XENSIV™ magnetic switch family with extended diagnostic

Features

RoHS

AEC Qualified

ISO 26262 compliant

- ASIL B compliant device
- Magnetic sensing using a horizontal Hall element for orthogonal sensing on PCB
- ISO 26262 safety element out of context for safety requirements up to ASIL B
- Built-in diagnostic with fault indication
- Highly accurate magnetic sensitivity over temperature and life time
- Over current protection
- Over temperature protection
- High robustness to thermal and mechanical stresses by active error compensation (chopping technique)
- Defined power on state at initial start-up
- Optimized for pre-regulated power supply stages
- Reverse battery protection (-18 V)
- Load dump capability up to 42 V
- ESD performance ± 4 kV

Potential applications

- Window lift / sun roof
- Power closure actuators
- Seat positioning / seat belt pretensioner
- BLDC commutation for automotive and industrial applications
- Shutter & garage door openers

Product validation

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

Description

This sensor measures the magnetic field orthogonal to the PCB direction in Z direction. The sensor has an open drain output providing speed information. The sensor is developed according to ISO 26262 and provides built-in diagnosis functions to support functional safety applications with requirements up to ASIL B. The device is AEC-100 compliant and Grade 0 qualified.

Product type	Package	Marking	Ordering code
TLE49601-1M-S2	SOT23-3	11M	SP005924303
TLE49601-3M-S2	SOT23-3	13M	SP005924485
TLE49601-5M-S2	SOT23-3	15M	SP005924491
TLE49604-1M-S2	SOT23-3	41M	SP005924627
TLE49604-2M-S2	SOT23-3	42M	SP005924552
TLE49604-4M-S2	SOT23-3	44M	SP005924634
TLE49604-6M-S2	SOT23-3	46M	SP005924642
TLE49604-7M-S2	SOT23-3	47M	SP005924558
TLE49608-1M-S2	SOT23-3	81M	SP005924532

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1 Block diagram

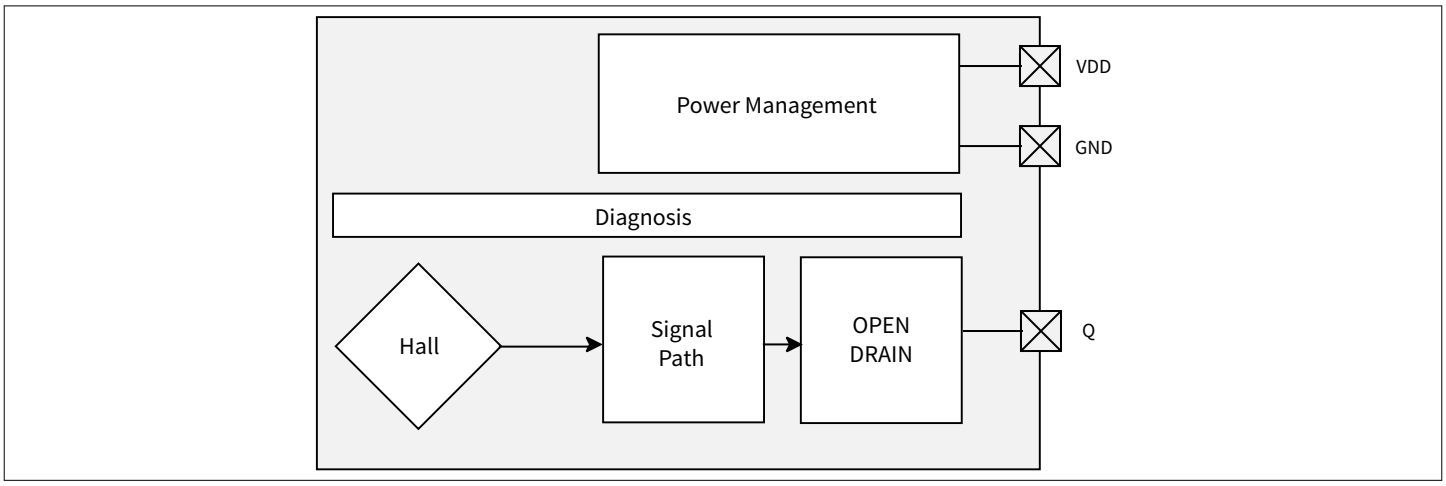

Figure 1 Functional block diagram

2 Pin configuration

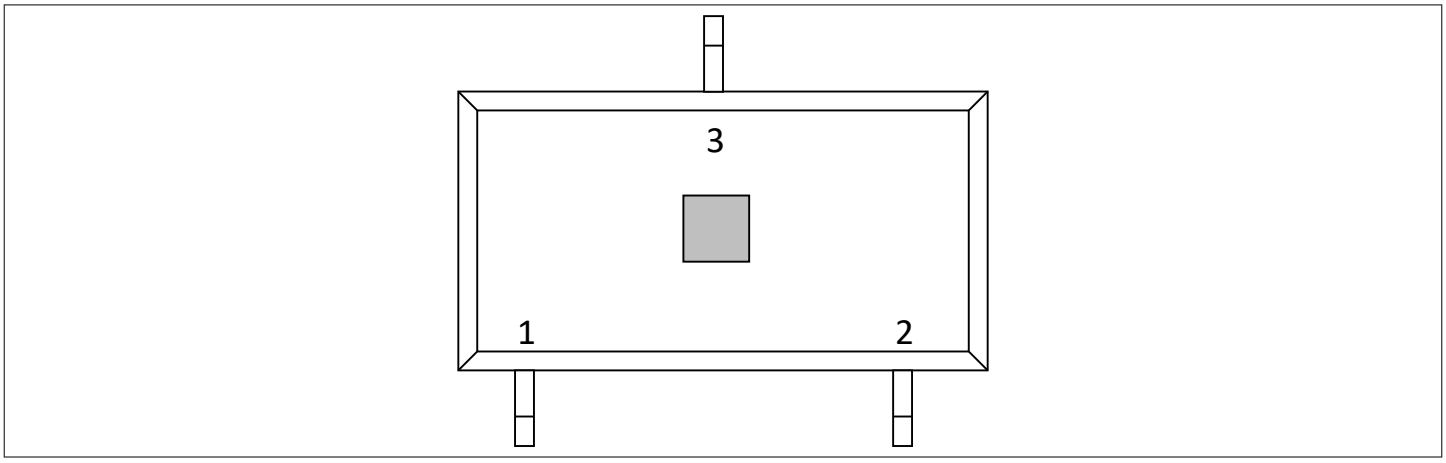

Figure 2 Pin out (PG-SOT23-3)

Table 1 Pin definition and function

Pin no.	Symbol	Function
1	VDD	Chip supply voltage
2	Q	Output
3	GND	Ground

***Note**: GND is reference of all voltages*

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" is not implied. Furthermore, only single error cases are assumed. More than one stress/error case may also damage the device. A positive current is flowing out of 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 shall 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 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply voltage	V_{DD}	-18.0	–	32.0	V	
Supply voltage extended	V_{DD}	–	–	42.0	V	10 h, no external resistor required
Output voltage	V_{Q}	-0.5	–	32.0	V	
Reverse output current	I_{Q_REV}	-30.0	–	–	mA	
Junction temperature 155 °C	T_{J}	-40.0	–	155.0	°C	for 2000 h (not additive)
Junction temperature 165 °C	T_{J}	-40.0	–	165.0	°C	for 1000 h (not additive)
Junction temperature 175 °C	T_{J}	-40.0	–	175.0	°C	for 168 h (not additive)
Junction temperature 195 °C	T_{J}	-40.0	–	195.0	°C	for 3 x 1 h (additive)
Storage temperature	T_{S}	-40.0	–	150.0	°C	
Thermal resistance junction to ambient	R_{th_JA}	–	–	300.0	K/W	for PG-SOT23-3

(table continues...)

Table 2 (continued) Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Thermal resistance junction to lead	R_{th_JL}	–	–	100.0	K/W	
Maximum magnetic flux density	B_{MAX}	-1000	–	1000	mT	

Table 3 ESD protection

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ESD voltage (HBM)	V_{ESD}	-4.0	–	4.0	kV	
ESD voltage (CDM, all pins)	V_{ESD}	-0.75	–	0.75	kV	Method AEC-Q100 -011, C = 200 pF, R = 0.0 Ω

3.2 Functional range

The following functional range shall 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 Operating range

All voltages with respect to ground, positive current flowing into pin.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply voltage (operating)	V_{DD}	3.0	–	32.0	V	
Output voltage	V_Q	-0.3	–	32.0	V	
Output current	I_Q	0.0	–	10.0	mA	
Junction temperature	T_J	-40.0	–	170.0	°C	
Magnetic signal input frequency	f_{mag}	0.0	–	10.0	kHz	For life tick indication see SOA safe operating area of life tick

Table 5 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply current	I_{DD}	1.1	1.7	2.5	mA	

(table continues...)

Table 5 (continued) Electrical characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Reverse supply current	I_{DDR}	–	0.05	1.0	mA	for V_{DD} = -18 V
Output saturation voltage	V_{QSAT}	–	0.2	0.5	V	I_Q = 10 mA
Output leakage current	I_{QLEAK}	–	–	10.0	µA	
Output current limitation	I_{QLIMT}	15.0	22.5	30.0	mA	Internally limited
Output fall time	t_f	0.17	0.4	1.0	µs	R_L = 1.2 kΩ; C_L = 50 pF no bypass capacitance
Output rise time	t_r	0.4	0.5	1.0	µs	R_L = 1.2 kΩ; C_L = 50 pF (oscilloscope capacitance); no bypass capacitor
Delay time	t_d	9.0	15.0	30.0	µs	
Power-on time	t_{PON}	–	80.0	150.0	µs	V_{DD} > 3 V, $B \le B_{RP}$ - 0.5 mT or $B \ge B_{OP}$ + 0.5 mT

3.2.1 Magnetic characteristics

Table 6 Magnetic characteristics overall

Magnetic parameters valid for each device

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Effective noise	B_{Neff}	–	62.0	–	μT_{RMS}	rms = 1 sigma @ 25°C

Table 7 Magnetic characteristics TLE49601-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	0.7	2.3	3.8	mT	
Operating point at 25°C (default)	B_{OP}	0.5	2.0	3.5	mT	
Operating point at 170°C	B_{OP}	0.1	1.4	2.8	mT	
Release point at -40°C	B_{RP}	-3.8	-2.3	-0.7	mT	
Release point at 25°C (default)	B_{RP}	-3.5	-2.0	-0.5	mT	

(table continues...)

Table 7 (continued) Magnetic characteristics TLE49601-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Release point at 170°C	B_{RP}	-2.8	-1.4	-0.1	mT	
Hysteresis at -40°C	B_{HYS}	3.1	4.5	6.0	mT	
Hysteresis at 25°C	B_{HYS}	2.6	4.0	5.4	mT	
Hysteresis at 170°C	B_{HYS}	1.9	2.8	3.7	mT	
Magnetic offset	B_{OFF}	-1.0	–	1.0	mT	
Temperature compensation of magnetic thresholds	TC	–	-2000	–	ppm/K	

Table 8 Magnetic characteristics TLE49601-3M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	5.4	8.5	11.6	mT	
Operating point at 25°C (default)	B_{OP}	4.6	7.5	10.4	mT	
Operating point at 170°C	B_{OP}	3.0	5.3	7.7	mT	
Release point at -40°C	B_{RP}	-11.6	-8.5	-5.4	mT	
Release point at 25°C (default)	B_{RP}	-10.4	-7.5	-4.6	mT	
Release point at 170°C	B_{RP}	-7.7	-5.3	-3.0	mT	
Hysteresis at -40°C	B_{HYS}	11.5	17.0	22.4	mT	
Hysteresis at 25°C	B_{HYS}	10.2	15.0	19.8	mT	
Hysteresis at 170°C	B_{HYS}	7.2	10.7	14.1	mT	
Magnetic offset	B_{OFF}	-1.0	–	1.0	mT	

(table continues...)

Table 8 (continued) Magnetic characteristics TLE49601-3M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

Table 9 Magnetic characteristics TLE49601-5M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	11.7	17.0	22.2	mT	
Operating point at 25°C (default)	B_{OP}	10.3	15.0	19.8	mT	
Operating point at 170°C	B_{OP}	7.0	10.7	14.3	mT	
Release point at -40°C	B_{RP}	-22.2	-17.0	-11.7	mT	
Release point at 25°C (default)	B_{RP}	-19.8	-15.0	-10.3	mT	
Release point at 170°C	B_{RP}	-14.3	-10.7	-7.0	mT	
Hysteresis at -40°C	B_{HYS}	23.1	33.9	44.7	mT	
Hysteresis at 25°C	B_{HYS}	20.4	30.0	39.6	mT	
Hysteresis at 170°C	B_{HYS}	14.5	21.3	28.1	mT	
Magnetic offset	B_{OFF}	-1.0	–	1.0	mT	
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

Table 10 Magnetic characteristics TLE49608-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	-0.3	1.0	2.3	mT	

(table continues...)

Table 10 (continued) Magnetic characteristics TLE49608-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at 25°C (default)	B_{OP}	-0.3	1.0	2.3	mT	
Operating point at 170°C	B_{OP}	-0.3	1.0	2.3	mT	
Release point at -40°C	B_{RP}	-2.3	-1.0	0.3	mT	
Release point at 25°C (default)	B_{RP}	-2.3	-1.0	0.3	mT	
Release point at 170°C	B_{RP}	-2.3	-1.0	0.3	mT	
Hysteresis at -40°C	B_{HYS}	1.1	2.0	2.9	mT	
Hysteresis at 25°C	B_{HYS}	1.1	2.0	2.9	mT	
Hysteresis at 170°C	B_{HYS}	1.1	2.0	2.9	mT	
Temperature compensation of magnetic thresholds	*TC*	–	0.0	–	ppm/K	

Table 11 Magnetic characteristics TLE49604-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	14.3	20.3	26.4	mT	
Operating point at 25°C (default)	B_{OP}	12.5	18.0	23.5	mT	
Operating point at 170°C	B_{OP}	8.6	12.8	17.0	mT	
Release point at -40°C	B_{RP}	9.6	14.1	18.7	mT	
Release point at 25°C (default)	B_{RP}	8.4	12.5	16.6	mT	
Release point at 170°C	B_{RP}	5.7	8.9	12.1	mT	
Hysteresis at -40°C	B_{HYS}	4.2	6.2	8.2	mT	

(table continues...)

Table 11 (continued) Magnetic characteristics TLE49604-1M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Hysteresis at 25°C	B_{HYS}	3.7	5.5	7.3	mT	
Hysteresis at 170°C	B_{HYS}	2.7	3.9	5.2	mT	
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

Table 12 Magnetic characteristics TLE49604-2M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	22.7	31.6	40.6	mT	
Operating point at 25°C (default)	B_{OP}	20.0	28.0	36.0	mT	
Operating point at 170°C	B_{OP}	13.9	19.9	25.9	mT	
Release point at -40°C	B_{RP}	18.1	25.4	32.8	mT	
Release point at 25°C (default)	B_{RP}	15.9	22.5	29.1	mT	
Release point at 170°C	B_{RP}	11.0	16.0	21.0	mT	
Hysteresis at -40°C	B_{HYS}	4.7	6.2	8.5	mT	
Hysteresis at 25°C	B_{HYS}	4.1	5.5	7.5	mT	
Hysteresis at 170°C	B_{HYS}	2.9	3.9	5.3	mT	
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

Table 13 Magnetic characteristics TLE49604-4M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	7.5	11.3	15.1	mT	
Operating point at 25°C (default)	B_{OP}	6.5	10.0	13.5	mT	
Operating point at 170°C	B_{OP}	4.3	7.1	9.9	mT	use adequate B-field
Release point at -40°C	B_{RP}	6.2	9.6	13.0	mT	
Release point at 25°C (default)	B_{RP}	5.4	8.5	11.6	mT	
Release point at 170°C	B_{RP}	3.5	6.0	8.5	mT	use adequate B-field
Hysteresis at -40°C	B_{HYS}	1.0	1.7	2.4	mT	
Hysteresis at 25°C	B_{HYS}	0.8	1.5	2.2	mT	
Hysteresis at 170°C	B_{HYS}	0.5	1.1	1.7	mT	
Temperature compensation of magnetic thresholds	TC	–	-2000	–	ppm/K	

Table 14 Magnetic characteristics TLE49604-6M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	2.0	4.0	6.0	mT	
Operating point at 25°C (default)	B_{OP}	1.6	3.5	5.4	mT	
Operating point at 170°C	B_{OP}	0.9	2.5	4.1	mT	use adequate B-field
Release point at -40°C	B_{RP}	1.1	2.8	4.5	mT	
Release point at 25°C (default)	B_{RP}	0.9	2.5	4.1	mT	
Release point at 170°C	B_{RP}	0.3	1.8	3.2	mT	use adequate B-field

(table continues...)

Table 14 (continued) Magnetic characteristics TLE49604-6M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Hysteresis at -40°C	B_{HYS}	0.8	1.1	1.5	mT	
Hysteresis at 25°C	B_{HYS}	0.7	1.0	1.3	mT	
Hysteresis at 170°C	B_{HYS}	0.5	0.7	0.9	mT	
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

Table 15 Magnetic characteristics TLE49604-7M-S2

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating point at -40°C	B_{OP}	7.1	10.7	14.4	mT	
Operating point at 25°C (default)	B_{OP}	6.1	9.5	12.9	mT	
Operating point at 170°C	B_{OP}	4.1	6.8	9.4	mT	
Release point at -40°C	B_{RP}	4.9	7.9	10.9	mT	
Release point at 25°C (default)	B_{RP}	4.3	7.0	9.8	mT	
Release point at 170°C	B_{RP}	2.7	5.0	7.2	mT	
Hysteresis at -40°C	B_{HYS}	1.9	2.8	3.7	mT	
Hysteresis at 25°C	B_{HYS}	1.7	2.5	3.3	mT	
Hysteresis at 170°C	B_{HYS}	1.2	1.8	2.3	mT	
Temperature compensation of magnetic thresholds	*TC*	–	-2000	–	ppm/K	

3.2.2 Magnetic sensing direction

Positive magnetic fields are defined with the south pole of the magnet as shown in Figure 3. A field applied to the branded side of the package is in Z-direction

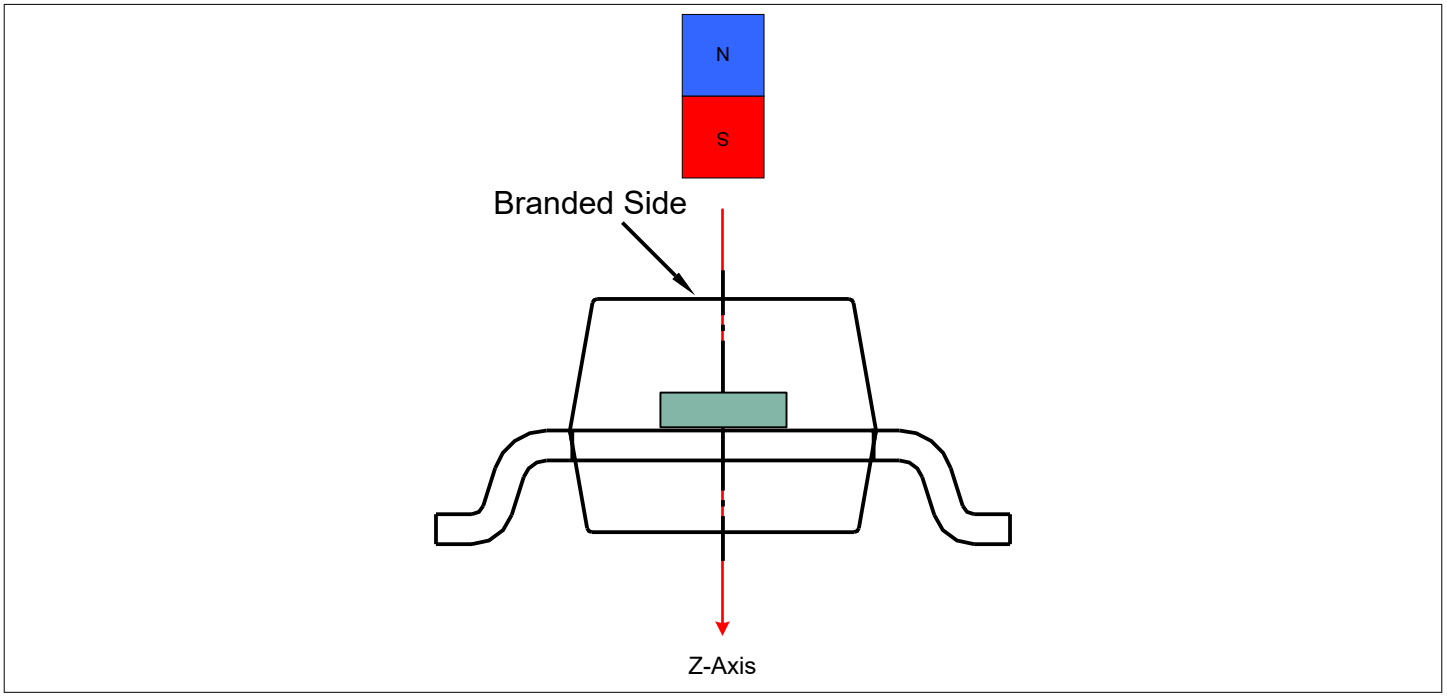

Figure 3 Field direction definition

The magnet wheel can be placed for example as shown in Figure 4

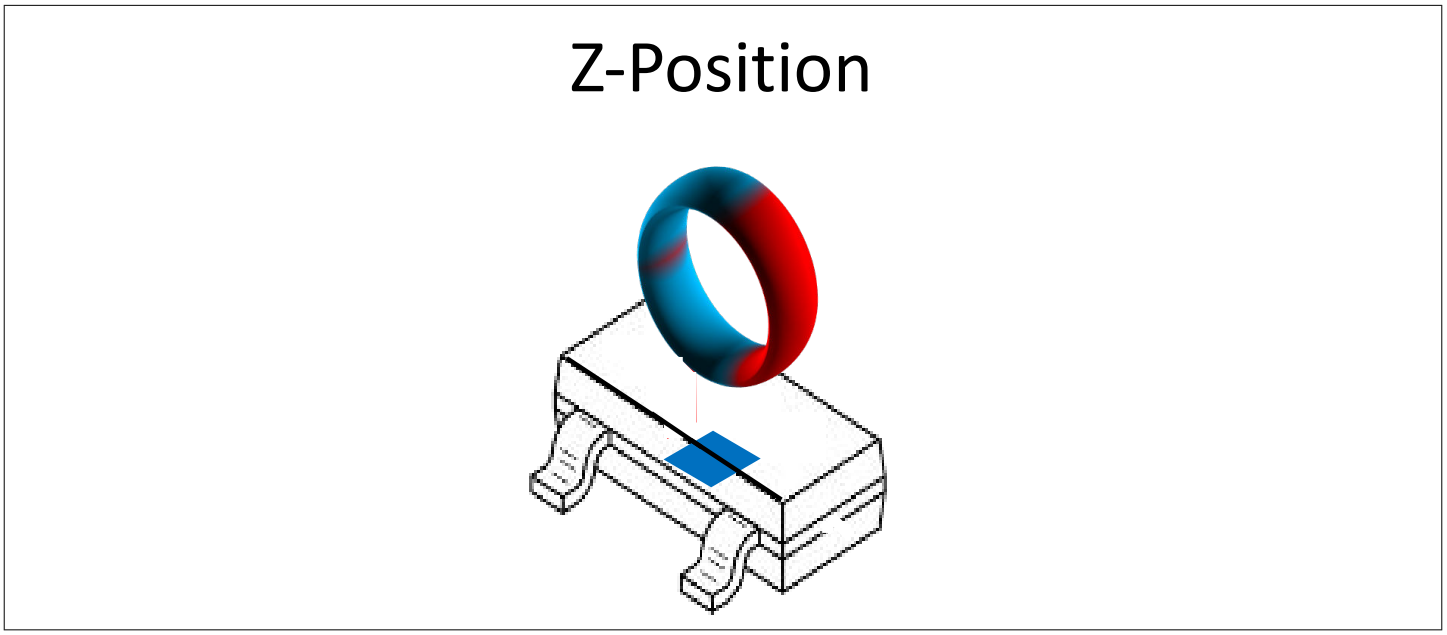

Figure 4 Example of usage of magnet wheel

4 Product features

4.1 Functional description

The new Infineon Hall sensor provides an open drain speed output Q in order to detect a magnetic signal. A NMOS output transistor for continuous current is implemented. It operates from a regulated supply voltage of V_{DD_min} up to V_{DD_max}.

The signal delay time t_d is a propagation time from detecting a signal to proceed the output. When a magnetic field is applied or removed from the sensor, it switches as shown in the course of the switching process see Figure 5.

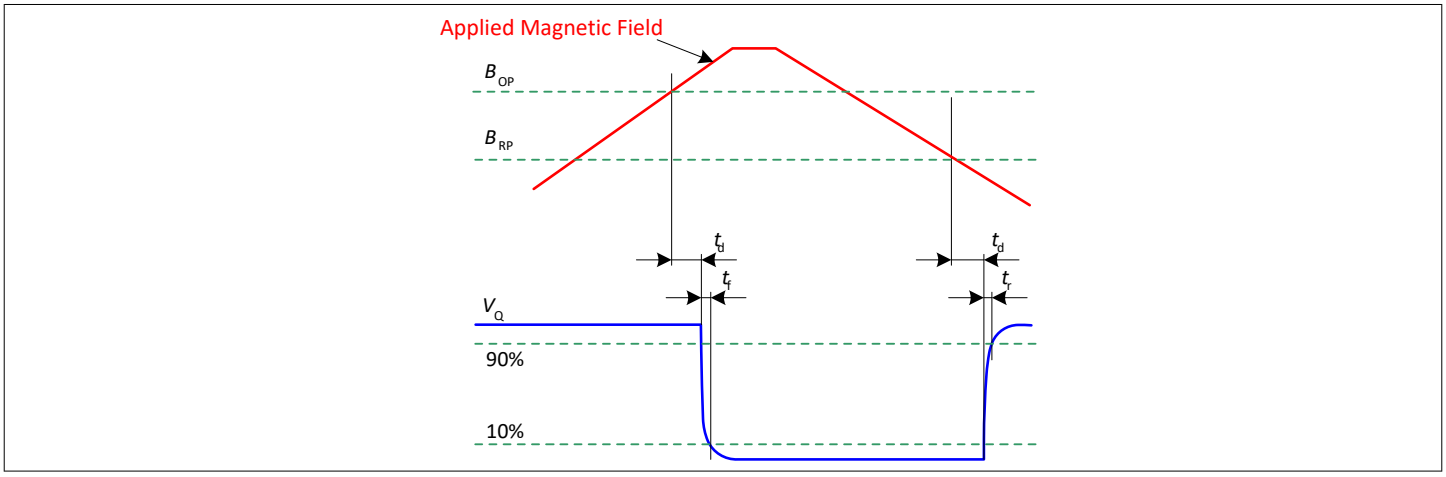

Figure 5 Timing diagram

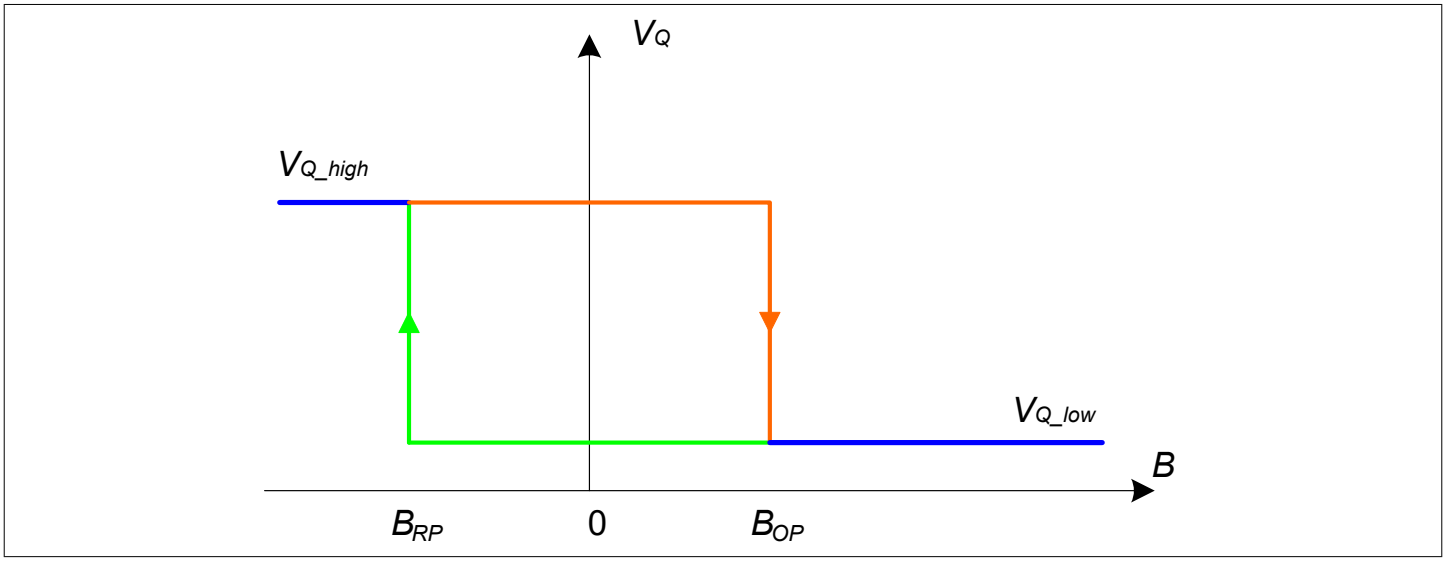

Figure 6 Output signal of bipolar latch when magnet field is applied

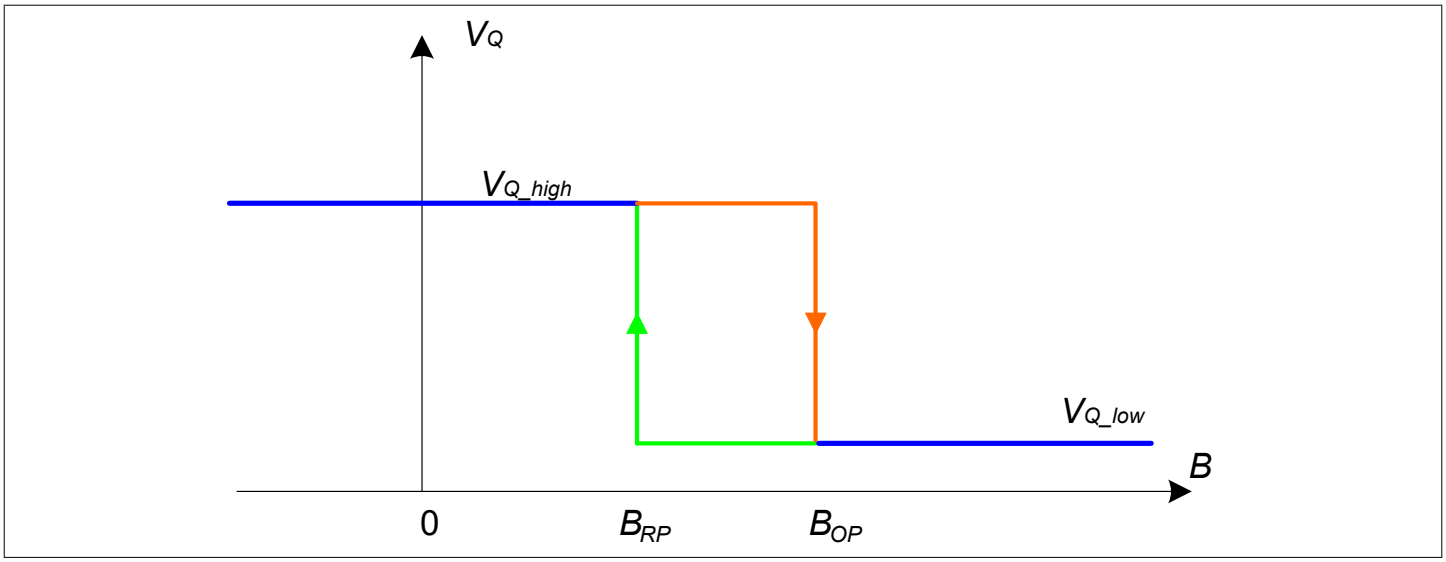

Figure 7 Output signal of unipolar switch when magnet field is applied

The magnetic thresholds exhibit a hysteresis $B_{HYS} = B_{OP} - B_{RP}$. In case of a power-on with a magnetic field B within hysteresis ($B_{RP} < B < B_{OP}$) the output of the sensor is set to the pull up voltage level (V_Q) per default. After the first crossing of B_{OP} or B_{RP} of the magnetic field the internal decision logic is set to the corresponding magnetic input value. This means for $B > B_{OP}$ the output is switching to low for $B > B_{RP}$ and $B_{OP} > B > B_{RP}$ the output stays at V_Q. See in Figure 8.

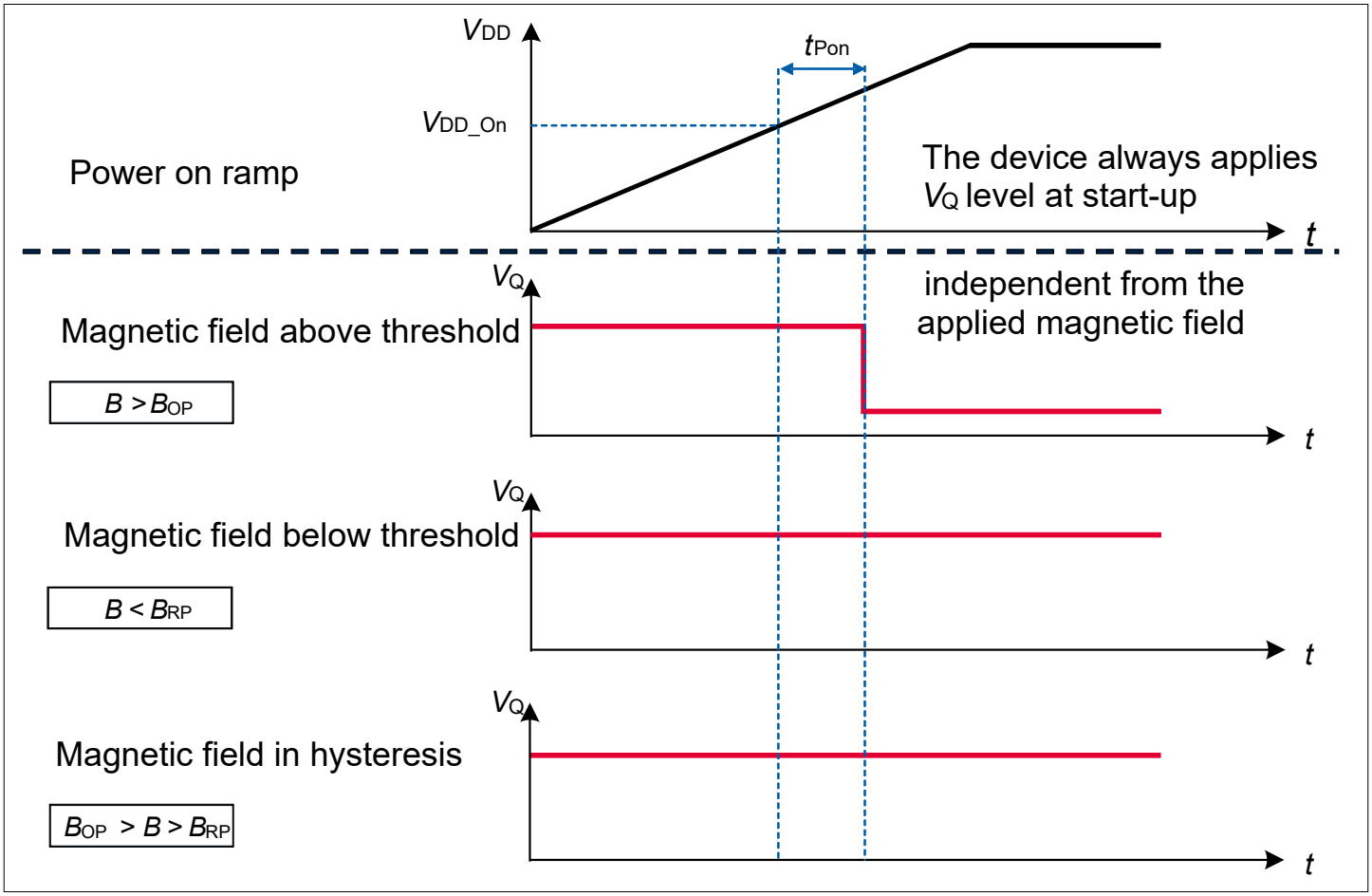

Figure 8 Initial start-up behavior

The device has an overtemperature protection (OTP). In case an OTP is triggered, the device will drive the output to High-Z (high-impedance on output pin). This fault indication is maintained until OTP initiator is no longer present. The open drain is released and switch resumes the normal behavior.

4.2 Diagnostic

Table 16 Diagnostic timing

The table shows the timing of the internal diagnostic according to the drawings.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Trigger time	$t_{Trigger}$	6.0	10.0	15.0	ms	
Pulse width life tick	t_{Width}	6.0	10.0	16.0	µs	
Blind time	t_{Blind}	–	–	200.0	µs	

4.2.1 Life tick

In respect to Figure 9

North is present: When no movement and the north pole is present, the signal output (red) is HIGH during operation. The life tick signal is send out with a falling edge first.

South is present: When no movement and the south pole is present, the signal output (red) is LOW during operation. The life tick signal is send out with a rising edge first.

Description: the missing life tick defines a fault indication. The output is latched in the last state during fail.

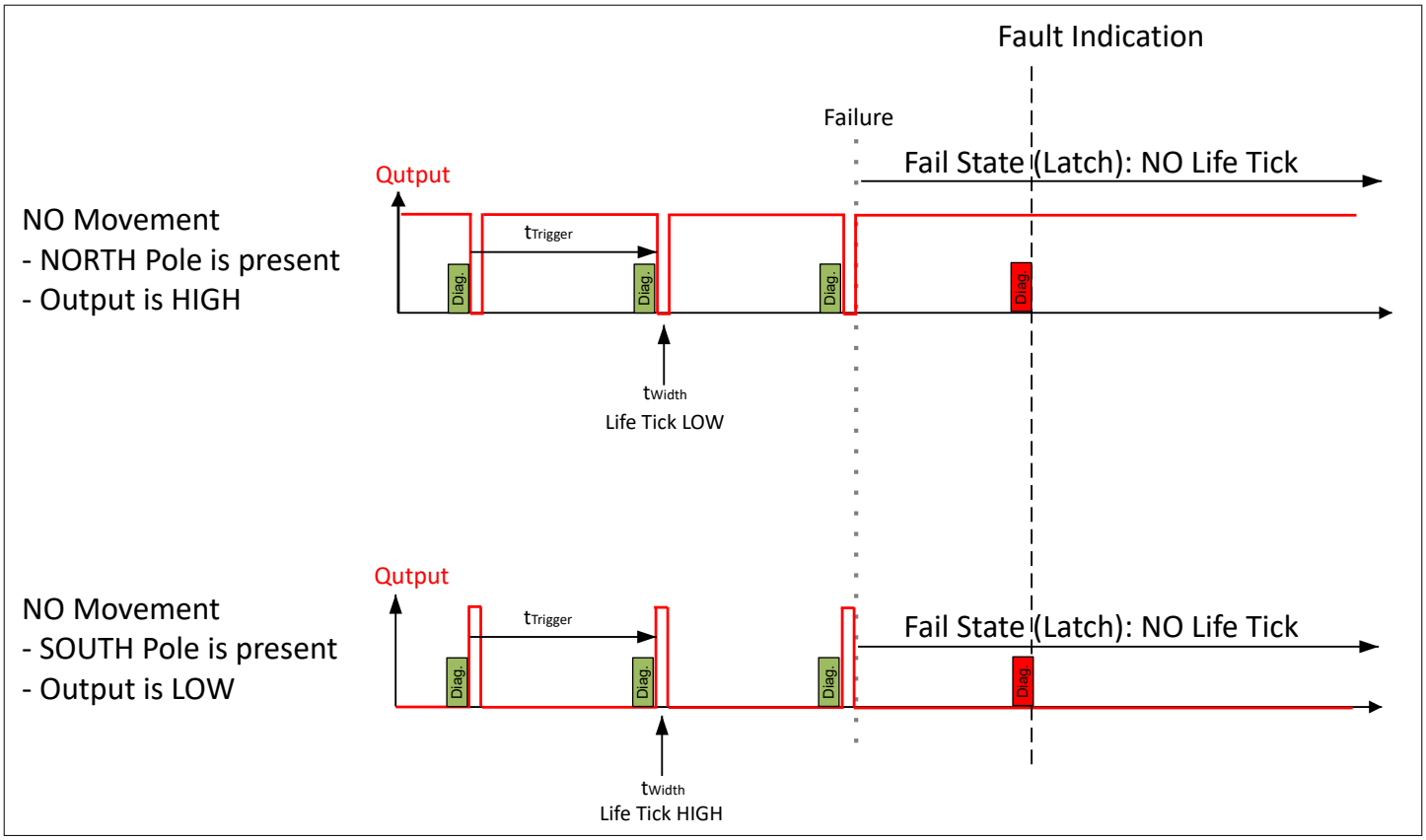

Figure 9 Life tick operating principle

4.2.2 Signal path

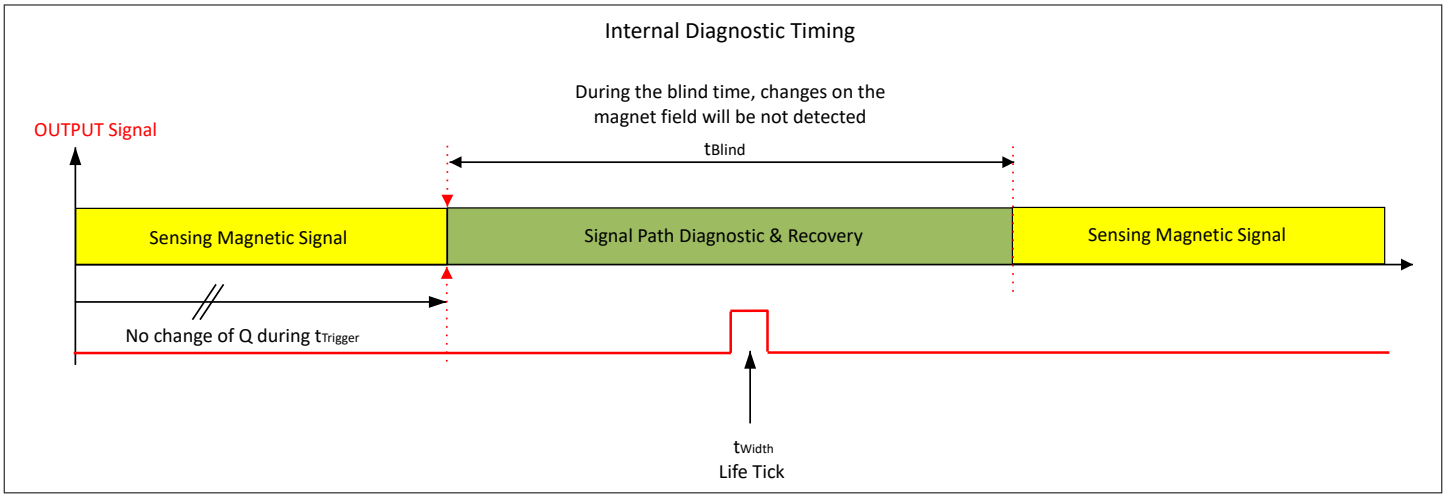

Figure 10 Internal diagnostic diagram

***Note**: The sensor is able to run a self diagnosis on the signal path and in case of a fail a fault indication state will be provided on the output.*

4.2.3 Safe operating area SOA Life Tick

The life tick is only present during passive mode (no moving encoder) or slow frequent active mode (slow moving encoders) with a worst case corner frequency of f_corner_max = 83 Hz.

The boarder frequency for the active mode is moving between:

- f_corner_max = 83 Hz ($t_{Trigger\_min}$ = 6 ms)
- f_corner_typ = 50 Hz ($t_{Trigger\_typ}$ = 10 ms)
- f_corner_min = 33 Hz ($t_{Trigger\_max}$ = 15 ms)

NO Life Tick:

f_{mag} > 83Hz (active mode)

The safe operating shown in Figure 11 area shows when ever the life tick is present or not.

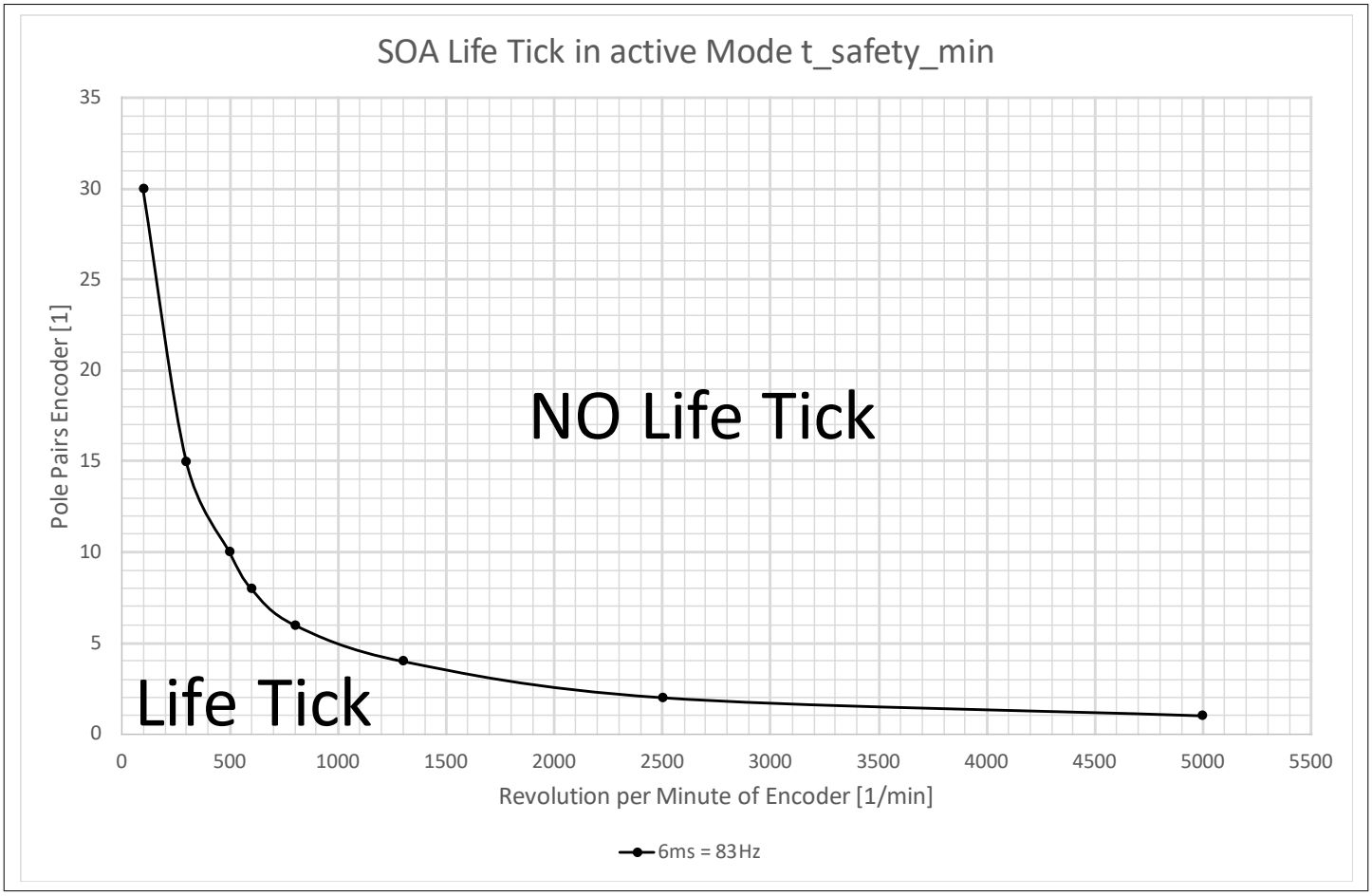

Figure 11 SOA of life tick characteristic - number of pole pairs vs. rotational speed.

5 Application information

EMC verification is performed based on standardized test methods under nominal environmental and operational conditions within a typical application circuit, which are clearly documented in the test report. The procedure is consistent with Generic IC EMC Test Specification (BISS v2.1) and according ISO 26262 Part 5, Clause 10.

EMC test pass/fail criteria are derived from product specifications, application requirements and top-level safety requirements. A defined relevant subset of the functional behavior and parameters of an IC is monitored during EMC tests. Observed deviations from the intended IC behavior are part of the test documentation.

EMC requirements are not subject to production test and are verified by design and/or characterization based on typical samples from a typical lot.

The characterization results will be assessed by technical experts and shared with the customer as a reference. Given the dependency of EMC performance on the integration on system level, it is the system integrators responsibility to ensure performance on system level..

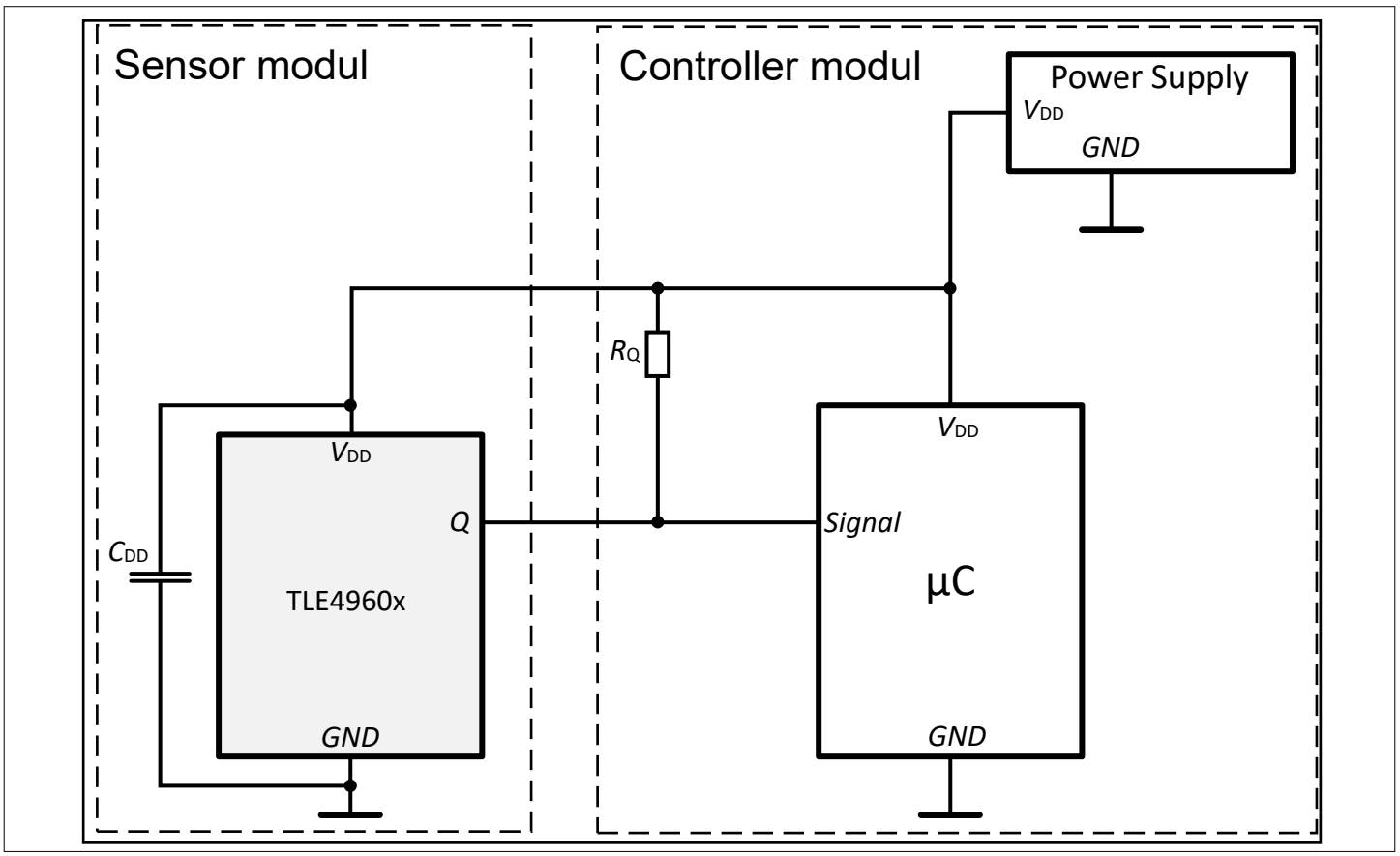

Figure 12 Example application diagram in 3-wire configuration

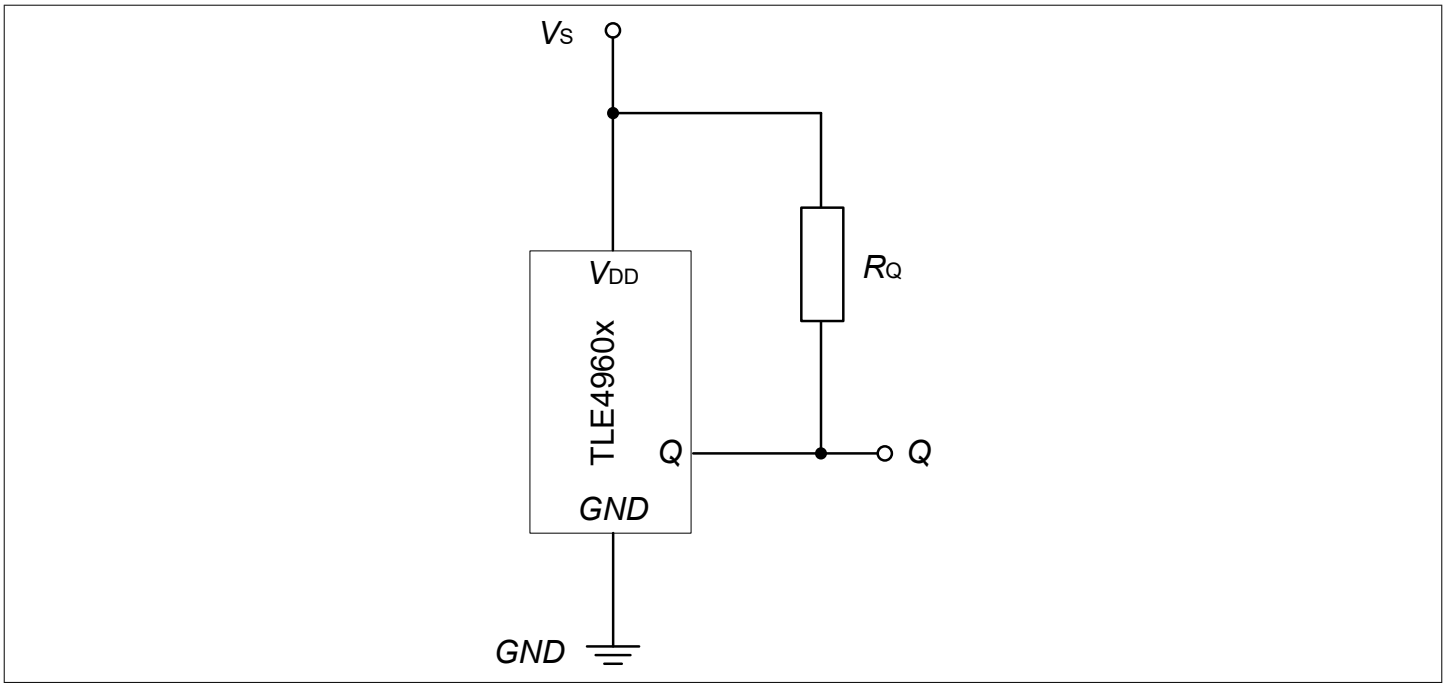

Figure 13 Basic application circuitry

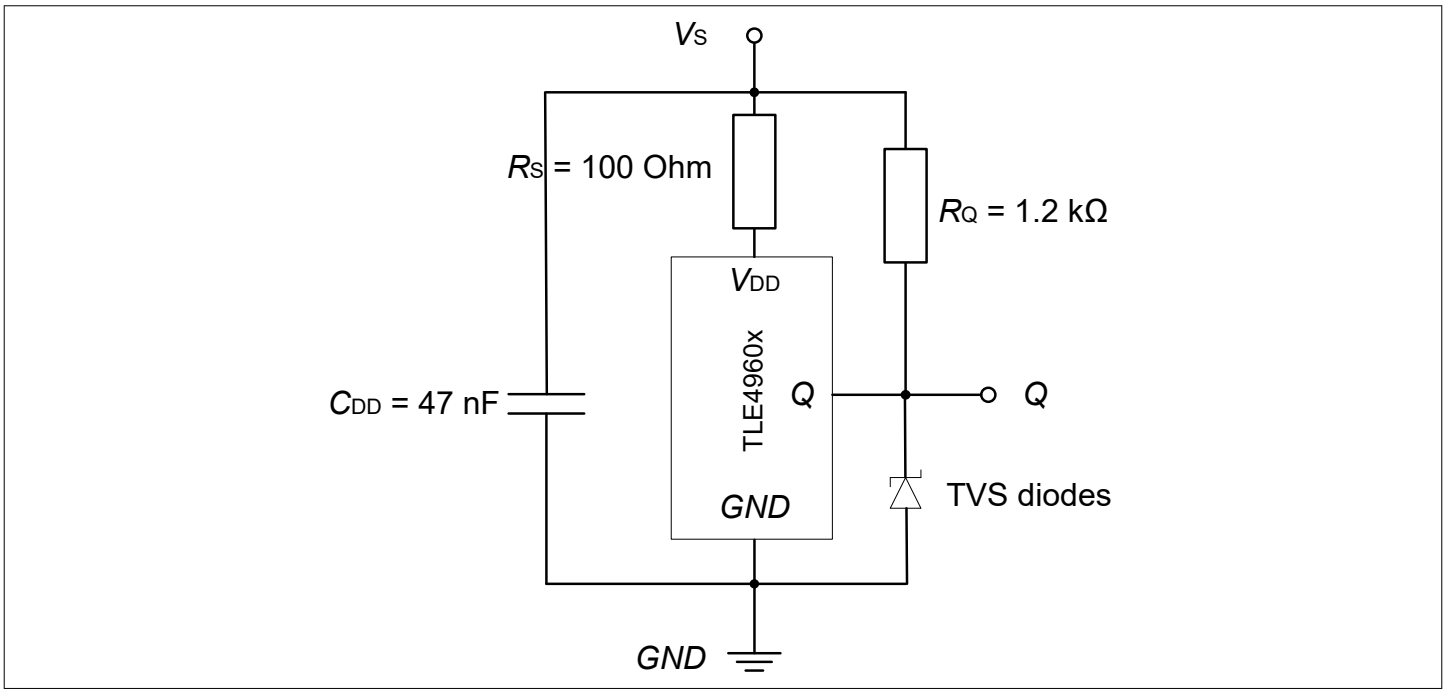

Figure 14 Application circuitry for harsh environmental conditions

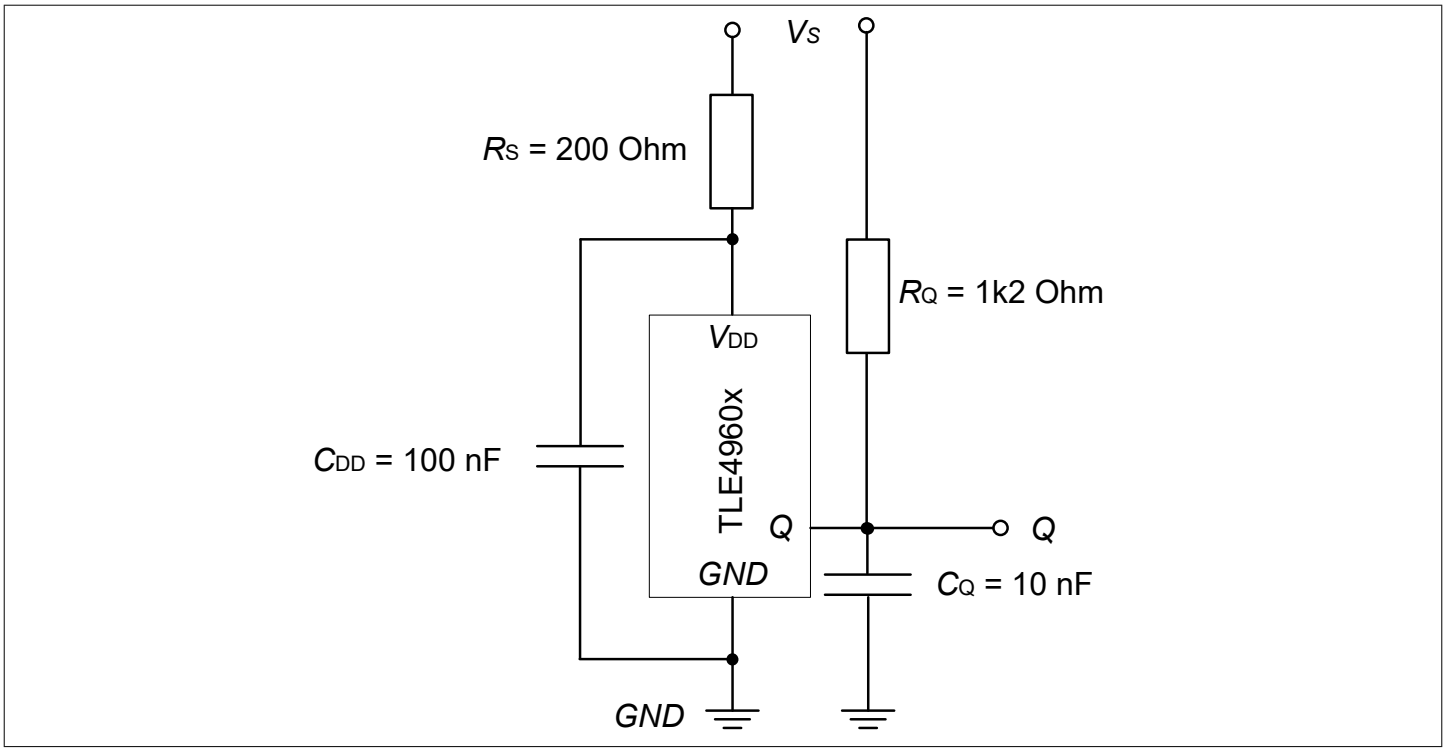

Figure 15 ISO 7637-2 test circuit

6 Package

6.1 SOT23-3

The TLE4960x is available in a small halogen-free SMD package PG-SOT23-3. Figure 16 and Figure 17 show the appearance of the used package as well as the dimensions. Figure 18 shows the footprint information of the device for PCB design. The dimensions of the transport packaging is shown in Figure 19.

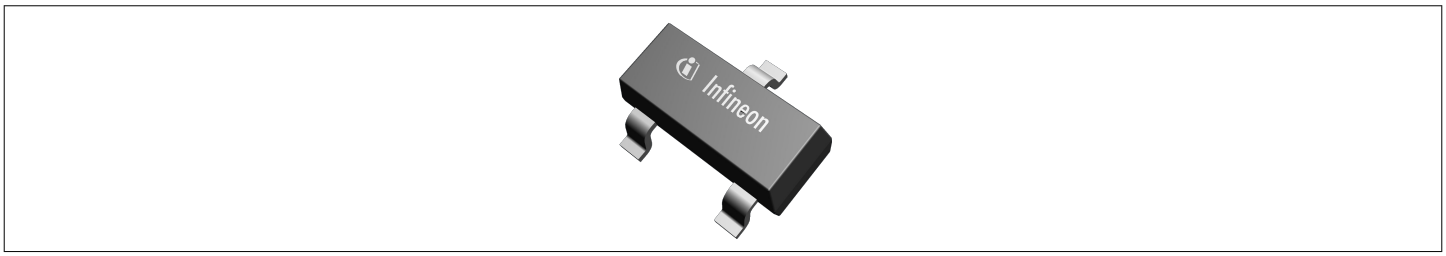

Figure 16 Package SOT23-3

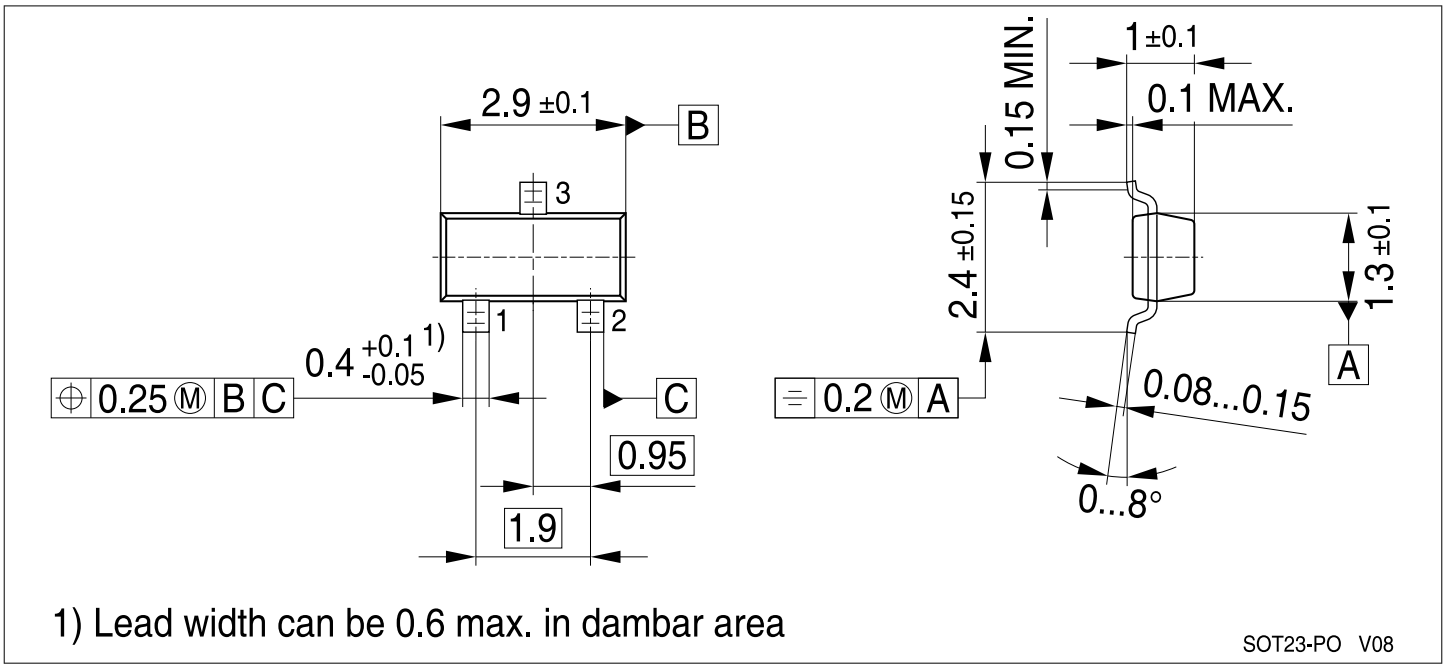

Figure 17 Outline of package SOT23-3 with dimensions

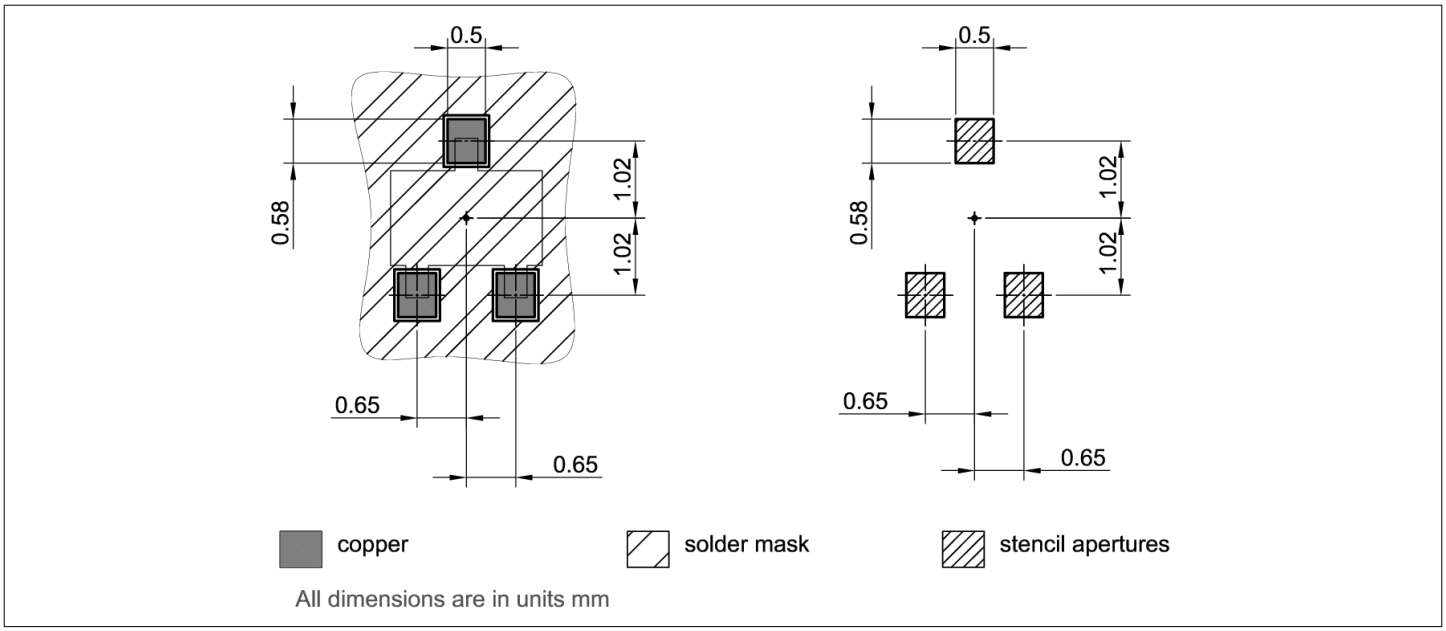

Figure 18 Footprint of package SOT23-3

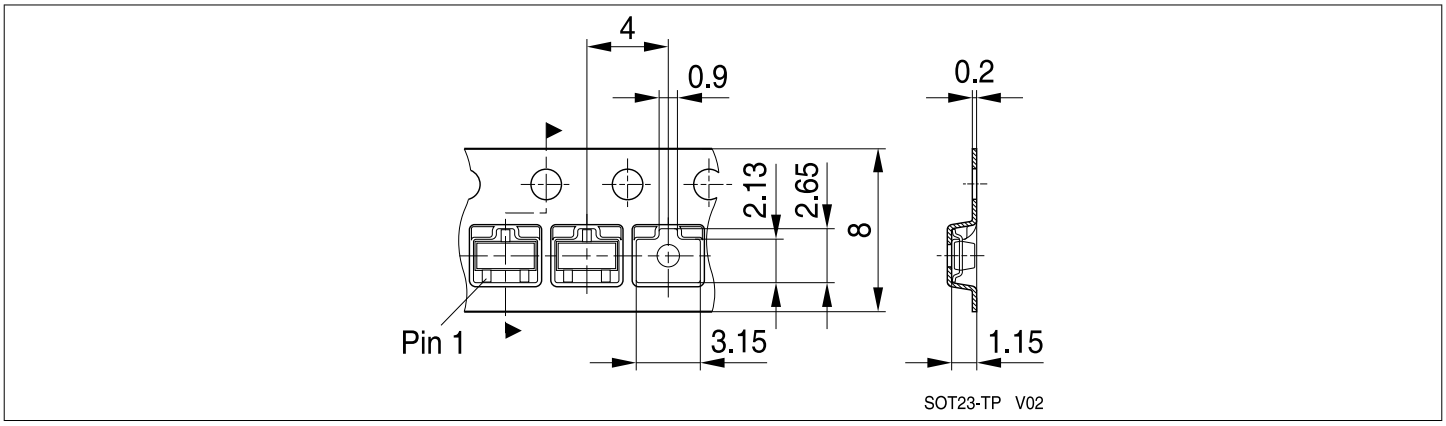

Figure 19 Outline of package SOT23-3 with dimensions

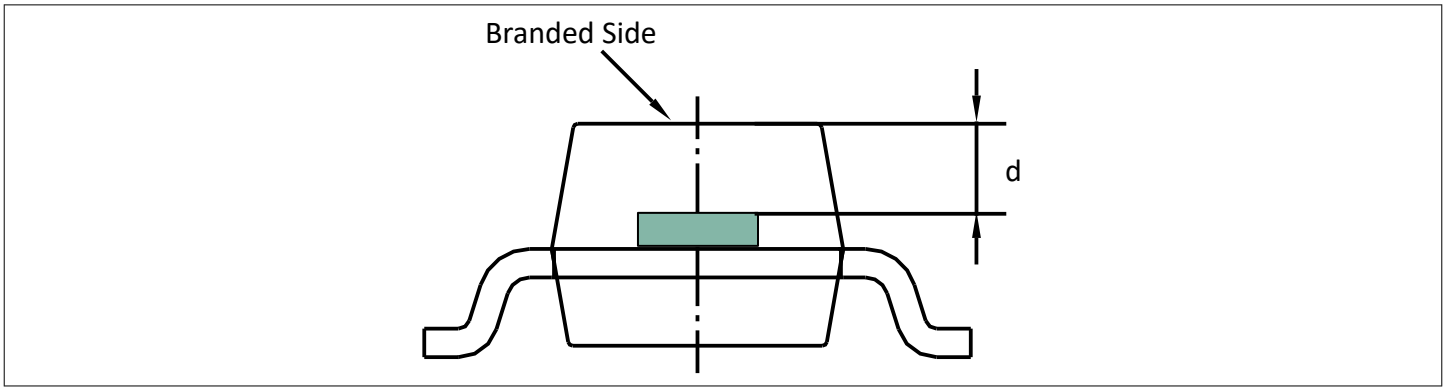

Figure 20 Distance between chip and package. d = 0.385 mm

7 Revision history

Table 17 Revision history

Revision number	Date of release	Description of changes
Rev. 1.00	2024-10-31	Initial release

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