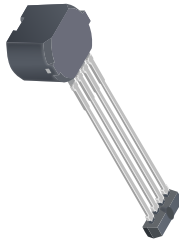


## Three-Wire, Differential, Vibration Resistant Sensor IC with Speed and Direction Output

### FEATURES AND BENEFITS

- Three-wire, pulse width output protocol
- Digital output representing target profile
- Speed and direction information of target
- Vibration tolerance
  - Small signal lockout for small amplitude vibration
  - Proprietary vibration detection algorithms for large amplitude vibration
- Air gap independent switch points
- Large operating air gap capability
- Undervoltage lockout
- True zero-speed operation
- Wide operating voltage range
- Single chip sensing IC for high reliability
- Robust test coverage capability with Scan Path and IDDQ measurement

### Package: 4-pin SIP (suffix SG)



Not to scale

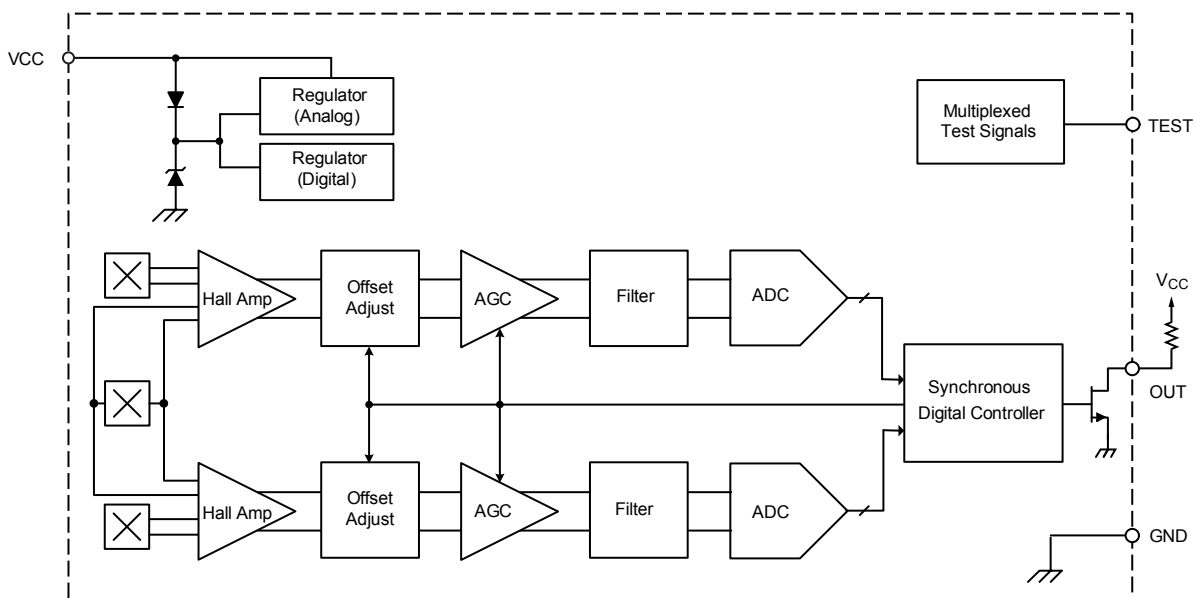
### DESCRIPTION

The ATS693LSG is an optimized Hall-effect integrated circuit (IC) and rare earth pellet combination that provides a user-friendly solution for direction detection and true zero-speed, digital gear tooth sensing. The small package can be easily assembled and used in conjunction with a wide variety of gear tooth sensing applications.

The IC employs patented algorithms for the special operational requirements of automotive transmission applications. The speed and direction of the target are communicated through a variable pulse width output protocol. The ATS693 is particularly adept at handling vibration without sacrificing maximum air gap capability or creating any erroneous direction information. Even higher angular vibration caused by engine cranking is completely rejected by the device. The advanced vibration detection algorithm systematically calibrates the sensor IC on the initial teeth of true target rotation and not on vibration, always guaranteeing an accurate signal in running mode.

Advanced signal processing and innovative algorithms make the ATS693 an ideal solution for a wide range of speed and direction sensing needs.

This device is available in a lead (Pb) free 4-pin SIP package with a 100% matte tin plated leadframe.



Functional Block Diagram

**SPECIFICATIONS**

**Selection Guide**

<b>Part Number</b>
ATS693LSGTN-RSNYBH-T

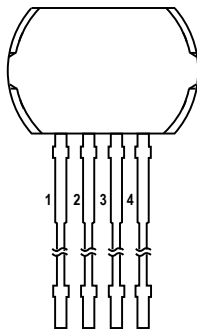
\*Contact Allegro™ for additional packing options.



**Absolute Maximum Ratings**

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	$V_{CC}$	Refer to Power Derating section	28	V
Reverse Supply Voltage	$V_{RCC}$		-18	V
Reverse Output Voltage	$V_{ROUT}$		-0.5	V
Output Sink Current	$I_{OUT}$		25	mA
Operating Ambient Temperature	$T_A$	L temperature range	-40 to 150	°C
Maximum Junction Temperature	$T_J(max)$		165	°C
Storage Temperature	$T_{stg}$		-65 to 170	°C

**Pin-out Diagram and Terminal List Table**



**Package SG, 4-Pin SIP Pin-out Diagram**

**Terminal List Table**

Number	Name	Function
1	VCC	Supply voltage
2	OUT	Open collector output
3	TEST	Test pin: float *
4	GND	Ground

\*Connection of TEST to VCC and/or GND may cause undesired additional current consumption in the IC.

**OPERATING CHARACTERISTICS:** valid throughout full operating and temperature ranges; using Reference Target 60-0; unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ. <sup>1</sup>	Max.	Unit
<b>General Electrical Characteristics</b>						
Supply Voltage <sup>2</sup>	V <sub>CC</sub>	Operating, T <sub>J</sub> < T <sub>J</sub> (max)	4.0	–	24	V
Under Voltage Lockout	V <sub>CC(UV)</sub>	V <sub>CC</sub> 0 → 5 V or 5 → 0 V	–	3.6	3.95	V
Reverse Supply Current <sup>3</sup>	I <sub>RCC</sub>	V <sub>CC</sub> = V <sub>RCC</sub> (max)	–	–	–10	mA
Supply Zener Clamp Voltage	V <sub>Z(SUPPLY)</sub>	I <sub>CC</sub> = I <sub>CC</sub> (max) + 3 mA, T <sub>A</sub> = 25°C	28	–	–	V
Supply Current	I <sub>CC</sub>		5.0	–	12	mA
Test Pin Zener Clamp Voltage <sup>4</sup>	V <sub>Z(TEST)</sub>		–	6	–	V
Power-On State	POS	Output, when connected as in figure 9	–	High	–	–
<b>Output Stage</b>						
Low Output Voltage	V <sub>OUT(sat)</sub>	I <sub>SINK</sub> = 10 mA, Output = On	–	200	500	mV
Output Zener Clamp Voltage	V <sub>ZOUT</sub>		26.5	–	–	V
Output Current Limit	I <sub>lim</sub>	V <sub>OUT</sub> = 12 V, T <sub>J</sub> < T <sub>J</sub> (max)	25	55	70	mA
Output Leakage Current	I <sub>OFF</sub>	Output = Off, V <sub>OUT</sub> = 24 V	–	–	10	μA
Output Rise Time	t <sub>r</sub>	R <sub>PULLUP</sub> = 825 Ω, C <sub>LOAD</sub> = 4.7 nF 10% to 90%, connected as in Figure 9	–	10	–	μs
Output Fall Time	t <sub>f</sub>	R <sub>PULLUP</sub> = 825 Ω, C <sub>LOAD</sub> = 4.7 pF 90% to 10%, connected as in Figure 9	–	0.9	–	μs
<b>Output Pulse Characteristics<sup>5</sup></b>						
Pulse Width (Forward Rotation)	t <sub>w(FWD)</sub>	R <sub>L</sub> = 500 Ω, C <sub>L</sub> = 10 pF	38	45	52	μs
Pulse Width (Reverse Rotation)	t <sub>w(REV)</sub>	R <sub>L</sub> = 500 Ω, C <sub>L</sub> = 10 pF	76	90	104	μs
Pulse Width (Non-Direction)	t <sub>w(ND)</sub>	R <sub>L</sub> = 500 Ω, C <sub>L</sub> = 10 pF	306	360	414	μs
<b>General Operating Characteristics</b>						
Operate Point	B <sub>OP</sub>	% of peak-to-peak V <sub>PROC</sub>	–	69	–	%
Release Point	B <sub>RP</sub>	% of peak-to-peak V <sub>PROC</sub>	–	31	–	%
Operating Frequency (Forward Rotation) <sup>6</sup>	f <sub>FWD</sub>		0	–	11.1	kHz
Operating Frequency (Reverse Rotation) <sup>6</sup>	f <sub>REV</sub>		0	–	7	kHz
Operating Frequency (Non-Direction Pulses) <sup>6</sup>	f <sub>ND</sub>		0	–	2.2	kHz
<b>DAC Characteristics</b>						
Allowable User-Induced Offset	B <sub>OFFSET</sub>	Magnitude valid for both differential magnetic channels	–60	–	60	G

Continued on the next page...

**OPERATING CHARACTERISTICS (continued): valid throughout full operating and temperature ranges; using Reference Target 60-0; unless otherwise specified**

Characteristic	Symbol	Test Conditions	Min.	Typ. <sup>1</sup>	Max.	Unit	
<b>Performance Characteristics</b>							
Air Gap Range	AG	Using Allegro Reference Target 60-0	0.5	–	2.75	mm	
Vibration Immunity (Startup)	err <sub>VIB(SU)</sub>		T <sub>TARGET</sub>	–	–	deg.	
Vibration Immunity (Running Mode)	err <sub>VIB</sub>		T <sub>TARGET</sub>	–	–	deg.	
<b>Input Magnetic Characteristics</b>							
Allowable Differential Sequential Signal Variation <sup>7</sup>	B <sub>SEQ(n+1)</sub> / B <sub>SEQ(n)</sub>	Signal cycle-to-cycle variation (see figure 2)	0.6	–	–	–	
<b>Calibration</b>							
First Direction Output Pulse <sup>8</sup>		Amount of target rotation (constant direction) following power-on until first electrical output pulse of either t <sub>w(FWD)</sub> or t <sub>w(REV)</sub> , see figure 1	AG ≥ 0.5 mm AG < 2.25 mm	–	2 × T <sub>TARGET</sub>	<3 × T <sub>TARGET</sub>	deg.
			AG ≥ 2.25 mm AG ≤ 2.75 mm	–	2.5 × T <sub>TARGET</sub>	<4 × T <sub>TARGET</sub>	deg.
First Direction Pulse Output Following Direction Change	N <sub>CD</sub>		1 × T <sub>TARGET</sub>	2 × T <sub>TARGET</sub>	<3 × T <sub>TARGET</sub>	deg.	
First Direction Pulse Output Following Running Mode Vibration			1 × T <sub>TARGET</sub>	2 × T <sub>TARGET</sub>	<3 × T <sub>TARGET</sub>	deg.	

<sup>1</sup>Typical values are at T<sub>A</sub> = 25°C and V<sub>CC</sub> = 12 V. Performance may vary for individual units, within the specified maximum and minimum limits.

<sup>2</sup>Maximum voltage must be adjusted for power dissipation and junction temperature; see Power Derating section.

<sup>3</sup>Negative current is defined as conventional current coming out of (sourced from) the specified device terminal.

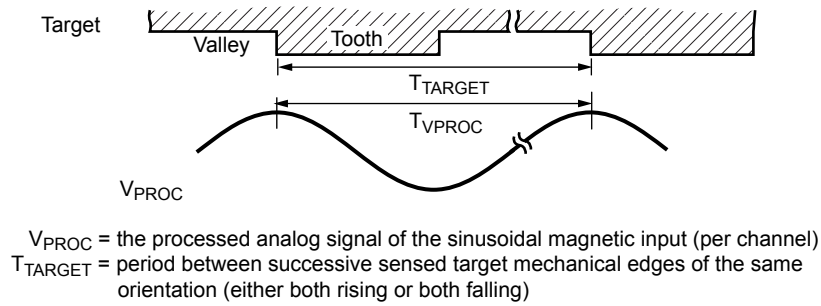
<sup>4</sup>Sustained voltages beyond the clamp voltage may cause permanent damage to the IC.

<sup>5</sup>Pulse duration measured at a threshold of V<sub>PULLUP</sub> / 2.

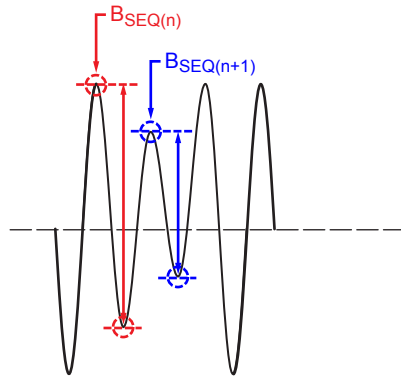
<sup>6</sup>Maximums of both Operating Frequency (Reverse Rotation) and Operating Frequency (Non-Direction Pulses) are determined by satisfactory separation of output pulses: V<sub>OUT(HIGH)</sub> of t<sub>w(FWD)</sub>(min). If the customer can resolve shorter high-state durations, maximum f<sub>FWD</sub>, f<sub>REV</sub>, and f<sub>ND</sub> may be increased.

<sup>7</sup>If the minimum signal phase separation is not maintained during or after a signal variation event, output may be blanked or non-direction pulses may occur. A signal variation event during power-on may increase the quantity of edges required to get correct direction pulses.

<sup>8</sup>Power-on frequency ≤ 200 Hz. Higher power-on frequencies may require more input magnetic cycles until directional output pulses are achieved.



**Figure 1: Definition of  $T_{TARGET}$**

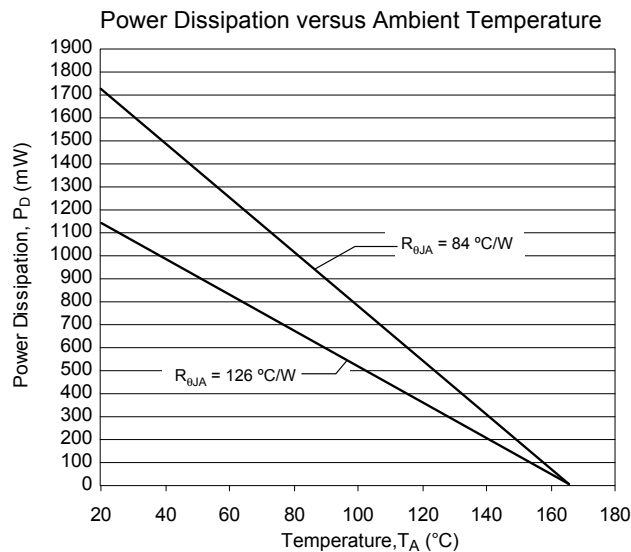
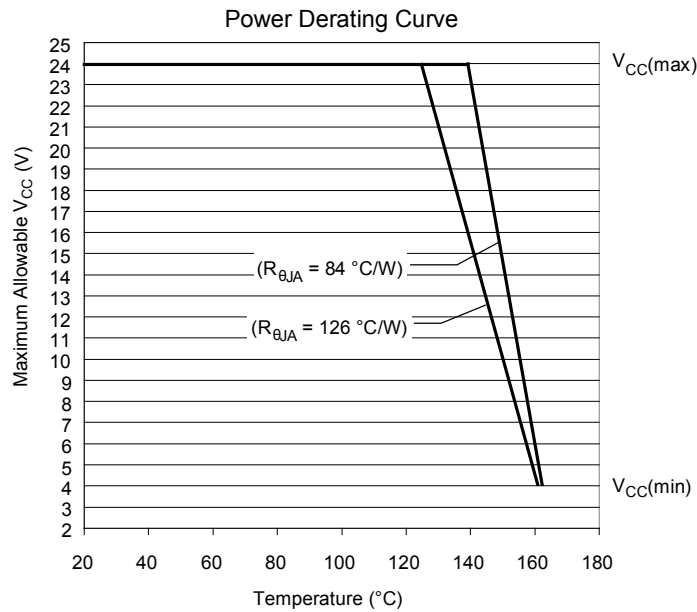


**Figure 2: Definition of Differential Signal Variation**

Thermal Characteristics may require derating at maximum conditions, see Power Derating section

Characteristic	Symbol	Test Conditions*	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	Single layer PCB, with copper limited to solder pads	126	$^{\circ}\text{C}/\text{W}$
		Single layer PCB, with copper limited to solder pads and 3.57 in. <sup>2</sup> (23.03 cm <sup>2</sup> ) copper area each side	84	$^{\circ}\text{C}/\text{W}$

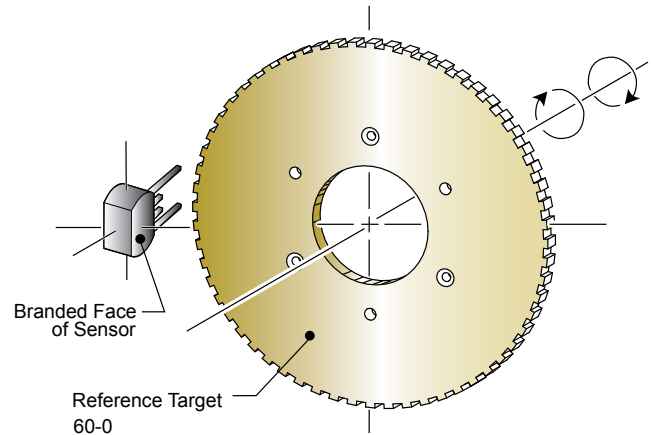
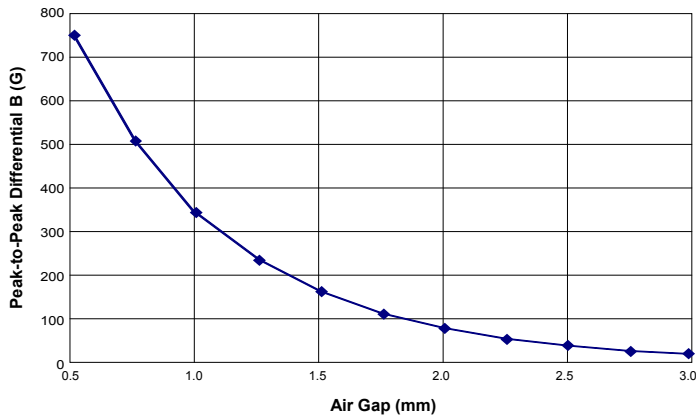
\*Additional thermal information available on the Allegro website



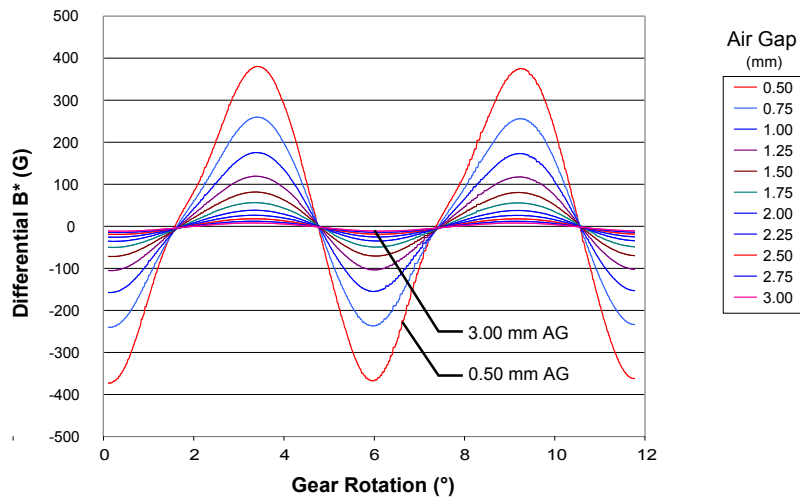
**Reference Target 60-0 (60 Tooth Target)**

Characteristics	Symbol	Test Conditions	Typ.	Units	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	
Angular Tooth Thickness	t	Length of tooth, with respect to branded face	3	deg.	
Angular Valley Thickness	$t_v$	Length of valley, with respect to branded face	3	deg.	
Tooth Whole Depth	$h_t$		3	mm	
Material		Low Carbon Steel	-	-	

**Reference Gear Magnetic Gradient Amplitude versus Air Gap**  
Reference Target 60-0

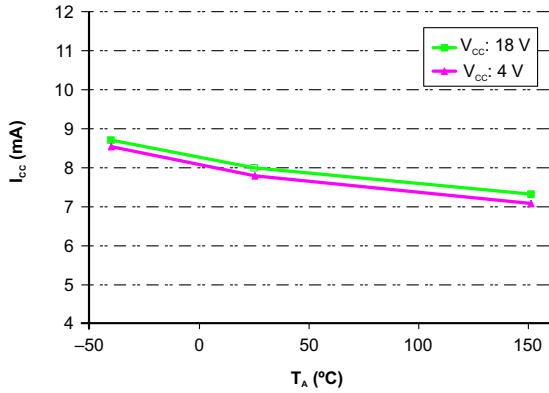


**Reference Gear Magnetic Profile  
Two Tooth-to-Valley Transitions**

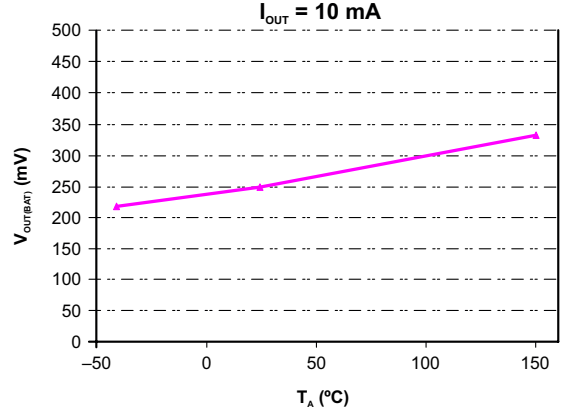


**CHARACTERISTIC DATA**

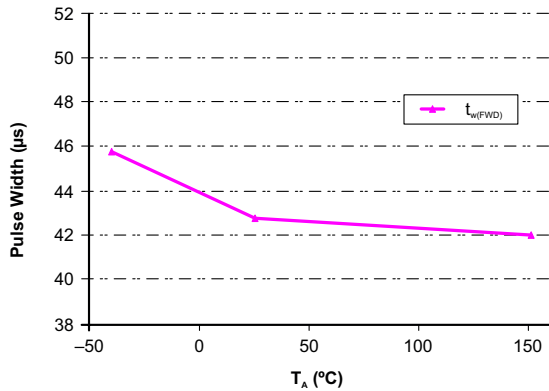
**Supply Current versus Ambient Temperature**



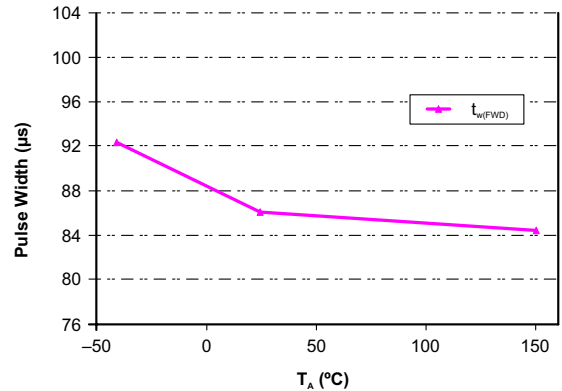
**Low Output Voltage versus Ambient Temperature**



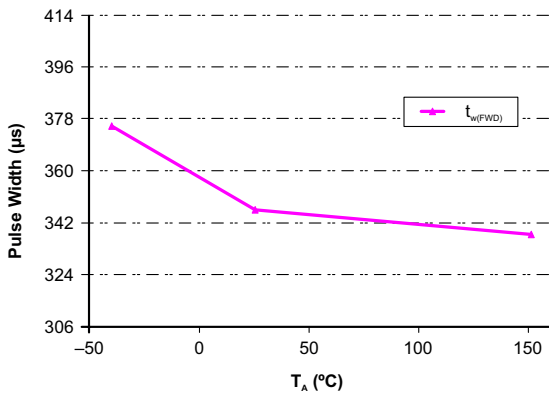
**Output Pulse Width versus Ambient Temperature**



**Output Pulse Width versus Ambient Temperature**



**Output Pulse Width versus Ambient Temperature**





**FUNCTIONAL DESCRIPTION**

**Sensing Technology**

The sensor IC contains a single-chip Hall-effect circuit that supports a trio of Hall elements. These elements are used in differential pairs to provide electrical signals containing information regarding edge position and direction of target rotation. The ATS693 is intended for use with ferromagnetic targets.

After proper power is applied to the sensor IC, it is capable of providing digital information that is representative of the magnetic features of a rotating target. The waveform diagrams in figure 4 present the automatic translation of the target profiles, through their induced magnetic profiles, to the digital output signal of the sensor IC.

**Direction Detection**

The sensor IC compares the relative phase of its two differential channels to determine in which direction the target is moving. The relative switching order is used to determine the direction, which is communicated through the output protocol.

**Data Protocol Description**

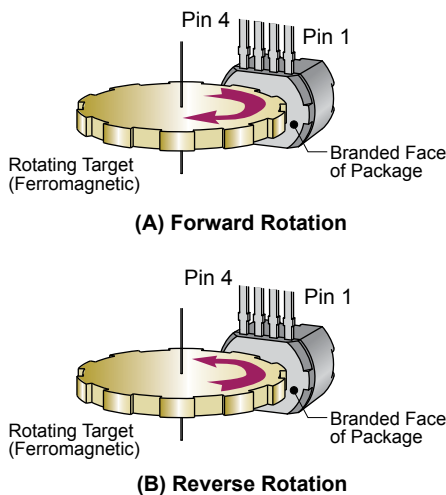
When a target passes in front of the device (opposite the branded face of the package case), the ATS693 generates an output pulse for each tooth of the target. Speed information is provided by the output pulse rate, while direction of target rotation is provided by the duration of the output pulses. The sensor IC can sense target movement in both the forward and reverse directions.

**FORWARD ROTATION (SEE PANEL A IN FIGURE 3)**

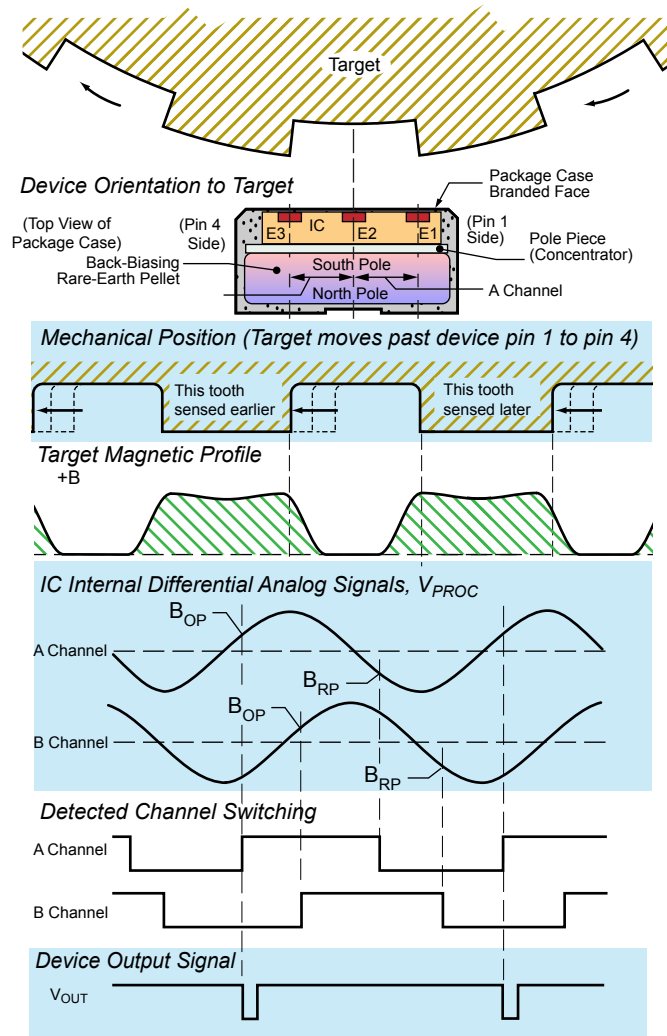
When the target is rotating such that a tooth near the sensor IC passes from pin 4 to pin 1, this is referred to as *forward rotation*. Forward rotation is indicated on the output by a  $t_{w(FWD)}$  (45  $\mu$ s typical) pulse width.

**REVERSE ROTATION (SEE PANEL B IN FIGURE 3)**

When the target is rotating such that a tooth passes from pin 1 to pin 4, it is referred to as *reverse rotation*. Reverse rotation is indicated on the output by pulse widths of  $t_{w(REV)}$  (90  $\mu$ s (typical)).



**Figure 3: Target Rotation**



**Figure 4: Magnetic Profile**

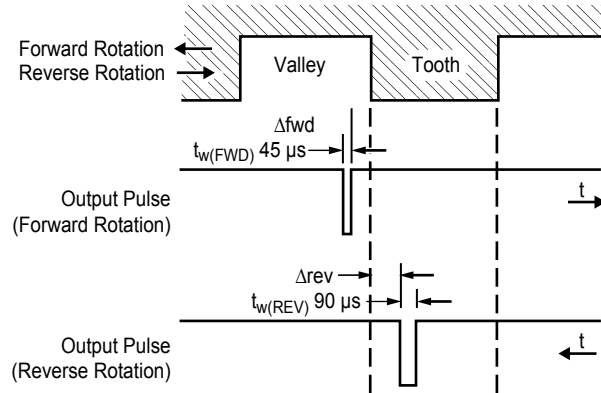
The magnetic profile reflects the features of the target, allowing the sensor IC to present an accurate digital output.

**TIMING**

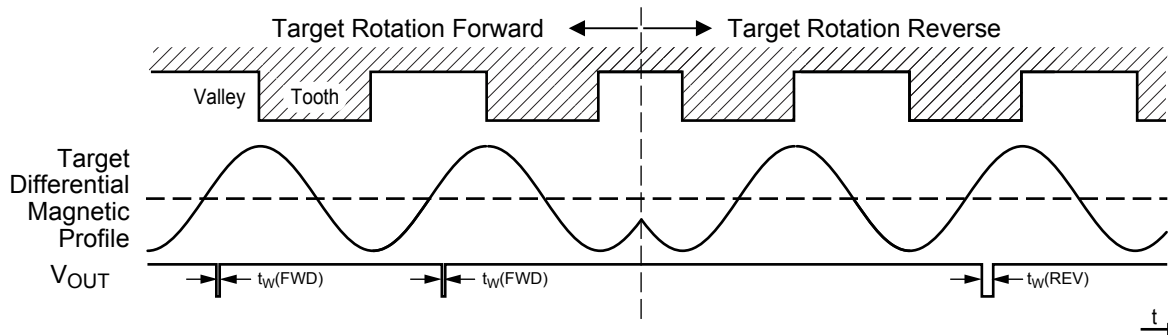
As shown in figure 5, the pulse appears at the output slightly before the sensed magnetic edge traverses the package branded face. For targets in forward rotation, this shift,  $\Delta_{fwd}$ , results in the pulse corresponding to the valley with the sensed mechanical edge, and for targets in reverse rotation, the shift,  $\Delta_{rev}$ , results in the pulse corresponding to the tooth with the sensed edge. The sensed mechanical edge that stimulates output pulses is kept the same for both forward and reverse rotation by using only one channel to control output switching.

**Direction Validation**

Following a direction change in Running mode, output pulses are not present until direction information is validated. An example of the waveforms is shown in figure 6.



**Figure 5: Output Protocol**



**Figure 6: Example of Direction Change in Running Mode**

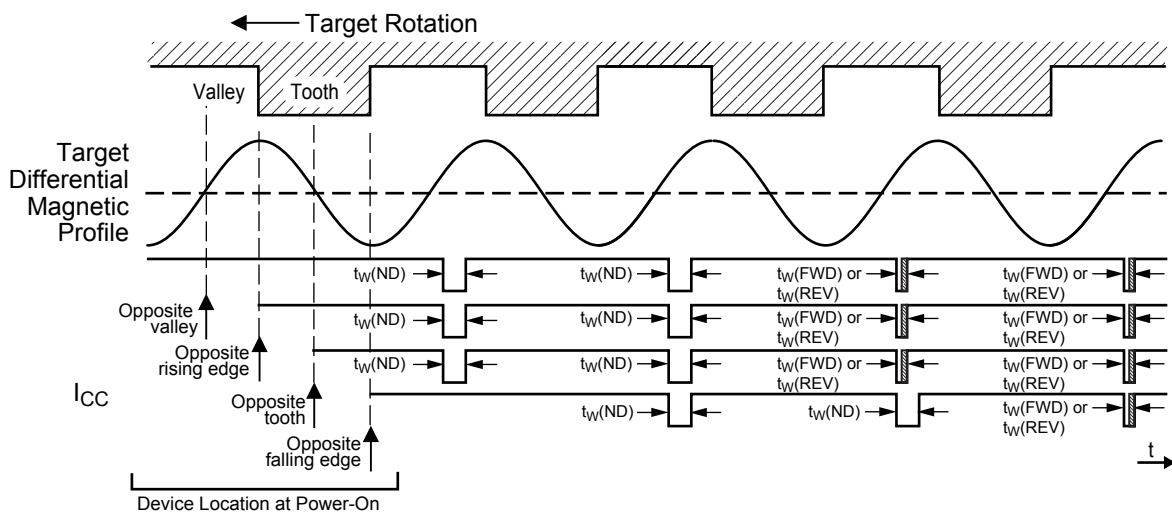
**Start-Up Detection / Calibration**

When power is applied to the ATS693, the sensor IC internally detects the profile of the target. The gain and offset of the detected signals are adjusted during the calibration period, normalizing the internal signal amplitude for the air gap range of the device.

The Automatic Gain Control (AGC) feature ensures that operational characteristics are isolated from the effects of installation air gap variation.

Automatic Offset Adjustment (AOA) is circuitry that compensates for the effects of chip, magnet, and installation offsets. This circuitry works with the AGC during calibration to adjust  $V_{PROC}$  in the internal A-to-D range to allow for acquisition of signal peaks. AOA and AGC function separately on the two differential signal channels.

Direction information is available after calibration is complete. Figure 7 shows where the first output edges may occur for various starting target phases.

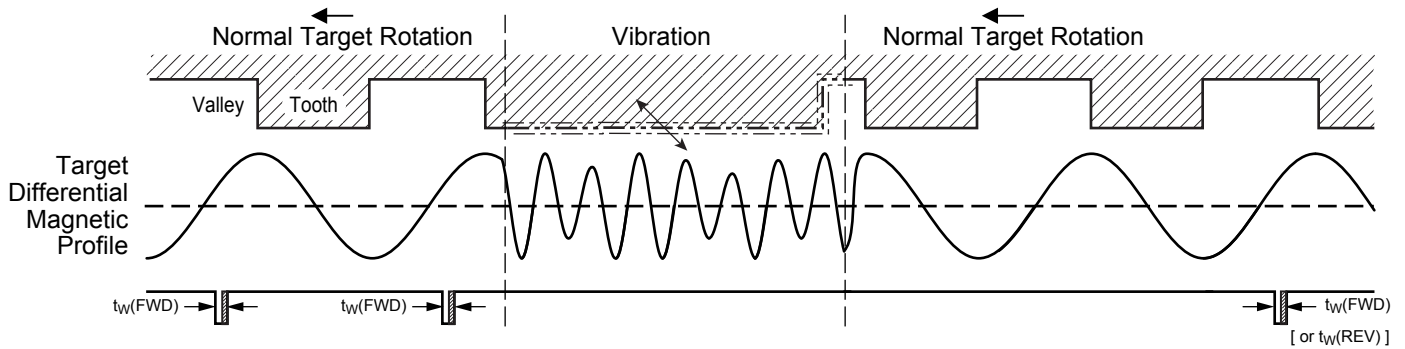


**Figure 7: Start-up Position Effect on First Device Output Switching**

**Vibration Detection**

Algorithms embedded in the IC digital controller detect the presence of target vibration through analysis of the two magnetic input channels.

In the presence of vibration, the output is blanked and no output pulses will occur for vibrations less than the specified vibration immunity. Output pulses containing the proper direction information will resume when direction information is validated on constant target rotation.



**Figure 8: Output Functionality in the Presence of Running Mode Target Vibration**

**APPLICATION INFORMATION**

**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 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:  $T_A = 25^\circ C$ ,  $V_{CC} = 12 V$ ,  $I_{CC} = 6.5 mA$ , and  $R_{\theta JA} = 126^\circ C/W$ , then:

$$P_D = V_{CC} \times I_{CC} = 12 V \times 6.5 mA = 78 mW$$

$$\Delta T = P_D \times R_{\theta JA} = 78 mW \times 126^\circ C/W = 9.8^\circ C$$

$$T_J = T_A + \Delta T = 25^\circ C + 9.8^\circ C = 34.8^\circ C$$

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

*Example:* Reliability for  $V_{CC}$  at  $T_A = 150^\circ C$ , package SG, using a single-layer PCB.

Observe the worst-case ratings for the device, specifically:  $R_{\theta JA} = 126^\circ C/W$ ,  $T_{J(max)} = 165^\circ C$ ,  $V_{CC(max)} = 24 V$ , and  $I_{CC(max)} = 12 mA$ .

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

$$\Delta T_{max} = T_{J(max)} - T_A = 165^\circ C - 150^\circ C = 15^\circ C$$

This provides the allowable increase to  $T_J$  resulting from internal power dissipation. Then, invert equation 2:

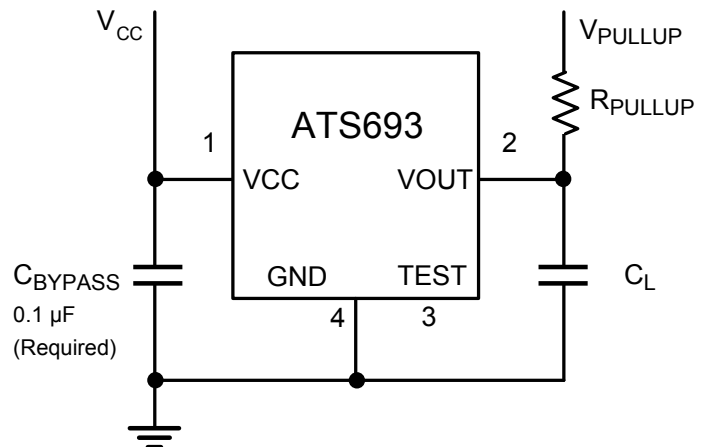
$$P_D(max) = \Delta T_{max} \div R_{\theta JA} = 15^\circ C \div 126^\circ C/W = 119 mW$$

Finally, invert equation 1 with respect to voltage:

$$V_{CC(est)} = P_D(max) \div I_{CC(max)} = 119 mW \div 12 mA = 9.9 V$$

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.

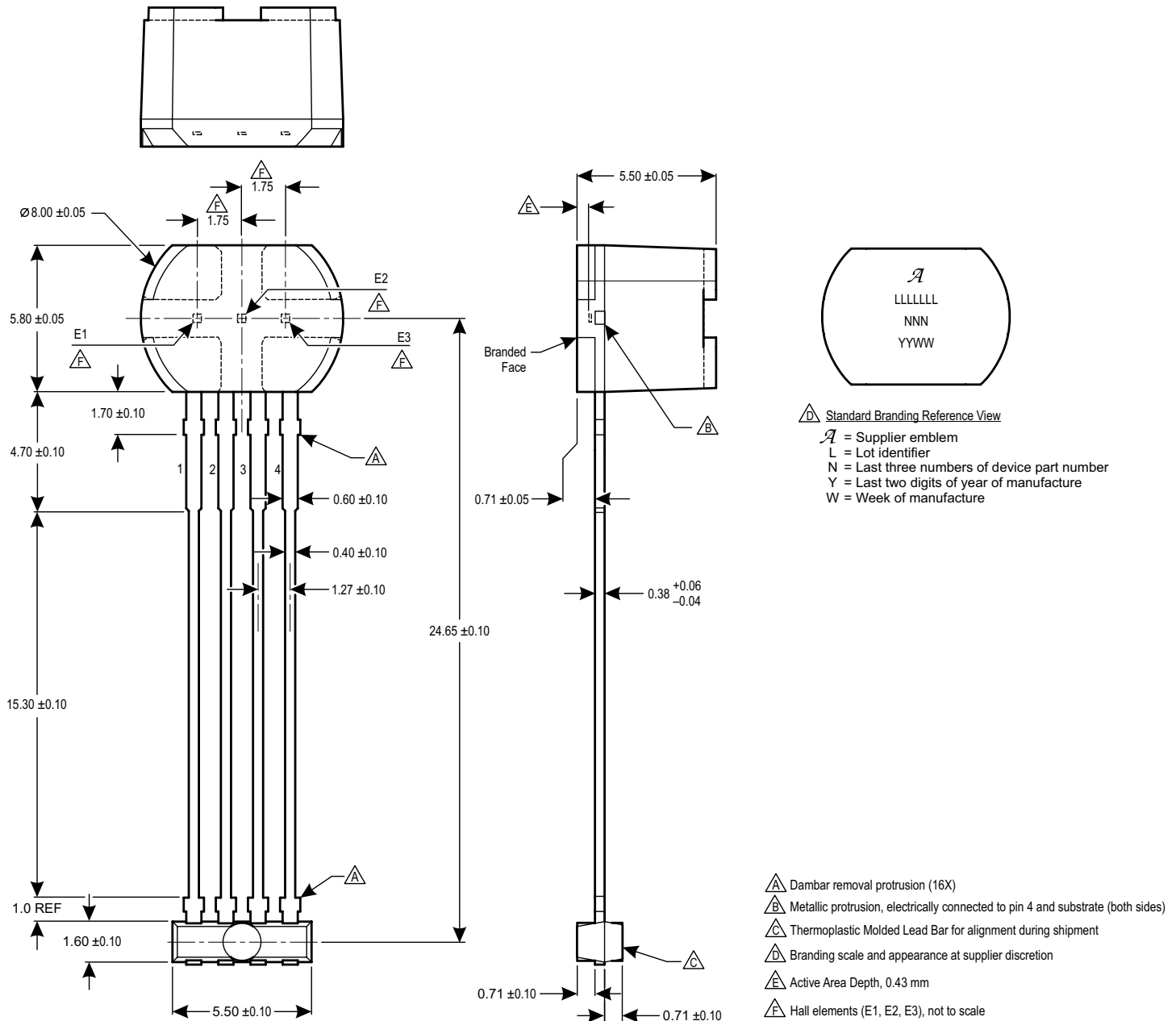


**Figure 9: Typical Application Circuit**

**PACKAGE OUTLINE DRAWING**

**For Reference Only – Not for Tooling Use**

(Reference DWG-9200)  
Dimensions in millimeters  
NOT TO SCALE



**Figure 10: Package SG, 4-Pin SIP**

**Document Revision History**

Revision	Date	Change
–	September 25, 2014	Initial Release

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