3-Wire Programmable Crankshaft Position Sensor

1. Features

- AEC-Q100 qualified
- ISO 26262 ASIL-B
- Detect the speed and position of targets
- Magnetic stray-field robustness due to differential Hall Sensing
- Direction detection and Stop-Start-Algorithm
- Vibration Suppression Algorithm
- Temperature Compensation Algorithm
- Customer-side Programming Enable
- Programmable switching threshold for better accuracy
- 3-pin PCB-less TS-3 package

2. Applications

- Crankshaft position detection
- Transmission speed detection
- High accuracy gear position detection

3. Description

The SC9669 produced by Bi-CMOS technology, it's a chopper-stabilized & active differential Hall sensor ideally suited for crankshaft and transmission rotate detection applications. It have the auto-adjust function to keep the performance with high accuracy and low jitter capabilities.

Superior high-temperature performance is made possible through dynamic offset cancellation & internal temperature compensation algorithm, which reduces the residual offset voltage normally caused by device over molding, temperature dependencies, and thermal stress. Each device includes on a single silicon chip a voltage regulator, Hall-voltage generator, small-signal amplifier, chopper stabilization circuits, digital process circuits, EEPROM, diagnostic circuits.

An onboard regulator permits with supply voltages of 4V to 16V which makes the device suitable for a wide range of industrial and automotive applications

The device is available in a 3-pin package (TS-3) Which integrated with capacitor.

It is lead (Pb) free, with 100% matte tin-plated lead frame.

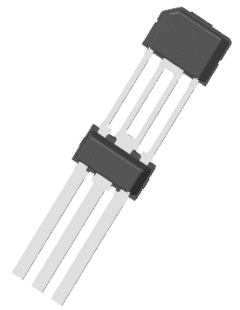

Fig.1 TS-3 Package Outline

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4. Terminal Configuration

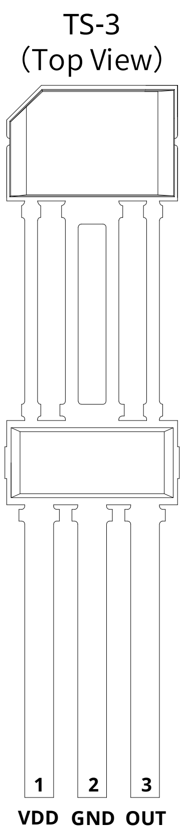


Fig.2 Pin Description

Terminal		Type	Description
Name	Number TS-3		
VDD	1	PWR	4V~16V power supply
GND	2	Ground	Ground terminal
OUT	3	Output	Open-drain output. The open drain requires a pull-up resistor

5. Ordering Information

Ordering Information	Marking	Ambient, T_A(℃)	Package	Packing	Quantity
SC9669T3-TR-Q	9669	-40 ~ 150	TS-3	Tape & reel	1500 /reel

6. Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

Symbol	Parameter	Test conditions	Min.	Max.	Units
V_{DD}	Power supply voltage (1)	continuous, $T_J \leqslant 170℃$	-16	18	V
		max. 60s, $T_J \leqslant 170℃$	-18	27	V
$V_{OUT\text{-}Off}$	Output Off voltage (1)	continuous, $T_J \leqslant 170℃$	-0.3	26.5	V
		max. 1h, $T_{Amh} \leqslant 40℃$	-1.0	26.5	V
$V_{OUT\text{-}On}$	Output On voltage (1)	continuous, $T_{Amh} \leqslant 40℃$	-1.0	16	V
		max. 1h, $T_{Amh} \leqslant 40℃$	-0.3	18	V
		max. 60s, $T_{Amh} \leqslant 40℃$	-0.3	26.5	V
T_A	Operating ambient temperature		-40	150	℃
T_J	Maximum junction temperature	Exposure time: max. 10×1h, V_{DD}=16V	-4	175	℃
	Magnetic field induction (2)	Magnetic pulse during magnet magnetization. Valid with $T_{ambient} \leq 80°C$	-4	4	T

Note :

(1) tresses above those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

(2) Guaranteed by design.

7. ESD Protection

Symbol	Parameter	Test conditions	Min.	Max.	Units
V_{ESD}	ESD-Protection	Refer to AEC-Q100-002E HBM standard,R=1.5kΩ, C=100pF	-8	8	kV

8. Thermal Characteristics

Symbol	Parameter	Test conditions	Min.	Max.	Units
$R_{\theta JA}$	Package thermal resistance	Without PCB, welding process with lead-frame	-	190	℃/W

9. Operating Characteristics

over operating free-air temperature range (V_{DD}=5.0V, unless otherwise noted)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Electrical parameters						
V_{DD}	Supply voltage without supply resistance R_s		4	–	16	V
V_{Q_OFF}	Continuous Output Off voltage		1	–	16	V
dV_{DD}/dt	Supply voltage power- up/down voltage ramp		3	–	10000	V/ms
V_{Qsat}	Output saturation voltage	$I_Q \leq 15mA$	-	-	500	mV
V_{DD_clamp}	Clamping voltage V_{DD}-Pin	Leakage current through ESD diode<0.5mA	42	-	-	V
V_{Qclamp}	Clamping voltage V_Q-Pin	leakage current through ESD-diode<0.5mA	42	-	-	V
V_{DD_reset}	Reset voltage		-	-	3.6	V
I_{DD}	Supply current		8	–	13.4	mA
I_{Q_ON}	Continuous output On current	$V_{Q\_LOW}<0.5V$	0.01	–	15	mA
I_{Qleak}	Output leakage current	V_Q=18V	-	0.1	10	μA
I_{Qshort}	Output current limit during short-circuit condition		30	-	80	mA
Time & Frequency Related						
t_{power_on}	Power on time	During this time the output is locked to high.	0.8	0.9	1	ms
t_{delay}	Delay time between magnetic signal switching point and corresponding output signal falling edge switching event	Falling edge	10	14	19	μs
t_{delay2}	Further options on delay time accessible using EEPROM	Option 2	13	17	22	μs
t_{delay3}		Option 3	16	20	25	μs
t_{delay4}		Option 4	19	23	28	μs
t_{fall}	Output fall time	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8nF (±15%), valid between 80%-20%	2.0	2.5	3.0	μs
		V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8nF (±15%), valid between 90%-10%	3.2	4.5	5.8	μs
t_{rise}	Output rise time	R_{Pullup}=1.2kΩ (±10%), C_Q=1.8nF (±15%), valid between 10%-90%	4	-	11.4	μs
f_{Dir}	Frequency range for direction detection	For increasing rotational frequency	0	–	1800	Hz
		For decreasing rotational frequency	0	–	1500	Hz
N_{PROG}	Maximum No. of EEPROM programming cycles	T_J<150℃	–	–	80	n
f	Magnetic signal frequency range	Full accuracy	0	–	8000	Hz
		10% degraded jitter	8000	–	10000	Hz
C_{VDD}	Capacitance between IC supply & ground pins		90	100	110	nF

Operating Characteristics（continued1）

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
C_Q	Output capacitance between IC output and ground pins		1.62	1.8	1.98	nF
Magnetic Signal						
$DR_{mag\_field\_dir}$	Dynamic range of the magnetic field of the direction channel		-60	-	60	mT
$SR_{mag\_field\_s\_bb}$	Static range of the magnetic field of the outer Hall probes in back-bias configuration	No wheel in front of module / Offset-DAC- Compensation-range	0	-	550	mT
$SR_{mag\_field\_s\_pw}$	Static range of the magnetic field of the outer Hall probes in magnetic encoder wheel configuration	Static absolute offset for pole wheel / Offset-DAC- Compensation-range / independent from Bit “POLE_WHEEL”	-10	-	10	mT
$SR_{mag\_field\_dir}$	Static range of the magnetic field of the center Hall probe	No wheel in front of module / Center-Offset- DAC-Compensation-range	-100	-	450	mT
$SR_{mag\_field\_diff}$	Allowed static difference between outer probes	No wheel in front of module	-30	-	30	mT
ΔBSpeed_Stop,Start	Magnetic differential field amplitude for full performance on stop-start	No false pulses for temperature drift of ≤60K during stop-start state. Tolerated change of speed-channel mean value≤3mT	9	-	-	mT_{pkpk}
		No false pulses for temperature drift of ≤ 40K during stop-start state. Tolerated change of speed-channel mean value≤2mT	6	-	-	mT_{pkpk}
		No false pulses for temperature drift of ≤20K during stop-start state. Tolerated change of speed-channel mean value ≤1.5mT	4	-	-	mT_{pkpk}
DNC_{mi}	Digital noise constant of speed channel during start up(change in differential field)	EEPROM “DNC_MIN”: Option 00(5)	0.53	0.75	0.97	mT_{pkpk}
		EEPROM “DNC_MIN”: Option 01	1.22	1.5	1.78	mT_{pkpk}
		EEPROM “DNC_MIN”: Option 10	2.14	2.5	2.86	mT_{pkpk}
		EEPROM “DNC_MIN”: Option 11	4.44	5	5.56	mT_{pkpk}
Hysteresis Of Switching Threshold						
$HYS_{adaptive}$	Adaptive hysteresis threshold of speed channel	EEPROM “HYST_ADAPT”: Option 0	-	25	-	%
		EEPROM “HYST_ADAPT”: Option 1	-	31.25	-	%
Switch_Off set,Error	Switching level offset	For magnetic speed signal =10mT_{pkpk} : resulting in phase error/duty cycle error.	-350	-	350	μT
k-factor	Programming switching level offset (k-factor)	EEPROM “K_FACTOR”: Option 0000	-	39.1	-	%
		EEPROM “K_FACTOR”: Option 0001	-	40.6	-	%
		EEPROM “K_FACTOR”: Option 0010	-	42.2	-	%

Operating Characteristics（continued2）

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
k-factor	Programming switching level offset (k-factor)	EEPROM "K_FACTOR": Option 0011	–	43.8	–	%
		EEPROM "K_FACTOR": Option 0100	–	45.3	–	%
		EEPROM "K_FACTOR": Option 0101	–	46.9	–	%
		EEPROM "K_FACTOR": Option 0110	–	48.4	–	%
		EEPROM "K_FACTOR": Option 0111	46.3	50.0	53.7	%
		EEPROM "K_FACTOR": Option 1000	–	51.6	–	%
		EEPROM "K_FACTOR": Option 1001	–	53.1	–	%
		EEPROM "K_FACTOR": Option 1010	–	54.7	–	%
		EEPROM "K_FACTOR": Option 1011	–	56.3	–	%
		EEPROM "K_FACTOR": Option 1100	–	57.8	–	%
		EEPROM "K_FACTOR": Option 1101	–	59.4	–	%
		EEPROM "K_FACTOR": Option 1110	–	60.9	–	%
		EEPROM "K_FACTOR": Option 1111	–	62.5	–	%
Accuracy Related						
Jitter	Repeatability (Jitter)	3 sigma, ΔB_{pkpk}=20mT_{pkpk}, FILTER_SELECT=0	–	–	0.015	°Crank
		3 sigma, ΔB_{pkpk}=9mT_{pkpk} , measured on coil using sinus signal, T_A=150°C, f=8kHz, FILTER_SELECT=0	–	–	0.025	°Crank
nStart	Number of wrong pulses at start-up	Engine starts in continuous forward rotational direction	–	–	0	n
		Engine starts in continuous ackward rotational direction	0	–	1	n
nStop,start	Number of wrong pulses after stop-start	Multiple rotational direction changes>6°Crank allowed	–	–	0	n
Phirunning	Maximum phase error	ΔB_{Speed}>9mT_{pkpk} ,signature excluded, accuracy on mentioned wheel in Figure 4	-0.2	–	0.2	°Crank
Phistop,start	Maximum phase error after stop-start	Reduced phase accuracy only for first pulse after stop-start-state / signature excluded	-1.7	–	3.2	°Crank
Run Out Capabilities						
Run_out global	Global run out (speed and direction channel)	Ratio=Amplitude (max)pkpk / Amplitude (min)pkpk	1.0	–	1.67	-
		Ratio=Amplitude (max)pkpk/Amplitude (min)pkpk. Reduced performance in Stop-Start- behavior.	1.0	–	2.5	-
Run_out tooth-tooth(7)	Magnetic overshoot of signature region in speed signal. Magnetic overshoot from tooth to tooth (polepair to polepair)	Ratio = Amplitude (signature) / Amplitude (before/after). Valid for toothed target wheel.	1.0	–	1.67	-
		Ratio = Amplitude (signature) / Amplitude (before/after). Valid for magnetic target wheel.	1.0	–	2.5	-

Operating Characteristics（continued3）

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Temperature Related						
T_J	Normal operating junction temperature	Exposure time: max. 2500h at T_J=175°C, V_{DD}=16V	-40	–	175	°C
		Exposure time: max. 10×1h at T_J=185°C, V_{DD}=16V, additive to other lifetime	-40	-	185	°C
T_{no}	Not operational lifetime	Without sensor function. Exposure time max 500h @ 150°C; increased time for lower temperatures according to Arrhenius-Model, additive to other lifetime	-40	-	150	°C
T_{RDPROG}	Ambient temperature range for customer programming		15	25	130	°C
$\Delta T_{Stop,start}$	Allowed temperature variations between engine stop and restart.	Device powered continuously	–	–	60	°C
T_C	Temperature compensation range of magnetic material	Internal compensation of magnetic signal amplitude of speed signal	1900	–	0	ppm
Output Protocol						
–	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	–	–	–	–
t_{fwd}	Crankshaft protocol with direction (option 1)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	38	45	52	μs
t_{bwd}			76	90	104	μs
$t_{standstill}$			152	180	208	μs
t_{fwd}	Crankshaft protocol with direction (option 2)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	38	45	52	μs
t_{bwd}			152	180	208	μs
$t_{standstill}$			304	360	416	μs
t_{fwd}	Crankshaft protocol with direction (option 3)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	38	45	52	μs
t_{bwd}			114	135	156	μs
$t_{standstill}$			152	180	208	μs
t_{fwd}	Crankshaft protocol with direction (option 4)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ(±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	63	75	87	μs
t_{bwd}			507	600	693	μs
$t_{standstill}$			304	360	416	μs
t_{fwd}	Crankshaft protocol with direction (option 5)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	18	22	26	μs
t_{bwd}			38	45	52	μs
$t_{standstill}$			76	90	104	μs
t_{fwd}	Crankshaft protocol with direction (option 6)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8 nF (±15%), valid between 50% of falling edge to 50% of next rising edge	51	60	69	μs
t_{bwd}			101	120	339	μs
$t_{standstill}$			304	360	416	μs

Operating Characteristics（continued4）

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
t_{fwd}	Crankshaft protocol with direction (option 7)	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_Q=1.8nF (±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-sensorwithout direction protocol.	25	30	35	μs
t_{bwd}			51	60	69	μs
t_{fwd}	Crankshaft protocol with direction (option 8)	V_{Pullup}=5V, R_{Pullup}=1.2 kΩ (±10%), C_Q=1.8nF (±15%), valid between 50% of falling edge to 50% of next rising edge	76	90	104	μs
t_{bwd}			114	135	156	μs
$t_{standstill}$			304	360	416	μs

10. Block Diagram

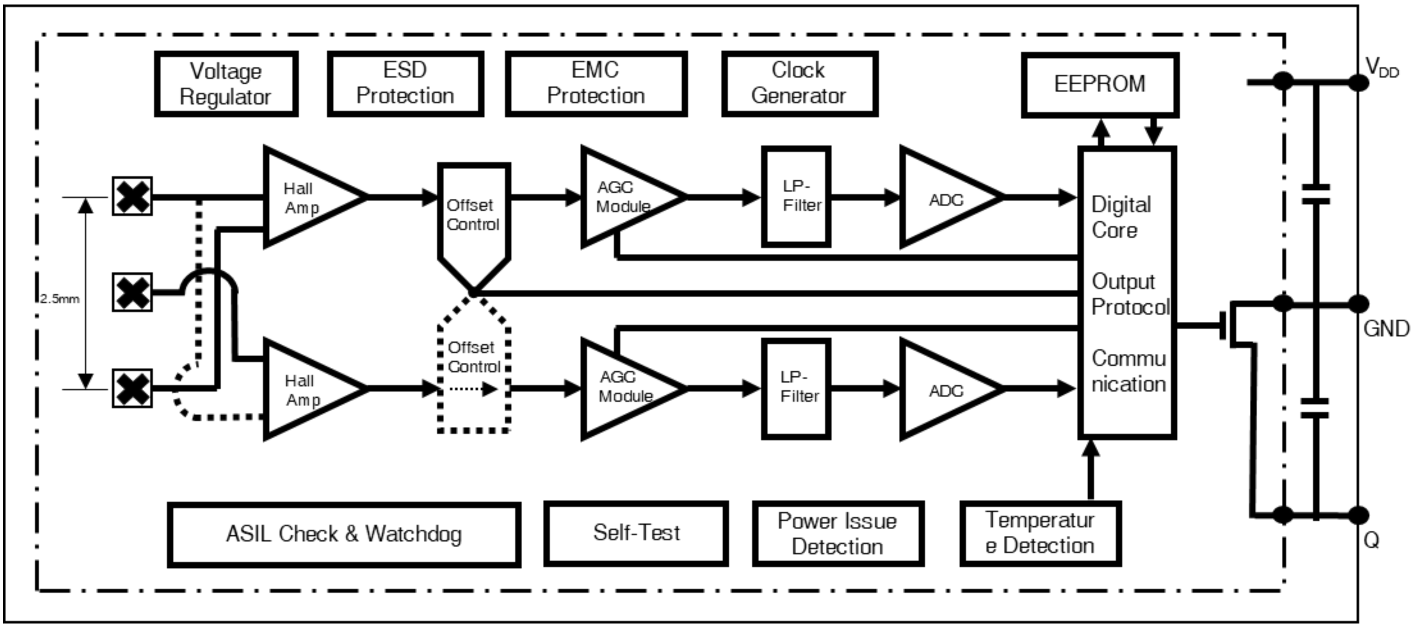


Fig.3 Block Diagram

Contains several circuits:

Chopped Hall Amplifier	Under/Over Voltage Detection
Offset Calibration ADC	POR
PGA + LPF	OSC
Channel ADC(Tracking ADC)	EEPROM programmable
Analog & Digital V_{DD} Regulator	EMC Protection
Current Bias	ASIL / Diagnostic

11 Function Description

- **Working Principle**

Speed detection configuration of SC9669 is illustrated in below Pic. It contains a toothed wheel or magnetic encoder on a rotating shaft, the speed-sensor itself where connecting cables are attached and the back-bias magnet or magnetic encoder which generates a static field on the position of the sensing elements (Hall probes). The movement of the target wheel modulates the flux-lines of the magnetic field. This modulation is measured as speed-signal and direction-signal. Out of these signals, the sensor generates pulse-width modulated output-pulses on the open drain output to indicate a certain direction. The length of the output-pulse is either rotational direction clock-wise (CW) or counter-clock-wise (CCW).

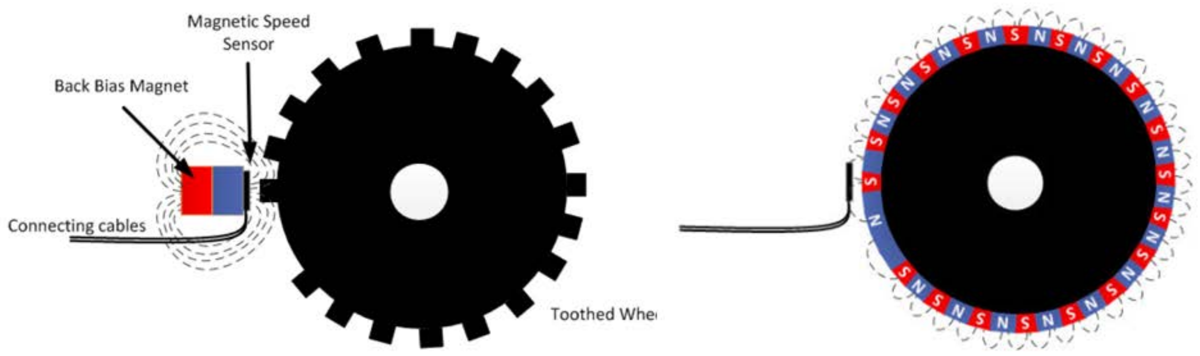


Fig.4 Detection Principle

- **Differental Hall Technology**

SC9669 use the differential Hall technology to achieve the measurement of magnetic field variations. The Hall voltage collected by the two outer Hall points is subtracted to obtain a sinusoidal magnetic field profile(as the speed channel signal). The purpose of this is to enhance the signal variation and eliminate the bias (especially for back-magnetic applications).

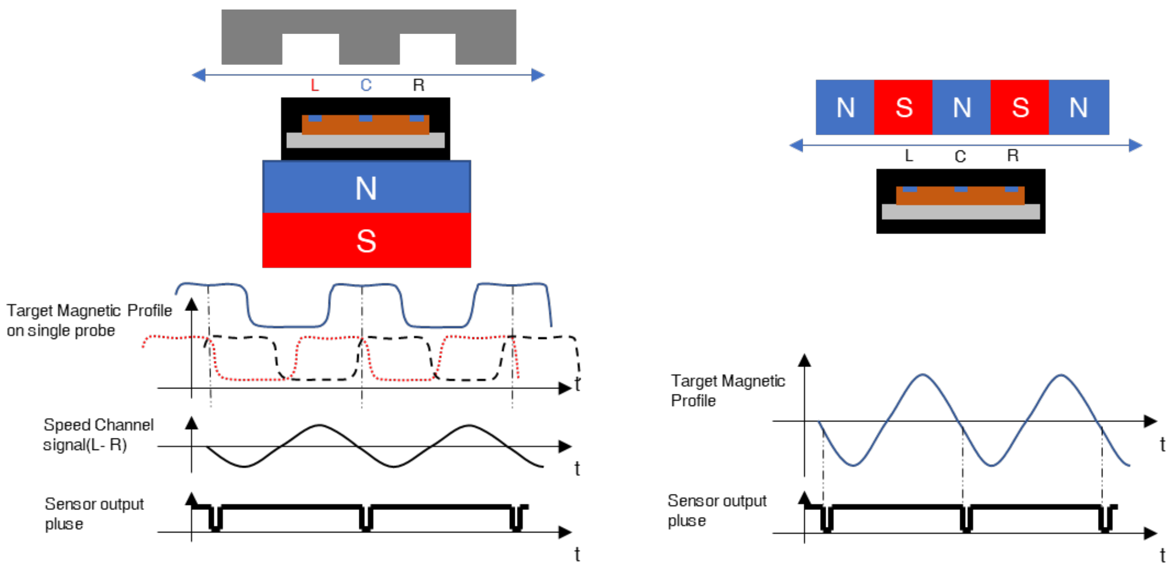


Fig.5 Gear position-differential magnetic field-output response diagram

- **Detection Channel**

This sensor have two independent signal path to monitor the magnetic field changing caused by target rotating. One is speed channel and the other is direction channel.

Speed channel signal use the differential signal between left Hall probe and the right Hall probe.

Direction channel directly use the signal of center Hall probe.

- **Sensor Application Environment**

This sensor can be used for crankshaft rotate detection in combustion engine system.

With different programming parameter, this sensor also can be use for transmission speed detection in powertrain.

The environment of both application is quite harsh, will contain:

- Rapidly changing temperatures;
- Random vibration;
- Ferromagnetic powder;
- Power fluctuations;

- **Operation Temperature**

- Ambient temperature：-40℃~150℃
- Peak temperature: 150℃ during 3h
- Frequency (peak temperature): 160 times during lifetime
- Nominal temperature: T=80℃~110℃
- Temperature Profile:

Temperature(℃)	**-40**	**-20**	**25**	**80**	**100**	**110**	**125**	**150**
Vehicle lifetime(%)	0.03	0.67	1.5	27	43.89	23	3.5	0.41

- **Magnetic Pole Definition**

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 this Sensor, the field at the sensor position is positive.

- **Rotate Direction & Edge Polarity Definition**

Sensor need 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.

- Edge_Polar is needed to parametrize the sensor to one of the edges.
- CW/CCW to be defined as forward pluse is also needed.
- These two definition are independent from each other.

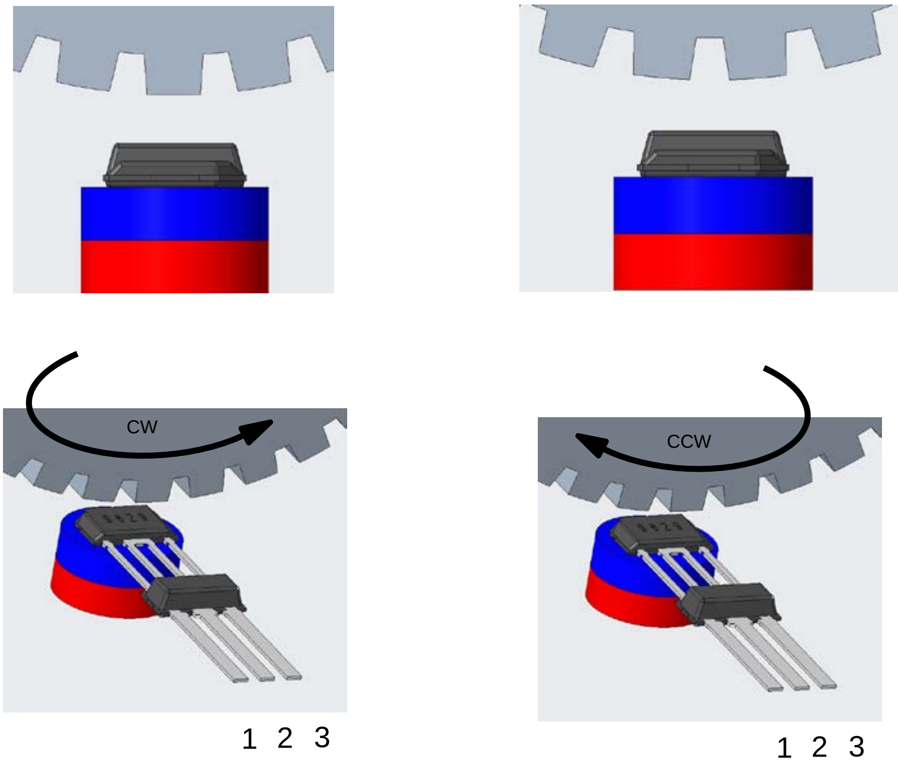


Fig.5 Definition of forward and reverse rotation directions

- **Operation Steps**

The basic operation of this sensor 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.The correspondence between field polarity and output polarity can be set according to the application needs.By definition a magnetic field is considered as positive if the magnetic North Pole is placed at the rear side of the sensor.

the operation need to be split to five different phases :

- 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;
  - starts after Power-on phase;
  - lasts one clock cycle;
  - IC enables output switching, extrema detection and threshold adaption;

- Calibration phase 1
  - 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 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;
  - 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;

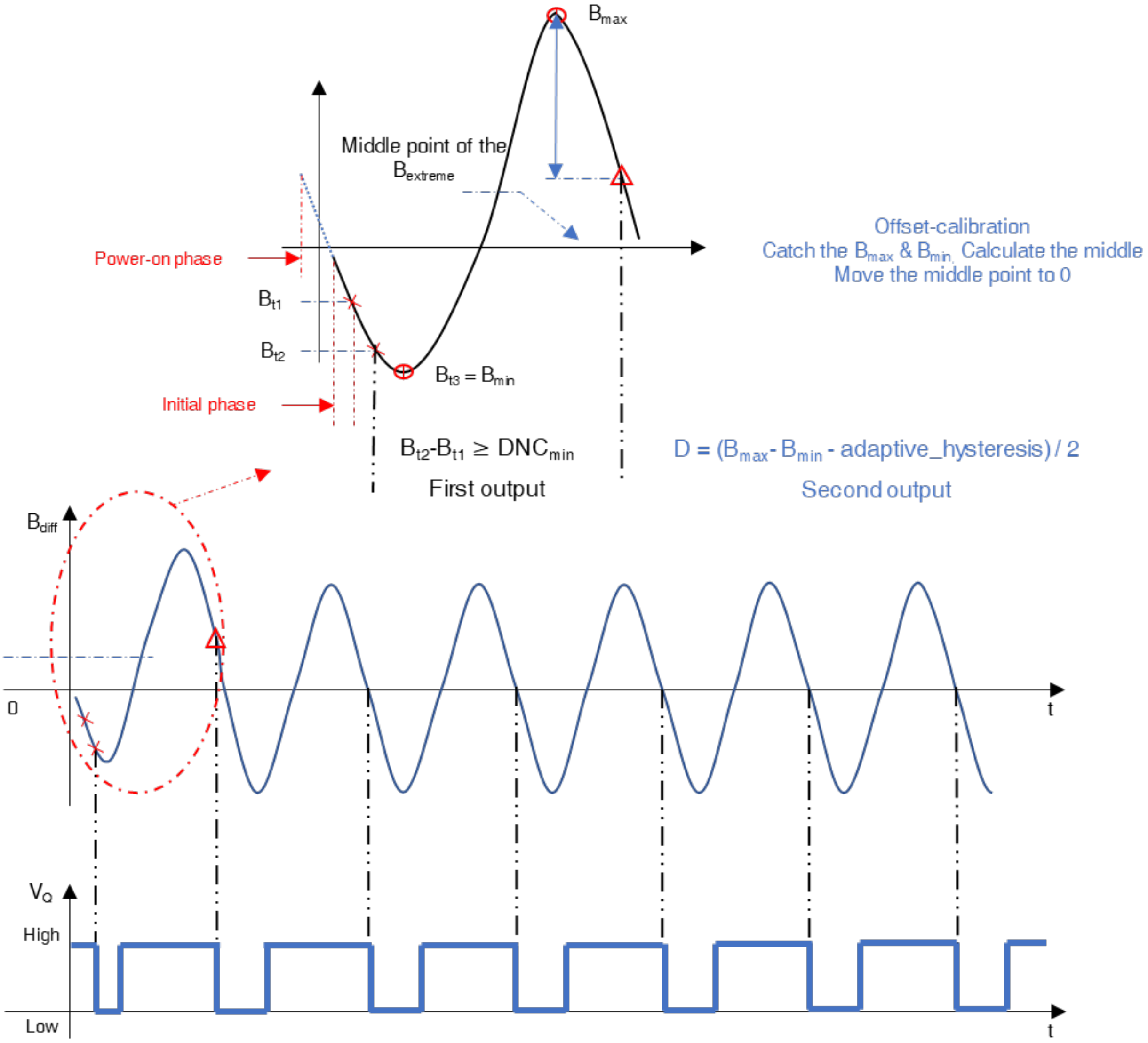


Fig.6 Calibration mode

- **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.

The algorithm can be able to choose different number of teeth for averaging.

And the algorithm can be set to : Once the feature signal is captured, the offset calibration value can be updated to previous round result.

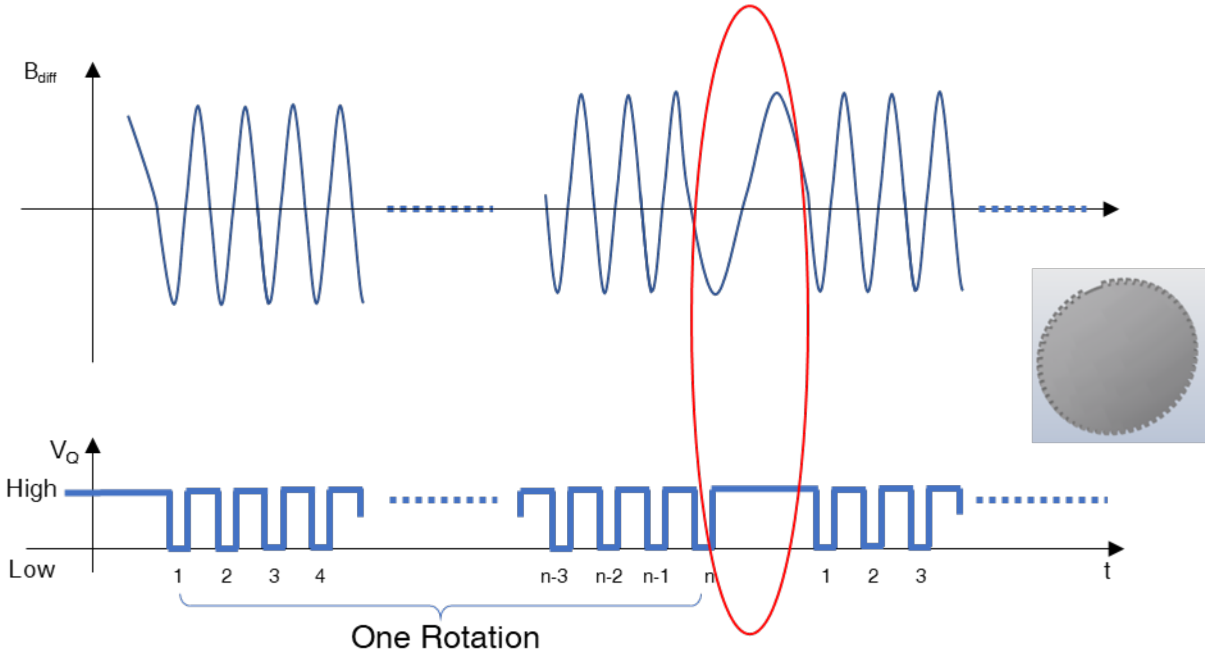


Fig.7 Averaging Algorithm

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

Available offset update algorithm to be choosen in EEPROM						
Symbol	**Parameter**	**Test Conditions**	**Min.**	**Typ.**	**Max.**	**Units**
58 teeth	Offset update algorithm	one revolution of a 60-2 target	-	58	-	-
56 teeth		one revolution of a 60-2-2 teeth /pole- pair target	-	56	-	-
34 teeth		one revolution of a 36-2 teeth /pole-pair target	-	34	-	-
32 teeth		one revolution of a 32-teeth /pole-pair target	-	32	-	-
5 times the same sign for offset-update		suggested for wheels with different number of teeth or for large run-out.	5	-	-	-

- **Hysteresis Concept**

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 8.

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 10 adaptive hysteresis is calculated as 25% of the differential Speed-signal peak to peak. The minimum hysteresis is derived from EEPROM setting.

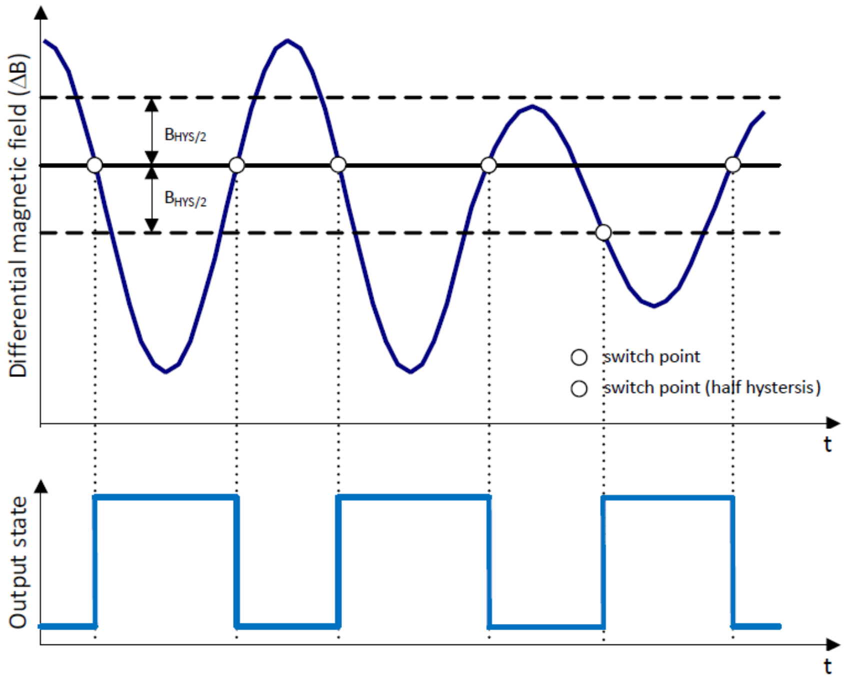


Fig.8 Definition of Hysteresis

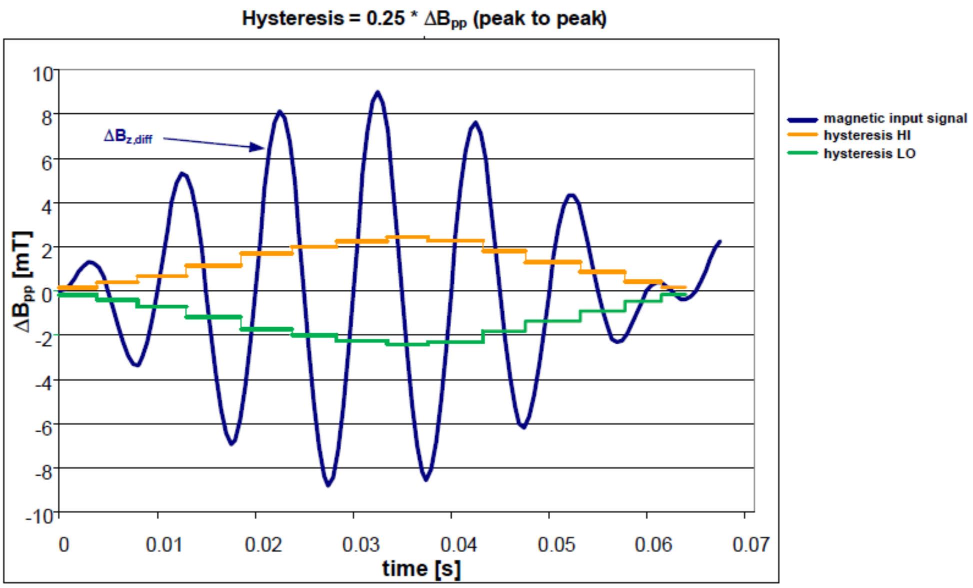


Fig.9 Adaptive Hysteresis

- **Adjust the proper k-factor**

Due to position tolerances of the sensor and of the magnet (X – displacement) the middle of the sensor is not always the middle of the module. And even if the sensor and the module would have the mechanical middle and the magnet is displaced there would be a deviation of the magnetic middle to the module middle.

These tolerances cause a wrong crankshaft position sensed and calculated in the engine control unit. Translated to magnetic parameters the teeth are modulating the back bias magnet field lines. The sensor detects the modulation of these field lines.

As all components have their own magnetic and mechanical tolerances, an overall tolerance of something like +/-0.3°crank is the accuracy of the sensed crankshaft position. With the introduction of adjustable switching threshold (k-factor) the accuracy of each module can be increased to +/-0.1°crank.

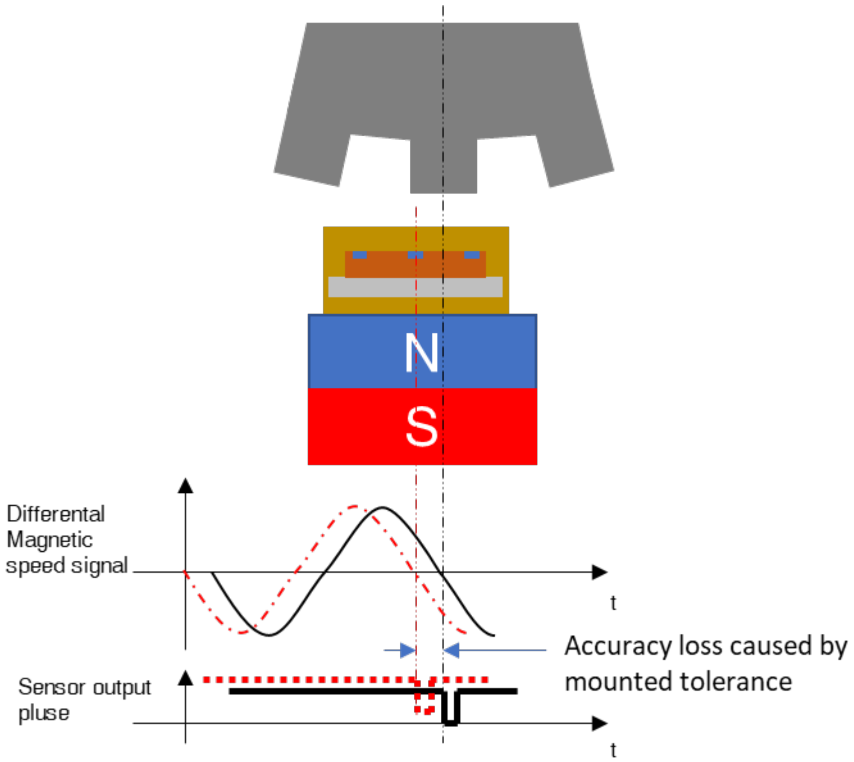


Fig.10 Compensation for mechanical installation errors

To offer better accuracy, several settings between 39% and 63% should be 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

- **Temperature compensation**

This sensor should have a constant temperature-measurement of the sensor itself and compensates the difference in the amplitude already in the analog signal path.So the main-comparator as well as the digital core can always see the same amplitude of the signal, independent from temperature of the magnet circuit.

As a natural consequence of changing back bias field during the stop-phase, the sensor has to recognize a different signal amplitude. When the engine is stopped at a temperature of 90°Celsius and 5 minutes later restarted again at 130°C (some conditions) the loss of signal amplitude is about 10% in a ferrite magnetic circuit.

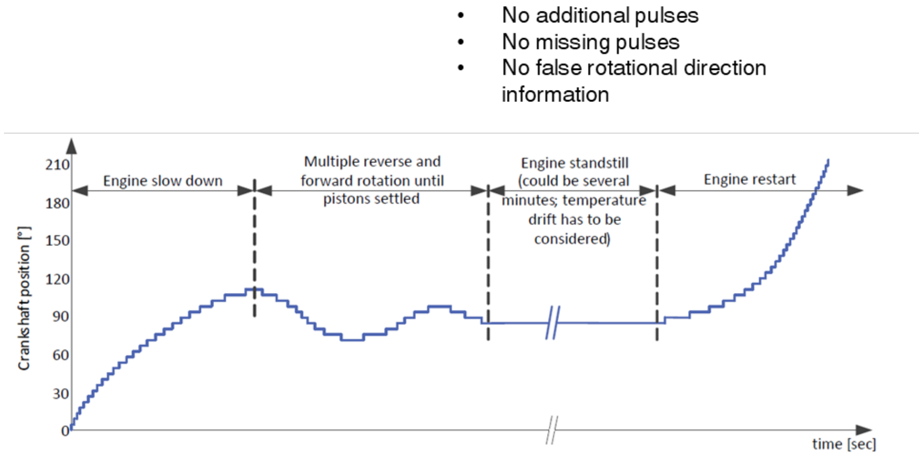


Fig.11 Start-Stop Algorithm

After a signal-change in speed channel above DNC (crankshaft wheel rotates again) the sensor should use known signal-amplitude and perform output-switching with the new switching threshold at the new temperature.

- **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 SC9669 is able to recover itself. The system watchdog can be enabled by EEPROM setting “WATCH_DOG_EN”.

- **Stop Start Watchdog**

The Stop Start Watchdog allows SC9669 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 SC9669 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 SC9669 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.

- **Time Watchdog**

The Time Watchdog allows SC9669 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.

- **Hybrid Vehicle Watchdog**

The Hybrid Vehicle Watchdog allows SC9669 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 SC9669 has to be entered once to take advantage of this feature.

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

- **High Speed Mode**

The high speed mode can be switched on or off by EEPROM bit “HIGH_SPEED”. Switched to state “off” the SC9669 behaves as described. Switched to state “on” the SC9669 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.

- **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.

12. Typical Application

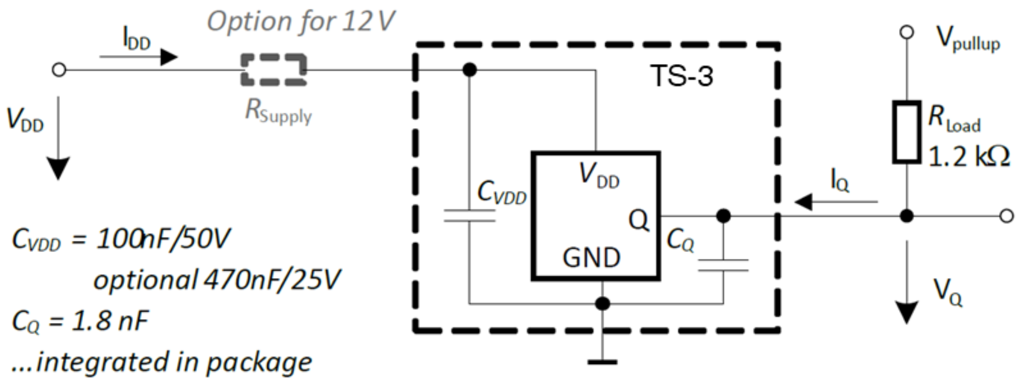
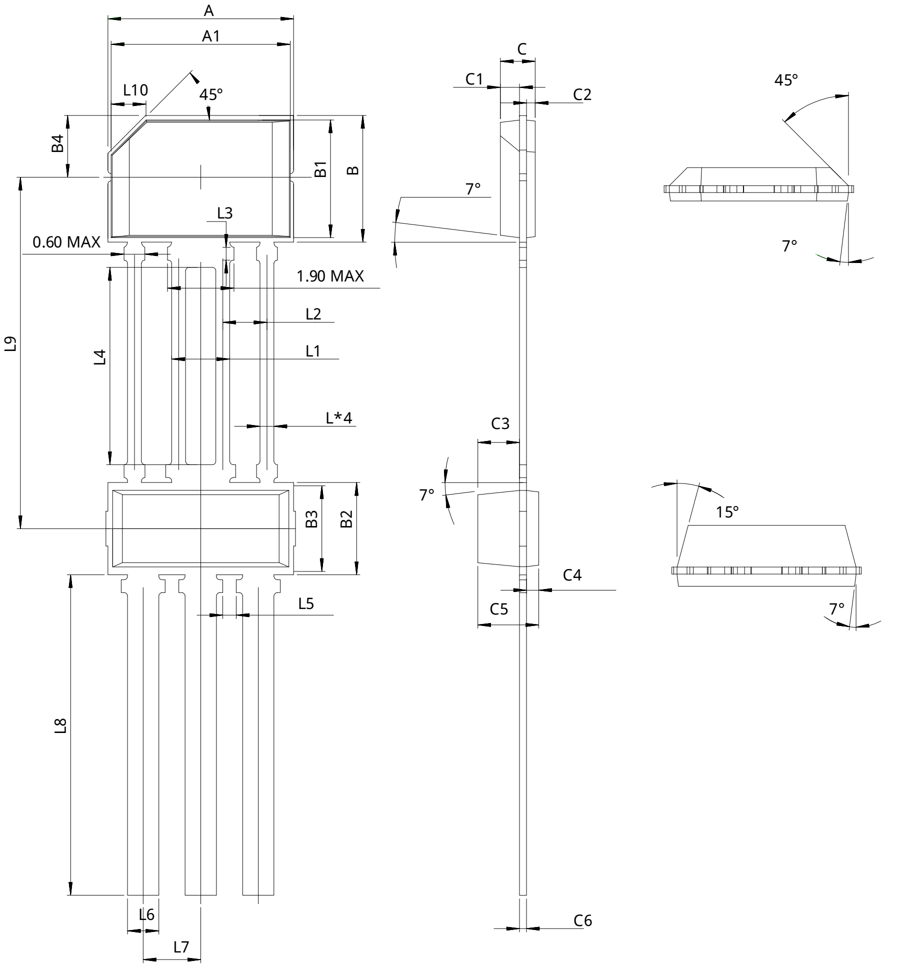


Fig.12 Typical Application Circuit

13. Package Information “TS-3”



Dimensions in Millimters			
Symbol	MIN	TYP	MAX
A	5.24	5.34	5.44
A1	5.05	5.15	5.25
B	3.52	3.64	3.76
B1	3.28	3.38	3.48
B2	2.40	2.65	2.90
B3	2.10	2.20	2.30
B4	1.68	1.78	1.88
C	0.92	0.96	1.00
C1	0.47	0.52	0.57
C2	0.19	0.24	0.49
C3	1.15	1.20	1.25
C4	0.30	0.35	0.40
C5	1.65	1.75	1.85
C6	—	0.20	—
L	0.35	0.40	0.45
L1	1.62	1.67	1.72
L2	—	1.27	—
L3	0.319	0.369	0.419
L4	5.62	5.67	5.72
L5	0.35	0.39	0.44
L6	0.85	0.90	0.95
L7	1.62	1.665	1.72
L8	9.16	9.21	9.26
L9	9.905	10.105	10.305
L10	—	1.00	—

Fig.13 Package Dimension

14. Packing Information

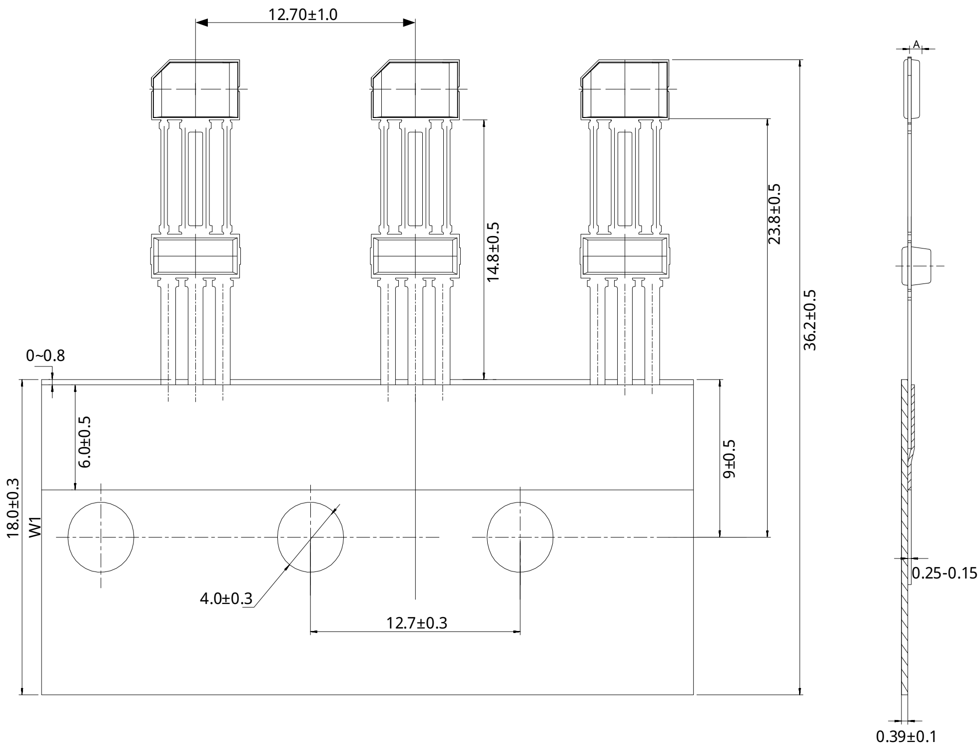


Fig.14 Packing Dimension

14. Revision History

Revision	Date	Description
Rev.E0.1	2024-03-20	Draft Version
Rev.E0.2	2025-06-11	Version & Format Updates