XENSIV™ TMR-based magnetic angle sensor

AEC Qualified

RoHS

ISO 26262 compliant

Features

- Tunneling Magneto Resistance (TMR)-based principle
- 360° angle measurement
- Large output signals of up to 0.33 V/V for direct microcontroller connection
- Discrete bridge with differential sine and cosine output
- Ratiometric output signals
- Two different pin-outs:
  - S0002: de-coupled P/N-bridges for redundant external angle calculation and highest diagnostic coverage
  - S0003: SIN/COS bridge design
- ISO 26262 Safety Element out of Context for safety requirements up to ASIL D (requires use of external safety mechanisms)
- Safety documentation available on request
- ESD > 2 kV (HBM)
- RoHS compliant and halogen free package

Potential applications

The TLE5502 TMR-based angle sensor is designed for angular position sensing in automotive applications with focus on steering angle sensing and BLDC motor commutation.

Product validation

Qualified for automotive applications. Product validation according to AEC-Q100, grade 0.

Description

The TLE5502 is a 360° TMR-based angle sensor that detects the orientation of a magnetic field. This is achieved by measuring sine and cosine angle components with Tunneling Magneto Resistance (TMR) elements. These raw signals (sine and cosine) are provided as a differential output signal and can directly be further processed within a microcontroller. The large output voltage of the bridge renders any further signal amplification unnecessary.

Following derivatives are available:

- TLE5502D S0002 is a dual-die version which has two independent V_{DD} and GND pins, for the P- and N-bridge respectively. In this way, two completely independent bridge signals are generated which can be used in an advanced safety concept to perform a cross-check of the P- and N- signals and achieve high diagnostic coverage for any sensor malfunction
- TLE5502D S0003 is a dual-die with one supply pin for the sine bridge (generating a differential signal SIN_P and SIN_N) and a supply pin for the cosine bridge (generating COS_P and COS_N)

Product type	Package	Marking	Ordering code
TLE5502D S0002	PG-VQFN-16	xyS22	SP005446220
TLE5502D S0003	PG-VQFN-16	xyS23	SP005446223

xy: two-digit consecutive number

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1 Block diagram

The TLE5502D consists of two chips (dual-die), each of them has 8 TMR resistors, which are arranged in 2 Wheatstone bridges. The resistance of these resistors depends on the direction of the external magnetic field. Each die provides a differential output signal, X (cosine) and Y (sine), which can further be processed for angle calculation.

Two different versions, S0002 and S0003, are available.

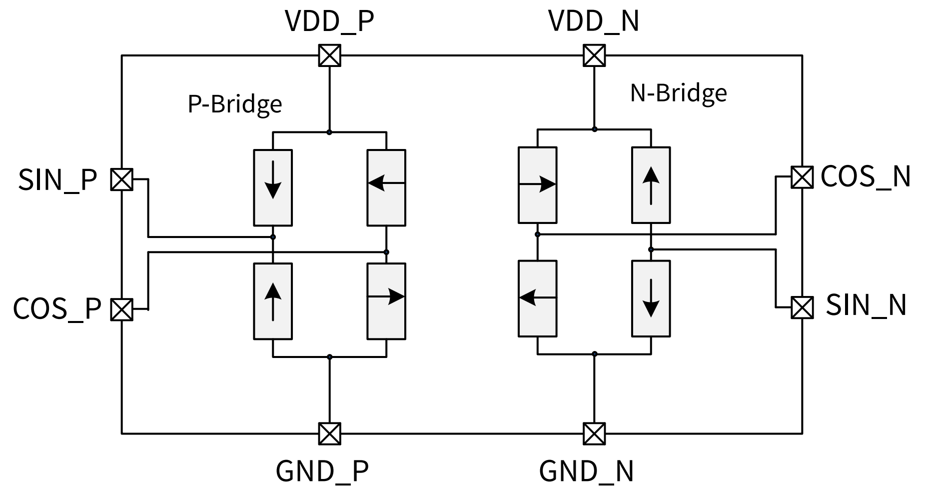

Figure 1 **Bridge layout of one chip of TLE5502D S0002. The dual-die contains two of these chips**

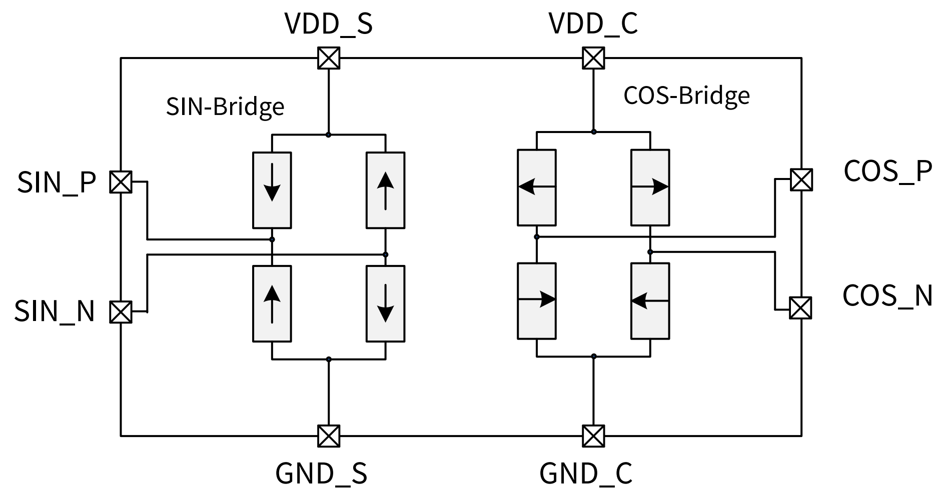

Figure 2 **Bridge layout of one chip of TLE5502D S0003. The dual-die contains two of these chips**

The rotation direction is defined as:

Counter-clockwise (CCW) is an increasing angle value.

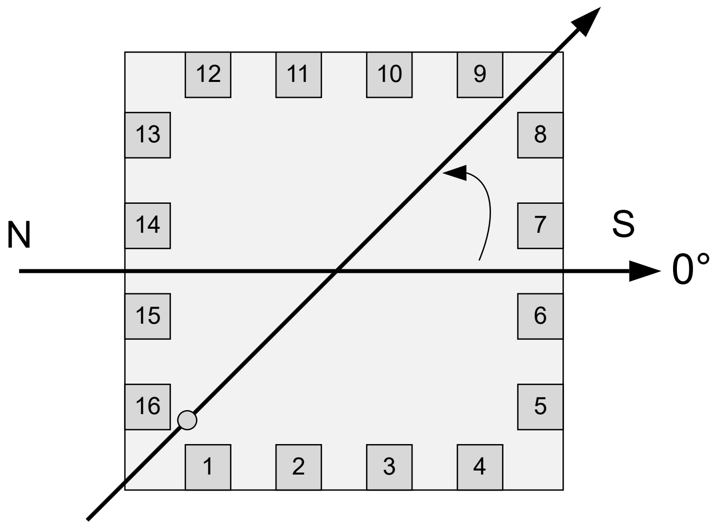

Figure 3 **Definition of zero-angle and rotation direction (top view)**

2 Pin configuration

The pin-out of the device is shown below.

It is different for the TLE5502D S0002 and TLE5502D S0003 version.

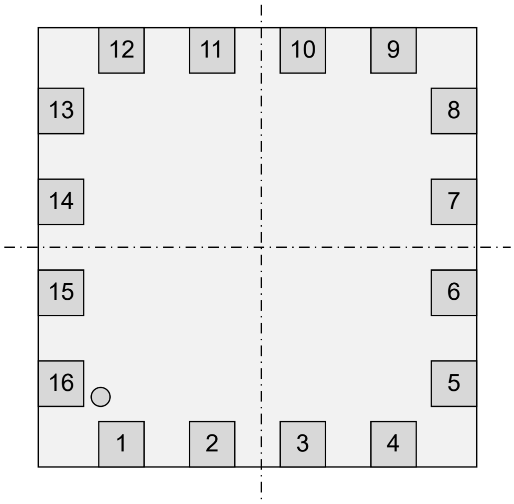

Figure 4 **Pin-out PG-VQFN-16 package (top view)**

Table 1 **TLE5502D S0002, dual-die**

Pin	Signal	Function
1	SIN_P_1	SIN_P output of die 1
2	GND_P_1	Ground for P-bridge of die 1
3	COS_P_2	COS_P output of die 2
4	VDD_P_2	Supply for P-bridge of die 2
5	SIN_P_2	SIN_P output of die 2
6	GND_P_2	Ground for P-bridge of die 2
7	SIN_N_2	SIN_N output of die 2
8	VDD_N_2	Supply for N-bridge of die 2
9	COS_N_2	COS_N output of die 2
10	GND_N_2	Ground for N-bridge of die 2
11	SIN_N_1	SIN_N output of die 1
12	VDD_N_1	Supply for N-bridge of die 1
13	COS_N_1	COS_N output of die 1
14	GND_N_1	Ground for N-bridge of die 1
15	COS_P_1	COS_P output of die 1
16	VDD_P_1	Supply for P-bridge of die 1

Table 2 **TLE5502D S0003, dual-die**

Pin	Signal	Function
1	SIN_P_1	SIN_P output of die 1
2	GND_S_1	Ground for SIN-bridge of die 1
3	SIN_N_2	SIN_N output of die 2
4	VDD_S_2	Supply for SIN-bridge of die 2
5	SIN_P_2	SIN_P output of die 2
6	GND_S _2	Ground for SIN-bridge of die 2
7	COS_P_2	COS_P output of die 2
8	VDD_C_2	Supply for COS-bridge of die 2
9	COS_N_2	COS_N output of die 2
10	GND_C_2	Ground for COS-bridge of die 2
11	COS_P_1	COS_P output of die 1
12	VDD_C_1	Supply for COS-bridge of die 1
13	COS_N_1	COS_N output of die 1
14	GND_C_1	Ground for COS-bridge of die 1
15	SIN_N_1	SIN_N output of die 1
16	VDD_S_1	Supply for SIN-bridge of die 1

The exposed pad needs to be soldered to the PCB in order to reduce the thermal resistance and increase mechanical stability.

The exposed pad needs to be floating.

3 General product characteristics

3.1 Absolute maximum ratings

Attention: ***Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the section "functional range" of this data sheet is not implied. Furthermore, only single error cases are assumed. More than one stress/error case may also damage the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. During absolute maximum rating overload conditions the voltage on VDD pins with respect to ground (GND) must not exceed the values defined by the absolute maximum ratings. Lifetime statements are an anticipation based on an extrapolation of Infineon's qualification test results. The actual lifetime of a component depends on its form of application and type of use etc. and may deviate from such statement. Lifetime statements shall in no event extend the agreed warranty period.***

Table 3 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Maximum supply voltage	V_{DD}	-8	-	8	V	limited to 40 h over lifetime
Maximum ambient temperature range	T_A	-40	-	150	°C	150°C for 1000 h / grade 0
Maximum ambient temperature range	T_A	-	-	155	°C	155°C for 120 h
Maximum allowed magnetic field (5 min)	B_{max}	-	-	200	mT	max. 5 min. at $T_A = 25°C$
Maximum allowed magnetic field (5 h)	B_{max}	-	-	150	mT	max. 5 h at $T_A = 25°C$
ESD HBM	V_{ESD}	2	-	-	kV	ESD (HBM) discharge according to ANSI/ ESDA/JEDEC JS-001-2017. For dual-die: all grounds of die 1 (GND_x_1) are connected to all grounds of die 2 (GND_x_2)
ESD HBM (dual-die)	V_{ESD}	1	-	-	kV	ESD (HBM) discharge according to ANSI/ ESDA/JEDEC JS-001:2017. For dual-die: grounds of die 1 (GND_x_1) are not connected to grounds of die 2 (GND_x_2)
ESD CDM (no corner pin)	V_{ESD}	500	-	-	V	according to JESD22-C101 (no corner pin)

(table continues...)

Table 3 (continued) Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ESD CDM (corner pins)	V_{ESD}	750	-	-	V	according to JESD22-C101 (corner pin)
Total lifetime	t_{tot}	19	-	-	a	
Short circuit condition	t_{sc}	40	-	-	h	short circuit condition of an output pin to GND or V_{DD} (V_{DD} < 5.5 V)
Isolation capability single-die	V_{iso}	12	-	-	V	from any pin N-bridge to any pin P-bridge (S0002) or S-bridge and C-bridge (S0003)
Isolation capability dual-die	V_{iso}	12	-	-	V	from any pin of die 1 to any pin of die 2
Isolation capability dual-die	V_{iso}	100	-	-	V	from any pin of die 1 to any pin of die 2, limited to 60 s
Isolation capability dual-die	V_{iso}	300	-	-	V	from any pin of die 1 to any pin of die 2, limited to 100 µs
Isolation capability dual-die	V_{iso}	80	-	-	V	from any pin of die 1 to any pin of die 2, limited to 1 h
Isolation capability dual-die	V_{iso}	60	-	-	V	from any pin of die 1 to any pin of die 2, limited to 7 h
Isolation capability dual-die	V_{iso}	28	-	-	V	from any pin of die 1 to any pin of die 2, limited to 24 h

3.2 Functional range

The following functional range must not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operating conditions unless otherwise indicated.

Table 4 Functional range

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating supply voltage	V_{DD}	2.7	-	5.5	V	
Operating magnetic field range	B_{op}	20	-	80	mT	due to the physical properties of magnet materials with a negative temperature coefficient, the maximum magnetic field occurs at the lowest temperature of -40°C whereas the minimum magnetic field occurs at the highest temperature. A temperature coefficient T_C of the magnet of at least T_C = -1000 ppm/K is assumed
Extended operating magnetic field range	B_{ext}	80	-	130	mT	In the extended magnetic field range, the output amplitude can be below the specified minimum value
Operating temperature range	T_A	-40	-	150	°C	
Operating lifetime	t_{op}	12000	-	-	h	
Buffer capacitor	C_b	33	-	-	pF	
Angle speed	ω	-	-	1E6	°/s	

Taking the physical properties of the magnet material with a negative temperature coefficient into account, the below pictures show the magnetic field operating range for which the specified accuracy is valid. It is based on a magnet temperature coefficient of T_C = -1000 ppm/K and thus includes for example NdFeB and Ferrite based magnets. It has to be ensured that the magnetic field stays inside this specified region.

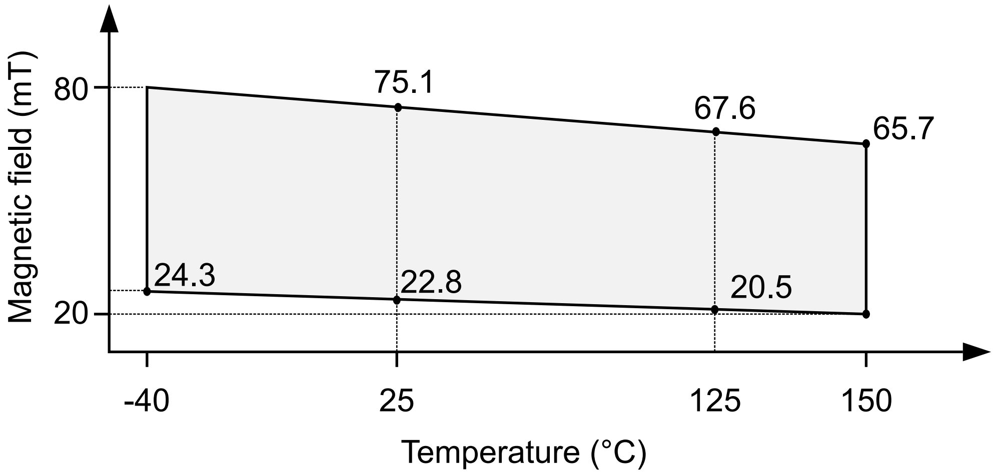

Figure 5 Magnetic field operating range

3.3 Thermal resistance

Table 5 Thermal resistance

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Thermal resistance dual-die	$R_{th,JA}$	-	-	240	K/W	junction to air, JEDEC 2s2p, exposed pad soldered to PCB

4 Product features

4.1 Functional description

The measurement principle of the sensor is based on the TMR (tunneling magnetoresistance) effect. The sensor measures the angular orientation of the magnetic field vector parallel to the package surface. The sensor provides a differential sine and a differential cosine analog output signal for external angle calculation. The provided output signal is ratiometric to the supply voltage. The sensor has a measurement range of 360°.

The device has no internal safety mechanisms implemented. All diagnostics to verify correct sensor functionality must be implemented externally in the microcontroller.

As the device has no implemented safety mechanisms, potential chip errors cannot be indicated by the sensor. They can be detected, however, by proper external mechanisms. The sensor can withstand a short of any pin to ground without any damage of the sensor. The sensor can withstand a short of any pin to sensor supply voltage without any damage of the sensor. The sensor can also withstand a short of a pin to a neighbors pin without any damage.

4.2 Electrical characteristics

The indicated parameters apply to the full operating range, unless otherwise specified. The typical values correspond to a supply voltage V_{DD} = 5.0 V and an ambient temperature T_A = 25°C, unless individually specified.

Table 6 Electrical charactristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply current	I_S	-	-	3	mA	for a supply voltage of 5 V, at T_A = 25°C, valid for the complete chip (both bridges)
Power-on delay	t_{pon}	-	-	1	ms	delay after power on until output is valid, for a load capacity of C_L < 30 nF
Power-on delay	t_{pon}	-	-	4	µs	delay after power on until output is valid, for a load capacity of C_L < 100 pF
Step response time	t_{del}	-	-	50	µs	corresponds to a step (ideally abrupt) change in the magnetic angle input. Load capacitance C_L < 2.2 nF to GND, 99% of final voltage signal change is reached after t_{del}

The sensor has a remaining angle error as shown in the table below. The error value refers to B_z = 0 mT. This error describes the deviation from the reference line after zero-angle definition (done at the calibration condition of temperature and magnetic field strength after initial calibration). The reference line is defined in a way that the angle error is symmetric to this line. It is valid for a static magnetic field.

Table 7 Angle accuracy

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Angle error, differential, T = 125°C / LT	α_{err}	-	-	0.9	°	for T_A < 125°C, lifetime stress according to grade 1 qualification, after compensation of amplitude, orthogonality error and offset at 25°C, magnetic field range 30 mT - 80 mT

(table continues...)

Table 7 (continued) Angle accuracy

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Angle error, differential, T = 150°C / LT	α_{err}	-	-	1.0	°	for T_A < 150°C, lifetime stress according to grade 0 qualification, after compensation of amplitude, orthogonality error and offset at 25°C, magnetic field range 30 mT - 80 mT
Angle error adder, extended range	$\alpha_{err,ext,add}$	-	-	0.4	°	adder to the angle error in extended magnetic field range 80 mT - 130 mT
Angle error adder, low field	$\alpha_{err,low,add}$	-	-	0.2	°	adder to the angle error in low magnetic field range 20 mT - 30 mT
Angle error adder, single-ended	$\alpha_{err,SE,add}$	-	-	0.1	°	adder to the angle error in case single-ended signals are used for angle calculation
Hysteresis	α_{hys}	-	-	0.05	°	magnetic field range 20 mT - 130 mT, due to the physical properties of magnet materials with a negative temperature coefficient, the maximum magnetic field occurs at the lowest temperature of -40°C whereas the minimum magnetic field occurs at the highest temperature. A temperature coefficient T_C of the magnet of at least T_C = -1000 ppm/K is assumed

***Note**: Hysteresis is included in the angle accuracy specification*

The definition of amplitude and offset for single-ended and differential output are shown below:

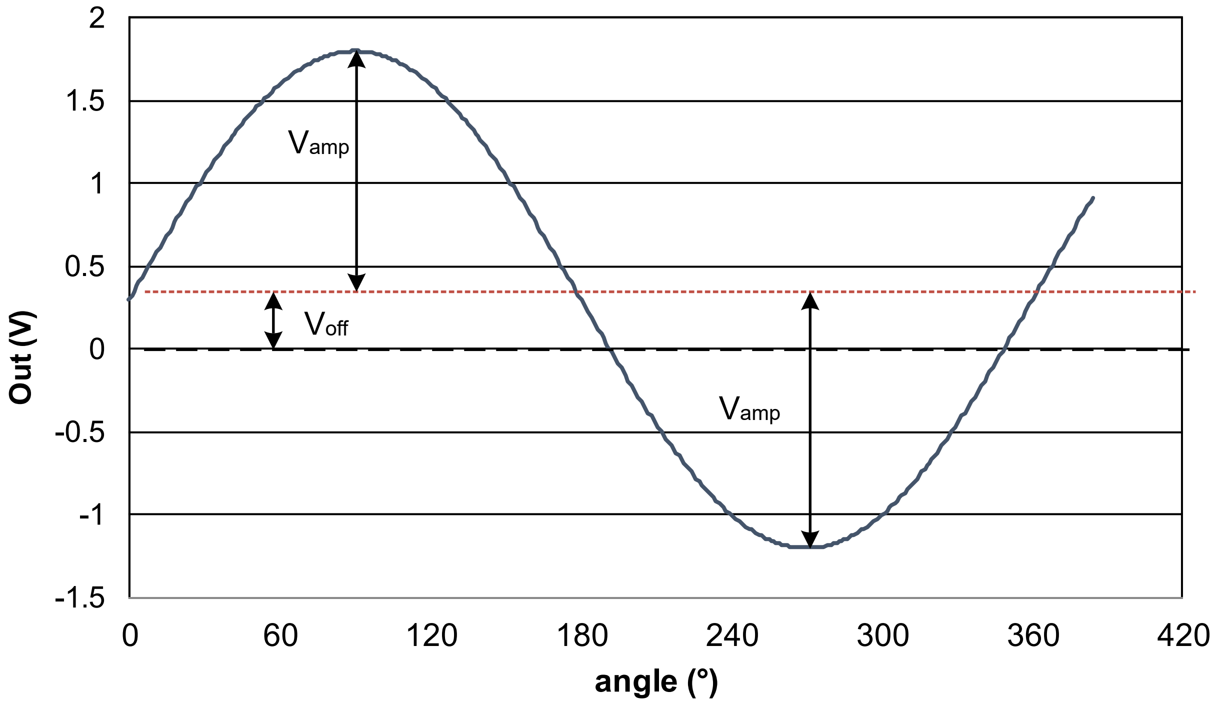

Figure 6 Amplitude and offset for differential output (V_{DD} = 5 V)

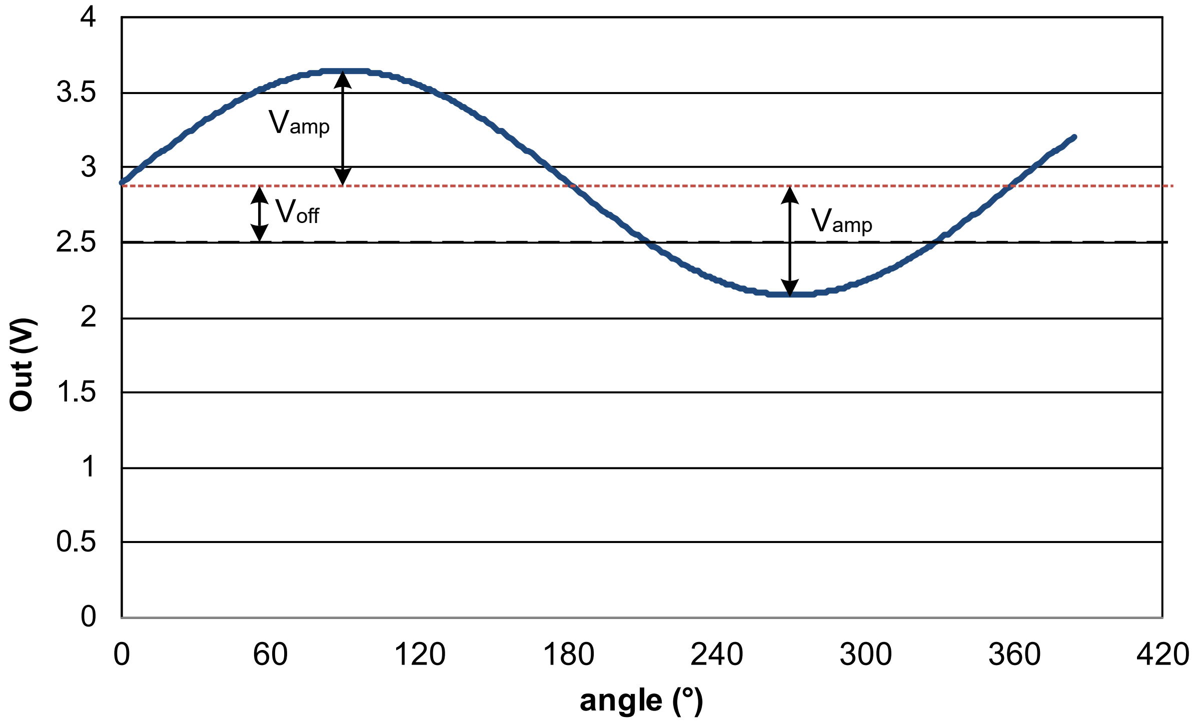

Figure 7 Amplitude and offset for single-ended output (V_{DD} = 5 V)

Table 8 Bridge characteristic

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
TMR bridge resistivity	R_{bridge}	3300	4650	6000	Ohm	at T_A = 25°C
Differential output amplitude (Peak)	V_{amp}	270	300	330	mV/V	at T_A = 25°C, magnetic field range 20 mT - 80 mT
Single-ended output amplitude (Peak)	V_{amp}	135	150	165	mV/V	at T_A = 25°C, magnetic field range 20 mT - 80 mT
Offset voltage	V_{off}	-5	-	5	mV/V	at T_A = 25°C, valid for single-ended and differential
Amplitude synchronicity	k	95	100	105	%	at T_A = 25°C, valid for single-ended and differential
Orthogonality error	Φ	-5	-	5	°	at T_A = 25°C, valid for single-ended and differential
TC of offset voltage	TC_{Voff}	-5	-	5	µV/V/K	
TC of output amplitude	TC_{Vout}	-0.145	-0.120	-0.095	%/K	reference temperature 25°C
TC of amplitude synchronicity	TC_k	-0.012	-	0.012	%/K	reference temperature 25°C
TC of bridge resistivity	$TC_{Rbridge}$	-0.1	-0.075	-0.05	%/K	reference temperature 25°C

4.2.1 TC calculation

The provided temperature coefficients for amplitude, synchronicity and bridge resistivity are relative and calculated in respect to their reference value at T_A = 25°C:

$$TC = \frac{Y(HT) - Y(LT)}{Y(25°C) \times (HT - LT)} \times 100 \quad \left[\frac{\%}{K}\right] \tag{1}$$

The TC of offset voltage TC_{Off} is an absolute value normalized to the bridge supply voltage V_{DD}:

$$TC_{Voff} = \frac{Off(HT) - Off(LT)}{(HT - LT) \times V_{DD}} \quad \left[\frac{\mu V}{V \times K}\right] \tag{2}$$

HT: high temperature, HT = 150°C
LT: low temperature, LT = -40°C

4.2.2 Calculation of synchronicity

The amplitude synchronicity k is defined as the ratio of the sine amplitude V_{amp}(sine) to the cosine amplitude V_{amp}(cosine) within one bridge (P-bridge or N-bridge).

$$k[\%] = \frac{V_{amp}(\text{sine})}{V_{amp}(\text{cosine})} \times 100 \tag{3}$$

5 Application information

5.1 Application circuit

The below circuitry shows the application circuit which is proposed for TLE5502. The value for the buffer capacitor C_b has to be adjusted according to the speed of the magnetic input signal. It represents a low-pass filter together with the TMR resistor and limits the bandwidth of the sensor, improves, however, noise performance. Even without any buffer capacitor C_b, the bandwidth of the device is determined by the TMR resistor and the input capacitor of the used ADC. It has to be considered and the ADC sample and hold time has to be adjusted accordingly. In case the TLE5502 is used in a single-ended configuration, it is recommended to keep the unused pins open.

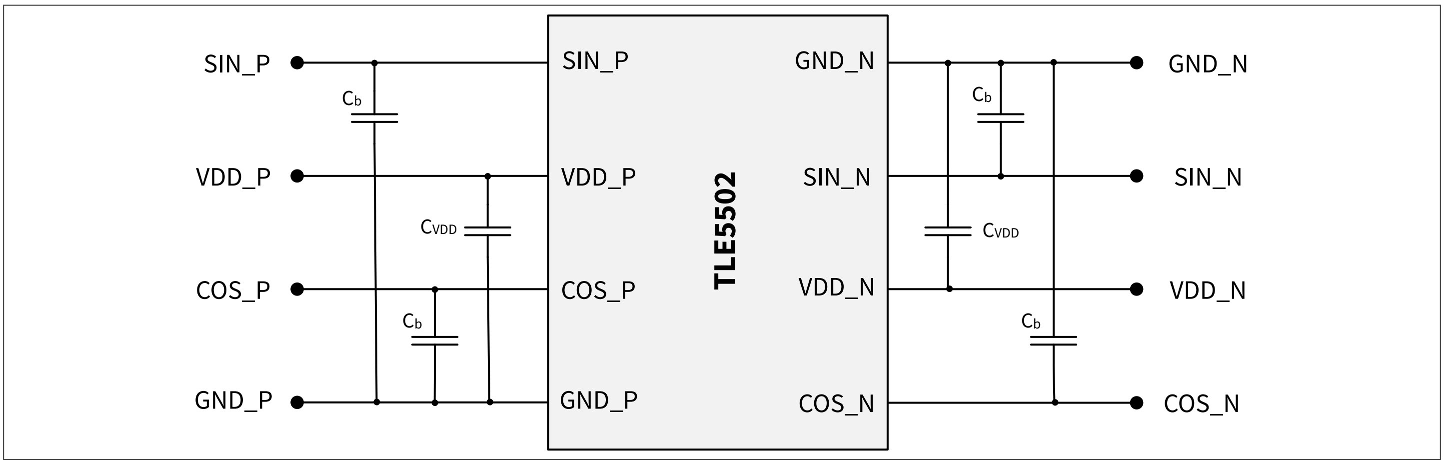

Figure 8 **Application circuit for TLE5502 S0002 version, in the dual-die configuration, circuit for the 2nd die accordingly**

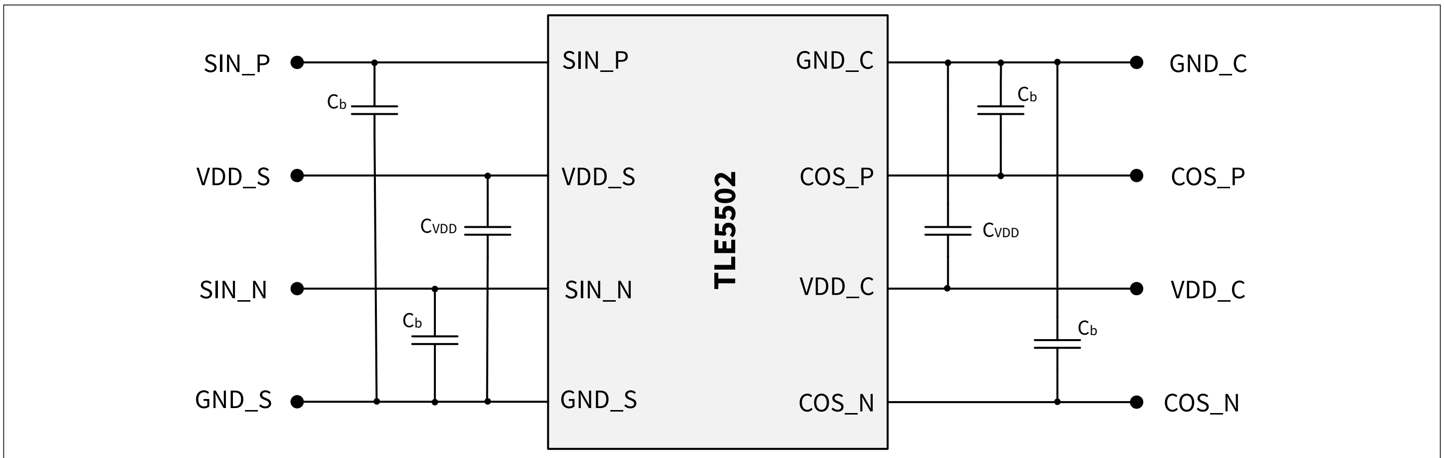

Figure 9 **Application circuit for TLE5502 S0003 version; in the dual-die configuration, circuit for the 2nd die accordingly**

5.2 Typical performance

A typical sensor performance is shown below:

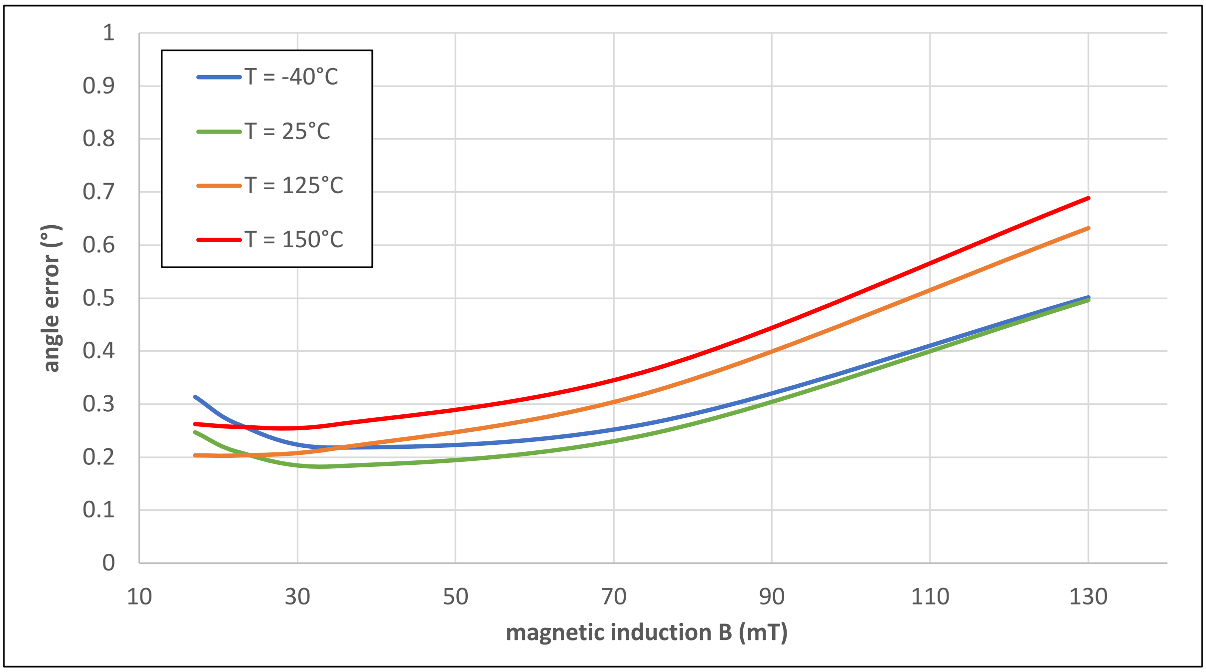

Figure 10 **TLE5502D typical performance, one-time compensation of offset, amplitude and orthogonality at 25°C / 30 mT**

6 Package

The sensor is available in a PG-VQFN-16 package.

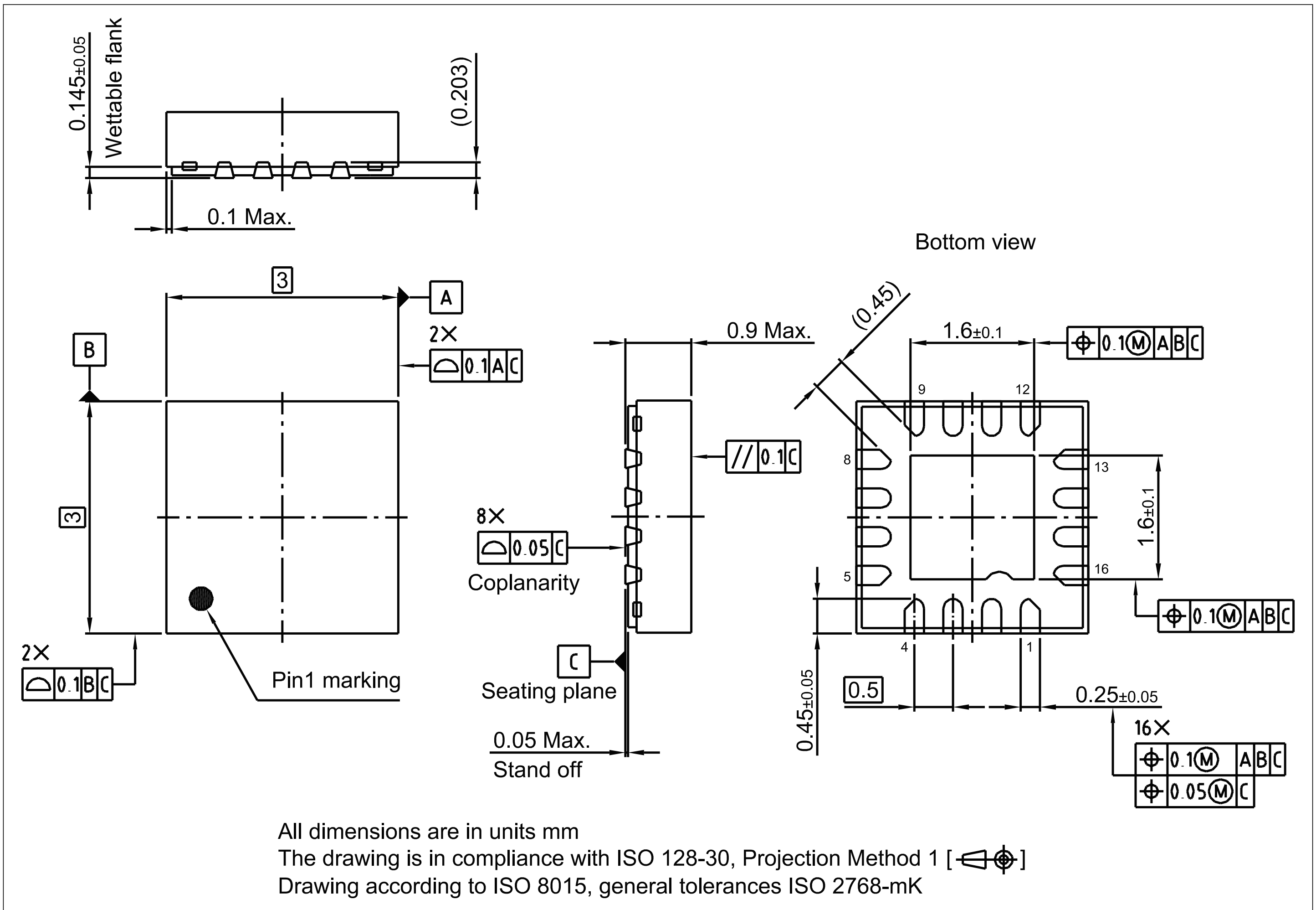

Figure 11 **PG-VQFN-16 package drawing**

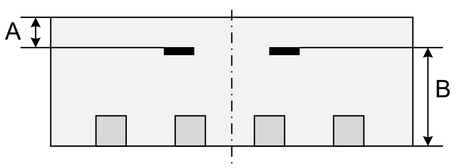

Figure 12 **PG-VQFN-16: die position (active area) in package, dual-die**

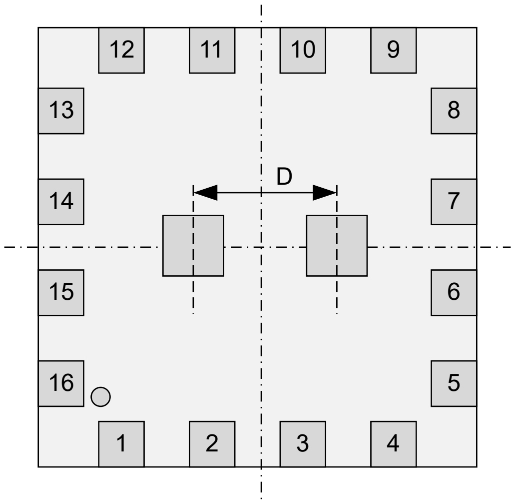

Figure 13 **PG-VQFN-16: die and active area position, dual-die (top view)**

Table 9 **Die in package**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
x, y die placement tolerance	Δx, Δy	-100	-	100	µm	deviation from nominal position: x = ±D/2; y = 0
Die tilt in package	α_{tilt}	-3	-	3	°	in respect to the seating plane
Die rotation in package	α_{rot}	-3	-	3	°	in respect to the package edge
Die to top of package	*A*	190	290	390	µm	
Die to seating plane	*B*	470	570	670	µm	measured to the bottom of the housing (plastic), without solder layer on pin
Distance dual-die in package	*D*	700	800	900	µm	measured from sensing element (center of active area) of die 1 to sensing element (center of active area) of die 2

The marking of the package identifies the type of the sensor, the manufacturing lot information and the manufacturing date code.

It includes a two-digit consecutive number, an identification code of the sensor variant and a DMC (data matrix code) with the detailed manufacturing information.

The package marking of the device is as shown in the figure below.

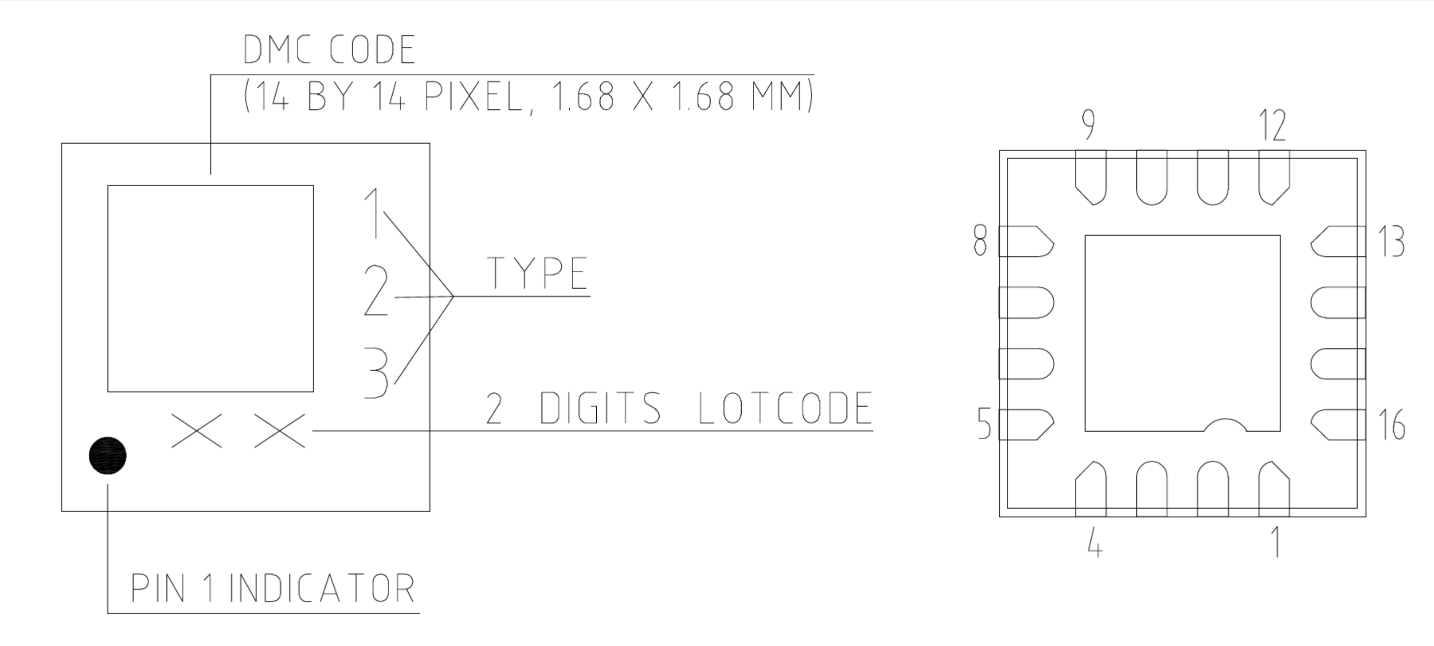

Figure 14 **Package marking, left: front side; right: rear side**

The package fulfils the MSL level 1 according to IPC/JEDEC J-STD-020.

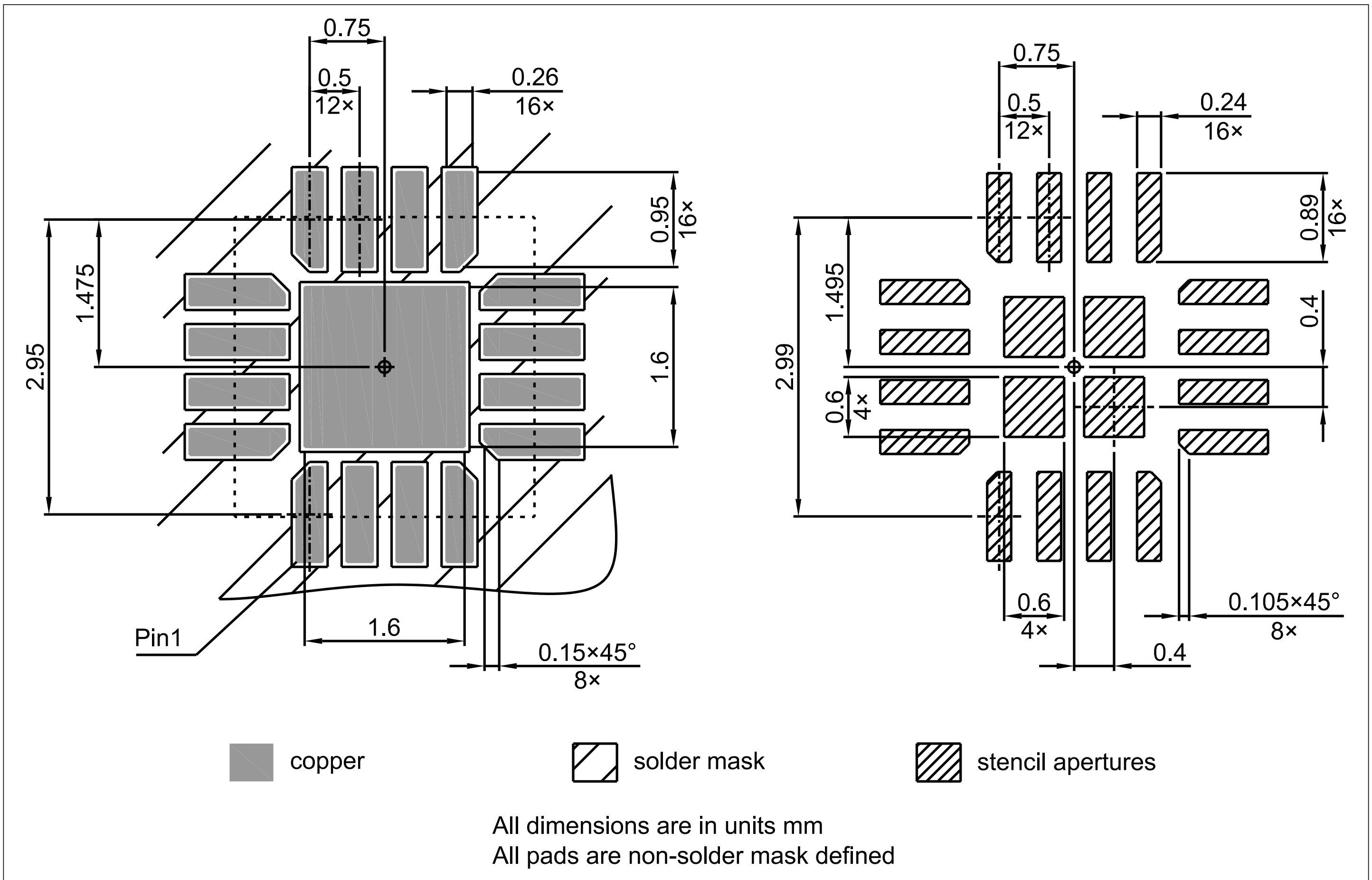

Figure 15 **PG-VQFN-16 footprint**

7 Logistics

The device is delivered in a tape & reel.

Table 10 Packing

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Reel outer diameter	d_{out}	-	330	-	mm	
Reel width	w_{reel}	-	-	18.4	mm	
Tape width	w_{tape}	-	12	-	mm	

8 Revision history

Revision number	Date of release	Description of changes
1.10	2026-03-09	Editorial changes Variant TLE5502 S0002 added Specification for T_A = 150°C added Specification for extended magnetic field range > 80 mT added
1.00	2025-03-05	Initial release

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