

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

### FEATURES AND BENEFITS

- Two-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 SH)



Not to scale

### DESCRIPTION

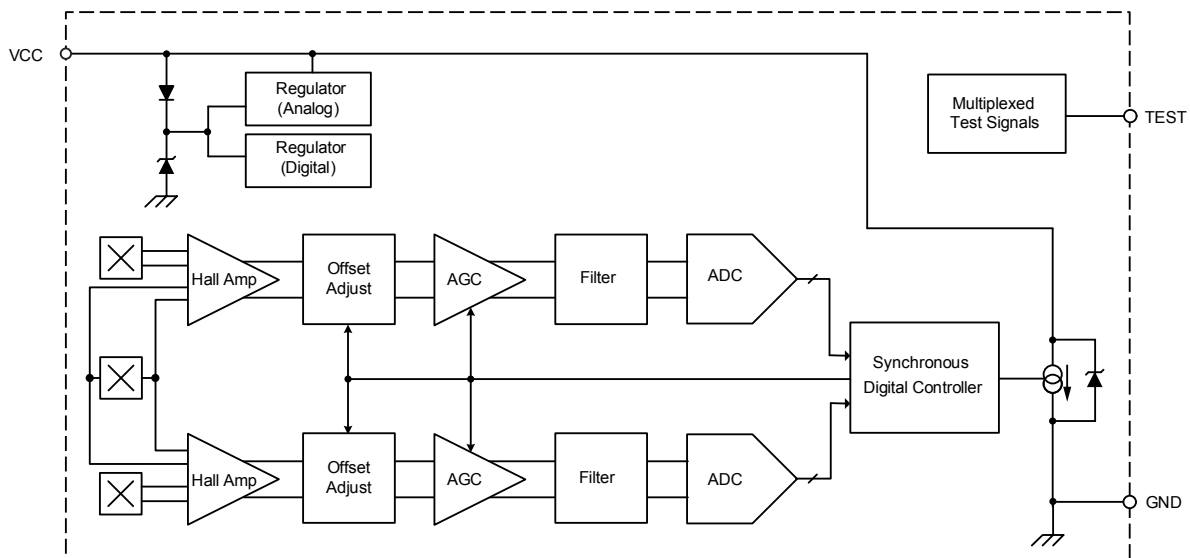
The ATS692LSH is an optimized Hall-effect integrated circuit (IC) and rare earth pellet combination that provides a user-friendly solution for direction detection and true zero-speed, digital gear tooth sensing. The small package can be easily assembled and used in conjunction with a wide variety of 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 ATS692 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 ATS692 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



# ATS692LSH(RSNPH)

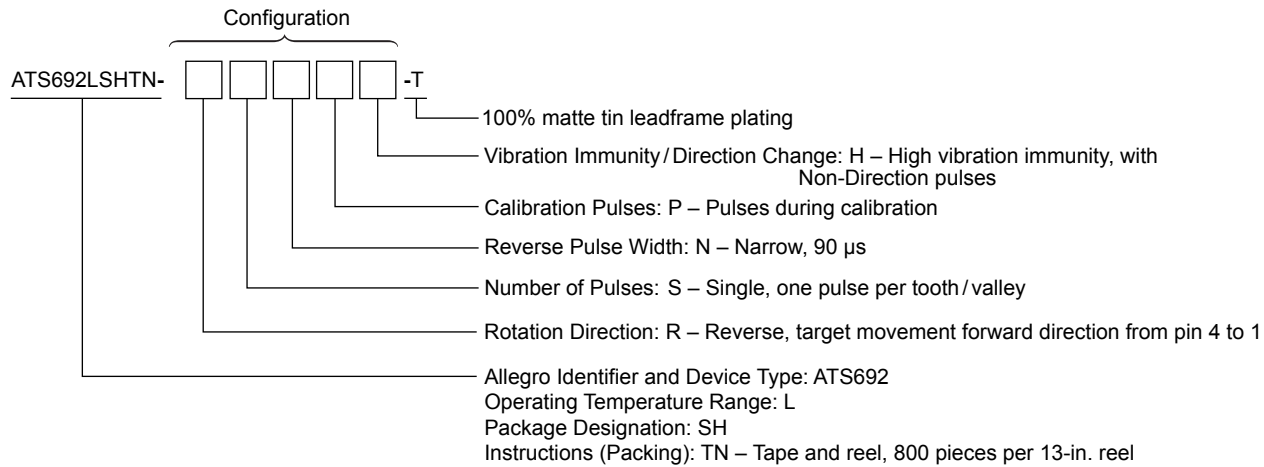
# Two-Wire, Differential, Vibration Resistant Sensor IC with Speed and Direction Output

## SELECTION GUIDE

Part Number	Packing*	$t_{w(ND)}$ (nom)	Direction Change Function	Vibration Immunity (Running Mode)
ATS692LSHTN-RSNPH-T	800 pieces per reel	180 $\mu$ s	$t_{w(ND)}$ until direction validated	$T_{TARGET}$



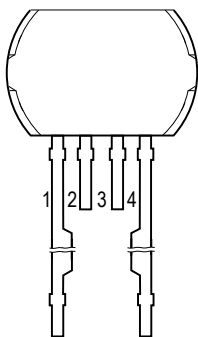
\*Contact Allegro™ for additional packing options.



## 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
Operating Ambient Temperature	$T_A$	L temperature range	-40 to 150	$^{\circ}$ C
Maximum Junction Temperature	$T_{J(max)}$		165	$^{\circ}$ C
Storage Temperature	$T_{stg}$		-65 to 170	$^{\circ}$ C

## Pinout Diagram



## Terminal List Table

Number	Name	Function
1	VCC	Supply voltage
2	TEST	Test pin: float *
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 at throughout full operating and temperature ranges; using Reference Target 60-0; unless otherwise specified

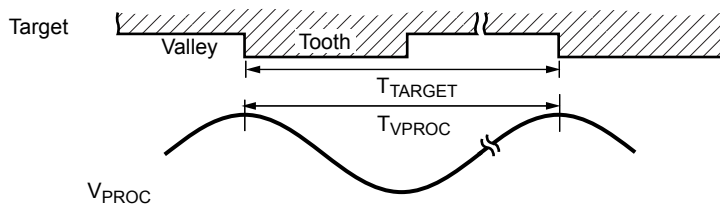
Characteristic	Symbol	Test Conditions	Min.	Typ. [1]	Max.	Unit
<b>GENERAL ELECTRICAL CHARACTERISTICS</b>						
Supply Voltage [2]	$V_{CC}$	Operating, $T_J < T_{J(max)}$	4.0	–	24	V
Under Voltage Lockout	$V_{CC(UV)}$	$V_{CC} 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V}$	–	3.6	3.95	V
Reverse Supply Current [3]	$I_{RCC}$	$V_{CC} = V_{RCC(max)}$	–	–	–10	mA
Supply Zener Clamp Voltage	$V_{Z(SUPPLY)}$	$I_{CC} = I_{CC(max)} + 3\text{ mA}$ , $T_A = 25^\circ\text{C}$	28	–	–	V
Supply Current	$I_{CC(LOW)}$	Low-current state (Running mode)	5.0	–	8.0	mA
	$I_{CC(HIGH)}$	High-current state (Running mode)	12.0	–	16.0	mA
	$I_{CC(SU)(LOW)}$	Startup current level (Power-On mode)	5.0	–	8.5	mA
	$I_{CC(SU)(HIGH)}$	High-current state (Calibration)	12.0	–	16.5	mA
Supply Current Ratio	$\frac{I_{CC(HIGH)}}{I_{CC(LOW)}}$	Measured as ratio of high current to low current	1.9	–	–	–
Test Pins Zener Clamp Voltage [4]	$V_{Z(TEST)}$		–	6	–	V
<b>OUTPUT STAGE</b>						
Output Slew Rate	$SR_{OUT}$	$R_L = 100\ \Omega$ , $C_L = 10\text{ pF}$ ; $I_{CC(HIGH)} \rightarrow I_{CC(LOW)}$ , $I_{CC(LOW)} \rightarrow I_{CC(HIGH)}$ , 10% to 90% points	7.0	16	–	mA / $\mu\text{s}$
<b>OUTPUT PULSE CHARACTERISTICS [5]</b>						
Pulse Width (Forward Rotation)	$t_{w(FWD)}$		38	45	52	$\mu\text{s}$
Pulse Width (Reverse Rotation)	$t_{w(REV)}$		76	90	104	$\mu\text{s}$
Pulse Width (Non-Direction)	$t_{w(ND)}$		153	180	207	$\mu\text{s}$
<b>GENERAL OPERATING CHARACTERISTICS</b>						
Operate Point	$B_{OP}$	% of peak-to-peak $V_{PROC}$	–	69	–	%
Release Point	$B_{RP}$	% of peak-to-peak $V_{PROC}$	–	31	–	%
Operating Frequency (Forward Rotation)	$f_{FWD}$		0	–	12	kHz
Operating Frequency (Reverse Rotation) [6]	$f_{REV}$		0	–	7	kHz
Operating Frequency (Non-Direction Pulses) [6]	$f_{ND}$		0	–	4	kHz
<b>DAC CHARACTERISTICS</b>						
Allowable User-Induced Offset	$B_{OFFSET}$	Magnitude valid for both differential magnetic channels	–60	–	60	G
<b>PERFORMANCE CHARACTERISTICS</b>						
Air Gap Range	AG	Using Allegro Reference Target 60-0	0.5	–	2.75	mm
Vibration Immunity (Startup)	$err_{VIB(SU)}$	See figure 1	$T_{TARGET}$	–	–	degrees
Vibration Immunity (Running Mode)	$err_{VIB}$	See figure 1	$T_{TARGET}$	–	–	degrees

Continued on the next page...

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

Characteristic	Symbol	Test Conditions	Min.	Typ. [1]	Max.	Unit	
<b>INPUT MAGNETIC CHARACTERISTICS</b>							
Allowable Differential Sequential Signal Variation [7]	$B_{SEQ(n+1)} / B_{SEQ(n)}$	Signal cycle-to-cycle variation (see figure 2)	0.6	–	–	–	
<b>CALIBRATION</b>							
First Direction Output Pulse [8]		Amount of target rotation (constant direction) following power-on until first electrical output pulse of either $t_{w(FWD)}$ or $t_{w(REV)}$ , see figure 1	AG $\geq 0.5$ mm AG $< 2.25$ mm	–	$2 \times T_{TARGET}$	$< 3 \times T_{TARGET}$	deg.
			AG $\geq 2.25$ mm AG $\leq 2.75$ mm	–	$2.5 \times T_{TARGET}$	$< 4 \times T_{TARGET}$	deg.
First Direction Pulse Output Following Direction Change	$N_{CD}$	Amount of target rotation (constant direction) following event until first electrical output pulse of either $t_{w(FWD)}$ or $t_{w(REV)}$ , see figure 1	$1 \times T_{TARGET}$	$2 \times T_{TARGET}$	$< 3 \times T_{TARGET}$	deg.	
First Direction Pulse Output Following Running Mode Vibration		Amount of target rotation (constant direction) following event until first electrical output pulse of either $t_{w(FWD)}$ or $t_{w(REV)}$ , see figure 1	$1 \times T_{TARGET}$	$2 \times T_{TARGET}$	$< 3 \times T_{TARGET}$	deg.	

- [1] Typical values are at  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 12\text{ V}$ . 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] Negative current is defined as conventional current coming out of (sourced from) the specified device terminal.
- [4] Sustained voltages beyond the clamp voltage may cause permanent damage to the IC.
- [5] Load circuit is  $R_L = 100\ \Omega$  and  $C_L = 10\ \text{pF}$ . Pulse duration measured at a threshold of  $(I_{CC(HIGH)} + I_{CC(LOW)}) / 2$ .
- [6] Maximums of both Operating Frequency (Reverse Rotation) and Operating Frequency (Non-Direction Pulses) are determined by satisfactory separation of output pulses:  $I_{CC(LOW)}$  of  $t_{w(FWD)(min)}$ . If the customer can resolve lower low-state durations, maximum  $f_{REV}$  and  $f_{ND}$  may be increased.
- [7] 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.
- [8] Power-on frequency  $\leq 200\ \text{Hz}$ . Higher power-on frequencies may require more input magnetic cycles until directional output pulses are achieved.



$V_{PROC}$  = the processed analog signal of the sinusoidal magnetic input (per channel)  
 $T_{TARGET}$  = period between successive sensed target mechanical edges of the same orientation (either both rising or both falling)

Figure 1. Definition of  $T_{TARGET}$

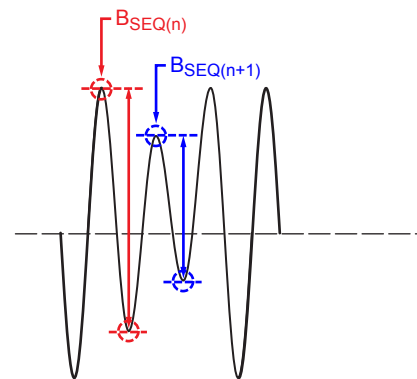
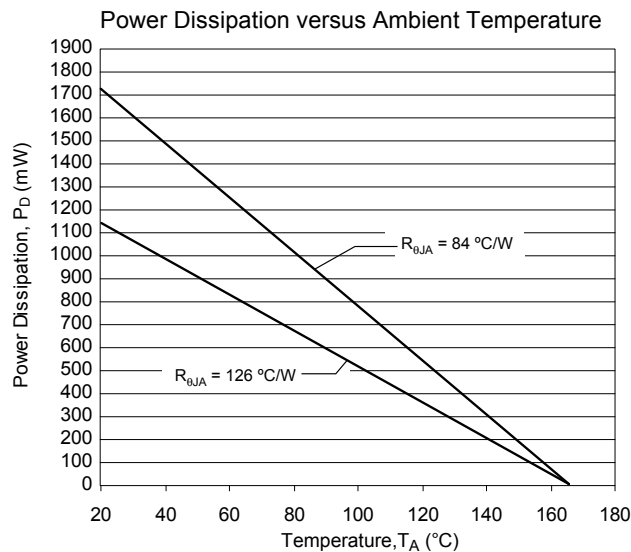
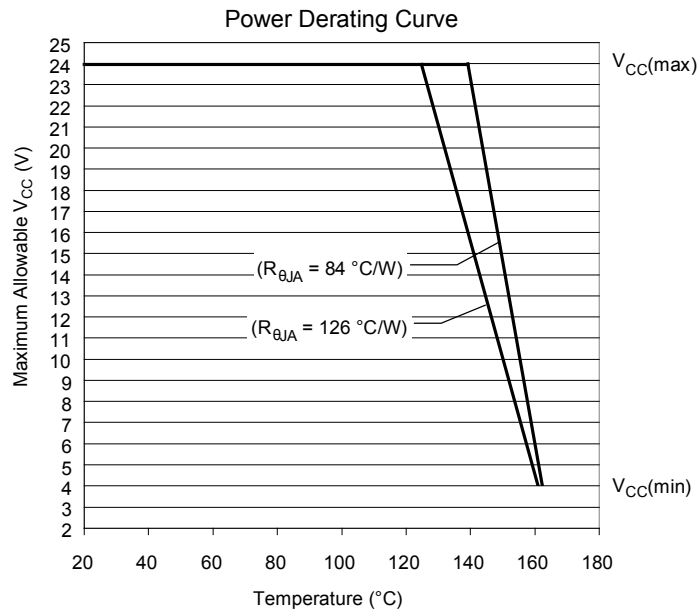


Figure 2. Differential signal variation

**THERMAL CHARACTERISTICS:** May require derating at maximum conditions; see Power Derating section

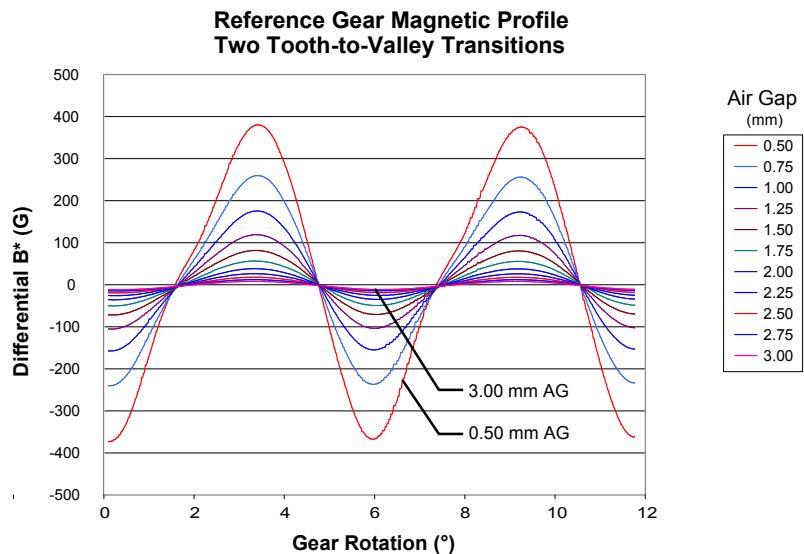
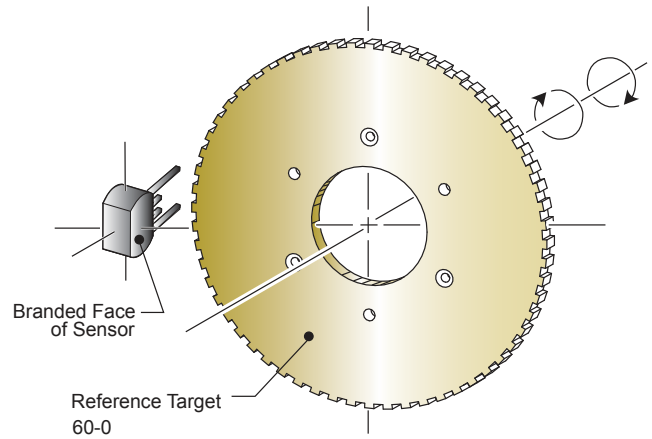
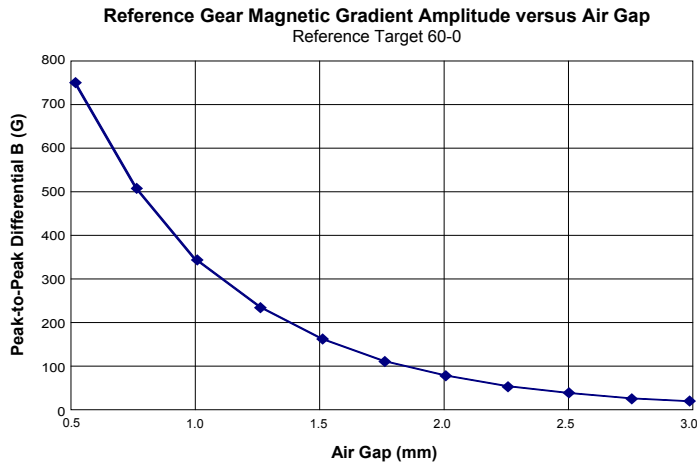
Characteristic	Symbol	Test Conditions*	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	Single layer PCB, with copper limited to solder pads	126	$^{\circ}\text{C}/\text{W}$
		Single layer PCB, with copper limited to solder pads and 3.57 in. <sup>2</sup> (23.03 cm <sup>2</sup> ) copper area each 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	degrees	
Angular Valley Thickness	$t_v$	Length of valley, with respect to branded face	3	degrees	
Tooth Whole Depth	$h_t$		3	mm	
Material		Low Carbon Steel	-	-	



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 ATS692 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 3 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 ATS692 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 2) 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 2) 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).

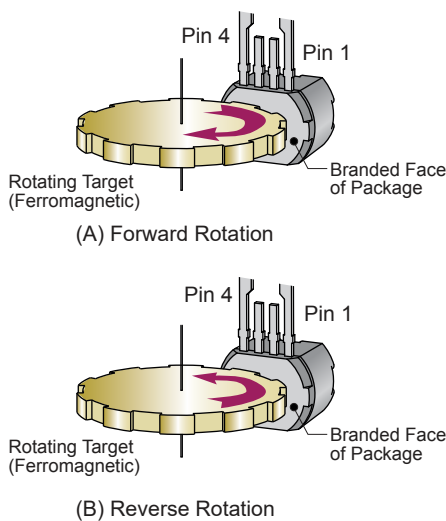


Figure 2. Target rotation

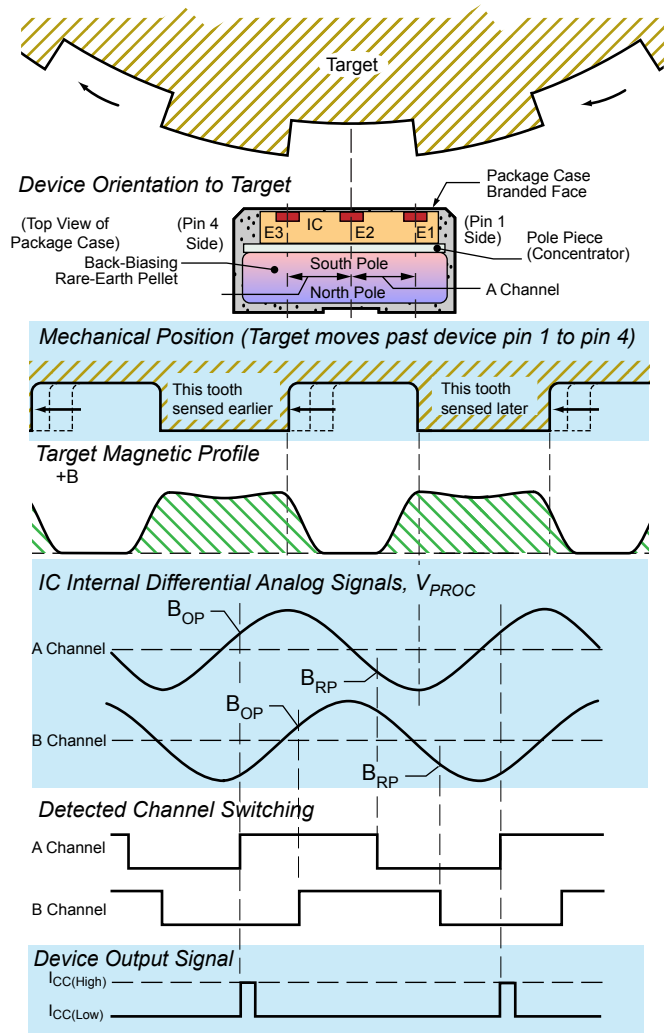


Figure 3. The magnetic profile reflects the features of the target, allowing the sensor IC to present an accurate digital output.

**Timing.** As shown in figure 4, 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 have a width of  $t_{w(ND)}$  until direction information is validated. An example of the waveforms is shown in figure 5.

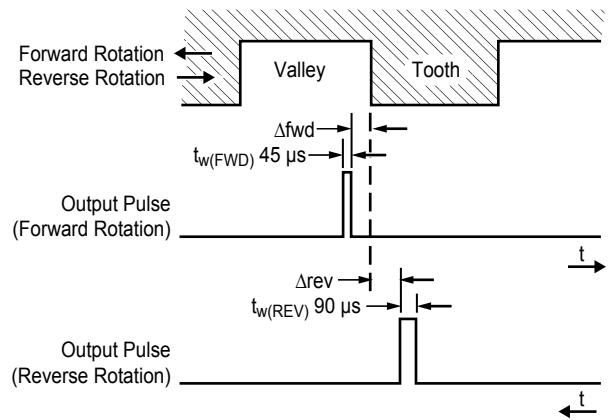


Figure 4. Output protocol

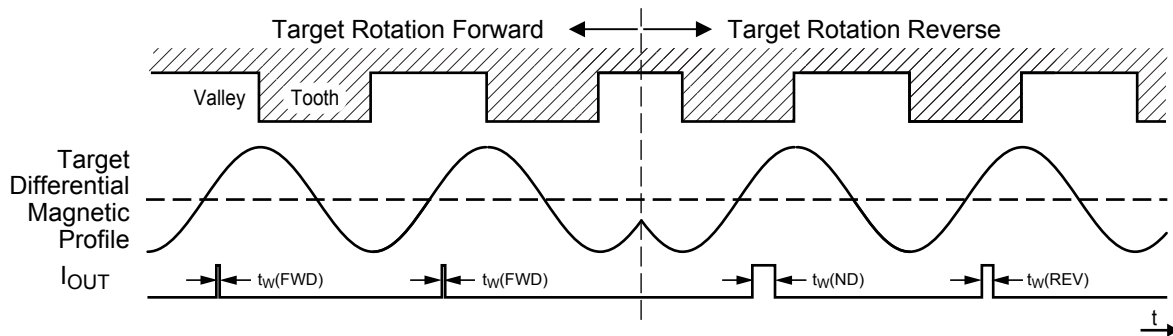


Figure 5. Example of direction change in Running mode



**Start-Up Detection / Calibration**

When power is applied to the ATS692, 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. Output pulses of  $t_{w(ND)}$  are supplied during calibration. Figure 6 shows where the first output edges may occur for various starting target phases.

**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, output pulses of  $t_{w(ND)}$  may occur or no pulses may occur, depending on the amplitude and phase of the vibration (figure 7). Output pulses have a width of  $t_{w(ND)}$  until direction information is validated on constant target rotation.

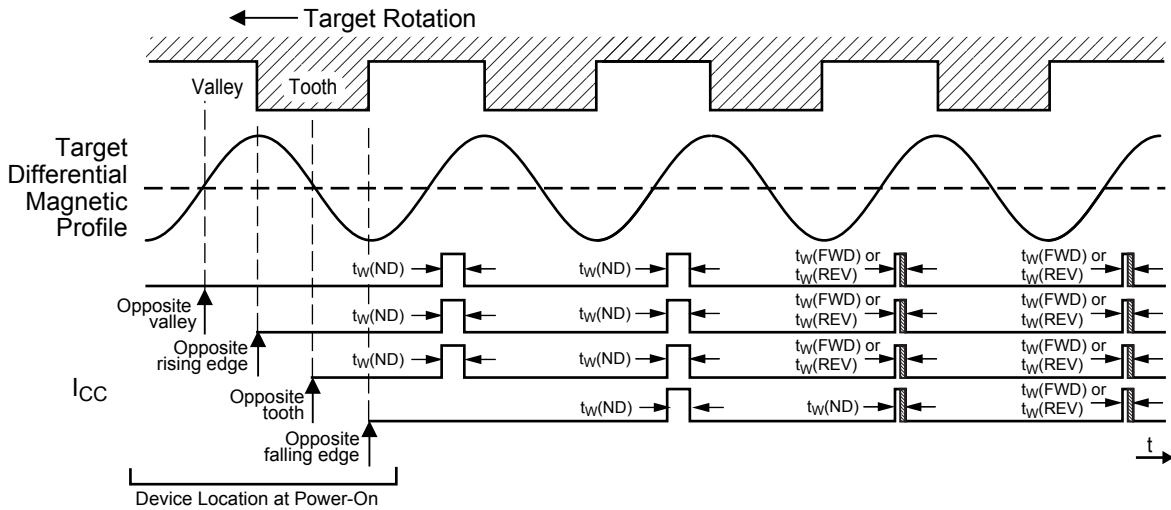


Figure 6. Start-up position effect on first device output switching

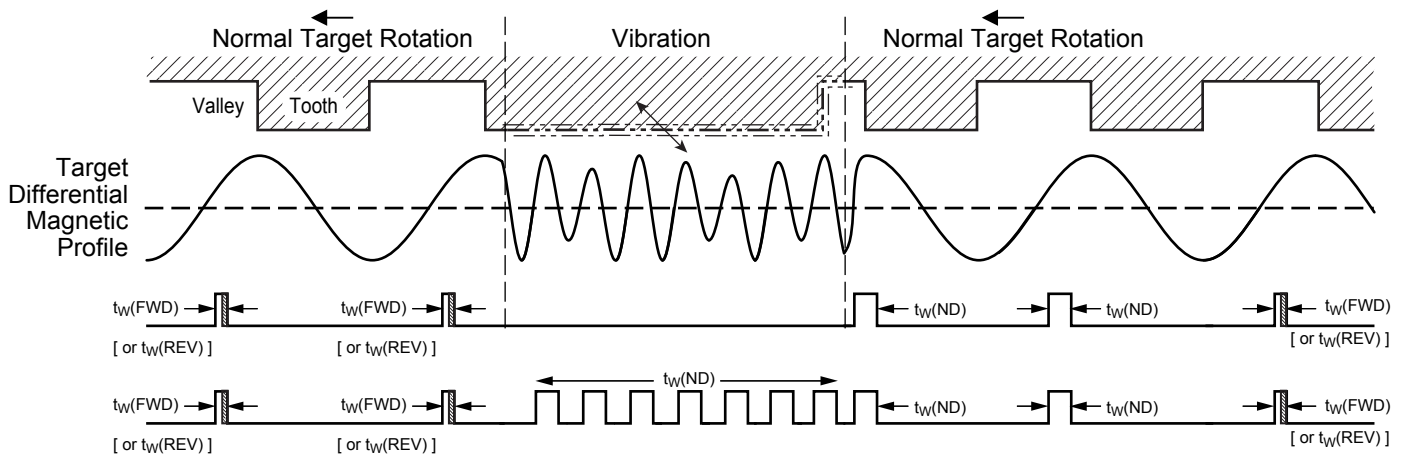


Figure 7. Output functionality in the presence of Running mode target vibration

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 SH, 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  $I_{CC(mean)} = 13 mA$ . (Note: At maximum target frequency,  $I_{CC(LOW)} = 8 mA$ ,  $I_{CC(HIGH)} = 16 mA$ , and maximum pulse widths, the result is a duty cycle of 62.4% and a worst case  $I_{CC(mean)}$  of 13 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:

$$V_{CC(est)} = P_D(max) \div I_{CC(max)} = 119 mW \div 13 mA = 9.2 V$$

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.

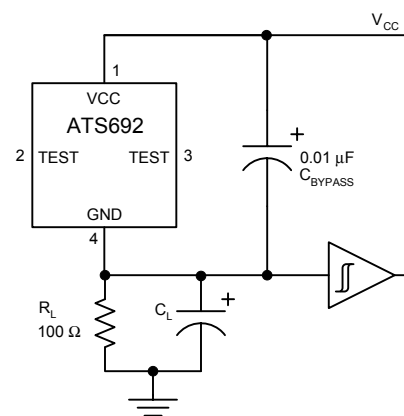


Figure 8. Typical application circuit

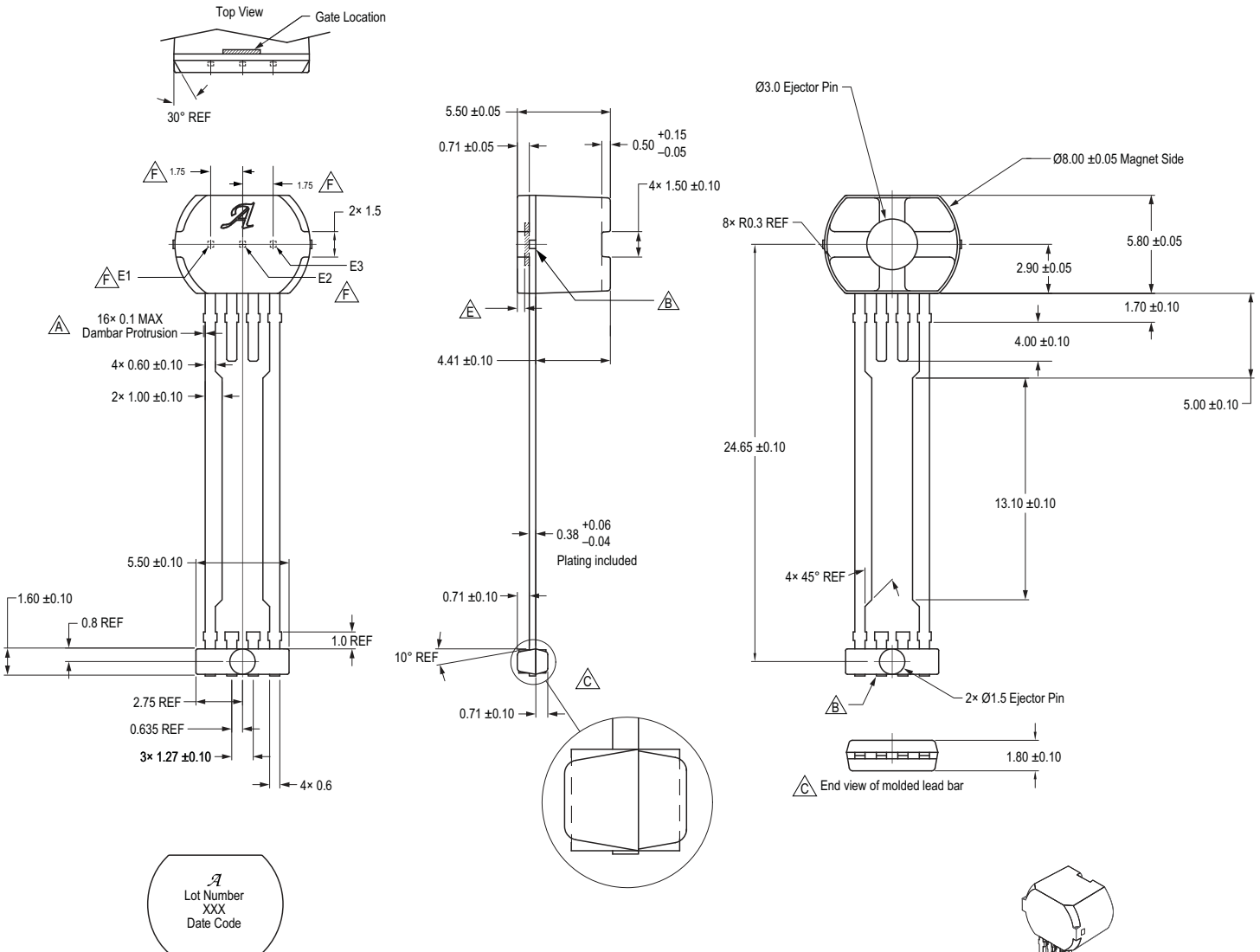
## Package SH, 4-Pin SIP

### For Reference Only – Not for Tooling Use

(Reference DWG-0000393)

Dimensions in millimeters. NOT TO SCALE.

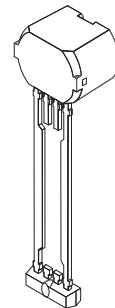
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions  
Exact case and lead configuration at supplier discretion within limits shown



#### 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 (16x)
- B** Metallic protrusion, electrically connected to pin 4 and substrate (both sides)
- C** Thermoplastic Molded Lead Bar for alignment during shipment
- D** Branding scale and appearance at supplier discretion
- E** Active Area Depth 0.43 mm REF
- F** Hall elements (E1, E2, E3); not to scale



**REVISION HISTORY**

Number	Date	Description
3	August 27, 2013	Upgrades to select graphics, $T_{tsg}$
4	May 27, 2020	Minor editorial updates
5	March 18, 2022	Updated package drawing (page 11)

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