TLE5009A16(D)

GMR Angle Sensor

AEC Qualified · RoHS · HAL

Features

- Available as single die and dual die with separate supplies for each die
- Low current consumption and quick start up
- 360° contactless angle measurement
- Output amplitude optimized for circuits with 3.3 V or 5 V supply voltage
- Pre-amplified output signals for differential or single-ended applications
- Immune to airgap variations due to GMR based sensing principle
- Operating temperature range: -40°C to 125°C (ambient temperature)
- Green product (RoHS compliant)
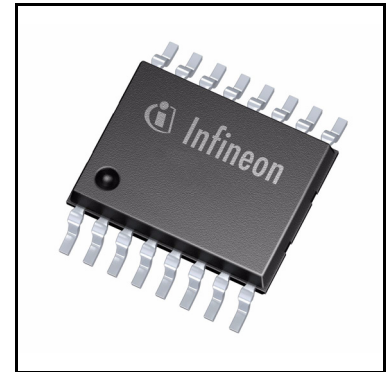
Product Validation

Developed for automotive applications. Product qualification according to AEC-Q100.

Potential Applications

The TLE5009A16(D) angle sensor is designed for angular position sensing in automotive and non-automotive applications. Its high accuracy and 360° measurement range combined with short propagation delay makes it suitable for systems with high speeds and high accuracy demands such as brush-less DC (BLDC) motors for actuators and electric power steering systems (EPS). At the same time its fast power-up time and low overall power consumption enables the device to be employed for low-power turn counting. Extremely low power consumption can be achieved with power cycling, where the advantage of fast power on time reduces the average power consumption.
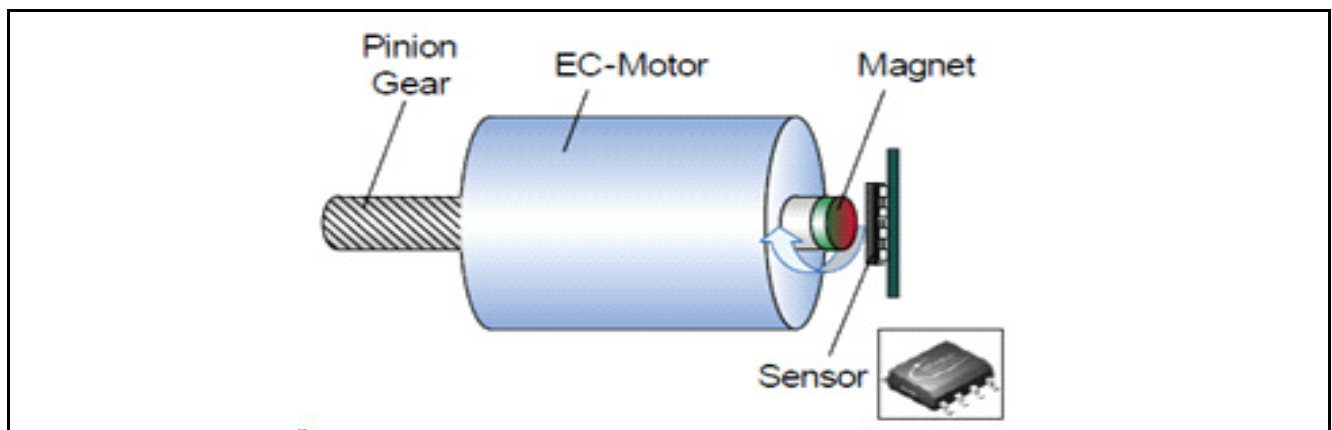

Figure 1   A usual application for TLE5009A16(D) is the electrically commutated motor

Description

The TLE5009A16(D) is an angle sensor with analog outputs. It detects the orientation of a magnetic field by measuring sine and cosine components with **G**iant **M**agneto **R**esistive (**GMR**) elements. It provides analog sine and cosine output voltages that describe the magnet angle in a range of 0° to 360°.

The differential MR bridge signals are independent of the magnetic field strength, and the output voltages are designed to use the dynamic range of an A/D-converter using the same supply as the sensor as voltage reference.

The sensor is available as single die version (TLE5009A16) and dual die version (TLE5009A16D) for safety applications that require redundancy. The two versions are pin-compatible for easy scalability. In the dual die TLE5009A16D, both sensor dice are supplied independently by separate supply and ground pins.

Table 1   Derivate Ordering codes

Product Type	Marking	Ordering Code	Package	Description
TLE5009A16 E1200	09A11200	SP001285624	PG-TDSO-16	3.3 V, single die, without TCO[1]
TLE5009A16 E1210	09A11210	SP001296110	PG-TDSO-16	3.3 V, single die, with TCO[1]
TLE5009A16 E2200	09A12200	SP001296118	PG-TDSO-16	5.0 V, single die, without TCO[1]
TLE5009A16 E2210	09A12210	SP001296114	PG-TDSO-16	5.0 V, single die, with TCO[1]
TLE5009A16D E1200	09A21200	SP001285628	PG-TDSO-16	3.3 V, dual die, without TCO[1]
TLE5009A16D E1210	09A21210	SP001296122	PG-TDSO-16	3.3 V, dual die, with TCO[1]
TLE5009A16D E2200	09A22200	SP001296126	PG-TDSO-16	5.0 V, dual die, without TCO[1]
TLE5009A16D E2210	09A22210	SP001296130	PG-TDSO-16	5.0 V, dual die, with TCO[1]

1) Temperature Compensation Offset.

Table of Contents

1 Functional Description

1.1 General

The **G**iant **M**agneto **R**esistive (**GMR**) sensors are implemented using vertical integration. This means that the MR sensitive areas are integrated above the analog portion of the ICs. These MR elements change their resistance depending on the direction of the magnetic field.

On each sensor, four individual MR elements are connected in a Wheatstone bridge arrangement. Each MR element senses 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 MR signal is doubled and temperature effects cancel out. The output signal of a GMR bridge is unambiguous in a range of 180°. Therefore two bridges are oriented orthogonally to each other to measure 360°.
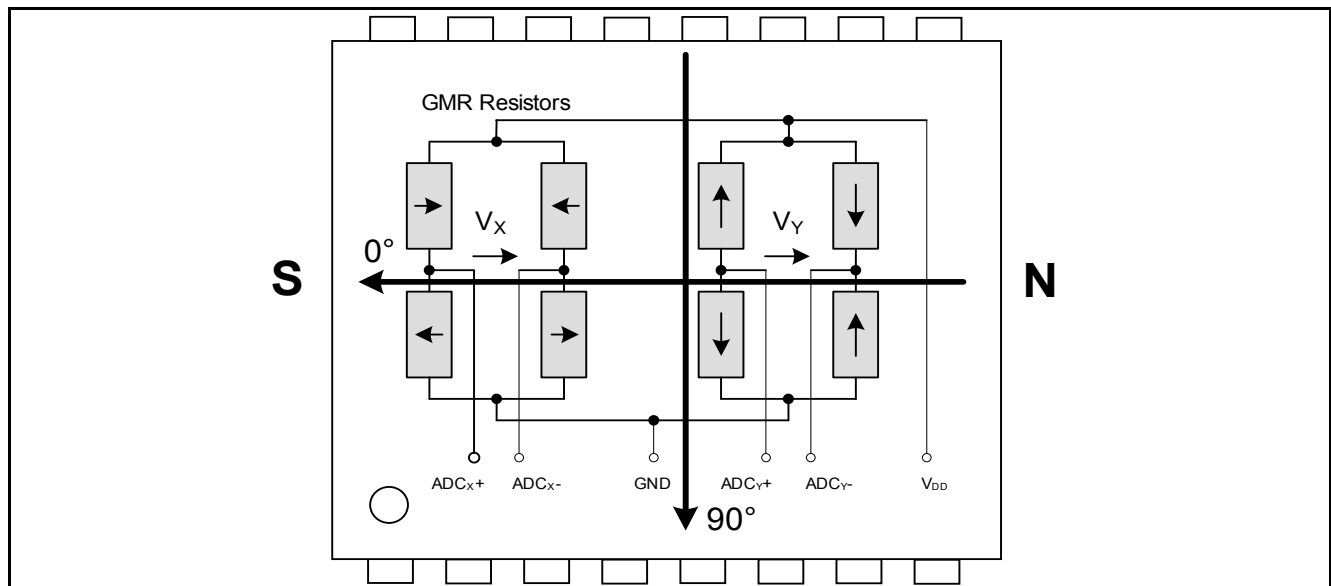

Figure 2   Sensitive bridges of the GMR sensor (one die, not to scale)

Attention: Due to the rotational placement inaccuracy of the sensor IC in the package, the sensors 0° position may deviate by up to 3° from the package edge direction indicated in Figure 2.

In Figure 2, the arrows in the resistors represent the magnetic direction which is fixed in the Reference Layer. On top of the Reference Layer, and separated by a non magnetic layer, there is a Free Layer. When applying an external magnetic field the Free Layer moves in the same direction as the external magnetic field, while the Reference Layer remains fix. The resistance of the GMR elements depends on the magnetic direction difference between the Reference Layer and the Free Layer.

When the external magnetic field is parallel to the direction of the Reference Layer, the resistance is minimal (Reference Layer and Free Layer are parallel). When the external magnetic field and the Reference Layer are anti-parallel (Reference Layer and Free Layer are anti-parallel), resistance is maximal.

The output signal of each bridge is only unambiguous over 180° between two maxima. Therefore two bridges are oriented orthogonally to each other to measure 360°.

Functional Description

With the trigonometric function ARCTAN2, the true 360° angle value is calculated out of the raw X and Y signals from the sensor bridges. The ARCTAN2 function is a microcontroller library function which resolves an angle within 360° using the x and y coordinates on a unit circle.
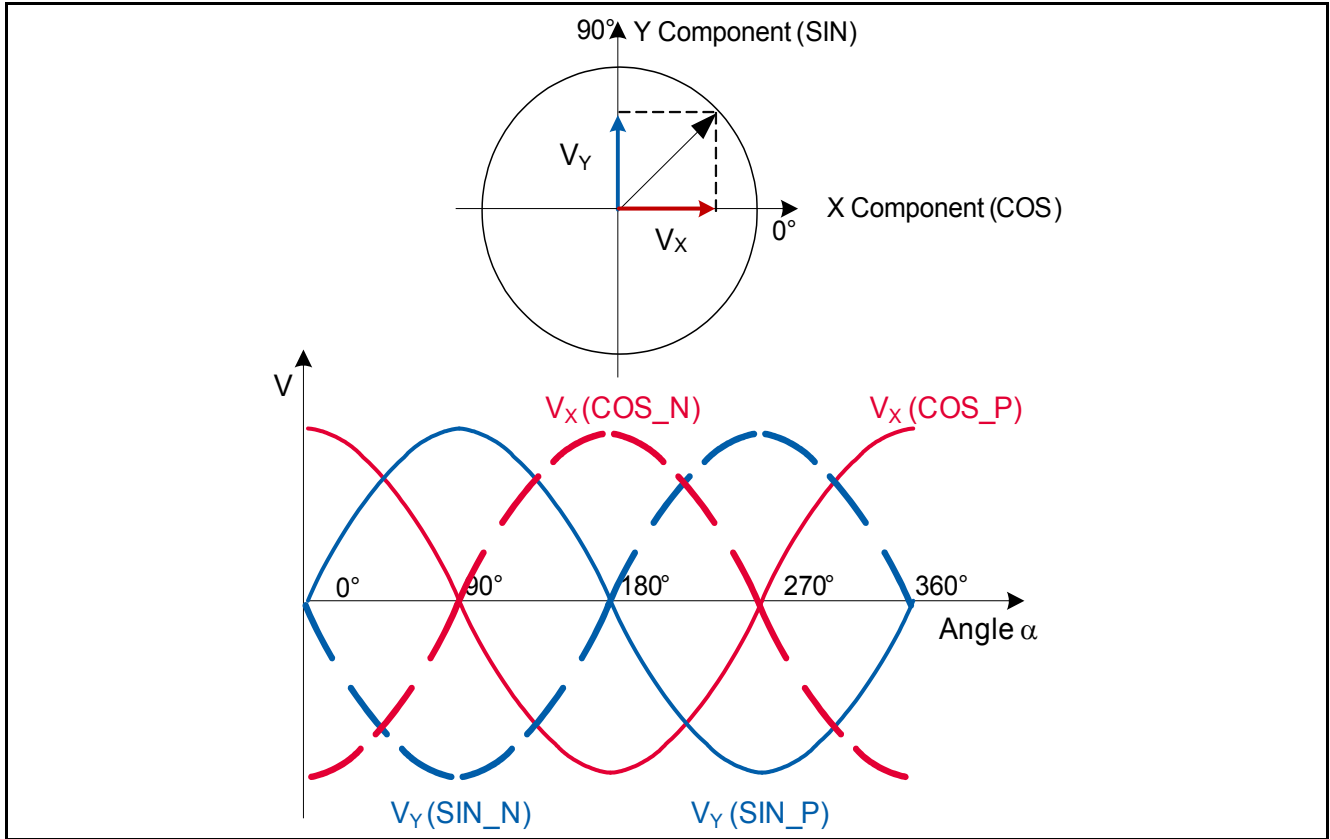

Figure 3   Ideal output of the GMR sensor bridges
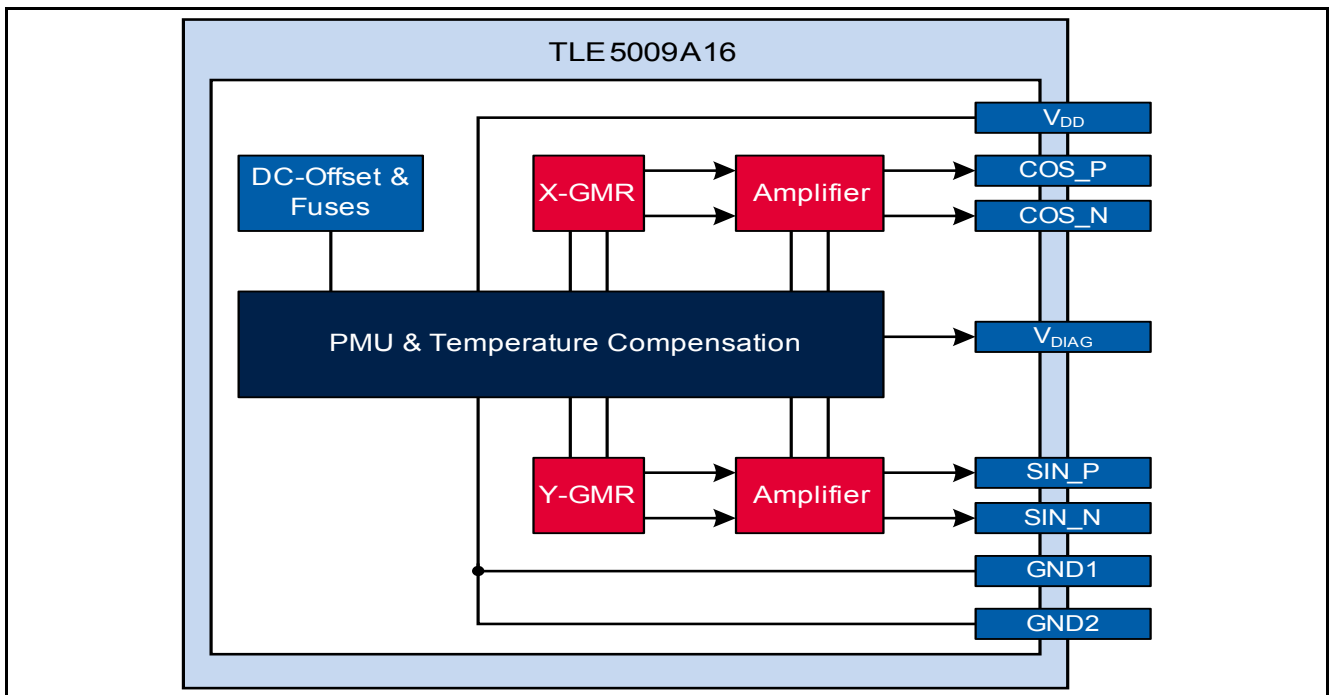
1.2 Block Diagram

Figure 4 TLE5009A16(D) block diagram (one die only)

1.3 Pin Configuration

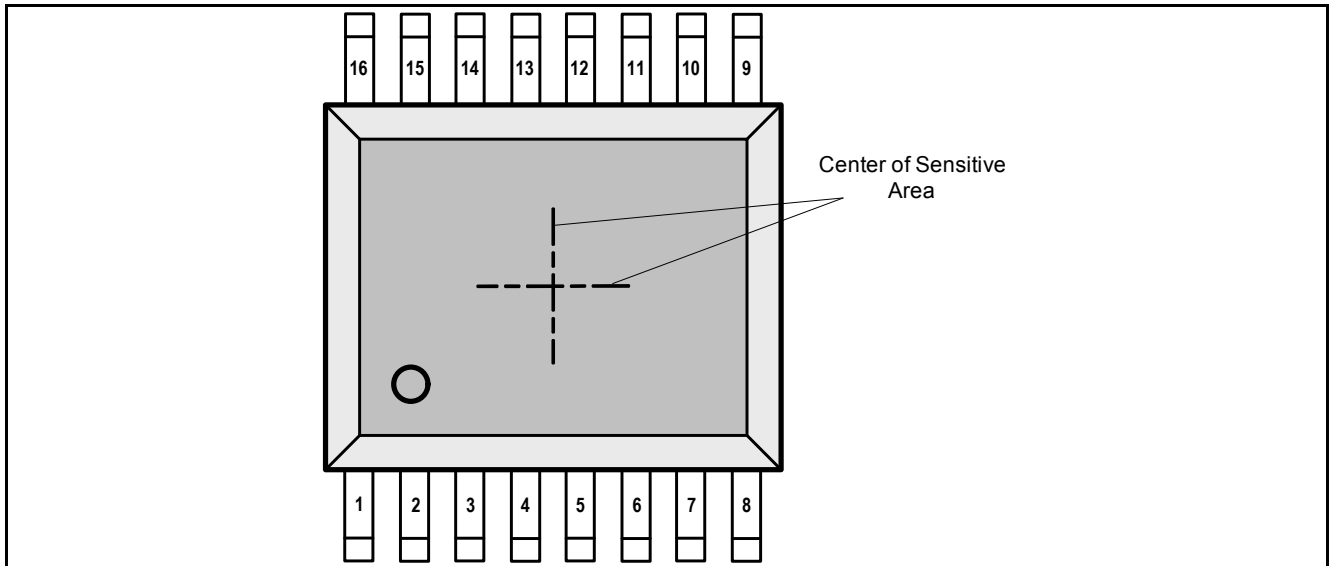The sensitive area is located at the center of the package.

Figure 5 Pin configuration (top view)

1.4 Pin Description

Table 2 Pin description

Pin No.	Pin Name	In/Out	TLE5009A16 - Function	TLE5009A16D - Function
1	$V_{DIAG}1$	O	Die 1 bridge voltage proportional to temperature. Diagnostic function	Die 1 bridge voltage proportional to temperature. Diagnostic function
2	$V_{DD}1$		Die 1 Supply voltage	Die 1 Supply voltage
3	SIN_N1	O	Die 1 Analog negative sine output	Die 1 Analog negative sine output
4	SIN_P1	O	Die 1 Analog positive sine output	Die 1 Analog positive sine output
5	SIN_P2	O	Not connected	Die 2 Analog positive sine output
6	SIN_N2	O	Not connected	Die 2 Analog negative sine output
7	$V_{DD}2$		Not connected	Die 2 Supply voltage
8	$V_{DIAG}2$	O	Not connected	Die 2 bridge voltage proportional to temperature. Diagnostic function
9	GND2		Not connected	Die 2 Ground
10	GND2		Not connected	Die 2 Ground
11	COS_N2	O	Not connected	Die 2 Analog negative cosine output
12	COS_P2	O	Not connected	Die 2 Analog positive cosine output
13	COS_P1	O	Die 1 Analog positive cosine output	Die 1 Analog positive cosine output
14	COS_N1	O	Die 1 Analog negative cosine output	Die 1 Analog negative cosine output
15	GND1		Die 1 Ground	Die 1 Ground
16	GND1		Die 1 Ground	Die 1 Ground

1.5 Dual Die Angle Output

The TLE5009A16D comprises two GMR sensor ICs mounted on the top and bottom of a package leadframe in a flipped configuration, so the positions of the sensitive elements in the package-plane coincide. This mounting technique ensures a minimum deviation of the magnetic field orientation sensed by the two chips.

Due to the flipped mounting, the two GMR ICs sense opposite rotation directions. This behavior is illustrated in Figure 6, which shows the angle calculated from the output of the two dice, respectively, for a given external magnetic field orientation.
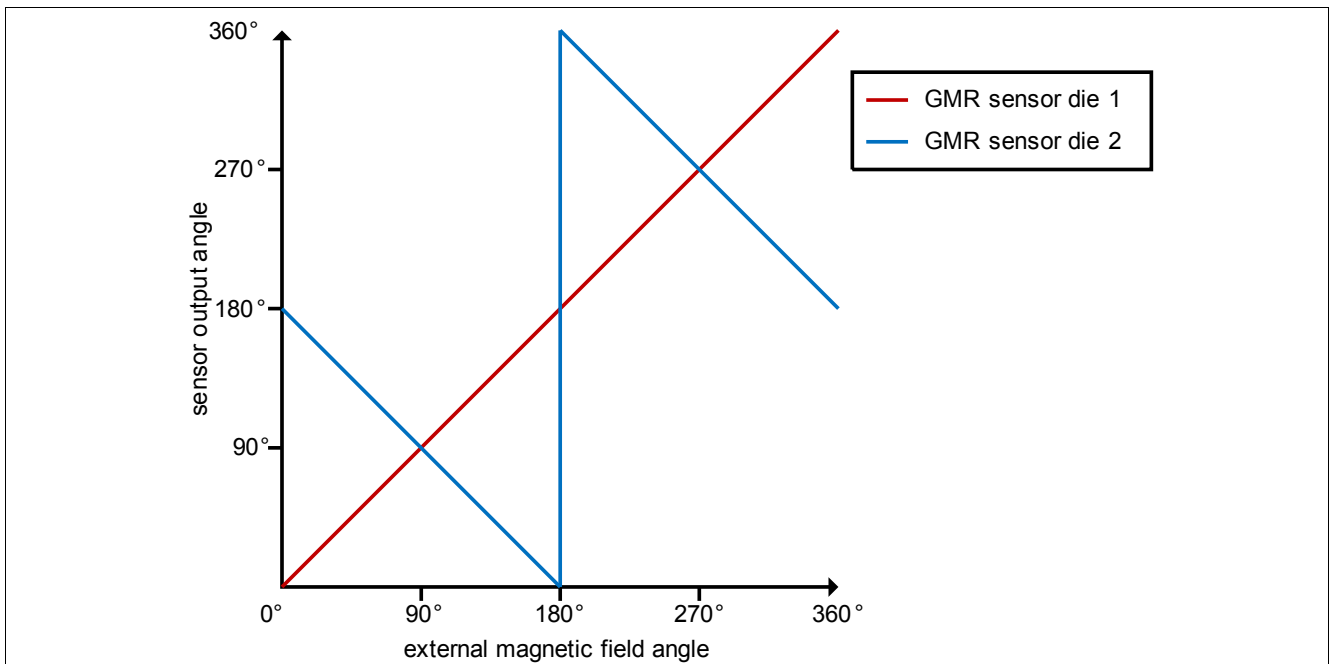

Figure 6   Dual die angle output

Attention: The positioning accuracy of each sensor IC in the package is ±3°. Thus, the relative rotation of the two sensor ICs can be up to 6°, resulting in a constant offset of the angle output of up to 6°, which has to be measured in an end-of-line calibration and taken into account during operation of the TLE5009A16D.

2 Specification

2.1 Application Circuit

The TLE5009A16(D) sensor can be used in single-ended or differential output mode. Figure 7 shows a typical application circuit for the TLE5009A16D in single-ended output mode using the positive output channels. For single-ended operation the positive or negative output channels can be used. Unused single-ended output pins should preferably be floating or connected to GND with a high-ohmic resistance (> 100 kΩ). The TLE5009A16D has separate supply pins for the two GMR sensor dice. The microcontroller comprises up to 10 A/D inputs used to receive the sensor output signals in differential output mode, illustrated in Figure 8. For reasons of EMC and output filtering, the following RC low pass arrangement is recommended. The RC low pass has to be adapted according to the applied rotation speed[1].

The recommended application circuit for the TLE5009A16 is identical, with the pins of die 1 connected only.
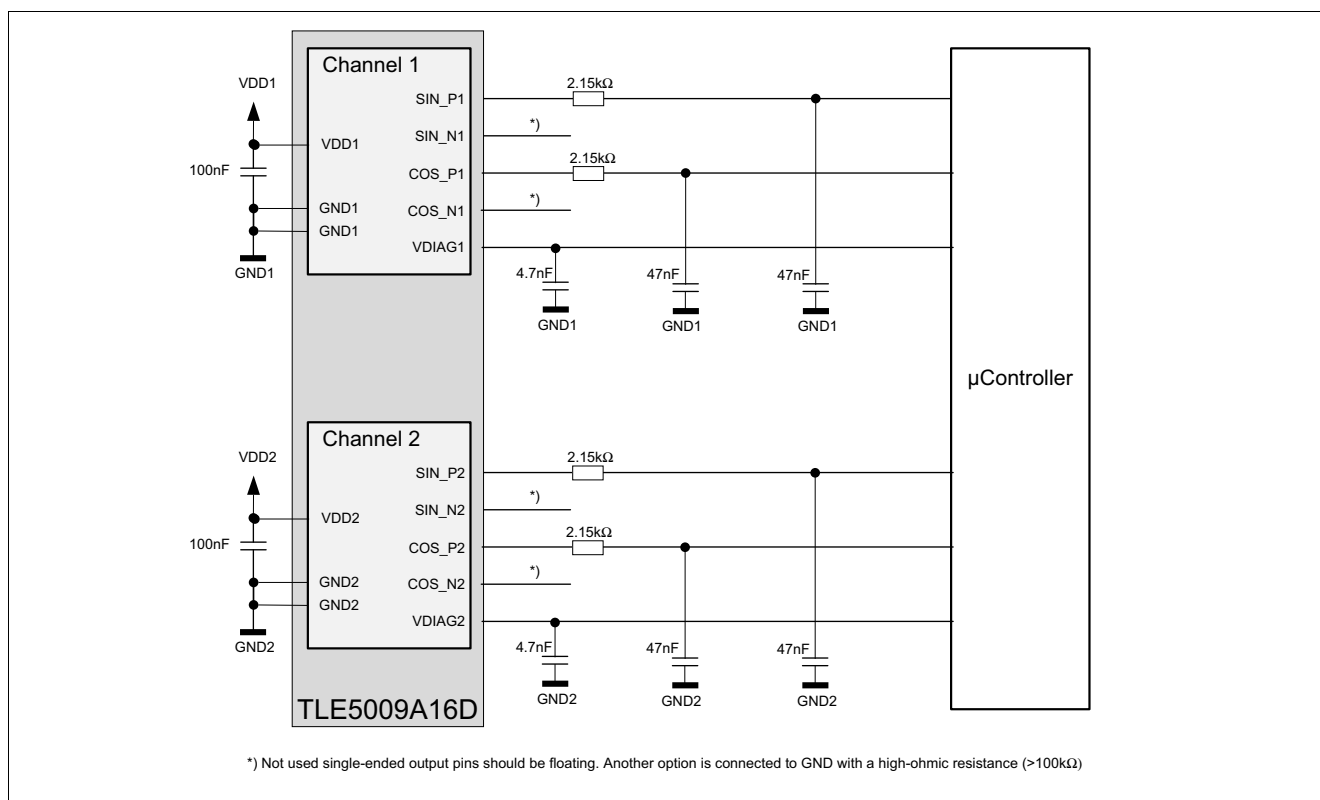

Figure 7 Application circuit for the TLE5009A16D in single-ended output mode; positive output channels used

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1) E. g. the RC low pass with R=2.15kΩ and C=47nF is appropriate for a rotation speed up to 60,000 rpm.
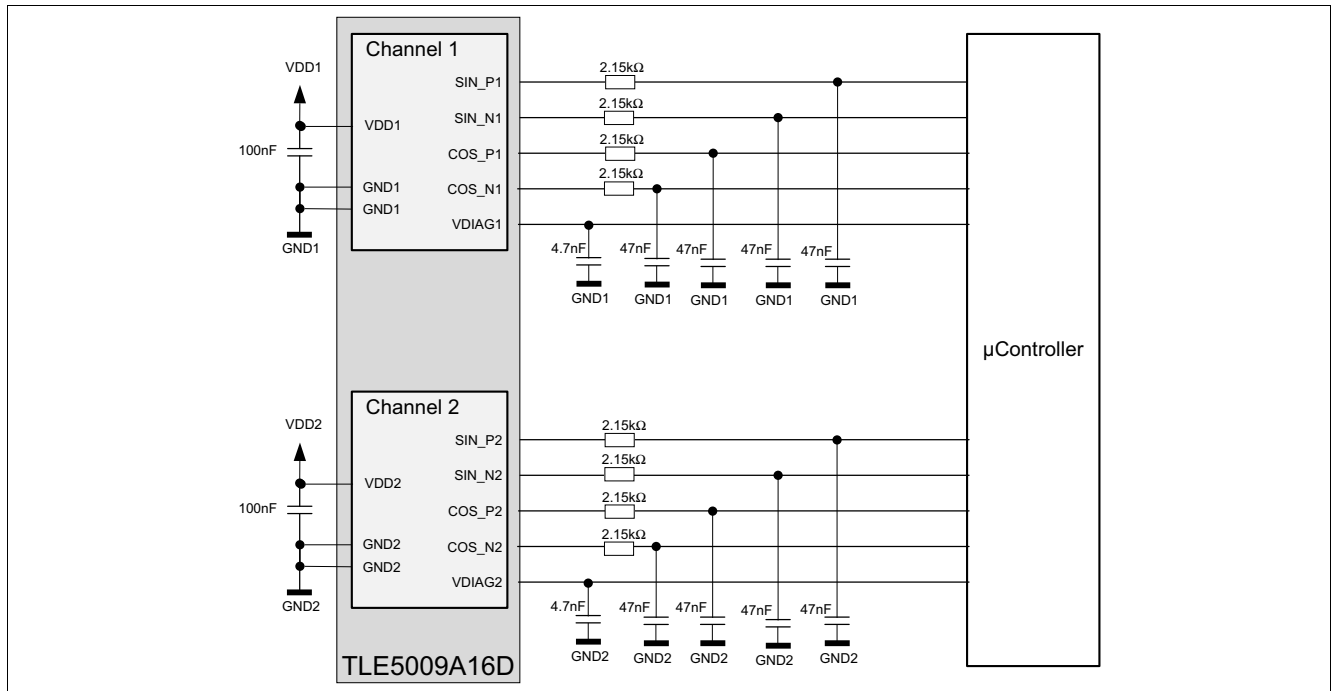
Specification

Figure 8   Application circuit for the TLE5009A16D in differential output mode.

Pull-down resistors for partly diagnostics

It is also possible to use pull-down resistors to get partly diagnostics. With this setting it is not required to use the V_{DIAG} pin. The application circuit with pull-down resistors is shown in Figure 9 for single-ended output respectively in Figure 10 for differential output. For further details please refer to the Safety Manual.

*) $100k\Omega < R < 500k\Omega$

**) VDIAG is an output pin and can be floating. Another option is connected to GND with a high-ohmic resistance (e.g. 100kΩ)

***) Not used single-ended output pins should be floating. Another option is connected to GND with a high-ohmic resistance (>100kΩ)
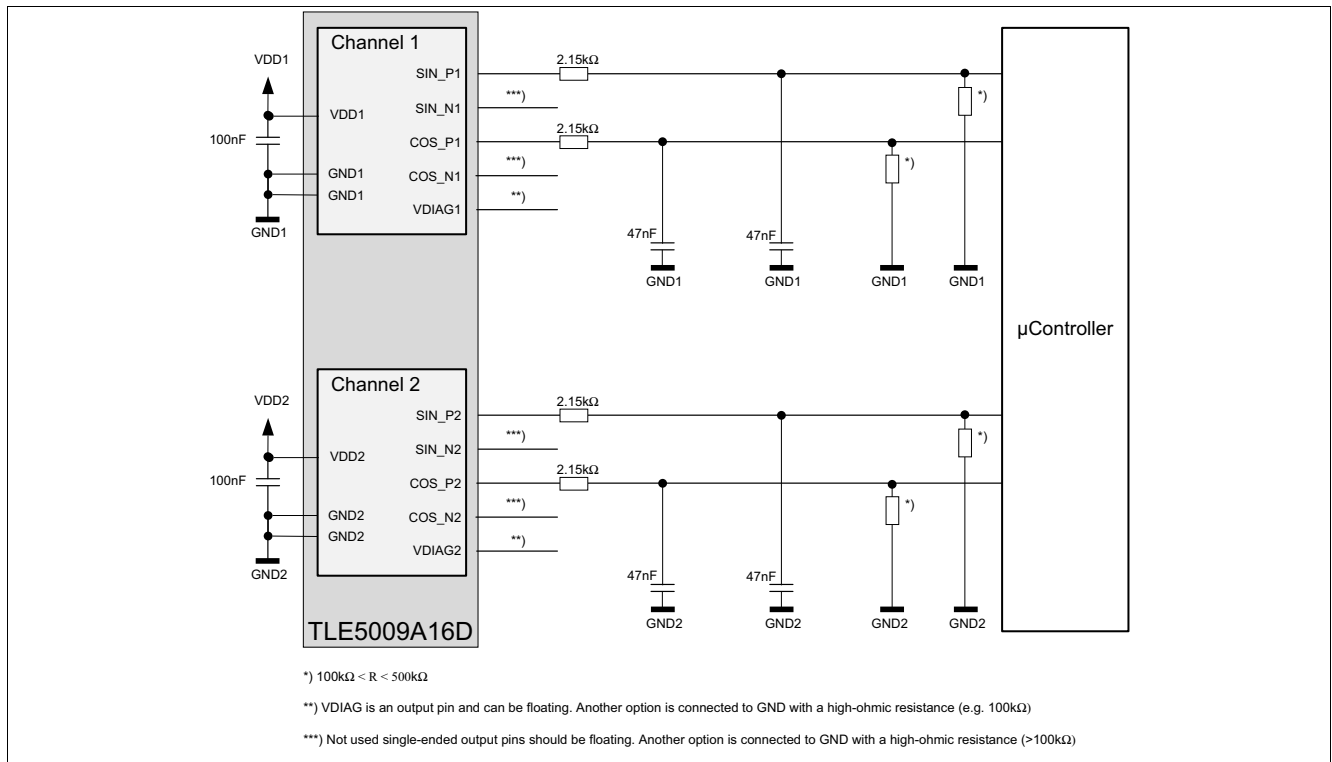
Figure 9   Application circuit for the TLE5009A16D for partial diagnostics with pull-down resistors in single-ended output mode; positive output channels used
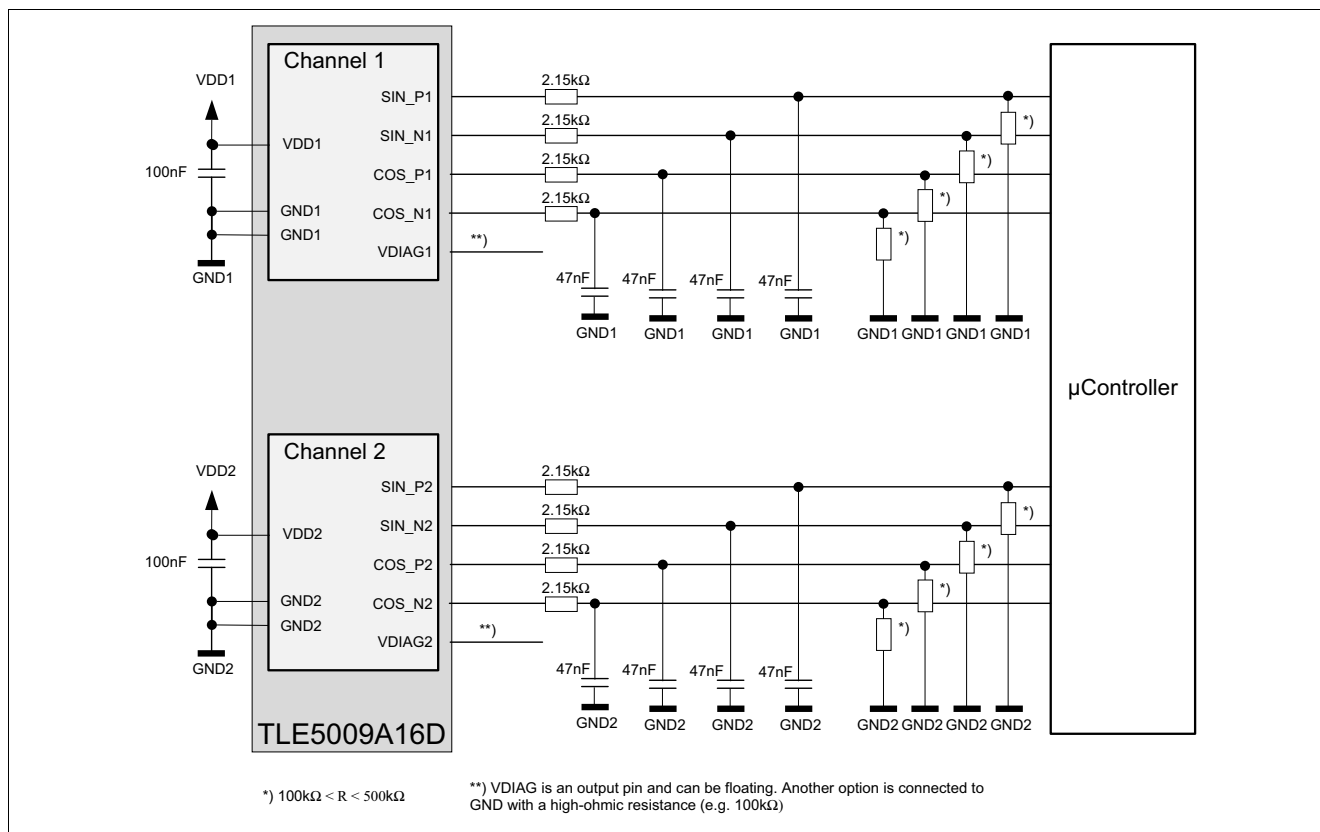
Figure 10 Application circuit for the TLE5009A16D for partial diagnostics with pull-down resistors in differential output mode

2.2 Absolute Maximum Ratings

Table 3 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	-0.5		6.5	V	Max 40 h over lifetime
Ambient temperature[1]	T_A	-40		140	°C	
Magnetic field induction	|B|			200	mT	Max. 5 min at $T_A = 25°C$
				150	mT	Max. 5 h at $T_A = 25°C$

1) Assuming a thermal resistance of the sensor assembly in the application of 150 K/W or less.

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.*

2.3 Sensor Specification

The following operating conditions must not be exceeded in order to ensure correct operation of the TLE5009A16(D). All parameters specified in the following sections refer to these operating conditions, unless otherwise noted. Table 4 is valid for -40°C < T_A < 125°C and through the TLE5009A16(D) lifetime.

2.3.1 Operating Range

Table 4   Operating range

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Ambient temperature[1]	T_A	-40		125	°C	
Supply voltage[2]	$V_{DD, GMR}$	3.0	3.3	3.6	V	E1200, E1210
		4.5	5	5.5	V	E2200, E2210
Output current[3][4]	I_Q	0		0.5	mA	COS_N; COS_P; SIN_N; SIN_P
		0		0.1	mA	V_{DIAG}
Load capacitance[3][5]	C_L	0		4.7	nF	all output pins
Magnetic field[3][6][7]	B_{XY}	24		60	mT	in X/Y direction, at T_A = 25°C
		26		100	mT	in X/Y direction, at T_A = -40°C
		21		50	mT	in X/Y direction, at T_A = 125°C
Angle range	α	0		360	°	
Rotation speed[3][8]	n			30,000	rpm	
				150,000	rpm	No signal degradation observed in lab

1) Assuming a thermal resistance of the sensor assembly in the application of 150 K/W or less.
2) Supply voltage V_{DD} buffered with 100 nF ceramic capacitor in close proximity to the sensor.
3) Not subject to production test - verified by design/characterization.
4) Assuming a symmetrical load.
5) Directly connected to the pin.
6) Values refer to a homogenous magnetic field (B_{XY}) without vertical magnetic induction (B_Z = 0 mT).
7) Min/Max values for magnetic field for intermediate temperatures can be obtained by linear interpolation.
8) Typical angle propagation delay error is 1.62° at 30,000 rpm.

2.3.2 Electrical Parameters

The indicated electrical parameters apply to the full operating range, unless otherwise specified. The typical values correspond to the specified supply voltage range and 25°C, unless individually specified. All other values correspond to -40°C < T_A < 125°C and through the TLE5009A16(D) lifetime.

Table 5   Electrical parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Supply current	I_{DD}		7	10.5	mA	per sensor IC, without load on output pins
POR level	V_{POR}	2.3	2.65	2.97	V	Power-On Reset
POR hysteresis[1]	V_{PORhy}		50		mV	

Table 5   Electrical parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Power-On time[2]	t_{PON}		40	70	µs	settling time to 90% of full output voltages
Temperature reference voltage	V_{DIAG}	0.5	1.05	2.0	V	**Temperature proportional** output voltage; available on pin **V**DIAG
Diagnostic function	V_{DIAG}	0		0.39	V	**Diagnostic** for internal errors; available on pin **V**DIAG
Temperature coefficient of V_{DIAG}[1]	TC_{VDIAG}		0.4		%/K	

1)   Not subject to production test - verified by design/characterization.

2)   Time measured at chip output pins.

2.3.3   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. For variable names please refer to Figure 11 "Single-ended output signals" on Page 14 and Figure 12 "Differential output of ideal cosine" on Page 15.

The following equations describe various types of errors that combine to the overall angle error.

The maximum and zero-crossing of the SIN and COS signals do not occur at the precise angle of 90°. The difference between the X and Y phases is called the **orthogonality** error. In Equation (2.1) the angle at zero crossing of the **X** COS output is subtracted from the angle at the maximum of the **Y** SIN output, which describes the orthogonality of X and Y.

$$\varphi = \alpha [Y_{max}] - \alpha [X_0] \tag{2.1}$$

The amplitudes of SIN and COS signals are not equal to each other. The amplitude mismatch is defined as **syncronism**, shown in Equation (2.2). This value could also be described as amplitude ratio mismatch.

$$k = 100 \quad * \quad \frac{A_X}{A_Y} \tag{2.2}$$

The sensor outputs 4 single-ended signals SIN_N, SIN_P, COS_N and COS_P, which are centered at the voltage offset of $0.5*V_{DD}$. The **differential signals** are calculated from the single-ended signals. The differential voltages for X or Y are defined in Equation (2.3).

$$V_{Xdiff} = V_{COSP} - V_{COSN}$$
$$V_{Ydiff} = V_{SINP} - V_{SINN} \tag{2.3}$$

The maximum amplitudes for the differential signals are centered at 0 V and defined for X or Y as given in Equation (2.4):

$$A_{Xdiff} = \frac{(X_{diff\_MAX} - X_{diff\_MIN})}{2}$$
$$A_{Ydiff} = \frac{(Y_{diff\_MAX} - Y_{diff\_MIN})}{2} \tag{2.4}$$

Specification

Differential offset is of X or Y is defined in Equation (2.5).

$$O_{Xdiff} = \frac{(X_{diff\_MAX} + X_{diff\_MIN})}{2}$$

$$O_{Ydiff} = \frac{(Y_{diff\_MAX} + Y_{diff\_MIN})}{2}$$

(2.5)

In **single-ended mode** the offset is defined as the mean output voltage and equals typically $0.5*V_{DD}$. For further details please refer to the application note **"TLE5009 Calibration"**.

Table 6   Single-ended output parameters over temperature and lifetime

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
X, Y amplitude	A_X, A_Y	0.7		1.3	V	sensors with 3.3 V supply
		1.2		1.95	V	sensors with 5.0 V supply
X, Y synchronism	k	94	100	106	%	
X, Y orthogonality error	φ	-12		12	°	
Mean output voltage	V_{MVX}, V_{MVY}	$0.47*V_{DD}$	$0.5*V_{DD}$	$0.53*V_{DD}$	V	$V_{MV}=(V_{max}+V_{min})/2$[1]
X,Y cut off frequency[2]	f_c		30		kHz	-3 dB attenuation
X,Y delay time[2][3]	t_{adel}		9		µs	
Output noise[2]	V_{Noise}		5		mV	RMS

1) Vmax and Vmin correspond to the maximum and minimum voltage levels of the X and Y signals respectively.
2) Not subject to production test - verified by design/characterization.
3) Time measured at chip output pins.
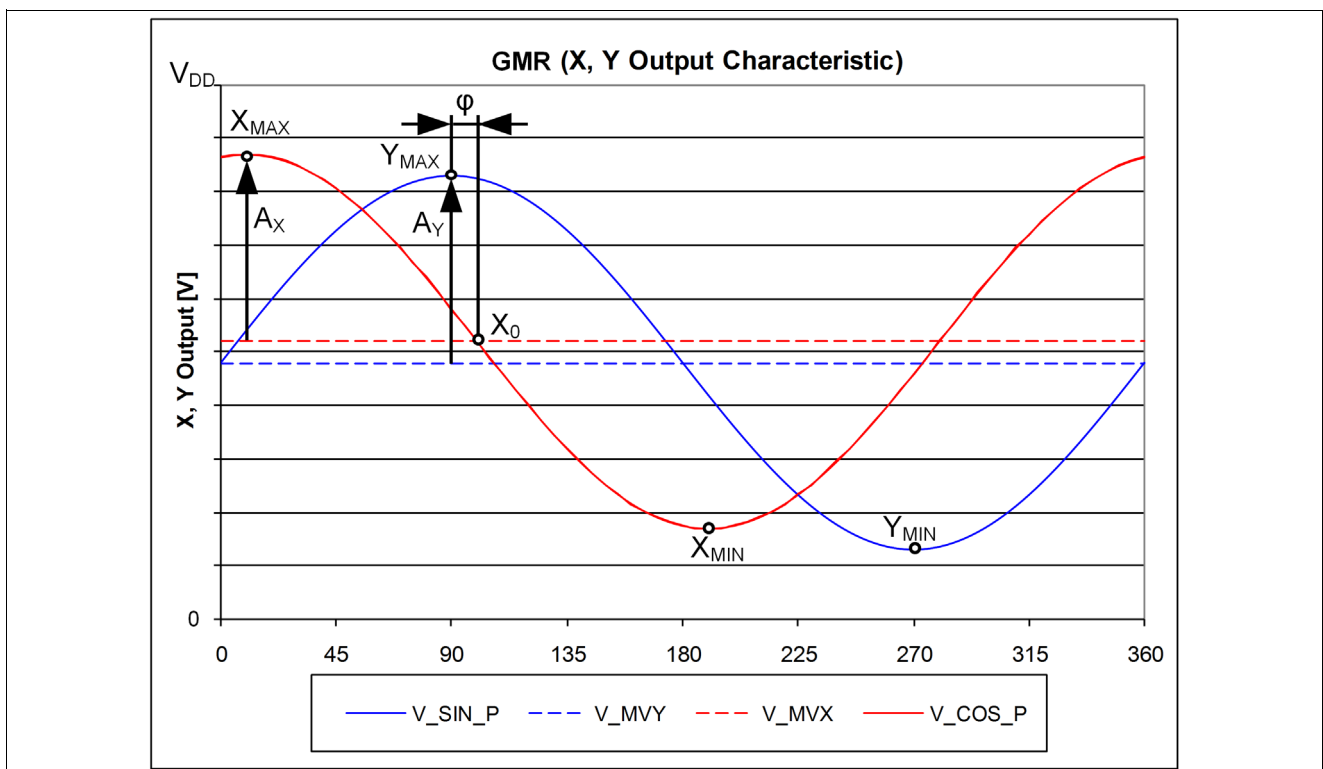
Figure 11   Single-ended output signals

Table 7 Differential output parameters over temperature and lifetime

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
X, Y amplitude	A_{Xdiff}, A_{Ydiff}	1.4		2.6	V	sensors with 3.3 V supply
		2.4		3.9	V	sensors with 5.0 V supply
X, Y synchronism	k	94	100	106	%	
X, Y orthogonality error	φ	-12		12	°	
X, Y offset	O_{Xdiff}, O_{Ydiff}	-100	0	100	mV	
X,Y cut-off frequency[1]	f_c		30		kHz	-3dB attenuation
X,Y delay time[1][2]	t_{adel}		9		µs	
Vector Length (V_{VEC} = Sqrt(X_{Diff}^2 + Y_{Diff}^2))[3]	V_{VEC}	1.5		2.8		sensors with 3.3 V supply
		2.5		3.9		sensors with 5.0 V supply
Output noise[1]	V_{Noise}		5		mV	RMS

1) Not subject to production test - verified by design/characterization.
2) Time measured at chip output pins.
3) Vector length check described in the TLE5009 Safety Manual.

Figure 12 Differential output of ideal cosine

TLE5009A16(D)
GMR Angle Sensor
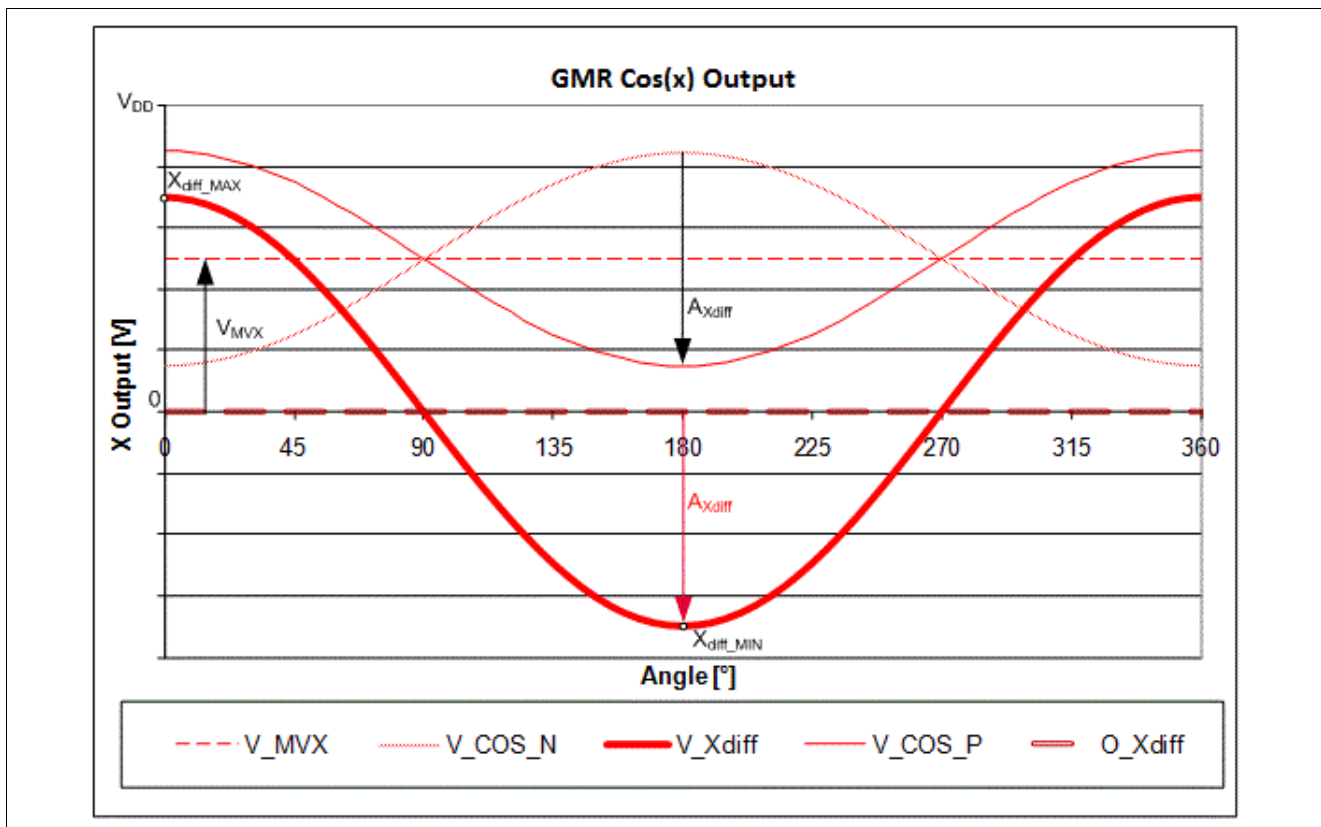
Specification

2.4 Error diagnosis

Each sensor provides two functions at its V_{DIAG} pin. During normal operation the voltage measured at this pin is temperature dependent. The typical voltage at room temperature and the temperature coefficient are given in Table 5 "Electrical parameters" on Page 12.

The second purpose of pin V_{DIAG} is the diagnosis functionality. In case the device detects an internal error, the pin is driven to a low level. The errors that can be detected by monitoring the status of the V_{DIAG} pin are:

- Overvoltage at V_{DD} (supply)
- Undervoltage at V_{DD} (supply)
- Undervoltage at internal nodes (analog voltage regulator and/or GMR voltage regulator)
- Bandgap failure
- Oscillator failure (only tested at startup)
- Parity check of configuration fuses (only tested at startup)

2.5 Angle Performance

The overall angle error represents the relative angular error. This error describes the deviation from the reference line after zero angle definition. The typical value corresponds to an ambient temperature of 25°C. All other values correspond to the operating ambient temperature range -40°C < T_A < 125°C and through the TLE5009A16(D) lifetime.

Fully compensated performance (ongoing calibration)

Using the algorithm described in the application note "TLE5009 Calibration", it is possible to implement an ongoing automatic calibration on the microcontroller to greatly improve the performance of the TLE5009A16(D) in applications where a rotor is turning continuously.

With this autocalibration algorithm, it is possible to reach an angular accuracy as good as the residual error of the sensing elements, which means the remaining error after perfect compensation of offset, amplitude synchronicity mismatch and orthogonality error. A typical behavior of a fully compensated angle error with this ongoing calibration is shown in Figure 13 for different temperatures. The accuracy of the fully compensated angle is listed in Table 8, which is divided into single-ended and differential output of the sensor.

Table 8   Residual angle error over temperature and lifetime[1]

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Fully compensated angle error (single-ended)[2][3]	$\alpha_{ERR,C}$		< 0.6	0.9	°	
Fully compensated angle error (differential)[2]	$\alpha_{ERR,C}$		< 0.6	0.9	°	

1) After perfect compensation of offset, amplitude synchronicity mismatch and orthogonality error.
2) Including hysteresis error.
3) Assuming a symmetrical load.

Angle Performance with one-time calibration

After assembly of the TLE5009A16(D) in a sensor module, the sensor IC(s) in the TLE5009A16(D) have to be end-of-line calibrated for offset, synchronism and orthogonality error at 25°C and the compensation parameters have to be stored and applied on the microcontroller. For the detailed calibration procedure refer to the

application note "TLE5009 Calibration". Table 9 characterizes the accuracy of the angle, which is calculated from the single-ended output respectively the differential output of the sensor and the compensation parameters acquired in the end-of-line calibration.

Table 9   One- time calibrated angle error over temperature and lifetime

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Angle error (single-ended)[1][2]	α_{ERR}			4.8	°	E1200, E2200
				4.0	°	E1210, E2210
Angle error (differential)[1]	α_{ERR}			3.8	°	E1200, E2200
				3.0	°	E1210, E2210

1) Including hysteresis error.
2) Assuming a symmetrical load.

Typical behaviour of angle error compensation

The angle accuracy performance for ideal compensation and one-time compensation is listed in Table 8 respectively in Table 9. Figure 13 shows the typical behavior of the residual angle error with ongoing respectively one-time calibration at different ambient temperatures and demonstrates the superior performance of the full compensation method over lifetime and temperature with an average residual error below 0.6° operating in the specified magnetic field. With one-time compensation an additional residual angle error occurs due to the temperature dependency of the sensor.
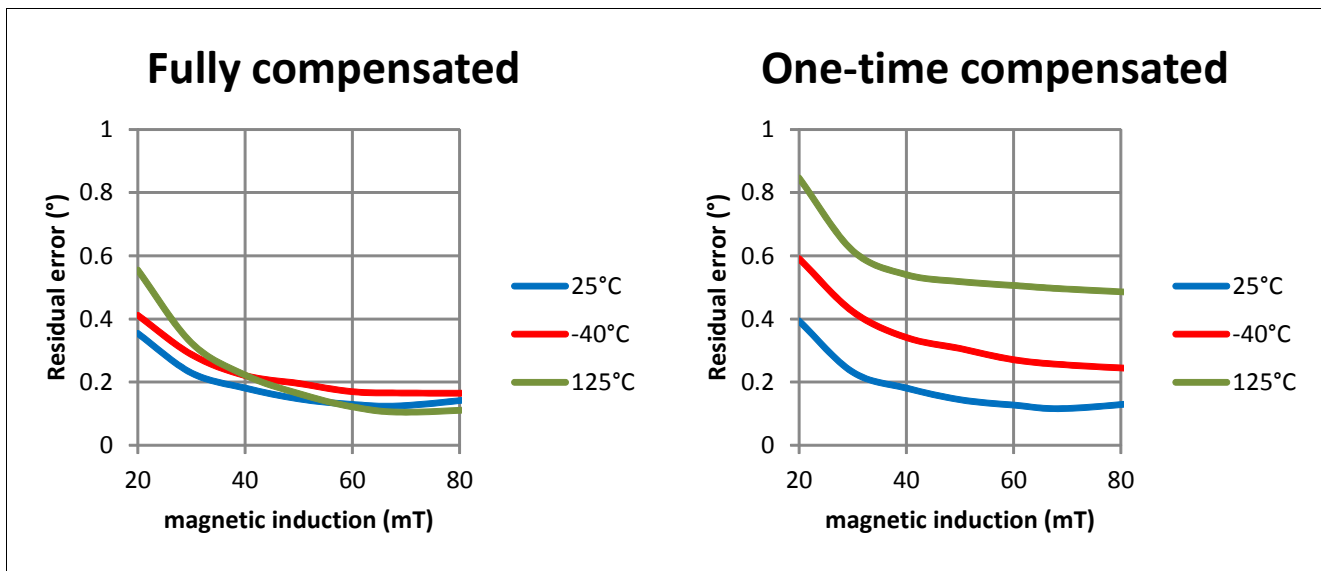
Figure 13   Typical residual angle error of fully and one-time compensated sensor for differential output at different temperatures (measured at 0 h); one-time compensation is calibrated at T = 25°C and B = 40 mT; TLE5009A16(D) derivative with TCO[1] and 3.3 V supply voltage is used

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1) Temperature Compensation Offset

2.6 Electrostatic discharge protection

Table 10   ESD protection for TLE5009A16 (single die)

Parameter	Symbol	Values		Unit	Notes
		min.	max.		
ESD voltage	V_{HBM}		±4.0	kV	[1]
	V_{CDM}		±0.5	kV	[2]
			±0.75	kV	[2] for corner pins

1) Human Body Model (HBM) according to: ANSI/ESDA/JEDEC JS-001.
2) Charged Device Model (CDM) according to: JESD22-C101.

Table 11   ESD protection for TLE5009A16D (dual die)

Parameter	Symbol	Values		Unit	Notes
		min.	max.		
ESD voltage	V_{HBM}		±4.0	kV	[1] ground pins connected
			±2.0	kV	[1]
	V_{CDM}		±0.5	kV	[2]
			±0.75	kV	[2] for corner pins

1) Human Body Model (HBM) according to: ANSI/ESDA/JEDEC JS-001.
2) Charged Device Model (CDM) according to: JESD22-C101.

2.7 Electro Magnetic Compatibility (EMC)

The TLE5009A16(D) is characterized according to the EMC requirements described in the "Generic IC EMC Test Specification" Version 1.2 from November 15, 2007. The classification of the TLE5009A16(D) is done for local pins.

3 Package Information

The TLE5009A16(D) is delivered in a green SMD package with lead-free plating, the same **PG-TDSO-16** package is used for the single die (TLE5009A16) and the dual die (TLE5009A16D) derivates.

3.1 Package Parameters

Table 12   Package parameters

Parameter	Symbol	Limit Values			Unit	Notes
		min.	typ.	max.		
Thermal Resistance	R_{thJA}		130	150	K/W	Junction-to-Air[1]
	R_{thJC}			35	K/W	Junction-to-Case
	R_{thJL}			70	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

3.2 Package Outline
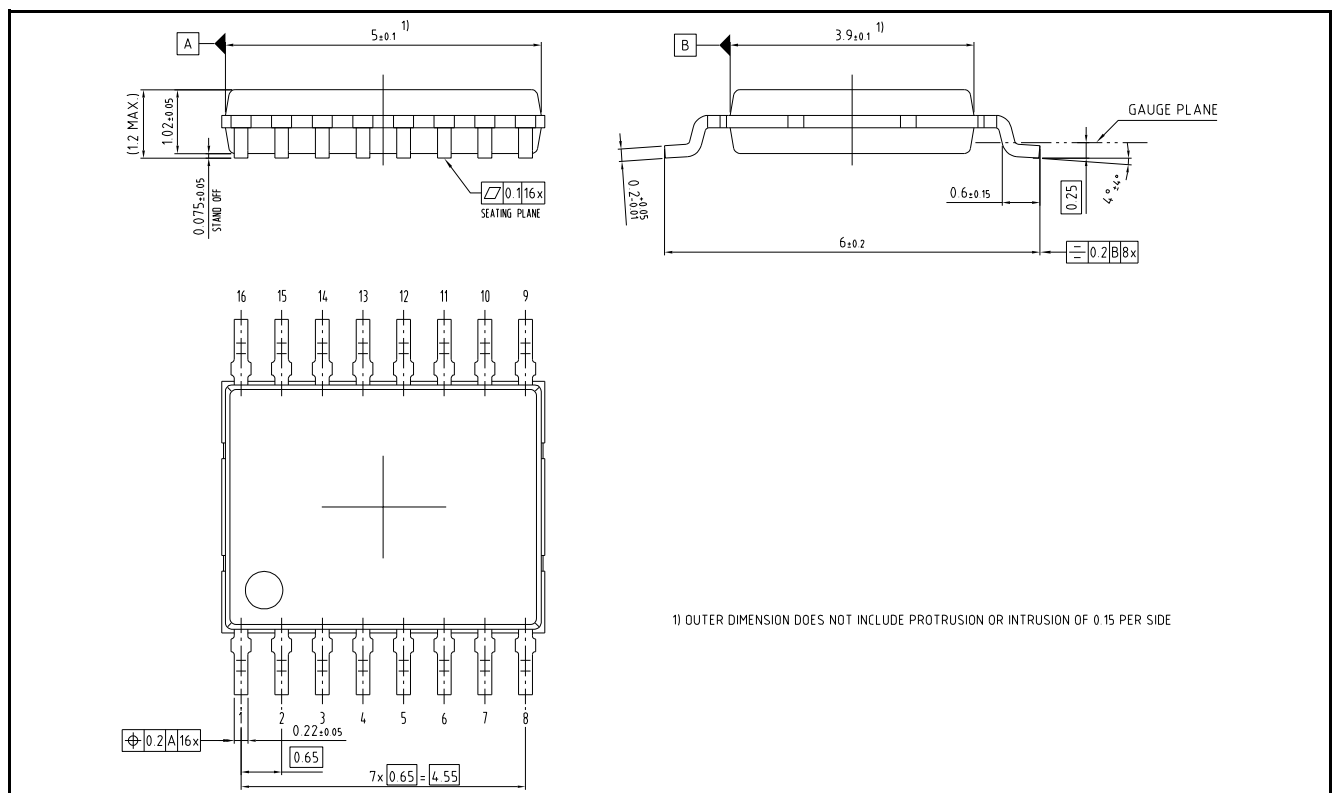
Figure 14   Package dimensions

Package Information
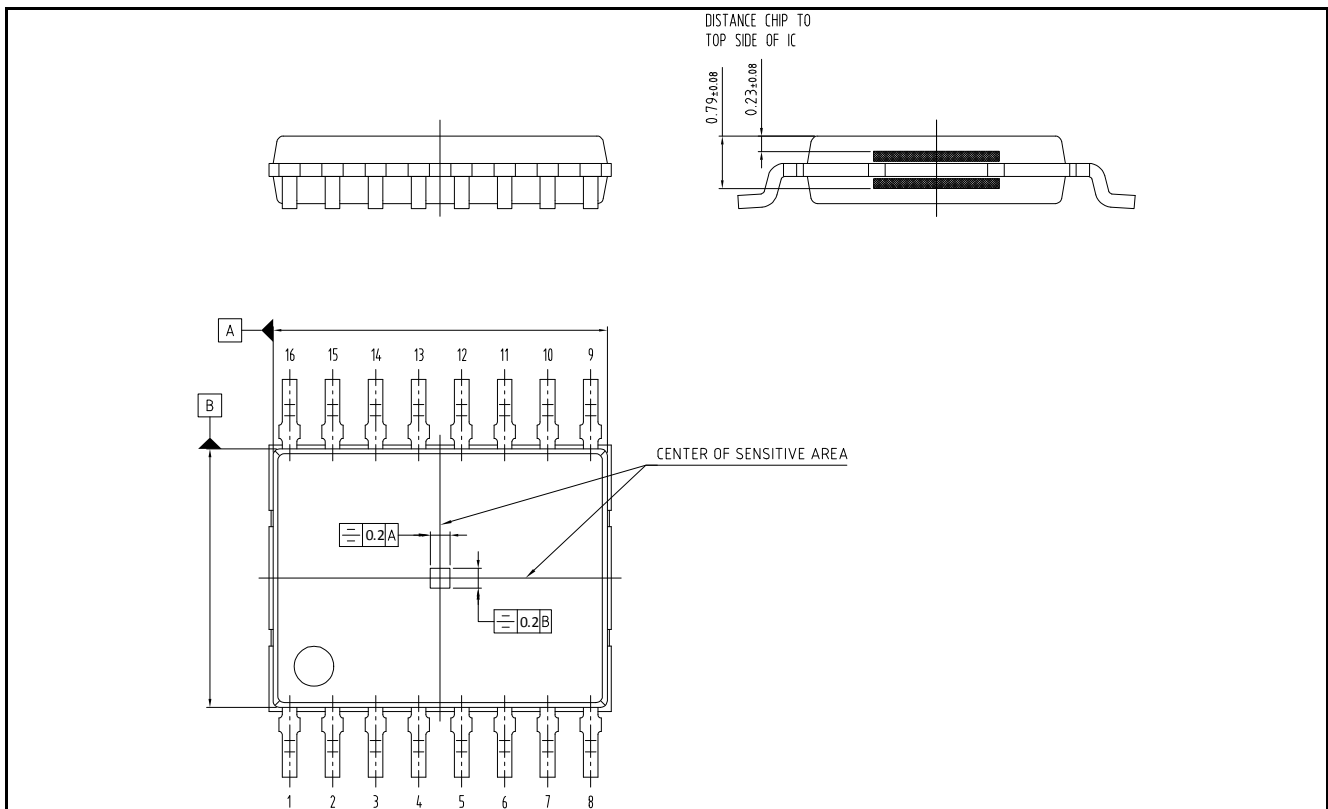
Figure 15   Position of sensing element

Note: Figure 15 shows the positioning of the two sensor dice in the TLE5009A16D. In the TLE5009A16, only the top die is mounted.

Table 13   Sensor IC placement tolerances in package

Parameter	Values		Unit	Notes
	Min.	Max.		
position eccentricity	-100	100	µm	in X- and Y-direction
rotation	-3	3	°	affects zero position offset of sensor
tilt	-3	3	°	

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

For further information on alternative packages, please visit our website:
http://www.infineon.com/packages.

Dimensions in mm
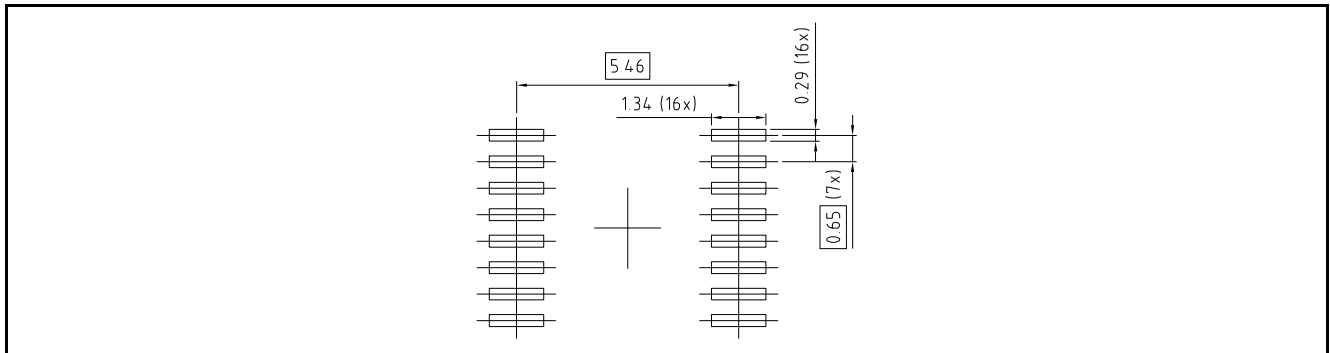
3.3 Footprint

Figure 16 Footprint

3.4 Packing
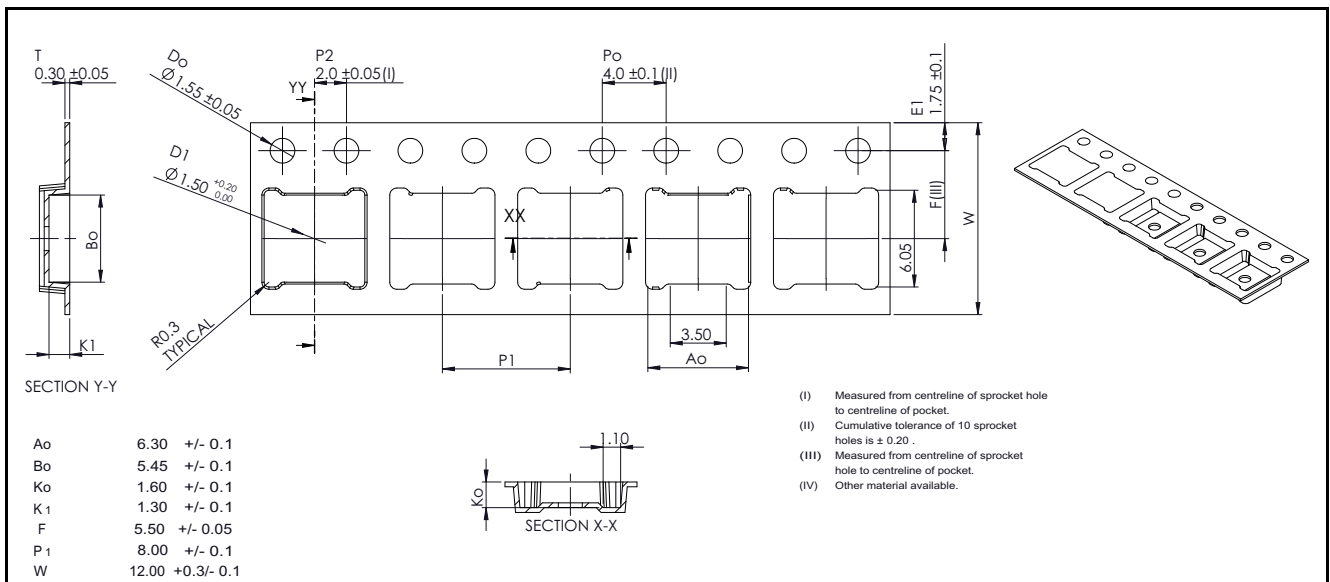
Figure 17 Tape and reel

3.5 Marking

The device is marked on the frontside with a data code, the device type and a lot code. On the backside there is a 8 x 18 data matrix code and an OCR-A code.

Position	Marking	Description
1st Line	Gxxxx	G..green, 4-digit..date code
2nd Line	09A1xxxx 09A2xxxx	single die dual die
3rd Line	xxx	Lot code

Package Information
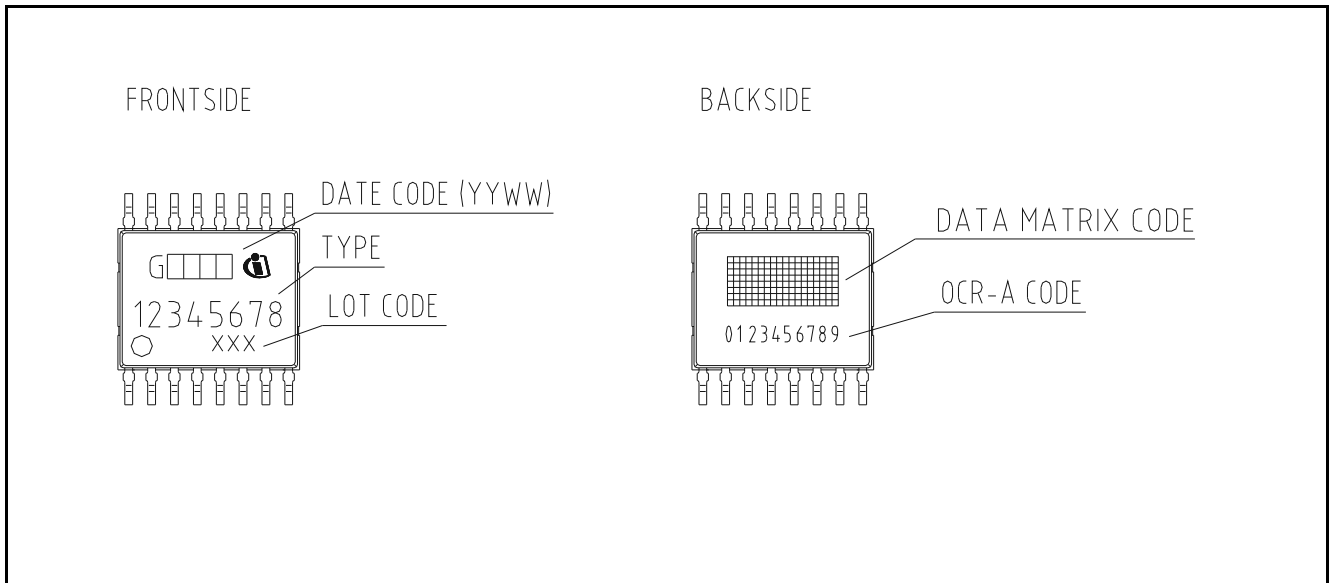
Figure 18   Marking

4 Revision History

Revision	Date	Changes
1.0	2016-06	Initial release
1.1	2017-04	Table 1: single die types added. Table 2: single die pin description added. Chapter 3: Table 6 splitted in single-ended and differential output parameters, type description replaced by VDD value. Figure 8 added (Single-ended output signals). Table 8: single-ended fully compensated angle error added. Table 9: single-ended angle error added. Chapter 3: Typical behavior of angle error compensation added. Figure 13: Typical residual angle error for full and one-time compensation added. Chapter 3: ESD protection splitted in single and dual die. Figure 15 added (Marking). Layout changed.
1.2	2017-10	Chapter References removed. Table 2: Pin description changed. Figure 7: Application circuit in single-ended output mode added. Figure 9: Application circuit for partial diagnostics with pull-down resistors in single-ended output mode added. Figure 10: Application circuit for partial diagnostics with pull-down resistors in differential output mode added. Table 6: single-ended output noise changed.