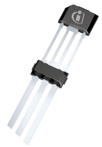
TLE4929C-X2A

Customized crankshaft sensor supporting misfire detection



Applications

The TLE4929C-X2A is an active Hall sensor ideally suited for crankshaft applications in 2 wheeler application based on 32 teeth wheel.

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
- Digital output signal including diagnosis interface
- Direction detection
- High accuracy and low jitter
- Wide automotive operating temperature range

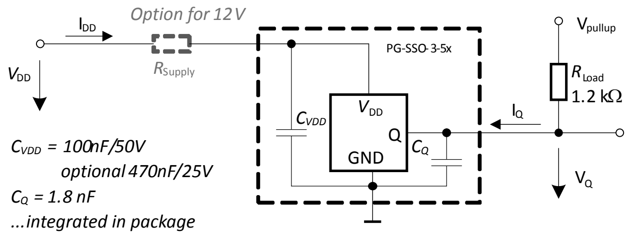


Figure 1 Typical Application Circuit

Description

The TLE4929C-X2A comes in a RoHs compliant three-pin package, qualified for automotive usage. It has two integrated capacitors on the lead frame. These capacitors increase the EMC resistivity of the device. 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-X2A-M38N	Nickel plating, 470nF/25V	29AJC8	SP005429409	PG-SSO-3-53

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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}[1]	-16	–	18	V	continuous, $T_J \leq 175°C$
		-18	–	27	V	max. 60s, $T_J \leq 175°C$
Temperatures						
Junction temperature range	T_J[2]	-40	–	185	°C	Exposure time: max. 10 × 1 h, V_{DD} = 16 V
Induction						
Magnetic field induction	B_Z[3]	-5	–	5	T	Magnetic pulse during magnet magnetization. Valid 10 s with $T_{ambient} \leq 80°C$

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 Not subject to production test - specified by component verification
2 Not subject to production test - specified by qualification
3 Not subject to production test - specified by design

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[4)]						
Capacitance between IC supply & ground pins for type TLE4929C-X2A-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	
Dynamic range of the magnetic field of the direction channel	$DR_{mag\_field\_dir}$	-60	-	60	mT	

4 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.		
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
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
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

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
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} [5]	4	-	11.4	µs	R_{Pullup} = 1.2 kΩ (±10%), C_Q = 1.8 nF (±15%), valid between 10% - 90%
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}	1.22	1.5	1.78	mT_{pkpk}	

5 Not subject to production test - specified by calculation. Application parameter, IC does not increase the rise time (max. value).

Table 4 Electrical and Magnetic Parameters (continued)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Hysteresis Of Switching Threshold						
Adaptive hysteresis threshold of speed channel	$HYS_{adaptive}$	–	25	–	%	
Switching level offset	SwitchOffset,Error	-350	–	350	µT	For magnetic speed signal = 10 mT_{pkpk} : resulting in phase error / duty cycle error.
Accuracy and Repeatability						
Repeatability (Jitter)	Jitter[6]	–	–	0.015	°Crank	3 sigma, ΔBpkpk = 20 mT_{pkpk}
		–	–	0.025	°Crank	3 sigma, ΔBpkpk = 9 mT_{pkpk} , measured on coil using sinus signal, Ta = 150°C, f = 8kHz
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
Maximum phase error	Phirunning [6]	-0.2	–	0.2	°Crank	ΔB_{Speed} > 9 mT_{pkpk} ,signature excluded, accuracy on mentioned wheel in ***Figure 2***
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)	Runouttooth,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.
Crankshaft protocol with direction	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	

6 Not subject to production test - specified by component characterization, based on Jitter measurement > 1000 falling edges.

7 Not subject to production test - specified by component characterization and by design.

2 Electrical and Magnetic Characteristics

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.

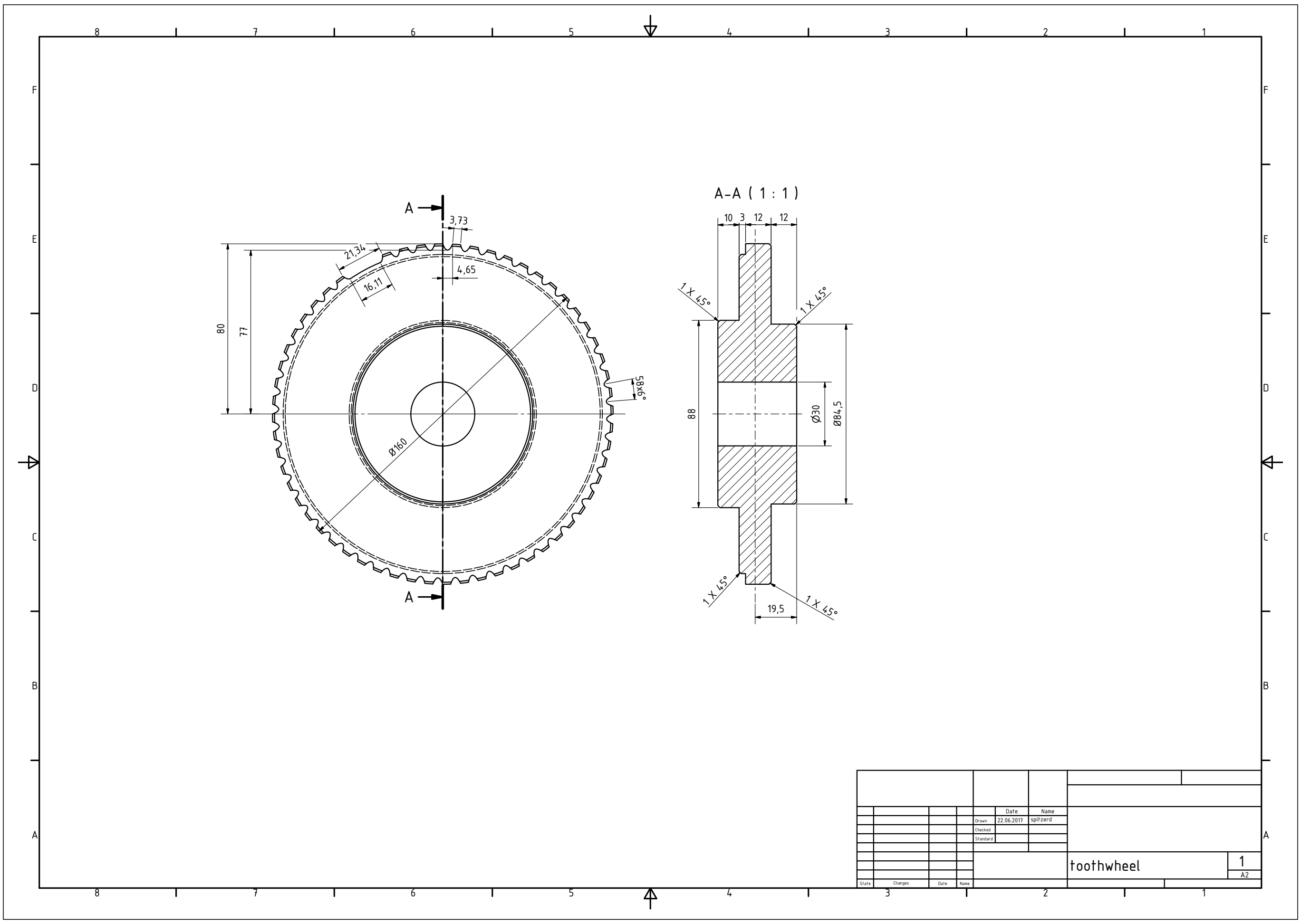

Figure 2 **OEM-crankshaft wheel (outer diameter = 160 mm)**

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 , the field at the sensor position is positive, as shown in .

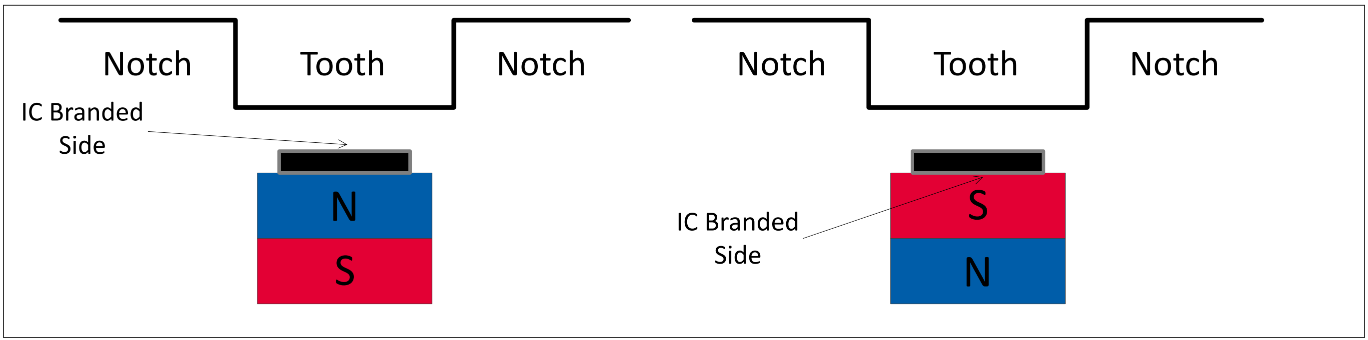

Figure 3 Definition of the Positive Magnetic Field Direction

3.2 Block Diagram

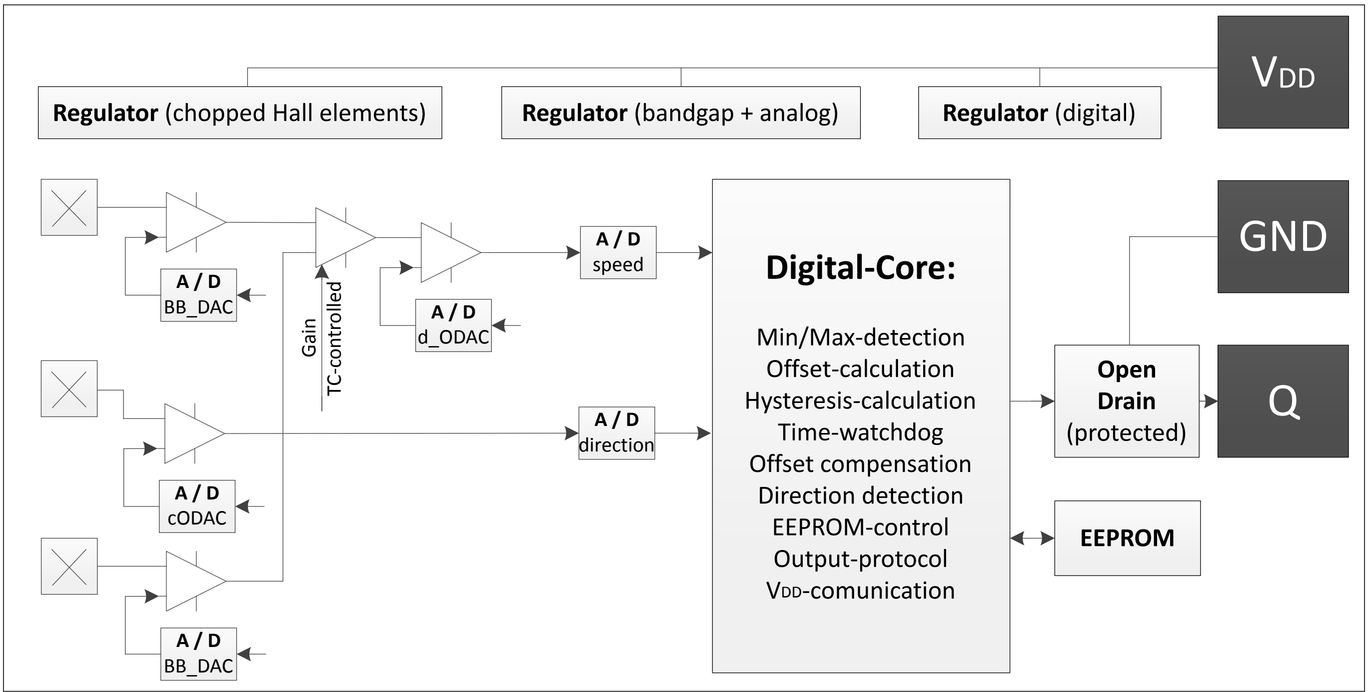

Figure 4 Block Diagram

3.3 Basic Operation

The basic operation of the TLE4929C-X2A 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.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 $t_{\text{power-on}}$ (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” (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 32 teeth
  - 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
  - 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

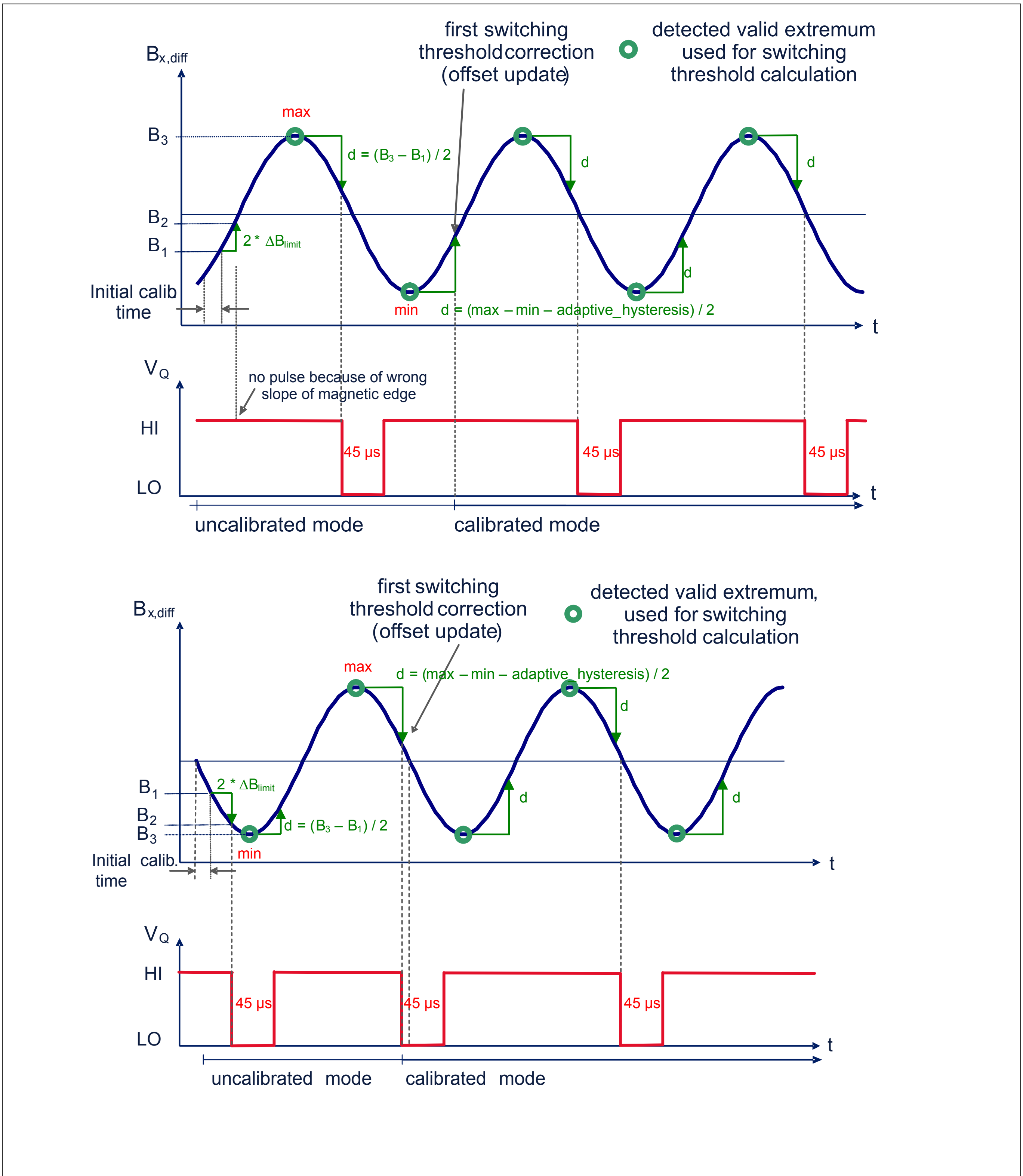

Figure 5 **Operating Phases - Power-on to Running Phase**

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

An average of 32 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.

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. Forward-puls issued when wheel rotates from pin 3to pin 1. Falling edge of output-pulse occurs at middle of the tooth.

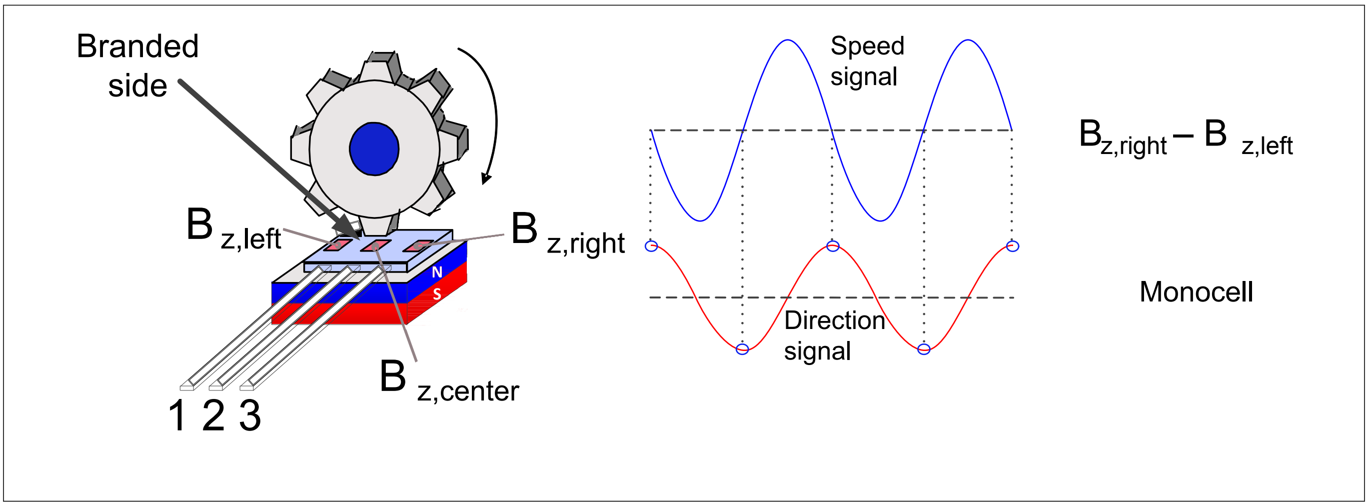

Figure 6 **Direction Detection Principle: TLE4929C-X2A issues forward-pulses at each middle of tooth**

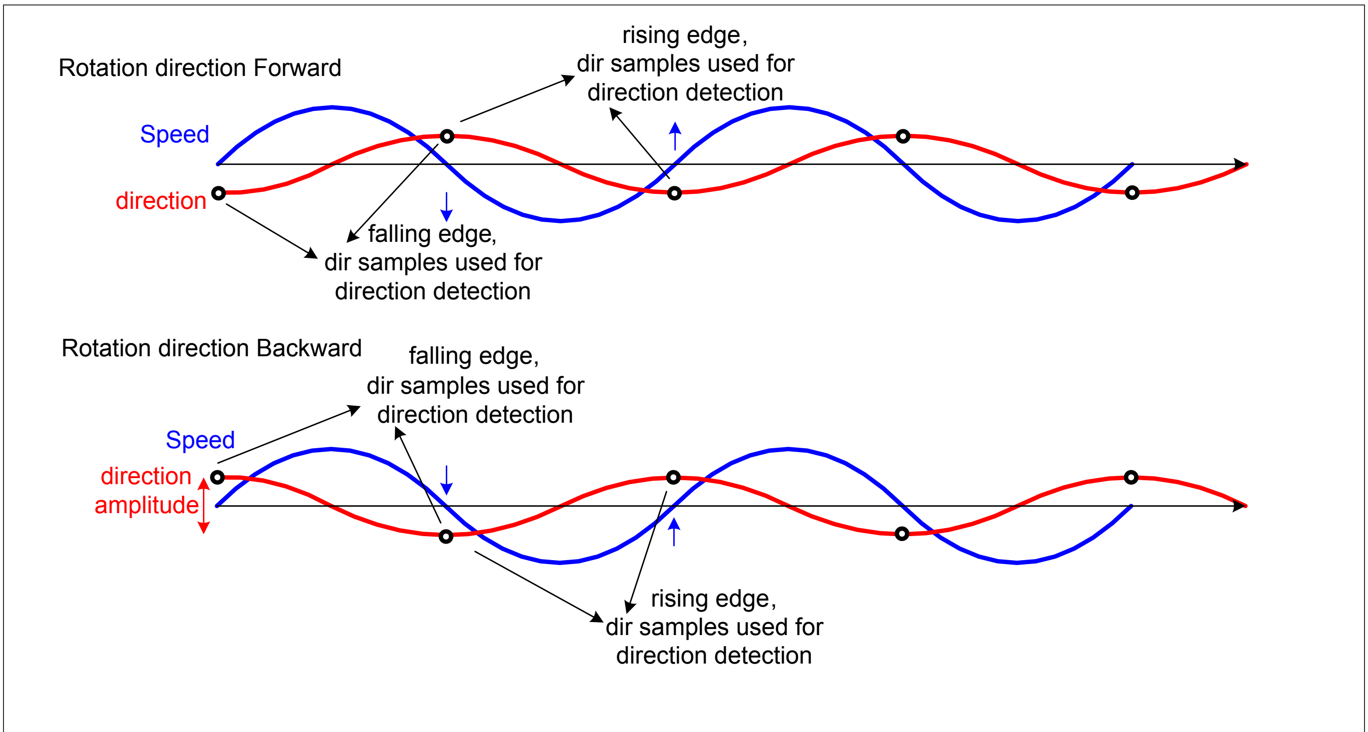

Figure 7 **Direction Detection Principle: Rotation Direction Forward And Backward**

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.

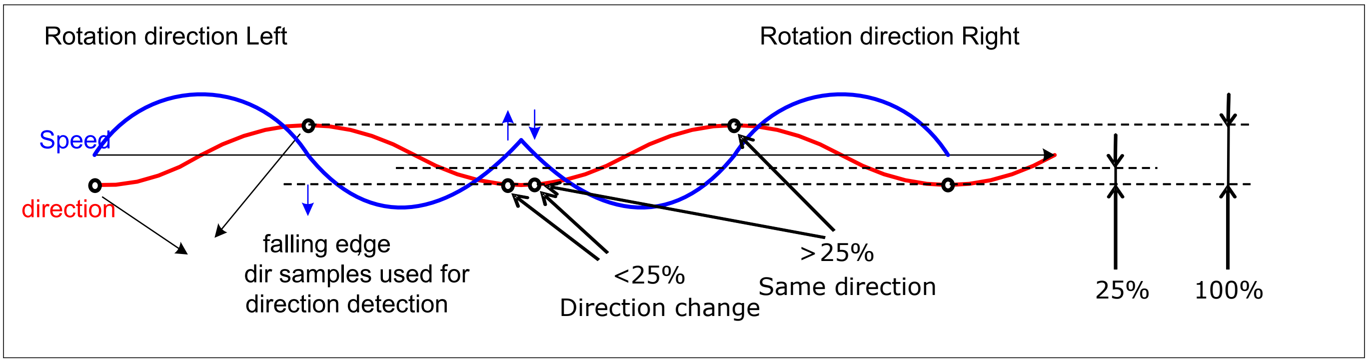

Figure 8 Direction Threshold Level

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.

3.4 Hysteresis Concept

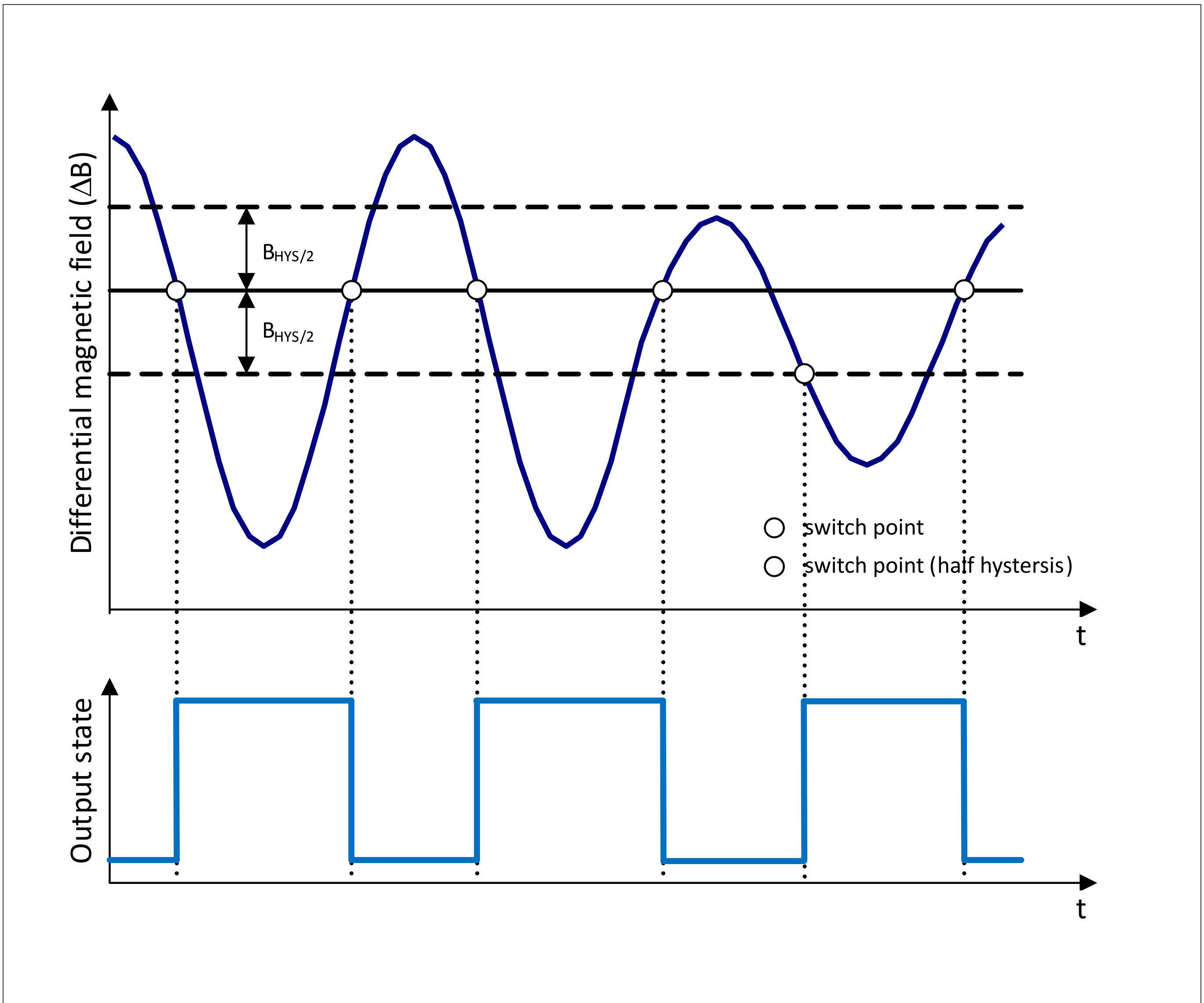

Figure 9 **Hidden Hysteresis in protocol-variant without direction detection**

The prefered switching behavior for crankshaft application in terms of hysteresis is called hidden adaptive hysteresis.

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***.

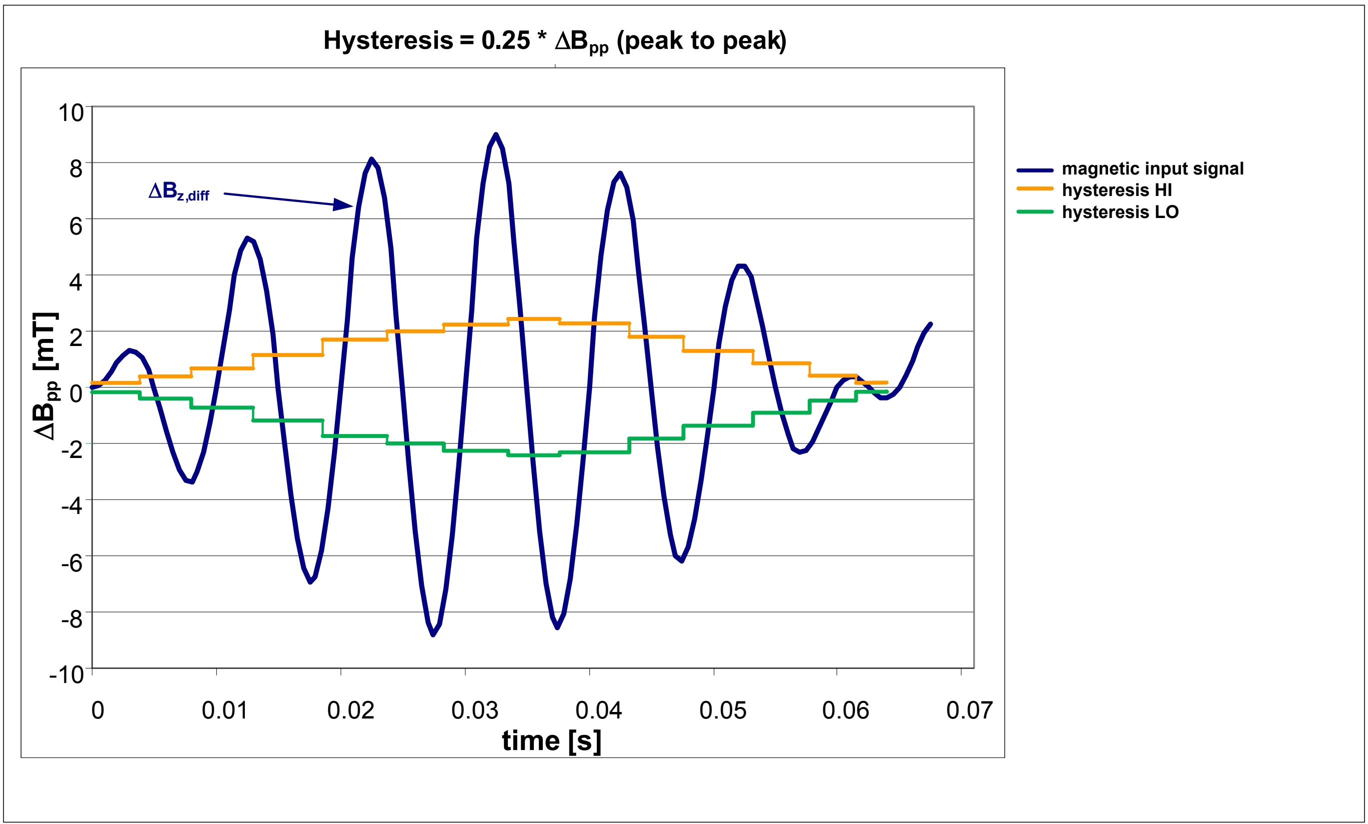

Figure 10 **Adaptive Hysteresis**

3.5 Time Watchdog

The Time Watchdog allows TLE4929C-X2A to go to uncalibrated mode during stand-still of the target wheel at power on. 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.

3.6 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 Package Information

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.

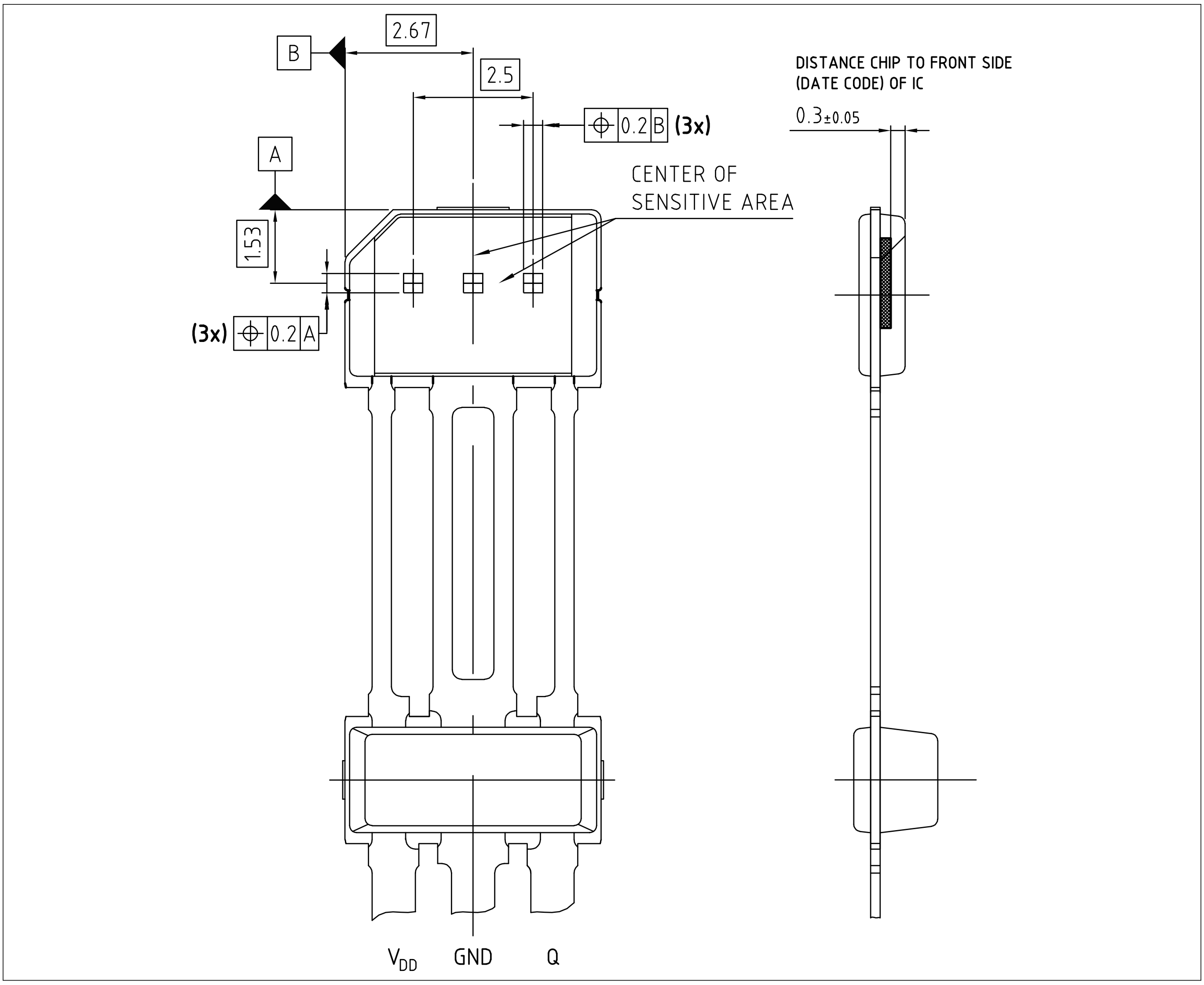

Figure 11 **Pin Configuration and Sensitive Area / Position of the Hall Elements in PG-SSO-3-5x and Distance to the Branded Side**

Table 5 **Pin Description**

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

4.1 Package Outline

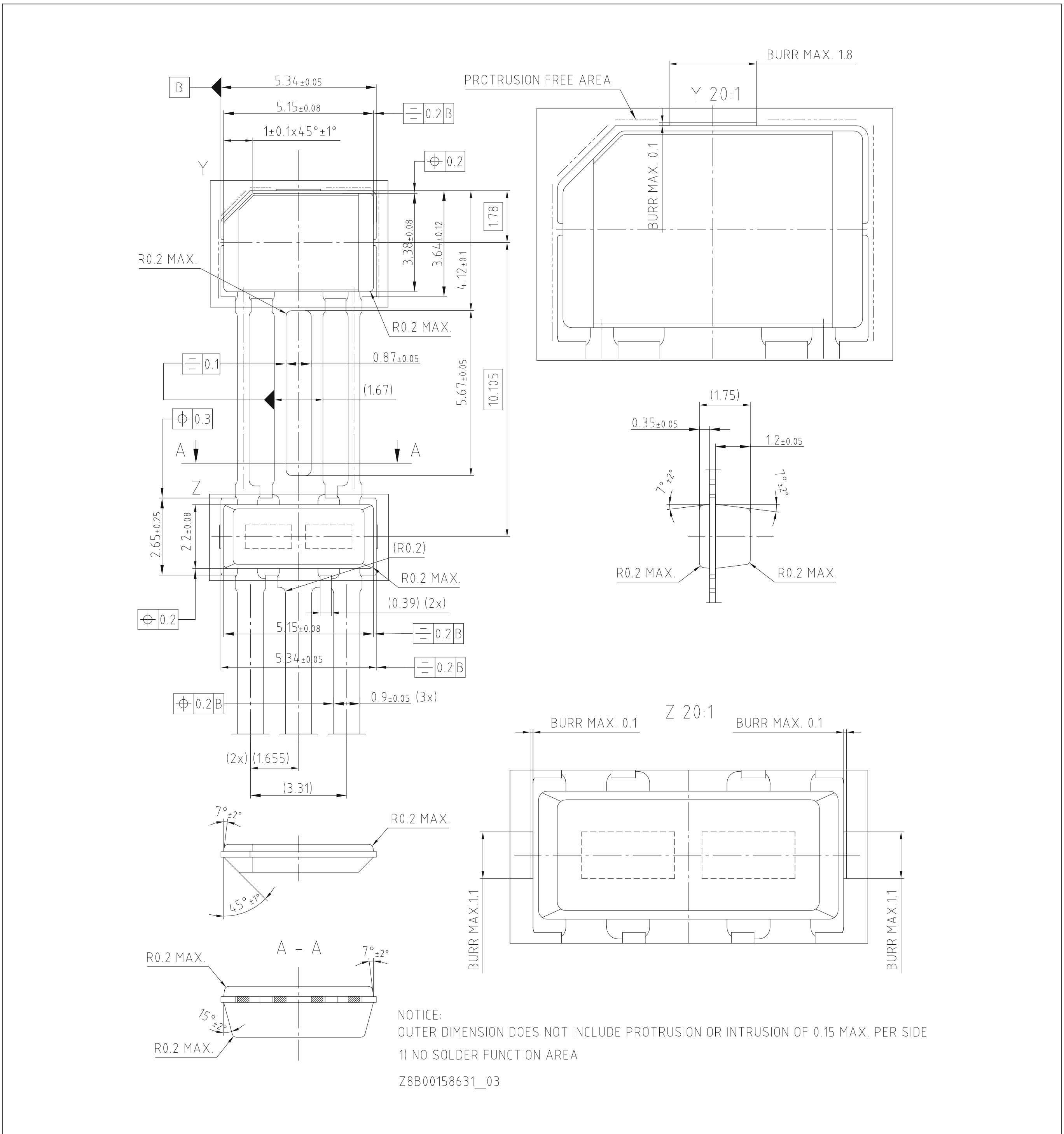

Figure 12 **PG-SSO-3-5x (Plastic Green Single Slim Outline), Package Dimensions**

4.2 Marking and Data Matrix Code

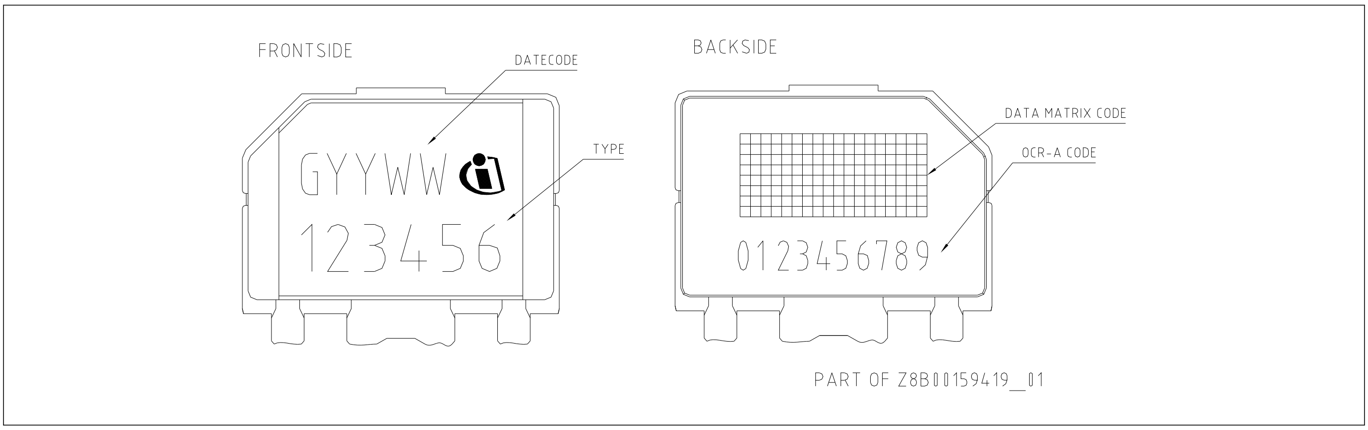

Figure 13 Marking of PG-SSO-3-5x Package

4.3 Packing Information

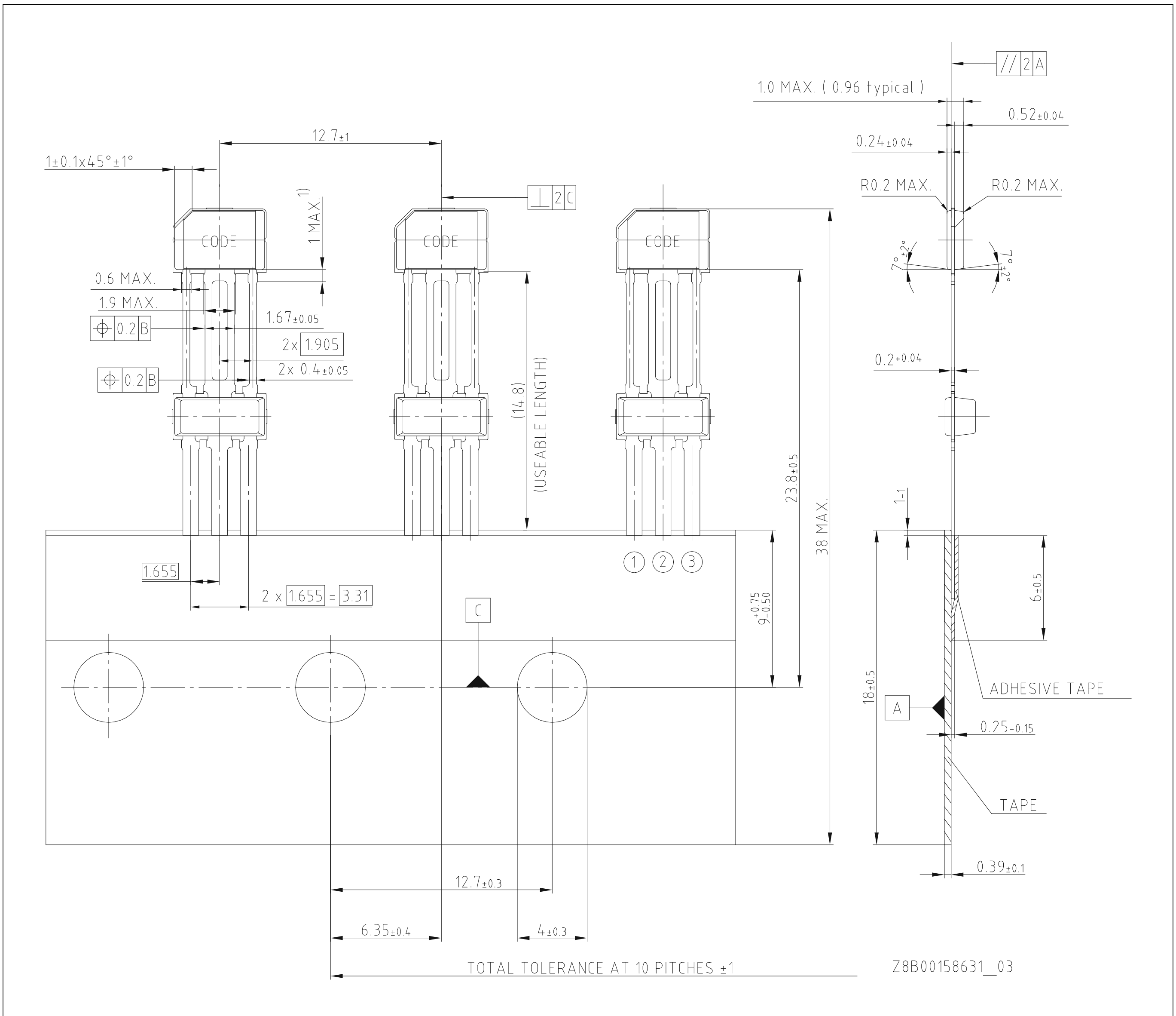

Figure 14 **PG-SSO-3-5x Ammopack**

5 Revision History

Revision	Date	Changes
1.00	2021-04-12	Initial Release

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