caused by an uneven unwanted coupling between the Tx and Rx coils. They can be for example due to feeding lines from and to the sensor PCB or metal objects close to the sensor PCB. This coil system asymmetry level causes a first-order harmonic error on the measured angle and should be compensated using the MLX90510 DC-offset compensation methods, refer to Section 9.5.1.

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
INx input signal envelope	A_{Rotor}	5		100	mV$_P$	
INx common mode voltage	A_{Common}			17 x A_{Rotor}	V	≤700 mV
Asymmetry voltage caused by the sensor structure	A_{Asym}	-0.7 x A_{Rotor}		0.7 x A_{Rotor}	V	≤10 mV A_{Asym} = max($|A_{\text{Asym0}}|$, $|A_{\text{Asym1}}|$, $|A_{\text{Asym2}}|$)

Table 8 – Input signal requirements

The system accuracy specified in Table 5 is achieved within the standard rotational speed and acceleration ranges specified in Table 9. The MLX90510 can be also operated within extended rotational speed and acceleration ranges, also specified in Table 9, within which the accuracy is degraded as specified in Table 10.

Operating Characteristics, VS = 4.5 V to 5.5 V, T$_A$ = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Standard rotational speed		-240 000		240 000	e-rpm	
Extended rotational speed		-660 000		660 000	e-rpm	
Standard rotational acceleration		-480 000		480 000	e-rpm/s	MLX90510GGO-BBA-100-RE
		-3 600 000		3 600 000		MLX90510GGO-BBA-101-RE
		-12 000 000		12 000 000		MLX90510GGO-BBA-102-RE
Extended rotational acceleration		-1 080 000		1 080 000	e-rpm/s	MLX90510GGO-BBA-100-RE
		-7 200 000		7 200 000		MLX90510GGO-BBA-101-RE
		-72 000 000		72 000 000		MLX90510GGO-BBA-102-RE

Table 9 – Electrical rotational speed and acceleration

Operating Characteristics, VS = 4.5 V to 5.5 V, T$_A$ = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Position signal accuracy		-0.36		0.36	° el	Standard speed, standard acceleration
		-0.66		0.66		Standard speed, extended acceleration
		-0.66		0.66		Extended speed, standard acceleration
		-0.96		0.96		Extended speed, extended acceleration

Table 10 - Accuracy within the various rotational speed and acceleration ranges

Figure 6 shows how the input signal intensity (A$_{Rotor}$) affects the quasi-static maximum (peak) angular error. The same picture shows how the error can be reduced by means of ECU based compensation, which can remove the contribution of the offset and gain mismatch of the ABE (see Section 9.5.3). Figure 7 shows on the other hand how the input signal rotational speed affects the absolute angular. This is a consequence of the increasing importance of the system propagation delay component with increased speed.
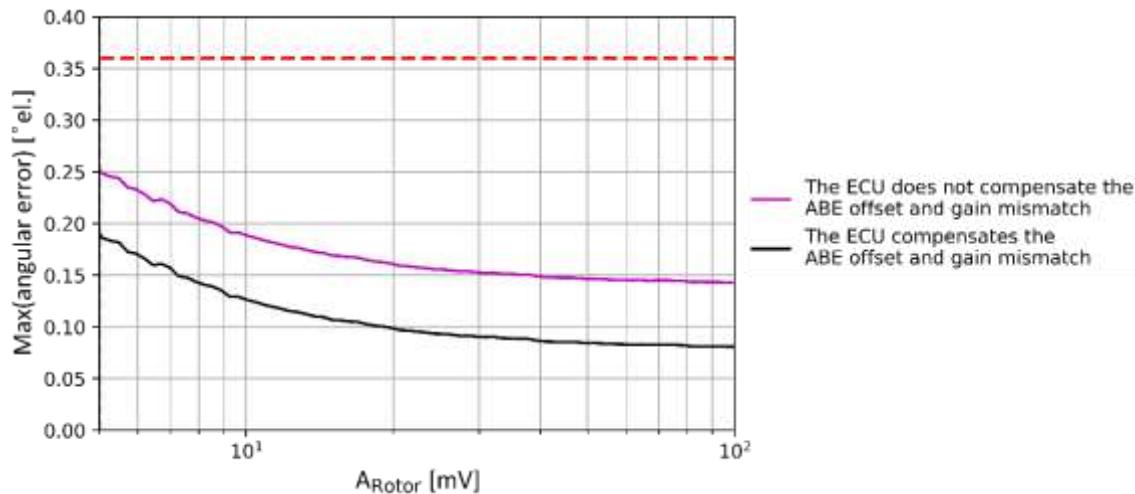
Figure 6 - Maximum quasi-static angular error as a function of A_{Rotor}
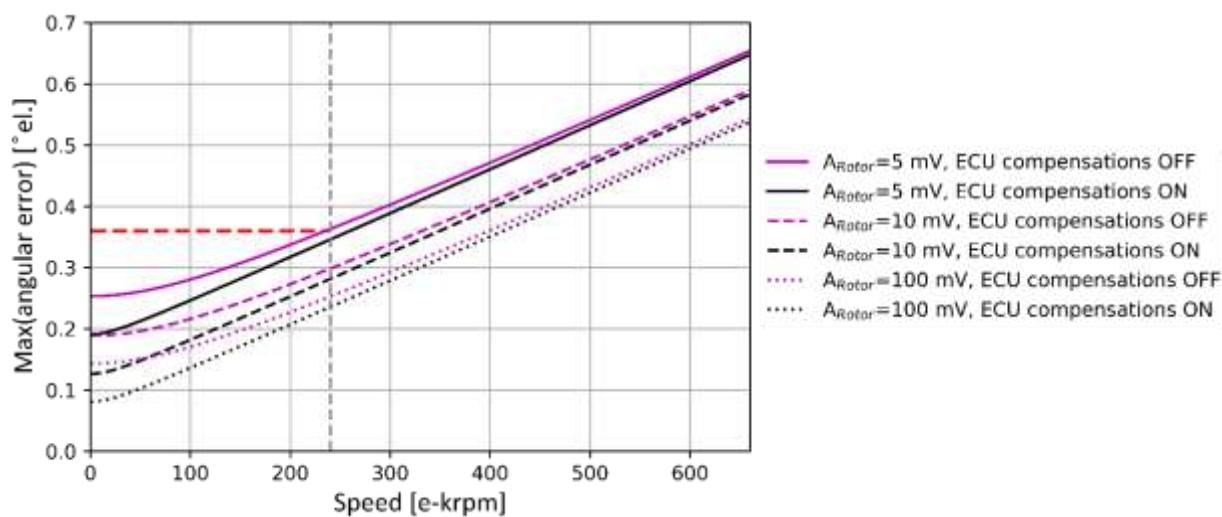
Figure 7 - Maximum angular error as a function of rotational speed for different conditions

9.4.2. Automatic Gain Control

To adapt to the input signal dynamic range of A_{Rotor} the MLX90510 has an automatic gain control (AGC) with 5 gain settings. The EEPROM fields AGC_GAIN_MIN [2:0] and AGC_GAIN_MAX [2:0] allow to restrict the AGC dynamic range or to lock the AGC value by programming AGC_GAIN_MIN [2:0] equal to AGC_GAIN_MAX [2:0].

Restricting the AGC range is not recommended as it results in a reduced available range for A_{Rotor} as shown in Figure 8.
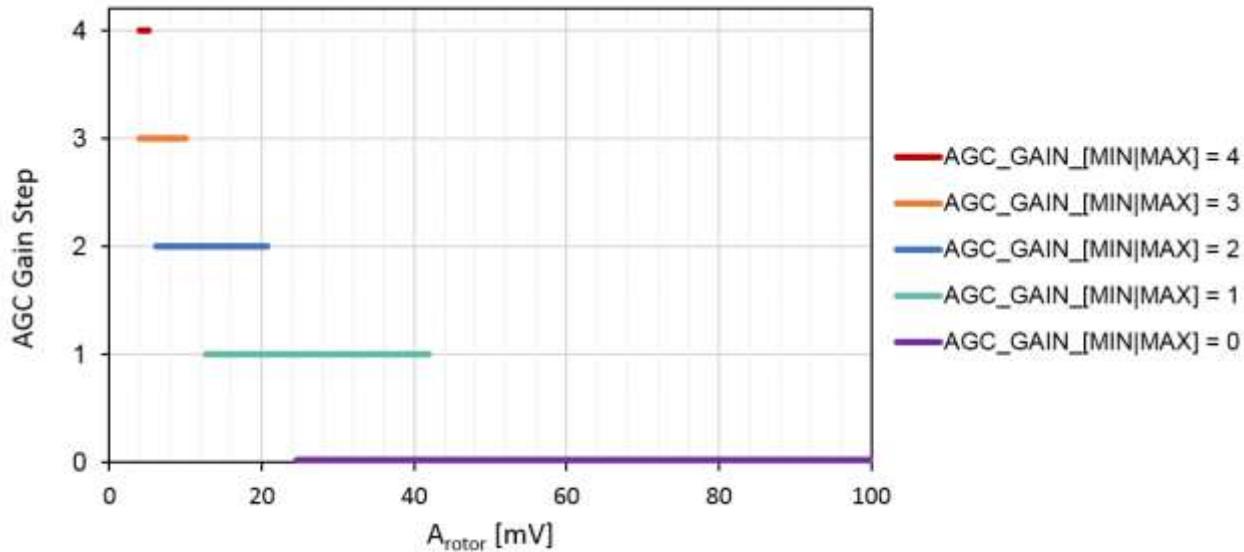
Figure 8 - AGC gain settings as a function of A_{Rotor}

9.5. Digital Signal Processing

The ADC permanently provides sequential samples to the DSP including samples of the three INx input phase differences and LCO amplitude.

The DSP features a DC offset compensation, interpolation (to align all three phases to a common sampling point), conversion from 3-phase to I/Q domain, a tracking phase-locked loop and a linearization option. The resulting instant angle is compensated regarding processing delay utilizing estimated temperature, speed and acceleration.

9.5.1. Digital Offset Compensations Methods

In Section 9.4.1 the composition of the INx signals is given. The signals A_{Asym0}, A_{Asym1} and A_{Asym2} are DC offsets of the input signals (INx), being mainly caused by asymmetries of the PCB coil design (Rx and Tx coils), and caused by feeding lines from and to the sensor or metal objects close to the sensor. This asymmetry can be compensated in MLX90510 by setting the EEPROM fields DC01_CONST [15:0], DC12_CONST [15:0], DC20_CONST [15:0]. The methods to determine the values of the offset compensation are described in the application note "Getting started with the MLX90510 EEPROM programming". The application note is available on request via http://softdist.melexis.com/. Please contact your local sales representative to get access. To ensure ASIL C compliance and accuracy, it is mandatory to perform DC offset compensation.

The offset compensation is subject to thermal drifts whose magnitude is dependent on the LCO frequency and the ratio between the amount of compensated A_{Asym} and the useful signal strength A_{Rotor}. The thermal drift dependence on these two parameters is illustrated in Figure 9 assuming that the offset compensation is performed at 35 °C.
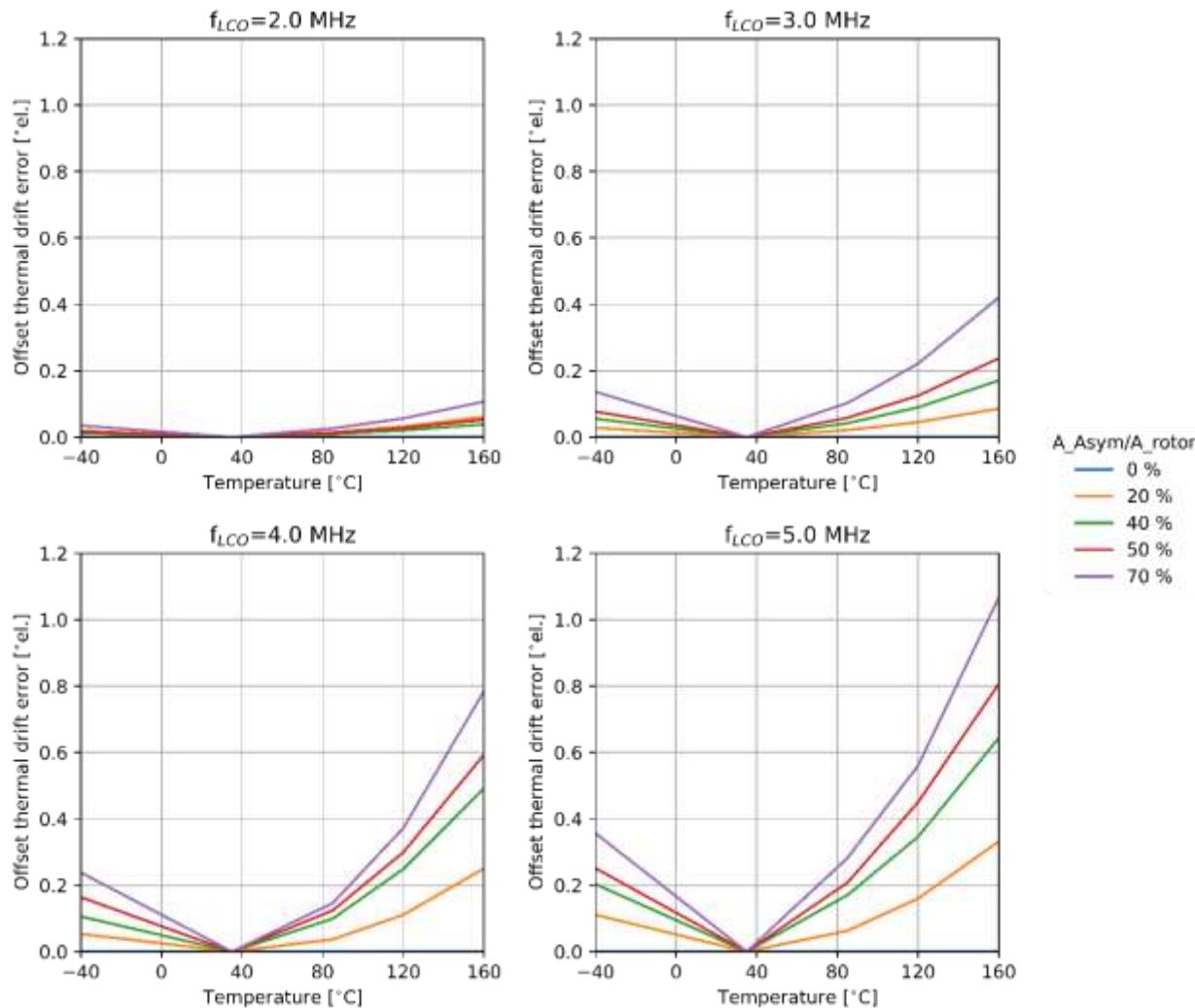
9.5.2. Angular 16-Points Linearization

The 16-points linearization feature allows equalizing angular deviations that are not fully removed by the digital offset compensation method, refer to Section 9.5.1. The 16 signed equalization values PEQ00 [7:0] to PEQ15 [7:0] and the PEQ_GAIN [2:0] EEPROM field define a set of angular error correction values $\Delta\varphi$ equally distributed in the [0, 360) electrical angle range. All intermediate values are linearly interpolated, see Figure 10. After equalization, the residual error curve is the difference between input error curve and interpolated equalization curve.
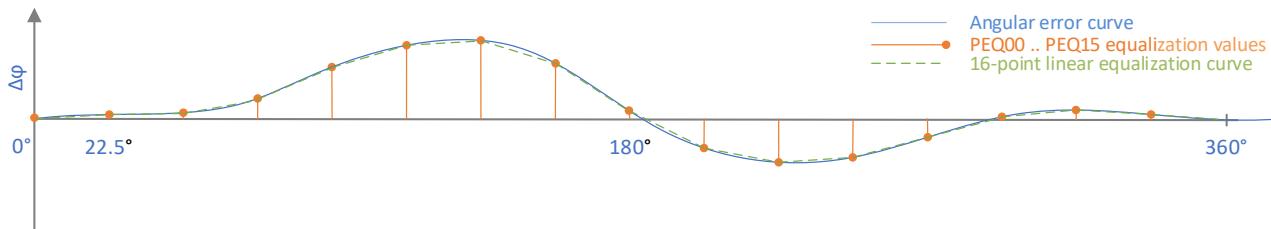
Figure 10 – Angular error curve compensation

The 16 angular error correction values shall be determined from the angular error curve, defined as the difference between the output angle and the reference angle, expressed as a function of the reference angle. It is recommended to choose for the reference angle zero position a value that minimizes the error average, in order to fully exploit the linearization range. The angular error curve shall be measured with the PHASE_OFFS field set to 0, refer to Section 9.5.3, and under quasi-static rotation conditions. With increasing rotational speed, the 16-points linearization automatically adapts to the low pass band limitation of the error curve. Depending on PEQ_GAIN [2:0] the equalization strength versus resolution can be adjusted. If PEQ_GAIN is set to 0, no equalization is applied. For PEQ_GAIN [2:0] = [1 ... 7] the error curve is adjusted per sample point as:

$$\Delta\varphi = -\,\text{signed(PEQxx)} \cdot 2^{\text{PEQ\_GAIN}-17} \cdot 360 \text{ [deg]}$$

The signed equalization values PEQ00 [7:0] to PEQ15 [7:0] each have a range of [-127 … 127]. Table 11 indicates the equalization range versus resolution per sample point.

PEQ_GAIN [2:0]	Resolution [deg]	Range (+/-) [deg]
0	0	0
1	0.0055	0.70
2	0.011	1.40
3	0.022	2.79
4	0.044	5.58
5	0.088	11.16
6	0.176	22.32
7	0.352	44.65

Table 11 – Equalization range

9.5.3. Zero output-angle position adjustment

The angular position of the target resulting in zero output angle can be adjusted by setting the EEPROM field PHASE_OFFS [15:0]. Note that the zero output-angle position adjustment shall be performed after the linearization calibration, refer to Section 9.5.2.

9.6. Analog Sine/Cosine Outputs

The Sine/Cosine output signals are generated based on the angle calculation in the DSP and buffered by two differential ABE output drivers. The MLX90510 can be used with either full differential Sine/Cosine outputs or with single-ended Sine/Cosine outputs. The differential outputs are recommended for best signal integrity and EMC performance. The ECU can again calculate the angle back by calculating the arctangent of the Sine/Cosine signals. It is recommended for single-ended operation to permanently track the common mode voltage V_{OUT_CM} to ensure the highest angular accuracy. In Figure 11, the differential Sine/Cosine output signals are given under typical conditions.

When one of the MLX90510 safety diagnostic mechanisms triggers, the Sine/Cosine outputs go in High-Z mode (safe state). Depending if pull-up or pull-down resistors are used, refer to Figure 15, the output voltages transition to Fault Band High (FBH) or Fault Band Low (FBL), respectively. The description of the safe state mechanisms can be found in Section 11.3.

The Sine/Cosine outputs are protected against overvoltage, overcurrent and reverse polarity and provide excellent EMC and ESD protection.
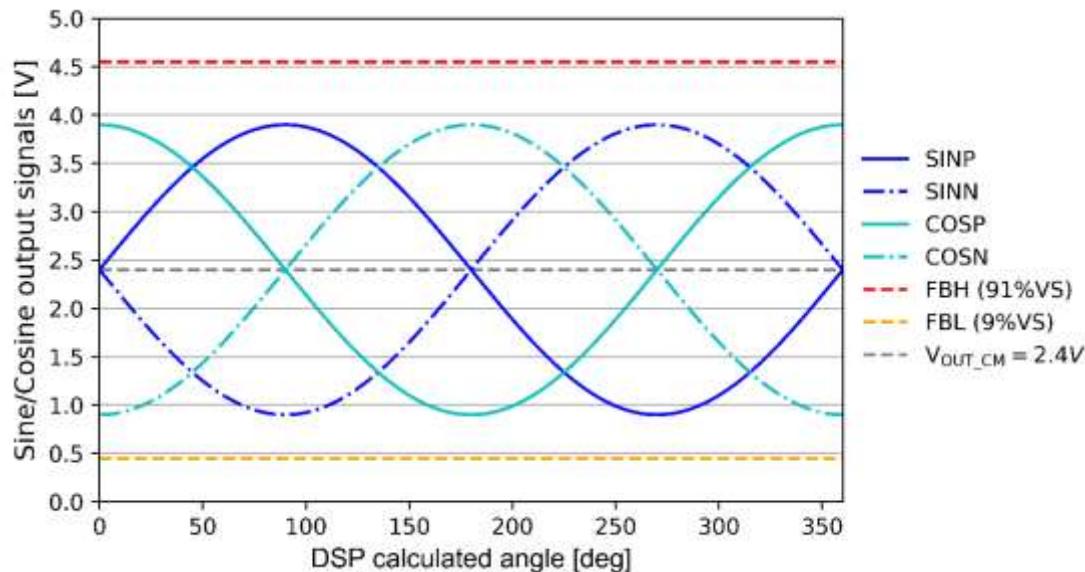
Figure 11 – Differential Sine/Cosine output signals

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Amplitude of SINP, SINN, COSP, COSN	V_{OUT_AMP}	1.4	1.5	1.6	V_p	For typical C_1 = 10 nF, C_3 = 4.7 nF (see Figure 15)
Output common mode (SINP+SINN)/2, (COSP+COSN)/2	V_{OUT_CM}	2.34	2.4[1]	2.46	V	
Differential offset SINP-SINN, COSP-COSN	V_{OUT_OFS}	-5		5	mV	
Output amplitude mismatch	ΔV_{OUT_AMP}	-0.32		0.32	%	
SIN/COS orthogonally			±0.030		°el.	
Valid signal range		10		90	%VS	
Failure band high level	FBH	91		100	%VS	R_{PU} connected to the ECU supply [2]
Failure band low level	FBL	0		9	%VS	R_{PD} connected to the ECU ground [2]

Table 12 – Sine/Cosine electrical specification

[1] When the MLX90510 single-ended configuration is used it is advised to perform an output common mode compensation in the ECU.

[2] Specification is only valid when the MLX90510 and the ECU have the same supply voltage.

9.7. Supply System

The MLX90510 has an integrated supply system providing regulated supply and reference voltages, as well as bias currents.

These regulated supply voltages guarantee immunity against disturbances on the external power supply, required for the correct functionality of the sensor IC. The capacitor C_2 at the pin VCAP serves as an energy storage during short VS voltage disturbances, refer to Figure 15.

The supply system offers safety mechanisms and monitors for over and undervoltage protection, reverse-polarity protection and power control to ensure correct sensor operation.

9.8. Sensor Bias

The Rx coils are DC biased by the MLX90510 internal Sensor Bias. Three individual DC operating points can be chosen by EEPROM register CID [1:0] programming, refer Section 12.2.

For a single sensor module, the default Sensor Bias setting can be used.

For a multi-sensor module including two or more sensor coil systems, the DC operating point of the individual sensors must be programmed to different values (CID [1:0] setting) for the correct safety function of the sensor short detection.

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Sensor Bias operating point	V_{SOP}		0.7		V	CID = 0 (default)
			1.04		V	CID = 1
			1.41		V	CID = 2 / 3

Table 13 – Sensor DC operating point programming

10. Identification items

To ensure traceability and unique identification of the individual parts, the EEPROM stores in read only mode an identifier for the wafer fab (D_FAB_ID[9:6]), for the wafer lot (D_LOT_ID_HI[5:0], D_LOT_ID_LO[15:5]), for the wafer number within the lot (D_WFR_ID[9:6]), and the X and Y coordinates of the chip within the wafer (D_X_POS_ID[7:0] and D_Y_POS_ID[15:8], respectively). The option code can be identified via the LFC [15:14] field, see Section 12.2 for the values associated to each option code.

11. Functional Safety

The MLX90510 is developed according to ISO 26262 and is compliant to ASIL C.

11.1. Safety Manual

The safety manual, available upon request, contains the necessary information to integrate the MLX90510 component in a safety related item. The product is developed 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, including:

  - assumption on the context, including its external interfaces

  - assumption on the safety goals for the component

  - assumption on the component safe states (SS)

  - assumptions on fault detection time interval to support the FTTI on item level

- The description of safety analysis results at the component level, hardware architectural metrics and description of dependent failures initiators as useful for the system integrator

- The description and the result of the functional safety assessment process; list of confirmation measures and description of the independency level

11.2. MLX90510 Safety Goal

Description	Electrical Angle error	FDTI
The angular error (difference between real electrical angle and the reported angle by the SIN/COS channels) that shall not be exceed without a safe state condition within the FDTI.	±3° el	500 µs

Table 14 – Functional safety specification

11.3. Safety Mechanism and Monitors

The MLX90510 provides numerous self-diagnostic features (safety mechanisms). Those features increase the safeness of the full sensor system by preventing the random hardware faults of the inductive sensor connected to the MLX90510 that may lead to erroneous output signals. In Table 15 only the monitors related to sensor events are listed. For a complete overview of the safety mechanism and monitors refer to the safety manual.

No.	Category and Safety mechanism name	Reporting Mode (SINP, SINN, COSP, COSN)
1	Overvoltage event on VS or output pin(s)	High-Z
2	Undervoltage event on VS ("Brownout")	High-Z
3	Overcurrent event on ABE output pin(s) (short circuit current)	High-Z
4	Power supply connection to VS or GND broken	High-Z
5	Rx coils open, short circuit to VS or GND, short circuit to Tx coil	High-Z
6	Rx coils amplitude error (out of range) or offset error	High-Z
7	Tx coil open, short circuit to VS or GND, short circuit to Rx coils	High-Z
8	LC Oscillator failure	High-Z

Table 15 – List of diagnostics on sensor events

11.3.1. Safe State Indication

A detected fault is indicated by the Sine/Cosine outputs in High-Z mode within the Failure Bands High (FBH) or Failure Band low (FBL) as described in Table 12. The FBH and FBL voltages are realized by a pull-up resistor R_{PU} connected to the ECU supply or pull-down resistor R_{PD} to GND, refer to Figure 15. The EEPROM register PULL_DIR shall be programmed to 1 in case of a pull-up resistor, or to 0 in case of pull-down resistor at the ECU according to Section 12.2.

In case of single-ended application, the EEPROM register PULL_SE shall be programmed to 1, refer to Section 12.2. By default, this register is set to 0 for differential operation. In a single-ended application, only one pull-down or pull-up resistor is expected on SINP and COSP outputs. In Chapter 13 the application diagrams and recommended values of the R_{PU} and R_{PD} resistors are described.

11.3.1.1. Transition from normal operation to High-Z mode

To speed-up the transition from the valid signal range to the failure band region, the Sine/Cosine outputs are driven actively to the failure band for a duration defined in the EEPROM register EH_DRV_SS2_PERIOD [5:3]. The active failure band transition can be bypassed if EH_DRV_SS2_PERIOD [5:3] is set to 0. After the transition, the Sine/Cosine outputs will go in High-Z mode. Note that in case an IC supply (VS) overvoltage is detected, the Sine/Cosine outputs will follow the IC supply voltage (which may be different from the ECU supply voltage) during the active failure band period when the pull-up resistor configuration is used.

11.3.1.2. Transition from High-Z mode to normal operation

When all safety mechanisms indicate return to operational conditions within the safety goal, the Sine/Cosine outputs will exit the High-Z mode and return to the operation within a maximum recovery time t_{REC} as shown

in the IC operating ranges in Figure 12. With EEPROM register EH_MIN_SS_PERIOD [2:0], a minimum period for the safe state indication can be programmed to support the detection of the safe state in the ECU.

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Recovery time	t_{REC}			30	µs	

Table 16 – Recovery time

11.3.2. Supply System Monitoring

The MLX90510 has a supply system monitoring to detect under and overvoltage events. Reporting of the under and overvoltage status is done via the Sine/Cosine output pins in High-Z.

Figure 12 describes the MLX90510 operating modes as a function of VS supply range including start-up, VS undervoltage (red), VS normal operating range (green) and VS overvoltage range (yellow) with the corresponding ABE Sine/Cosine outputs modes. The supply system undervoltage and overvoltage monitors are described in Table 17 whereas the POR levels are described in Chapter 8, Table 5.
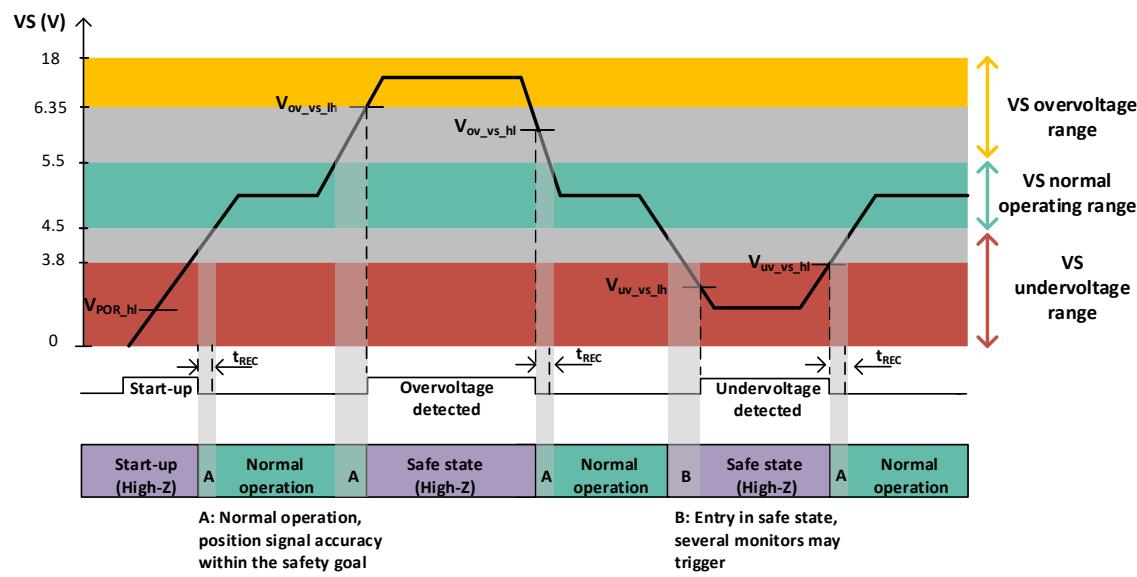
Figure 12 – MLX90510 operating modes

Operating Characteristics, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
VS undervoltage detection	$V_{uv\_vs\_lh}$	3.23	3.5[1]	3.73	V	VS decreasing
	$V_{uv\_vs\_hl}$	3.53	3.8	4.03	V	VS rising

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
VS overvoltage detection	$V_{ov\_vs\_lh}$	5.89	6.35	6.80	V	VS rising. Entry into low power mode with I_{VS_LP} current consumption
	$V_{ov\_vs\_hl}$	5.7	6	6.45	V	VS decreasing
VS voltage detection hysteresis	V_{hyst_vs}		0.3		V	

Table 17 – Supply system monitoring

[1] Safety monitors other than the VS undervoltage monitor may trigger when VS is reduced below 4.5 V.

11.3.3. Sensor Monitor

The sensor coil system is monitored and reporting via the ABE output pins as described in Section 11.3. There are two short detection monitors built in, see Figure 13 left and Figure 14, and one open or high ohmic connection monitor, see Figure 13 right.
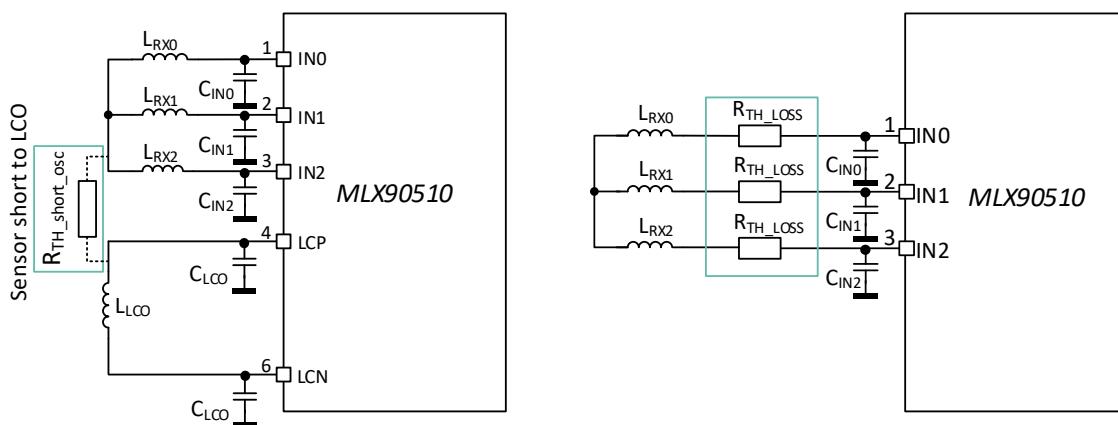
Figure 13 – Left: Rx to Tx coil short detection. Right: Sensor loss detection

The short detection monitor shown in Figure 14 is designed for multi-sensor modules using two sensor coil systems within one inductive sensor system, for example for application with a redundant coil system.

The DC operating point of the individual sensors must be programmed to different values, for CID [1:0] setting refer to Section 9.8, for the correct safety function of the sensor short detection.
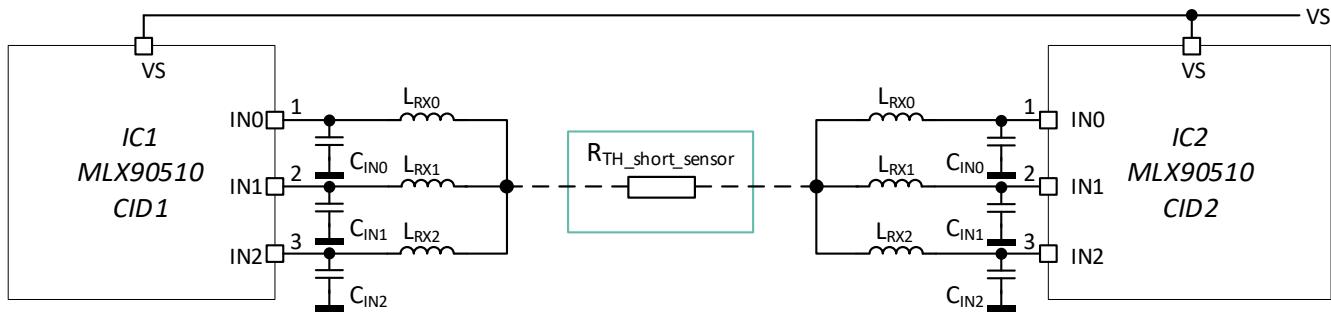
Figure 14 – Multi-Sensor Module - Sensor coil system #1 to sensor coil system #2 short detection

In Table 18 the characteristics of the sensor monitor are given.

Operating Characteristics, VS = 4.5 V to 5.5 V, T_A = -40°C to 160°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Rx coil(s) to Tx coil short detection threshold resistance	$R_{TH\_short\_osc}$	0	100		kΩ	Short between Rx and Tx coil(s)
Sensor loss detection resistance threshold	R_{TH_loss}	30			kΩ	Assuming the sensor resistance 100 Ω for all CID [1:0] settings
Rx coil 1 to Rx coil 2 short detection threshold resistance	$R_{TH\_short\_sensor}$	0	20		kΩ	Short between two sensors with different CID [1:0] settings

Table 18 – Sensor monitor functions

12. Description of Memory and Registers

The MLX90510 offers a variety of programming options. It is recommended to program values different than the default ones only if the application requires it.

Both, programming and register reading, are supported by using the Melexis programming tool.

The MLX90510 programming address space has the following configuration:

Chapter	Block Name	Description
Device version	VERSION	Device version
EEPROM	CEE_MAP	EEPROM content (non-volatile memory). Allows accessing the device configurations and calibration values.

Table 19 – Address space

12.1. Device Version

VERSION Field	Address	Bit	R/W	Value	Description
VERSION_L	128	[15:0]	R	36539	The 16-LSBs of the version number.
VERSION_H	130	[15:0]	R	353	The 16-MSBs of the version number.

Table 20 – Device version

12.2. EEPROM Map – CEE_MAP

MLX90510 features an EEPROM to permanently store customized system configuration and calibration data. The programming of the EEPROM is performed using the PGI.

CEE_MAP Field	Address	Bit	R/W	Default Value	Description
Reserved	256	[15:14]	R	0	Reserved; W: no effect
PHASE	256	[13:10]	R/W	0	Reserved, set to 0. LC oscillator phase delay trimming. This field should not be modified by the user.
LC_OSC_AMP	256	9	R/W	0	LCO amplitude. 0: full, 1: half amplitude
LC_OSC_EN	256	8	R/W	1	LCO enable. 1: LCO enabled, 0: LCO disabled
CUS_PGI_ID	256	[7:6]	R/W	0	PGI device ID
PULL_SE	256	5	R/W	0	1: single-ended pull resistor configuration, else differential
EN_POR_RDY	256	4	R/W	0	1: Readiness after POR is indicated by inverse failure-band after latent fault checks for period according to EH_MIN_SS_PERIOD
PULL_DIR	256	3	R/W	1	Output pull resistor connection. 1: pull-up, 0: pull-down
OUT_RAW	256	2	R/W	0	1: RAW-IQ Mode on, 0: RAW-IQ Mode OFF. This field should be modified only for debugging purposes. The content of this datasheet is not valid if OUT_RAW = 1[1]
CID	256	[1:0]	R/W	0	Chip ID, refer to Section 9.8
LC_P_MON_LIM_HI	258	[15:8]	R/W	166	LC oscillator period monitoring limit. This field should not be modified by the user
LC_P_MON_LIM_LO	258	[7:0]	R/W	60	LC oscillator period monitoring limit. This field should not be modified by the user
DC01_CONST	260	[15:0]	R/W	0	DC Offset compensation constant for channel D01. D01 = IN0 − IN1

CEE_MAP Field	Address	Bit	R/W	Default Value	Description
DC12_CONST	262	[15:0]	R/W	0	DC Offset compensation constant for channel D12. D12 = IN1 − IN2
DC20_CONST	264	[15:0]	R/W	0	DC Offset compensation constant for channel D20. D20 = IN2 − IN0
PEQ_GAIN	266	[15:13]	R/W	0	Phase Equalizer gain, refer to Section 9.5.2
AGC_GAIN_MIN	266	[12:10]	R/W	0	AGC: minimum PGA gain setting, range [0 … 4]
AGC_GAIN_MAX	266	[9:7]	R/W	4	AGC: maximum PGA gain setting, range [0 … 4]
Reserved	266	6	R	0	Reserved; W: no effect
EH_DRV_SS2_PERIOD	266	[5:3]	R/W	2	Min. period the IC will actively drive failure band; If > 0, T = $2^{(3+EH\_DRV\_SS2\_PERIOD)}$ µs, else 0
EH_MIN_SS_PERIOD	266	[2:0]	R/W	5	Min. period the device will remain in safe state after the error source has disappeared If>0, T=$2^{(3+EH\_MIN\_SS\_PERIOD)}$ µs, else 0
PEQ01	268	[15:8]	R/W	0	Phase Equalizer value 01, refer to Section 9.5.2
PEQ00	268	[7:0]	R/W	0	Phase Equalizer value 00, refer to Section 9.5.2
PEQ03	270	[15:8]	R/W	0	Phase Equalizer value 03, refer to Section 9.5.2
PEQ02	270	[7:0]	R/W	0	Phase Equalizer value 02, refer to Section 9.5.2
PEQ05	272	[15:8]	R/W	0	Phase Equalizer value 05, refer to Section 9.5.2
PEQ04	272	[7:0]	R/W	0	Phase Equalizer value 04, refer to Section 9.5.2
PEQ07	274	[15:8]	R/W	0	Phase Equalizer value 07, refer to Section 9.5.2
PEQ06	274	[7:0]	R/W	0	Phase Equalizer value 06, refer to Section 9.5.2
PEQ09	276	[15:8]	R/W	0	Phase Equalizer value 09, refer to Section 9.5.2
PEQ08	276	[7:0]	R/W	0	Phase Equalizer value 08, refer to Section 9.5.2
PEQ11	278	[15:8]	R/W	0	Phase Equalizer value 11, refer to Section 9.5.2
PEQ10	278	[7:0]	R/W	0	Phase Equalizer value 10, refer to Section 9.5.2
PEQ13	280	[15:8]	R/W	0	Phase Equalizer value 13, refer to Section 9.5.2
PEQ12	280	[7:0]	R/W	0	Phase Equalizer value 12, refer to Section 9.5.2
PEQ15	282	[15:8]	R/W	0	Phase Equalizer value 15, refer to Section 9.5.2
PEQ14	282	[7:0]	R/W	0	Phase Equalizer value 14, refer to Section 9.5.2
PHASE_OFFS	284	[15:0]	R/W	0	Constant output phase offset, resolution 360/2^{16} deg (signed 2's-complement)
LFC	350	[15:14]	R		DSP phase tracking adaptive loop filter control
				0	MLX90510GGO-BBA-100-RE
				1	MLX90510GGO-BBA-101-RE

CEE_MAP Field	Address	Bit	R/W	Default Value	Description
				2	MLX90510GGO-BBA-102-RE
EN_ALF	350	13	R	1	DSP phase tracking adaptive loop filter control enable
D_Y_POS_ID	378	[15:8]	R		Chip Y position within the wafer
D_X_POS_ID	378	[7:0]	R		Chip X position within the wafer
D_LOT_ID_LO	380	[15:5]	R		The 5 LSB of the lot ID
D_WFR_ID	380	[4:0]	R		Wafer ID
D_FAB_ID	382	[9:6]	R		FAB-ID
D_LOT_ID_HI	382	[5:0]	R		The 5 MSB of the lot ID

Table 21 – EEPROM map

[1] When RAW-IQ mode is ON, the DSP phase tracking, propagation delay compensation and linearization steps are disabled. The system only performs a Clarke's transformation on the digitized input signals after offset compensation. The resulting I/Q signals are directly fed to the ABE for Sine/Cosine output signal generation.

13. Recommended Application Diagrams

Figure 15 and Figure 16 show the recommended application diagrams for differential Sine/Cosine and single-ended Sine/Cosine outputs, respectively. It is advised to use the differential Sine/Cosine outputs configuration whenever a wire harness is used.
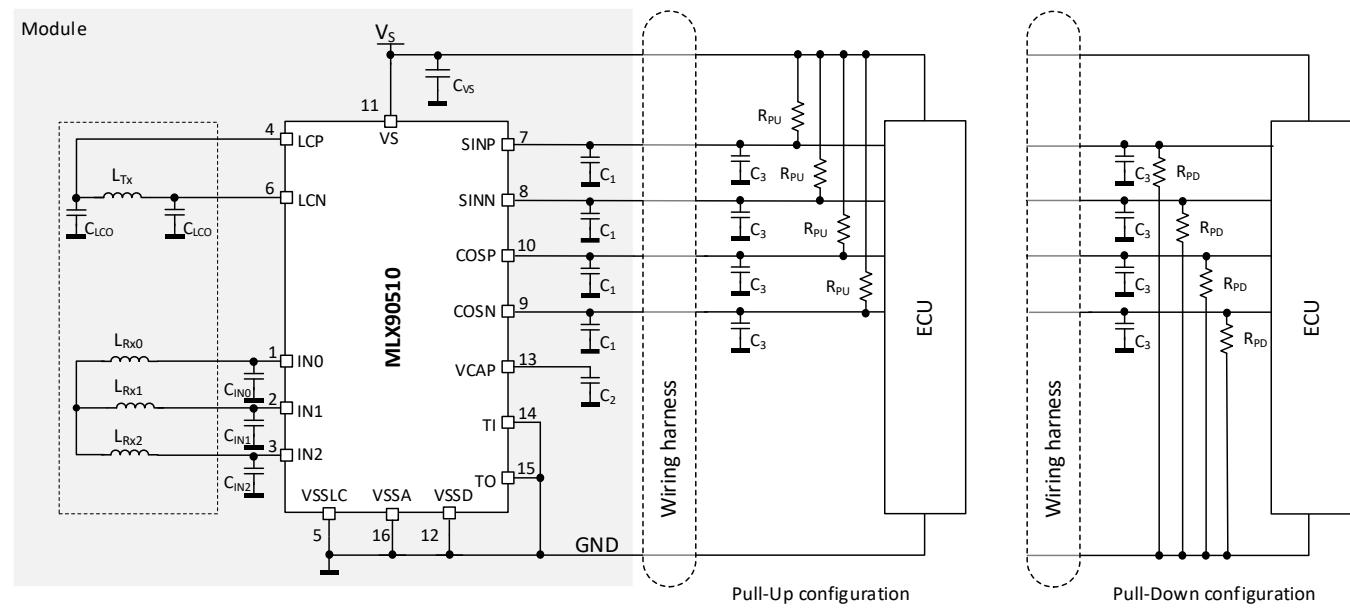

*Figure 15 – Application circuit for differential Sine/Cosine outputs*
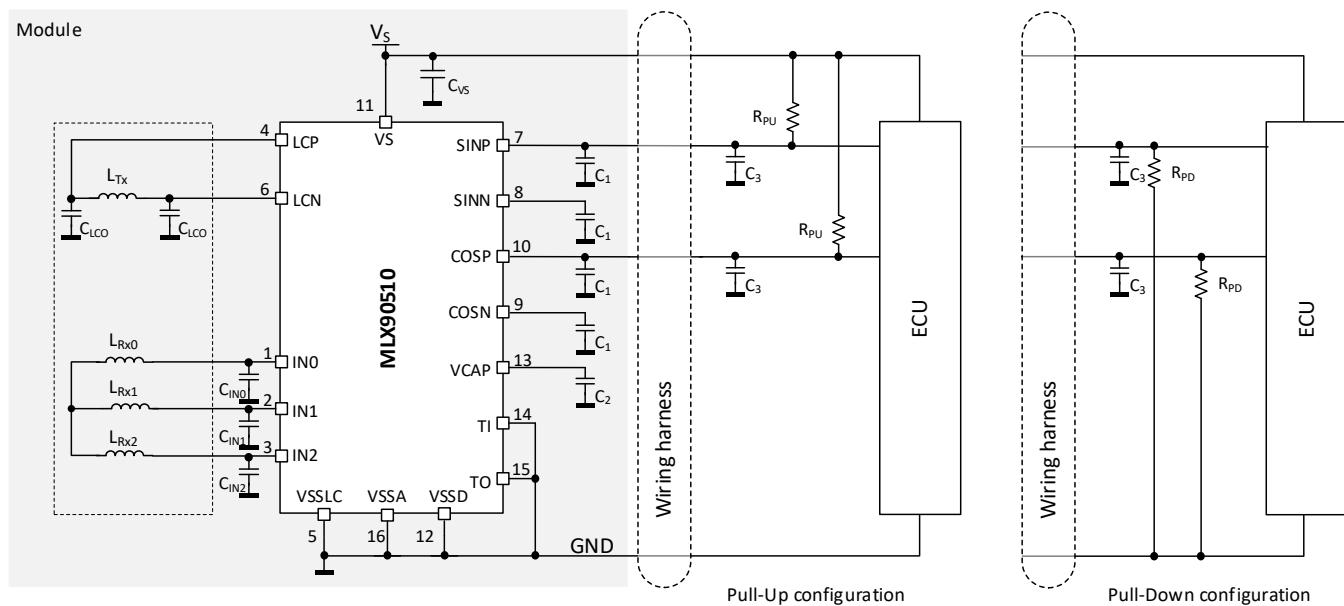
Figure 16 – Application circuit for single-ended Sine/Cosine outputs

It is recommended to connect the ground pins VSSA, VSSD, VSSLC to a common, low impedance ground plane on the PCB (GND).

For multi-sensor applications where two sensors are sharing the same power supply, it is possible to connect the TI pin to the VCAP pin via a 1 kΩ resistor. This allows to independently program the two sensors.

The component values for a typical application schematic are given in Table 22:

Component	Symbol	Min.	Typ.	Max.	Unit	Comment
Capacitor	C_1		$10^{[1]}$		nF	$C_1 + C_3 \leq 27$ nF
Capacitor	C_2	10	470	1000	nF	
Capacitor	C_3		4.7		nF	$C_1 + C_3 \leq 27$ nF
Resistor Pull-up	R_{PU}	5	10	12	kΩ	
Resistor Pull-down	R_{PD}	5	10	12	kΩ	
Capacitor	C_{VS}	100	470		nF	
Inductor (Tx coil)	L_{Tx}	1	4	10	µH	
Capacitor	C_{LCO}		1.2		nF	
Capacitor	$C_{IN0,1,2}$		$100^{[2]}$		pF	

Table 22 – Application circuit components

[1] For ESD immunity reasons it is advised to use an output load capacitor C_1 = 10 nF.
[2] For EMC immunity reasons it is advised to add capacitors $C_{IN0,1,2}$ on the inputs.

14. Package Information

14.1. TSSOP-16 Package Dimensions

NOTES:

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

Figure 17 – TSSOP16 package dimensions

15. Standard Information

Our products are classified and qualified regarding soldering technology, solder ability 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. 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.

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

16. ESD Precautions

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

17. Revision History Table

17/03/2021 (001)	Preliminary datasheet release
16/12/2021 (002)	Official datasheet release
01/08/2022 (003)	Datasheet revision

Table 23 – Revision history table

18. Contact

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

Europe, Africa	Email : sales_europe@melexis.com
Americas	Email : sales_usa@melexis.com
Asia	Email : sales_asia@melexis.com

19. Disclaimer

The content of this document is believed to be correct and accurate. However, the content of this document is furnished "as is" for informational use only and no representation, nor warranty is provided by Melexis about its accuracy, nor about the results of its implementation. Melexis assumes no responsibility or liability for any errors or inaccuracies that may appear in this document. Customer will follow the practices contained in this document under its sole responsibility. This documentation is in fact provided without warranty, term, or condition of any kind, either implied or expressed, including but not limited to warranties of merchantability, satisfactory quality, non-infringement, and fitness for purpose. Melexis, its employees and agents and its affiliates' and their employees and agents will not be responsible for any loss, however arising, from the use of, or reliance on this document. Notwithstanding the foregoing, contractual obligations expressly undertaken in writing by Melexis prevail over this disclaimer.

This document is subject to change without notice, and should not be construed as a commitment by Melexis. Therefore, before placing orders or prior to designing the product into a system, users or any third party should obtain the latest version of the relevant information. Users or any third party must determine the suitability of the product described in this document for its application, including the level of reliability required and determine whether it is fit for a particular purpose.

This document as well as the product here described may be subject to export control regulations. Be aware that export might require a prior authorization from competent authorities. The product is not designed, authorized or warranted to be suitable in applications requiring extended temperature range and/or unusual environmental requirements. High reliability applications, such as medical life-support or life-sustaining equipment or avionics application are specifically excluded by Melexis. The product may not be used for the following applications subject to export control regulations: the development, production, processing, operation, maintenance, storage, recognition or proliferation of:
1. chemical, biological or nuclear weapons, or for the development, production, maintenance or storage of missiles for such weapons;
2. civil firearms, including spare parts or ammunition for such arms;
3. defense related products, or other material for military use or for law enforcement;
4. any applications that, alone or in combination with other goods, substances or organisms could cause serious harm to persons or goods and that can be used as a means of violence in an armed conflict or any similar violent situation.

No license nor any other right or interest is granted to any of Melexis' or third party's intellectual property rights.

If this document is marked "restricted" or with similar words, or if in any case the content of this document is to be reasonably understood as being confidential, the recipient of this document shall not communicate, nor disclose to any third party, any part of the document without Melexis' express written consent. The recipient shall take all necessary measures to apply and preserve the confidential character of the document. In particular, the recipient shall (i) hold document in confidence with at least the same degree of care by which it maintains the confidentiality of its own proprietary and confidential information, but no less than reasonable care; (ii) restrict the disclosure of the document solely to its employees for the purpose for which this document was received, on a strictly need to know basis and providing that such persons to whom the document is disclosed are bound by confidentiality terms substantially similar to those in this disclaimer; (iii) use the document only in connection with the purpose for which this document was received, and reproduce document only to the extent necessary for such purposes; (iv) not use the document for commercial purposes or to the detriment of Melexis or its customers. The confidentiality obligations set forth in this disclaimer will have indefinite duration and in any case they will be effective for no less than 10 years from the receipt of this document.

This disclaimer will be governed by and construed in accordance with Belgian law and any disputes relating to this disclaimer will be subject to the exclusive jurisdiction of the courts of Brussels, Belgium.

The invalidity or ineffectiveness of any of the provisions of this disclaimer does not affect the validity or effectiveness of the other provisions.
The previous versions of this document are repealed.

Melexis © - No part of this document may be reproduced without the prior written consent of Melexis. (2022)

IATF 16949 and ISO 14001 Certified