

# TLE5028C

## GMR Speed Sensor with best in class Jitter Performance



### Features

- Supporting misfire detection and precise ignition control with best-in-class jitter performance
- Very low current consumption of 7mA
- Advanced stop-start capabilities enabled by
  - Detection of rotation direction
  - Temperature compensation
  - Temperature watchdog
- Three-wire voltage interface short circuit protection
- Compatibility with a large range of magnetic wheels via dynamic self-calibration
- Digital diagnostic interface supports in-system end-of-line test
- Small sensor packages with integrated capacitors save space and enable design freedom
- Assembly instructions available

### Applications

- Optimized for automotive crankshaft applications with two available output protocols.
- Suitable for camshaft application.
- Position and rotation direction sensing with high resolution for industrial applications.

### Description

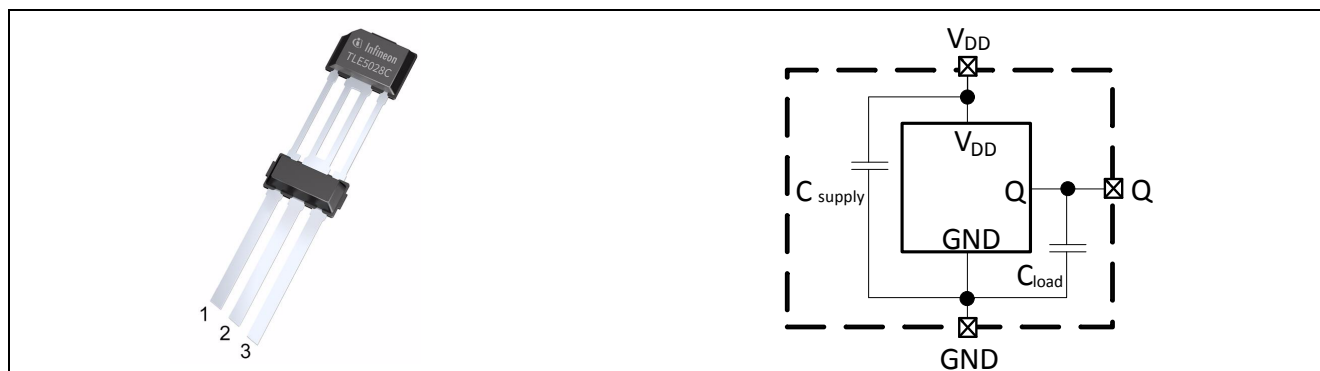
The TLE5028 product family is Infineon's next generation speed sensor. The successor of TLE5027/TLE5025 comes up with lower jitter and higher accuracy making it the best choice for crankshaft sensor modules but also suitable for the camshaft application. The sensor has a fast start up and switches with hidden adaptive hysteresis, which ensures high accuracy over air gap jumps, vibration and runout events. Its wide temperature range, as well as high ESD and EMC robustness make the TLE5028 product family the best choice for harsh automotive and industrial environmental conditions.

Product Type	Protocol	Marking	Ordering Code	Package
TLE5028C-XAA-D28	45/90μsec	28B1C3	SP001271356	PG-SSO-3-52
TLE5028C-XBA-D28	45/135μsec	28B1C4	SP001271360	PG-SSO-3-52
TLE5028C-XAI-D28	45/90μsec	28A1C5	SP001777442	PG-SSO-3-52
TLE5028C-XBI-D28	45/135μsec	28A1C6	SP001698888	PG-SSO-3-52

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# 1 Pin Configuration, Implemented capacitors and Block diagram



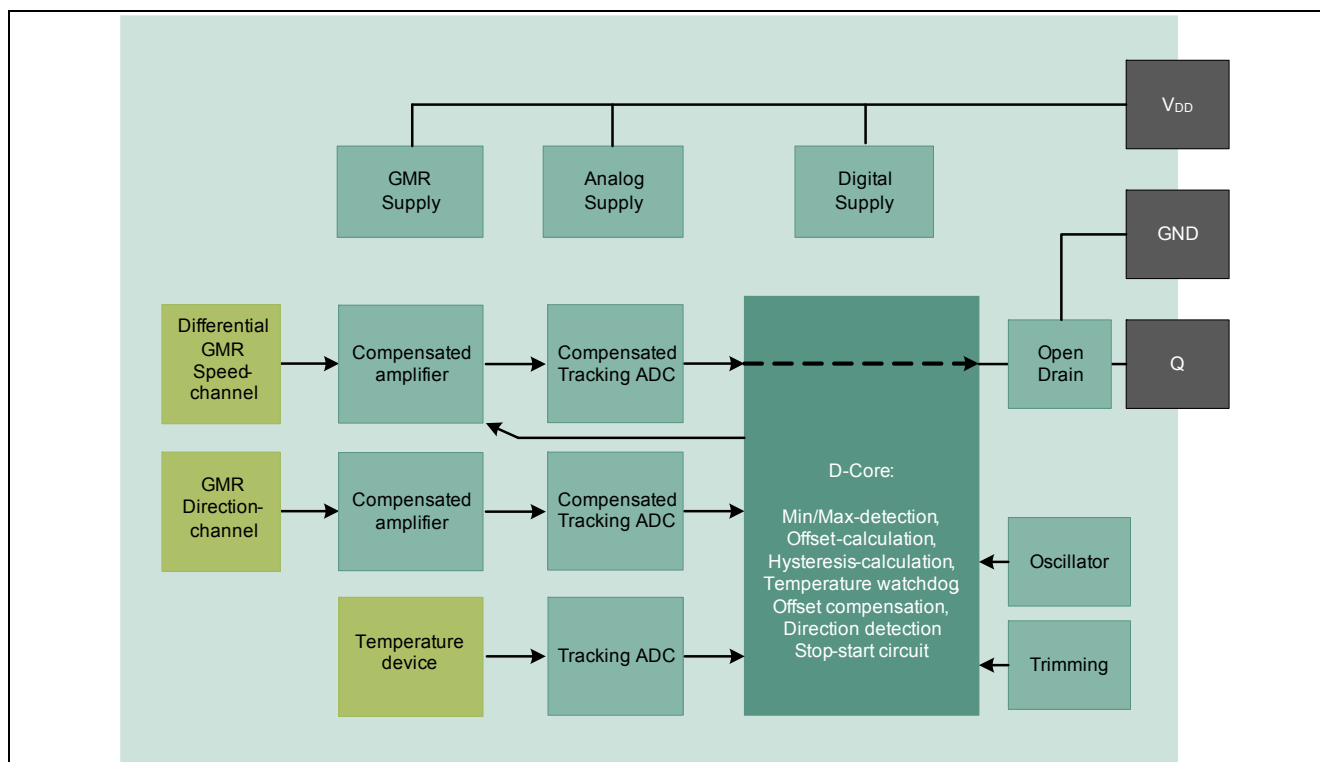
**Figure 1** Pin Configuration PG-SSO-3-52

**Table 1** Pin Definitions and Functions

Pin No.	Symbol	Function
1	$V_{DD}$	Supply voltage
2	GND	Ground
3	Q	Open drain output

**Table 2** Implemented capacitors in PG-SSO-3-52

Capacitor	Value
$C_{LOAD}$	1.8 nF
$C_{SUPPLY}$	220 nF



**Figure 2** Block Diagram

Functional Description

## 2 Functional Description

Counter Clock Wise (CCW) rotational direction is emitted as forward pulse at the signal output. Clock Wise (CW) rotational direction is emitted as backward pulse at the signal output. Forward output pulses are issued on the transition from south-pole to north pole. Backward output pulses are issued on the transition from north-pole to south pole.

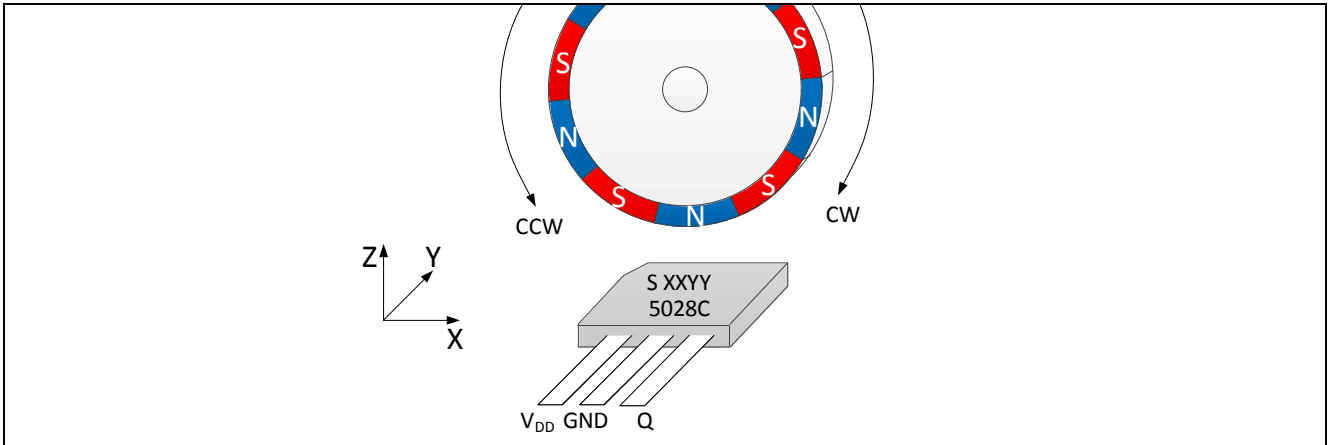


Figure 3 Definition of rotating direction

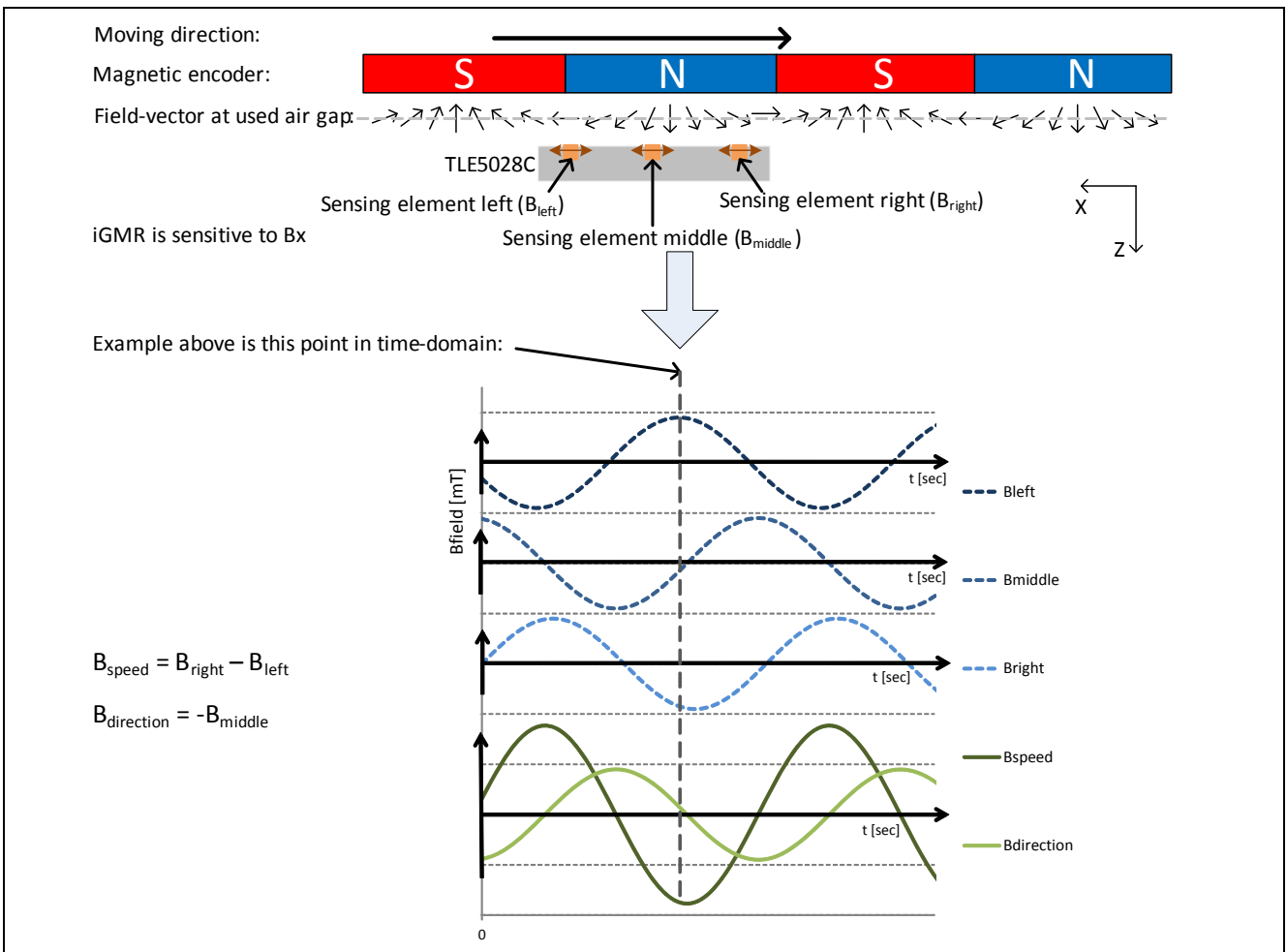


Figure 4 Definition of magnetic Speed-signal and magnetic Direction-signal

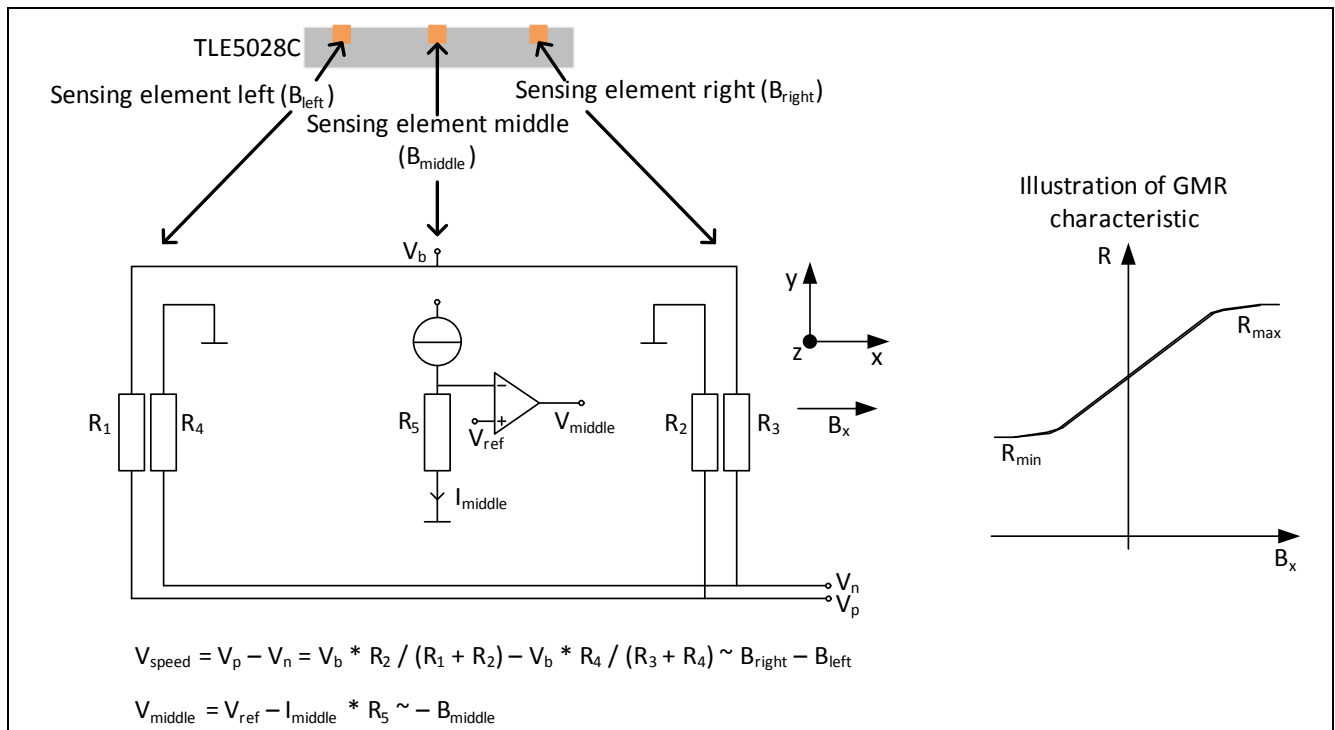
**Functional Description**

The basic operation of the TLE5028C is to detect the motion, position and rotation direction of a magnetized pole-wheel or of a toothed wheel (back bias application). For this purpose a full resistor bridge of GMR elements is integrated on the IC. Each half bridge, consisting of two GMR sensor elements, is in a spatial distance of 2.5 mm. The bridge is used to provide a differential speed signal. Magnetic signals and electrical signals have the same relationship in terms of polarity and phase.

A fifth GMR sensor element is used in order to obtain the direction information (see **Figure 5**).

Calculating the switching level is based on the computation of the average value between minima and maxima of the magnetic field's X-component of the input signal. Differential Hall sensors are sensitive to the Z-component of the field.

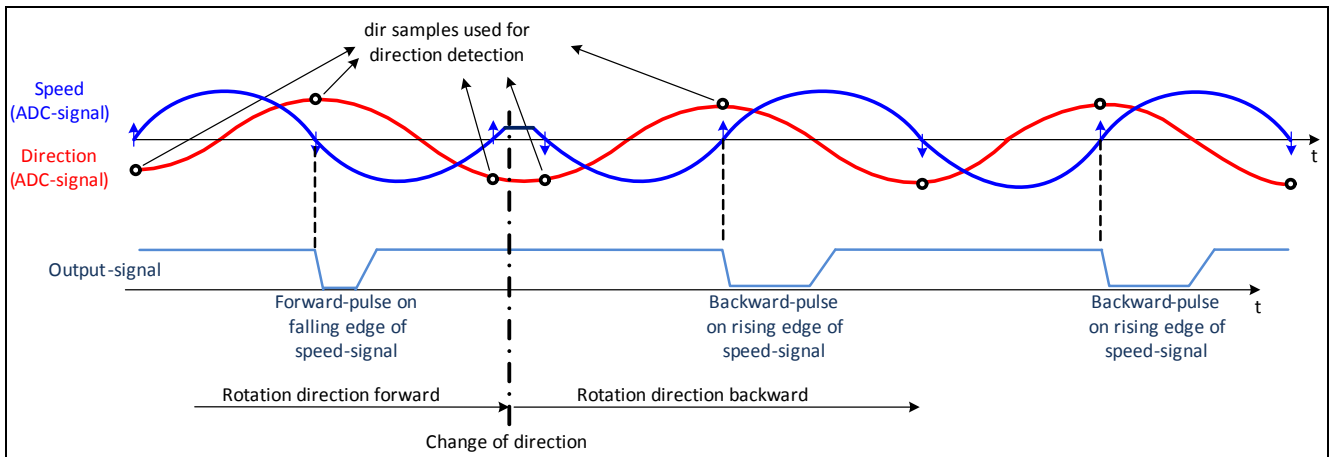
Due to nonlinearity of iGMR sensor this works only if at least two of the four sensing elements are operated in the linear range of the sensor characteristics: approximately +/- 5 mT  $B_x$ , see also GMR characteristic curve in **Figure 5**



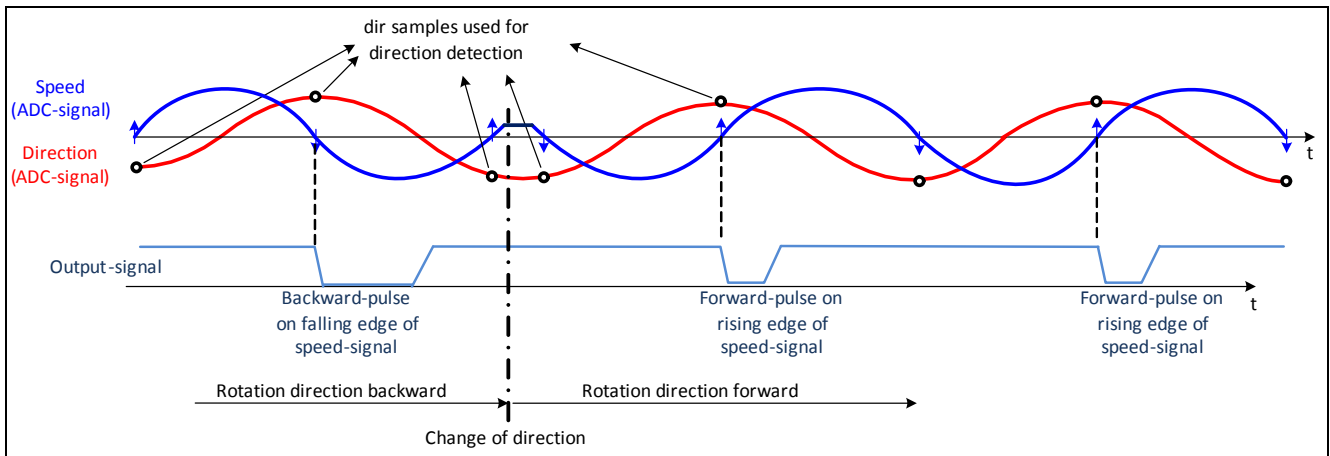
**Figure 5 Top view GMR full bridge configuration and GMR characteristic curve**

The direction is evaluated based on the three sensing element concept: right, left and center probes. The direction signal ( $-B_{middle}$ ) is sampled at the zero crossing of the speed signal ( $B_{right} - B_{left}$ ). The relation between speed signal and direction signal gives the direction information.

Functional Description



**Figure 6 Functional description of direction detection demonstrated at a change of direction: TLE5028C-XAA-D28, TLE5028C-XBA-D28**



**Figure 7 Functional description of direction detection demonstrated at a change of direction: TLE5028C-XAI-D28, TLE5028C-XBI-D28**

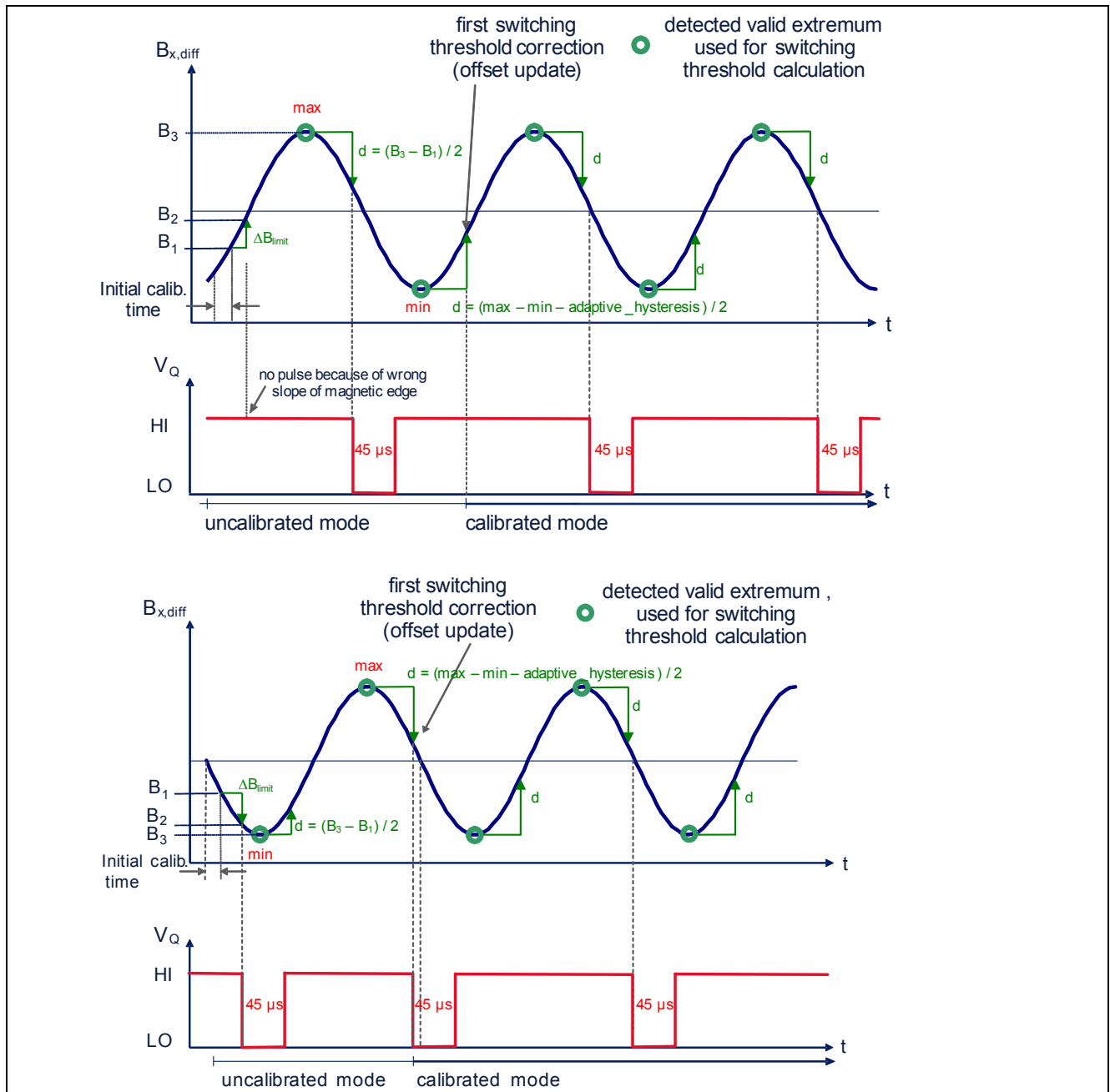
Depending on the phase shift of  $B_{speed}$  to  $B_{direction}$  the rotational direction is calculated. According to **Figure 6** a lagging  $B_{direction}$  indicates forward rotational direction. Typically the direction signal is  $90^\circ$  shifted. Rotational direction backwards is detected when  $B_{direction}$  is typically  $90^\circ$  ahead of the speed-signal.

The typical signal of a direction change is indicated in **Figure 6** where in the middle of the chart the rotational direction changes from forward to backward. If the difference of the direction samples in the speed zero crossing is very small compared to the last direction signal amplitude peak to peak, then a direction change is recognized.

Output forward pulse is issued on falling edge of  $B_{speed}$ , output backward pulse is issued on rising edge of  $B_{speed}$ .

The inverse types of TLE5028C changed rotational direction (inverse direction). Therefore the inverse types (TLE5028C-XAI-D28 and TLE5028C-XBI-D28) issue the forward-pulse at the same direction and position where the non inverse types (TLE5028C-XAA-D28 and TLE5028C-XBA-D28) issue the backward-pulse.

Functional Description



**Figure 8 Start-up behaviour and output signal triggering (direction forward). Drawing valid for TLE5028C-XAA-D28 and TLE5028C-XBA-D28**

The first output pulse is generated when the input field exceeds the minimal magnetic threshold “DBlimit”. This leads to reduced phase accuracy but ensures the first pulse occur on the first pole pair. After minimum and maximum are detected, output switching occurs at zero-crossing of the differential magnetic signal (Figure 8).

Due to missing direction information the first output pulse in uncalibrated mode is always stated as a forward pulse. This ensures:

- After startup, while direction is still undetected, a valid signal is issued.
- During any distortion at high engine speed the sensor will always start up with forward direction. The ECU will not be interrupted by a single backward-pulse which might confuse.

Electrical Parameters

### 3 Electrical Parameters

The listed characteristics are ensured over the operating range and lifetime of the integrated circuit.

#### 3.1 Typical Application Circuit

Typically two external components are used. Rload is mandatory as pull up for the open drain output.

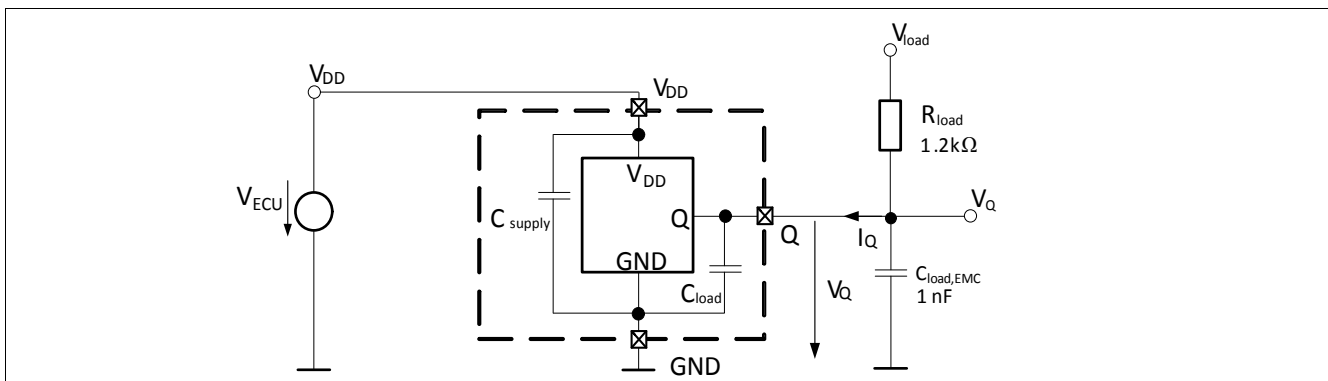


Figure 9 Application Circuit

#### 3.2 Absolute Maximum Ratings

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 integrated circuit.

Table 3 Absolute Maximum Ratings

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max		
Supply voltage	$V_{DD}$	-18	-	-	V	max. 1 min
		-	-	20	V	
	$V_{DD}$	-	-	28	V	max. 60 min
Supply current	$I_{DD}$	-10	-	20	mA	
Output OFF voltage	$V_Q$	-1	-	-	V	max. 60 min
		-0.3	-	20	V	
		-	-	28	V	max. 1 min; $T_a \leq 40^\circ\text{C}$
Output ON voltage	$V_Q$	-	-	20	V	
		-	-	28	V	max. 1 min; $T_a \leq 40^\circ\text{C}$
Maximum magnetic induction over life time	$B_x, B_y$	-300	-	300	mT	$T_j \leq 25^\circ\text{C}$ ; Conversion: $B = \mu_0 \times H$ ; $\mu_0 = 4 \times \pi \times 10^{-7} \text{ m.T/A}$
	$B_z$	-1000	-	1000	mT	
Passive overall life time	$T_{Pol}$	-		0.3	years	$V_{DD} = 0\text{V}$ ; $T_a = 150^\circ\text{C}$ ; lower temperature and longer duration according to Arrhenius-Model
		-		15	years	$V_{DD} = 0\text{V}$ ; $T_a = 50^\circ\text{C}$
ESD compliance	$ESD_{HBM}$	-6		+6	kV	HBM according ANSI/ESDA/JEDEC JS-001

Electrical Parameters

3.3 Operating Range

Table 4 Operating Range

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Supply voltage	$V_{DD}$	4.0	–	18	V	
		4.0	–	24	V	duration of 1 h during life time
Continuous output ON current	$I_Q$	0	–	15	mA	
Power on time	$t_{ON}^{1)}$	–	–	1	ms	
Operating junction temperature	$T_j$	-40	–	155	°C	2000 h (not additive)
		-40	–	165	°C	1000 h (not additive)
		-40	–	175	°C	168 h (not additive)
Magnetic field amplitude, x-Direction	$B_x$	-60	–	60	mT	Dynamic magnetic signal amplitude at the position of each GMR sensing element
Magnetic frequency	$f$	0	–	10	kHz	Magnetic parameters are characterized and valid between 1 Hz and 10 kHz

1) The parameter is not subject to production test. Verified by design/verification.

3.4 Electrical Characteristics

Unless individually specified, typical values correspond to a supply voltage  $V_{DD} = 5\text{ V}$  and  $T_j = 25\text{ °C}$

Table 5 Electrical Parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Supply current	$I_{DD}$	6.0	7.5	8.5	mA	
		6.0	7.5	8.2	mA	$V_{DD} = 5\text{ V}, 0\text{ °C} < T_j < 150\text{ °C}$
Reset voltage	$V_{reset}$	–	2.9	–	V	Measured on IC-leads, $T_j = 25\text{ °C}$
Output saturation voltage	$V_{QSAT}$	–	–	0.5	V	$I_Q = 15\text{ mA}$
		–	–	0.3 <sup>1)</sup>	V	$I_Q = 10\text{ mA}, T_j < 125\text{ °C}$
		–	–	0.15 <sup>1)</sup>	V	$I_Q = 4\text{ mA}, T_j < 125\text{ °C}$
Output leakage current	$I_{QLEAK}$	–	–	10	µA	$V_Q = 18\text{ V}$
Current limit for short-circuit protection	$I_{QSHORT}$	–	62	80	mA	valid for rms current
Output fall time	$t_f^{2)}$	1.4	2.3	3.2	µs	$V_{LOAD} = 5\text{ V}$ $C_{LOAD}$ included in package $R_{LOAD} = 1.2\text{ k}\Omega$
Output rise time	$t_r^{2)}$	3.0	4.6	6.4	µs	$R_{LOAD} = 1.2\text{ k}\Omega$ $C_{LOAD}$ included in package 1 nF load capacitance to ground Pull-up to $V_{pull-up} = 5.0\text{ V}$

1) The parameter is not subject to production test. Verified by design/verification.

2) Time between 20% and 80% of  $V_{LOAD}$

Electrical Parameters

3.5 Accuracy Requirements

°crank refers to a standard crankshaft wheel with 58 (60-2) pole-pairs where a pole-pair has a width of 6°.

Table 6 Accuracy Requirements

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Number of rising magnetic edges required for first output switching	$n_{START}^{1)}$	–	1	2	–	Valid for forward pulse. Minimum magnetic amplitude must be exceeded. See <a href="#">Figure 3</a> .
Number of rising magnetic edges required to be calibrated	$n_{CALIB}^{1)}$	–	2	3	–	Valid for forward pulse. Minimum magnetic amplitude must be exceeded. See <a href="#">Figure 3</a> .
Number of emitted pulses with wrong direction information at start-up	$n_{DR-startup}^{1)}$	–	0	0	–	Forward direction
		–	2	2	–	Backward direction
Allowed pulse failure at target wheel restart or at direction change	$P_{fr}^{1)}$	–	–	0	–	No additional pulse, no lost pulse, no false direction pulse
Threshold limit speed <sup>1)2)</sup>	$\Delta B_{limit}$	0.55	0.73	1.04	mT <sub>pp</sub>	No temperature drift
		0.55	0.73	1.43	mT <sub>pp</sub>	Stop-Start condition: frequency < 200Hz; temperature drift < 60K
Threshold limit direction <sup>1)2)</sup>	$B_{limit\_dir}$	0.35	0.52	0.67	mT <sub>pp</sub>	No temperature drift
		0.35	0.52	1.73	mT <sub>pp</sub>	Stop-Start condition: frequency < 200Hz; temperature range 25°C to 150°C
		0.35	0.52	2.56	mT <sub>pp</sub>	Stop-Start condition: frequency < 200Hz; temperature range 25°C to 170°C
Output falling edge repeatability (phase jitter) in calibrated mode	$\phi_{jitter}^{1)3)}$	–	± 0.003	± 0.015	°crank	Definition see <a href="#">Figure 13</a> , Valid for three areas of By-influence as stated in <a href="#">Figure 11</a>
		–	± 0.003	± 0.025	°crank	Definition see <a href="#">Figure 13</a>
Relative phase error in calibrated mode	$\phi_{rel}^{1)4)}$	–	0.0	± 0.3	°crank	Definition see <a href="#">Figure 14</a> , Reference air gap = 1.5mm
Delay time TLE5028C-XAA-D28 TLE5028C-XBA-D28	$t_d^{1)5)}$	10	14	18	µs	Definition see <a href="#">Figure 10</a> $V_{LOAD} = 5V, C_{LOAD}$ included in package
Delay time TLE5028C-XAI-D28 TLE5028C-XBI-D28	$t_d^{1)5)}$	17	21	25	µs	Definition see <a href="#">Figure 10</a> $V_{LOAD} = 5V, C_{LOAD}$ included in package

1) The parameter is not subject to production test; verified by design/verification

Electrical Parameters

- 2) Measured from sensor branded side to reference wheel without external disturbance fields. Measurement criterion: 99% of correct pulses available. According to [Figure 12](#)  $B_x$ -sensitivity is reduced by  $B_y$ -field influence. Numbers valid for  $T_j = 25^\circ\text{C}$ . Temperature compensation +1900 ppm (ferrite material of encoder wheel)
- 3)  $\pm 3$  sigma assuming a Gauss distribution,  $\pm 8^\circ$  IC radial tilt (Z-axis), Excluded pole-pair: #1 and #58
- 4) Forward and backward rotation direction, Excluded pole-pair: #1 and #58
- 5) Zero crossing of sensing element output to 50% value at falling edge of sensor-output

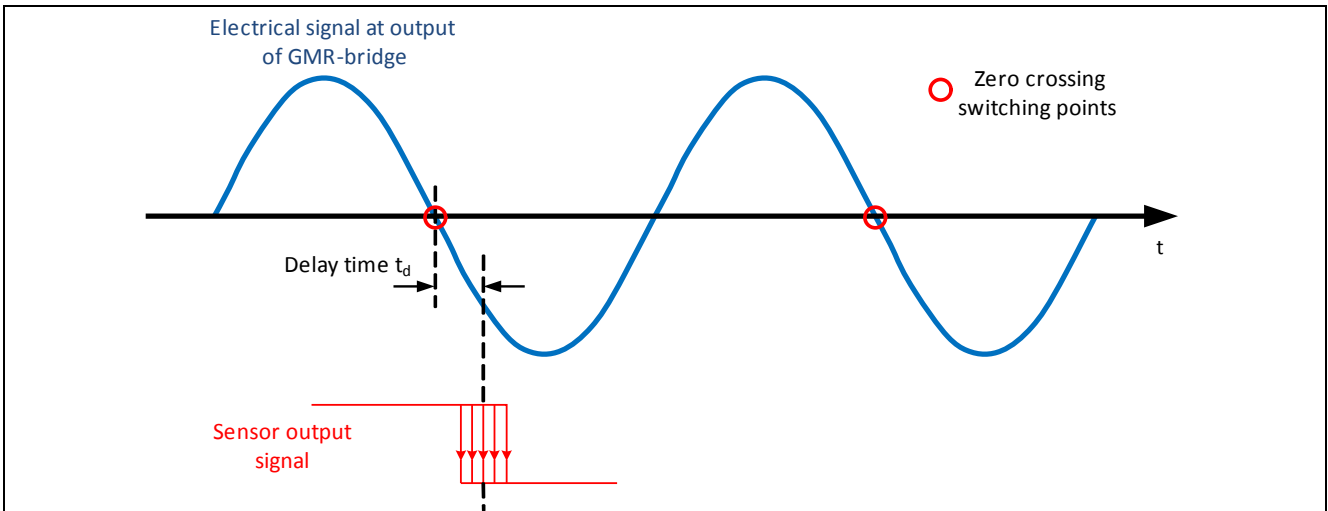


Figure 10 Delay time definition

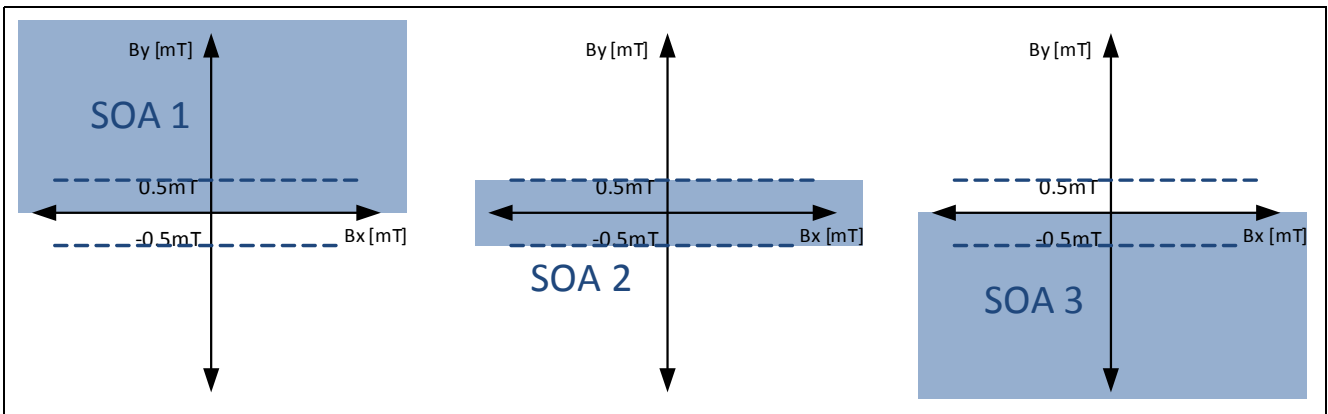


Figure 11 Safe Operating Area

High performance is achieved in each operating area. Using a static  $B_y$ -offset reduces the sensitivity according to [Figure 12](#).

Electrical Parameters

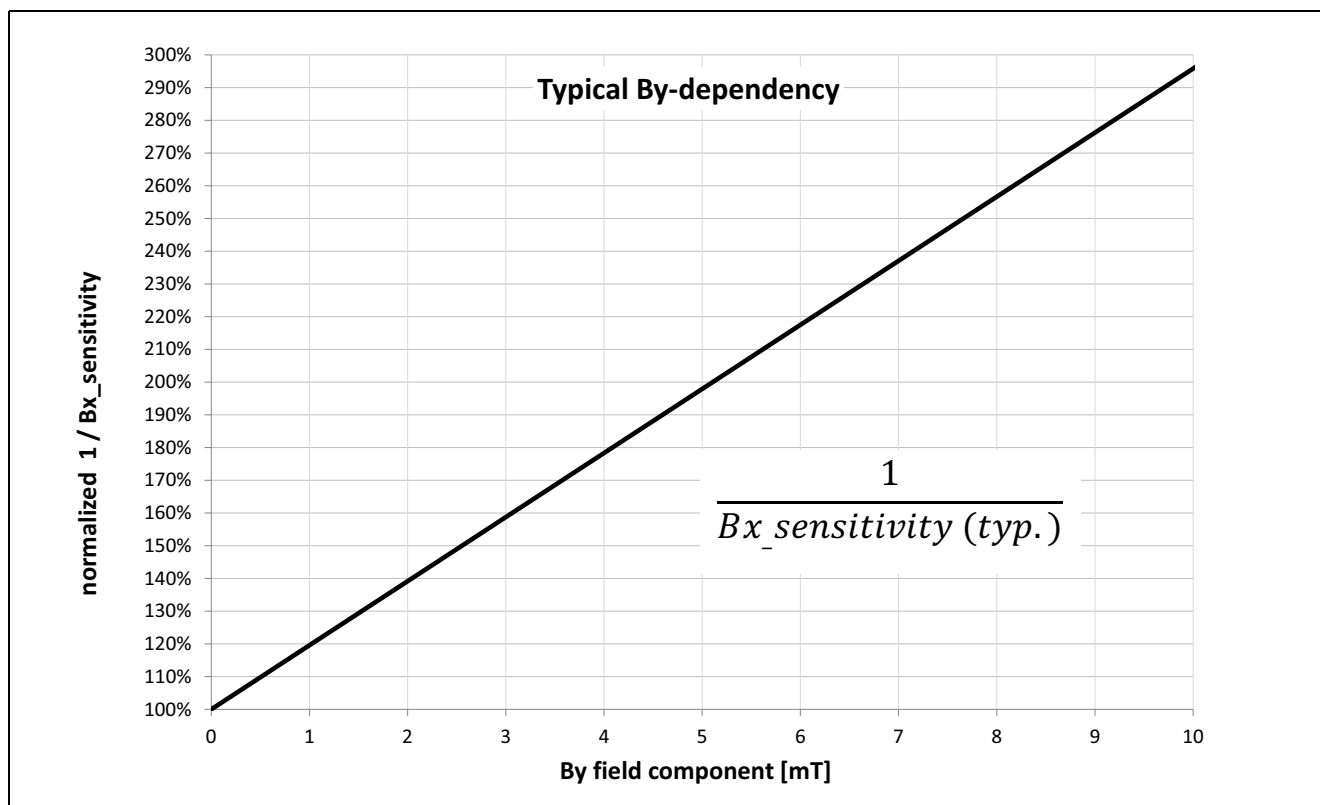


Figure 12  $B_y$ -dependency of  $1/B_x$ -sensitivity

Static or dynamic  $B_y$ -field influences the  $B_x$ -sensitivity of the sensing element with an inverse proportional factor. The stronger the  $B_y$ -field, the more the  $B_x$ -sensitivity is reduced. This curve must be applied to magnetic parameters of [Table 6](#).

For the application there is a lower maximum air gap. On the other side  $B_y$ -field allows more operating range before GMR-stack saturates.

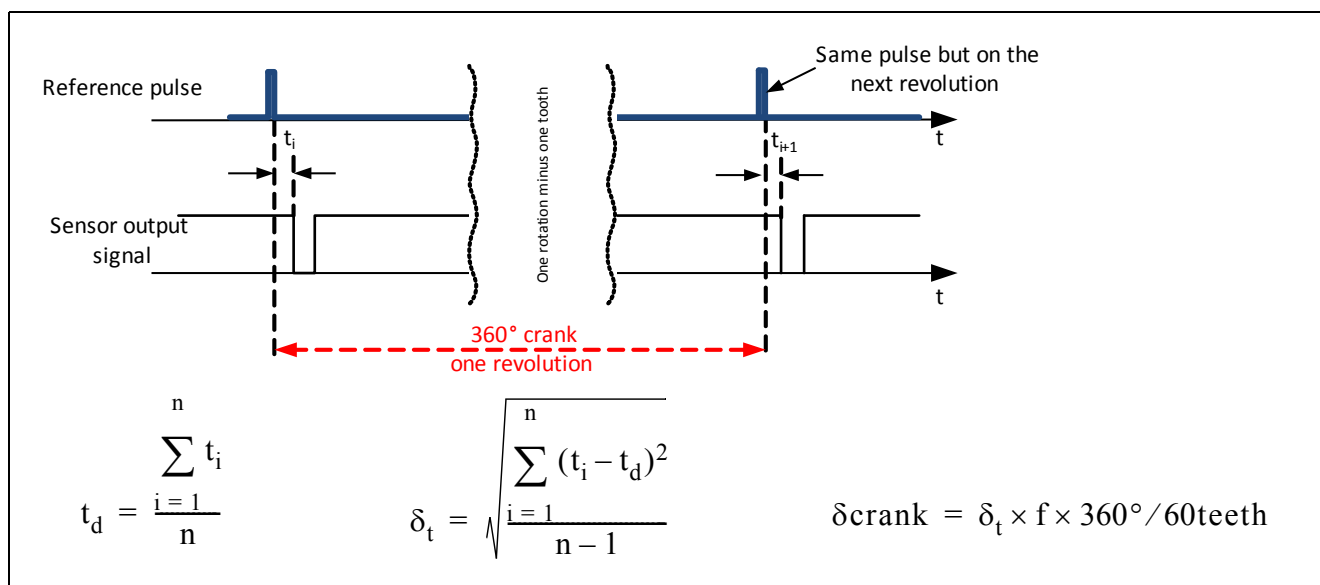


Figure 13 Phase jitter definition

Electrical Parameters

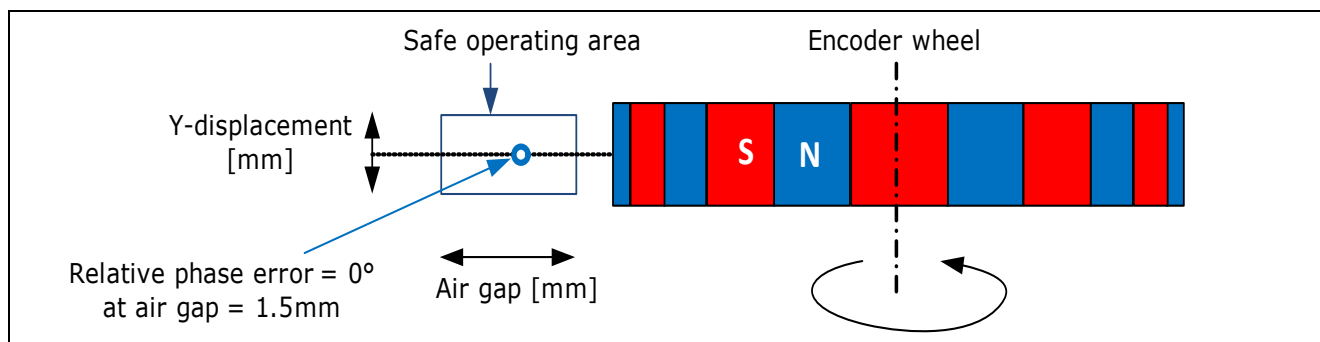


Figure 14 Relative phase error definition

For relative phase error an accuracy-measurement is performed on the entire safe operating area with respect to an external high precision encoder. The relative phase accuracy is the mean value of the jitter measurement. Relative phase error is referred to zero degree crank at air gap = 1.5 mm.

3.6 Output Signal Protocols

Table 7 Timing Characteristics

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Forward pulse width	$t_{fwd}^{1)}$	38	45	52	$\mu$ s	$R_{LOAD} = 1.2\text{ k}\Omega$ $C_{LOAD}$ included in package
Backward pulse width option1 TLE5028C-XAA-D28 and TLE5028C-XAI-D28	$t_{bwd}^{1)}$	76	90	104	$\mu$ s	$R_{LOAD} = 1.2\text{ k}\Omega$ $C_{LOAD}$ included in package
Backward pulse width option2 TLE5028C-XBA-D28 and TLE5028C-XBI-D28	$t_{bwd}^{1)}$	113	135	157	$\mu$ s	$R_{LOAD} = 1.2\text{ k}\Omega$ $C_{LOAD}$ included in package

1) Pulse width is measured from 50% of falling edge to 50% of following rising edge

Electrical Parameters

3.7 Electromagnetic Compatibility (EMC)

The High End Crankshaft Sensor will be characterized according to the IC level EMC requirements described in the “Generic IC EMC Test Specification” Version 1.2 of 2007<sup>1)</sup>.

Additionally component level EMC characterizations according to ISO 7637-2:2011, ISO 7637-3:2007 and ISO 16750-2:2010 regarding pulse immunity and CISPR 25 (2009-01) Ed. 3.0 regarding conducted emissions are performed.

Figure 15 outlines all needed external components to operate the DUT under application conditions. The (additional) outlined components can effect the final EMC result. They are treated as inherent part of the DUT during component level EMC characterizations.

Note: Characterisation of Electromagnetic Compatibility (EMC) are carried out on sample base of one qualification lot. Key parameters e.g. supply current and protocols are monitored.

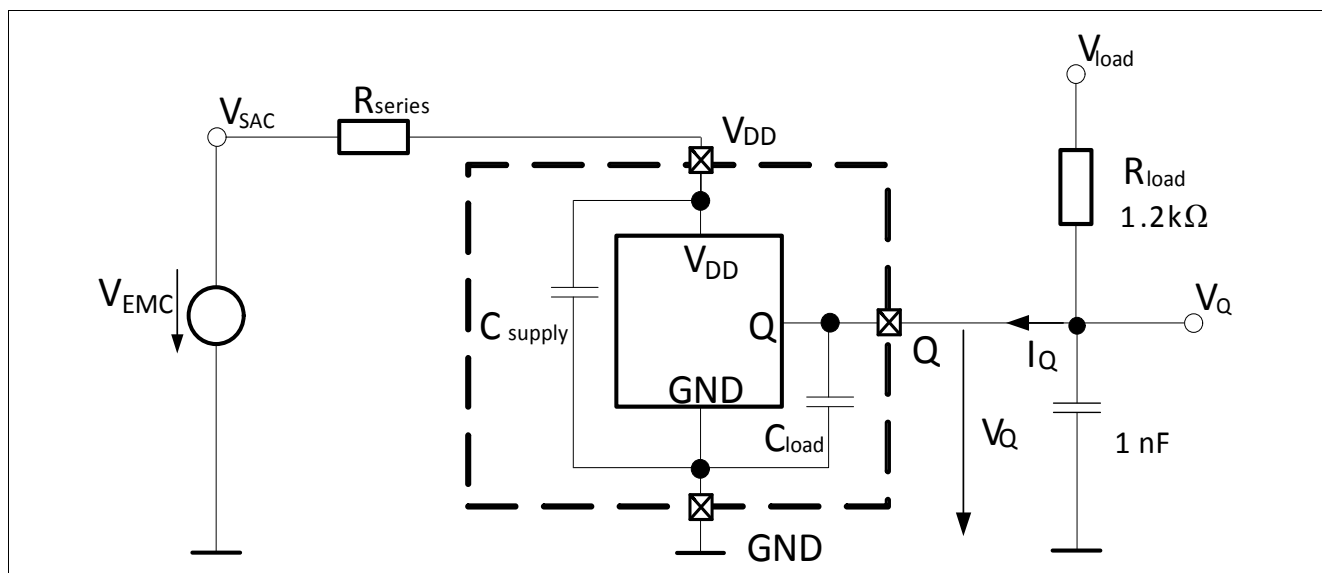


Figure 15 Test Circuit for EMC Tests

3.8 Application and System

For further information on the application, the system or manufacturing hints of this device please have a look into the TLE5028x user manual coming soon.

1) The document is available at <http://www.zvei.org/Verband/Publikationen/Seiten/Generic-IC-EMCTest-Specification-english.aspx>

Typical Performance

## 4 Typical Performance

Based on characterization results the following typical data was evaluated.

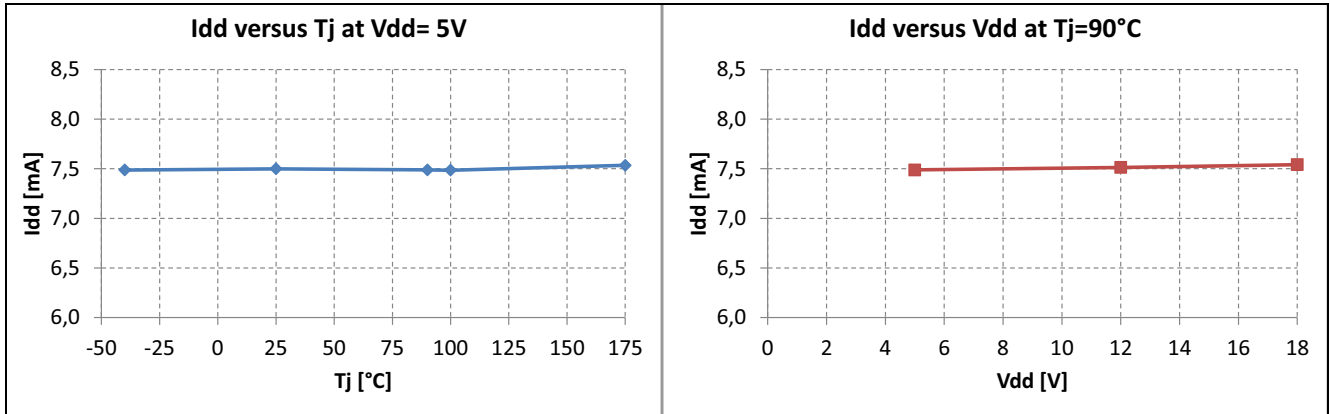


Figure 16 Typical current consumption at pin V<sub>DD</sub>

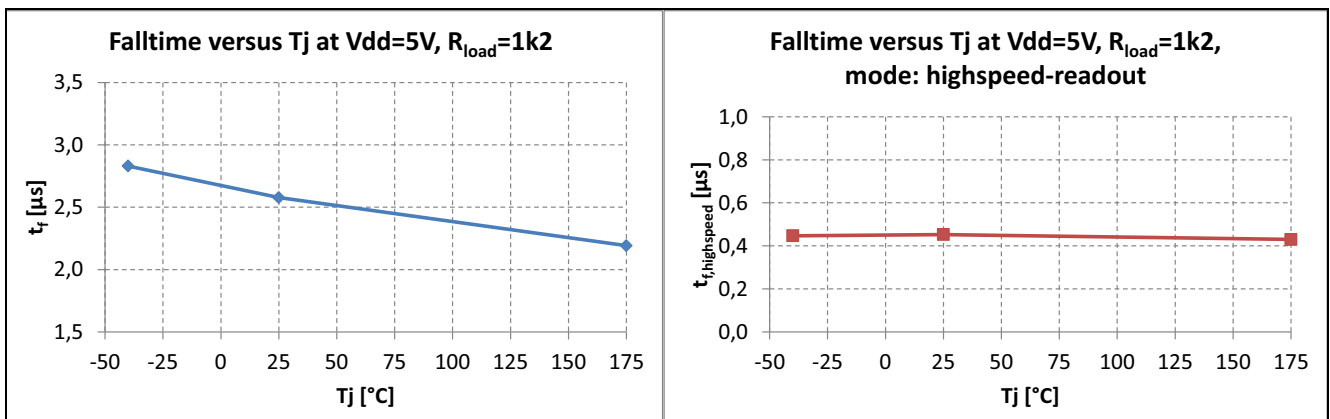


Figure 17 Typical fall time performance

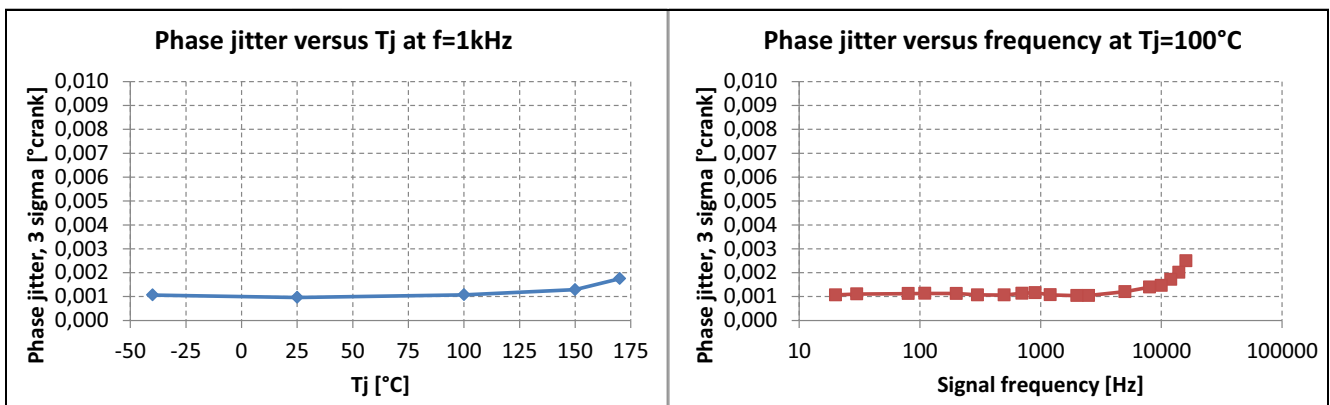


Figure 18 Typical jitter performance measured on coil-setup:  $B_{\Delta X} = 4 \text{ mT}$ ,  $B_Y = 0 \text{ mT}$

Package

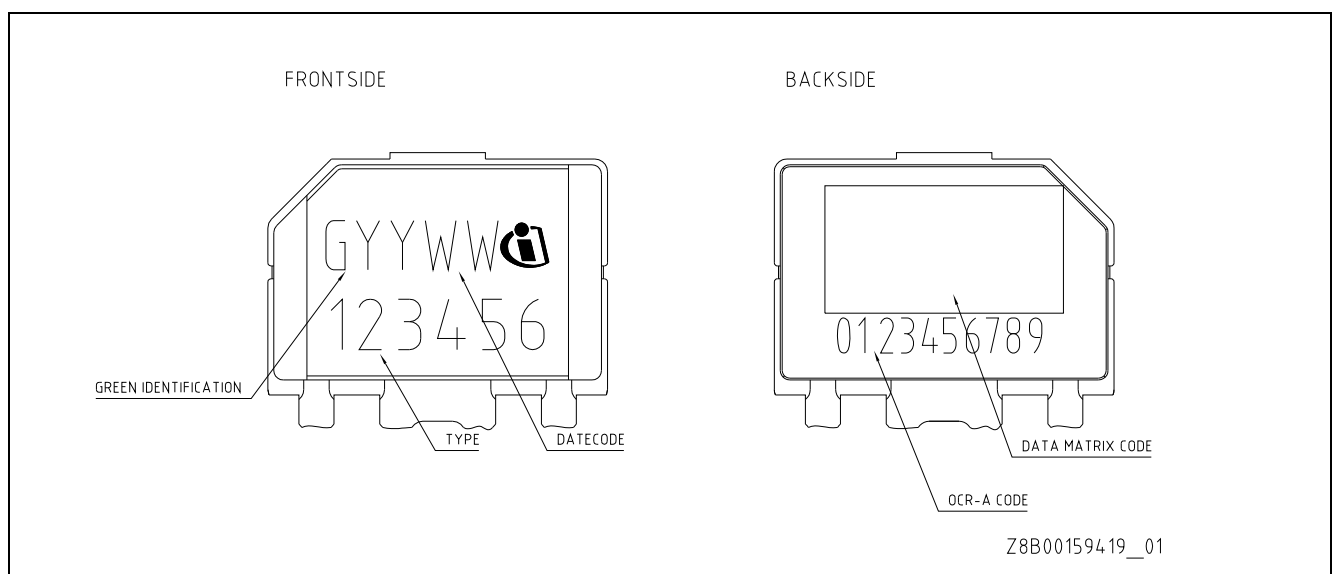
## 5 Package

Product is RoHS (restriction of hazardous substances) compliant when marked with letter G in front or after the data code marking and contains a data matrix code on the back side of the package (see also information note 136/03). Please refer to your key account team or regional sales if you need further information.

Pure tin plating (green lead plating) is used with the plastic single small outline package PG-SSO-3-52. The product complies to restrictions of hazardous substances (RoHS) when marked with the letter G in front or after the date code. Additionally it shows a data matrix on the back side of the package.

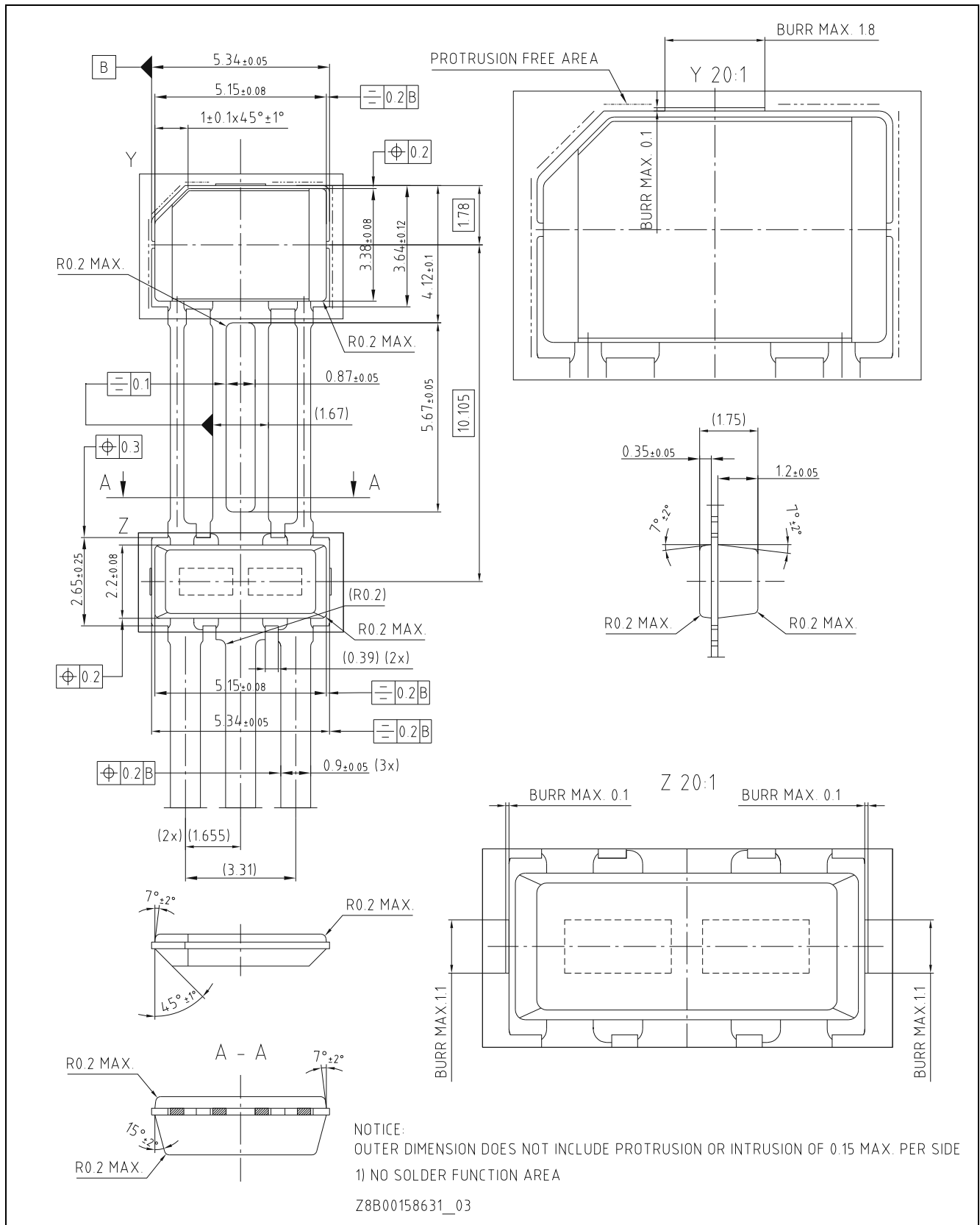
**Table 8 Package Parameters PG-SSO-3-52**

Parameter	Symbol	Limit Values			Unit	Notes
		Min.	Typ.	Max.		
Lead Plating	Sn					



**Figure 19 Back side marking, front side marking PG-SSO-3-52**

Package



Package

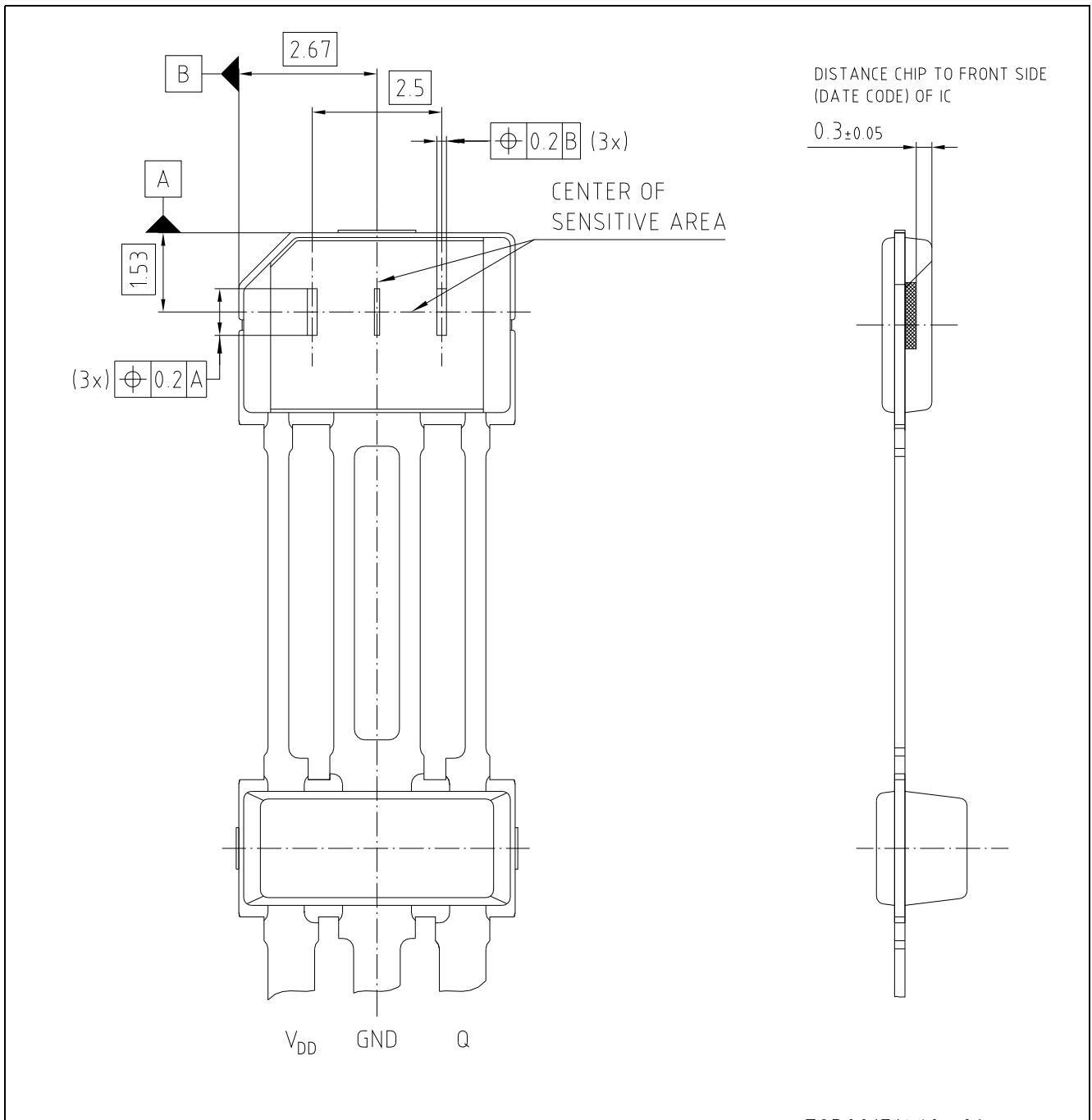


Figure 21 Positioning tolerance of sensitive elements PG-SSO-3-52

Package

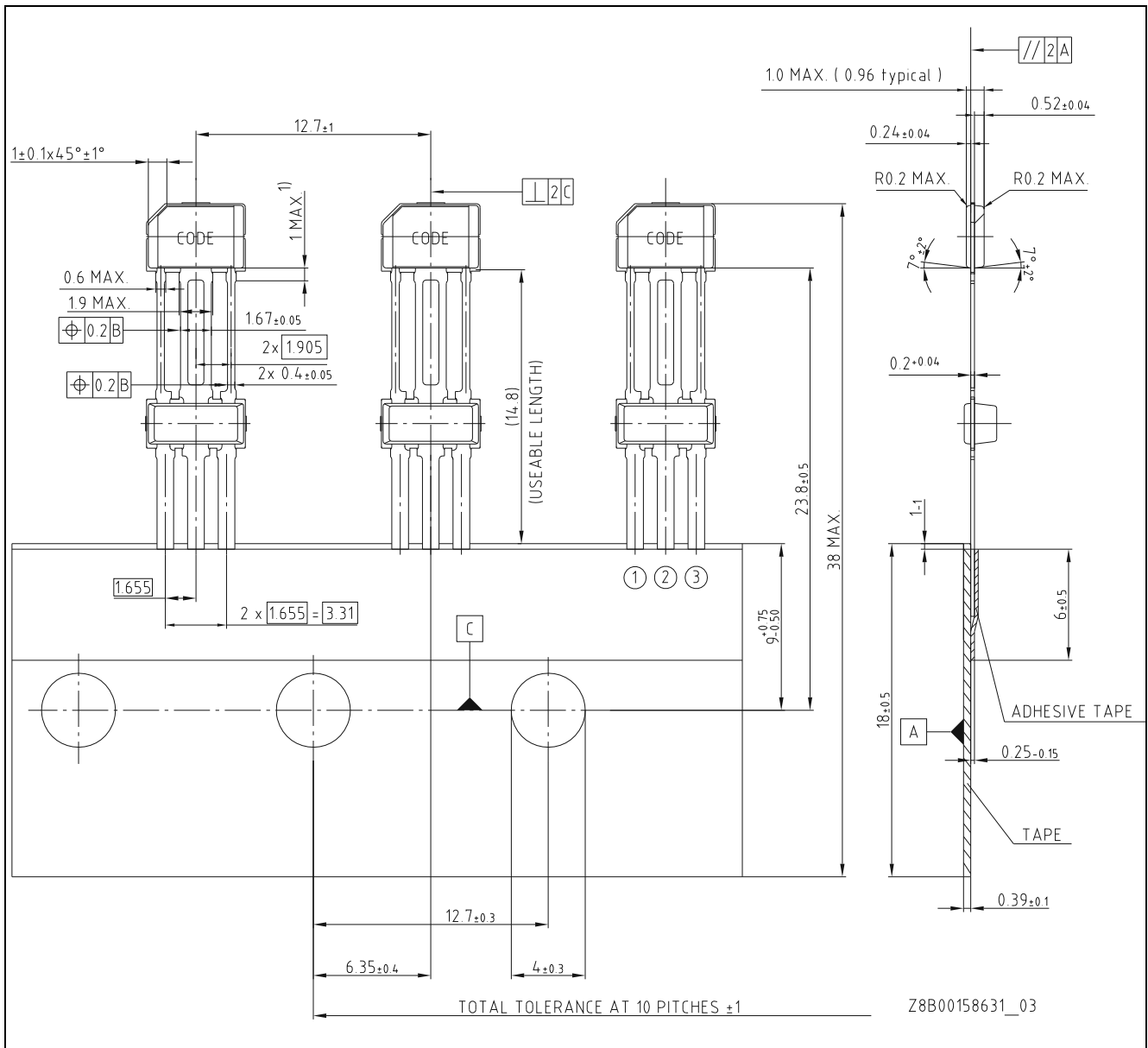


Figure 22 Packing ammo pack PG-SSO-3-52

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**Revision History**

## **6 Revision History**

<b>Revision</b>	<b>Date</b>	<b>Changes</b>
1.0	2017-10-12	- Initial Version of Data Sheet introducing option “inverse”: TLE5028C-XAI-D28, TLE5028C-XBI-D28
1.1	2017-12-20	- Note in IQSHORT updated

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**Email: [erratum@infineon.com](mailto:erratum@infineon.com)**

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