Preliminary Data Sheet
Subject to Change Without Notice
June 3, 2004

ATS650LSH

Two-Wire Direction Detection Gear Tooth Sensor with Diagnostic Output

Package SH

1. VCC
2. Test pin, Channel 1
3. Test pin, Channel 2
4. GND

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC}	**28 V**
Reverse-Supply Voltage, V_{RCC}	**–18 V**
Reverse-Output Current, I_{ROUT}	**–50 mA**
Reverse-Output Voltage, V_{ROUT}	**–50 mA**
Operating Temperature	
Ambient, T_A	**–40ºC to 150ºC**
Maximum Junction, $T_{J(MAX)}$	**165ºC**
Storage Temperature, T_S	**–65ºC to 170ºC**

The ATS650 is an optimized Hall effect sensor combining sensor element, integrated circuit, and magnet in a manufacturer-friendly solution for digital gear-tooth sensing in two-wire applications. It provides true zero-speed sensing as well as detection of the direction of target movement. The device consists of a single-shot molded plastic package that includes a samarium cobalt magnet, a pole piece, and a Hall effect IC that has been optimized to the magnetic circuit. This small package can be easily assembled and used in conjunction with a wide variety of gear shapes and sizes.

The Hall effect sensor IC is a single chip solution that integrates three highly sensitive Hall effect transducers and precise signal processing circuitry that switches in response to magnetic signals created by ferrous gear teeth.

The circuitry contains a sophisticated digital circuit to minimize the effects of magnet and system offsets and to achieve optimal, true zero-speed operation. Signal optimization is performed each time the sensor is powered-on. Internal circuitry maintains signal optimization and encodes diagnostic information in the output signal of the device.

The regulated current output is configured for two-wire operation. It has direction and diagnostic capabilities incorporated into the speed signal output.

The ATS650 is ideal for obtaining speed, direction, and diagnostic information using gear-tooth–based targets found in ABS and transmission applications.

For ring magnet applications, use the A1650.

Features and Benefits

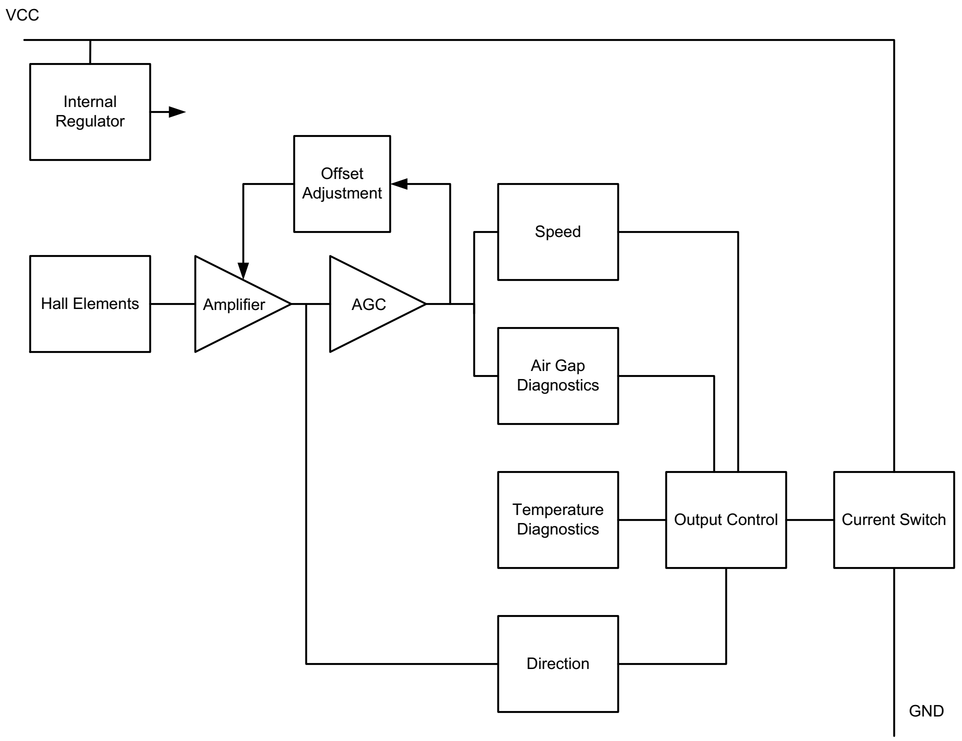
- Fully optimized digital differential gear tooth sensor
- Single chip sensing IC for high reliability
- Small mechanical size (8 mm diameter x 5.5 mm depth)
- Internal current regulator for 2-wire operation
- Rotational direction detection
- Digital output protocol with integrated diagnostic information
- On-chip temperature sensing for diagnostic capability
- On-chip air gap diagnostics
- Automatic Gain Control (AGC) and reference adjust circuit
- 3-bit factory trimming for tight pulse width accuracy
- True zero-speed operation
- Wide operating voltage range
- Undervoltage lockout
- Defined power-on state
- ESD and reverse polarity protection

Use the following complete part numbers when ordering:

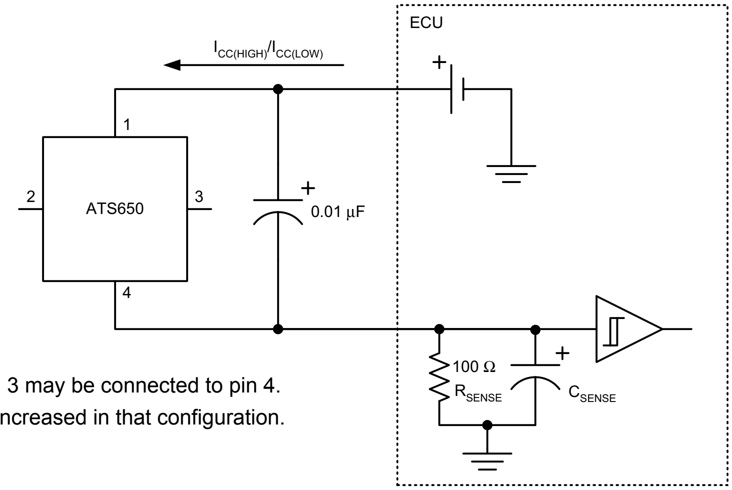
Part Number	I_{CC} Typical (mA)
ATS650LSH-I1	4.0 Low to 16.0 High
ATS650LSH-I2	5.9 Low to 16.8 High

Engineering samples available on a limited basis. Contact your local sales or applications support office for additional information.

Functional Block Diagram



Typical Application Diagram



Note: Pins 2 and 3 may be connected to pin 4.
However, I_{CC} is increased in that configuration.

ELECTRICAL CHARACTERISTICS Valid for –40°C ≤ T_A ≤ 150°C; T_J ≤ 165°C, unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}	Running mode	4.3	–	24	V
Undervoltage Lockout	$V_{CC(UV)}$	V_{CC} = 5 V → 0 V	–	–	< $V_{CC(MIN)}$	V
Reverse Supply Current	I_{RCC}	V_{CC} = –18 V	–	–	–10	mA
Supply Zener Clamp Voltage	V_{ZCC}	$I_{CC} = I_{CC(MAX)}$ + 3 mA; T_A = 25°C	28	–	–	V
Output Zener Clamp Voltage	V_{ZOUT}	I_{OUT} = 3 mA; T_A = 25°C	30	–	–	V
Supply Zener Current	I_{ZCC}	V_{CC} = 28 V	–	–	$I_{CC(MAX)}$+3	mA
Output Zener Current	I_{ZOUT}	V_{OUT} = 30 V	–	–	3	mA
Power-On State	I_{PO}		–	$I_{CC(LOW)}$	–	mA
Power-On Time	t_{PO}		–	0.32	1.00	ms
Supply Current[1]	$I_{CC(LOW)}$	ATS650-I1 package	4.0	6.0	8.0	mA
		ATS650-I2 package	5.9	7.0	8.4	mA
	$I_{CC(HIGH)}$	ATS650-I1 package	12.0	14.0	16.0	mA
		ATS650-I2 package	11.8	14.0	16.8	mA
SWITCHING						
Operate Point	O_P	$I_{CC(HIGH)} \rightarrow I_{CC(LOW)}$; Positive peak referenced	–	100	–	mV
Release Point	R_P	$I_{CC(LOW)} \rightarrow I_{CC(HIGH)}$; Negative peak referenced	–	100	–	mV
Initial Calibration Cycle[2]	N_{Cal}	Calibration occurs at each power-on	–	–	3	Edges
Direction Calibration Cycle	N_{Dir}	Calibration occurs at each power-on	–	–	0	Edges
Direction Change Detection[3]	N_{CD}	Running mode direction change	–	–	1	Edges
Protocol Pulse Width Tolerance	PW_{TOL}	Reference Gear 60-0	–15	–	15	%
Axial/Radial Runout	$W_{A/R}$	Total Indicated Runout (TIR)	–	–	0.5	mm
Output Current Slew Rate	dI_{OUT}/dt	$I_{CC(HIGH)} \rightarrow I_{CC(LOW)}$, $I_{CC(LOW)} \rightarrow I_{CC(HIGH)}$; R_{SENSE} = 100 Ω, C_{SENSE} = 10 pF; 10/90% pts.	–	16	–	mA/µs
Maximum Operating Frequency[4]	f_R	Rotation right to left (pin 4 → pin 1); L_D = 38 µs	2.04	2.29	2.62	kHz
	f_L	Rotation left to right (pin 1 → pin 4); L_D = 38 µs	5.55	6.02	6.58	kHz
Diagnostic Data Drop-Out Frequency[5]	f_{DO}	No diagnostics beyond this frequency	3.52	3.70	4.39	kHz

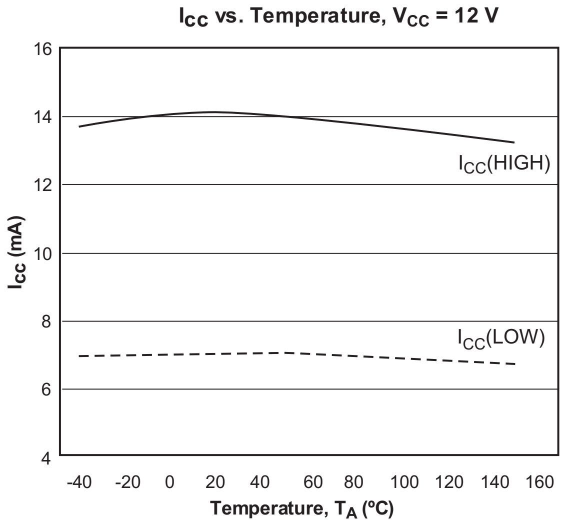
Continued on the next page.

ELECTRICAL CHARACTERISTICS (Continued) Valid for –40°C ≤ T_A ≤ 150°C; T_J ≤ 165°C, unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Units
DIAGNOSTIC CHARACTERISTICS						
Maximum Air Gap Threshold[6]	B_{Limit}	Maximum air gap limit exceeded	12	17	25	$G_{PK\text{-}PK}$
Air Gap Warning Threshold[7]	B_{Thresh}	Apporaching maximum air gap limit	20	29	44	$G_{PK\text{-}PK}$
Installation Threshold	$B_{Install}$	Nominal operating threshold	43	62	94	$G_{PK\text{-}PK}$
Low Temperature Threshold	$T_{J(LOW)}$	IC junction temperature	–20	–5	10	°C
High Temperature Threshold	$T_{J(HIGH)}$	IC junction temperature	75	95	115	°C
PROTOCOL PULSE CHARACTERISTICS						
Low State Duration[4]	L_D	Falling output signal edge to subsequent rising output signal edge	10	–	–	μs
Pulse Width Right Rotation	PW_R	Rotation right to left (pin 4 → pin 1)	153	180	207	μs
Pulse Width Left Rotation	PW_{L0}	Rotation left to right (pin 1 → pin 4); Data Bit 0	38	45	52	μs
	PW_{L1}	Rotation left to right (pin 1 → pin 4); Data Bit 1; $f_L < f_{DO}$	76	90	104	μs

[1] $I_{CC(HIGH)} / I_{CC(LOW)} \geq 1.85$ mA.
[2] Edge count is based on mechanical edges. On the N_{Cal} edge, direction and speed information is valid.
[3] Edge count is based on mechanical edges. On the N_{CD} edge, direction and speed information is valid.
[4] Maximum Operating Frequency may be increased if the application can resolve at $L_{D(MIN)}$.
[5] Diagnostic Data Drop-Out Frequency is based on a fixed internal clock frequency and is independent of L_D.
[6] Diagnostic gauss levels track each other such that proper order is maintained.
[7] Nonsinusoidal target magnetic profiles may result in an incorrect direction signal for field levels below B_{Thresh}.

Characterization Data


I_{CC} vs. Temperature, V_{CC} = 12 V

Applications Information

Data Protocol Description

As the target passes the branded face of the sensor, each gear tooth edge of the target generates a pulse from the sensor. The combination of pulses is used to provide data. Examples are shown in figure 2, on the next page.

Target rotational speed is indicated by the pulse rate (the sum of the pulse width and the following L_D). Direction is indicated by the width of the pulse: a pulse of 180 µs indicates right-to-left rotation, and a pulse width of 45 or 90 µs indicates left-to-right rotation, as shown in figure 1.

The two pulse widths of the left-to-right rotation signal allow it to also convey binary diagnostic information. The 45 µs pulse indicates not only left-to-right rotation, but also a logic zero data bit. The 90 µs pulse indicates a logic one data bit.

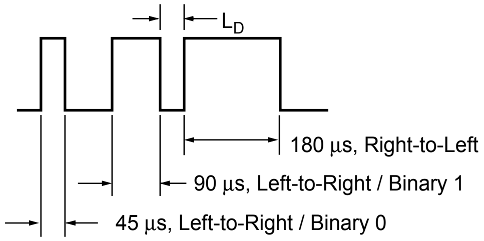


Figure 1. Data encoding pulse widths

Decoding Diagnostic Data Transmissions

The protocol provides diagnostic information in the form of 3-bit data words. Each data sequence consists of a Start Data Sequence word and two data words. To distinguish the data words from the Start Data Sequence word, the third bit of the data words acts as a delimiter, and is always 0 (logic low). Because the delimiter occupies one bit, only four possible states can be indicated by each word. The code sequence and meanings of the diagnostic signals are shown in the table below.

Rotation Speed Considerations

As the speed of the target increases, the rate of pulse generation increases as well, and the gap between the data pulses decreases. The left-to-right direction can support higher rotational speeds because of the shorter pulse widths it generates. At very high rotational speeds, when the pulse rate exceeds the Diagnostic Data Drop-Out Frequency, F_{DO}, the sensor transmits only the shortest pulse, 45 µs. This allows the sensor to provide speed and directional data at very high speeds. Because the 90 µs pulse width is not used, however, diagnostic data is not available. The right-to-left rotational direction is indicated by the longest of the three pulse widths, and consequently, the gaps between the pulses begin to collapse at a lower speed.

Diagnostic Data Codes

Word		Initialization			Data 1			Data 2		
Bit		1	2	3	4	5	6	7	8	9
Name	Description									
Start Data Sequence	Initializes data stream	1	1	1						
Air Gap Diagnostics										
Maximum Air Gap Threshold	$B < B_{LIMIT}$				0	0	0			
Air Gap Warning Threshold	$B_{LIMIT} < B < B_{THRESH}$				0	1	0			
Installation Threshold	$B_{THRESH} < B < B_{INSTALL}$				1	1	0			
Air Gap OK	$B > B_{INSTALL}$				1	0	0			
Temperature Diagnostics										
Temperature Low	$T_J < T_{J(LOW)}$							0	0	0
Temperature Midrange	$T_{J(LOW)} < T_J < T_{J(HIGH)}$							1	0	0
Temperature High	$T_J > T_{J(HIGH)}$							1	1	0

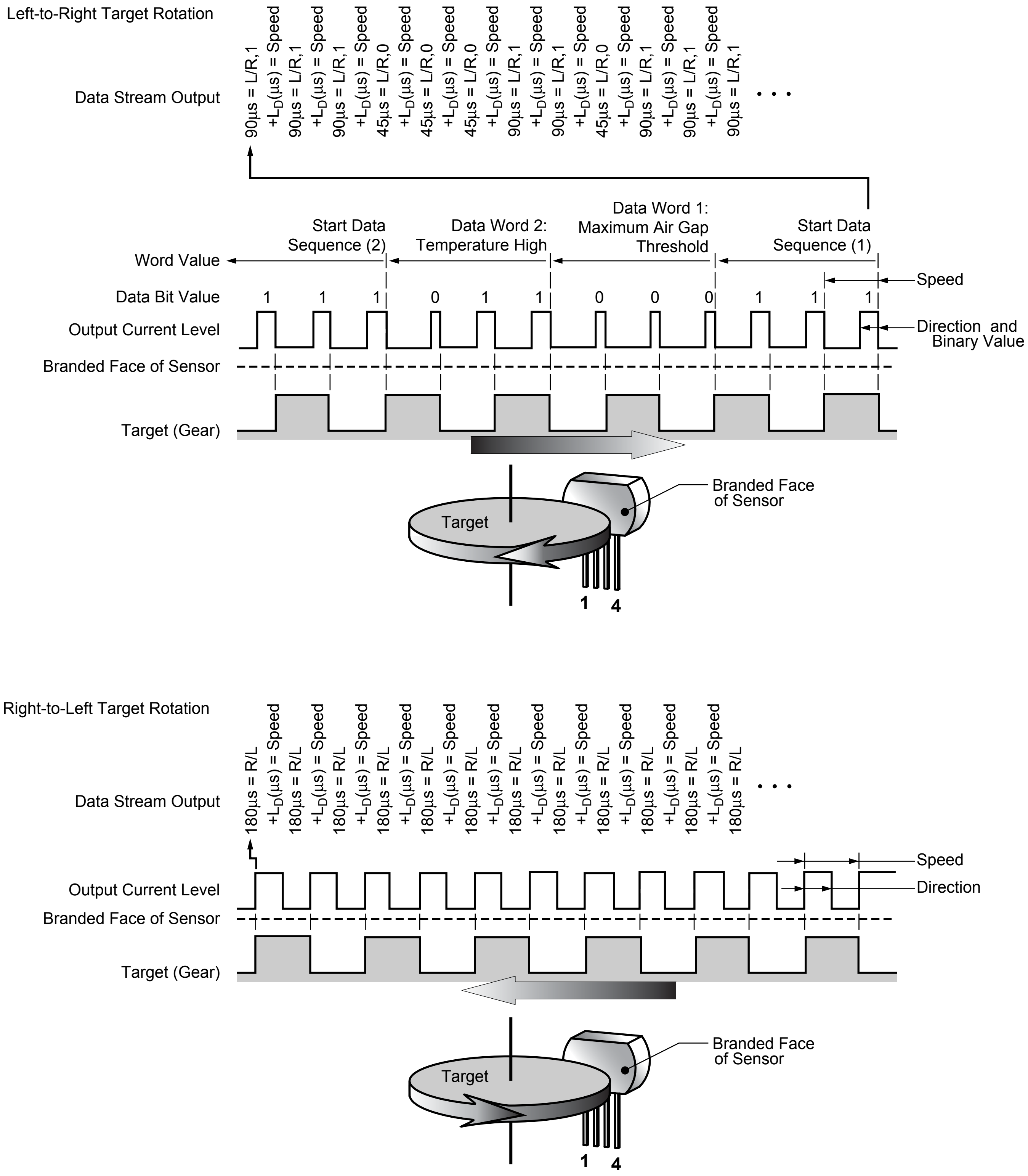
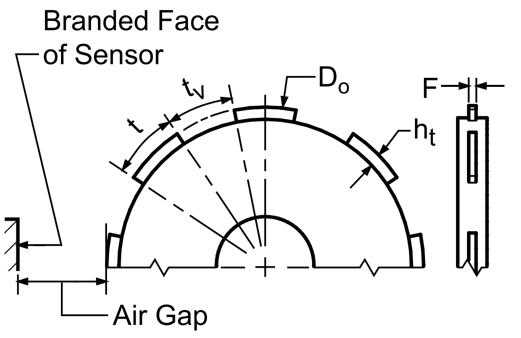
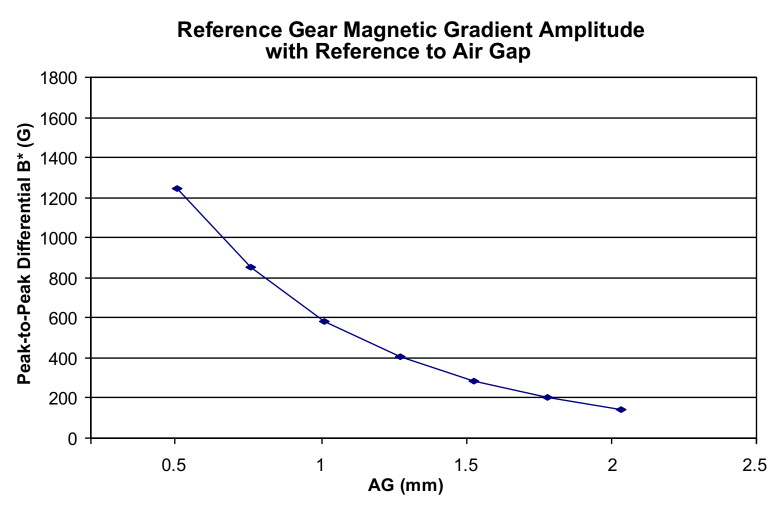
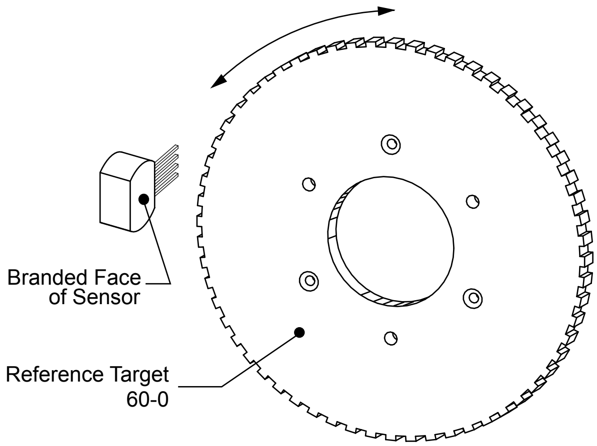


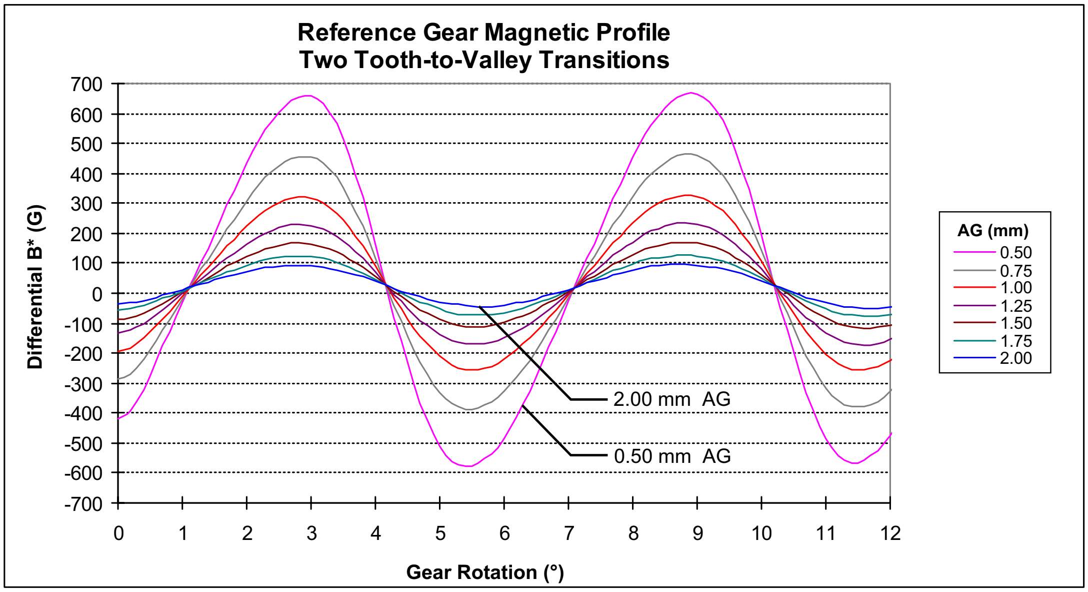
Figure 2. Examples of data encoding capabilites by rotation direction. The upper panel illustrates a typical data sequence that can be generated when the target is rotating left-to-right relative to the sensor. The lower panel illustrates a typical data stream output when the target is rotating in a right-to-left direction relative to the sensor.

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 sensor	6	mm	
Circular Tooth Length	t	Length of tooth, with respect to sensor; measured at D_o	3	mm	
Circular Valley Length	t_v	Length of valley, with respect to sensor; measured at D_o	3	mm	
Tooth Whole Depth	h_t		3	mm	
Material		Low Carbon Steel	–	–	



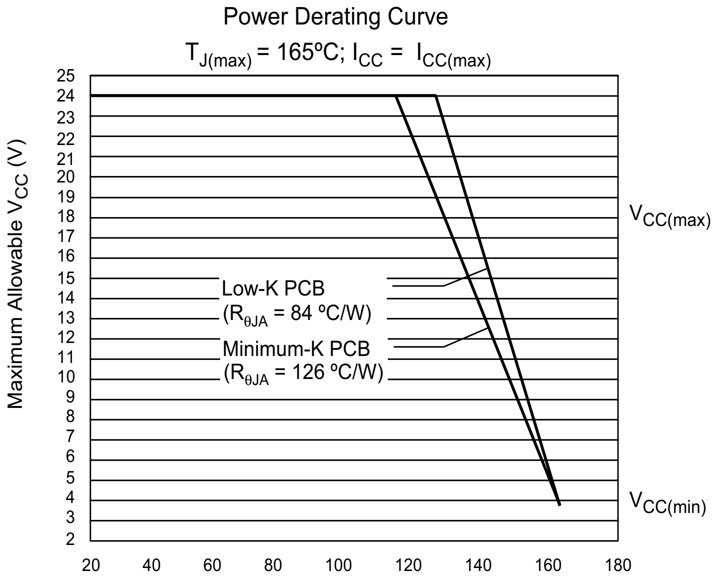


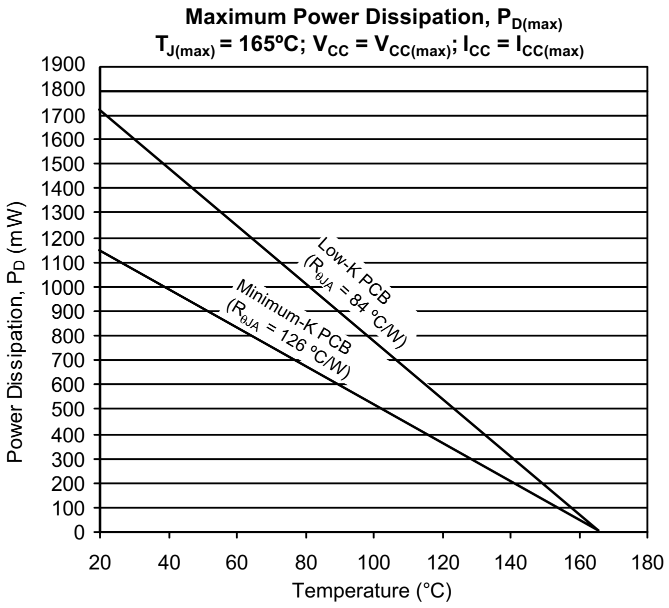


*Differential B corresponds to the calculated difference in the magnetic field as sensed simultaneously at the two Hall elements in the device ($B_{DIFF} = B_{E1} - B_{E2}$).

THERMAL CHARACTERISTICS may require derating at maximum conditions, see application information

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max	Units
Package Thermal Resistance	$R_{\theta JA}$	Minimum-K PCB (single-sided with copper limited to solder pads)	126	–	–	ºC/W
		Low-K PCB (single-sided with copper limited to solder pads and 3.57 in.^{2} (23.03 cm^2) of copper area)	84	–	–	ºC/W





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 Web site.)

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.

$$P_D = V_{IN} \times I_{IN} \qquad (1)$$

$$\Delta T = P_D \times R_{\theta JA} \qquad (2)$$

$$T_J = T_A + \Delta T \qquad (3)$$

For example, given common conditions such as: $T_A = 25°C$, $V_{CC} = 12$ V, $I_{CC} = 4$ mA, and $R_{\theta JA} = 140$ °C/W, then:

$$P_D = V_{CC} \times I_{CC} = 12 \text{ V} \times 4 \text{ mA} = 48 \text{ mW}$$

$$\Delta T = P_D \times R_{\theta JA} = 48 \text{ mW} \times 140 \text{ °C/W} = 7\text{°C}$$

$$T_J = T_A + \Delta T = 25\text{°C} + 7\text{°C} = 32\text{°C}$$

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 $T_A = 150°C$, package L-I1, using minimum-K PCB

Observe the worst-case ratings for the device, specifically: $R_{\theta JA} = 126°C/W$, $T_{J(max)} = 165°C$, $V_{CC(max)} = 24$ V, and $I_{CC(max)} = 16$ mA.

Calculate the maximum allowable power level, $P_{D(max)}$. First, invert equation 3:

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

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

$$P_{D(max)} = \Delta T_{max} \div R_{\theta JA} = 15\text{°C} \div 126 \text{ °C/W} = 119 \text{ mW}$$

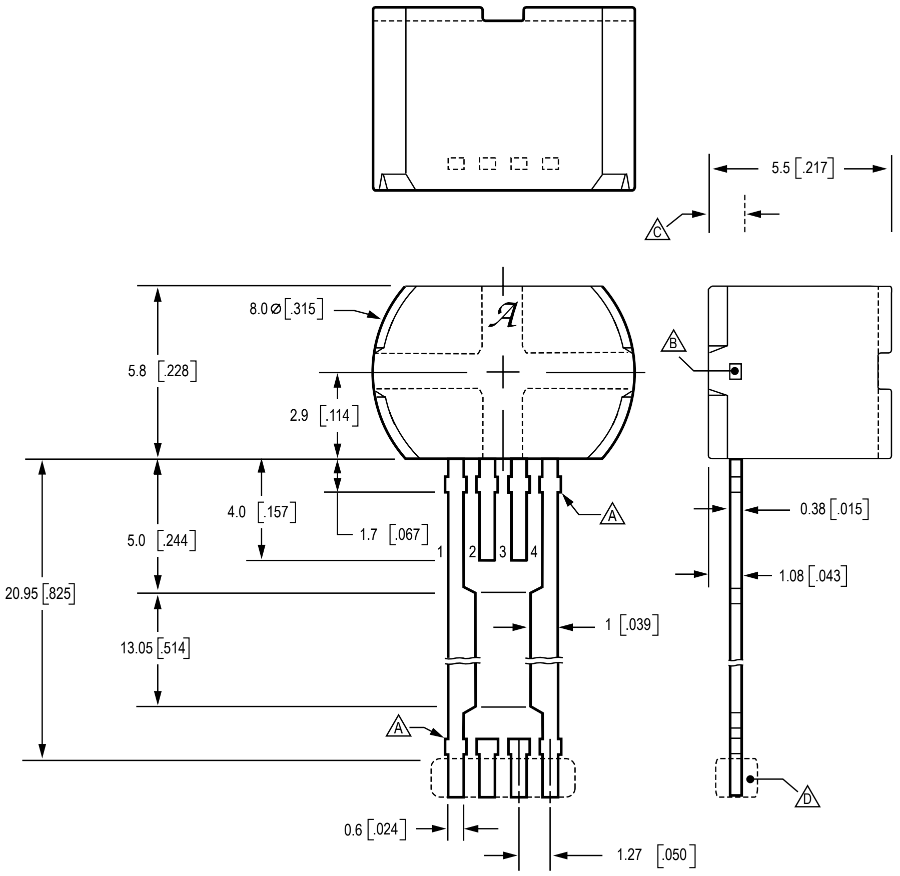
Finally, invert equation 1 with respect to voltage:

$$V_{CC(est)} = P_{D(max)} \div I_{CC(max)} = 119 \text{ mW} \div 16 \text{ mA} = 7 \text{ V}$$

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 SH



Dimensions in millimeters. Untoleranced dimensions are nominal.
U.S. Customary dimensions (in.) in brackets, for reference only
A Dambar removal protrusion
B Metallic protrusion, electrically connected to pin 4 and substrate (both sides)
C Active Area Depth 0.43 mm [.017]
D Thermoplastic Molded Lead Bar for alignment during shipment

The products described herein are manufactured under one or more of the following U.S. patents: 5,045,920; 5,264,783; 5,442,283; 5,389,889; 5,581,179; 5,517,112; 5,619,137; 5,621,319; 5,650,719; 5,686,894; 5,694,038; 5,729,130; 5,917,320; and other patents pending.

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