Self-Calibrating TPOS Speed Sensor IC
Optimized for Automotive Cam Sensing Applications

FEATURES AND BENEFITS
- 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: 4-pin SIP (suffix SE)

Not to scale

DESCRIPTION

The ATS675 is a next generation member of the Allegro 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 ATS675 also includes a filter that increases the noise immunity and the signal-to-noise ratio of the IC.

The device is provided in a 4-pin SIP package (SE) that is lead (Pb) free with 100% matte tin leadframe plating.
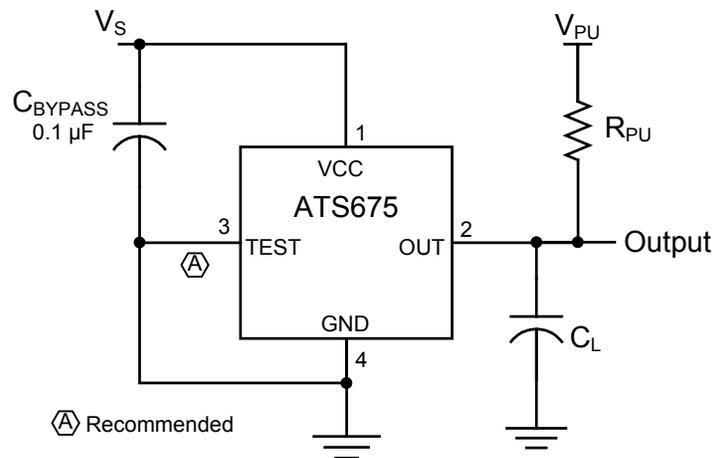
Typical Application

Figure 1. Operational circuit for the ATS675

Selection Guide

| Part Number	Output Protocol	Packing*
ATS675LSETN-LT-T	Output low opposite target tooth	13-in. reel, 450 pieces per reel
ATS675LSETN-HT-T	Output high opposite target tooth	

*Contact Allegro for additional packing options

Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{CC}	Refer to Power Derating curve	28	V
Reverse Supply Voltage	V_{RCC}		−18	V
Reverse Output Voltage	V_{ROUT}		−0.5	V
Reverse Supply Current	I_{RCC}		−50	mA
Output Current	$I_{OUT(sink)}$	Internal current limiting is intended to protect the device from output short circuits, but is not intended for continuous operation.	30	mA
Reverse Output Current	I_{ROUT}		−50	mA
Operating Ambient Temperature	T_A	Range L	−40 to 150	ºC
Maximum Junction Temperature	$T_J(max)$		165	ºC
Storage Temperature	T_{stg}		−65 to 170	ºC

Functional Block Diagram
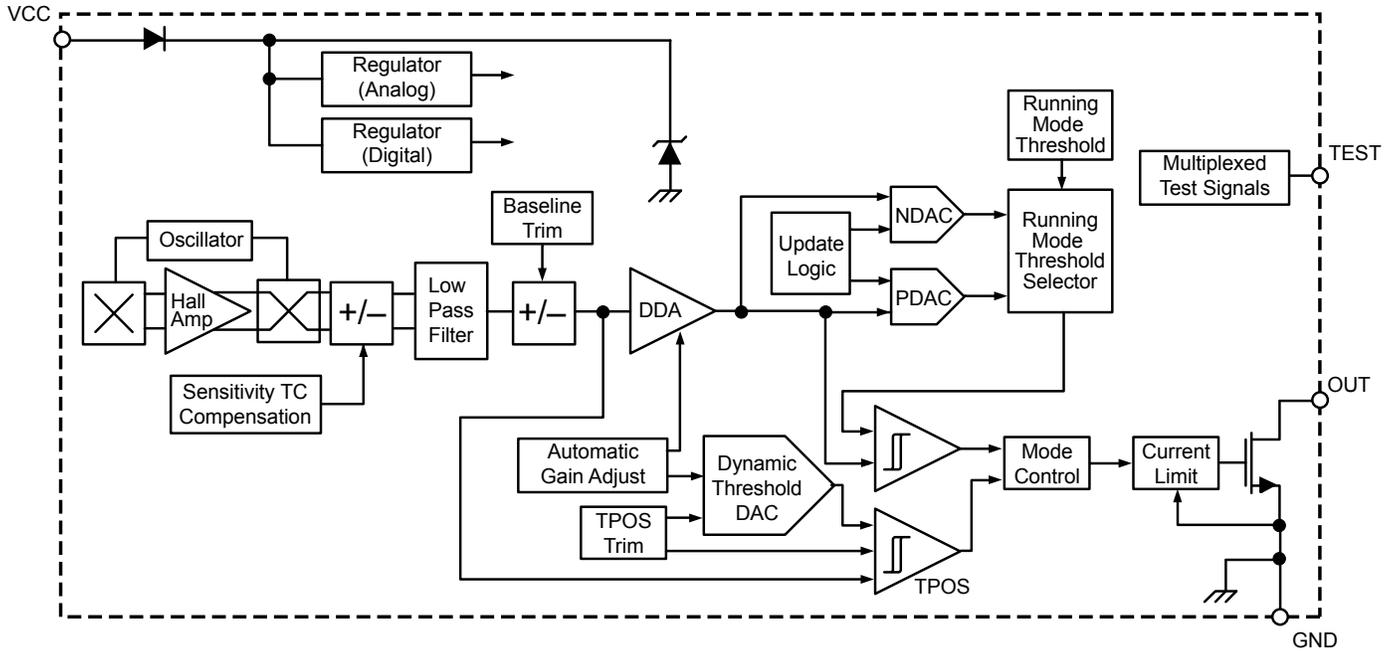
Pin-out Diagram
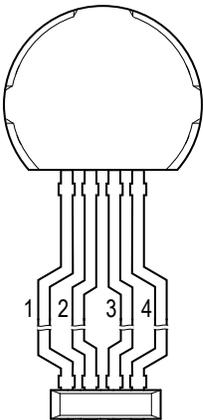
Terminal List

Number	Name	Function
1	VCC	Supply voltage
2	OUT	Open drain output
3	TEST	Test pin; connection to GND recommended
4	GND	Ground

OPERATING CHARACTERISTICS Valid using reference target 8X, T_A,T_J, and V_{CC} within specification, unless otherwise noted

Characteristics	Symbol	Test Conditions		Min.	Typ.[1]	Max.	Unit
Electrical Characteristics							
Supply Voltage[2]	V_{CC}	Operating, $T_J < T_J(max)$		3.3	–	24	V
Undervoltage Lockout	V_{CCUV}	$V_{CC} = 0 \rightarrow 5$ V or $5 \rightarrow 0$ V		–	–	3.3	V
Supply Zener Clamp Voltage	$V_{ZSUPPLY}$	$I_{CC} = I_{CC}(max) + 3$ mA, $T_A = 25°C$		28	33	40	V
Supply Zener Current[3]	$I_{ZSUPPLY}$	$V_{SUPPLY} = 28$ V		–	–	13	mA
Supply Current	I_{CC}			–	6.5	10	mA
Reverse Battery Current[4]	I_{RCC}	$V_{RCC} = -18$ V		–	–	–10	mA
Chopping Frequency	f_c			–	500	–	kHz
TEST Pin Zener Clamp Voltage[5]	V_{ZTEST}			–	6	–	V
Power-On Characteristics							
Power-On Time[6]	t_{PO}	$V_{CC} > V_{CC}(min)$, $f_{SIG} < 200$ Hz		–	–	1	ms
Output Stage Characteristics							
Output Profile Polarity[7]		LT option, measured as V_{OUT}, device electrically connected as in figure 1	Opposite to Tooth (Output State = On)	–	Low	–	V
			Opposite to Valley (Output State = Off)	–	High	–	V
		HT option, measured as V_{OUT}, device electrically connected as in figure 1	Opposite to Tooth (Output State = Off)	–	High	–	V
			Opposite to Valley (Output State = On)	–	Low	–	V
Output On Voltage	$V_{OUT(SAT)}$	$I_{OUT} = 10$ mA, Output State = On		–	–	400	mV
		$I_{OUT} = 15$ mA, Output State = On		–	–	450	mV
Output Zener Voltage	V_{ZOUT}	$T_A = 25°C$, $I_{OUT} = 3$ mA		30	–	–	V
Output Current Limit	I_{OUTLIM}	Output State = On		30	50	80	mA
Output Leakage Current	I_{OUTOFF}	$V_{OUT} = 24$ V, Output State = Off		–	–	10	µA
Output Rise Time	t_r	$R_{PU} = 1$ kΩ, $C_L = 4.7$ nF, $V_{PU} = 5$ V		–	10	–	µs
Output Fall Time[8]	$t_{f(OUT)}$	Measured from 90% to 10%, $T_A = 25°C$, $R_{PU} = 1$ kΩ, $C_L = 4.7$ nF, (see figure 2)	$V_{PU} = 5$ V	0.8	1.1	1.5	µs
			$V_{PU} = 12$ V	–	1.6	–	µs
Output Fall Time Variation with Temperature	$\Delta t_{f(OUT)}$	Maximum variation from $T_A = 25°C$ to $-40°C$ and then to $150°C$		–	±20	–	%
Output Delay Time[9]	$t_{d(OUT)}$	4 kHz sinusoidal input signal, falling electrical edge (see figure 2)		–	18	–	µs
Performance Characteristics							
Operational Air Gap Range[10]	AG_{TPOS}	TPOS functionality guaranteed		0.5	–	3.0	mm
Extended Air Gap Range[11]	AG_{EXTMAX}	Output switching in Running mode, TPOS function not guaranteed		3.0	–	4.5	mm
Analog Signal Bandwidth	BW	Equivalent to –3 dB cutoff frequency		–	20	–	kHz
Tooth Speed	f_{SIG}	Tooth signal frequency, sinusoidal input signal		0	–	8000	Hz

Continued on the next page…

OPERATING CHARACTERISTICS (continued) Valid using reference target 8X, T_A, T_J, and V_{CC} within specification, unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.[1]	Max.	Unit
Calibration[7]						
Initial Calibration[12,13]	CAL_I	Quantity of mechanical falling edges used to determine Running mode switch points level	–	1	3	edge
TPO to Running Mode Adjustment	CAL_{TPORM}	Quantity of mechanical falling edges after CAL_I to transition from TPOS switch points level to Running mode switch points level	–	–	1	tooth
Running Mode Switch Point Characteristics						
Running Mode Switch Point	B_{ST}	% of peak-to-peak, referenced to tooth signal (see figure 4)	–	30	–	%$_{pk–pk}$
Internal Hysteresis	$B_{HYS(int)}$	% of peak-to-peak signal	–	10	–	%
Signal Characteristics						
Maximum Allowable Signal Reduction[14]	B_{reduce}	Reduction in V_{PROC} amplitude from $V_{PROC(high)}$ to lowest peak $V_{PROC(reduce)}$, all specifications within range (see figure 3)	–	–	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 (see figure 3)	–	–	25	%$_{pk-pk}$
Relative Timing Accuracy[12,15]	Err_{RELR}	Rising mechanical edges after initial calibration, gear speed = 1000 rpm, target eccentricity < 0.1 mm	–	0.4	0.8	deg.
	Err_{RELF}	Falling mechanical edges after initial calibration, gear speed = 1000 rpm, target eccentricity < 0.1 mm	–	0.5	1.0	deg.

[1]Typical values are at T_A = 25°C and V_{CC} = 12 V. Performance may vary for individual units, within the specified maximum and minimum limits.
[2]Maximum voltage must be adjusted for power dissipation and junction temperature; see Power Derating section.
[3]Maximum current limit is equal to I_{CC}(max) + 3 mA.
[4]Negative current is defined as conventional current coming out of (sourced from) the specified device terminal.
[5]Sustained voltages beyond the clamp voltage may cause permanent damage to the IC.
[6]Power-On Time is the duration from when V_{CC} rises above V_{CC}(min) until a valid output state is realized.
[7]For additional information see the Functional Description section.
[8]Characterization data shows 12 V fall time to be 1.5 times longer than 5 V fall time. See figure 2.
[9]Output Delay Time is the duration from when a crossing of the magnetic signal switching level, B_{ST}, occurs to when the electrical output signal, V_{OUT}, reaches 90% of V_{OUT}(high).
[10]The Operational Air Gap Range is the range of installation air gaps within which the TPOS (True Power-On State) function is guaranteed to correctly detect a tooth when powered-on opposite a tooth and correctly detecting a valley when powered-on opposite a valley, using reference target 8X.
[11]The Extended Air Gap Range is a range of installation air gaps, larger than AG_{TPOS}, within which the device will accurately detect target features in Running mode, but TPOS functionality is NOT guaranteed, possibly resulting in undetected target features during Initial Calibration. Relative Timing Accuracy (Err_{REL}) not guaranteed in Extended Air Gap Range.
[12]The term *mechanical edge* refers to a target feature, such as the side of a gear tooth, passing opposite the device. A rising edge is a transition from a valley to a tooth, and a falling edge is a transition from a tooth to a valley. See figure 6.
[13]Signal frequency for CAL_I is f_{SIG} < 200 Hz.
[14]Running mode; 4X target used. The Processed Internal Signal, V_{PROC}, is the internal signal generated by the Hall detection circuitry and normalized by Automatic Gain Control.
[15]Relative Timing Accuracy refers to the difference in accuracy, relative to a 0.5 mm air gap, through the entire Operational Air Gap Range, after initial calibration; gear speed = 1000 rpm, target eccentricity < 0.1 mm. See figure 7.

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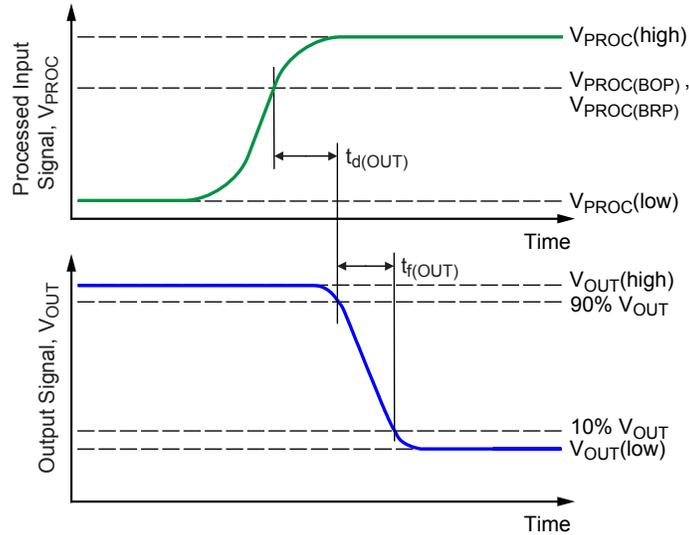microsystems

Definitions of Operating Characteristics

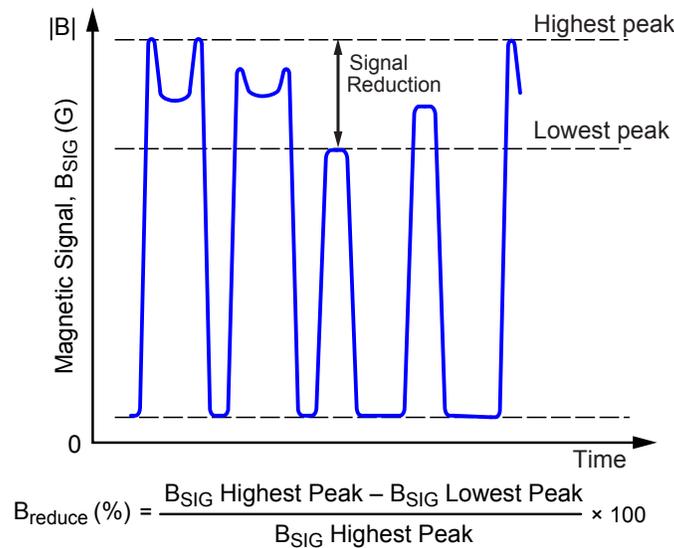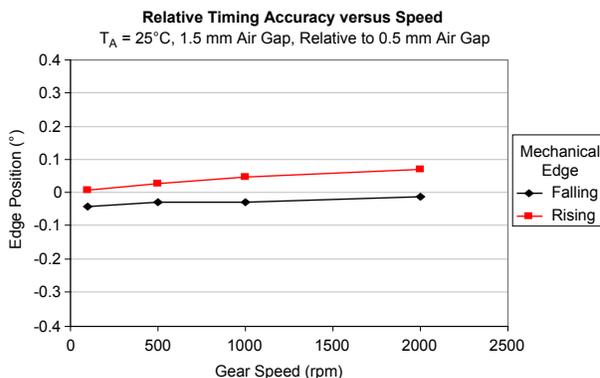Figure 2. Definition of Output Delay Time, $t_{d(OUT)}$, and Output Fall Time, $t_{f(OUT)}$.

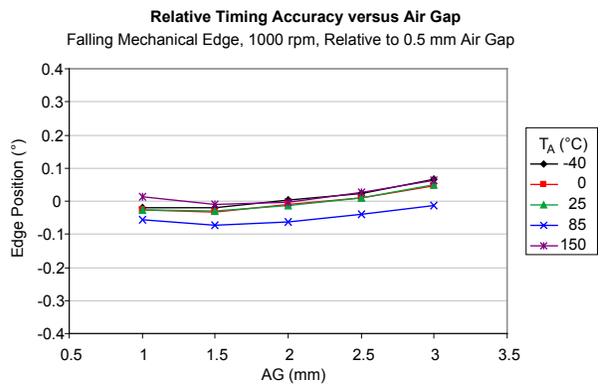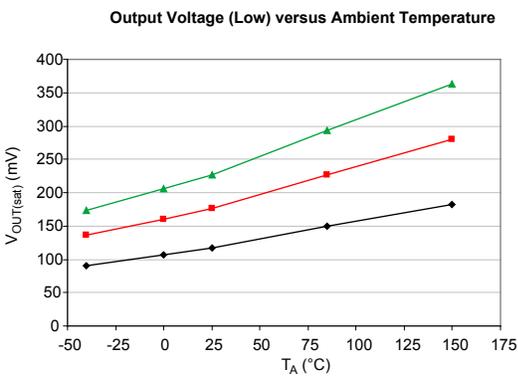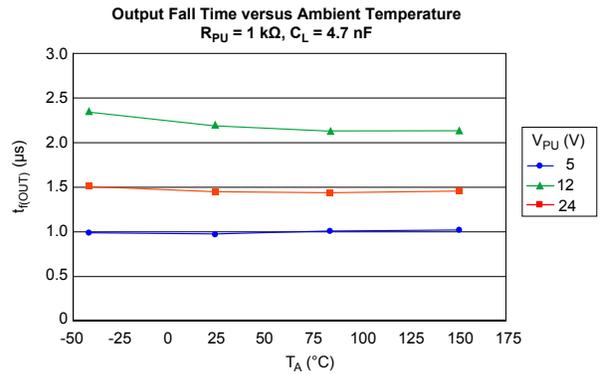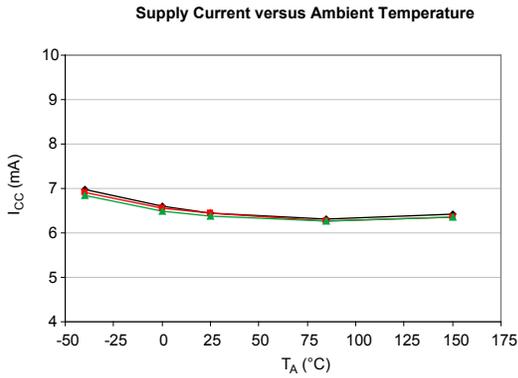$$B_{reduce} (\%) = \frac{B_{SIG} \text{ Highest Peak} - B_{SIG} \text{ Lowest Peak}}{B_{SIG} \text{ Highest Peak}} \times 100$$

Figure 3. Definition of Maximum Allowable Signal Reduction, B_{reduce}, as a percentage of the overall magnetic signal.

Characteristic Performance

Supply Current versus Ambient Temperature

Output Fall Time versus Ambient Temperature
$R_{PU} = 1\ k\Omega,\ C_L = 4.7\ nF$

Output Voltage (Low) versus Ambient Temperature

Relative Timing Accuracy versus Air Gap
Falling Mechanical Edge, 1000 rpm, Relative to 0.5 mm Air Gap

Relative Timing Accuracy versus Air Gap
Rising Mechanical Edge, 1000 rpm, Relative to 0.5 mm Air Gap

Relative Timing Accuracy versus Speed
$T_A = 25°C$, 1.5 mm Air Gap, Relative to 0.5 mm Air Gap

Thermal Characteristics may require derating at maximum conditions, see application information

Characteristic	Symbol	Test Conditions*	Value	Units
Package Thermal Resistance	$R_{\theta JA}$	1-layer PCB with copper limited to solder pads	101	ºC/W
		2-layer PCB with copper limited to solder pads and 3.57 in.^{2} of copper area each side	77	ºC/W

*Additional thermal information available on the Allegro website

Power Derating Curve
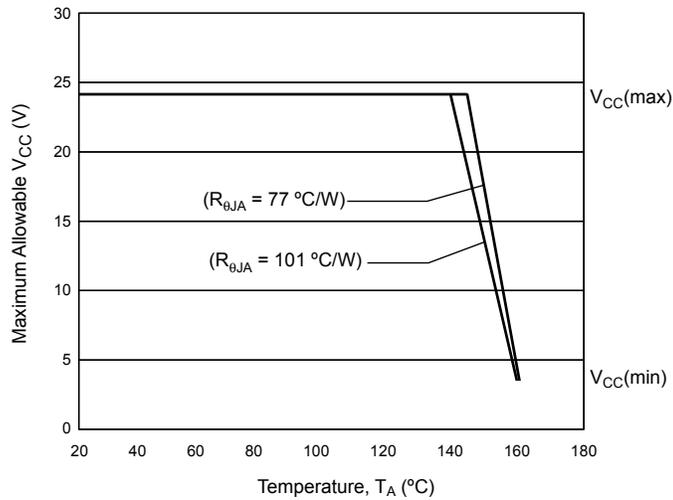
Power Dissipation versus Ambient Temperature
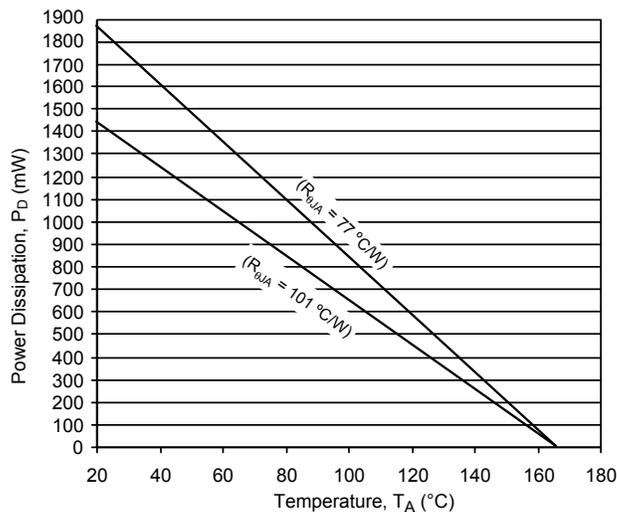
Reference Target 8x

| Characteristic	Symbol	Test Conditions	Typ.	Unit	Symbol Key
Outside Diameter	D_o	Outside diameter of target	120	mm	
Face Width	F	Breadth of tooth, with respect to branded face	6	mm	
Circular Tooth Length	t	Length of tooth, with respect to branded face; measured at D_o	23.6	mm	
Circular Valley Length	t_v	Length of valley, with respect to branded face; measured at D_o	23.6	mm	
Tooth Whole Depth	h_t		5	mm	
Material		CRS 1018	–	–	
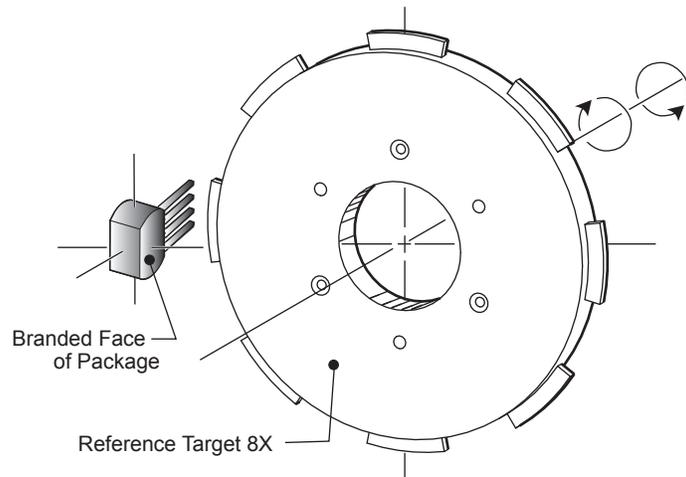
Figure 4. Configuration with Reference Target

Functional Description

Internal Electronics

This device contains a self-calibrating Hall effect IC that includes a Hall element, a temperature compensated amplifier, and offset cancellation circuitry. The IC also contains a voltage regulator that provides supply noise rejection over the operating voltage range. The Hall transducers and the electronics are integrated on the same silicon substrate by a proprietary BiCMOS process. Changes in temperature do not greatly affect this device, due to the stable amplifier design and the offset rejection circuitry. The Hall IC supports a chopper stabilized Hall element that measures the intensity of magnetic gradients and provides an electrical signal that represents the target features.

Hall Technology

The ATS675 contains a single-chip Hall effect sensor IC, a 4-pin leadframe, a specially designed rare-earth pellet, and a ferrous pole piece (a precisely mounted magnetic field concentrator). The Hall IC supports a chopper stabilized Hall element that measures the magnetic gradient created by the passing of a ferromagnetic object. This is illustrated in figure 5. The difference in the magnetic gradients created by teeth and valleys allows the devices to generate a digital output signal that is representative of the target features.

Output Profile Polarity (LT/HT Option)

Device output, V_{OUT}, is a digital representation of the mechanical profile of the target, as illustrated in figure 6. The customer can choose the relative polarity of the output waveform. This assigns the polarity opposite tooth features (the inverse polarity
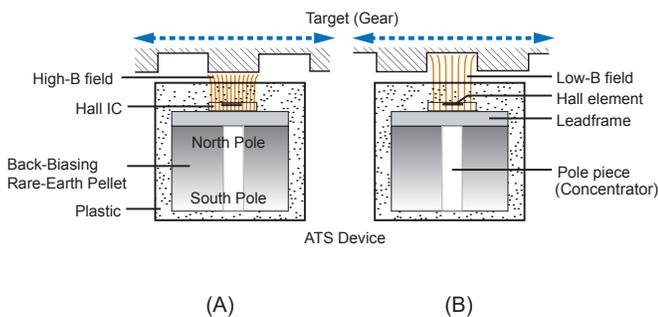
will be output opposite valley features). The LT option sets V_{OUT} low when a tooth is opposite the device, and the HT option sets V_{OUT} high when a target tooth is opposite the device. This polarity assignment applies throughout device operation. This ease of use reduces design time and incremental assembly costs for most applications.

Automatic Gain Control (AGC)

The Automatic Gain Control (AGC) feature ensures that the ATS675 initial switching thresholds are isolated from the effects of changes in the effective air gap (the total distance between the Hall element and the nearest feature of the target). AGC is implemented by unique patented self-calibrating circuitry, and normalizes the sensed magnetic gradient so the internal processed signal falls within the optimum processing range.
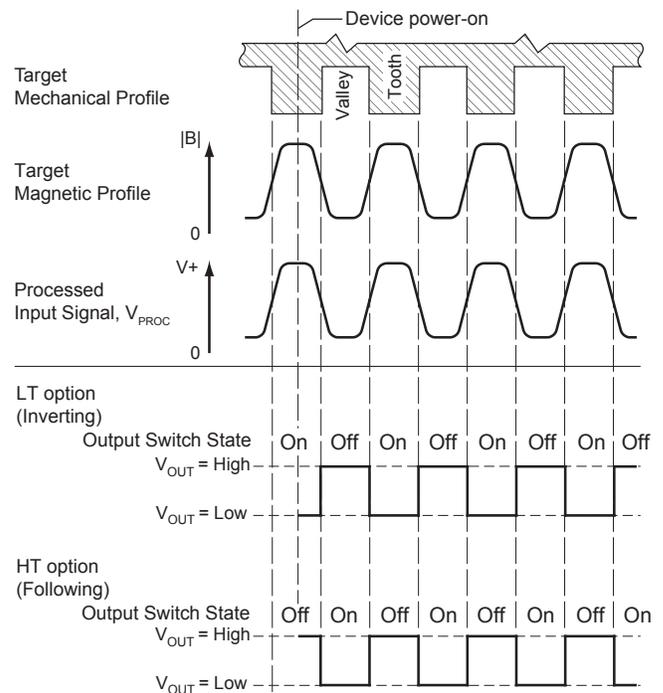
Figure 6. Output Profile Polarity options allow selection of V_{OUT} either inverted (LT option), or in-phase with the target profile (HT option), when electrically connected as in figure 1.

Figure 5. Application cross-section: (A) target tooth opposite device, and (B) target valley opposite device

AGC is activated during the Initial Calibration stage at each power-on. The device measures the peak-to-peak application magnetic gradient, and then the gain of the sensor IC is adjusted to normalize the internal processed signal, V_{PROC}, to accommodate any input signal amplitude within the specified Operating Magnetic Signal Range, B_{SIG}. AGC is referenced to the internal magnetic baseline. At the end of the Initial Calibration stage, the AGC results are latched and they are not readjusted while the device remains powered-on.

Power Supply Protection
The ATS675 provides features for protecting the device against power supply aberrations:

Undervoltage Lockout. When the supply voltage falls below the undervoltage lockout level, V_{CCUV}, the device Output State changes to Off. The device remains in that state until the voltage level is restored to the V_{CC} 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 from propagating to the output of the sensor IC.

EMC Protection. The ATS675 contains an on-chip regulator that operates throughout a wide range of supply voltage levels. For applications using an unregulated power supply, protection against transients may be added externally. For applications using a regulated supply line, EMI and RFI protection may still be required. Contact Allegro for information on EMC specification compliance.
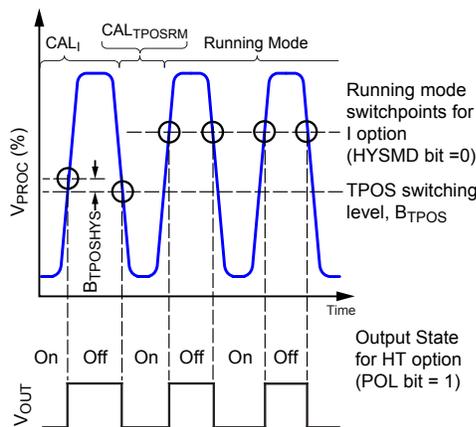

Figure 7. Calibration mode waveforms.

Operating Modes
The device provides three operating modes: TPOS, Calibration, and Running. TPOS and Calibration initialize simultaneously at power-on. TPOS generates immediate device output, controlling device switching while the calibration functions are performed. After calibration is complete, normal operation in Running mode begins.

TPOS (True Power-On State) Operation
After the power-on time, t_{PO}, the device immediately generates an output voltage corresponding to the target feature opposite the device. It does so by comparing the existing level of the application magnetic gradient, B_{APP}, to the TPOS switching level, an internal threshold used to distinguish a tooth from a valley during TPOS operation (from power-on until the end of the Initial Calibration stage). If B_{APP} is less than the threshold, that target feature is evaluated as a valley, and if B_{APP} is greater, the feature is evaluated as a tooth.

Calibration Mode Operation
At power-on (simultaneous with TPOS operation) Calibration mode begins. Calibration mode is performed in two stages: the Initial Calibration stage, followed immediately by the TPOS to Running Mode Transition stage (see figure 7). After the second calibration stage, Running mode begins immediately.

In Calibration mode, the operating range of the application magnetic gradient, B_{APP}, is detected and evaluated, and then the ATS675 electronics are adapted for optimal output switching. Calibration is performed quickly, without reading the entire target, because the ATS675 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 the beginning of this stage, TPOS operation terminates, and throughout this stage the device automatically adjusts the output switching levels from the original preset switching level to the Running mode switch points. This transition takes place over one tooth, immediately swapping from TPOS to Running mode switch points.

Running Mode Operation

Running mode begins immediately at the end of Calibration mode. During Running mode, switch points are established dynamically, based on the sensed application magnetic gradient, B_{APP}. To determine switch points, B_{APP} is normalized by the AGC feature, and processed to generate the internal processed signal, V_{PROC}. Two peak-detecting DACs track the V_{PROC} waveform, and the output switch points are established as percentages of the values held by the two DACs. Because the switch points are established dynamically as a percentage of the peak-to-peak signal, the effects of an application baseline shift are minimized.

Running Mode Switch Points

The values used to define Running mode switch points are cal-culated as a percentage of the peak-to-peak V_{PROC}. As shown in figure 11, this percentage is subtracted from the maximum V_{PROC} value, $V_{PROC}(high)$, a value corresponding to a minimum air gap, that is, at the most prominent target tooth. On the ATS675LSE, the switch points are referenced to approximately 30% of the peak-to-peak magnetic signal. This level closely corresponds to the mechanical target edges, resulting in optimal timing accuracy versus air gap.

Running Mode Hysteresis

The ATS675LSE uses an internal 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 12.
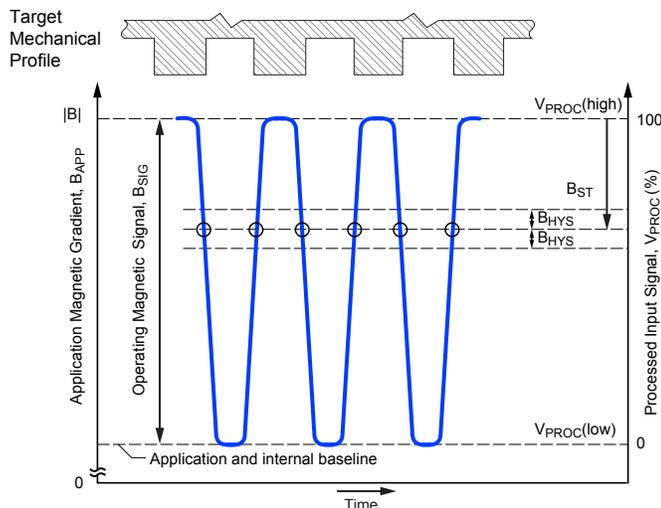

Figure 11. Switch Points Level for Running Mode definition
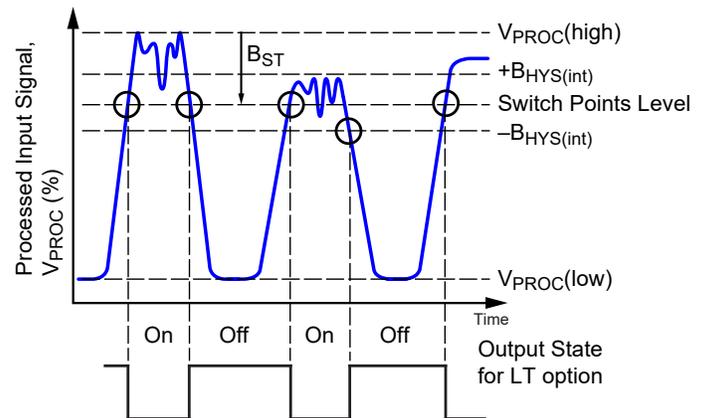(switch points indicated by circles).

Figure 12. Running mode switching on anomalous peak
(switch points indicated by circles).

Power Derating

The device must be operated below the maximum junction temperature of the device, $T_{J(max)}$. Under certain combinations of peak conditions, reliable operation may require derating supplied power or improving the heat dissipation properties of the application. This section presents a procedure for correlating factors affecting operating T_J. (Thermal data is also available on the Allegro MicroSystems website.)

The Package Thermal Resistance, $R_{\theta JA}$, is a figure of merit summarizing the ability of the application and the device to dissipate heat from the junction (die), through all paths to the ambient air. Its primary component is the Effective Thermal Conductivity, K, of the printed circuit board, including adjacent devices and traces. Radiation from the die through the device case, $R_{\theta JC}$, is relatively small component of $R_{\theta JA}$. Ambient air temperature, T_A, and air motion are significant external factors, damped by overmolding.

The effect of varying power levels (Power Dissipation, P_D), can be estimated. The following formulas represent the fundamental relationships used to estimate T_J, at P_D.

$$P_D = V_{IN} \times I_{IN} \tag{1}$$

$$\Delta T = P_D \times R_{\theta JA} \tag{2}$$

$$T_J = T_A + \Delta T \tag{3}$$

For example, given common conditions such as: $T_A = 25°C$, $V_{CC} = 12$ V, $I_{CC} = 7$ mA, and $R_{\theta JA} = 77$ °C/W, then:

$$P_D = V_{CC} \times I_{CC} = 12 \text{ V} \times 7 \text{ mA} = 84 \text{ mW}$$

$$\Delta T = P_D \times R_{\theta JA} = 84 \text{ mW} \times 77 \text{ °C/W} = 6.5°C$$

$$T_J = T_A + \Delta T = 25°C + 6.5°C = 31.5°C$$

A worst-case estimate, $P_{D(max)}$, represents the maximum allowable power level, without exceeding $T_{J(max)}$, at a selected $R_{\theta JA}$ and T_A.

Example: Reliability for V_{CC} at $T_A = 150°C$.

Observe the worst-case ratings for the device, specifically: $R_{\theta JA} = 101$ °C/W, $T_J(max) = 165°C$, $V_{CC}(max) = 24$ V, and $I_{CC}(max) = 10$ mA.

Calculate the maximum allowable power level, $P_D(max)$. First, invert equation 3:

$$\Delta T(max) = T_J(max) - T_A = 165°C - 150°C = 15°C$$

This provides the allowable increase to T_J resulting from internal power dissipation.

Then, invert equation 2:

$$P_D(max) = \Delta T(max) \div R_{\theta JA} = 15°C \div 101 \text{ °C/W} = 148.5 \text{ mW}$$

Finally, invert equation 1 with respect to voltage:

$$V_{CC}(est) = P_D(max) \div I_{CC}(max) = 148.5 \text{ mW} \div 10 \text{ mA} = 14.9 \text{ V}$$

The result indicates that, at T_A, the application and device can dissipate adequate amounts of heat at voltages $\leq V_{CC}(est)$.

Compare $V_{CC}(est)$ to $V_{CC}(max)$. If $V_{CC}(est) \leq V_{CC}(max)$, then reliable operation between $V_{CC}(est)$ and $V_{CC}(max)$ requires enhanced $R_{\theta JA}$. If $V_{CC}(est) \geq V_{CC}(max)$, then operation between $V_{CC}(est)$ and $V_{CC}(max)$ is reliable under these conditions.
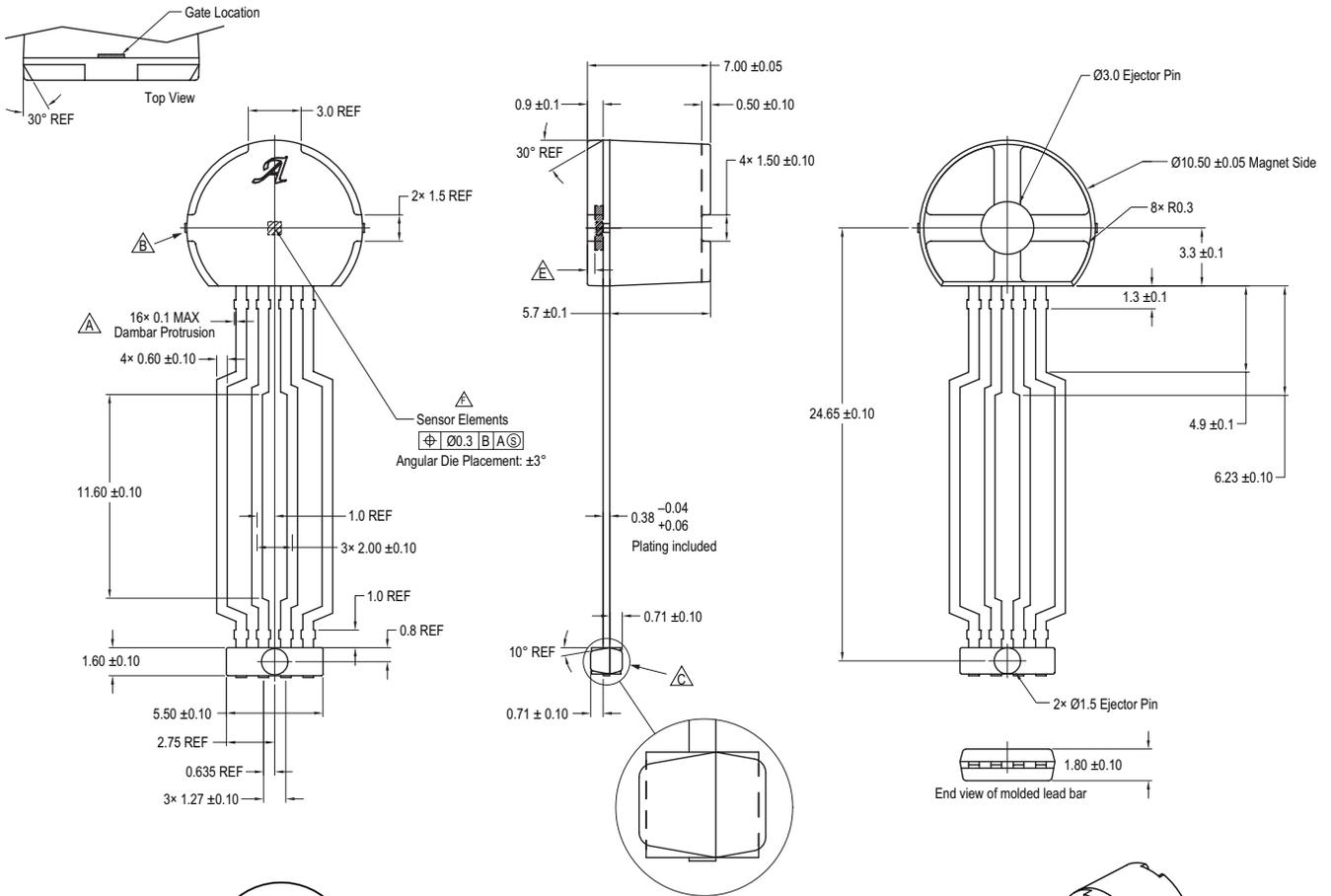
Package SE 4-Pin SIP

For Reference Only – Not for Tooling Use
(Reference DWG-0000391)
Dimensions in millimeters. NOT TO SCALE.
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown

Standard Branding Reference View
Lines 1, 2, 3 = 7 characters.
Logo A molded in
Line 1: 7 digit alpha numeric Lot Number
Line 2: Last 3 digit of Part Number.
Additional suffixes may be
added to Part number as required.
Line 3: 4 digit Date Code
Center align

A Dambar removal protrusion (16×)
B Metallic protrusion, electrically connected to pin 4 and substrate (both sides)
C Molded Lead Bar for alignment during shipment
D Branding scale and appearance at supplier discretion
E Active Area Depth 0.43 ±0.025 mm
F Hall element (not to scale)
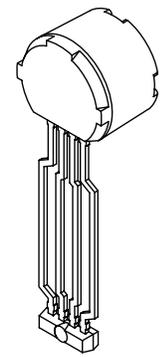
Revision History

Number	Date	Description
3	May 5, 2020	Minor editorial updates
4	May 4, 2021	Updated Package Outline Drawing (page 14)

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