Angle Sensor

GMR-Based Angular Sensor

TLE5009

TLE5009-E2000
TLE5009-E1000
TLE5009-E2010
TLE5009-E1010

Data Sheet

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Preliminary

ATV SC

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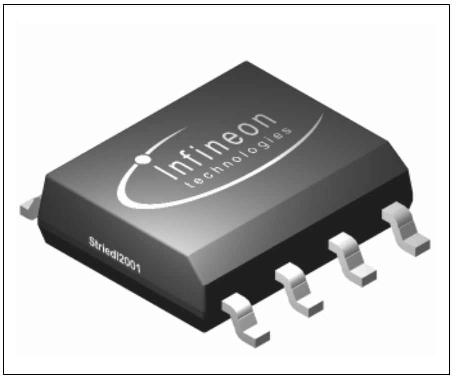
Last Trademarks Update 2009-10-19

Table of Contents

List of Figures

List of Tables

1 Product Description



1.1 Overview

The TLE5009 is a 360° angle sensor that detects the orientation of a magnetic field by measuring sine and cosine angle components with **G**iant **M**agneto **R**esistance (**GMR**) elements.

The differential GMR bridge signals are amplified and can be read out analog single ended or differential.

1.2 Features

- Giant Magneto Resistance (GMR)-based principle
- 360° contactless angle measurement
- Preamplified output signals
- 2 point offset compensated (TLE5009-E2010; TLE5009-E1010)
- Automotive qualified: -40°C to 150°C (junction temperature)
- Green package with lead-free (Pb-free) plating

1.3 Application Example

The TLE5009 GMR angle sensor is designed for angular position sensing in automotive applications, such as:

- Electrical Commutated Motor
- Rotary Switch
- Steering Angle
- General angular sensing

Product Type	Marking	Ordering Code	Package
TLE5009-E2000	0092000	SP000912760	PG-DSO-8
TLE5009-E1000	0091000	SP000912764	PG-DSO-8
TLE5009-E2010	0092010	SP000912770	PG-DSO-8
TLE5009-E1010	0091010	SP000912774	PG-DSO-8

2 Functional Description

2.1 General

The GMR sensor is implemented using vertical integration. This means that the GMR sensitive areas are integrated above the analog portion of the TLE5009 device. These GMR elements change their resistance depending on the direction of the magnetic field.

Four individual GMR elements are connected to one Wheatstone Sensor Bridge. These GMR elements sense one of two components of the applied magnetic field:

- X component, V_x (cosine) or the
- Y component, V_y (sine)

The advantage of a full-bridge structure is that the amplitude of the GMR signal is doubled and temperature effects cancel out each other.

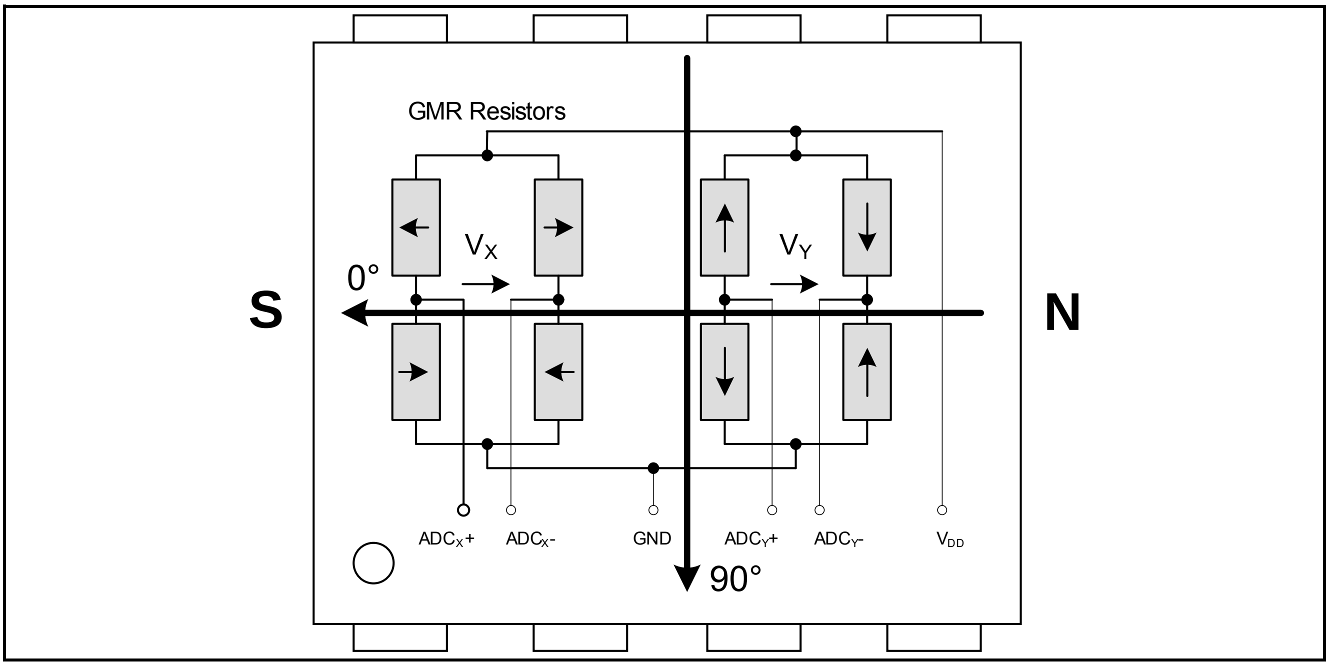


Figure 1 Sensitive bridges of the GMR sensor

*Note: In **Figure 1**, the arrows in the resistors symbolize the direction of the Reference Layer, which is used for the further explanation.*

The output signal of each bridge is unambiguous in a range of 180° between two maxima. Therefore two bridges are orientated orthogonally to each other to measure 360°.

With the trigonometric function ARCTAN, the true 360° angle value can be calulated which is represented by the relation of X and Y signals.

Because only the relative values influence the result, the absolute size of the two signals is of minor importance. Therefore, most influences from varying amplitudes are compensated.

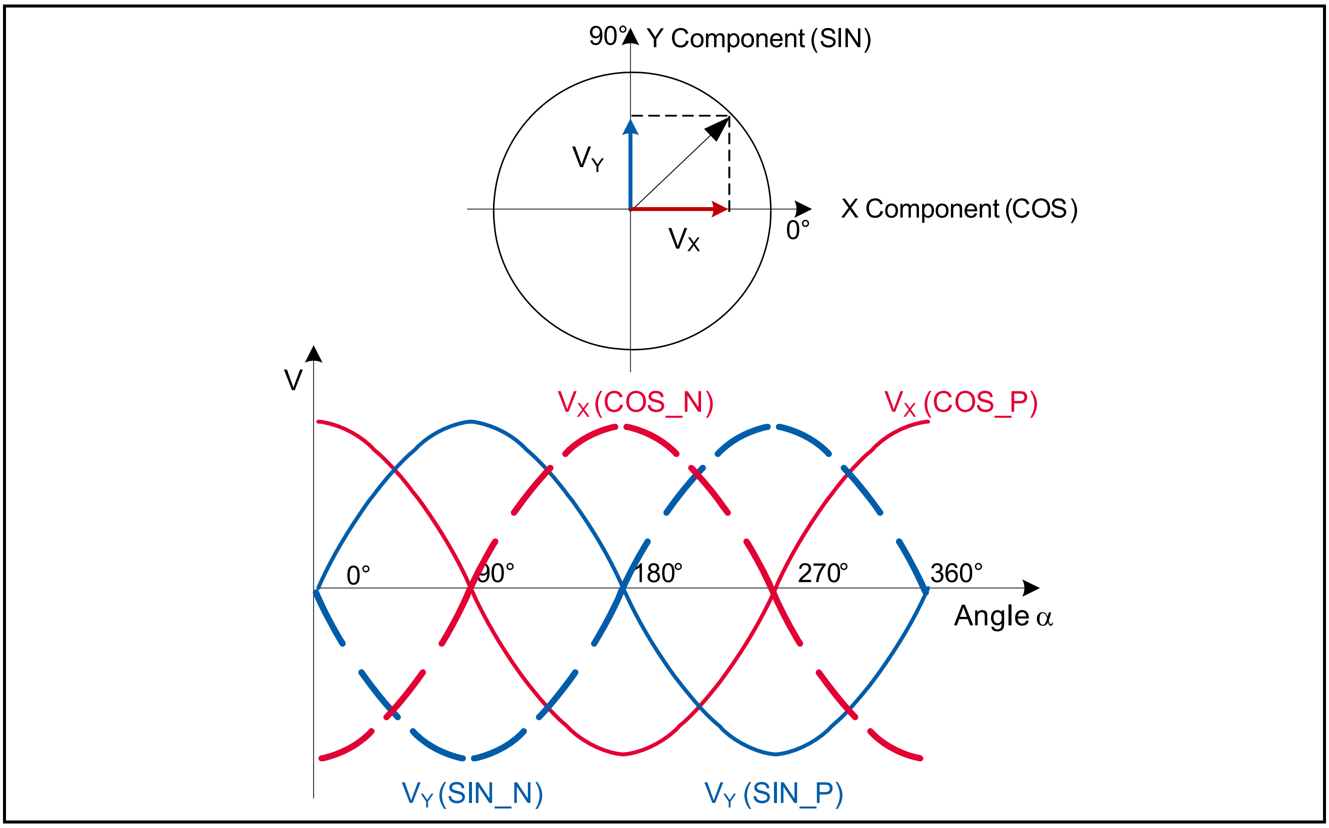


Figure 2 Ideal output of the GMR sensor bridges

2.2 Pin Configuration

The sensitive area is arranged centric.

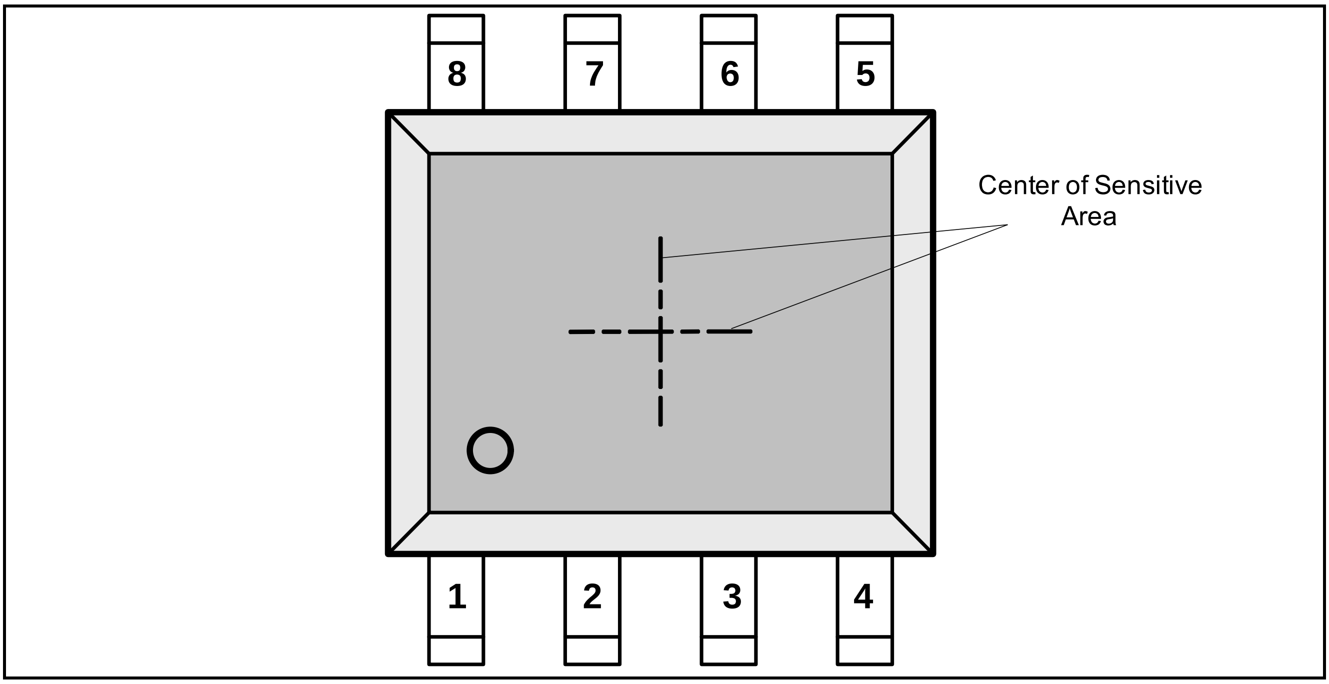


Figure 3 Pin configuration (top view)

2.3 Pin Description

Table 1 Pin description

Pin No.	Symbol	In/Out	Function
1	COS_P	O	Analog positive cosine output
2	COS_N	O	Analog negative cosine output
3	GND2	-	Ground
4	GND1	-	Ground
5	V_{GMR}	O	Voltage proportional to internal GMR-bridge supply voltage and temperature
6	V_{DD}	-	Supply voltage
7	SIN_N	O	Analog negative sine output
8	SIN_P	O	Analog positive sine output

2.4 Block Diagram

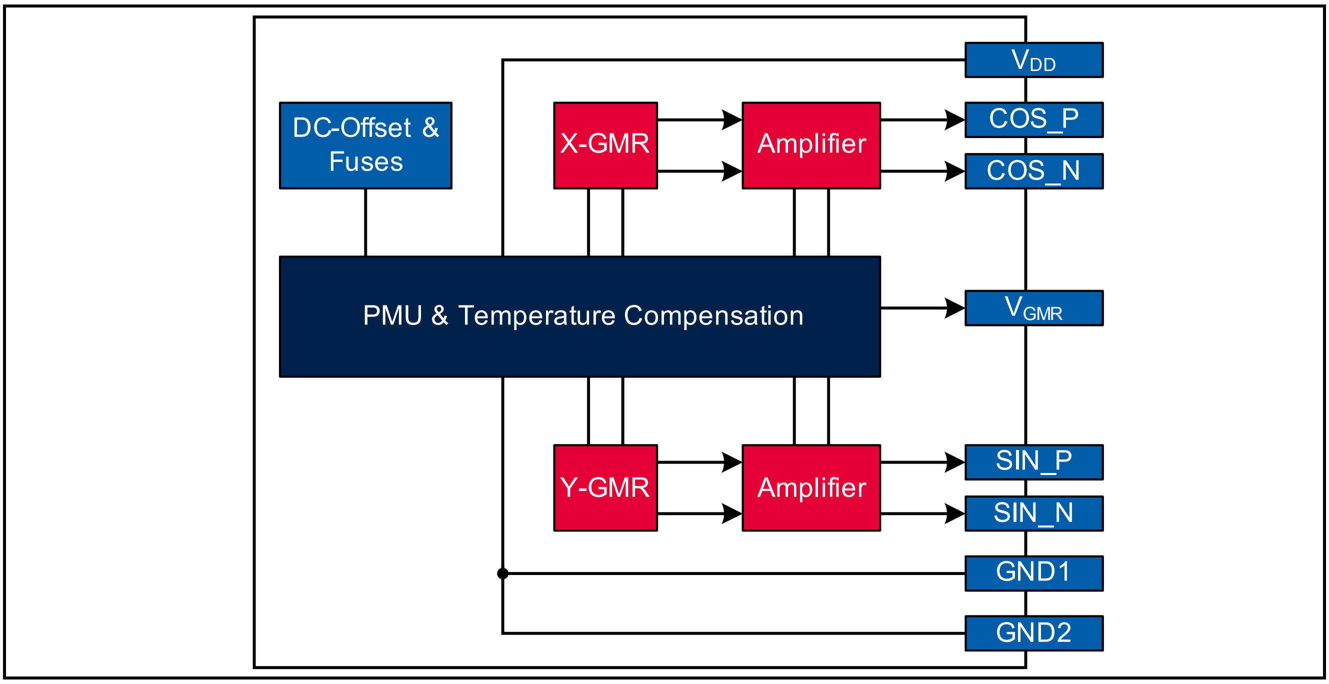


Figure 4 TLE5009 block diagram

3 Specification

3.1 Application Circuit

Figure 5 shows a typical 5V application circuit using a microcontroller for the angle calculation.

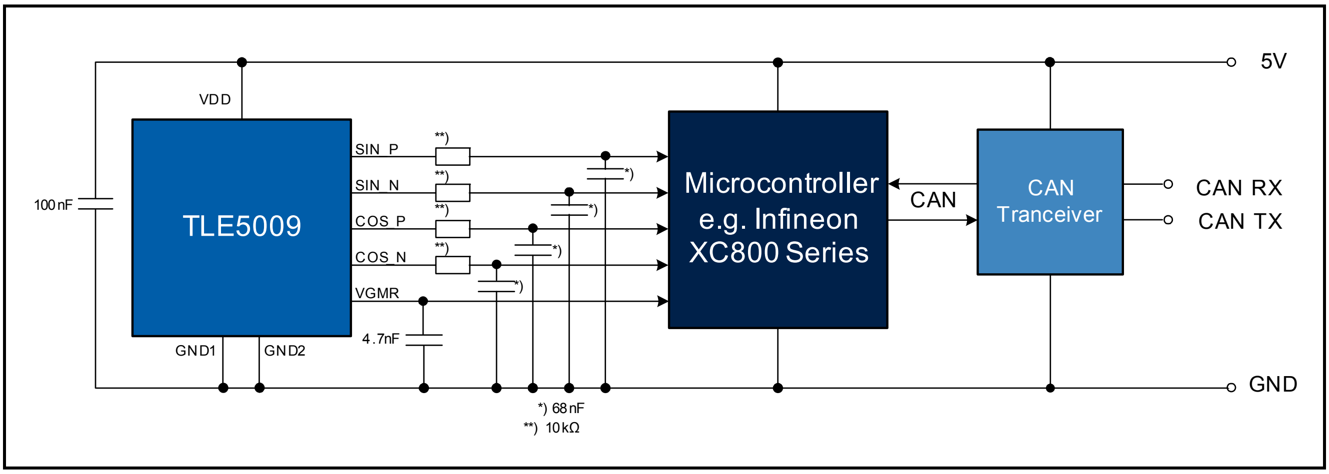


Figure 5 Application circuit for TLE5009

3.2 Absolute Maximum Ratings

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	-0.5	-	6.5	V	Max 40h / lifetime
Junction temperature	T_J	-40	-	150	°C	
		-	-	150		For 1000h not additive
Magnetic field induction	B	-	-	|200|	mT	Max. 5 min @ T_A = 25°C
		-	-	|150|		Max. 5 h @ T_A = 25°C
Storage temperature	T_{ST}	-40	-	150	°C	Without magnetic field

***Attention:** Stresses above the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the device.*

3.3 Operating Range

The following operating conditions must not be exceeded in order to ensure correct operation of the TLE5009.

All parameters specified in the following sections refer to these operating conditions, unless otherwise noticed. Table 3 is valid for -40°C < T_J < 150°C.

Table 3 Operating range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	4.5	5.0	5.5	V	TLE5009-E2000; TLE5009-E2010[1)]
		3.0	3.3	3.6	V	TLE5009-E1000; TLE5009-E1010[1)]
Output current[2)]	I_Q	0	-	0.5	mA	COS_N; COS_P; SIN_N; SIN_P
		0	-	0.1	mA	V_{GMR}
Load capacitance[2)3)]	C_L	0	-	4.7	nF	COS_N; COS_P; SIN_N; SIN_P; V_{GMR}
Magnetic induction[2)]	B_{XY}	24	-	50	mT	In X/Y direction[4)]
Angle range	Ang	0	-	360	°	
Rotation speed[2)]	n	-	-	30000	rpm	[5)]

1) Directly blocked with 100nF ceramic capacitor
2) Not subject to production test - verified by design/characterization
3) Directly connected to pin
4) Values refer to an homogenous magnetic field (B_{XY}) without vertical magnetic induction (B_Z = 0mT)
5) Typical angle delay 1.62° at 30000rpm

Note: The thermal resistances listed in ***Table 9 "Package Parameters" on Page 18*** *must be used to calculate the corresponding ambient temperature.*

Calculation of the Junction Temperature

The total power dissipation P_{TOT} of the chip increases its temperature above the ambient temperature.

The power multiplied by the total thermal resistance R_{thJA} (Junction to Ambient) leads to the final junction temperature. R_{thJA} is the sum of the addition of the values of the two components Junction to Case and Case to Ambient.

$$R_{thJA} = R_{thJC} + R_{thCA}$$
$$T_J = T_A + \Delta T$$
$$\Delta T = R_{thJA} \times P_{TOT} = R_{thJA} \times (V_{DD} \times I_{DD} + V_{OUT} \times I_{OUT}) \quad (I_{DD}, I_{OUT} > 0, \text{ if direction is into IC}) \tag{1}$$

Example (assuming no load on V_{out}):

$$V_{DD} = 5V$$
$$I_{DD} = 7mA$$
$$\Delta T = 150\left[\frac{K}{W}\right] \times (5[V] \times 0.007[A] + 0[VA]) = 5.25K \tag{2}$$

For molded sensors, the calculation with R_{thJC} is more adequate.

3.4 Characteristics

3.4.1 Electrical Parameters

The indicated electrical parameters apply to the full operating range, unless otherwise specified. The typical values correspond to a supply voltage V_{DD} = 3.0V - 5.5 V and 25 °C, unless individually specified. All other values correspond to -40°C < T_J < 150°C.

Table 4 Electrical parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply current	I_{DD}	-	7	10.5	mA	Without resistive or capacitive load on output pins
POR level	V_{POR}	2.4	2.65	2.97	V	Power-On Reset
POR hysteresis[1)]	V_{PORhy}	-	50	-	mV	
Power-On time	t_{PON}	-	30	40	µs	Measured on V_{GMR} pin without external circuit
Temperature reference voltage	V_{GMR}	-	1.052	-	V	Proportional to GMR bridge supply and temperature; available on pin V_{GMR}[2)]
Diagnostic function	V_{GMR}	0	-	0.39	V	Diagnostic of internal errors; available on pin V_{GMR}[2)]
Temperature coefficient of V_{GMR}	TC_{VGMR}	0.33	0.40	0.47	%/K	

1) Not subject to production test - verified by design/characterization
2) Max. output current 0.1mA

3.4.2 ESD Protection

Table 5 ESD protection

Parameter	Symbol	Values		Unit	Notes
		min.	max.		
ESD voltage	V_{HBM}	-	±4.0	kV	Human Body Model[1)]
	V_{SDM}	-	±0.5	kV	Socketed Device Model[2)]

1) Human Body Model (HBM) according to: AEC-Q100-002
2) Socketed Device Model (SDM) according to: ESDA/ANSI/ESD SP5.3.2-2008

3.4.3 Output Parameters

All parameters apply over the full operating range, unless otherwise specified. The parameters in **Table 6** refer to single ended output and **Table 7** to differential output.

Table 6 Single ended output parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
X, Y amplitude[1]	A_X, A_Y	1.50	-	1.85	V	TLE5009-E2000; TLE5009-E2010[2]
		0.95	-	1.20	V	TLE5009-E1000; TLE5009-E1010[2]
X, Y synchronism [3]	k	95	100	105	%	[2]
X, Y orthogonality error[1][4]	φ	-10	0	10	°	[2]
Mean output voltage	V_{MVX}, V_{MVY}	$0.48*V_{DD}$	$0.5*V_{DD}$	$0.52*V_{DD}$	V	[5]
X,Y cut off frequency[6]	f_c	-	30	-	kHz	-3dB attenuation
X,Y delay time[6]	t_{adel}	-	9	-	µs	
Output noise[6]	V_{Noise}	-	1.5	-	mV	RMS

1) See **Figure 6**
2) Trimmed at 25°C and 25mT
3) $k = 100*(A_X/A_Y)$
4) $\varphi=(\alpha[Y_{MAX}] - \alpha[X_0])$
5) Including X, Y offset
6) Not subject to production test - verified by design/characterization

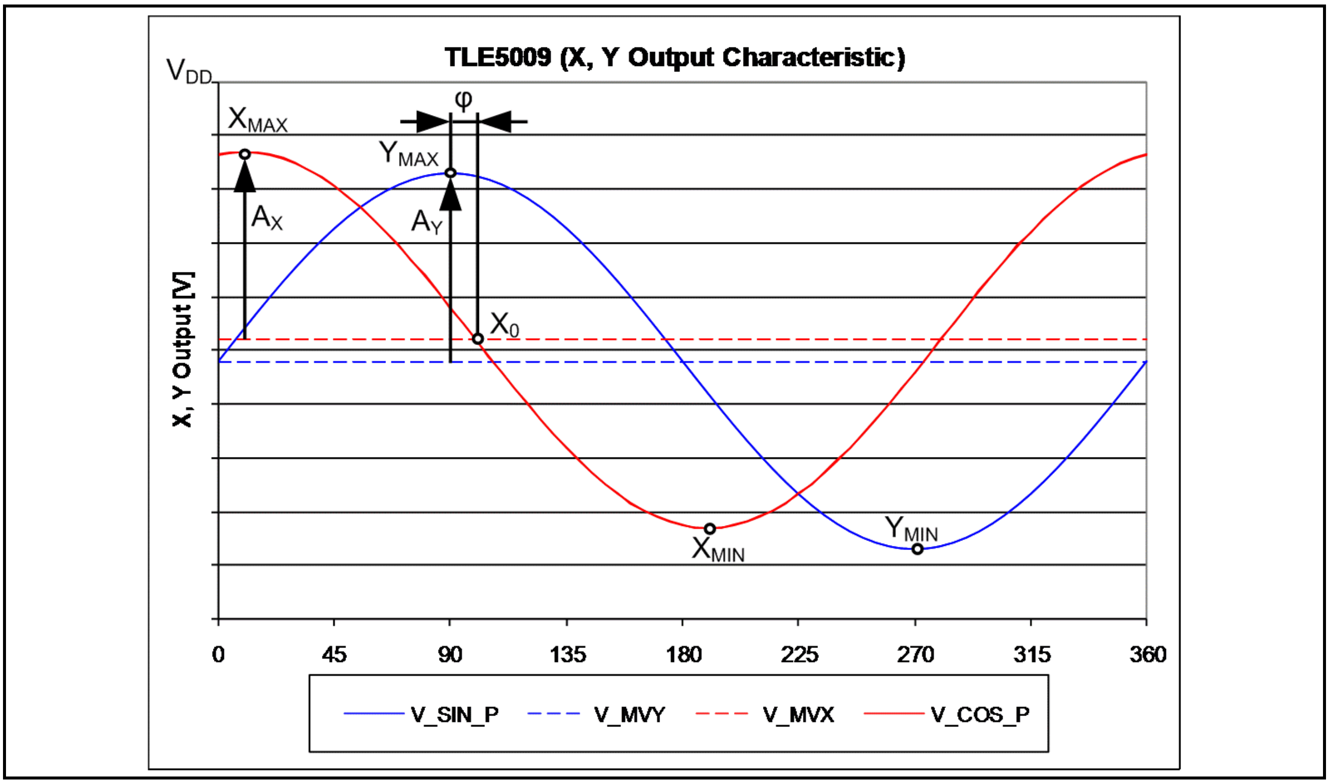


Figure 6 Single ended output signals

Table 7 Differential output parameters[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
X, Y amplitude[2)3)]	A_{Xdiff}, A_{Ydiff}	3.0	-	3.7	V	TLE5009-E2000; TLE5009-E2010[4)]
		1.9	-	2.4	V	TLE5009-E1000; TLE5009-E1010[4)]
X, Y synchronism [5)]	k	95	100	105	%	[4)]
X, Y offset [1)6)]	O_{Xdiff}, O_{Ydiff}	-50	0	50	mV	[4)]
X, Y orthogonality error[1)]	φ	-10	0	10	°	[4)]
X,Y cut off frequency[7)]	f_c	-	30	-	kHz	-3dB attenuation
X,Y delay time[7)]	t_{adel}	-	9	-	µs	
Output noise[7)]	V_{Noise}	-	3	-	mV	RMS

1) $V_{Xdiff} = V_{COS\_P} - V_{COS\_N}$; $V_{Ydiff} = V_{SIN\_P} - V_{SIN\_N}$
2) See **Figure 7**
3) $A_{Xdiff} = (X_{diff\_MAX} - X_{diff\_MIN})/2$; $A_{Ydiff} = (Y_{diff\_MAX} - Y_{diff\_MIN})/2$
4) Trimmed at 25°C and 25mT
5) $k = 100*(A_X/A_Y)$
6) $O_{Xdiff} = (X_{diff\_MAX} + X_{diff\_MIN})/2$; $O_{Ydiff}=(Y_{diff\_MAX} + Y_{diff\_MIN})/2$
7) Not subject to production test - verified by design/characterization

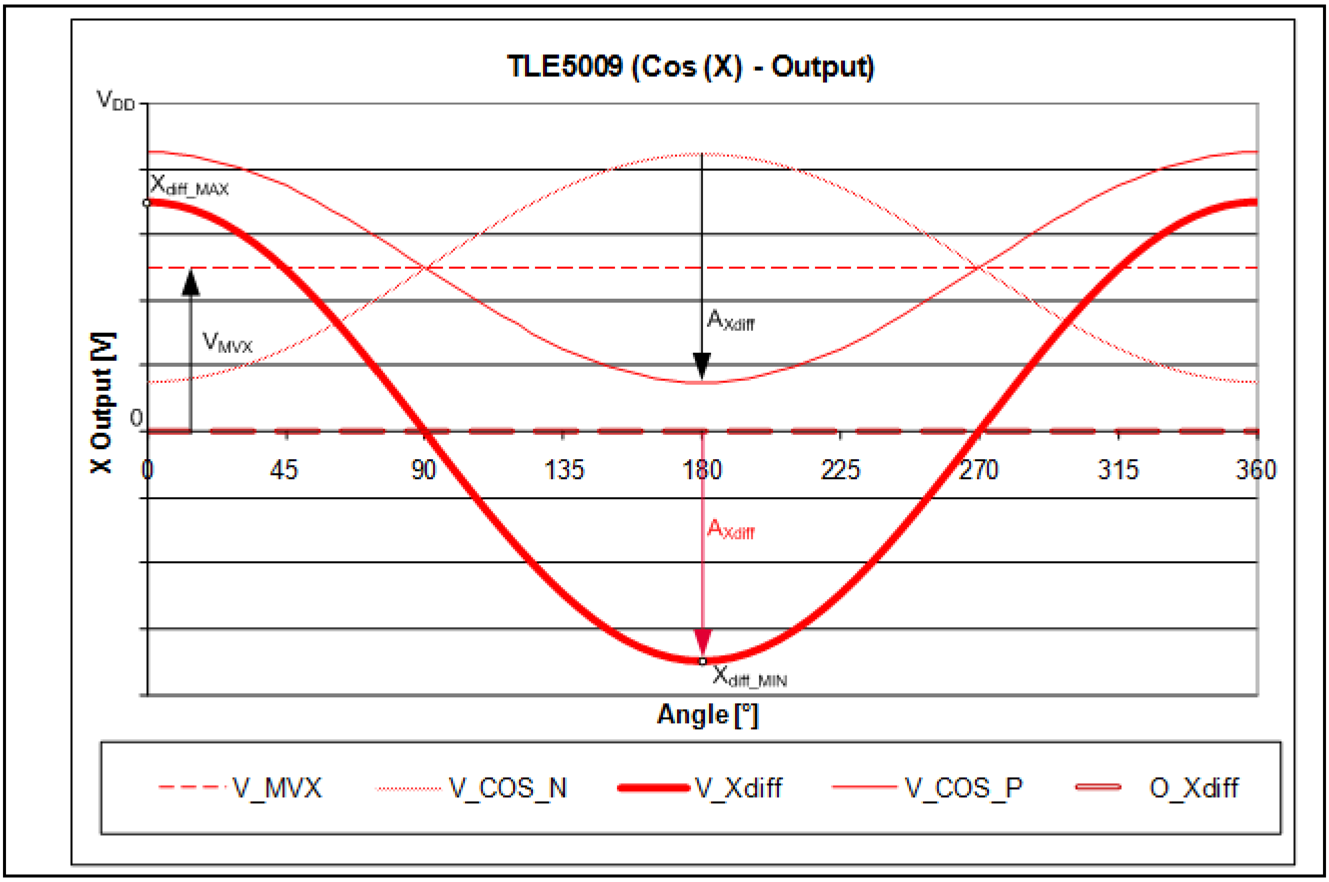


Figure 7 Differential output of ideal cosine

3.4.4 Angle Performance

The overall angle error represents the relative angle error. This error describes the deviation to the reference line after zero angle definition. The typical value correspond to a supply voltage V_{DD} = 3.0V - 5.5 V and 25 °C, unless individually specified. All other values correspond to -40°C < T_J < 150°C.

Table 8 Angle performance

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Overall angle error	α_{Err}	-	0.6	3.0	°	[1)2)3)4)] TLE5009-E2000; TLE5009-E1000
		-	0.6	2.2		[1)2)3)4)] With two point calibration at Infineon; TLE5009-E2010; TLE5009-E1010

1) Including hysteresis error
2) After offset / mean output voltage, synchronism and orthogonality calibration at 25°C
3) At 0h
4) Performance can be improved with error compensation in microcontroller

3.5 Electro Magnetic Compatibility (EMC)

The TLE5009 is characterized according to the EMC requirements described in the “Generic IC EMC Test Specification” Version 1.2 from November, 15^{th} 2007. The classification of the TLE5009 is done for local pins.

4 Package Information

4.1 Package Parameters

Table 9 Package Parameters

Parameter	Symbol	Limit Values			Unit	Notes
		min.	typ.	max.		
Thermal Resistance	R_{thJA}	-	150	200	K/W	Junction to Air[1]
	R_{thJC}	-	-	75	K/W	Junction to Case
	R_{thJL}	-	-	85	K/W	Junction to Lead
Soldering Moisture Level	MSL 3					260°C
Lead Frame	Cu					
Plating	Sn 100%					> 7 µm

1) according to Jedec JESD51-7

4.2 Package Outline

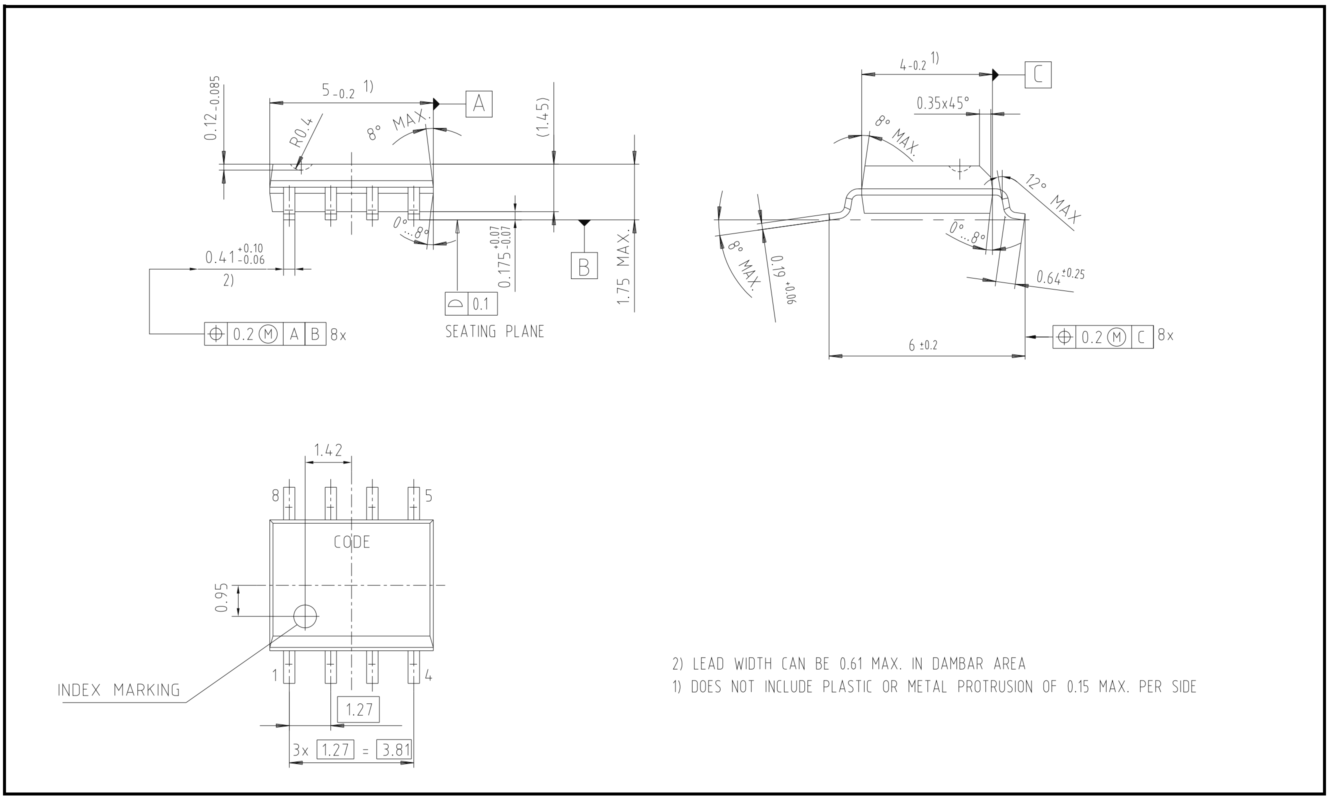


Figure 8 PG-DSO-8 package dimension

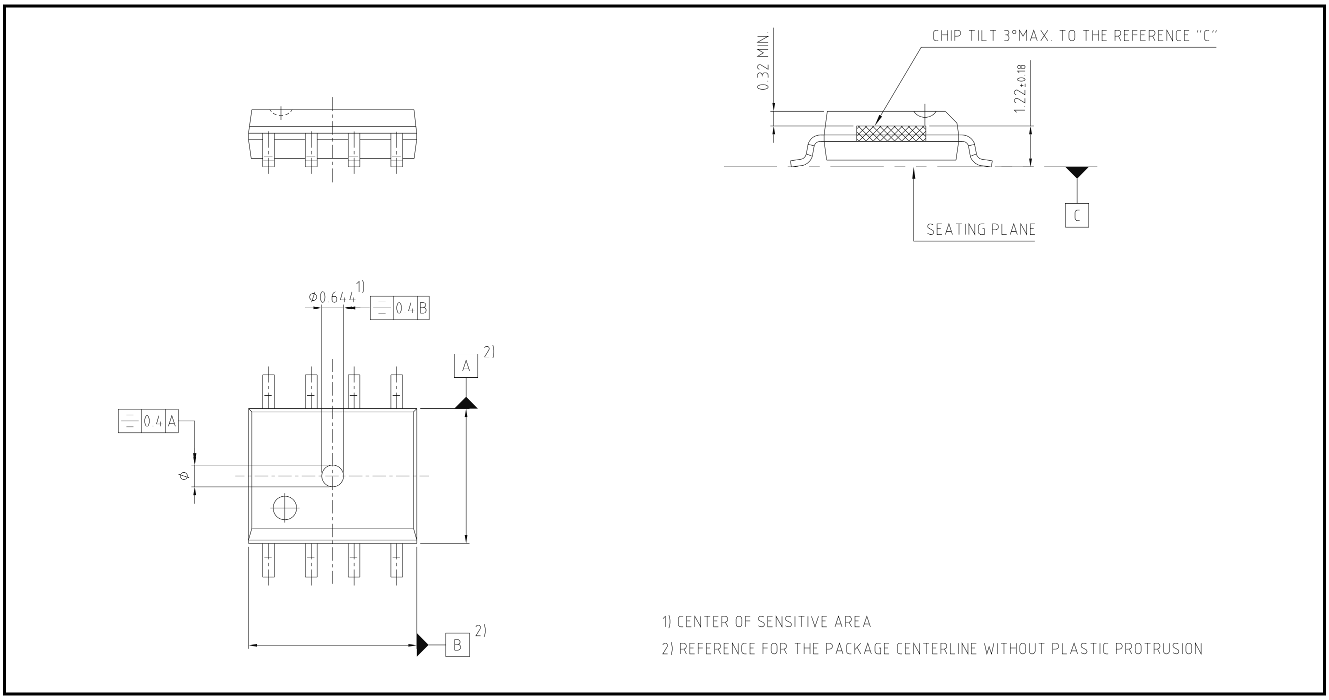


Figure 9 Position of sensing element

4.3 Footprint

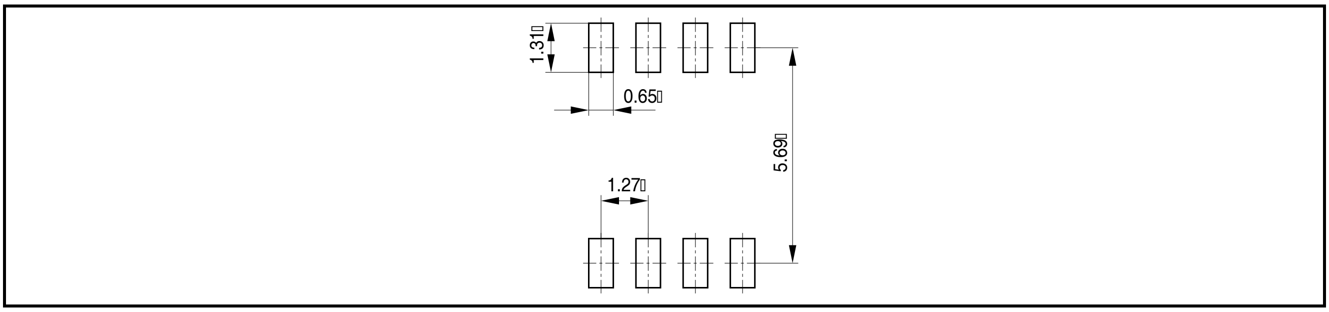


Figure 10 Footprint PG-DSO-8

4.4 Packing

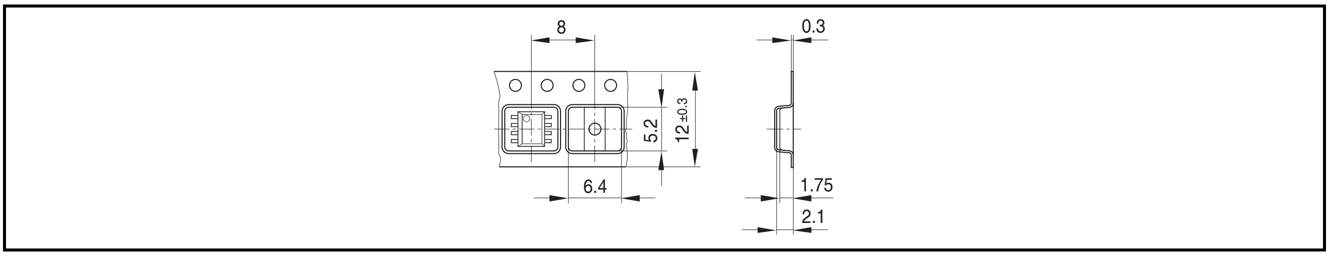


Figure 11 Tape and reel

4.5 Marking

Position	Marking	Description
1st Line	5009xxx	See ordering table on **Page 7**
2nd Line	xxx	Lot code
3rd Line	GSxxxx	G..green, 4-digit..date code

Processing

Note: For processing recommendations, please refer to Infineon's Notes on processing

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