Self-Calibrating TPOS Speed Sensor IC

1. Features

- AEC-Q100 Grade0 qualified
- Optimized for automotive camshaft sensing
- True target state recognition at power-on
- Zero target speed detection
- Chopper stabilization reduces offset drift
- Digital output polarity option
- Rapid calibration and transition to Running mode
- Automatic Gain Control (AGC) during calibration eliminates effects of air gap variations
- High accuracy over full operating temperature range
- Operation at supply voltages as low as 3.3 V
- AEC-Q100 Grade0 qualified
- Package：IM-P

2. Product Application

- Camshaft sensor
- Speed sensor

3. Description

The SC9675 is the first-generation member of the SEMIMENT True Power-On State (TPOS) sensor IC family, offering improved accuracy compared to prior generations, and performing at absolutely zero target speed. An output polarity option allows customization for specific applications.

The device incorporates a single Hall-element IC with an optimized custom magnetic circuit that switches in response to magnetic signals. The resulting output of the device is a digital representation of a ferromagnetic target profile.

The IC contains a sophisticated digital circuit designed to eliminate the detrimental effects of magnetic and system offsets. Signal processing is used to provide target state recognition at zero rotational speed, consistent switch points regardless of air gap, and dynamically adapt device performance to the typical operating conditions found in automotive environments, particularly cam sensing applications.

High-resolution peak-detecting DACs are used to set the adaptive switching thresholds of the device. The SC9675 also includes a filter that increases the noise immunity and the signal-to-noise ratio of the IC.

The device is packaged in a IM-P. It is lead (Pb) free, with 100% matte tin-plated lead frame.

Fig.1 IM-P Package Outline

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4. Terminal Configuration

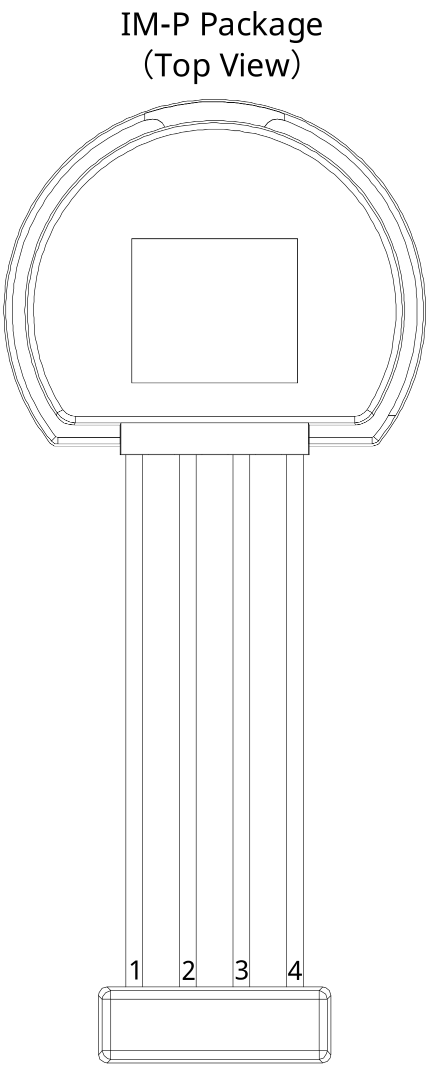


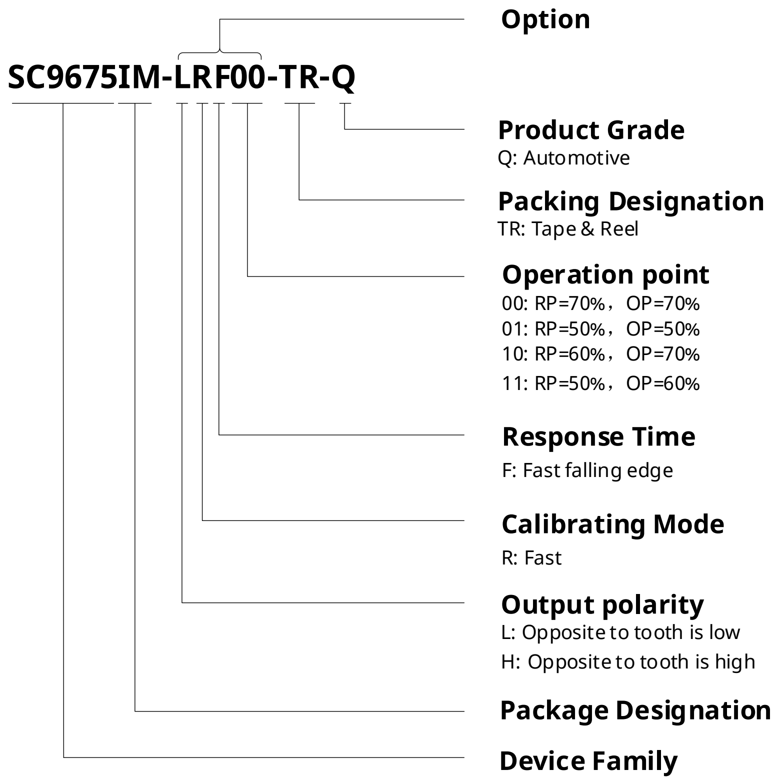
Fig.2 Pin Description

Terminal		Type	Description
Name	Number		
VDD	1	PWR	3.3V ~ 24 V power supply
OUT	2	Output	Open-drain output, requires a pull-up resistor
TEST	3	Test	Test pin, connect to the ground
GND	4	Ground	Ground

5. Ordering Information

Ordering Information	Marking	Option	Class	Ambient, T_A(℃)	Package	Packing	Quantity
SC9675IM-LRF00-TR-Q	9675	LRF00	Q	-40 ~ 150	IM-P	Tape & reel	500/reel
SC9675IM-LRF01-TR-Q	9675	LRF01	Q	-40 ~ 150	IM-P	Tape & reel	500/reel
SC9675IM-LRF10-TR-Q	9675	LRF10	Q	-40 ~ 150	IM-P	Tape & reel	500/reel
SC9675IM-HRF00-TR-Q	9675	HRF00	Q	-40 ~ 150	IM-P	Tape & reel	500/reel
SC9675IM-HRF11-TR-Q	9675	HRF11	Q	-40 ~ 150	IM-P	Tape & reel	500/reel

Ordering Information Format



6. Absolute Maximum Ratings

over operating free-air temperature range

Symbol	Parameter	Test conditons	Min.	Max.	Units
V_{DD}	Power supply reverse Voltage	Tj<150°C	-13	30	V
V_{OUT}	Output voltage	Tj<150°C	-0.5	30	V
I_{sink}	Output current	external current limitation required	30	80	mA
T_A	Operating ambient temperature		-40	150	℃
T_J	Maximum junction temperature		-55	150	℃
T_{STG}	Storage Temperature		-65	175	°C

Note :
Stresses above those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

7. ESD Protection

Symbol	Parameter	Test conditons	Min.	Max.	Units
V_{ESD_HBM}	HBM	Refer to AEC-Q100-002E HBM standard, R=1.5kΩ, C=100pF	-4	+4	KV
V_{ESD_CDM}	CDM	Refer to AEC-Q100-011C CDM standard	-750	750	V

8. Operating Characteristics

over operating free-air temperature range (V_{DD}=3.3V~24V, unless otherwise noted)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Supply Characteristics						
V_{DD}	Operating voltage	T_J<$T_{J(max)}$	3.3	5	24	V
I_{DD}	Operating supply current	V_{DD}=3.3V to 24 V	4.5	5.2	7.5	mA
V_{UVLO}	Undervoltage Lockout	V_{DD} from 5V to 0 V	-	2.7	3.3	V
V_{Supply}	Supply Zener Voltage	I_{DD} =30mA	28	33	40	V
I_{Supply}	Supply Zener Current	V_{SUPPLY} = 28V	-	6	8	mA
f_C	Chopping Frequency		387	500	875	KHz
V_{ZTEST}	TEST Zener Voltage	I_{TEST}=30mA	6	10	12	V
t_{PO}	Power-On Time	V_{DD} > 3.3V，f_{SIG} < 200Hz	-	0.4	1	ms
Output Characteristics						
State	LT option	opposite to tooth	-	Low	-	V
		opposite to valley	-	High	-	V
	HT option	opposite to tooth	-	High	--	V
		opposite to valley	-	Low		V
$V_{Q(SAT)}$	Output saturation voltage	I_{OUT}=10mA, output state=on	-	-	180	mV
		I_{OUT}=15mA, output state=on	-	-	270	mV
		I_{OUT}=20mA, output state=on	-	-	350	mV
I_{QL}	Output leakage current	V_{PU} =24V，output state=on	-	-	10	uA
I_{OUTLIM}	Output Current Limit	Output State = on	30	50	60	mA
V_{ZOUT}	Output Zener Voltage	I_{OUT} =30mA	30	35	40	V
t_r	Output Rise Time	R_{PU}=1K，C_L=4.7nF，V_{PU}=5V	-	10	11	us
t_f	Output Fall Time	R_{PU}=1K，C_L=4.7nF，V_{PU}=5V	1.5	1.6	2.3	us
		R_{PU}=1K，C_L=4.7nF，V_{PU}=12V	1.7	2	2.7	us
$\triangle t_{f(OUT)}$	Output Fall Time Variation with Temperature	from 25℃ to -40℃，and from 25℃ to 150℃	-20	-	20	%
$t_{d(OUT)}$	Output Delay Time	4KHz sinusoidal input signal ,falling electrical edge	-	18	-	us
Performance Characteristics						
AG[1,2]	Operational Air Gap	TPOS functionality guaranteed	0.5	-	2.8	mm
BW	Analog Signal Bandwidth	Equivalent to −3 dB cutoff frequency	-	20	-	KHz
f_{SIG}	Tooth Speed	Tooth signal frequency, sinusoidal input signal	0	-	8	KHz
$CAL_{Initial}$	Initial Calibration	Quantity of mechanical falling edges used to determine Running mode switchpoints level	-	1	3	edge

Operating Characteristics (continue)

CAL_{TPORM}	TPO to Running Mode Adjustment	Quantity of mechanical falling edges after CAL to transition from TPOS switchpoints level to Running mode switchpoints level	-	1	3	edge
$B_{ST}^{(3)}$	Running Mode Switchpoint	% of peak-to-peak, referenced to tooth signal	50	-	70	$\%_{pk\text{-}pk}$
$B_{HYS(int)}$	Internal Hysteresis	% of peak-to-peak signal	-	10	-	%
B_{reduce}	Maximum Allowable Signal Reduction	Reduction in V_{PROC} amplitude from $V_{PROC(high)}$ to lowest peak $V_{PROC(reduce)}$, all specifications within range	-	-	15	$\%_{pk\text{-}pk}$
		Reduction in V_{PROC} amplitude from $V_{PROC(high)}$ to lowest peak $V_{PROC(reduce)}$; output switches, other specifications may be out of range	-	-	25	$\%_{pk\text{-}pk}$
E_{rrRELR}	Relative rising Timing Accuracy	Rising mechanical edges after initial calibration, gear speed = 1000 rpm, target eccentricity < 0.1 mm	-	0.4	0.8	deg
E_{rrRELF}	Relative falling Timing Accuracy	Falling mechanical edges after initial calibration, gear speed = 1000 rpm, target eccentricity < 0.1 mm	-	0.5	1.0	deg

Note:

(1) The actual air gap range is 0.5 to 4mm, which can ensure the TPOS function of the chip, and the air gap of more than 2.8mm cannot guarantee E_{rrREL}

(2) The air gap parameters are applicable to the chip and teeth of semiment.

(3) There are 4 kinds of flip points, usually 70% or 50%, please contact us for details

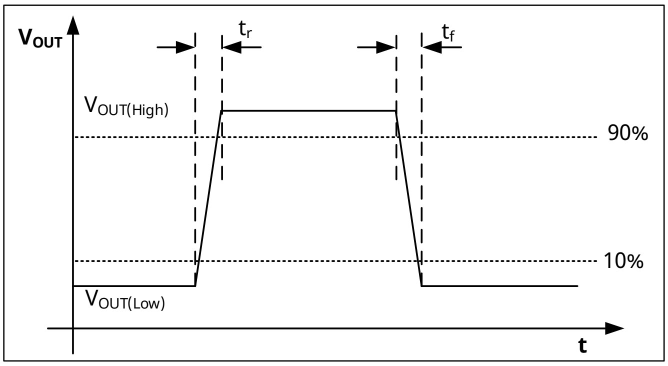


Fig.3 Definition of t_r and t_f

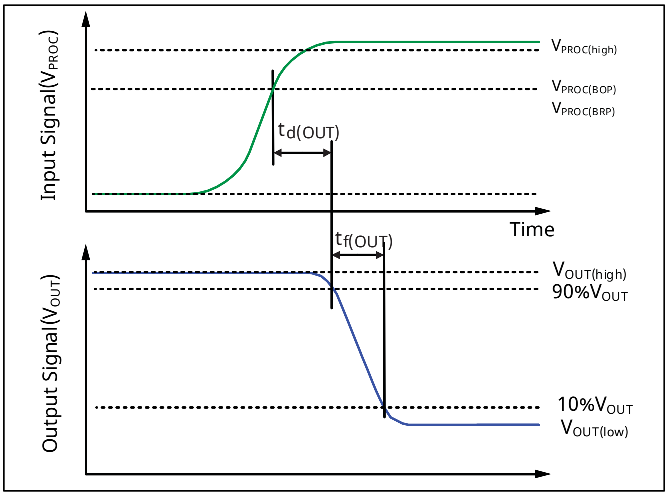


Fig.4 Definition of $t_{d(OUT)}$

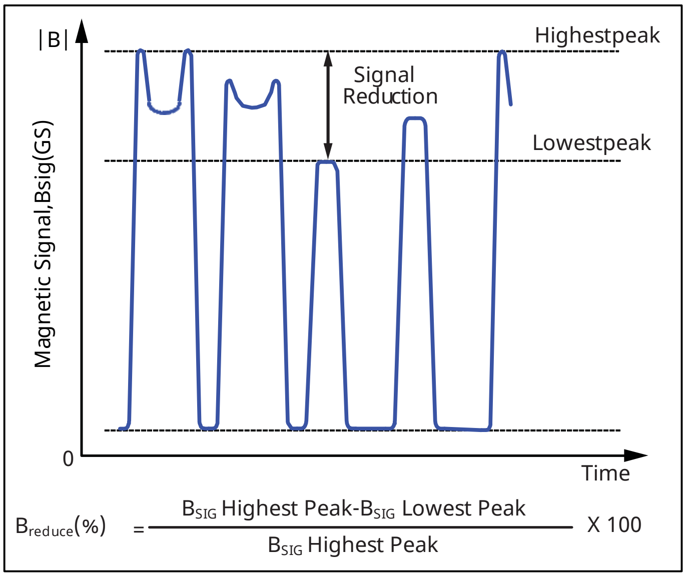


Fig.5 Definition of Maximum Allowable Signal Reduction

9. Typical Characteristics

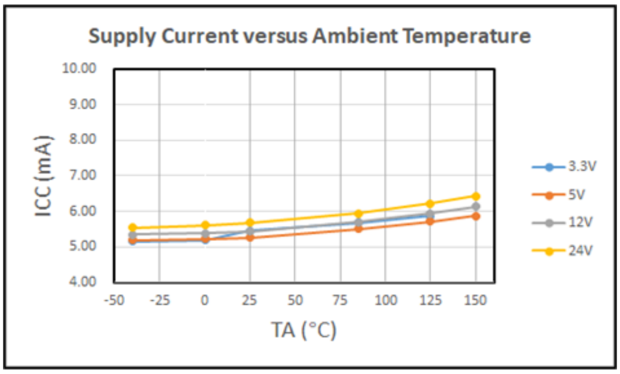


Fig.6 Supply Current versus Ambient Temperature

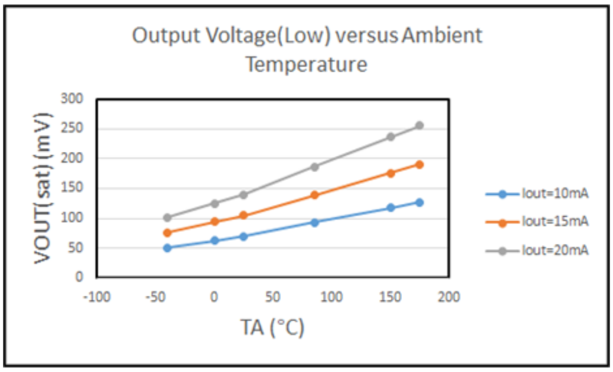


Fig.7 Output Voltage(Low) versus Ambient Temperature

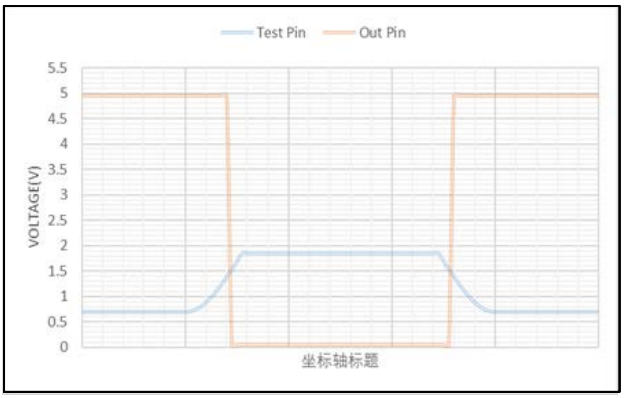


Fig.8 Definition of Switchpoints

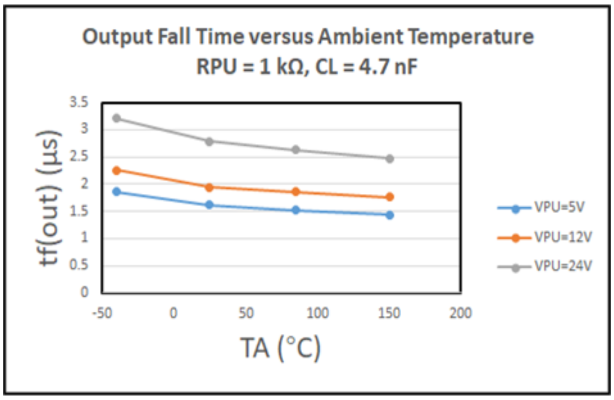


Fig.9 Output Fall time versus Ambient Temperature

10. Block Diagram

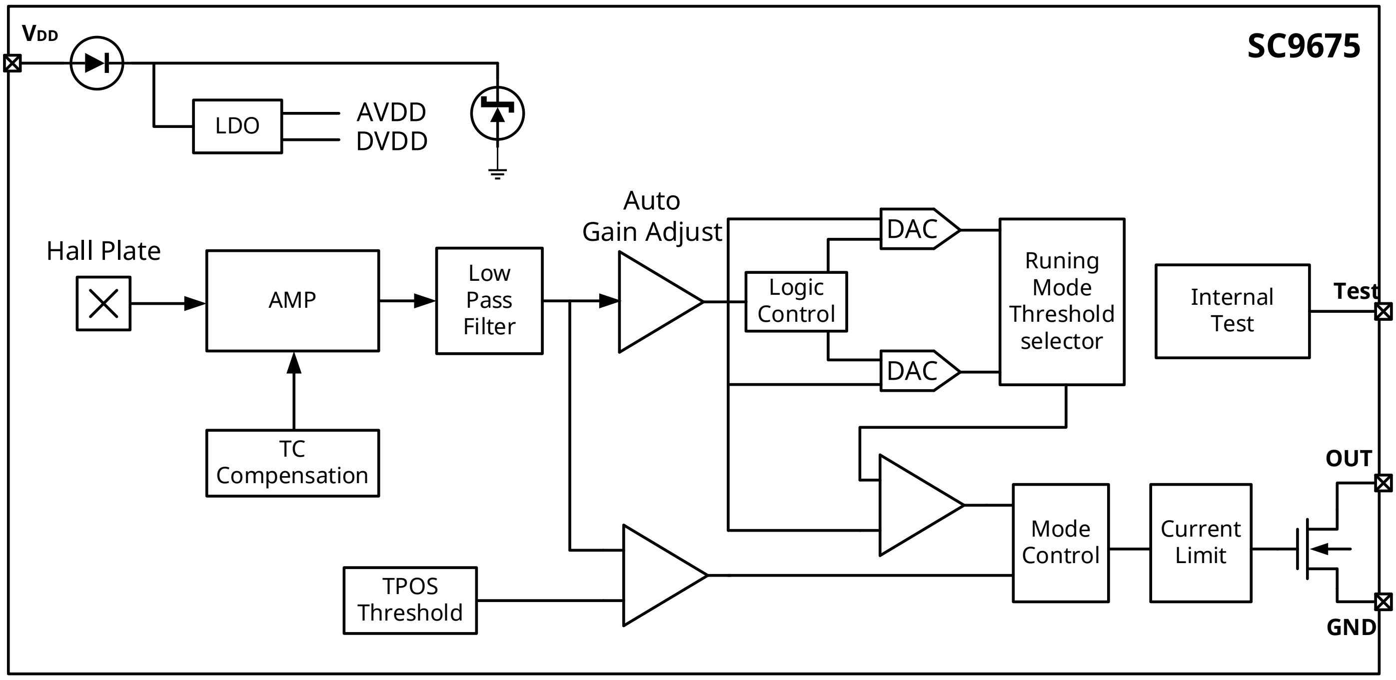


Fig.10 Block Diagram

11. Function Description

Internal Electronics

This device incorporates a self-calibrating Hall effect IC that incorporates a Hall element, a temperature-compensated amplifier, and offset cancellation circuitry. The IC also incorporates a voltage regulator that offers supply noise rejection across the operational voltage range. The Hall transducers and the electronics are seamlessly integrated on the same silicon substrate through a proprietary BiCMOS process. Temperature variations have minimal impact on the device due to the stable amplifier design and the offset rejection circuitry. The Hall IC supports a chopper-stabilized Hall element that gauges magnetic gradient intensity and provides an electrical signal that represents the target features.

Hall Technology

The SC9675 incorporates a monolithic Hall effect sensor IC, a 4-pin lead frame, a custom-engineered rare-earth pellet, and a precision-mounted ferrous pole piece, which serves as a magnetic field concentrator. The Hall IC incorporates a chopper-stabilized Hall element that precisely measures the magnetic gradient generated by the passage of a ferromagnetic object, as illustrated in Figure 11. The distinct magnetic gradients created by tooth and valley features enable the device to generate a digital output signal that accurately represents the characteristics of the target.

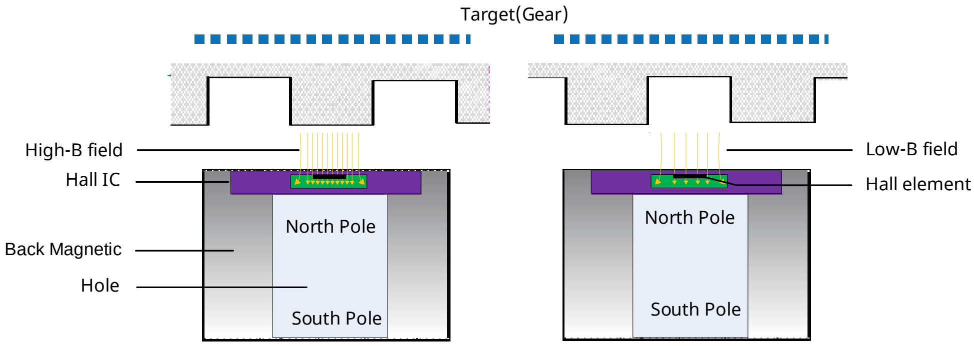


Fig.11 Target tooth opposite device Target valley opposite device

Output Profile Polarity (LT/HT Option)

As shown in Figure 12, the device output, represents the mechanical profile of the target digitally. The customer has the option to choose the relative polarity of the output waveform. This polarity assignment assigns the inverse polarity to tooth features and valley features. The LT option sets V_{OUT} to low when a tooth is facing the device, while the HT option sets V_{OUT} to high when a target tooth is facing the device. This polarity assignment remains consistent throughout device operation. This ease of use reduces design time and assembly costs for most applications.

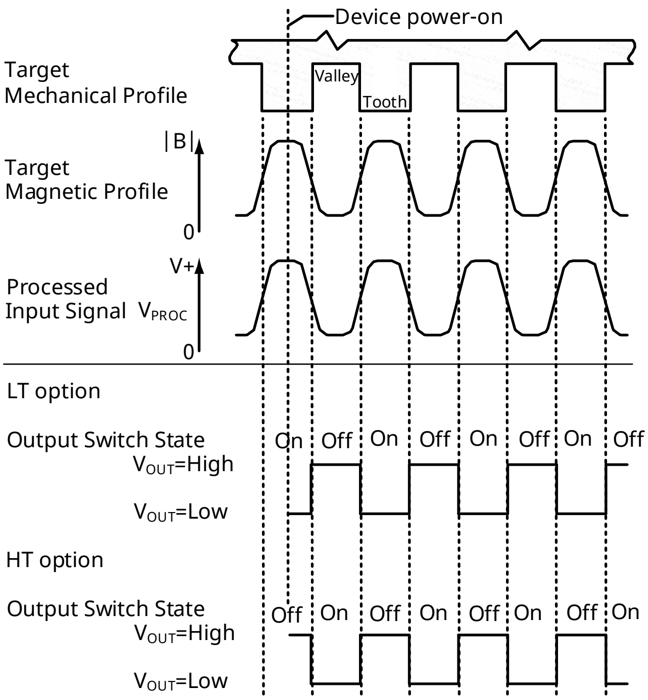


Fig.12 Definition of output profile

Automatic Gain Control (AGC)

The Automatic Gain Control (AGC) feature is a crucial element that ensures the stability and accuracy of the SC9675's initial switching thresholds. It effectively isolates these thresholds from any variations in the effective air gap, which is the total distance between the Hall element and the nearest feature of the target. To achieve this, AGC relies on a unique and patented self-calibrating circuitry. This circuitry normalizes the sensed magnetic gradient, ensuring that the internal processed signal remains within an optimal processing range.

During the Initial Calibration stage, which occurs at each power-on, AGC is automatically activated. The device measures the peak-to-peak application magnetic gradient and adjusts the gain of the sensor IC accordingly. This adjustment normalizes the internal processed signal, V_{PROC}, to accommodate any input signal amplitude within the specified Operating Magnetic Signal Range, B_{SIG}. It is important to note that AGC is referenced to the internal magnetic baseline. Once the Initial Calibration stage is complete, the AGC results are latched, and no further adjustments are made while the device remains powered-on.

Undervoltage Lockout

When the supply voltage becomes below the undervoltage lockout level, V_{DDUV}, the device output state changes to Off. The device remains in that state until the voltage level recovery to the VDD operating range. Changes in the target magnetic gradient have no effect until that voltage level is restored. This prevents false signals caused by undervoltage conditions.

EMC Protection

The SC9675 incorporates an on-chip regulator that can effectively operate across a comprehensive range of supply voltage levels. When implementing an application that employs an unregulated power source, it is essential to consider supplementing the system with external transient protection measures. Conversely, for applications utilizing a regulated power supply, it is still advisable to incorporate EMI and RFI safeguards. For detailed information on ensuring compliance with EMC specifications, please consult SEMIMENT.

Operating Modes

The device incorporates three operating modes: TPOS, Calibration, and Running. TPOS and Calibration start simultaneously at power-on. TPOS generates immediate device output, controlling device output status while the calibration functions are performed. After calibration, running mode begins.

TPOS (True Power-On State) Operation

After power-on, the TPO device will immediately generate an output voltage that is opposite to the target characteristic. This is achieved by comparing the current level of the application's magnetic gradient, B_{APP}, to the TPOS switching level. The TPOS switching level is an internal threshold used to distinguish between peaks and valleys during TPOS operation (from power-on to the end of the initial calibration phase). If B_{APP} is below the threshold, the target characteristic is evaluated as a valley, and if B_{APP} is above the threshold, the characteristic is evaluated as a tooth.

Calibration Mode Operation

At power-on (simultaneous with TPOS operation) Calibration mode begins. Calibration mode has two stages: the Initial Calibration stage, following the TPOS to Running Mode Transition stage. After the second calibration stage, running mode starts immediately.

In Calibration mode, the operating range of the application magnetic gradient, B_{APP}, is detected and evaluated, and then the SC9675 circuits are adapted for optimal output switching. Calibration is performed rapidly, without reading the all targets, because the SC9675 applies the internal magnetic baseline.

Initial Calibration Stage

During the Initial Calibration stage, TPOS operation controls device output switching while calibration starts. In this stage, the peak-detecting DACs acquire the application magnetic signal. Based on those results, the Automatic Gain Control (AGC) feature calculates the normalized Running mode switching range. This period is minimized, so swapping to the Running mode thresholds can occur as quickly as possible.

TPOS to Running Mode Transition Stage

At this stage, TPOS operation stops, and throughout this stage the device automatically adjusts the output switching levels from the original preset level to the Running mode switching level. This transition takes place over one tooth, immediately swapping from TPOS to Running mode switching level.

Running Mode Operation

Running Mode immediately follows calibration mode. During Running Mode, dynamic switching points are established based on the sensed application magnetic gradient, B_{APP}. To determine these switching points, B_{APP} is normalized using AGC and processed to generate the internal processed signal, V_{PROC}. Two peak-detecting DACs track the V_{PROC} waveform, and the output switching points are set as percentages of the values held by these DACs. As the switching points are established dynamically as a percentage of the peak-to-peak signal, the impact of any application shift is minimized.

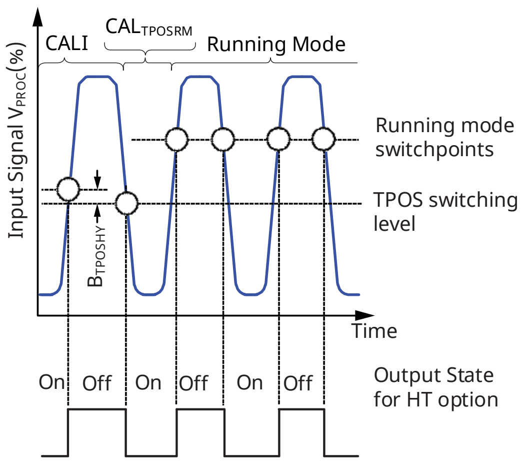


Fig.13 Calibration mode waveforms

Running Mode Switch-points

The Running mode switching points are determined by values calculated as a percentage of the V_{PROC}. According to Figure 14, this percentage is subtracted from the minimum $V_{PROC\,(high)}$ value, corresponding to a maximum air gap at the most prominent target tooth. On the SC9675, the switching points are referenced to approximately 70% or 50% of the peak-to-peak magnetic signal. This level closely aligns with the mechanical target edges, ensuring optimal timing accuracy.

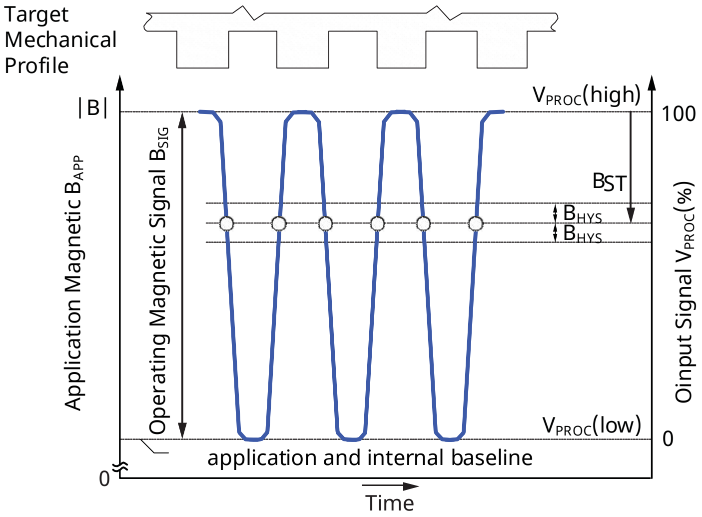


Fig.14 Switchpoints Level for Running Mode definition

Running Mode Hysteresis

The SC9675 was designed a hysteresis method, switching at a consistent point on both rising and falling edges. When a target anomaly is encountered, the internal hysteresis thresholds provide immunity to false switching, as illustrated in figure 15.

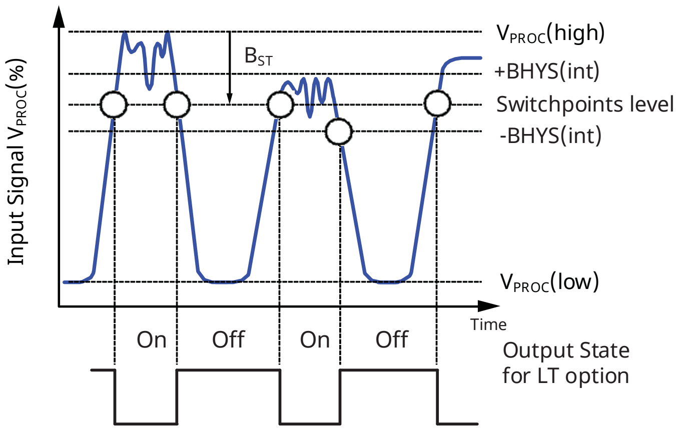


Fig.15 Running mode switching on anomalous peak

12. Typical Application

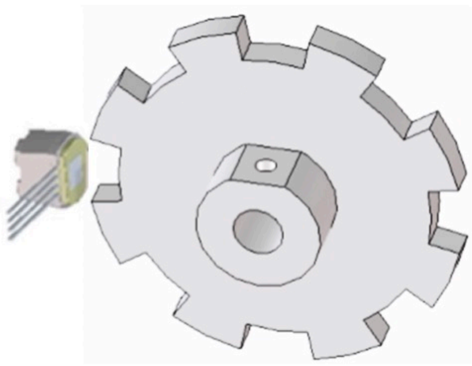


Fig.16 Typical Application

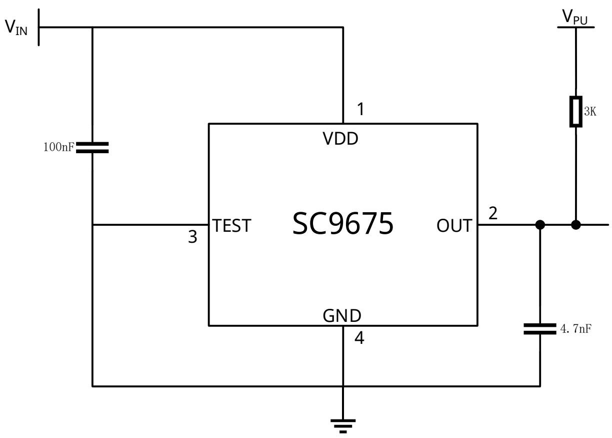
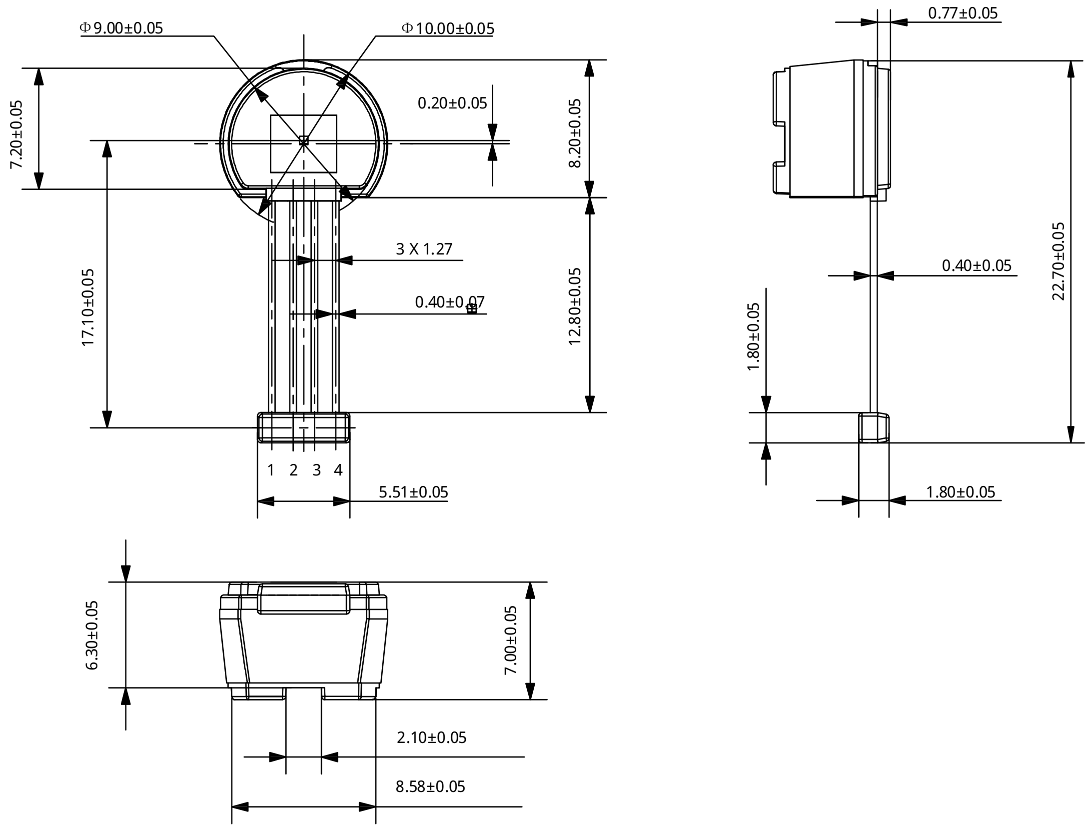


Fig.17 Operational circuit for the SC9675

Gear tooth parameters

Symbol	Characteristic	Test Conditions	Typ.	Units	
D_O	Outside Diameter	Outside diameter of gear	60	mm	
t	Tooth Thickness		11.78	mm	
t_V	Circular Tooth/Valley Length	Length of tooth/Valley,with respect to marking face	23.6	mm	
h_t	Tooth Whole Depth		5	mm	
	Meterial	45#			

13. Package Information "IM-P"



Notes:
1. *Exact body and lead configuration at vendor's option within limits shown.*
2. *Height does not include mold gate flash.*
3. *The deviation between the Y-axis direction of the Hall plate and the center of the package body is 0.2mm*

Where no tolerance is specified, dimension is nominal.

Fig.18 Package Dimensions

14. Revision History

Revision	Date	Description
Rev.0.1	2022-08-30	Initial revision
Rev.A1.0	2023-12-27	Official revision
Rev.A1.1	2025-02-13	Update ordering information and POD