General description

Features & benefits

- Arcminaxis™ Technology combining Multi-axis sensing with Vernier Technology.
- Reduces the complexity and effort involved in assembling robotic joints
- Pitch-independent, one IC fits various magnets
- Large air gap sensor to magnet (1.5 mm nominal)
- Generous magnet-sensor placement tolerance of ±0.5 mm
- Resolution up to 18 bits
- Triaxis® Hall Technology
- Communication via fast SPI interface
- TSSOP-16 Sensor Package RoHS compliant
- 3.3V supply
- Temperature range -20°C .. 85°C

Figure 1. Sensor Chip in TSSOP-16 package

Application examples

- Absolute Rotary Position Sensor
- High Accuracy Encoder
  - Robotic Joint Encoder
  - E-Mobility
  - Industrial Motors

Description

The MLX90384 comes as a four-component set for your high accuracy magnetic encoder solution:

a) a sensor chip with two monolithic magnetic position sensor ICs, each consisting of a Triaxis® Hall magnetic front end, analog-to-digital converter, hardware for high-speed signal conditioning, and a 10MHz high-speed SPI interface. The ICs are both configured to be sensitive to a first magnetic flux density component parallel with the chip plane and to a second component perpendicular to the chip.

b) a Vernier type magnet, with two tracks of eight and seven pole pairs. The MLX90384 sensor chip measures the axial and tangential magnetic components of both tracks and transmits this information to a microcontroller which in turn generates the accurate angular position and speed as well as the counted turn out of this information.

c) a precompiled software package for an STM32 microcontroller to calibrate and operate the system

d) a complete reference design to build your own encoder solution based on a), b) and c)

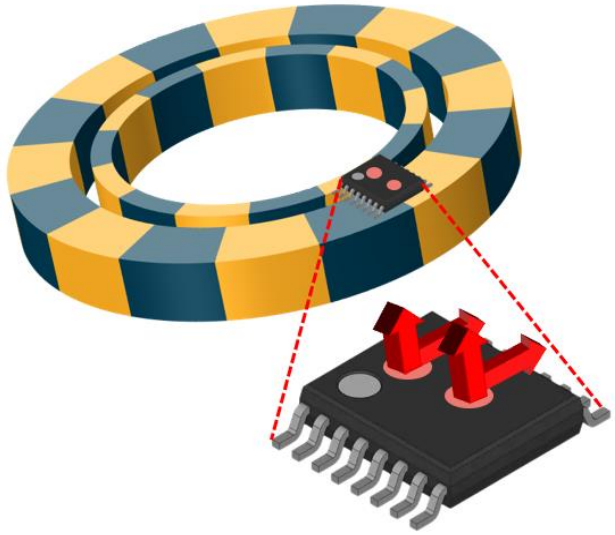


Figure 2. The Arcminaxis™ Vernier sensing concept combines two sensing spots with orthogonal components

Ordering Information

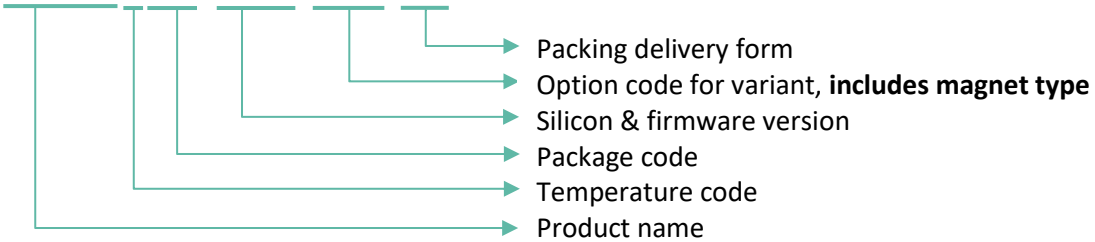
For the MLX90384 encoder system the MLX90384 sensor chip must be ordered together with one of the magnets as one package to guarantee the correct operation in the application.

The Software for the MLX90384 encoder system is provided by Melexis and must be programmed into the used microcontroller.

Order Code	Temperature range (°C)	Package	Packing	Definition
MLX90384SGO-0AA-001-RE	-20 to 85	TSSOP-16	Reel	MLX90384 Sensor chip with magnet 1
MLX90384SGO-0AA-002-RE	-20 to 85	TSSOP-16	Reel	MLX90384 Sensor chip with magnet 2

Table 1: *MLX90384 Order Codes*

MLX90384SGO-0AA-001-RE



Temperature Code:	**S**: -20 °C to 85 °C
Package Code:	**GO**: TSSOP-16 package (Dual-Die side-by-side)
Option Code - Chip revision	**0AA**: **Chip Revision** ▪ **0AA**: MLX90384 production version
Option Code - Application	**001**: **Application - Magnetic configuration** ▪ **001: Magnet 001 consisting of a magnet ring set** ▪ **002: Magnet 002 for 6mm shaft mounting**
Packing Form:	**RE**: Tape & Reel ▪ 4500 pcs/reel for TSSOP-16 package (Dual-Die), GO code

Table 2: *Ordering Codes Information*

1 MLX90384 Magnet

1.1 Magnet type

The MLX90384 magnet to be used in the MLX90384 encoder system is a Vernier type magnet with two tracks. It is made of ferrite material with a temperature coefficient of about -2000ppm/K for the magnetic field strength.
Melexis offers the magnet in the two following versions:

Magnet Type	Description
MLXMAGNT-VER-001-TR	Magnet ring set to be mounted into a holder (maximum flexibility)
MLXMAGNT-VER-002-TR	Overmolded magnet with brass bushing for direct mounting on a ⌀6mm shaft

Table 3: *MLX90384 Magnet ordering codes*

1.2 Magnet Specification

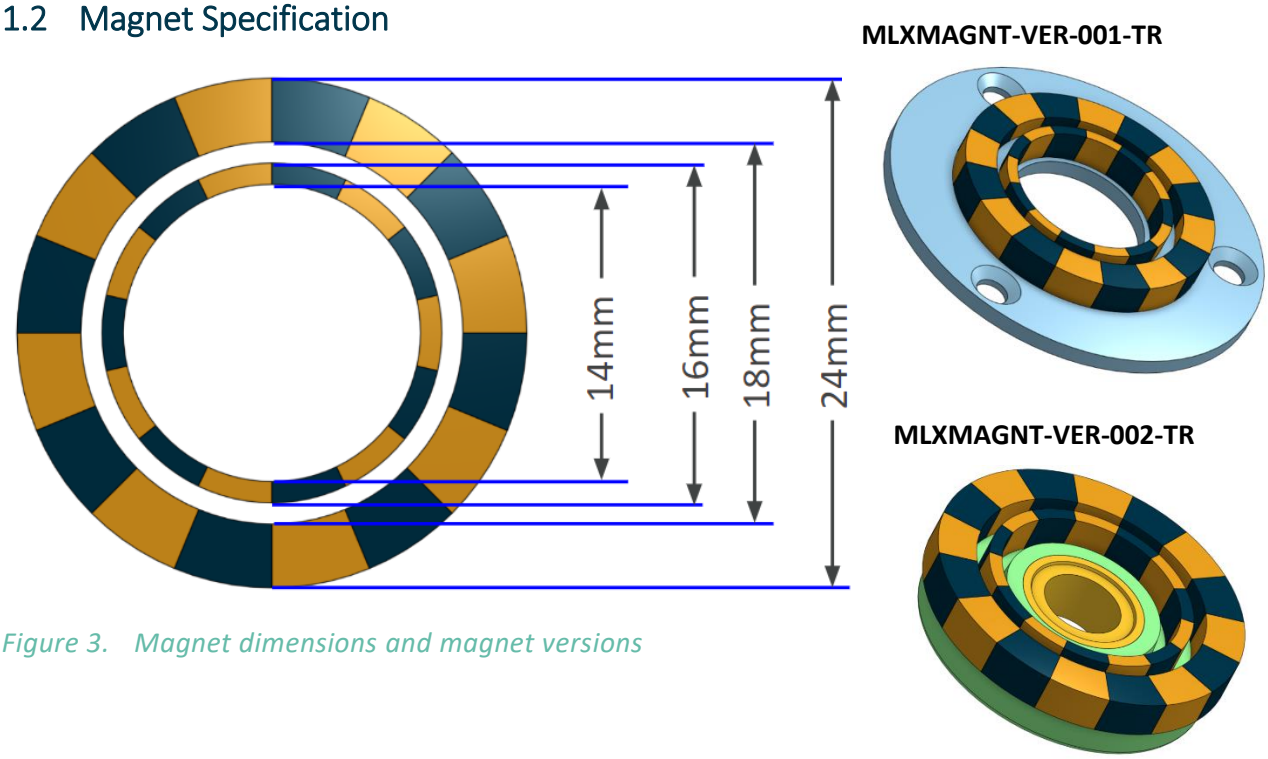


Figure 3. Magnet dimensions and magnet versions

The top right picture shows a mounting of **MLXMAGNT-VER-001-TR** onto a custom support (not provided) allowing for maximum inner clearance, whereas the bottom right picture shows the **MLXMAGNT-VER-002-TR** version with overmolding and an inner brass bushing for press-fit mounting on a ⌀6mm shaft.
Due to their difference in pole-pair count, the Master and Nonius magnets are manufactured separately and then assembled to form the Vernier magnet for the 90384 encoder system.

1.3 Magnet Dimensions

Magnet #	Inner diameter ID [mm]*	Outer diameter OD [mm]*	Thickness [mm]*	Npp Master track	Npp Nonius track
MLXMAGNT-VER-001-TR	12	24	3	8	7
MLXMAGNT-VER-002-TR	6	26	5	8	7

*for tolerances, see detailed mechanical drawings

Table 4: *Magnet Dimensions*

1.4 Detailed mechanical drawing of MLXMAGNT-VER-001-TR

This magnet is delivered as a 2-part ring set. The two magnets are positioned with each other by a protrusion on the master magnet and a corresponding notch in the nonius magnet, indicated as a and b in the following drawings. The inverse conical pillars are opposite to the magnetized surface and can be used for clip-mounting the magnet into a holder. By designing a custom holder the user has the highest flexibility for his own encoder design. For instructions how to assemble the magnet with the sensor chip, please refer to section 4.2.1

1.4.1 Part 1: Master magnet

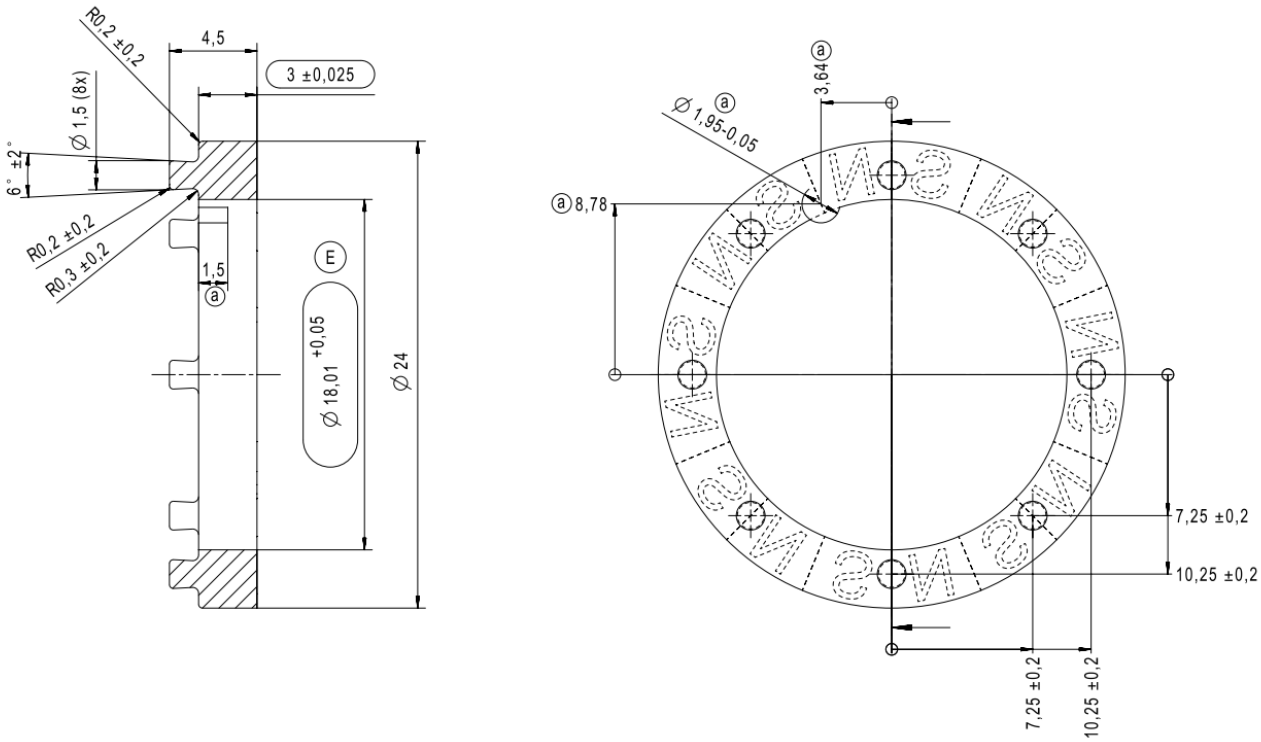


Figure 4. Dimensions of the Master magnet ring of MLXMAGNT-VER-001-TR

1.4.2 Part 2: Nonius magnet

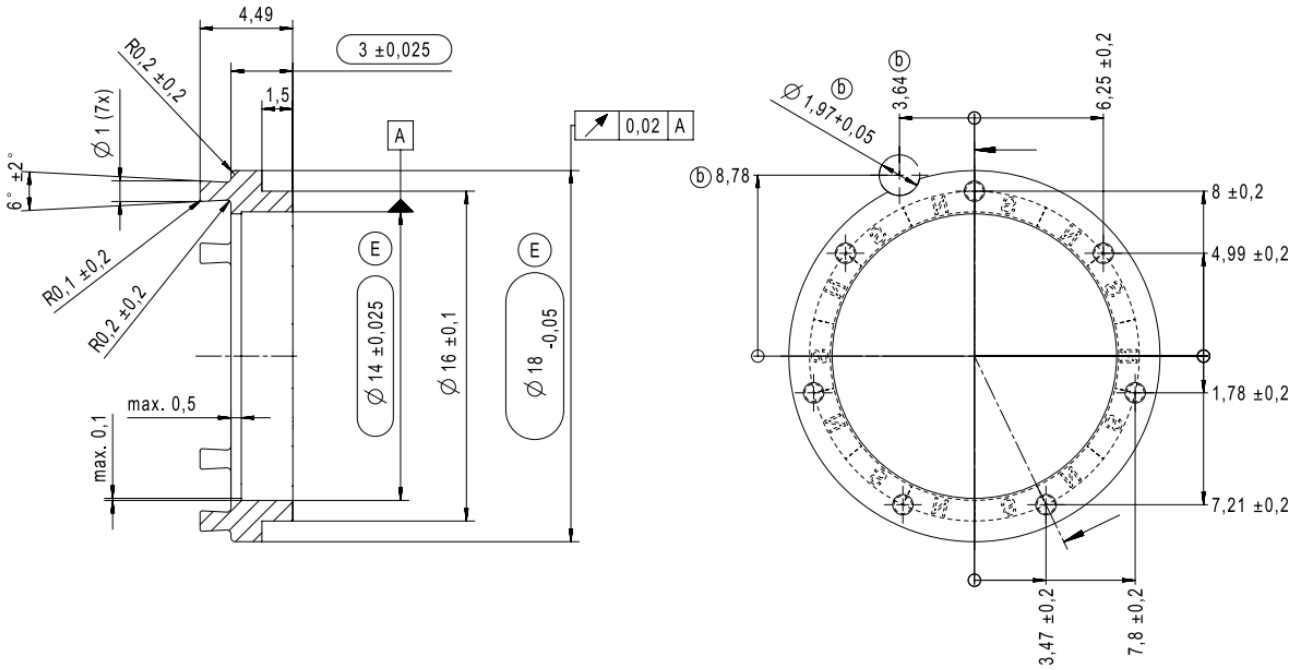


Figure 5. Dimensions of the Nonius magnet ring of MLXMAGNT-VER-001-TR

1.5 Detailed mechanical drawing of MLXMAGNT-VER-002-TR

This magnet contains a brass bushing in the center and is designed for press-fit mounting on a 6 mm shaft.

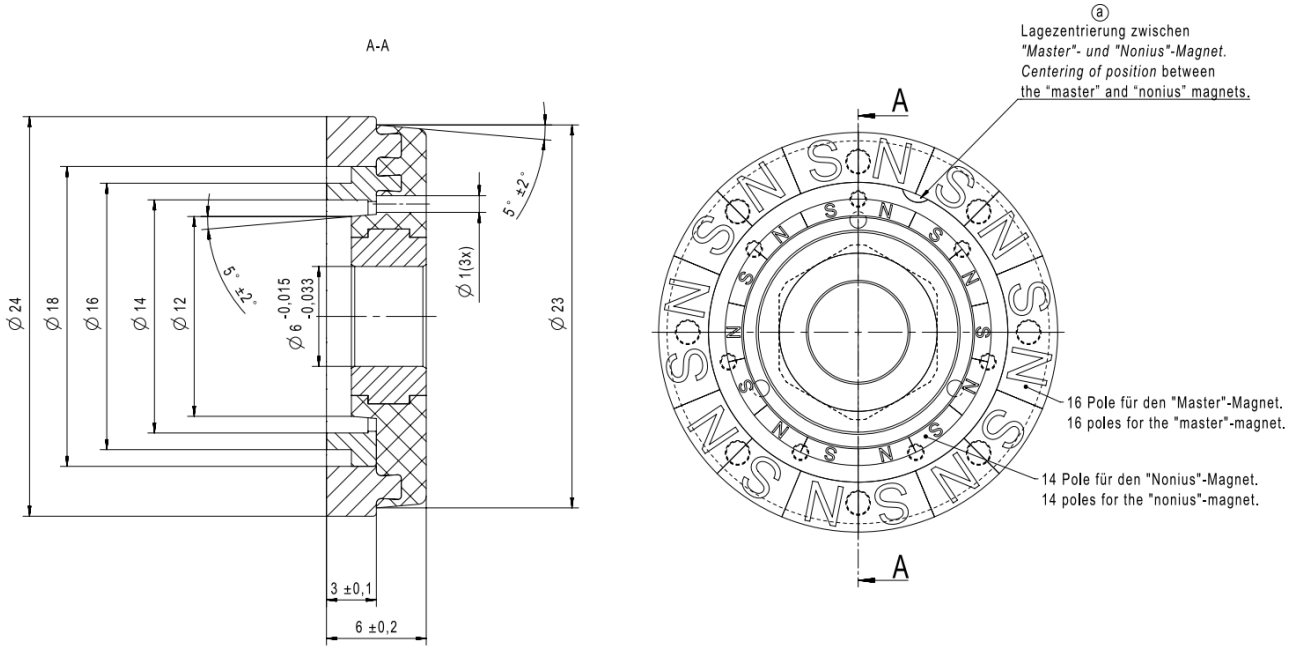


Figure 6. Dimensions of MLXMAGNT-VER-002-TR

1.6 Magnetic Field Specification

The table below lists the approximate field amplitudes seen by the two sensing spots in nominal position (see Table 12:) and 25degC with respect to the full magnet.

	Master Sensing Spot	Nonius Sensing Spot
Axial Field Amplitude Bz	40 mT	16 mT
Tangential Field Amplitude Bx	33 mT	25 mT
Radial field Amplitude By	0 .. 5 mT	0..30 mT
Amplitude drift 35°C to -20°C	+10%	
Amplitude drift 35°C to +85°C	-10%	

Table 5: *Magnetic flux density at sensor for nominal assembly position*

2 MLX90384 Sensor Chip

The MLX90384 sensor chip is a high-speed magnetic position sensor composed of two silicon circuits, each with a two-axis sensing spots for measuring axial and tangential field components representing the Sine and a Cosine signals of a two-track Vernier magnet.

As shown in the block diagram Figure 7, each of the sensing channels has its own Triaxis Hall sensor frontend, amplification chain, ADC and output stages.

2.1 Functional Block Diagram

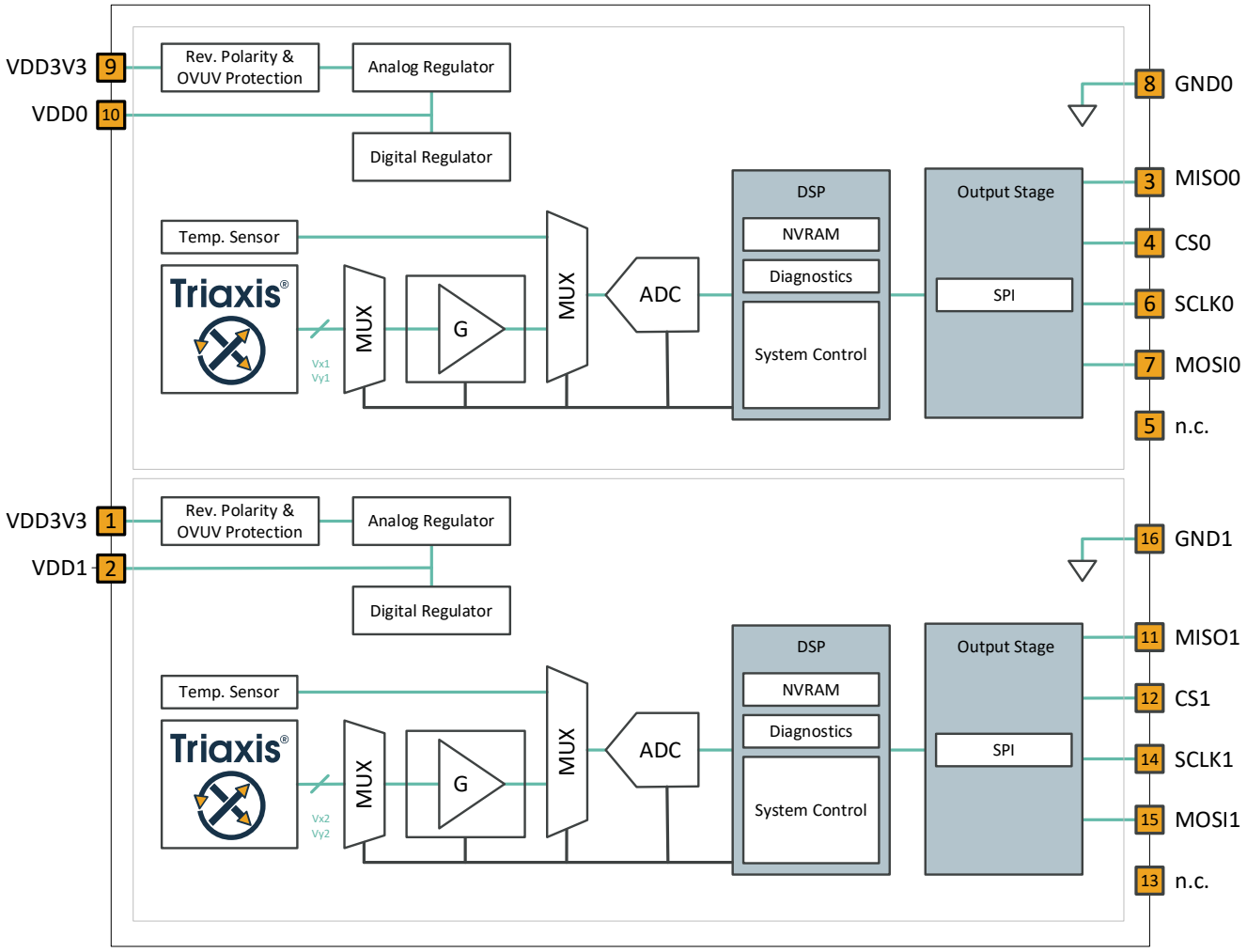


Figure 7. TSSOP-16 Dual die block diagram

The distance of the two sensing spots inside the package is 1.9mm so that for nominal position, the master sensor is positioned above the center of the master track and the nonius sensor right between master and nonius track.

2.2 TSSOP-16 package with sensing spots

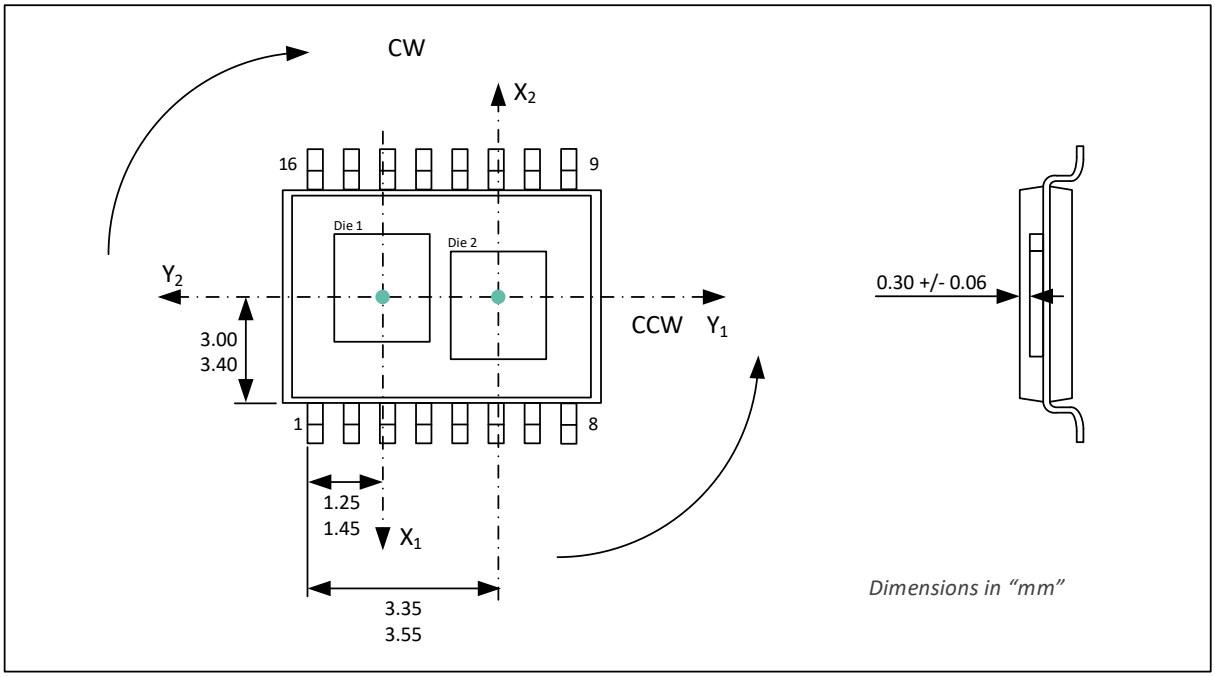


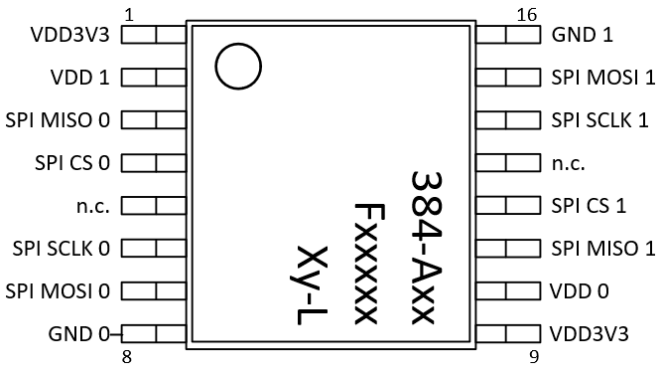
Figure 8. Indication of the locations of the two sensitivity spots for nonius track (die 1) and master track (die 2)

To build an encoder with the MLX90384 magnet and the MLX90384 sensor, additional components including a microcontroller with embedded software (delivered by Melexis) are required. The Microcontroller is communicating via the two high-speed SPI interfaces with the two sensing channels.

The complete reference design is provided by the MLX90384 reference design document.

2.3 Pin description for TSSOP-16 package

For optimal EMC and ESD behavior, connect the unused pins to 'Gnd'.



Pin #	Designation		Pin#	Designation
1	VDD3V3		16	GND1
2	VDD1		15	SPI MOSI1
3	SPI MISO0		14	SPI SCLK1
4	SPI CS0		13	not connected
5	not connected		12	SPI CS1
6	SPI SCLK0		11	SPI MISO1
7	SPI MOSI0		10	VDD0
8	GND0		9	VDD3V3

Table 6: *TSSOP-16 package pinout*

2.4 Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit	Condition
Supply Voltage at VDD Pin	V_{DD}	-0.3	6.0	V	
Supply Voltage at VDD3V3 Pin	V_{DD}	-0.3	4.0	V	
I/O Pin Voltage	V_{PIN}	-0.3	V_{DD}+0.3	V	
ESD CDM Robustness	V_{CDM}	-500	500	V	All pins, according to AEC-Q100-011
		-750	750	V	Package corner pins
ESD HBM Robustness	V_{HBM}	-2.0	2.0	kV	
Operating Temperature	T_{AMB}	-40.0	150.0	°C	
Junction Temperature	T_J		+175	°C	
Storage Temperature	T_{st}	-55	+170	°C	
Magnetic Flux Density	B_{max}	-1	1	T	

Table 7: *Absolute Maximum Ratings*

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

2.5 Electrical operating conditions & specifications

Unless otherwise specified, the electrical specifications of the MLX90384 sensor chip are valid for a temperature range of [-20, 85] °C and specified nominal supply voltage ranges.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Supply Voltage	V_{DD}	3	3.3	3.6	V	Pins VDD3V3 & VDD0/VDD1 shorted
Supply tolerance	ΔV_{DD}	-5		+5	% V_{DD}	
Supply Current*	I_{DD}			20.0	mA	excluding output I/F

*the supply current is for the MLX90384 sensor chip without the additional microcontroller required for the encoder system

Table 8: *Electrical operating conditions in 3.3 V operating mode*

2.5.1 Input channel specification

The specification for the input channels of the MLX90384 sensor chip are as follows:

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Input Low Voltage Detection Level		25.0	35.0	42.0	% V_{DD}	
Input High Voltage Detection Level		52.0	60.0	75.0	% V_{DD}	
Input Hysteresis Level		18.0	25.0	42.0	% V_{DD}	
Input Voltage Range		0		100	% V_{DD}	

Table 9: *Input channel specifications*

2.5.2 Output channel specification

The output driver for the MISO output pin is configured by default in push/pull mode with the specifications described below. Each output pin voltage ranges from 0 V to VDD external supply. The rise and fall time specifications are listed in the following table.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Rise/Fall Time Push-Pull Mode	$T_{rise\_fall\_pp}$	3.3		15.0	ns	LH or HL from 75 % VDD to 25 % VDD for 50 pF load in 5 V mode
		4.0		18.0	ns	LH or HL from 75 % VDD to 25 % VDD for 50 pF load in 3.3 V mode

Table 10: *Interface output timing specifications for 50pF load*

2.5.3 SPI Clock Frequency Specifications

This section is describing the SPI clock frequency used between the STM32 microcontroller and the MLX90384 sensor chip. The nominal value is the frequency used by the software of the STM32 microcontroller.

This communication is handled by the STM32 micro controller indicated in the reference design.

The capacitance C_L refers to the max. load on the signal wire.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
SPI Clock Frequency	f_{SCLK}		6.3		MHz	$C_L \leq 50$ pF, $f_{ac} \geq 2f_{SCLK}$

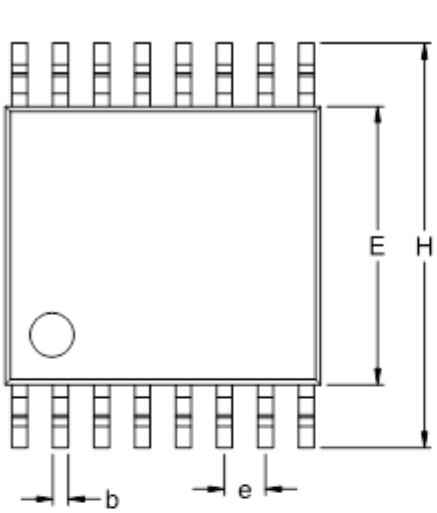
Table 11: *SPI Timing Specification*

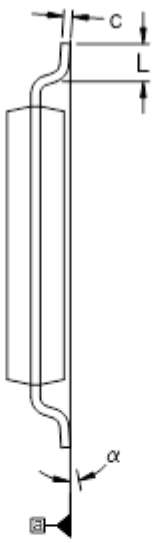
3 Package, IC handling and assembly

3.1 Package information for TSSOP-16 package

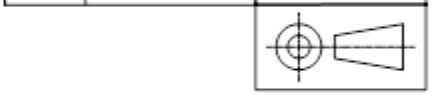
3.1.1 Package dimensions

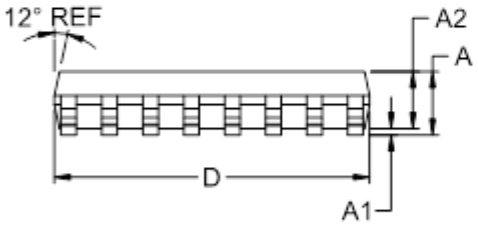
The following drawing indicates the dimensions of the MLX90384 Sensor package





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





NOTE :

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

Figure 9. MLX90384 TSSOP-16 package dimensions

3.1.2 TSSOP-16 package pinout and package marking

The drawing below shows the package pinout and

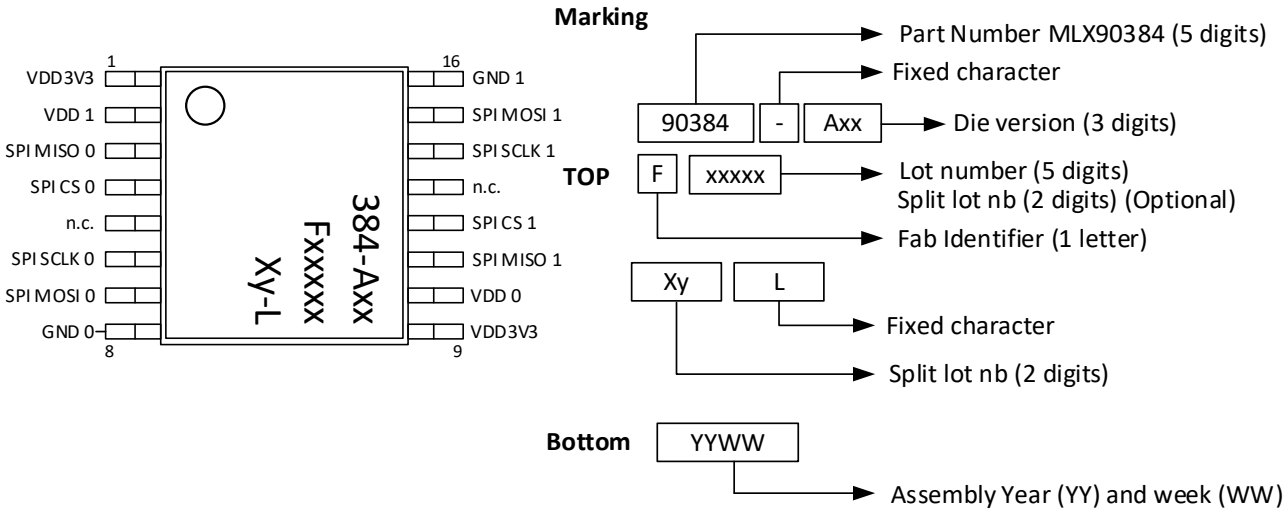


Figure 10. The package indicates the part and lot # for full traceability and identification

3.2 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]

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

4 MLX90384 Encoder System

The MLX90384 magnet and sensor chip are key components to realize a high accuracy/resolution encoder system with a nominal 1.5mm airgap between sensor and magnet. This section illustrates such a possible system by the Melexis reference design.

4.1 System Reference Design

The encoder reference design shown in Figure 11 uses the three elements delivered by Melexis: The magnet, the sensor chip and the software for the microcontroller. All other components must be provided by the customer. A detailed description of the reference design including full PCB schematics and component list is provided by the MLX90384 Evaluation Kit Manual.

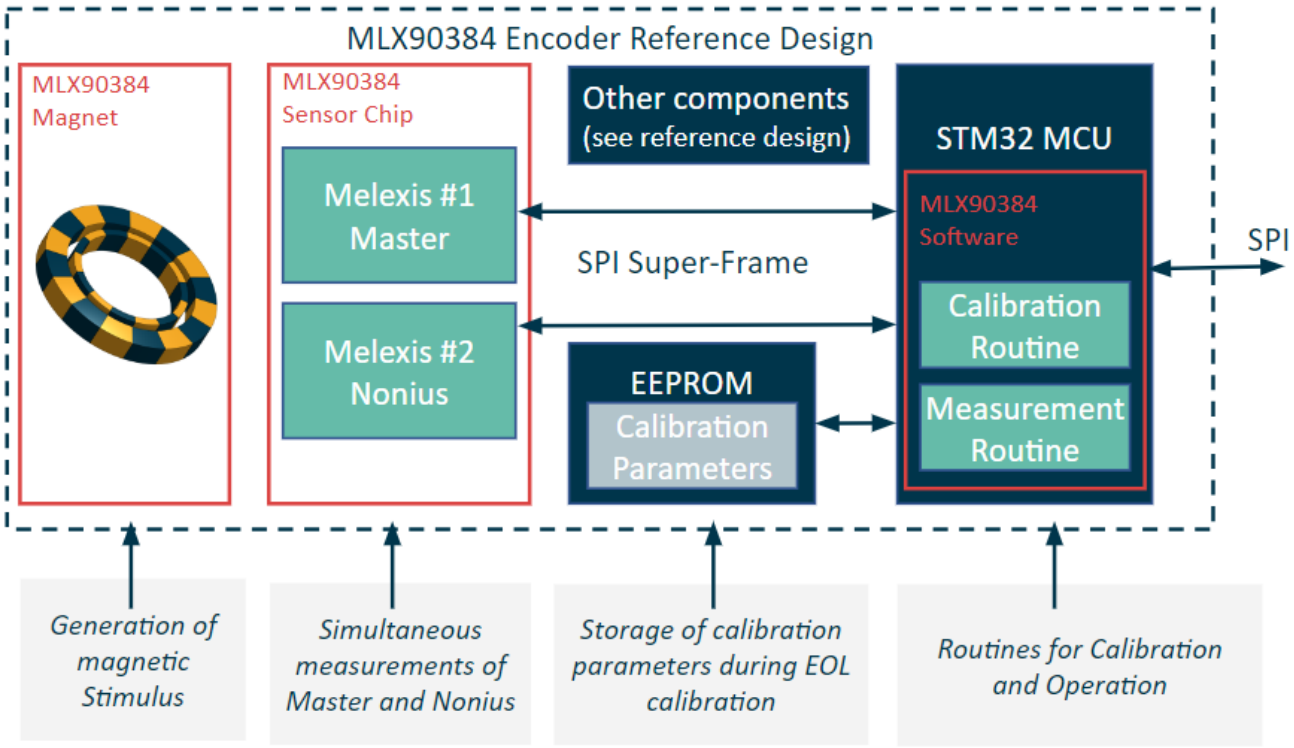


Figure 11. Encoder Reference Design with red marked items delivered by Melexis as product MLX90384

Besides the accuracy of the encoder system, which depends substantially on the calibration process performed in the application and which can be 0.1degrees or smaller, many applications also require very high angular resolution.

Following the reference design a resolution of up to 18 bits with a maximum rotation speed for the magnet of 6000rpm can be reached.

4.2 System Specification according to Reference Design

4.2.1 Assembly Specification

The installation of the encoder system is done by mounting the magnet on a rotating shaft and by mounting the sensor module (readhead) at the right position with respect to the magnet and connecting it the the SPI host controller.

Due to the Melexis Triaxis technology, the requirements for the initial position of the sensor module versus the magnet are substantially relaxed compared with most other magnetic encoder systems on the market.

The picture below shows the three orthogonal dimensions to be respected when placing the sensor chip with respect to the magnet: the radial position r_s, the tangential position t_s and the airgap z_s.

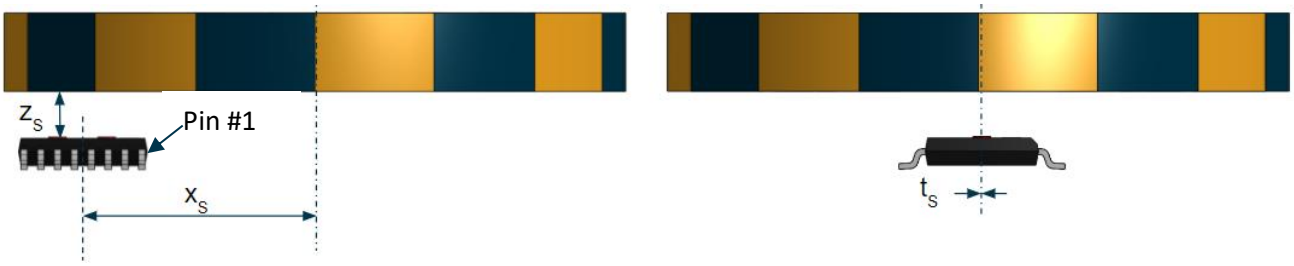


Figure 12. Assembly position of magnet and sensor chip. The chip is mounted with Pins #1 and 16 towards the ring center.

For each of those dimensions a tolerance of +/-0.5mm must be respected, as indicated in the table below.

Parameter	Description	Min.	Nom.	Max.	Unit
Sensor radial position (r_S)	The position of the center of the sensor chip as distance from the magnet center.	9.0	9.5	10.0	mm
Sensor tangential position (t_S)	The position of the center of the sensor as distance from the ideal tangential position.	-0.5	0	0.5	mm
Air gap (z_s)	Distance between the top of the package and the magnet.	1.0	1.5	2.0	mm

Table 12: *Assembly Position and Tolerances*

The assembly specifications given in this table guarantee

a) the magnetic operating range for the sensor chip over the full temperature range from -20degC to +85degC.
b) the system calibration with the software package running on the microcontroller

4.2.2 System Angular Speed

The encoder system works at angular speed between standstill and 10’000 rpm.

The system update rate and intrinsic delay by the integrated signal and data processing are as follows

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Angle update interval	t_{update}		40		us	without window filtering
Signal and data processing time	$t_{process}$		60		us	Magnetic angle to SPI output

Table 1: *System Speed Specifications*

When the window average filter is used, the update interval remains the same, but due to the averaging, the history of the magnetic angle increases linearly with the number of averaged samples.

4.2.3 System Angular Resolution

The following graph compares the typically measured angular resolution versus the theoretical one. The values are given in bit RMS versus the programmed sample integration at room temperature and for nominal airgap. For each doubling of the averaged samples, the resolution increases by half a bit.

With an integration step of 20µs and the number of integrated samples n_{int} the integration time t_{int} is calculated by $t_{int} = n_{int} * 20µs$. For very fast readings without any sample integration the resolution is about 15bit whereas for about 1.5ms integration time a resolution of 18bits is reached.

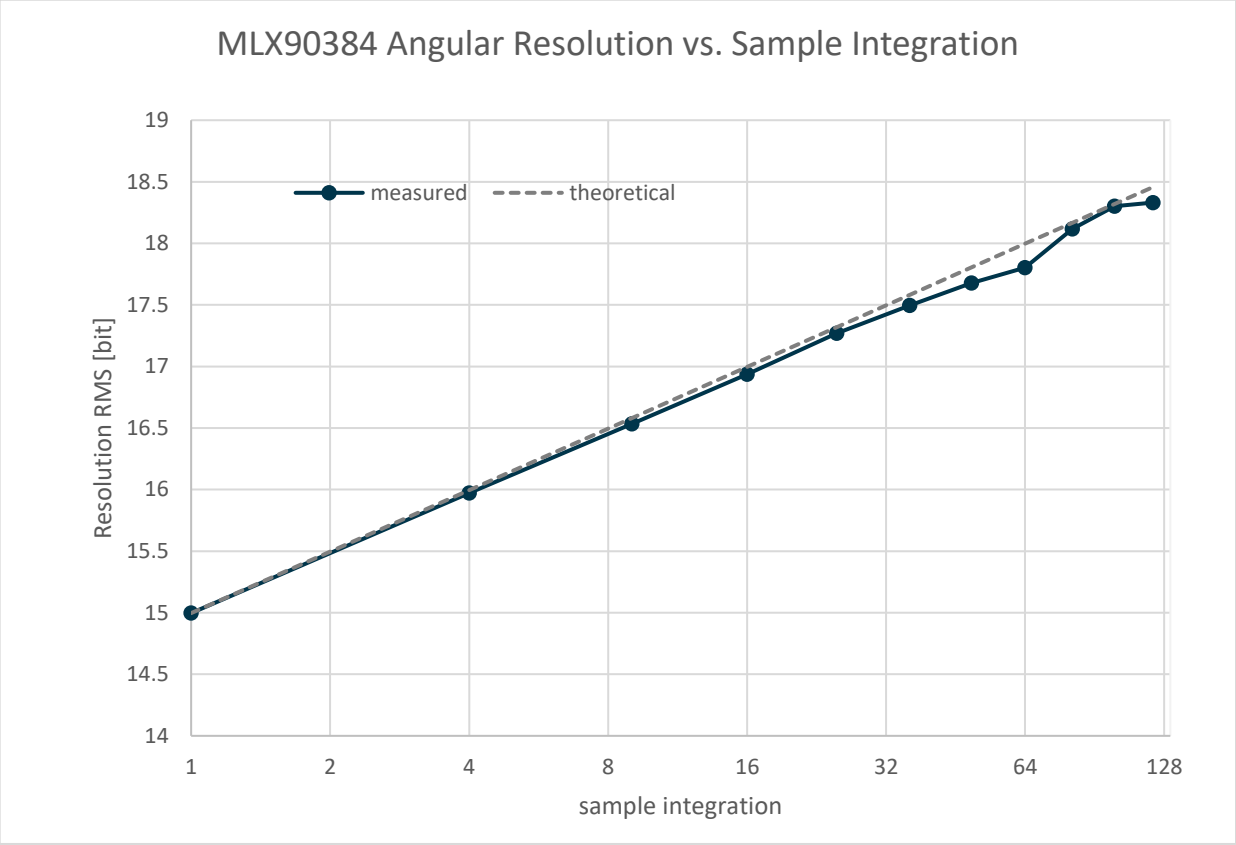


Figure 13. Angular Resolution vs. Integration time(programmable) for the MLX90384 encoder system

4.3 Encoder System Calibration

To deliver accurate angle and speed information, the encoder system must be calibrated by the customer after assembly.

Please refer to **MLX90384 Application Note** for details about the calibration.

5 Standard Information

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

For further details about test method references and for compliance verification of selected soldering method for product integration, Melexis recommends reviewing on our web site the General Guidelines soldering recommendation. For all soldering technologies deviating from the one mentioned in above document (regarding peak temperature, temperature gradient, temperature profile, etc.), additional classification and qualification tests have to be agreed upon with Melexis.

For package technology embedding trim and form post-delivery capability, Melexis recommends to consult the dedicated trim & form recommendation application note: lead trimming and forming recommendations

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

6 Revision history

Revision	Date	Change history
1.0	18-Oct-2024	Initial Version

7 Disclaimer

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3. defense related products, or other material for military use or for law enforcement;
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