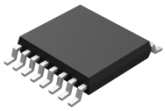
1. Features and Benefits

- High Speed Inductive Position Sensing Technology for speeds up to 660 000 e-rpm
- High accuracy: Maximum ±0.36° electrical
- Differential Sine and Cosine analog outputs
- Programmable on-chip input signal offset compensation
- 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 MLX90517 is designed to interface an inductive transducer, process the captured signals via filtering, amplification, demodulation, offset compensation and Clarke's transformation, and provide differential Sine & Cosine outputs, see Figure 3. The output signals are transmitted to an ECU which performs signal compensation and angle calculation.

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 MLX90517 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

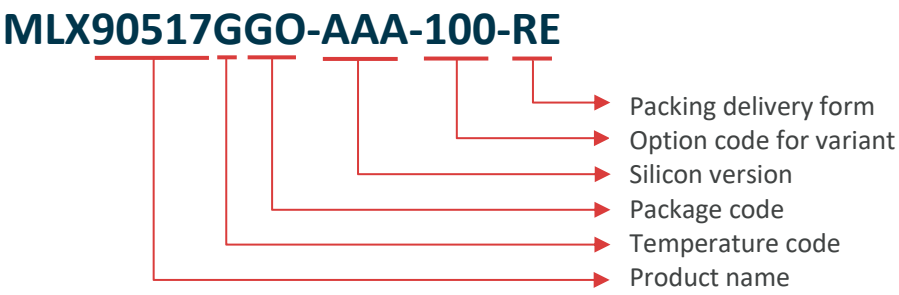
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4. Ordering Information

Ordering Code	Temperature	Package	Definition	Packing
MLX90517GGO-AAA-100-RE	-40°C to 160°C	TSSOP-16	Angular rotary SIN/COS	Reel

Table 1 – Ordering codes



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.

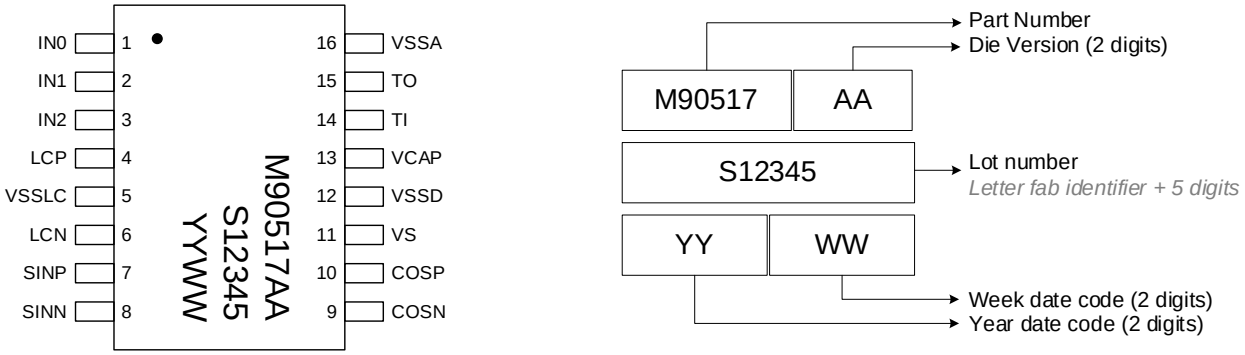


Figure 2 – TSSOP16 pin names and marking

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 12)
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 12)
13	VCAP	External supply buffer capacitor connection
14	TI	Test input (connect to GND, see Figure 12) [1]
15	TO	Test output (connect to GND, see Figure 12)
16	VSSA	Analog ground (connect to GND, see Figure 12)

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

MLX90517 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 21 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 9
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 9
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	
Differential Sine and Cosine analog signals noise	Acc_{noise}			1.5	mV	
System propagation delay	T_{delay}	13.3	13.7	14.2	µs	
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 is a ±3σ value includes gain mismatches and other nonidealities of the signal chain (noise excluded). Errors from the propagation delay of the IC and from output signals offsets are not included as it is assumed that they are corrected by means of ECU based compensations. Errors from non-ideal relations between the input signals electrical phase, refer to Section 9.4.1, and the target position are furthermore excluded.

9. Detailed Description

9.1. Block Diagram

The MLX90517 is an inductive position sensor which is used for absolute rotary motion/position sensing. The block diagram is given in Figure 3.

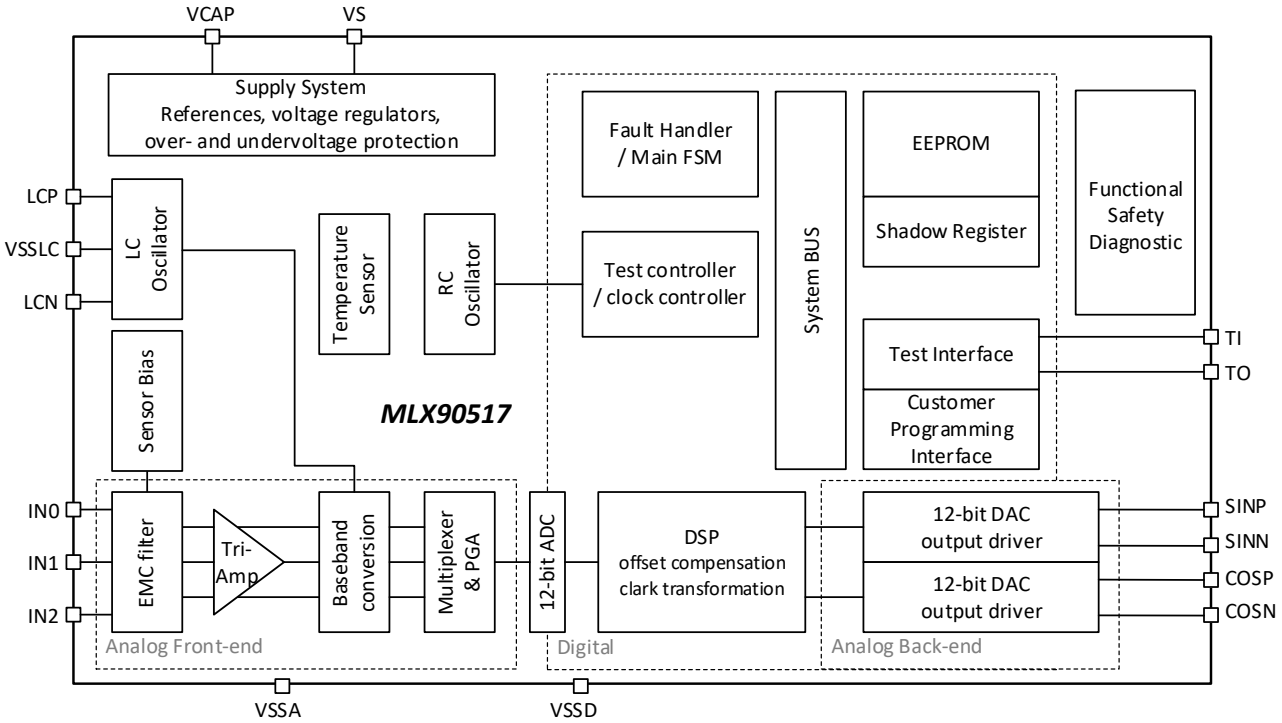


Figure 3 – Block diagram

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 MLX90517 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}.

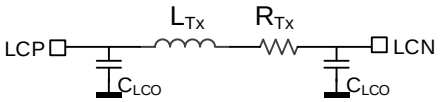


Figure 4 – LCO Tx coil model

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 12).
[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).

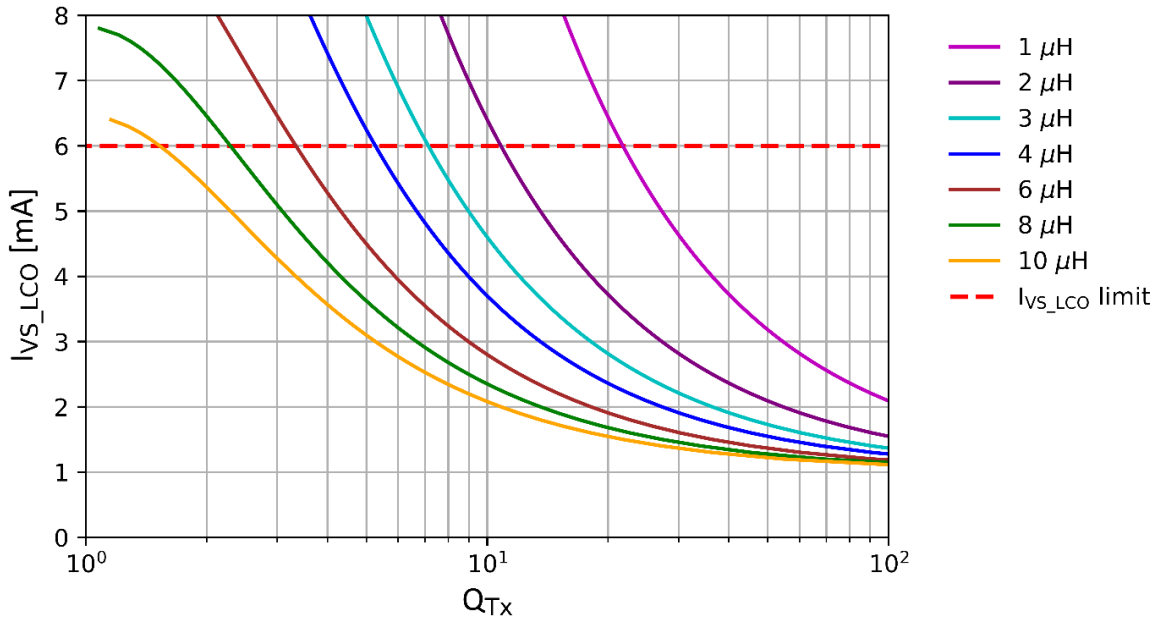


Figure 5 – I_{VS_LCO} as function of Q_{Tx} for LCO frequency of 3.5 MHz

9.4. Analog Signal Processing

The sensor coil system is connected to the MLX90517 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.

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

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 MLX90517.

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 MLX90517 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	Unrestricted AGC dynamic range, refer to Section 9.4.2
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_{Asym0}|, |A_{Asym1}|, |A_{Asym2}|)

Table 8 – Input signal requirements

The system accuracy specified in Table 5 is achieved within the speed ranges specified in Table 9.

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

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Rotational speed		-660 000		660 000	e-rpm	

Table 9 – Electrical rotational speed and acceleration

9.4.2. Automatic Gain Control

To adapt to the input signal dynamic range of A_{Rotor} the MLX90517 has an automatic gain control (AGC) with 5 gain settings whose ratio is tightly controlled. 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 dynamic range results in further limitations to the A_{Rotor} ranges with respect to the ones of Table 8, as specified in Table 10. Figure 6 illustrates the signal strength ranges covered by the individual AGC gain steps. The maximum A_{Rotor} value is reduced in case an offset in the input signals is present, as shown in Figure 6 and specified in Table 10. For the maximum level of allowed offset as function of the signal strength, refer to Table 8. If allowed by the programmed values of AGC_GAIN_MIN [2:0] and AGC_GAIN_MAX [2:0], the AGC gain step will adjust automatically according to the measured signal strength. Applying input signal strengths beyond the upper limit of the AGC step corresponding to AGC_GAIN_MAX [2:0] or below the lower limit of the AGC step corresponding to AGC_GAIN_MIN [2:0] leads to degraded angular accuracy and ultimately triggers a transition to safe state.

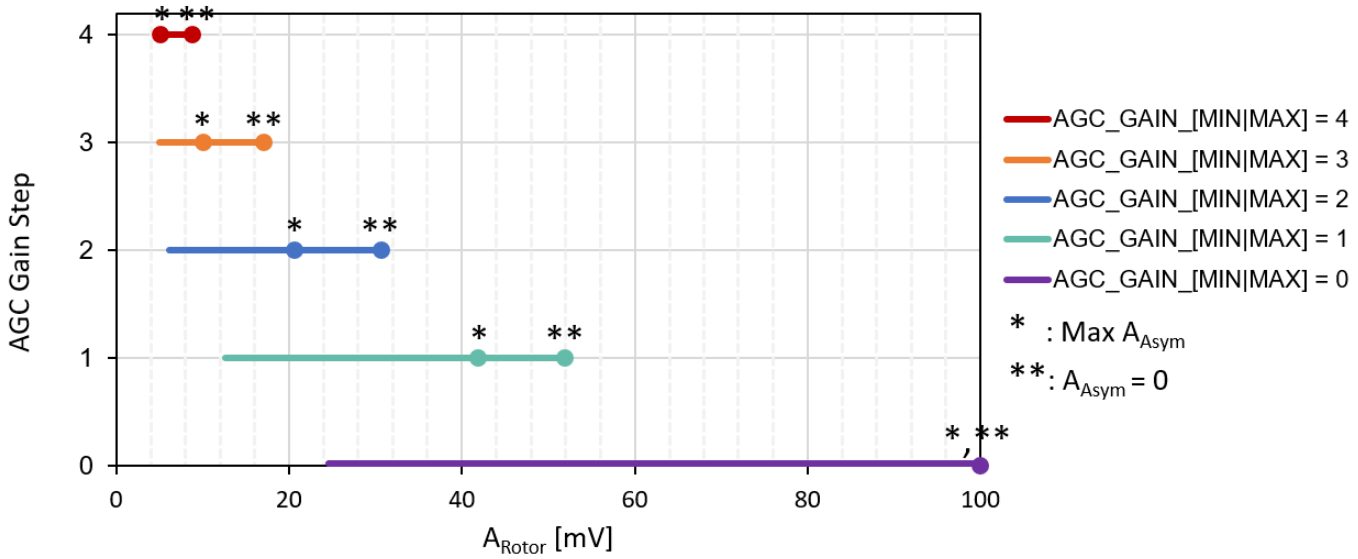


Figure 6 - AGC gain settings as a function of the input signals strength

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

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Gain ratio between adjacent AGC gain steps		1.99	2.00	2.01		
Input signal strength AGC_GAIN_[MIN|MAX] = 0	A_{Rotor}	24.7		100	mV	

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Input signal strength AGC_GAIN_[MIN|MAX] = 1	A_{Rotor}	12.6 12.6		41.9 51.9	mV	Max A_{Asym} A_{Asym} = 0
Input signal strength AGC_GAIN_[MIN|MAX] = 2	A_{Rotor}	6.2 6.2		20.6 30.6	mV	Max A_{Asym} A_{Asym} = 0
Input signal strength AGC_GAIN_[MIN|MAX] = 3	A_{Rotor}	5 5		10.0 17.0	mV	Max A_{Asym} A_{Asym} = 0
Input signal strength AGC_GAIN_[MIN|MAX] = 4	A_{Rotor}	5 5		5.2 8.5	mV	Max A_{Asym} A_{Asym} = 0

Table 10 – AGC gain steps specification

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 phase differences to a common sampling point) and conversion from 3-phase to I/Q domain via a Clarke's transformation on the offset compensated INx input phase differences:

$$\mathrm{I} = -\frac{1}{\sqrt{3}}(\mathrm{IN1} - \mathrm{IN2}) + \frac{1}{\sqrt{3}}(\mathrm{IN2} - \mathrm{IN0})$$
$$\mathrm{Q} = \frac{2}{3}(\mathrm{IN0} - \mathrm{IN1}) - \frac{1}{3}(\mathrm{IN1} - \mathrm{IN2}) - \frac{1}{3}(\mathrm{IN2} - \mathrm{IN0})$$

The DSP outputs I and Q are digital Cosine and Sine values, respectively, which are provided to the MLX90517 ABE for the generation of the output signals.

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), feeding lines from and to the sensor and eventual metal objects close to the sensor. This asymmetry can be compensated in MLX90517 by setting the EEPROM fields DC01_CONST [15:0], DC12_CONST [15:0], DC20_CONST [15:0]. These stored offset values are subtracted from the digitized INx phase differences IN0-IN1, IN1-IN2 and IN2-IN0, respectively, after proper rescaling for the LCO amplitude and the AGC gain step. A non-ideal offset compensation translates in offsets on the output Sine/Cosine signals. The methods to determine the values of the offset compensation are described in the application note "Getting started with the MLX90510/MLX90517 EEPROM programming". The application note is available on request. Please contact your local sales representative to get access.

The offset compensation is subject to thermal drifts which result in temperature dependent offset on the Sine/Cosine output signals, O_{Sine} and O_{Cosine}, respectively, whose magnitude depends on the LCO frequency and the ratio between the amount of compensated A_{Asym} and the useful signal strength A_{Rotor}. The thermal drift dependency of the output signals offset over these two parameters is illustrated in Figure 7 assuming

that the offset compensation is performed at 35 °C. Figure 7 reports the overall magnitude of the output signals offset thermal drift $\sqrt{O_{Sine}^2 + O_{Cosine}^2}$ as a percentage of the output signals modulation amplitude, thus covering both differential and single ended output modes.

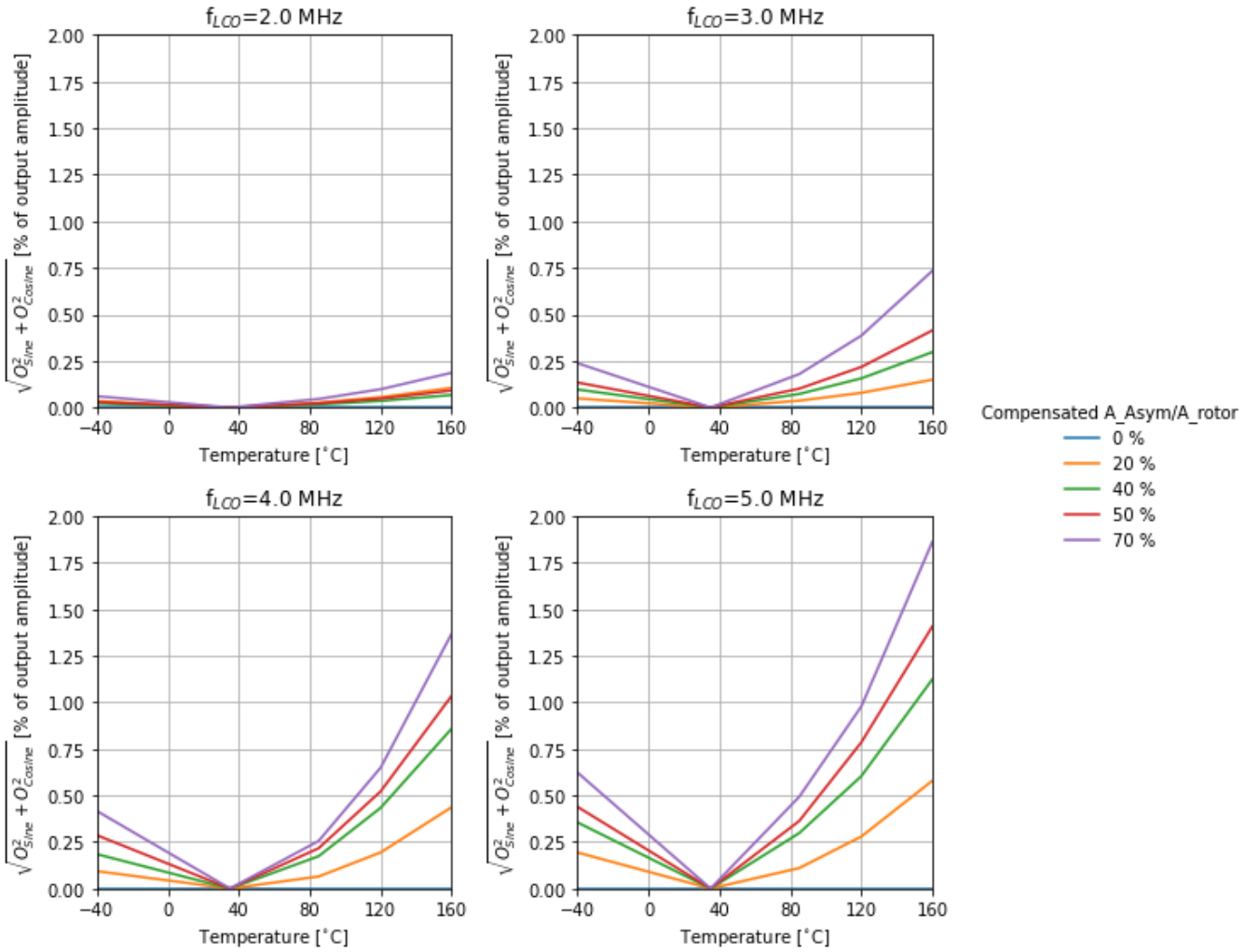


Figure 7 – Output signals offset thermal drift

9.6. Analog Sine/Cosine Outputs

The Sine/Cosine output signals are generated in the DSP, see Section 9.5, and buffered by two differential ABE output drivers. The MLX90517 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 calculate the angle by calculating the arctangent of the Sine/Cosine signals.

The differential Sine/Cosine output signals are illustrated in Figure 8. The relation between the input signals envelope modulation A_{Rotor} and the amplitude of the individual output signals SINP, SINN, COSP, COSN, VOUT_AMP, is given by:

$$V_{OUT_AMP} = G \cdot A_{Rotor} \cdot 2^{AGC_GAIN}$$

where G is the base gain factor specified in Table 11 and AGC_GAIN is the AGC gain step, refer to Section 9.4.2. Similarly, uncompensated input signals asymmetries translate in output signals offsets. To ensure ASIL C compliance and the highest angular accuracy it is recommended to permanently track the offset of the Sine/Cosine output signals.

When one of the MLX90517 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 12, 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.

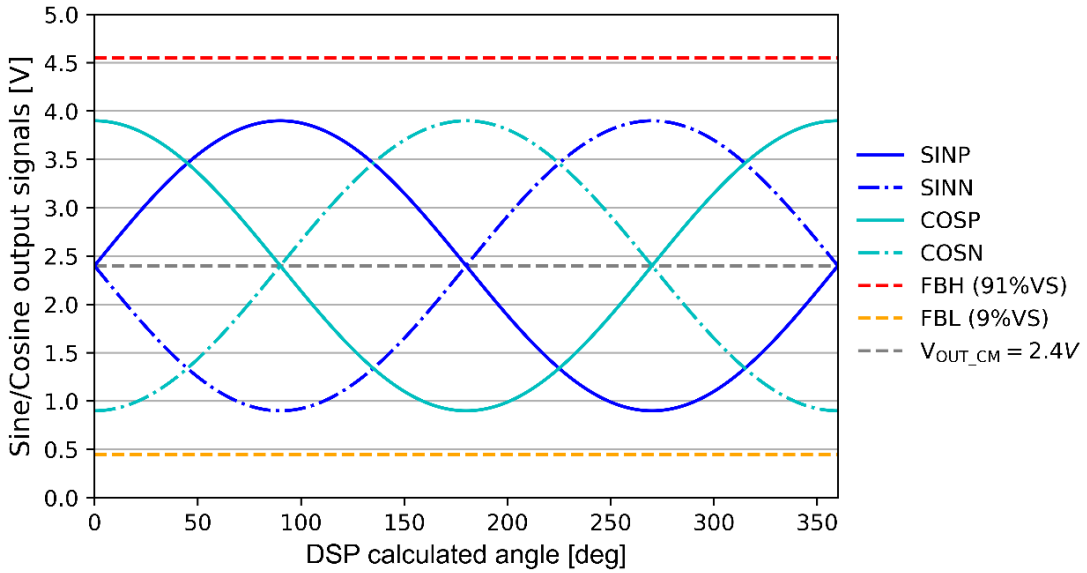


Figure 8 – Differential Sine/Cosine output signals

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

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Base gain factor	G		7.2			
Amplitude of SINP, SINN, COSP, COSN	V_{OUT_AMP}			1.3	V_p	For typical C_1 = 10 nF, C_3 = 4.7 nF (see Figure 12)
Output common mode (SINP+SINN)/2, (COSP+COSN)/2	V_{OUT_CM}	2.34	2.4	2.46	V	
Differential offset SINP-SINN, COSP-COSN[1]	V_{OUT_OFS}	-5		5	mV	
Output amplitude mismatch[1]	ΔV_{OUT_AMP}	-0.32		0.32	%	
SIN/COS orthogonally[1]			±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 11 – Sine/Cosine electrical specification

[1] Excluding contributions from INx input phases nonidealities like e.g. non-compensated asymmetries, amplitude mismatches or orthogonality errors of the INx signals.

[2] Specification is only valid when the MLX90517 and the ECU have the same supply voltage.

9.7. Supply System

The MLX90517 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 12.

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 MLX90517 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 1.04 1.41		V V V	CID = 0 (default) CID = 1 CID = 2 / 3

Table 12 – 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 MLX90517 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 MLX90517 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. MLX90517 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 13 – Functional safety specification

11.3. Safety Mechanism and Monitors

The MLX90517 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 MLX90517 that may lead to erroneous output signals. In Table 14 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 14 – 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 11. 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 12. 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 9. 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 15 – Recovery time

11.3.2. Supply System Monitoring

The MLX90517 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 9 describes the MLX90517 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 16 whereas the POR levels are described in Chapter 8, Table 5.

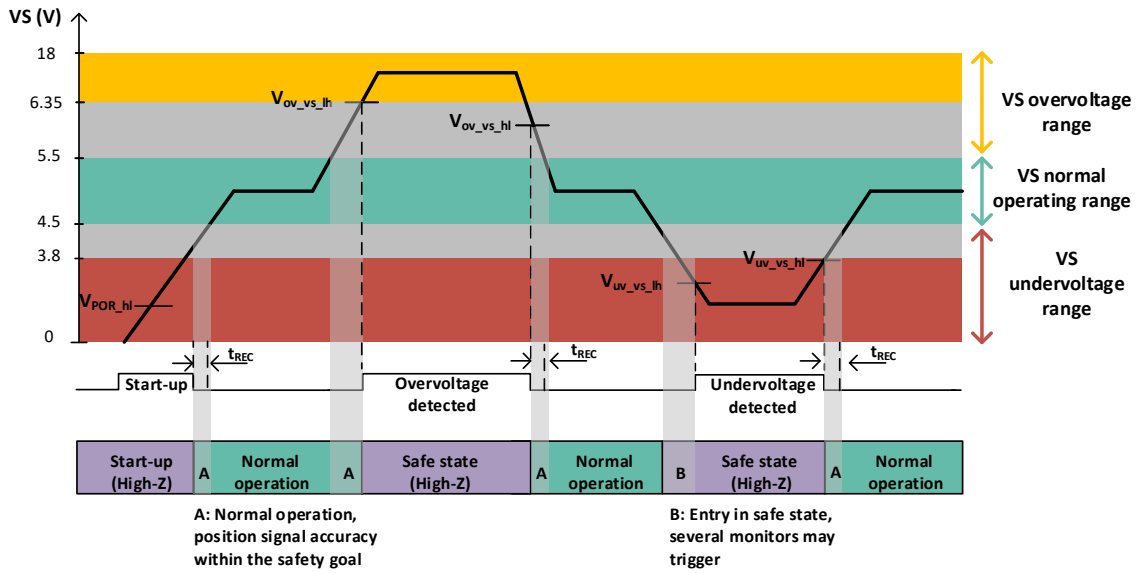


Figure 9 – MLX90517 operating modes

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
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 16 – 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 10 left and Figure 11, and one open or high ohmic connection monitor, see Figure 10 right.

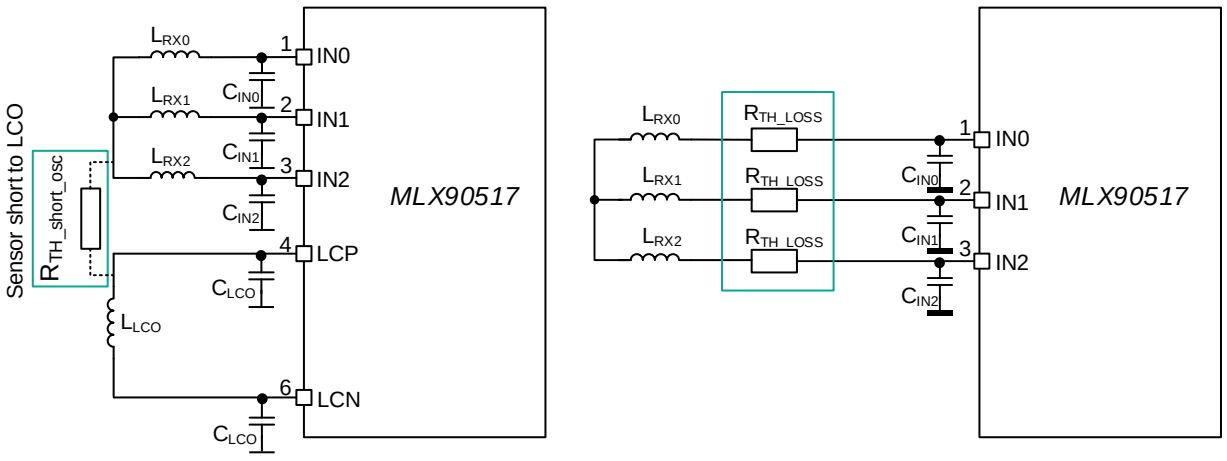


Figure 10 – Left: Rx to Tx coil short detection. Right: Sensor loss detection

The short detection monitor shown in Figure 11 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.

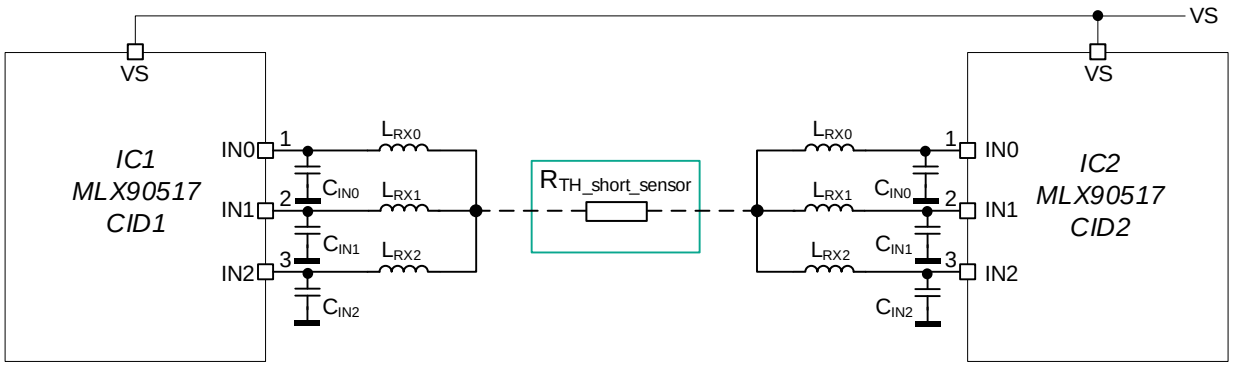


Figure 11 – Multi-Sensor Module - Sensor coil system #1 to sensor coil system #2 short detection

In Table 17 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 17 – Sensor monitor functions

12. Description of Memory and Registers

The MLX90517 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 MLX90517 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 18 – 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 19 – Device version

12.2. EEPROM Map – CEE_MAP

MLX90517 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
Reserved	256	2	R/W	0	Reserved; W: no effect
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
DC12_CONST	262	[15:0]	R/W	0	DC Offset compensation constant for channel D12. D12 = IN1 – IN2

CEE_MAP Field	Address	Bit	R/W	Default Value	Description
DC20_CONST	264	[15:0]	R/W	0	DC Offset compensation constant for channel D20. D20 = IN2 – IN0
Reserved	266	[15:13]	R/W	0	Reserved; W: no effect
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
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 20 – EEPROM map

13. Recommended Application Diagrams

Figure 12 and Figure 13 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.

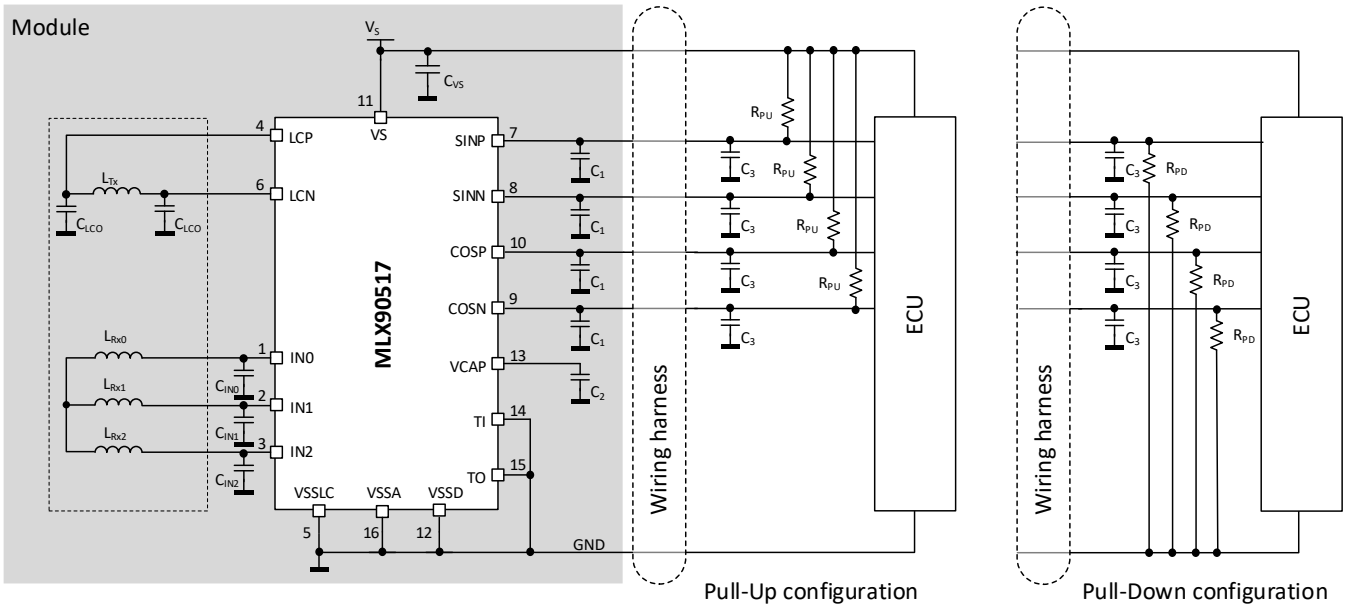


Figure 12 – Application circuit for differential Sine/Cosine outputs

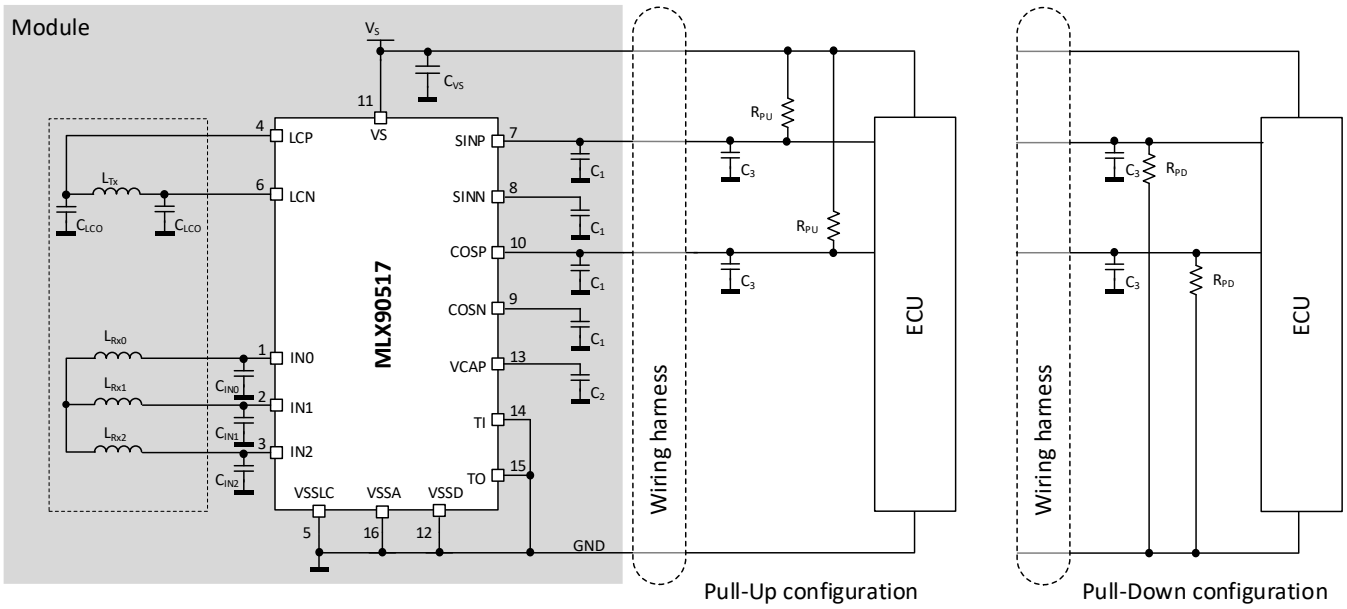


Figure 13 – Application circuit for single-ended Sine/Cosine outputs

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 21:

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	

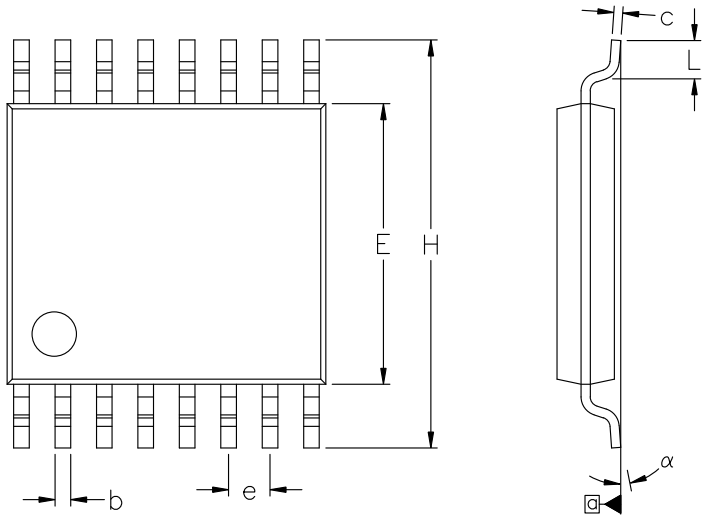
Table 21 – Application circuit components

[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.

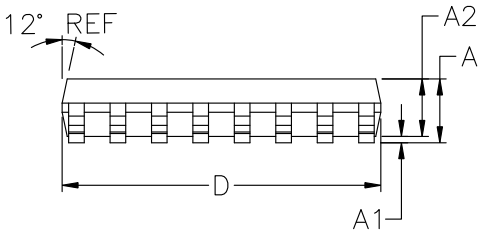
14. Package, IC handling and assembly

14.1. Package Information

TSSOP-16 Package Dimensions



SYMBOL	MINIMUM	MAXIMUM
A	---	1.10
A1	0.05	0.15
A2	0.85	0.95
D	4.90	5.10
E	4.30	4.50
H	6.40 REF	
L	0.45	0.75
b	0.19	0.30
c	0.09	0.20
e	0.65 BSC	
α	0°	8°



NOTE :

1. ALL DIMENSIONS IN MILLIMETERS (mm) UNLESS OTHERWISE STATED.
2. DIMENSION D DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS OF MAX 0.15 mm PER SIDE.
3. DIMENSION E DOES NOT INCLUDE INTERLEADS FLASH OR PROTRUSIONS OF MAX 0.25 mm PER SIDE.
4. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION OF MAX 0.08 mm.
5. LEAD TO LEAD COPLANARITY MAX 0.100 MILLIMETERS (mm) WITH RESPECT TO SEATING PLANE a.

Figure 14 – TSSOP16 package dimensions

14.2. Storage and handling of plastic encapsulated ICs

Plastic encapsulated ICs shall be stored and handled according to their MSL categorization level (specified in the packing label) as per J-STD-033.

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). The component assembly shall be handled in EPA (Electrostatic Protected Area) as per ANSI S20.20

For more information refer to Melexis *Guidelines for storage and handling of plastic encapsulated ICs* [1]

14.3. Assembly of encapsulated ICs

For Surface Mounted Devices (SMD, as defined according to JEDEC norms), the only applicable soldering method is reflow.

For Through Hole Devices (THD), the applicable soldering methods are reflow, wave, selective wave and robot point-to-point. THD lead pre-forming (cutting and/or bending) is applicable under strict compliance with Melexis *Guidelines for lead forming of SIP Hall Sensors* [1].

Melexis products soldering on PCB should be conducted according to the requirements of IPC/JEDEC and J-STD-001. Solder quality acceptance should follow the requirements of IPC-A-610.

For PCB-less assembly refer to the relevant application notes [1] or contact Melexis.

Electrical resistance welding or laser welding can be applied to Melexis products in THD and specific PCB-less packages following the *Guidelines for welding of PCB-less devices*[1].

Environmental protection of customer assembly with Melexis products for harsh media application, is applicable by means of coating, potting or overmolding considering restrictions listed in the relevant application notes [1]

For other specific process, contact Melexis via www.melexis.com/technical-inquiry

14.4. Environment and sustainability

Melexis is contributing to global environmental conservation by promoting non-hazardous solutions. For more information on our environmental policy and declarations (RoHS, REACH…) visit www.melexis.com/environmental-forms-and-declarations

[1] www.melexis.com/ic-handling-and-assembly

15. Revision History Table

15/12/2022 (003)	Initial datasheet release for website
14/08/2025 (004)	Official Release, formatting changes Sections 8, 14, 9.5.1 updated

Table 22 – Revision history table

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