Self-Calibrating TPOS Speed Sensor IC

FEATURES

- Optimized for automotive camshaft sensing
- True target state recognition at device power-on (TPOS) and at zero target speed
- Chopper stabilization reduces offset drift
- Digital output polarity option: follow or invert target profile
- Rapid calibration and transition to Running mode
- Automatic Gain Control (AGC) during calibration eliminates effects of air gap variations
- Tight timing accuracy over full operating temperature range
- Operation at supply voltages as low as 3.3 V
- Undervoltage lockout (UVLO)

PACKAGE：SIP-4M（suffix IM-P）

DESCRIPTION

The SC9675IM-P 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 SC9675IM-P also includes a filter that increases the noise immunity and the signal-to-noise ratio of the IC.

CONTENT

1. BLOCK DIAGRAM

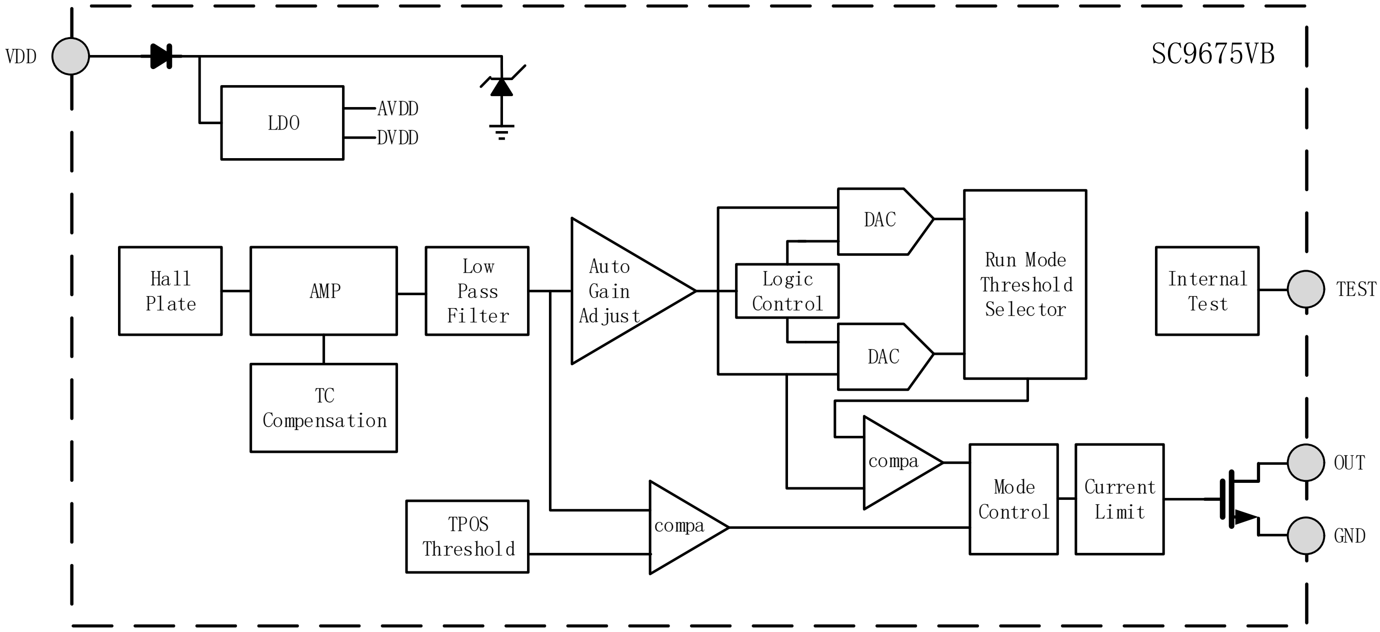
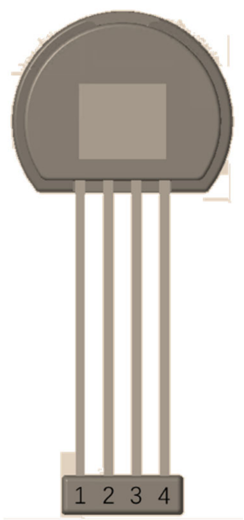


Figure 1. Functional Block Diagram

2. TERMINAL CONFIGURATION



Number	Name	Type	Description
1	VDD	Power	Supply Voltage 3.3V～24V
2	OUT	Output	Open-Drain output
3	TEST	Test	Test pin recommended connect to GND
4	GND	Ground	GND

3. ORDERING INFORMATION

Part Number	Packing	Mounting	Ambient, T_A	Marking
SC9675IM-P-XXXXX	real, 500 pieces per real	SIP-4M (Include Magnetic)	-40℃ to 150℃	9675 Date Code

*For further information as below

Part Number	Selected Programmable Option			
	Polarity	Calibration Mode	Response Time	Switch Point
SC9675IM-P-LRF00	L: Towards Tooth Low	R: Rapid Enter	F: Falling Edge Fast	00: RP=70% OP=70%
SC9675IM-P-LRF01	L: Towards Tooth Low	R: Rapid Enter	F: Falling Edge Fast	01: RP=50% OP=50%
SC9675IM-P-LRF10	L: Towards Tooth Low	R: Rapid Enter	F: Falling Edge Fast	10: RP=60% OP=70%
SC9675IM-P-LRF11	L: Towards Tooth Low	R: Rapid Enter	F: Falling Edge Fast	11: RP=50% OP=60%
SC9675IM-P-HRF00	H: Towards Tooth High	R: Rapid Enter	F: Falling Edge Fast	00: RP=70% OP=70%
SC9675IM-P-HRF01	H: Towards Tooth High	R: Rapid Enter	F: Falling Edge Fast	01: RP=50% OP=50%
SC9675IM-P-HRF10	H: Towards Tooth High	R: Rapid Enter	F: Falling Edge Fast	10: RP=60% OP=70%
SC9675IM-P-HRF11	H: Towards Tooth High	R: Rapid Enter	F: Falling Edge Fast	11: RP=50% OP=60%

*Further requirements, please contact Semiment.

4. ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Limit Values		Units
		Min.	Max.	
V_{DD}	Supply Voltage	-13	30	V
V_{OUT}	Output Voltage	-0.5	30	V
$I_{OUT\ (sink)}$	Output Current	30	80	mA
T_A	Operating Ambient Temperature	-40	150	℃
T_J	Junction Temperature	-40	165	℃
T_{STG}	Storage Temperature	-55	165	℃

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.

5. ESD PROTECTION

Human Body Model (HBM) tests according to: standard AEC-Q100-002

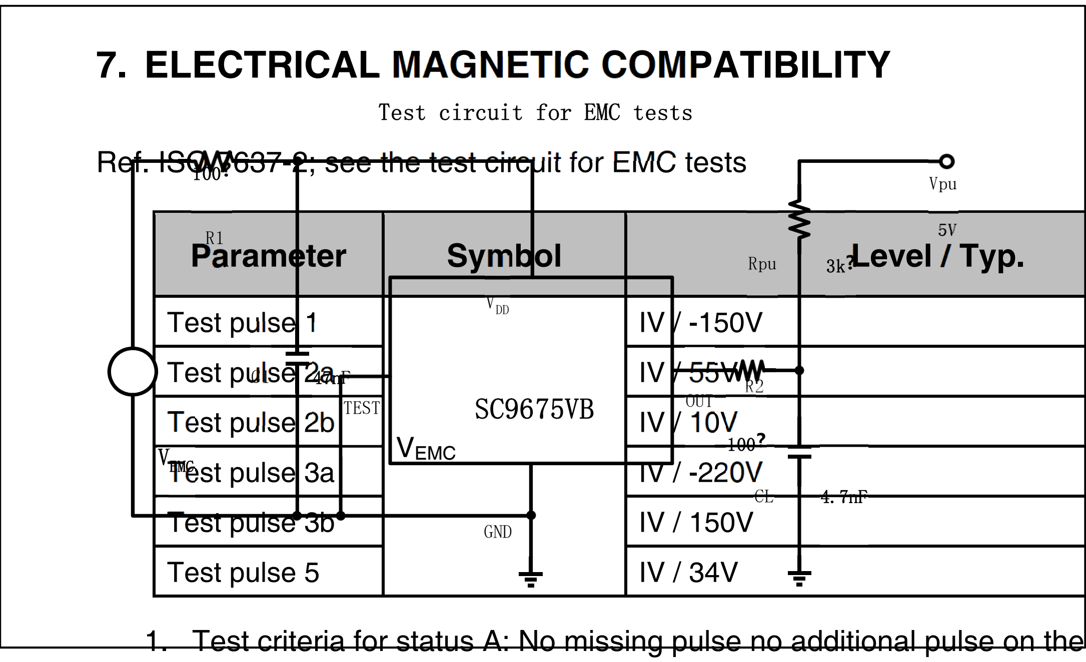
Symbol	Parameter	Limit Values		Units
		Min.	Max.	
V_{ESD} *	ESD-Protection	-4	4	KV

* Bare chip performance without any protection circuit.

6. THERMAL CHARACTERISTICS

Symbol	Parameter	Test Conditions	Rating	Units
$R_{\theta JA}$	Package thermal resistance	Single-layer PCB, with copper limited to solder pads	101	℃/W

7. ELECTRICAL MAGNETIC COMPATIBILITY



Ref. ISO7637-2; see the test circuit for EMC tests

Parameter	Symbol	Level / Typ.	Status
Test pulse 1	V_{EMC}	IV / -150V	C
Test pulse 2a		IV / 55V	C
Test pulse 2b		IV / 10V	B
Test pulse 3a		IV / -220V	C
Test pulse 3b		IV / 150V	C
Test pulse 5		IV / 34V	A

1. Test criteria for status A: No missing pulse no additional pulse on the IC output signal plus duty cycle and jitter are in specification limits.
2. Test criteria for status B: No missing pulse no additional pulse on the IC output signal.
3. Test criteria for status C: One or more parameter can be out of specification during the exposure but returns automatically to normal operation after exposure is removed.

Figure 2. Recommended EMC Protection & Application circuit

8. OPERATING CHARACTERISTICS

Over operating free-air temperature range (VDD=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	--	24	V
I_{DD}	Operating supply current	V_{DD}=3.3 to 24V	4.5	5.2	7.5	mA
V_{UVLO}	Undervoltage Lockout		--	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}>V_{DD} (min), f_{SIG}<200Hz	--	0.4	1	ms
Output Stage Characteristics						
Output 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	μA
$I_{OUTLimit}$	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}=1kΩ, C_L=4.7nF, V_{PU}= 5 V	--	10	11	us
t_f	Output Fall Time	R_{PU}=1kΩ, C_L=4.7nF, V_{PU}= 5 V	1.5	1.6	2.3	us
		R_{PU}=1kΩ, C_L=4.7nF, V_{PU}=12V	1.7	2.0	2.7	us
$t_{f\ (OUT)}$	Output Fall Time Variation with Temperature	Maximum variation from TA=25 ℃ to–40℃ and then to 150℃	-20	0	20	%
$t_{d\ (OUT)}$	Output delay time	4KHz input signal, falling electrical edge	--	18	--	us

Performance Characteristics						
AG1,2	Operational Air Gap Range (IC surface to target)	Switch point functionality guaranteed Referenced to Gear Tooth in Semiment	0.5	--	2.8	mm
BW	Analog Signal Bandwidth	Equivalent to -3dB 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 switch points level	--	1	3	edge
CAL_{TPORM}	TPO to Running Mode Adjustment	Quantity of mechanical falling edges after CALI to transition from TPOS switch points level to Running mode switch points level	--	--	1	tooth
B_{ST}	Running Mode Switch point	% of peak-to-peak Referenced to Gear Tooth in Semiment	50		70	$\%_{pk-pk}$
$B_{HYS (int)}$	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	$\%_{pk-pk}$
		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	$\%_{pk-pk}$
Err_{RELR}	Relative Timing Accuracy	Rising mechanical edges after initial calibration, gear speed = 1000rpm, target eccentricity < 0.1mm	--	0.4	0.8	deg.
Err_{RELF}		Falling mechanical edges after initial calibration, gear speed =1000rpm, target eccentricity< 0.1mm	--	0.5	1.0	deg.

1. The actual air gap range is 0.5~4mm, which ensures the TPOS function of the chip, but more than 2.8mm cannot guarantee
2. Airgap data base on the recommended mount direction between sensor and gear
3. There are 4 types of switching modes, typically 70% or 50%, please contact us for details

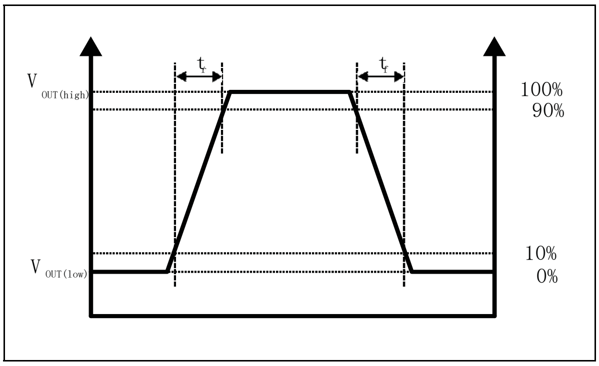


Figure 3. Rise time and Fall time

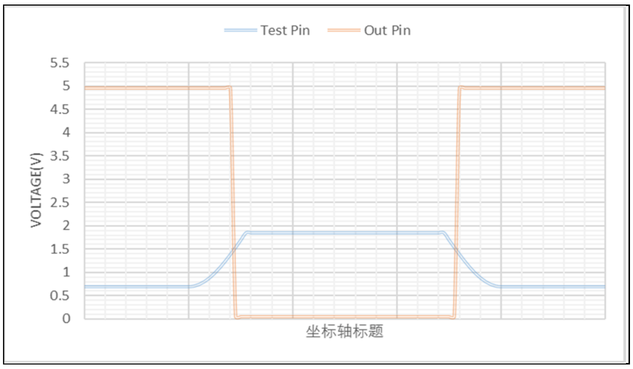


Figure 6. Definition of Switch Point

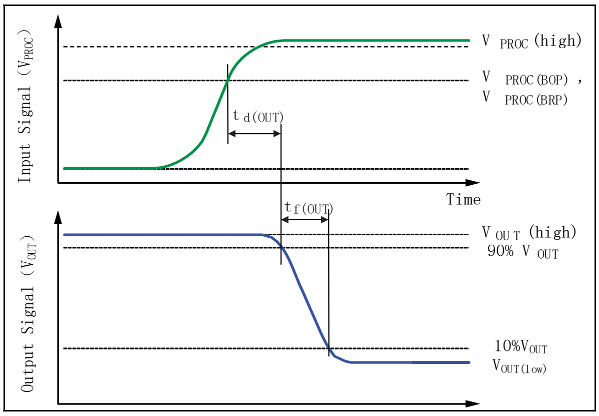


Figure 4. Definition of Output Delay time

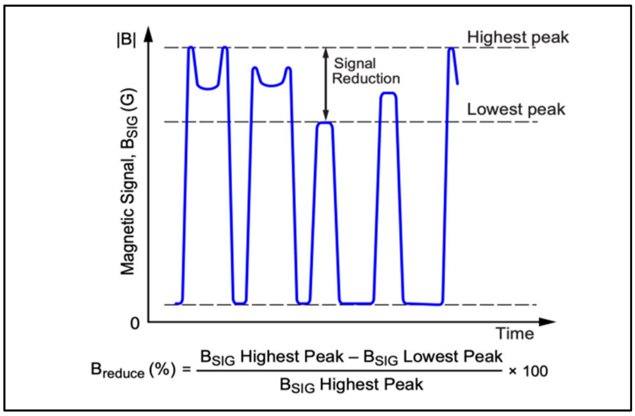


Figure 7. Definition of Maximum allowable signal reduction

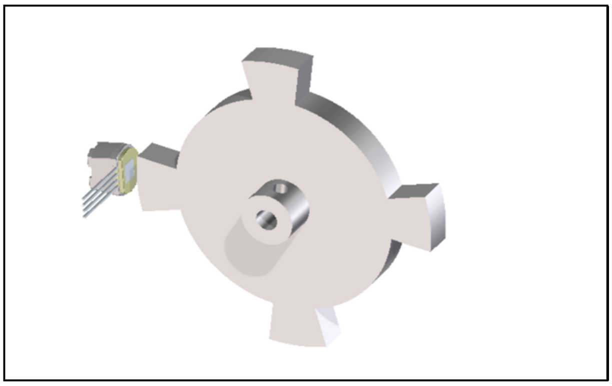


Figure 5. Recommended application scenarios

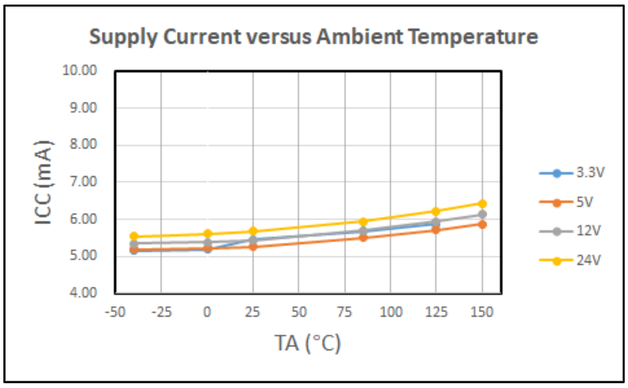


Figure 8. Supply Current

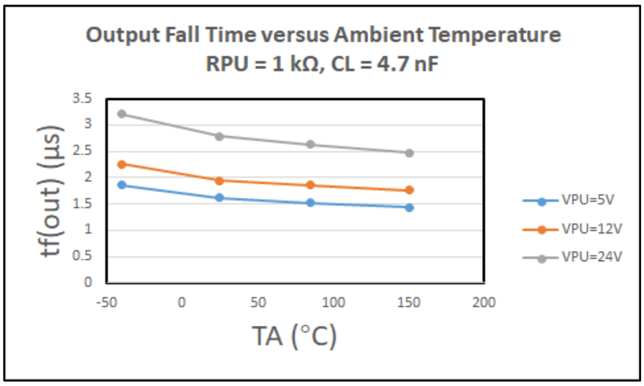


Figure 9. Fall time

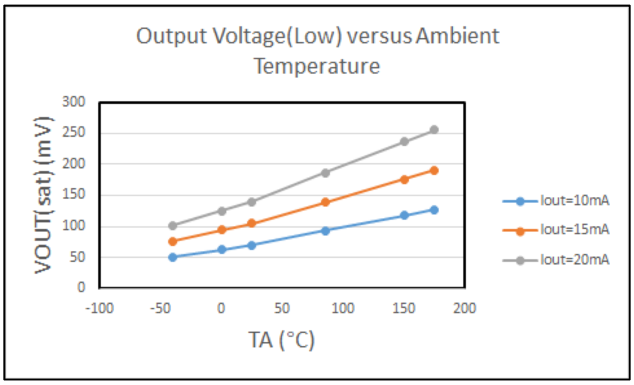
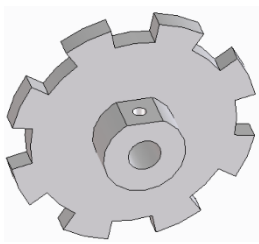


Figure 10. VOUT (sat)

9. APPLICATION GEAR TOOTH

Characteristic	Symbol	Test Conditions	Typ.	Unit	Symbol Key
Outside Diameter	Do	Outside diameter of target	60	mm	
Circular Tooth Length	t	Length of tooth, with respect to branded face; measured at Do	11.78	mm	
Circular Valley Length	t_V	Length of valley, with respect to branded face; measured at Do	23.6	mm	
Tooth Whole Depth	h_t		5	mm	Gear Tooth in SEMIMENT
Material		#45			

10. FUNCTIONAL DESCRIPTION

10.1 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.

10.2 Hall Technology

The SC9675IM-P 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.

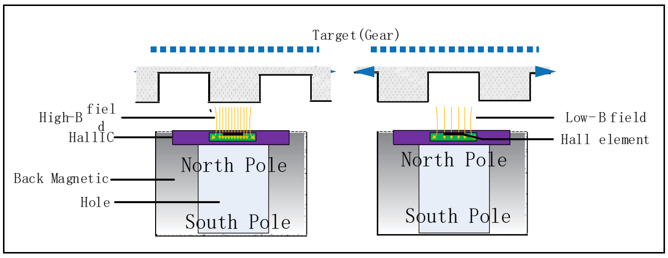


Figure 11. Application of device opposite to tooth and Valley

10.3 Output Profile Polarity (LT/HT Option)

As shown in Figure 12, the device output, VOUT, 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 VOUT low when a tooth is facing the device, while the HT option sets VOUT 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.

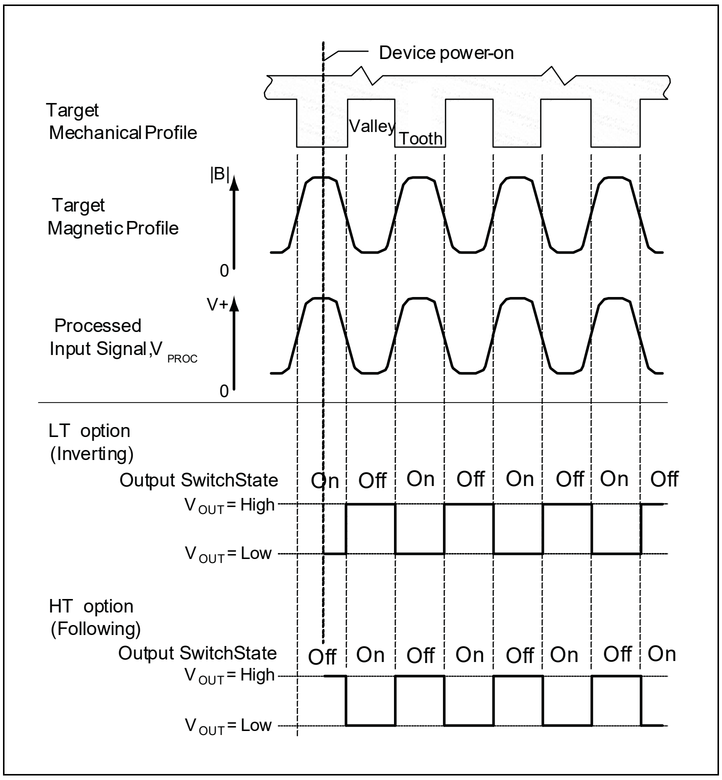


Figure 12. Output state of device opposite to tooth and valley

10.4 Automatic Gain Control (AGC)

The Automatic Gain Control (AGC) feature is a crucial element that ensures the stability and accuracy of the SC9675IM-P'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.

10.5 Power Supply Protection

The SC9675IM-P incorporates features that safeguard the device against power supply irregularities.

10.6 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 V_{DD} 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.

10.7 EMC Protection

The SC9675IM-P 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.

10.8 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.

10.9 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 peak.

10.10 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 SC9675IM-P circuits are adapted for optimal output switching. Calibration is performed rapidly, without reading the all targets, because the SC9675IM-P applies the internal magnetic baseline.

10.11 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.

10.12 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.

10.13 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.

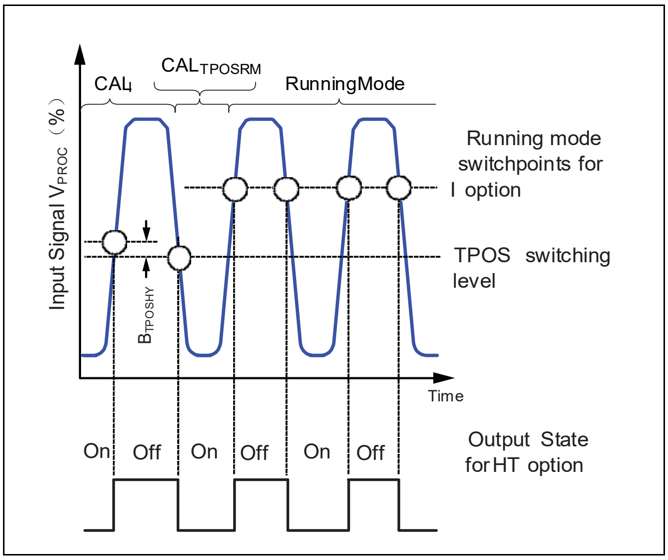


Figure 13. Calibration mode waveforms

10.14 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 SC9675IM-P, 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.

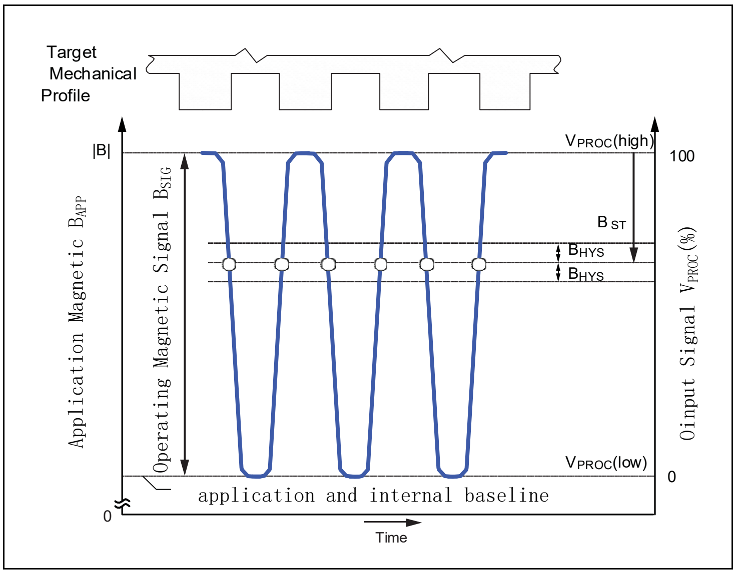


Figure 14. definition of switch points level for running mode

10.15 Running Mode Hysteresis

The SC9675IM-P 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.

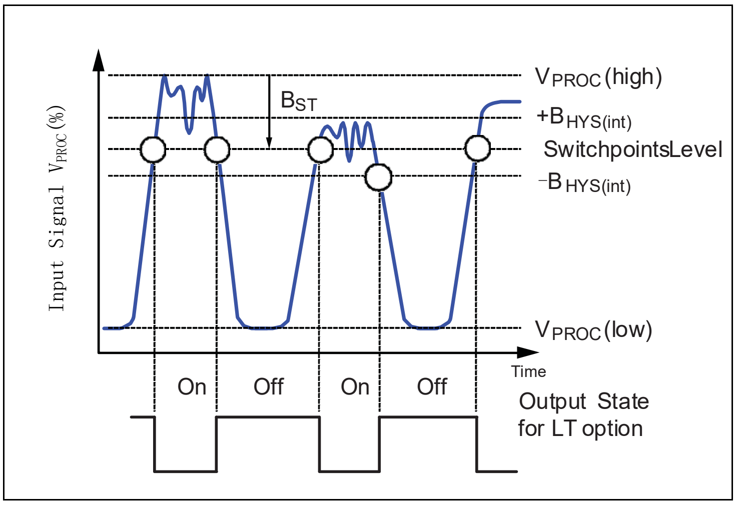


Figure 15. running mode switching on anomalous peak

11. PACKAGE INFORMATION

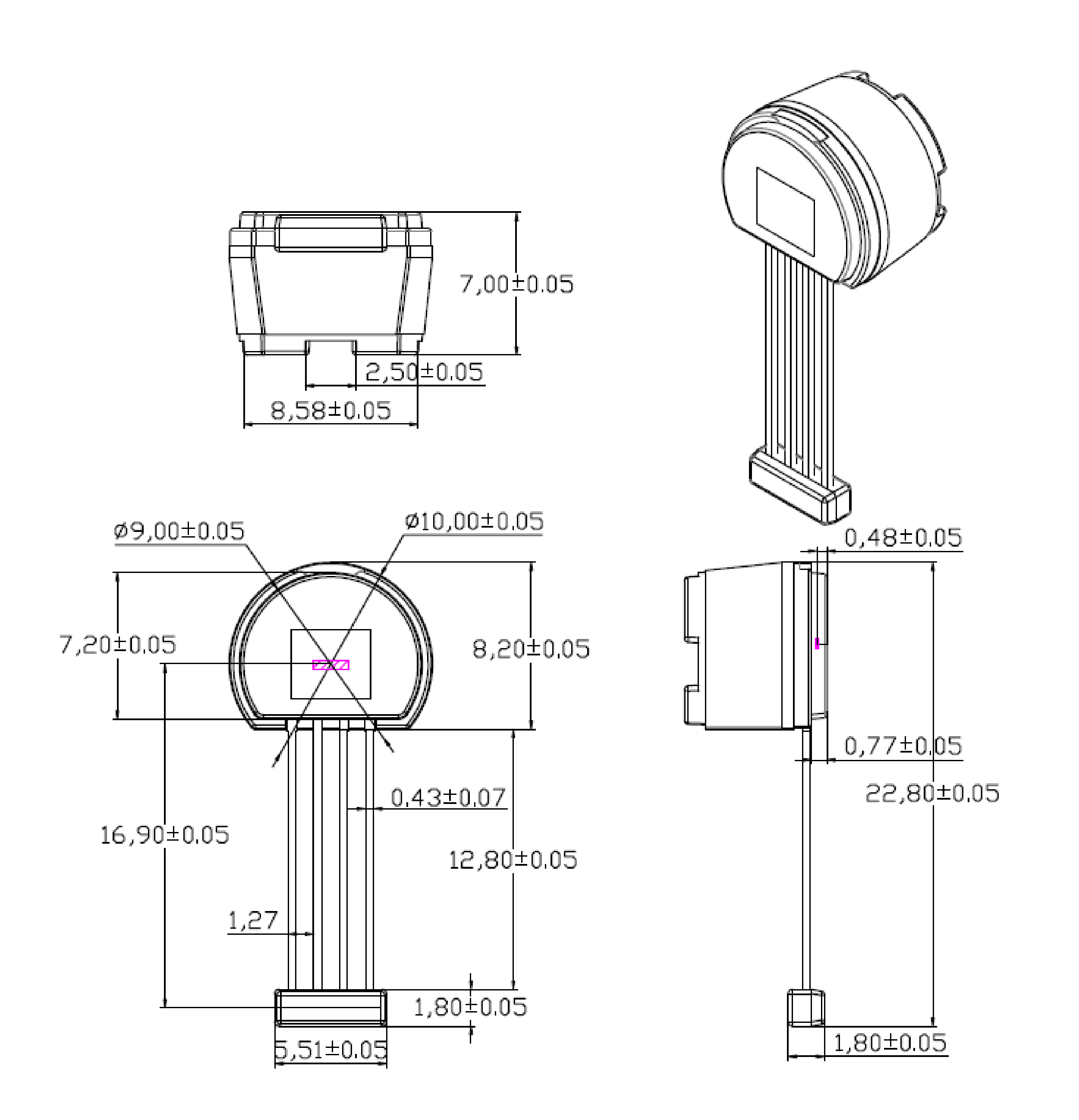


Figure 16. Package Information

12. REVISION INFORMATION

Version	Update Date	Remark
A0	2022-08-30	Initialize Version
A1	2023-02-09	Update 2D Dimension
A2	2023-04-13	Update Purchase Information and some notices
A3	2023-05-22	Update Order information
A4	2023-12-27	Release