TLE4929C-XHA

Universal Speed Sensor



Applications

The TLE4929C-XHA is an active Hall sensor ideally suited for crankshaft applications and similar industrial applications, such as speedometer or any speed-sensor with high accuracy and low jitter capabilities.

Features

- Measures speed and position of tooth/pole wheels
- Switching point in middle of the tooth enables backward compatibility
- Magnetic stray-field robustness due to differential sensing principle
- Direction detection and Stop-Start-Algorithm
- Programable switcing threshold for additional accuracy
- Hybrid-Algorithm keeps TLE4929C-XHA calibrated during electric drive

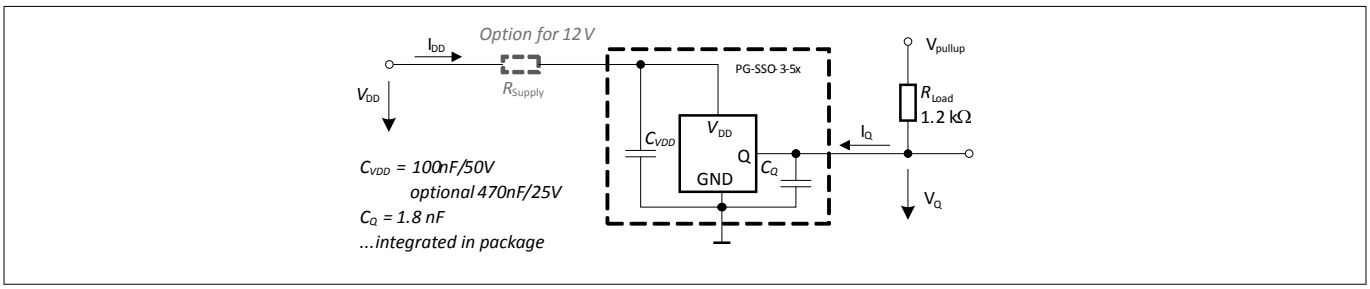


Figure 1 Typical Application Circuit

Description

The TLE4929C-XHA comes in a RoHs compliant three-pin package, qualified for automotive usage. It has two integrated capacitors on the lead frame (***Figure 1***). A pull-up resistor R_{Load} is mandatory on the output pin and determines the maximum current through the output transistor.

Table 1 Ordering Information

Type	Description	Marking	Ordering Code	Package
TLE4929C-XHA-M18N	Nickel plating, 100nF/50V	29AJC6	SP005355349	PG-SSO-3-53
TLE4929C-XHA-M38N	Nickel plating, 470nF/25V	29AJC7	SP005355351	PG-SSO-3-53

Table of contents

		1
	Applications	1
	Features	1
	Description	1
	Table of contents	2
1	**General Characteristics**	4
1.1	Absolute Maximum Ratings	4
1.2	Operating Range	5
2	**Electrical and Magnetic Characteristics**	8
3	**Functional Description**	13
3.1	Definition of the Magnetic Field Direction	13
3.2	Block Diagram	13
3.3	Basic Operation	14
3.3.1	Power-on Phase	16
3.3.2	Initial Phase	16
3.3.3	Calibration Phase	16
3.3.4	Running Phase	16
3.3.5	Averaging Algorithm	17
3.3.6	Direction Detection	17
3.3.7	Direction Detection Threshold	19
3.4	Hysteresis Concept	20
3.5	Rotational Direction Definition and Edge Polarity Definition	22
3.6	New crank protocol: forward on edges / backward on PWM	24
3.7	System Watchdog	24
3.8	Stop Start Watchdog	24
3.9	Time Watchdog	24
3.10	Hybrid Vehicle Watchdog	25
3.11	Programmable Adaptive Switching Threshold (K-FACTOR)	25
3.12	High Speed Mode	25
3.13	Serial Interface	25
4	**EEPROM Description**	26
5	**Package Information**	29
5.1	Package Outline	30
5.2	Marking and Data Matrix Code	31
5.3	Packing Information	32
6	**Revision History**	33

Table of contents

Disclaimer 34

1 General Characteristics

1.1 Absolute Maximum Ratings

Table 2 Absolute Maximum Ratings

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Voltages						
Supply voltage without supply resistor	V_{DD}	-16	–	18	V	continuous, $T_J \leq 175°C$
		-18	–	27	V	max. 60s, $T_J \leq 175°C$
Output OFF voltage	V_{Q_OFF}	-0.3	–	26.5	V	continuous, $T_J \leq 175°C$
		-1.0	–	26.5	V	max. 1 h, $T_{Amb} \leq 40°C$
Output ON voltage	V_{Q_ON}	-1.0	–	16	V	continuous, $T_{Amb} \leq 40°C$
		-0.3	–	18	V	max. 1 h, $T_{Amb} \leq 40°C$
		-0.3	–	26.5	V	max. 60 s, $T_{Amb} \leq 40°C$
Temperatures						
Junction temperature range	T_J	-40	–	185	°C	Exposure time: max. 10 × 1 h, V_{DD} = 16 V
Induction						
Magnetic field induction	B_Z [1)]	-5	–	5	T	Magnetic pulse during magnet magnetization. Valid 10 s with $T_{ambient} \leq 80°C$
ESD Resistivity						
ESD compliance	ESD_{HBM}	-6	–	6	kV	HBM [2)]

Note: 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.

1 Guaranteed by design.
2 ESD susceptibility, HBM according to EIA/JESD 22-A114B.

1.2 Operating Range

All parameters specified in the following sections refer to these operating conditions unless otherwise specified.

Table 3 General Operating Conditions

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Voltages						
Supply voltage without supply resistance R_s	V_{DD}	4.0	–	16	V	
Continuous Output Off voltage	V_{Q_OFF}	1.0	–	16	V	
Supply voltage power- up/down voltage ramp	dV_{DD}/dt	3.0	–	10000	V/ms	
Currents						
Supply current	I_{DD}	8.0	–	13.4	mA	
Continuous output On current	I_{Q_ON}	0.01	–	15	mA	V_{Q_LOW} < 0.5 V
Capacitance[3)]						
Capacitance between IC supply & ground pins for type TLE4929C-XHA-M18N	C_{VDD}	90	100	110	nF	
Capacitance between IC supply & ground pins for type TLE4929C-XHA-M38N	C_{VDD}	423	470	517	nF	
Output capacitance between IC output and ground pins	C_Q	1.62	1.8	1.98	nF	
Direction Detection						
Frequency range for direction detection	f_{Dir}	0	–	1800	Hz	For increasing rotational frequency
		0	–	1500	Hz	For decreasing rotational frequency
Programming						
Maximum No. of EEPROM programming cycles	N_{PROG}	–	–	100	n	
Magnetic Signal						
Magnetic signal frequency range	f	0	–	8000	Hz	Full accuracy
		8000	–	10000	Hz	10% degraded jitter
Dynamic range of the magnetic field of the differential speed channel	$DR_{mag_field_s}$	-120	-	120	mT	

3 Specified at a room temperature, test condition at 25°C with 1 V at 1 kHz , temperature variation to be added

Table 3 General Operating Conditions (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Dynamic range of the magnetic field of the direction channel	$DR_{mag_field_dir}$	-60	-	60	mT	
Static range of the magnetic field of the outer Hall probes in back-bias configuration	$SR_{mag_field_s_bb}$	0	-	550	mT	No wheel in front of module / Offset-DAC-Compensation-range
Static range of the magnetic field of the outer Hall probes in magnetic encoder wheel configuration	$SR_{mag_field_s_pw}$	-10	-	10	mT	Static absolute offset for pole wheel / Offset-DAC-Compensation-range / independent from Bit “POLE_WHEEL”
Static range of the magnetic field of the center Hall probe	$SR_{mag_field_dir}$	-100	-	450	mT	No wheel in front of module / Center-Offset-DAC-Compensation-range
Allowed static difference between outer probes	$SR_{mag_field_diff}$	-30	-	30	mT	No wheel in front of module
Magnetic differential field amplitude for full performance on stop-start	$\Delta B_{Speed_Stop,Start}$	9	-	-	mT_{pkpk}	No false pulses for temperature drift of ≤ 60 K during stop-start state. Tolerated change of speed-channel mean value ≤ 3 mT
		6	-	-	mT_{pkpk}	No false pulses for temperature drift of ≤ 40 K during stop-start state. Tolerated change of speed-channel mean value ≤ 2 mT
		4	-	-	mT_{pkpk}	No false pulses for temperature drift of ≤ 20 K during stop-start state. Tolerated change of speed-channel mean value ≤ 1.5 mT
Temperatures						
Normal operating junction temperature	T_J	-40	–	175	°C	Exposure time: max. 2500 h at T_J = 175°C, V_{DD} = 16 V
		-40	-	185	°C	Exposure time: max. 10 × 1 h at T_J = 185°C, V_{DD} = 16 V, additive to other lifetime

Table 3 General Operating Conditions (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Not operational lifetime	T_{no}	-40		150	°C	Without sensor function. Exposure time max 500 h @ 150°C; increased time for lower temperatures according to Arrhenius-Model, additive to other lifetime
Ambient temperature range for customer programming	T_{RDPROG}	15	25	130	°C	
Allowed temperature variations between engine stop and restart.	$\Delta T_{Stop,start}$	–	–	60	°C	Device powered continuously
Temperature compensation range of magnetic material	TC	-1900	–	0	ppm	Internal compensation of magnetic signal amplitude of speed signal

2 Electrical and Magnetic Characteristics

All values specified at constant amplitude and offset of input signal, over operating range, unless otherwise specified. Typical values correspond to VS = 5 V and $T_{Amb.}$ = 25°C.

Table 4 Electrical and Magnetic Parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Voltage						
Output saturation voltage	V_{Qsat}	-	-	500	mV	$I_Q \leq 15$ mA
Clamping voltage V_{DD}-Pin	V_{DD_clamp}	42	-	-	V	leakage current through ESD-diode < 0.5 mA
Clamping voltage V_Q-Pin	V_{Qclamp}	42	-	-	V	leakage current through ESD-diode < 0.5 mA
Reset voltage	V_{DD_reset}	-	-	3.6	V	
Current						
Output leakage current	I_{Qleak}	-	0.1	10	µA	V_Q = 18 V
Output current limit during short-circuit condition	I_{Qshort}	30	-	80	mA	
Temperature						
Junction temperature limit for output protection	T_{prot}	190	-	205	°C	
Time and Frequency						
Power on time	t_{power_on}	0.8	0.9	1	ms	During this time the output is locked to high.
Delay time between magnetic signal switching point and corresponding output signal falling edge switching event	t_{delay}	10	14	19	µs	Falling edge
Further options on delay time accessible using EEPROM	t_{delay2}	13	17	22	µs	Option 2
	t_{delay3}	16	20	25	µs	Option 3
	t_{delay4}	19	23	28	µs	Option 4
Output fall time	t_{fall}	2.0	2.5	3.0	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 80% - 20%
		3.2	4.5	5.8	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 90% - 10%
Output rise time	t_{rise} [4)]	4	-	11.4	µs	R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 10% - 90%

4 Application parameter, IC does not increase the rise time (max. value), Values are calculated and not tested.

Table 4 Electrical and Magnetic Parameters (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Minimum Field Change during Start up to generate Output Switching						
Digital noise constant of speed channel during start up (change in differential field)	DNC_{min}	0.53	0.75	0.97	mT_{pkpk}	EEPROM “DNC_MIN”: Option 00[5]
		1.22	1.5	1.78	mT_{pkpk}	EEPROM “DNC_MIN”: Option 01
		2.14	2.5	2.86	mT_{pkpk}	EEPROM “DNC_MIN”: Option 10
		4.44	5	5.56	mT_{pkpk}	EEPROM “DNC_MIN”: Option 11
Hysteresis Of Switching Threshold						
Adaptive hysteresis threshold of speed channel	$HYS_{adaptive}$	–	25	–	%	EEPROM “HYST_ADAPT”: Option 0
		–	31.25	–	%	EEPROM “HYST_ADAPT”: Option 1
Switching level offset	SwitchOffset,Error	-350	–	350	µT	For magnetic speed signal = 10 mT_{pkpk} : resulting in phase error / duty cycle error.
Programming switching level offset (k-factor)	k-factor[7]	–	39.1	–	%	EEPROM “K_FACTOR”: Option 0000
		–	40.6	–	%	EEPROM “K_FACTOR”: Option 0001
		–	42.2	–	%	EEPROM “K_FACTOR”: Option 0010
		–	43.8	–	%	EEPROM “K_FACTOR”: Option 0011
		–	45.3	–	%	EEPROM “K_FACTOR”: Option 0100
		–	46.9	–	%	EEPROM “K_FACTOR”: Option 0101
		–	48.4	–	%	EEPROM “K_FACTOR”: Option 0110
		46.3	50.0	53.7	%	EEPROM “K_FACTOR”: Option 0111
		–	51.6	–	%	EEPROM “K_FACTOR”: Option 1000
		–	53.1	–	%	EEPROM “K_FACTOR”: Option 1001
		–	54.7	–	%	EEPROM “K_FACTOR”: Option 1010
		–	56.3	–	%	EEPROM “K_FACTOR”: Option 1011
		–	57.8	–	%	EEPROM “K_FACTOR”: Option 1100
		–	59.4	–	%	EEPROM “K_FACTOR”: Option 1101
		–	60.9	–	%	EEPROM “K_FACTOR”: Option 1110
		–	62.5	–	%	EEPROM “K_FACTOR”: Option 1111
Accuracy and Repeatability						

5 Smallest setting is not recommended for harsh environment: long tooth, long notch, vibration, run-out of target-wheel.

7 Parameter not subject to productive test. Verified by laboratory characterization / design.

Table 4 Electrical and Magnetic Parameters (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Repeatability (Jitter)	Jitter[6]	–	–	0.015	°Crank	3 sigma, ΔBpkpk = 20 mT_{pkpk}, FILTER_SELECT = 0
		–	–	0.025	°Crank	3 sigma, ΔBpkpk = 9 mT_{pkpk} , measured on coil using sinus signal, Ta = 150°C, f = 8kHz, FILTER_SELECT = 0
Number of wrong pulses at start-up	nStart [7]	–	–	0	n	Engine starts in continuous forward rotational direction
		0	–	1	n	Engine starts in continuous backward rotational direction
Number of wrong pulses after stop-start	nStop,start [7]	–	–	0	n	Multiple rotational direction changes > 6°Crank allowed
Maximum phase error	Phirunning [6]	-0.2	–	0.2	°Crank	ΔB_{Speed} > 9 mT_{pkpk} ,signature excluded, accuracy on mentioned wheel in Figure 4
Maximum phase error after stop-start	Phistop,start [6]	-1.7	–	3.2	°Crank	Reduced phase accuracy only for first pulse after stop-start-state / signature excluded
Run Out Capabilities						
Global run out (speed and direction channel)	Runoutglobal [7]	1.0	–	1.67	-	Ratio = Amplitude(max)pkpk / Amplitude(min)pkpk
		1.0	–	2.5	-	Ratio = Amplitude(max)pkpk / Amplitude(min)pkpk . Reduced performance in Stop-Start-behavior.
Magnetic overshoot of signature region in speed signal. Magnetic overshot from tooth to tooth (polepair to polepair)	Runoutto oth,tooth [7]	0.8	1.2	1.6	-	Ratio = Amplitude(signature) / Amplitude(before/after). Valid for toothed target wheel.
		0.7	1.4	2.5	-	Ratio = Amplitude(signature) / Amplitude(before/after). Valid for magnetic target wheel.
Output Protocol Variants						
Crankshaft without direction detection: Output follows profile of target wheel	–	–	–	–	–	Output “Q” changes state (“LOW” or “HIGH”) in the middle of the tooth / middle of the notch

6 Parameter not subject to productive test. Verified by characterization in the laboratory based on jitter-measurement > 1000 falling edges.

7 Parameter not subject to productive test. Verified by laboratory characterization / design.

Table 4 Electrical and Magnetic Parameters (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Crankshaft protocol with direction (option 1)	t_{fwd}	38	45	52	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	76	90	104	µs	
	$t_{standstill}$	152	180	208	µs	
Crankshaft protocol with direction (option 2)	t_{fwd}	38	45	52	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	152	180	208	µs	
	$t_{standstill}$	304	360	416	µs	
Crankshaft protocol with direction (option 3)	t_{fwd}	38	45	52	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	114	135	156	µs	
	$t_{standstill}$	152	180	208	µs	
Crankshaft protocol with direction (option 4)	t_{fwd}	63	75	87	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	507	600	693	µs	
	$t_{standstill}$	304	360	416	µs	
Crankshaft protocol with direction (option 5)	t_{fwd}	18	22	26	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	38	45	52	µs	
	$t_{standstill}$	76	90	104	µs	
Crankshaft protocol with direction (option 6)	t_{fwd}	51	60	69	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	101	120	339	µs	
	$t_{standstill}$	304	360	416	µs	
Crankshaft protocol with direction (option 7)	t_{fwd}	25	30	35	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), Valid between 50% of falling edge to 50% of next rising edge, Forward pulse is issued only once after rotational direction change. Further forward movement is issued as two edges per period according to a crankshaft-sensor without direction protocol. Details please find in ***Chapter 3.6***.
	t_{bwd}	51	60	69	µs	
Crankshaft protocol with direction (option 8)	t_{fwd}	76	90	104	µs	V_{Pullup} = 5 V, R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge
	t_{bwd}	114	135	156	µs	
	$t_{standstill}$	304	360	416	µs	

Note: The listed Electrical and magnetic characteristics are ensured over the operating range of the integrated circuit. Typical characteristics specify mean values expected over the production spread. If not other specified, typical characteristics apply at T_{Amb} = 25°C and V_S = 5 V.

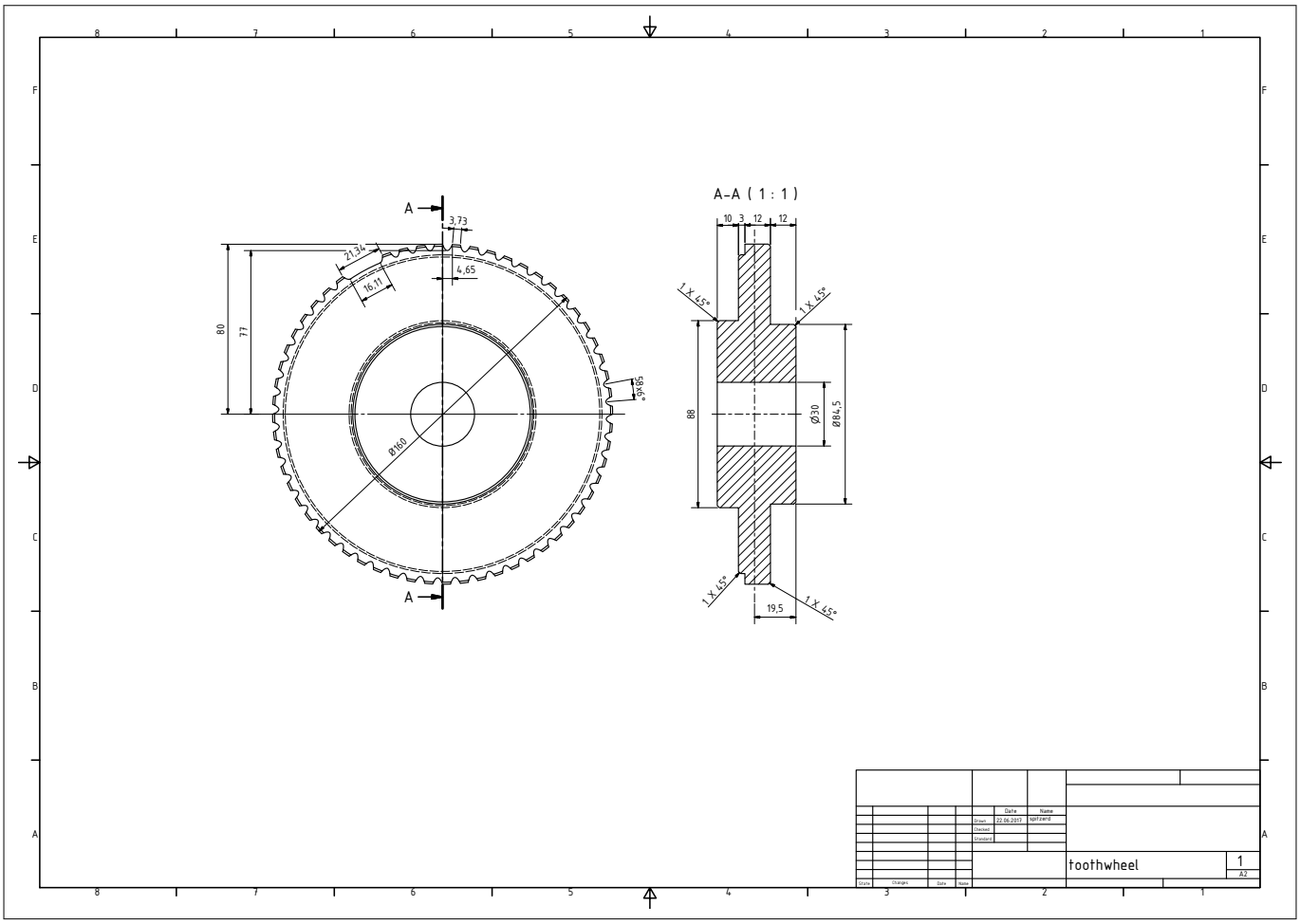


Figure 2 OEM-crankshaft wheel (outer diameter = 160 mm)

3 Functional Description

3.1 Definition of the Magnetic Field Direction

The magnetic field of a permanent magnet exits from the north pole and enters the south pole. If a north pole is attached to the backside of the High End Crankshaft Sensor, the field at the sensor position is positive, as shown in ***Figure 3***.

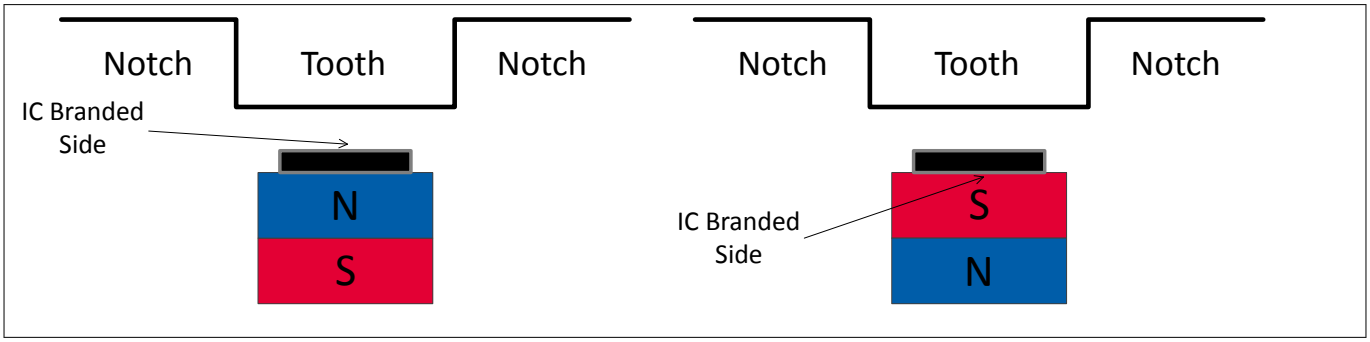


Figure 3 Definition of the Positive Magnetic Field Direction

3.2 Block Diagram

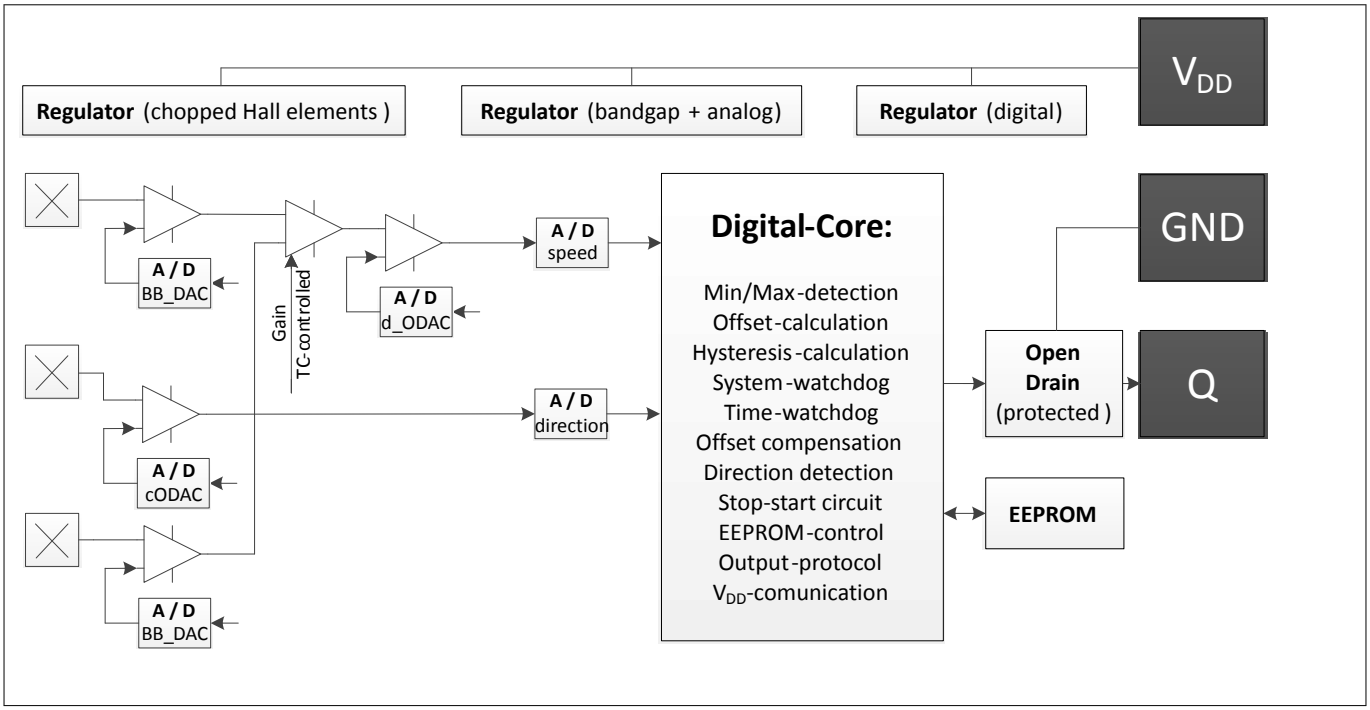


Figure 4 Block Diagram

3.3 Basic Operation

The basic operation of the TLE4929C-XHA is to transpose the magnetic field produced by a spinning target wheel into speed pulses with directional information at the output pin. The pulse width indicates forward or backward direction information and can be adjusted in EEPROM-options. It is also possible to parameterize output switching without direction information like it is requested for differential CAM-shaft sensors.The correspondence between field polarity and output polarity can be set according to the application needs as well. By definition a magnetic field is considered as positive if the magnetic North Pole is placed at the rear side of the sensor, see ***Figure 3***.

For understanding the operation five different phases have to be considered:

- Power-on phase
  - starts after supply release
  - lasts $t_{power\text{-}on}$ (power-on time)
  - IC loads configuration and settings from EEPROM and initializes state machines and signal path
  - output is locked HIGH
- Initial phase (***Figure 5*** ”Uncalibrated mode”)
  - starts after Power-on phase
  - lasts one clock cycle
  - IC enables output switching, extrema detection and threshold adaption
- Calibration phase 1 (***Figure 5*** ”Uncalibrated mode”)
  - starts after Initial phase
  - lasts until the sensor has observed 3 mangetic edges (maximum 4 magnetic edges) and is able to perform the most likely final threshold update needed for transition to “Calibration Phase 2”.
  - IC performs fast adaptation of the threshold according to the application magnetic field
  - initial and second switching (uncalibrated mode)of the output is performed according to the detected field change of the differential magnetic field
  - length of the output-pulse is derived from the center Hall probe (direction signal) sampled at the zero-crossing of the differential outer Hall probes (speed signal)
  - length of the very first pulse is “forward-pulse” according to choosen protocol in EEPROM (direction information is not valid at this time)
- Calibration phase 2
  - starts after “Calibration Phase 1”
  - lasts until the sensor has reached final offset-calibration which is minimum 5 teeth / maximum 64 teeth (pole-pairs) according to choosen alorithm in EEPROM
  - IC performs slow and accurate adaptation of the threshold according to the application magnetic field
  - output switching (calibrated mode) is performed according to magnetic zero-crossing of the differential magnetic field
  - length of the output-pulse is derived from the center Hall probe (direction signal) sampled at the zero-crossing of the differential outer Hall probes (speed signal)
- Running phase
  - starts after “Calibration Phase 2”
  - lasts indefinitely if no special condition is triggered (see ***Chapter 3.8***)
  - performs a filter algorithm in order to maintain superior phase accuracy and improved jitter
  - output switches according to the threshold value, according to the hidden hysteresis algorithm and according to the choosen output-protocol

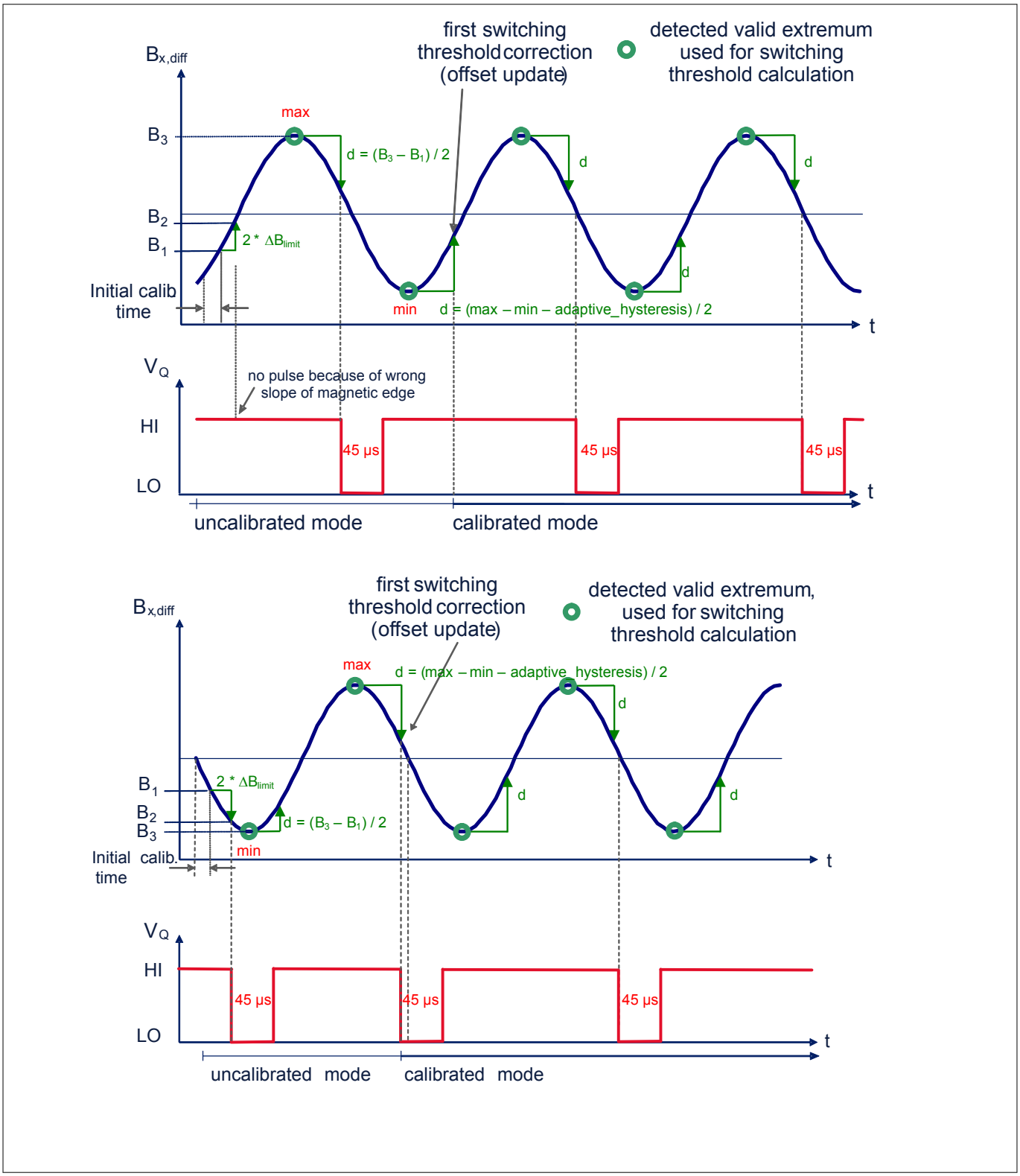


Figure 5 Operating Phases - Power-on to Running Phase

3.3.1 Power-on Phase

The operation in Power-on Phase is to refresh the trimming coefficients and algorithm settings from the EEPROM and to allow the signal path to stabilize.

If an unrecoverable error is found at EEPROM refresh, the output will remain locked HIGH during the entire operation.

3.3.2 Initial Phase

The magnetic field is measured by three chopped Hall probes. From the outer Hall probes located at a distance of 2.5 mm a differential magnetic field is measured which is named “speed” in this datasheet. From the center Hall probe the “direction” signal is derived. Both signals are converted to a digital value via an ADC.

3.3.3 Calibration Phase

The adaptation of the threshold to the magnetic field is performed in Calibration Phase. This adaptation is done based on the field values set by teeth and notches (or based on poles on the pole wheel). These variations in the magnetic field are followed by a local extrema detection state machine in the IC. During Calibration Phase the IC permanently monitors the magnetic signal. First and second switching is performed when the speed-path recognized a certain change of magnetic field and the polarity meets the switching criterion derived from the EEPROM. The third and further pulse of the output is performed at “zero-crossing” of the speed path. “Zero crossing” is the 50%-value between detected minimum and detected maximum - also known as “offset”.

3.3.4 Running Phase

According to the choosen algorithm in EEPROM an avaerage of 5 to 58 pulses is used to do an offset-calculation and an offset-update.

The following rules have to be verified before applying a computed update to the threshold register:

- Compatibility between threshold update sign and magnetic edge
- Threshold update has to be large enough not to be discarded (minimum_update)
- Threshold update is limited to a maximum value based on field amplitude and on comparison with absolute field value (maximum_update)
- Computed threshold update is always halved before being applied
- Threshold update is filtered to discourage consecutive updates in opposite direction (consecutive_upd_req)

Typically the offset is updated after one complete revolution of the target wheel, which is effectively 58 teeth.

Table 5 Available offset update algorithm to be choosen in EEPROM

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Offset update algorithm	58 teeth	-	58	-	-	one revolution of a 60-2 target
	56 teeth	-	56	-	-	one revolution of a 60-2-2 teeth /pole-pair target
	34 teeth	-	34	-	-	one revolution of a 36-2 teeth /pole-pair target
	32 teeth	-	32	-	-	one revolution of a 32-teeth /pole-pair target
	5 times the same sign for offset-update	5	-	-	-	suggested for wheels with different number of teeth or for large run-out.

3.3.5 Averaging Algorithm

To calculate the threshold within the running phase, valid maxima and minima are averaged to reduce possible offset-updates. Each offset-update gives an increased jitter, which has to be avoided.

3.3.6 Direction Detection

Direction is calculated from the amplitude-value of direction-signal sampled at zero-crossing of speed-channel. For each pole-pair or pair of tooth and notch two digital values are generated for detecting the direction. Subtracting the second value from the first value the direction is determined by its sign. According to EEPROM-setting a positive sign is either direction forward or direction backward.

Table 6 EEPROM-options for polarity and direction

EEPROM EDGE_POLAR	EEPROM FORWARD_DEF	Function
0	0	Forward-pulse is issued when wheel rotates from pin 1 to pin 3. Falling edge of output-pulse occurs at middle of the notch.
0	1	Forward-pulse is issued when wheel rotates from pin 3 to pin 1. Falling edge of output-pulse occurs at middle of the tooth.
1	0	Forward-pulse is issued when wheel rotates from pin 1 to pin 3. Falling edge of output-pulse occurs at middle of the tooth.
1	1	Forward-pulse is issued when wheel rotates from pin 3 to pin 1. Falling edge of output-pulse occurs at middle of the notch.

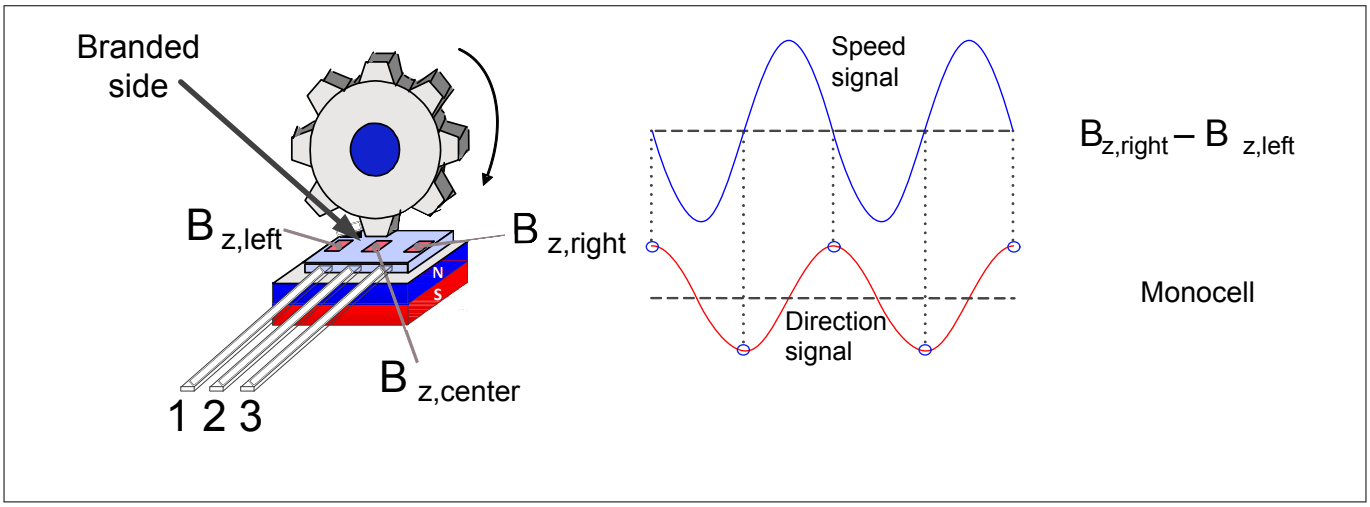


Figure 6 **Direction Detection Principle: TLE4929C-XHA-M18N issues forward-pulses at each middle of tooth**

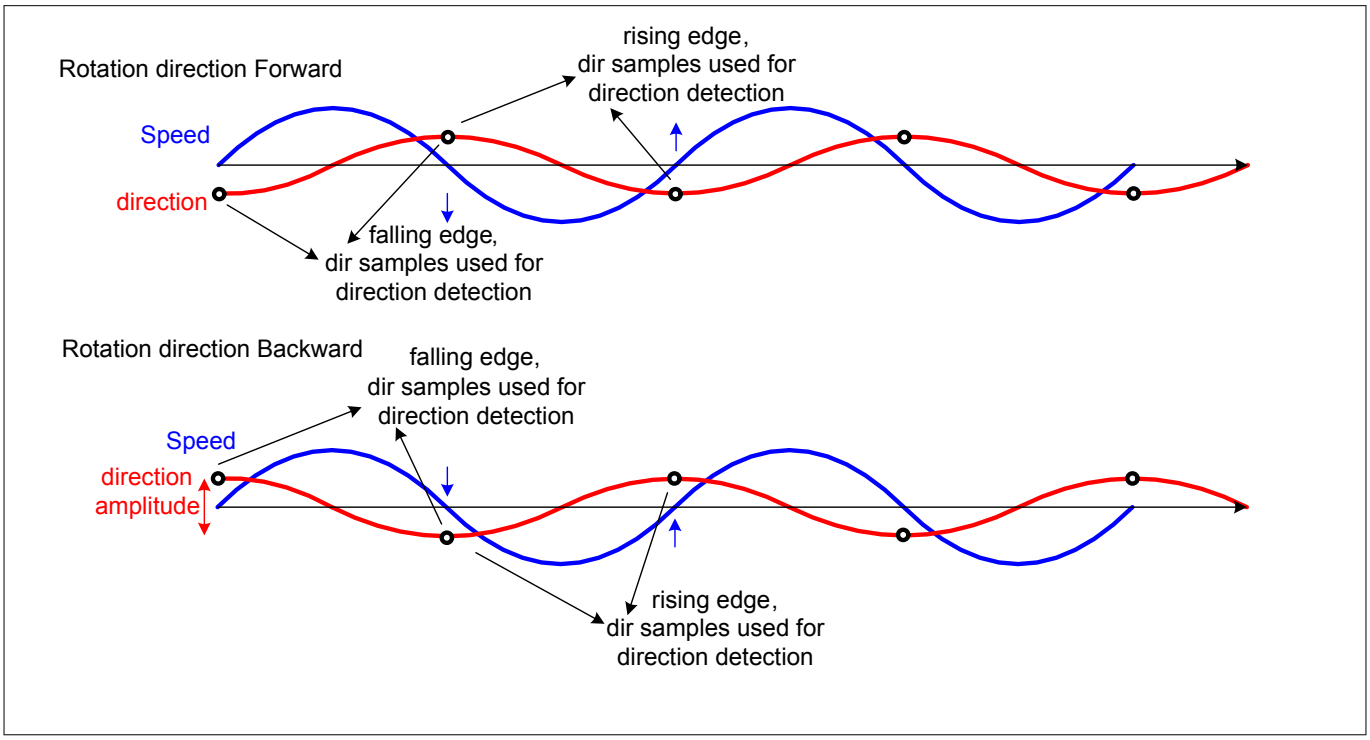


Figure 7 **Direction Detection Principle: Rotation Direction Forward And Backward**

3.3.7 Direction Detection Threshold

To recognize a change in rotational direction of the target wheel a threshold (***Figure 8***) is used. The peak-to-peak signal of direction is averaged over the last 5 teeth and is used as 100% value. Whenever a new minimum or a new maximum is measured, a threshold of 25% is calculated.

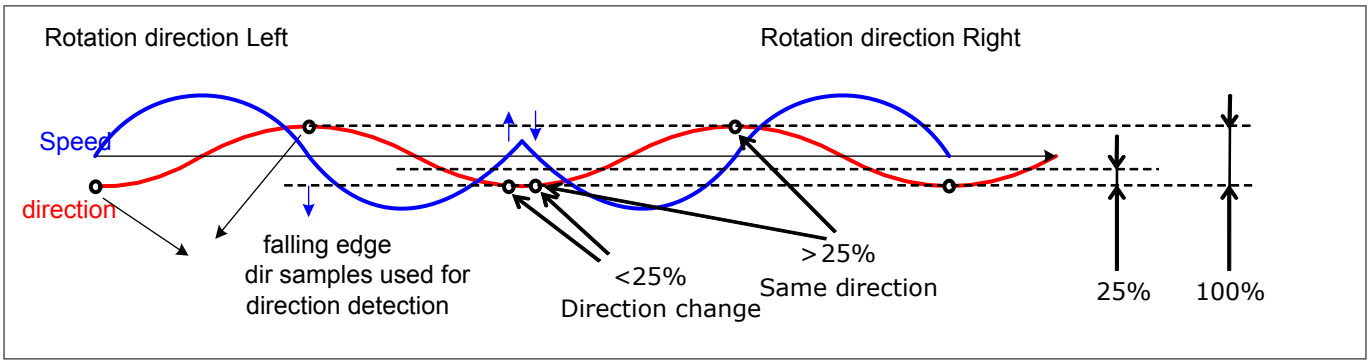


Figure 8 Direction Threshold Level

At a constant direction the next sample-point is expected to have another 100% signal amplitude. In the case of a rotational direction change the same value as before is expected. To distinguish between these two cases a virtual threshold of 25% is taken into account. Using EEPROM these 25% can be programmed to 12.5% (direction change criterion).

3.4 Hysteresis Concept

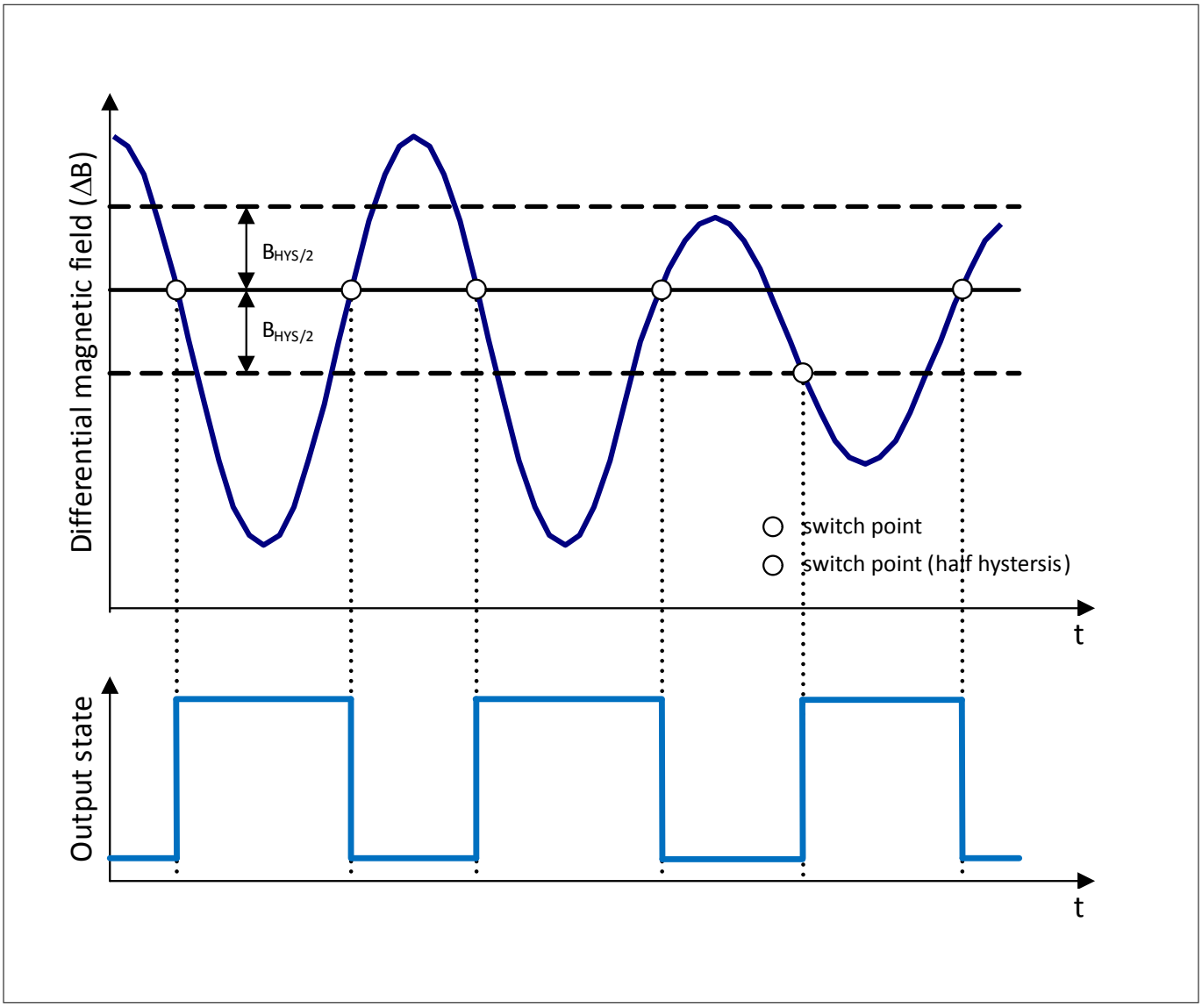


Figure 9 Hidden Hysteresis in protocol-variant without direction detection

The prefered switching behavior for crankshaft application in terms of hysteresis is called hidden adaptive hysteresis. For reason of long notches or long teeth there is the EEPROM possibility to go for visible hysteresis as well. Another EEPROM possibility is fixed hysteresis, which allows robustness against metalic flakes attached by the back-bias-magnet.

Hidden adaptive hysteresis means, the output always switches at the same level, centered between upper and lower hysteresis. These hysteresis thresholds needs to be exceeded and are used to enable the output for the next following switching event. For example, if the differential magnetic field crosses the lower hysteresis level, then the output is able to switch at the zero crossing. Next following upper hysteresis needs to be exceeded again in order to enable for the next switching. Furthermore, the function of half hysteresis maintains switching whenever the upper hysteresis level is not exceeded, but the lower hysteresis level is crossed again, then the output is allowed to switch, so that no edge is lost. However, this causes additional phase error, see ***Figure 9***.

Doing an adaptive hysteresis gives advantage at small airgap (large signal) to have big hysteresis. Compared with fixed hysteresis a small vibration cannot cause additional switching. According ***Figure 10*** the adaptive hysteresis is calculated as 25% of the differential Speed-signal peak to peak. The minimum hysteresis is derived from EEPROM-setting .

3 Functional Description

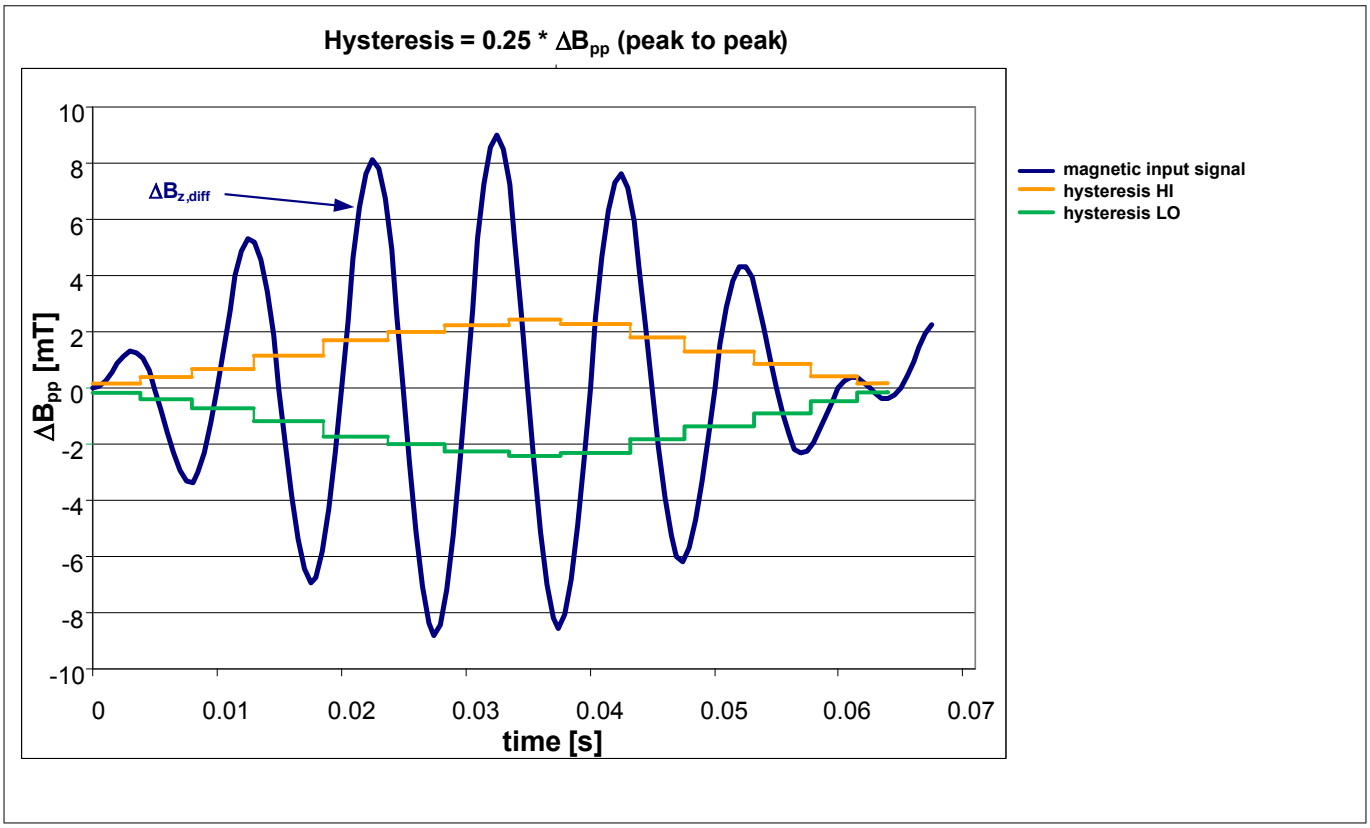


Figure 10 Adaptive Hysteresis

3.5 Rotational Direction Definition and Edge Polarity Definition

TLE4929C-XHA has EEPROM-options to change the position of the output-protocol. In the application the switching point is either the middle of the tooth or the middle of the notch (magnetic encoder wheel: middle of north pole or middle of south pole). From magnetic point of view it is zero crossing of the differential speed signal: Either rising edge or falling edge. The EEPROM-Bit “EDGE_POLAR” parametrizes the sensor to one of the edges.

In addition there is an option to issue “forward”-pulses either in CW rotational direction or CCW rotational direction: “FORWARD_DEF”.

Both EEPROM-bits are independent from each other.

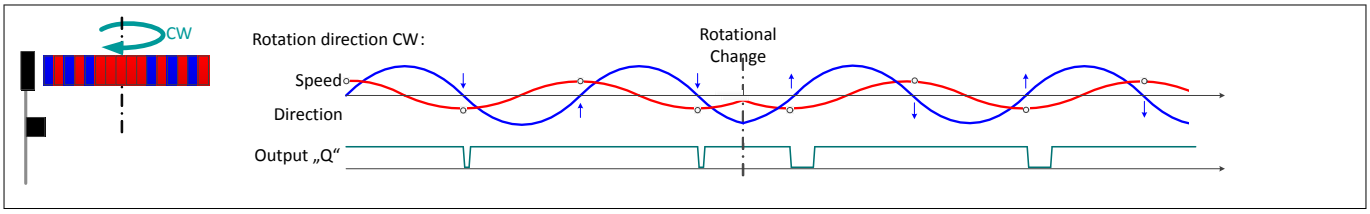


Figure 11 Signal output in setting “EDGE_POLAR = 0” and “FORWARD_DEF” = 0

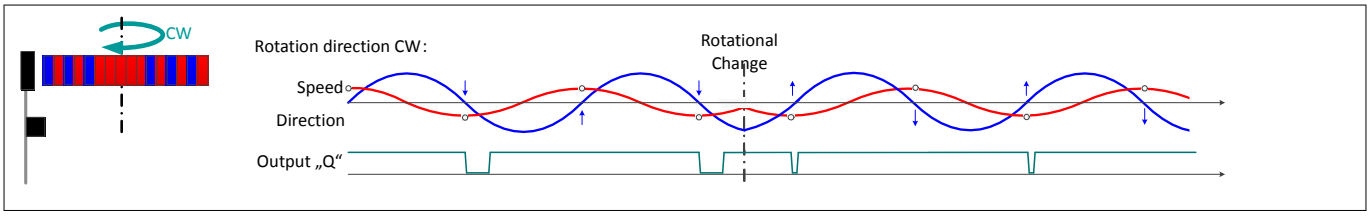


Figure 12 Signal output in setting “EDGE_POLAR = 1” and “FORWARD_DEF” = 1

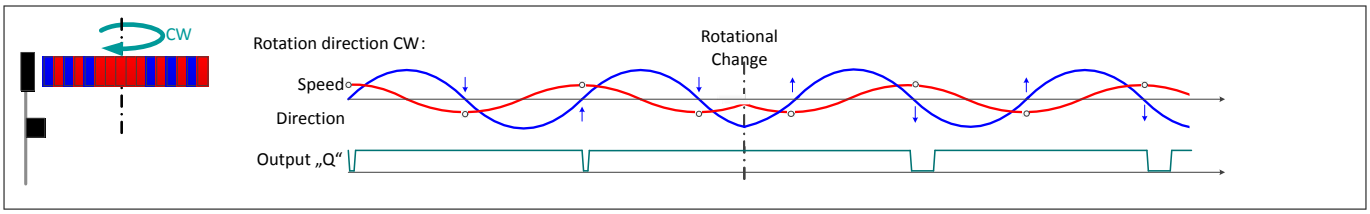


Figure 13 Signal output in setting “EDGE_POLAR = 1” and “FORWARD_DEF” = 0

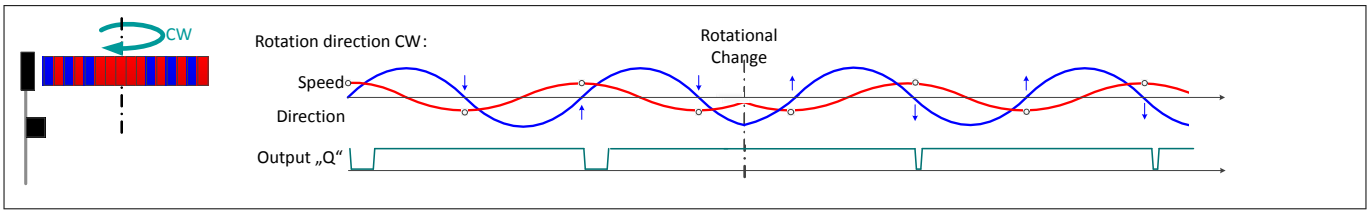


Figure 14 Signal output in setting “EDGE_POLAR = 0” and “FORWARD_DEF” = 1

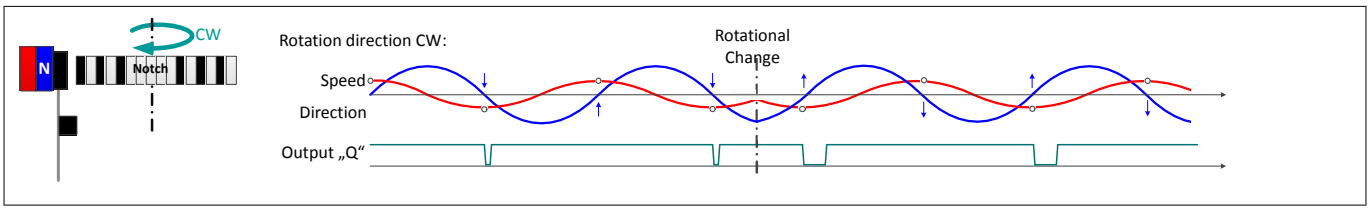


Figure 15 Signal output in setting “EDGE_POLAR = 0” and “FORWARD_DEF” = 0

3 Functional Description

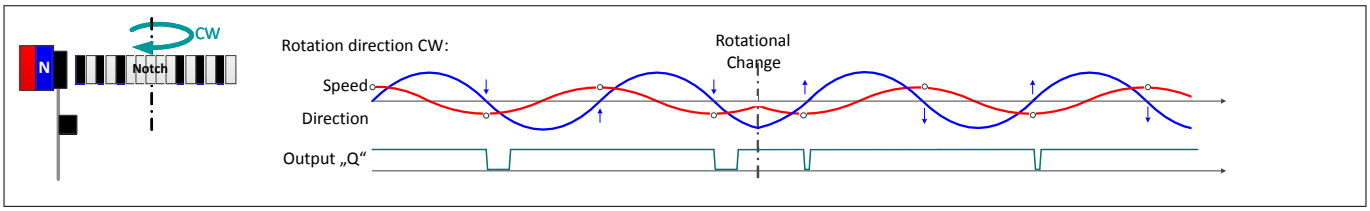


Figure 16 Signal output in setting “EDGE_POLAR = 1” and “FORWARD_DEF” = 1

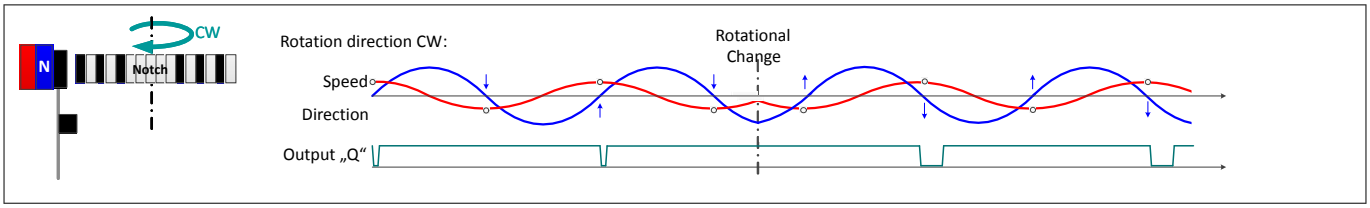


Figure 17 Signal output in setting “EDGE_POLAR = 1” and “FORWARD_DEF” = 0

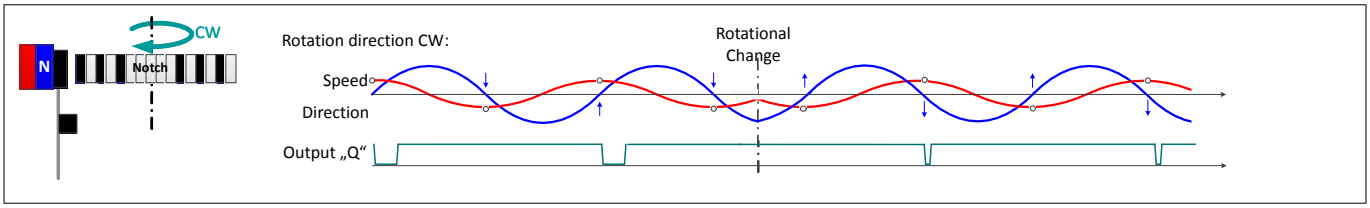


Figure 18 Signal output in setting “EDGE_POLAR = 0” and “FORWARD_DEF” = 1

3.6 New crank protocol: forward on edges / backward on PWM

According to specification of a major OEM there is a new protocol implemented.

In forward rotational direction the TLE4929C-XHA behaves like a crankshaft-sensor without direction detection and issues one falling and one rising edge per magnetic period of the target wheel. This includes the advantage to have double number of position information for each rotation of the wheel. On a typical crankwheel consisting of 58 teeth the position is transfered 116 times.

Using bit “OEM_FW_START” defines the start-up and calibration behavior.

3.7 System Watchdog

The system watchdog is monitoring following parts in the digital core and at the output:

- Finding valid maxim in the speed signal
- Finding valid minim in the speed signal
- Finding valid zero-crossing of the speed signal
- Monitoring the output switching

As long the speed signal and the corresponding output switching is fine the system watchdog will reset itself automatically at every output-switching. As soon the system watchdog detects valid maximum, valid minimum and valid zero-crossing without a switching event at the output, the system watchdog will increase its counter. Switching of the output sets the counter to zero. When the counter reaches its limit the offset will be reset.

The advantage of this system watchdog is to avoid “flat line” behavior at the output. Once there happened a massive event in the sensing system (i.e. hit on the tooth, sudden air gap jump, ...), the TLE4929C-XHA is able to recover itself. The system watchdog can be enabled by EEPROM setting “WATCH_DOG_EN”.

3.8 Stop Start Watchdog

The Stop Start Watchdog allows TLE4929C-XHA to stay calibrated during stand-still of the target wheel and a possible temperature-drift of 60K. It can be enabled by EEPROM-option.

Basically the Stop Start watchdog is a time-out of 1.4 seconds. After 1.4 seconds time out between two zero crossing of the speed channel (crankshaft wheel stopped) the Stop Start Watchdog will enter active state. No output switching is enabled during active watchdog state. After a signal-change in speed channel above DNC within 1.4 seconds (crankshaft wheel rotates) the TLE4929C-XHA will use known signal-amplitude and perform output-switching with the new switching threshold at the new temperature.

At standstill of the target wheel the stop start watchdog will enable TLE4929C-XHA to not issue any wrong pulse at the output:

- No additional pulses
- No missing pulses
- No false rotational direction information

Combining the System Watchdog and the Stop Start Watchdog an immunity to vibration can be added to the Stop-Start-behavior.

Further details are available on request.

3.9 Time Watchdog

The Time Watchdog allows TLE4929C-XHA to go to uncalibrated mode during stand-still of the target wheel at power on. It can be enabled by EEPROM-option and is similar to Stop Start Watchdog. A unintentional calibration will be supressed during start up due to vibration.

Basically the Time watchdog is a time-out of 1.4 seconds. It observes the time between two consecutive edges (rising to falling or falling to rising) of the output. When the time is longer than 1.4 seconds the Time Watchdog gets active.

In active mode of Time watchdog the behavior is similar as in Stop Start Watchdog. It is considered to have either stand-still or very slow vibration. In order to get a fast startup without missing or wrong pulses at the output the offset of the speed-channel is set to “uncalibrated mode”. This means full offset-update is allowed after starting with switching on DNC. The output will switch at zerocrossing after the first offset-update.

The Stop Start watchdog cannot be activated during the Time Watchdog is activated.

The Time Watchdog supports all crankshaft-protocol options and is active for the slow algorithm (ADAPT_FILT=0) until the first update after one complete revolution is done. As long as the Time Watchdog is active the Stop Start Watchdog is disabled.

3.10 Hybrid Vehicle Watchdog

The Hybrid Vehicle Watchdog allows TLE4929C-XHA to detect the stopped crankshaft during electric drive. Calibration is disabled during electric drive of the hybrid car. When combustion engine is started again the calibration is allowed to follow the update rules again. A wrong calibration on a vibrating crankshaft is avoided.

The state “Running Phase” of the TLE4929C-XHA (***Chapter 3.3.4***) has to be entered once to take advantage of this feature.

This mechanism can be enabled or disabled by EEPROM-Bit “WATCHDOG_HYBRID”.

3.11 Programmable Adaptive Switching Threshold (K-FACTOR)

To increase phase accuracy of TLE4929C-XHA the known feature from CAM application was implemented. In certain circumstances like the geometry of the trigger wheel the switching threshold of 50% between magnetic minimum and magnetic maximum of the speed channel is not the best choice. To offer better accuracy 8 settings between 39% and 63% are possible to program. The factor is known as k-factor.

The calculation of the adaptive programmable switching threshold is done as following:

Switching Threshold = Bmin + (Bmax - Bmin) * k

If the K-FACTOR is different than 50% only hidden hysteresis switching is possible.

3.12 High Speed Mode

The high speed mode can be switched on or off by EEPROM bit “HIGH_SPEED”. Switched to state “off” the TLE4929C-XHA behaves as described. Switched to state “on” the TLE4929C-XHA stops direction detection above a certain input signal frequency of typically 1.8 kHz and continues with the last detected direction. To switch to high speed mode the frequency has to be measured two times. Coming from high frequencies the direction detection is enabled again going below the frequency threshold of 1.5 kHz.

3.13 Serial Interface

The serial interface is used to set parameter and to program the sensor IC, it allows writing and reading of internal registers. Data transmission to the IC is done by supply voltage modulation, by providing the clock timing and data information via only one line. Data from the IC are delivered via the output line, triggered by as well clocking the supply line. In normal application operation the interface is not active, for entering that mode a certain command right after power-on is required.

4 EEPROM Description

Several options of TLE4929C-XHA can be configured via an EEPROM setting to optimize the sensor algorithm to the individual target wheel and application requirements. The EEPROM memory is organized in 2 customer lines, whereas each line is composed of 16 data bits and additional 6 bits for error detection and correction, based on ECC (Error Correction Code). For more detailed information about EEPROM access and programming an EEPROM Programming manual is available.

Table 7 Temperature-Compensation for used magnetic material

Type	Describtion	TC (typical)	fits magnetic material
TLE4929C-XHA-M18N	EEPROM unlocked / 100nF on Vdd	-825 ppm	SmCo, NdFeB
TLE4929C-XHA-M38N	EEPROM unlocked / 470nF on Vdd	-825 ppm	SmCo, NdFeB

Table 8 EEPROM Address 0x0

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
customer line #1															

Table 9 Functional Description Address 0x0

Field	Bit	Type	Description	default value
DNC_ADAPT	15	rw	Following value is used for uncalibrated mode: 0 = 25% 1 = 31.25%	0
STOP_ENABLE	14	rw	0 = Disable stop mode 1 = Enable stop mode	1
HIGH_SPEED	13	rw	0 = Enabled motion detection 1 = Same pulse and phase as before when above 1.5kHz	1
DIR_CHANGE	12	rw	0 = 1/4 Criteria for direction change 1 = 1/8 Criteria for direction change	0
WATCH_DOG_EN	11	rw	0 = Watchdog off 1 = Watchdog on	0
DELAY_TIME	10:9	rw	programmable delay time in speed-signal path: 00 = 14 µsec 01 = 17 µsec 10 = 20 µsec 11 = 23 µsec	00
PW_CHOICE	8:6	rw	Choice of pulse length at direction detection forwards/backwards time. Details please find on ***Table 4***. xxx = forward / reverse / optional standstill 000 = 45 / 90 / 180 µs 001 = 45 / 180 / 360 µs 010 = 45 / 135 / 180 µs	000

Table 9 Functional Description Address 0x0 (continued)

Field	Bit	Type	Description	default value
			011 = 75 / 600 / 360 µs 100 = 22/ 45/ 90 µs 101 = 60/ 120 / 360 µs 110 = 30 / 60 µs / - (OEM specific) 111 = 90 / 135 / 360 µs	
STAND_STILL_TIMEOUT	5	rw	Only used when STAND_STILL_ENABLE = 1: 0 = 40msec delaytime after the last sent pulse 1 = 80msec delaytime after the last sent pulse	0
WATCHDOG_TIMEOUT	4	rw	0 = WATCHDOG_TIMEOUT off 1 = 1.4 sec time out at power on to remain in calibration state	0
OEM_FW_START	3	rw	When “PW_CHOICE” is “110”: 0 = No pulse on first edge, on second edge delayed or active edge 1 = First edge is issued according forward-direction	0
WATCHDOG_HYBRID	2	rw	0 = WATCHDOG_HYBRID off 1 = No calibration during electric drive of hybrid vehicle	0
STAND_STILL_ENABLE	1	rw	0 = no optional stand still pulse 1 = optional stand still pulse activated	0
POLE_WHEEL	0	rw	0 = Back bias self calibration on startup – back bias applications 1 = Back bias in center and differential path set to ~0 mT	0

Table 10 EEPROM Address 0x1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
customer line #2															

Table 11 Functional Description Address 0x1

Field	Bit	Type	Description	default value
K-FACTOR	15:12	rw	Programmable switching threshold: 0000 = 39.1% 0001 = 40.6% 0010 = 42.2% 0011 = 43.8% 0100 = 45.3% 0101 = 46.9% 0110 = 48.4%	0111

Table 11 Functional Description Address 0x1 (continued)

Field	Bit	Type	Description	default value
			0111 = 50.0% 1000 = 51.6% 1001 = 53.1% 1010 = 54.7% 1011 = 56.3% 1100 = 57.8% 1101 = 59.4% 1110 = 60.9% 1111 = 62.5%	
FORWARD_DEF	11	rw	0 = none invertion of forward definition 1 = invertion of forward definition	0
EDGE_POLAR	10	rw	0 = non-inverted 1 = inverted	1
HYST_ADAPT	9	rw	0 = 25% 1 = 31.25%	0
FILTER_SELECT	8	rw	0 = Speed path optimized for low jitter 1 = Speed path optimized for frequency above 8 kHz	0
HYST_TYPE	7	rw	0 = Hidden adaptive hysteresis 1 = Visible adaptive hysteresis	0
DNC_MIN	6:5	rw	Minimal DNC (Digital Noise Constant): 00 = 0.75 mT_{pkpk} 01 = 1.5 mT_{pkpk} 10 = 2.5 mT_{pkpk} 11 = 5 mT_{pkpk}	01
CRANK_TEETH	4:3	rw	00 = 58 teeth 01 = 56teeth 10 = 34 teeth 11 = 32 teeth	00
DIR_ENABLE	2	rw	0 = Direction detection off 1 = Direction detection on	1
ADAPT_FILT	1	rw	0 = slow adaptation tracking: average over 32/34/56/58 (CRANK_TEETH / active edges) 1 = fast adaptation tracking: each valid min/max is considered if the extremes are bigger 5 times, with a full update of the ODAC	0
LOCK	0	rw	0 = User area of EEPROM is unlocked 1 = User area of EEPROM is locked (no reprogramming possible)	0

5 Package Information

Pure Nickel plating is used. The product is RoHS (Restriction of Hazardous Substances) compliant and marked with letter G in front of the data code marking and contains a data matrix code on the rear 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.

The specification for soldering and welding is defined in the latest revision of application note “Recommendation for Handling and Assembly of Infineon PG-SSO Sensor Packages”.

Position tolerance of sensing elements has CpK > 1.67 in both dimensions.

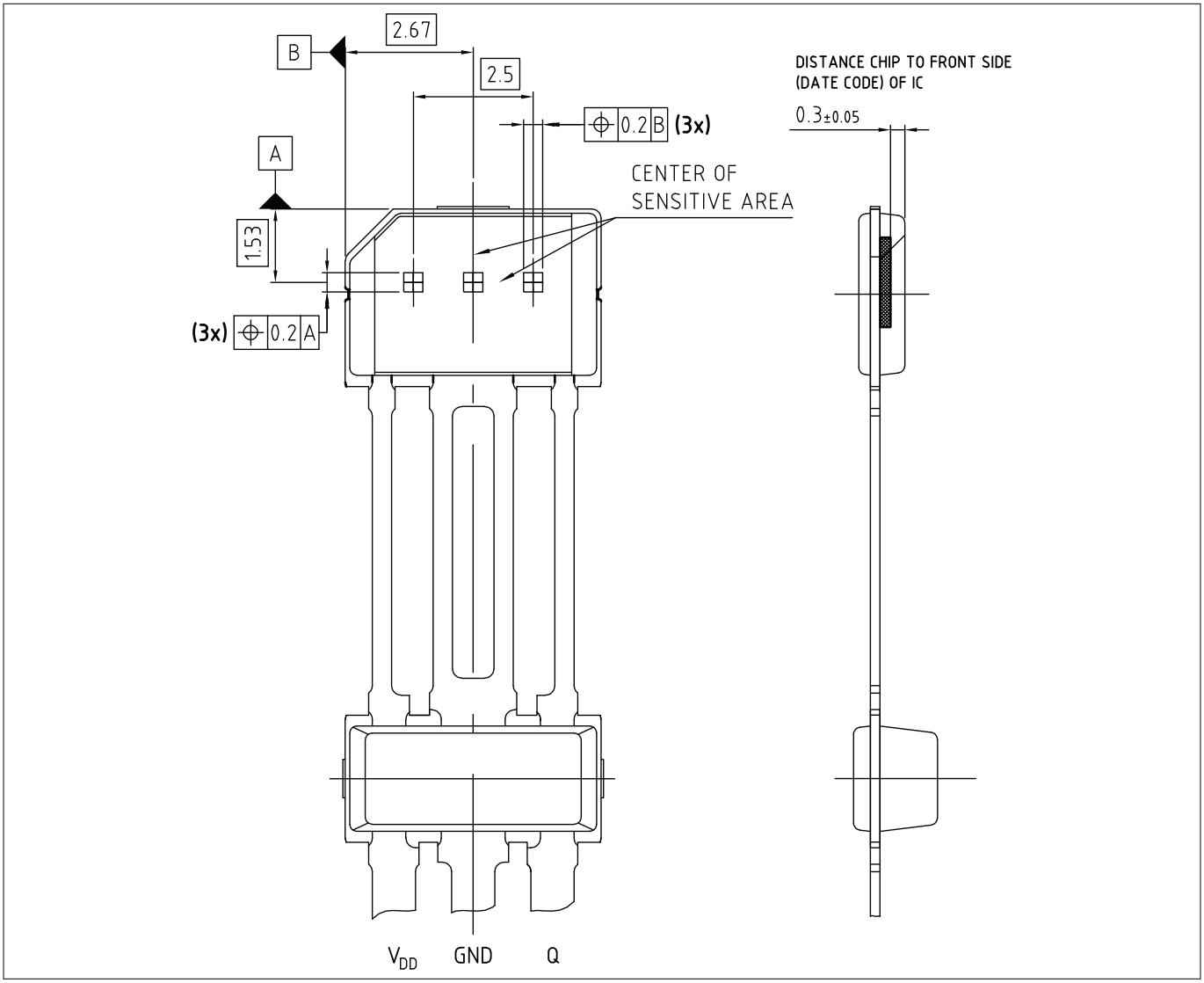


Figure 19 **Pin Configuration and Sensitive Area / Position of the Hall Elements in PG-SSO-3-5x and Distance to the Branded Side**

Table 12 **Pin Description**

Pin Number	Symbol	Function
1	V_{DD}	Supply Voltage
2	GND	Ground
3	Q	Open Drain Output

5.1 Package Outline

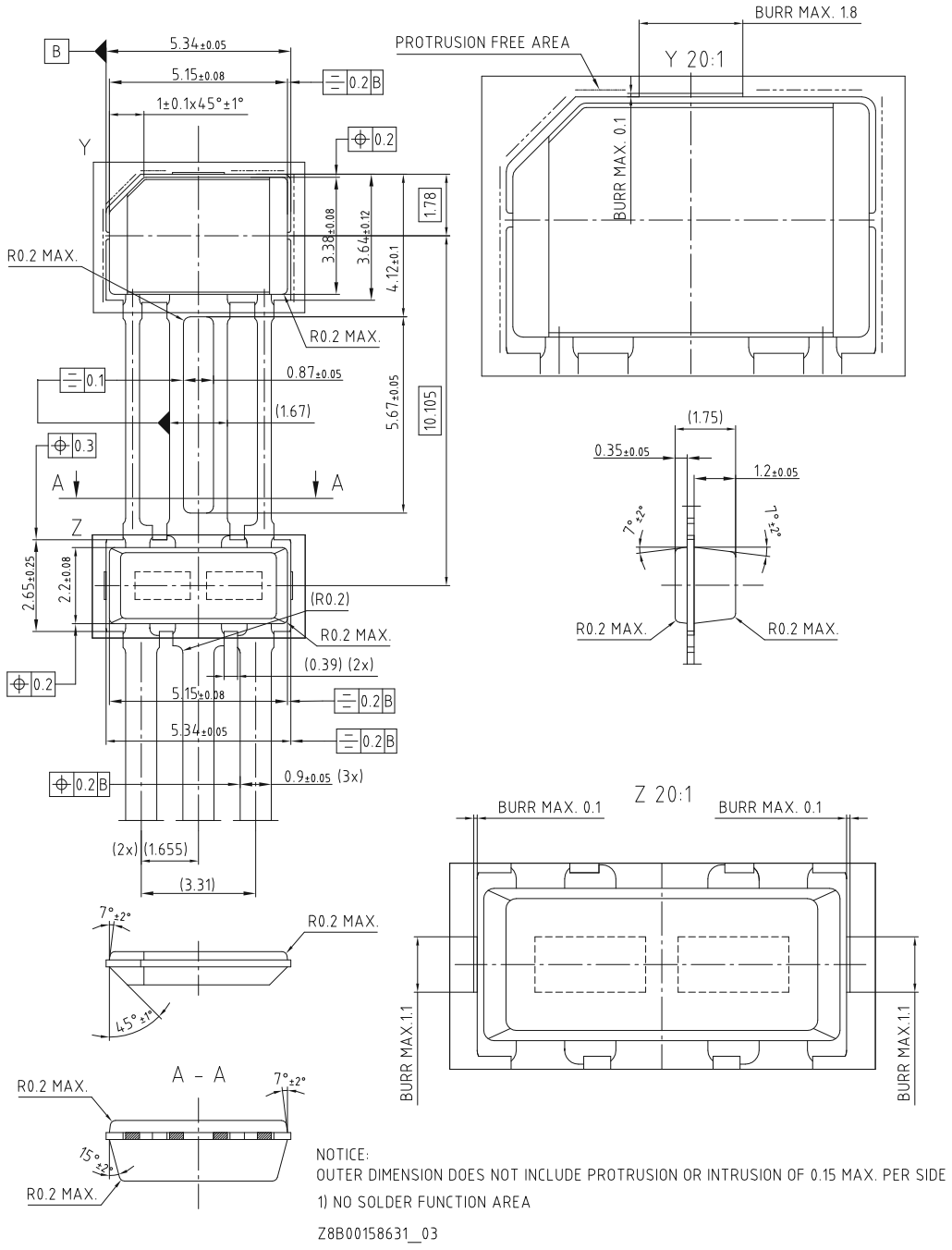


Figure 20 PG-SSO-3-5x (Plastic Green Single Slim Outline), Package Dimensions

5.2 Marking and Data Matrix Code

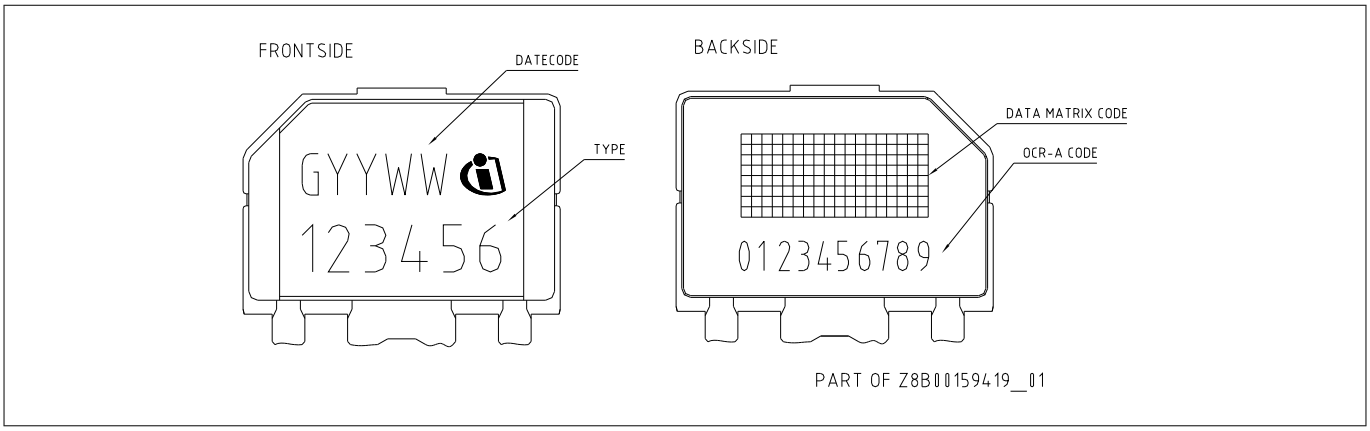


Figure 21 Marking of PG-SSO-3-5x Package

5.3 Packing Information

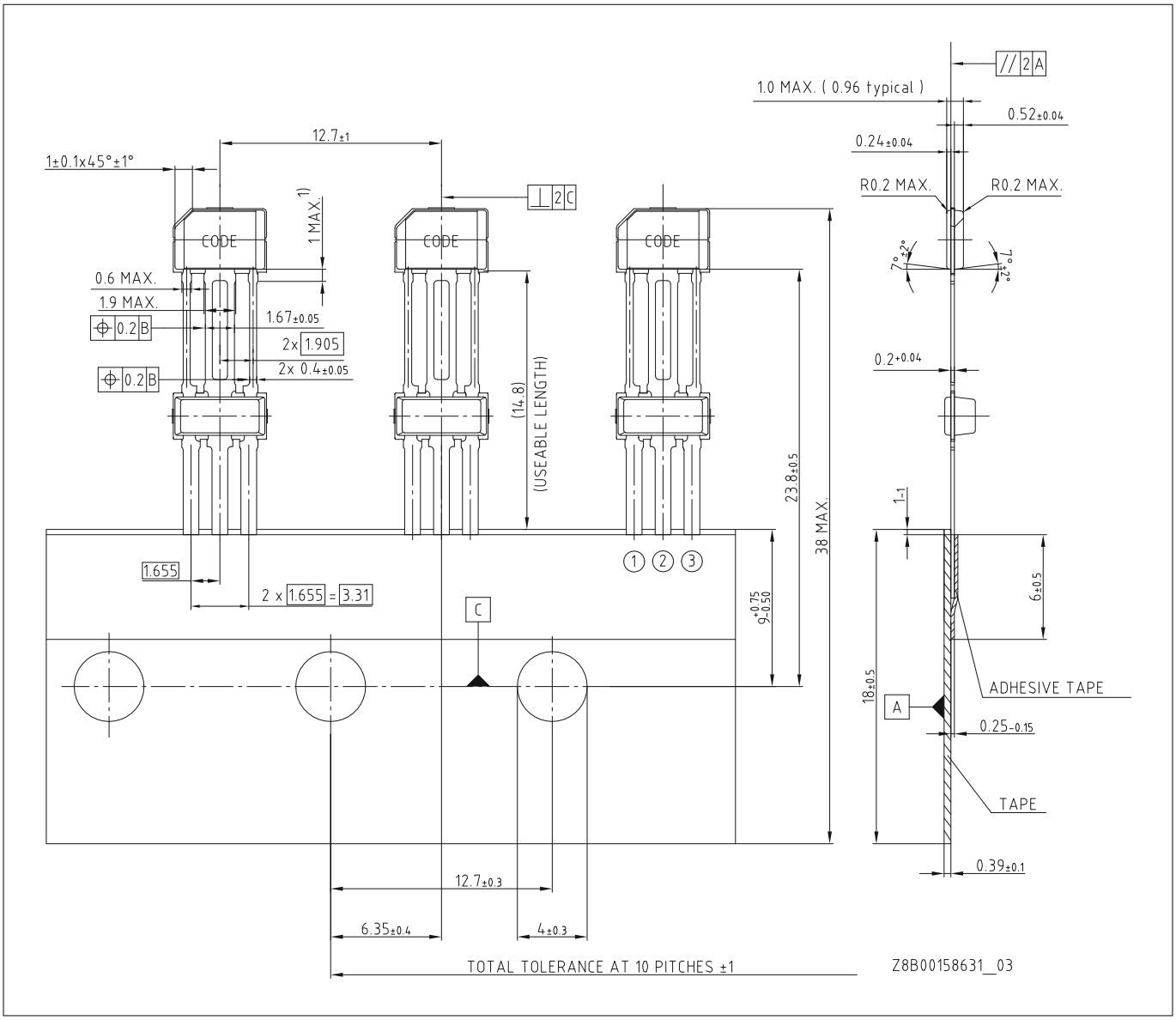


Figure 22 PG-SSO-3-5x Ammopack

6 Revision History

Revision	Date	Changes
1.0	2020-09-29	Initial Version of Datasheet

Trademarks

All referenced product or service names and trademarks are the property of their respective owners.

Edition 2020-09-29

Published by

Infineon Technologies AG

81726 Munich, Germany

© 2020 Infineon Technologies AG

All Rights Reserved.

Do you have a question about any aspect of this document?

Email: erratum@infineon.com

Document reference
IFX-ime1572362148084

IMPORTANT NOTICE

The information given in this document shall in no event be regarded as a guarantee of conditions or characteristics (“Beschaffenheitsgarantie”) .

With respect to any examples, hints or any typical values stated herein and/or any information regarding the application of the product, Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind, including without limitation warranties of non-infringement of intellectual property rights of any third party.

In addition, any information given in this document is subject to customer’s compliance with its obligations stated in this document and any applicable legal requirements, norms and standards concerning customer’s products and any use of the product of Infineon Technologies in customer’s applications.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer’s technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies’ products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.