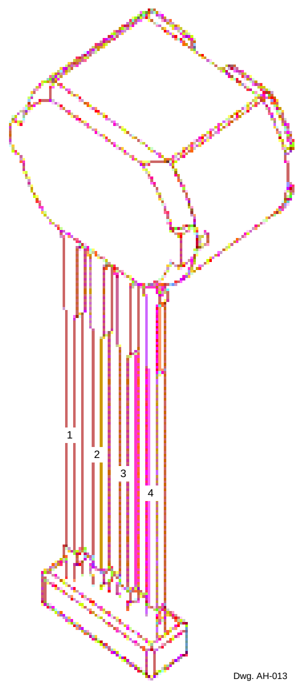
ATS665LSG

Data Sheet
27627.134

PRELIMINARY INFORMATION
(subject to change without notice)
July 2, 2003

TRUE ZERO-SPEED, HALL-EFFECT ADAPTIVE GEAR-TOOTH SENSOR



Pin 1 = Supply
Pin 2 = Output
Pin 3 = Test
Pin 4 = Ground

ABSOLUTE MAXIMUM RATINGS
at T_A = 25°C

Supply Voltage, V_{CC}	**26.5 V**
Reverse Supply Voltage, V_{RCC}	**-18 V**
Output OFF Voltage, V_{OUT}	**26.5 V**
Reverse Output Voltage, V_{ROUT}	**-18 V**
Continuous Output Current, I_{OUT}	**20 mA**
Reverse Output Current, I_{ROUT}	**-50 mA**
Package Power Dissipation, P_D	**See Graph**
Operating Temperature Range, T_A	**-40°C to +160°C**
Junction Temperature, (continuous), T_J	**+170°C**
(100 hr), T_{JM}	**+185°C**
Storage Temperature, T_S	**+170°C**

The ATS665LSG is an optimized Hall IC/magnet configuration packaged as a molded module that provides a user-friendly solution for digital gear-tooth-sensing applications. This digital differential Hall-effect sensor is the choice when repeatability and timing accuracy count. The module incorporates patented self-calibration circuitry that nulls out the effects of installation air gap, ambient temperature, and magnet offsets to provide superior timing accuracy with symmetrical targets over large operating air gaps — typical of targets used in speed-sensing automotive transmission applications. The self-calibration at power up keeps the performance optimized over the life of the sensor. The ATS665LSG has an open-collector output for direct digital interfacing with no further signal processing required.

The integrated circuit incorporates a dual-element Hall-effect sensor and signal processing that switches in response to differential magnetic signals created by a ferrous target. The circuitry contains a sophisticated digital circuit to reduce the detrimental effects of magnet and system offsets and to achieve true zero-speed operation. Digital processing of the analog signal provides zero-speed performance independent of air gap and also dynamic adaptation of device performance to the typical operating conditions found in automotive applications (reduced vibration sensitivity). High-resolution, peak-detecting DACs are used to set the switching thresholds; hysteresis reduces the negative effects of any anomalies in the magnetic signal associated with the target.

FEATURES & BENEFITS

- True zero-speed operation
- Air-gap independent switch points
- High vibration immunity
- Precise duty cycle over temperature
- Large operating air gap range
- Defined power-on state
- Wide operating voltage range
- Digital output representing target profile
- Single-chip sensing IC for high reliability
- Small mechanical size (8 mm diameter x 5.5 mm length)
- Optimized Hall IC magnetic circuit
- Short power up time
- AGC and reference adjust circuit
- Undervoltage lockout

Always order by complete part number: **ATS665LSG** .

ATS665LSG
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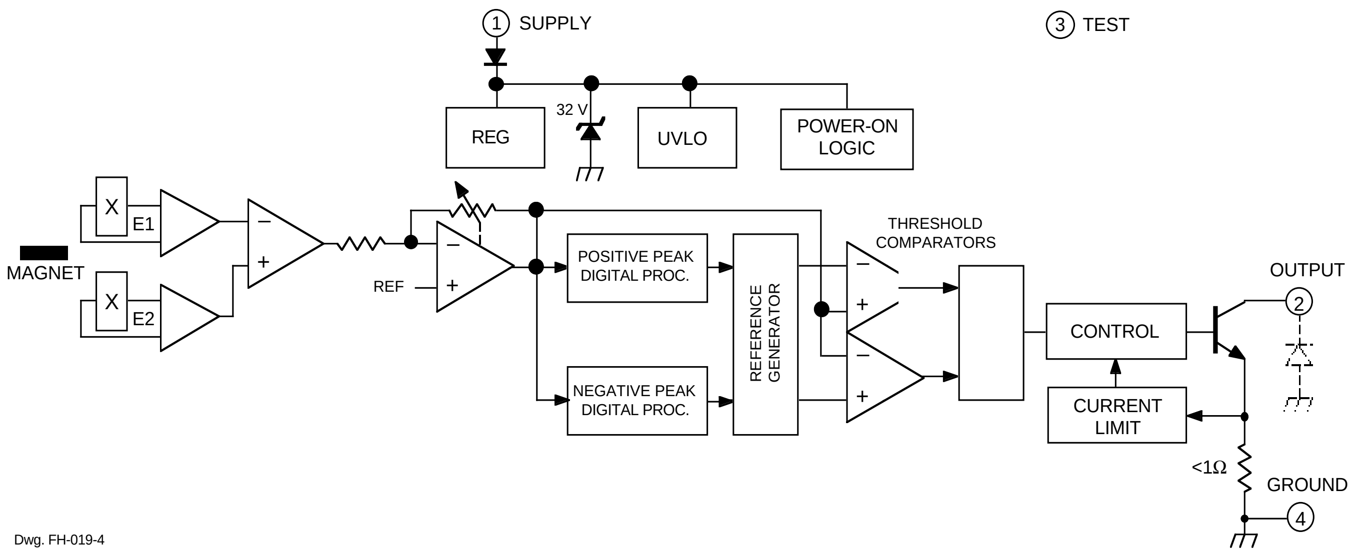
FUNCTIONAL BLOCK DIAGRAM



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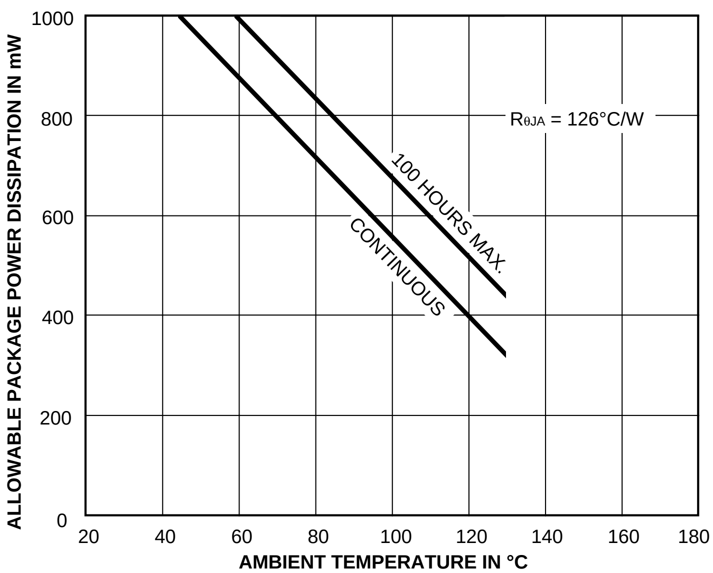

$R_{θJA}$ is measured on typical two-sided PCB with minimal copper ground area. $R_{θJA}$ can be reduced to 95°C/W with 1 square inch copper ground area at pin 4 or to 86°C/W with 3.5 square inch copper ground area at pin 4.

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ELECTRICAL CHARACTERISTICS over operating voltage and temperature ranges (unless otherwise noted).

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Supply Voltage	V_{CC}	Operating, T_J < 170°C	3.3	12	24	V
Power-On State	POS	V_{CC} = 0 → 5 V	HIGH*	HIGH*	HIGH*	–
Undervoltage Lockout	$V_{CC(UV)}$	V_{CC} = 0 → 5 V	–	–	3.3	V
Low Output Voltage	$V_{OUT(SAT)}$	I_{OUT} = 20 mA	–	200	400	mV
Output Current Limit	I_{OUTM}	V_{OUT} = 12 V	25	45	70	mA
Output LeakageCurrent	I_{OFF}	V_{OUT} = 24 V	–	–	10	µA
Supply Current	I_{CC}	Output off	–	8.2	15	mA
		Output on	–	8.2	15	mA
Reverse Supply Current	I_{RCC}	V_{CC} = -18 V	–	–	-10	mA
Output Rise Time	I_r	R_L = 500 Ω, C_L = 10 pF	–	1.0	2.0	µs
Output Fall Time	I_f	R_L = 500 Ω, C_L = 10 pF	–	0.6	2.0	µs
Power-On Time	t_{on}	Reference gear, <100 rpm	–	–	200	µs
Zener Voltage	V_Z	I_{ZT} = TBD	26.5	32	38	V

* Output transistor is off (high logic level).

ATS665LSG
TRUE ZERO-SPEED, HALL-EFFECT ADAPTIVE GEAR-TOOTH SENSOR

OPERATION with reference gear over operating voltage and temperature ranges.

Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
Air-Gap Range	AG	Operational	0.5	–	2.5	mm
Calibration Cycle	n_{cal}	Output edges before which calibration is completed	3	3	3	Teeth
Recalibration (Update)	n_{rcal}	Operating	Continuous			Teeth
Minimum Speed	v_{min}		–	0	–	rpm
Maximum Speed	v_{max}		12000*	–	–	rpm
Bandwidth	f_{max}	-3 dB	20*	–	–	kHz
Operate Point	$B_{OP\%}$	% of peak-to-peak signal, output high to low†	–	70	–	%
Release Point	$B_{RP\%}$	% of peak-to-peak signal, output low to high†	–	30	–	%
Duty Cycle Range	DC	1000 rpm, 0.5 mm < AG < 2.5 mm	43	48	53	%
Operating Signal	–	Bmax - Bmin	60	–	–	G

* Operation at a frequency (teeth per second) greater than the specified minimum value is possible but not warranteed.

† See switching references figure, page 11.

60-0 REFERENCE TARGET/GEAR DIMENSIONS (low carbon steel)

Characteristic	Symbol	Description	Limits			
			Min.	Typ.	Max.	Units
Diameter	D_O		–	120	–	mm
Tooth Width	T		–	3.0	–	mm
Valley Width	$(p_C – T)$		–	3.0	–	mm
Valley Depth	h_t		–	3.0	–	mm
Thickness	F		–	6.0	–	mm

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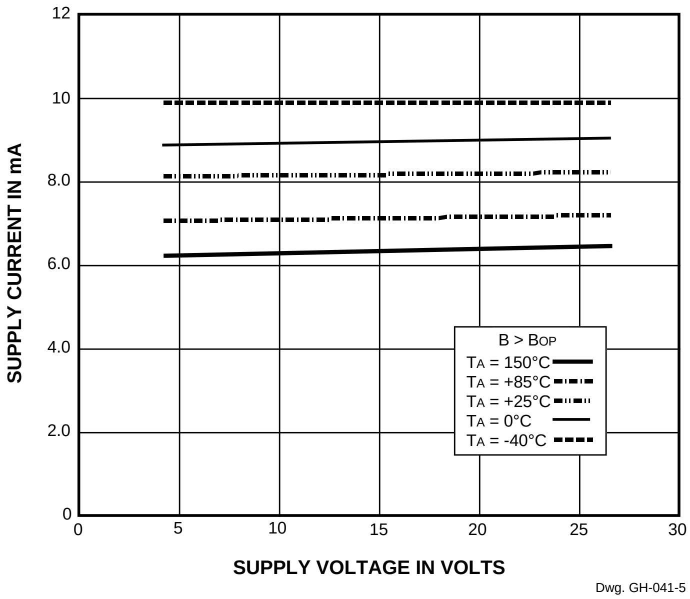
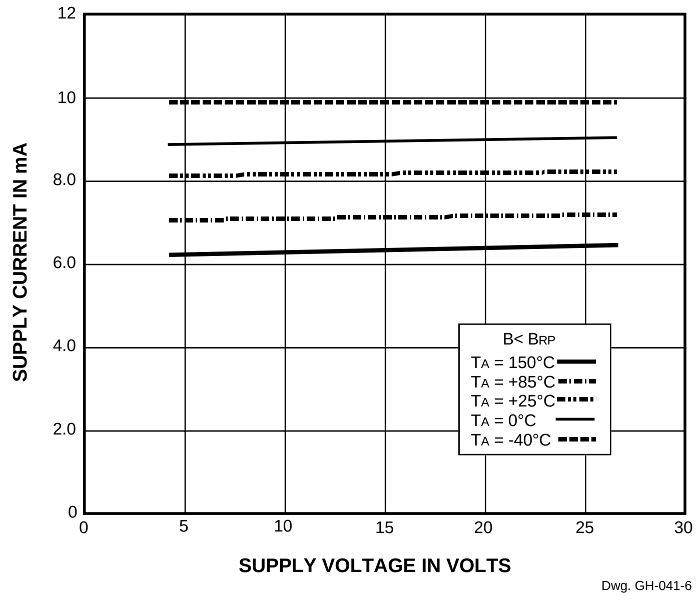
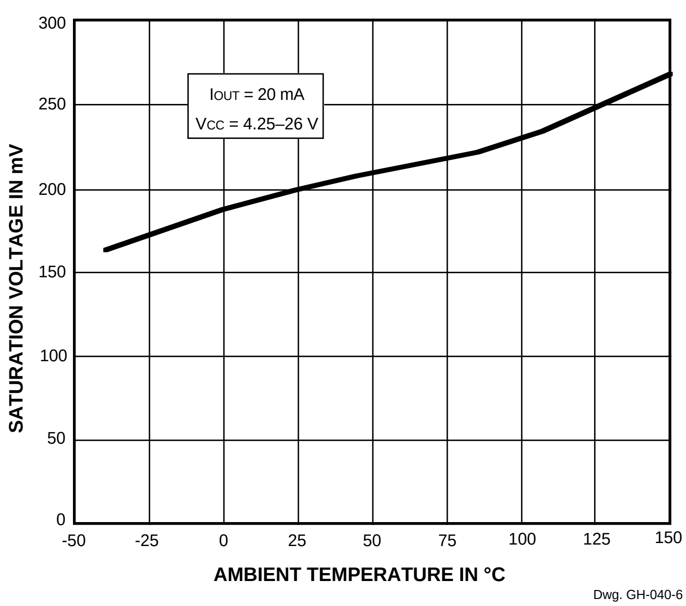
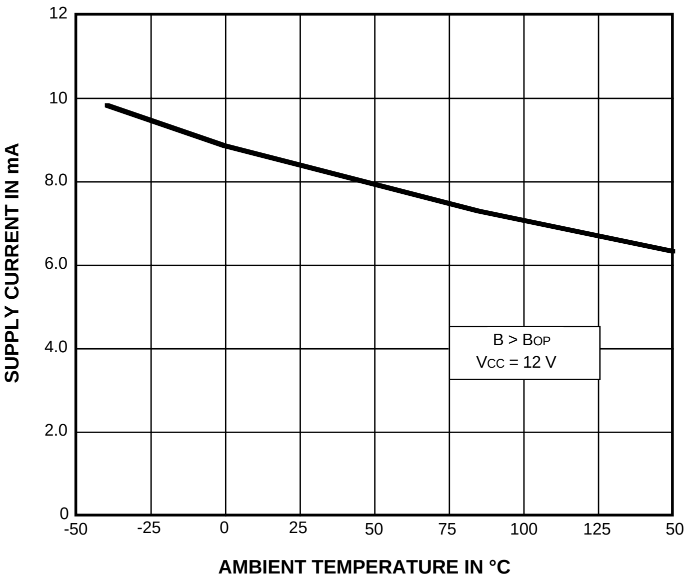
TYPICAL CHARACTERISTICS







TYPICAL CHARACTERISTICS (cont'd)



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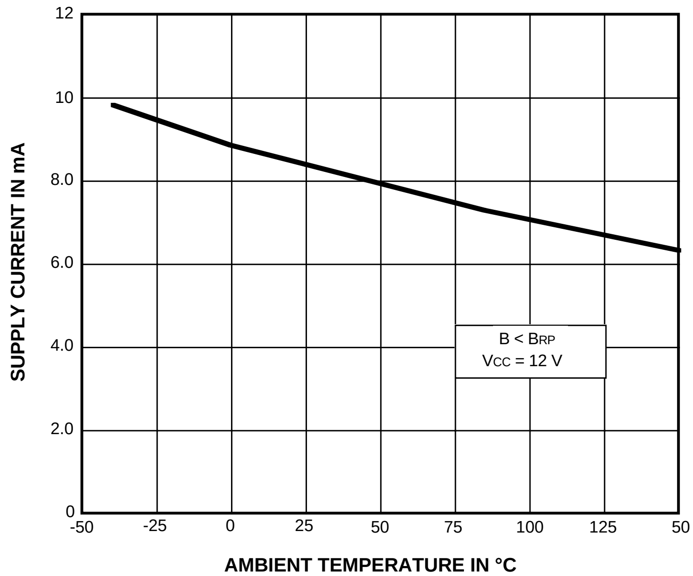

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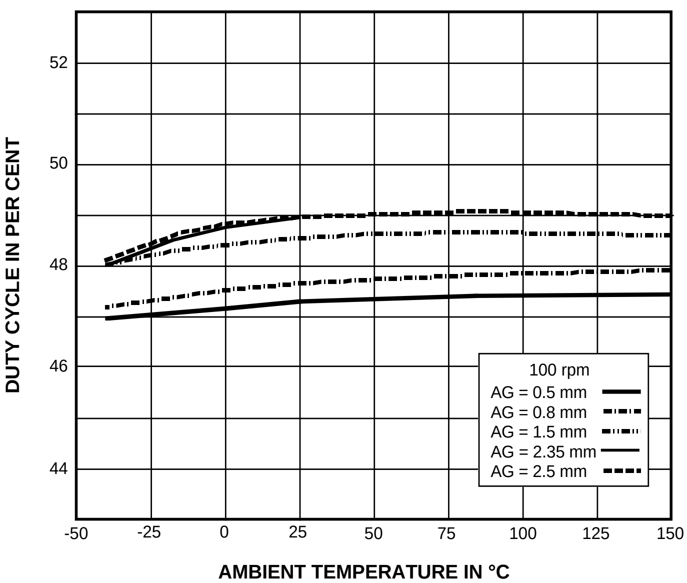

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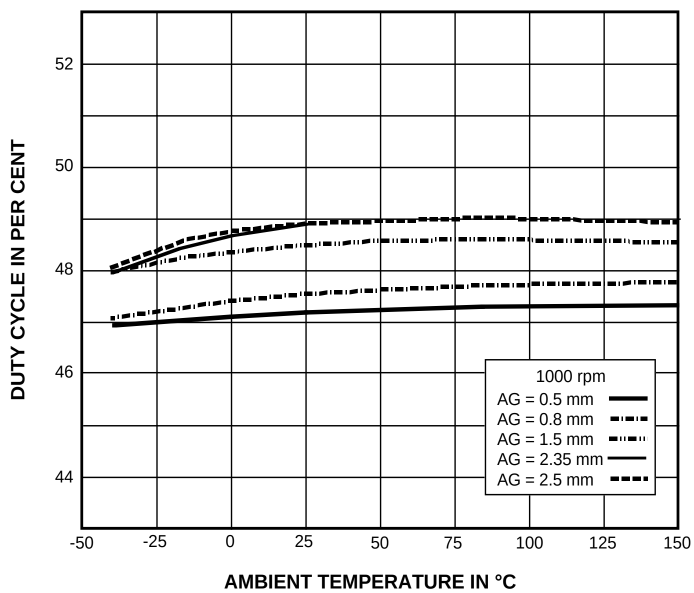

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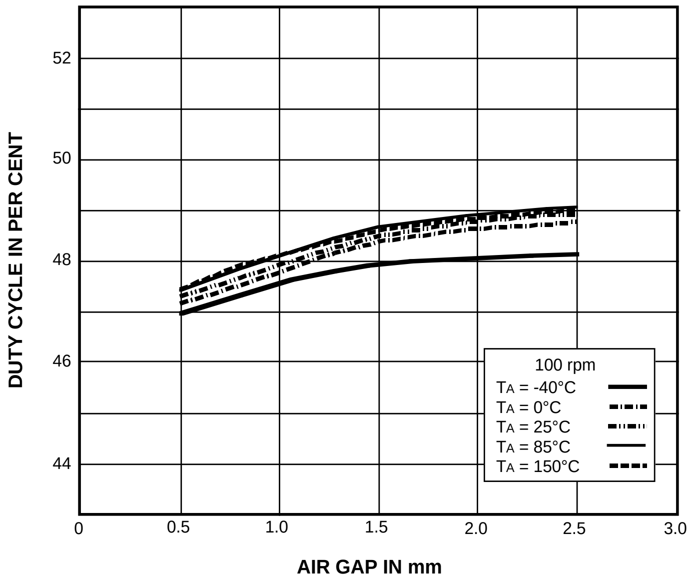
TYPICAL CHARACTERISTICS (cont'd)



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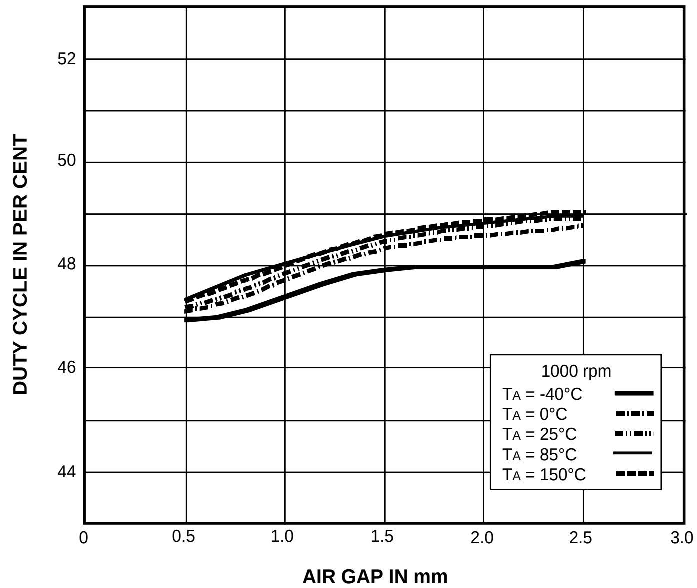

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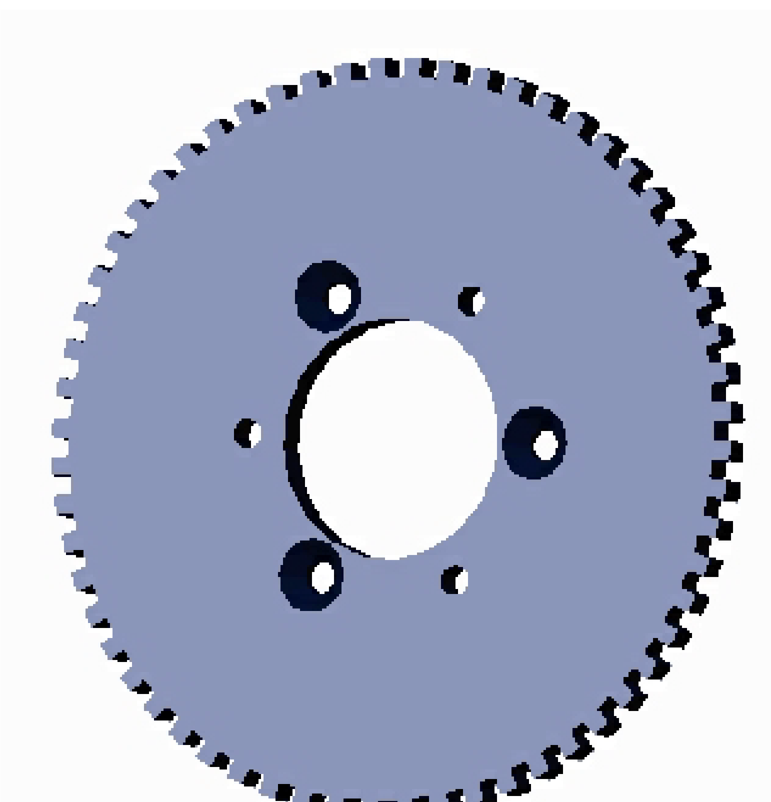


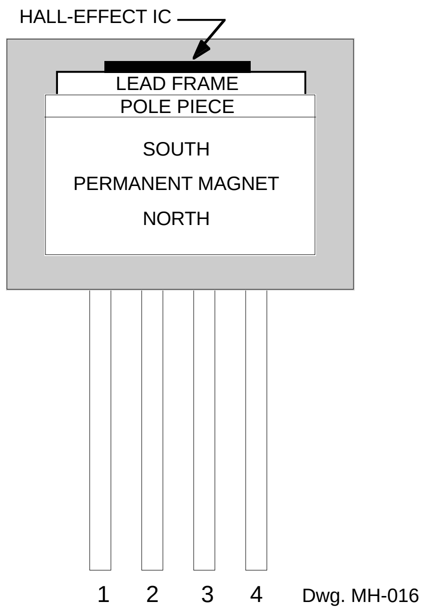
Dwg. AH-014

Typical 60-0 target
See page 4 for dimensions.

ATS665LSG
TRUE ZERO-SPEED,
HALL-EFFECT ADAPTIVE
GEAR-TOOTH SENSOR

DEVICE DESCRIPTION

Module description. The ATS665LSG true zero-speed gear-tooth sensor system is a Hall IC + magnet configuration that is fully optimized to provide digital detection of gear-tooth* edges in a small package size. The sensor is integraly molded into a plastic body that has been optimized for size, ease of assembly, and manufacturability. High operating-temperature materials are used in all aspects of construction.

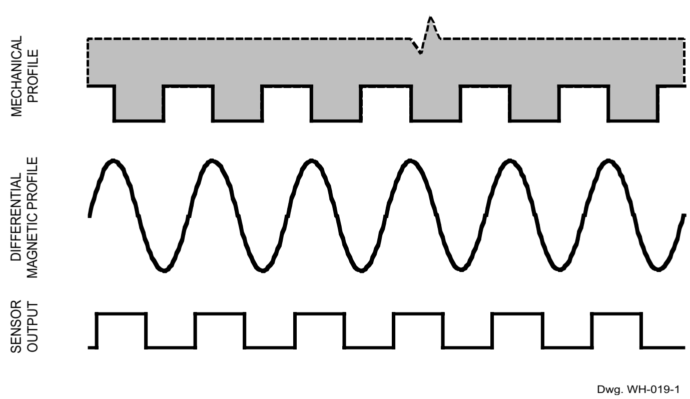


Internal construction

Sensing technology. The gear-tooth sensor contains a single-chip differential Hall-effect sensor IC, a samarium-cobalt magnet, and a flat ferrous pole piece. The Hall IC consists of two Hall elements spaced 2.2 mm apart, located so as to measure the magnetic gradient created by the passing of a ferrous object (a gear tooth). The two elements measure the field gradient and convert it to an analog voltage that is then processed to provide a digital output signal.

The two Hall transducers and the electronics are integrated on a single silicon substrate using a proprietary BiCMOS process.

Operation. After correct power is applied to the component, it is capable of providing digital information that is representative of the profile of a rotating gear. No additional optimization is needed and minimal processing circuitry is required. This ease of use should reduce design time and incremental assembly costs for most applications.



Digital output representative of target profile

Solution advantages. The ATS665LSG true zero-speed detecting gear-tooth sensor uses a differential Hall-element configuration. This configuration is superior in most applications to a classical single-element GTS. The single-element configuration commonly used requires the detection of an extremely small signal (often <100 G) that is superimposed on an extremely large back biased field, often 1500 G to 3500 G. For most gear configurations, the back-biased field values change due to concentration effects, resulting in a varying baseline with air gap, with eccentricities, and with vibration. The differential con-

* In application, the terms "gear" and "target" are often interchanged. However, "gear" is preferred when motion is transferred.

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DEVICE DESCRIPTION — Continued

figuration eliminates the effects of the back-biased field through subtraction and, hence, avoids the issues presented by the single Hall element. The signal-processing circuitry also greatly enhances the functionality of this device. Other advantages are

- temperature drift† — changes in temperature do not greatly affect this device due to the stable amplifier design and the offset rejection circuitry,
- timing accuracy/duty cycle variation due to air gap† — the accuracy variation caused by air-gap changes is minimized by the self-calibration circuitry. A two-to-three times improvement can be seen over conventional zero-crossing detectors,
- dual edge detection — because this device references the positive and negative peaks of the signal, dual edge detection is guaranteed,
- immunity to magnetic overshoot — the air-gap independent hysteresis minimizes the impact of overshoot on the switching of device output,
- response to surface defects in the gear — the gain-adjust circuitry reduces the effect of minor gear anomalies that would normally causes false switching,
- immunity to vibration and backlash — the gain-adjust circuitry keeps the hysteresis of the device roughly proportional to the peak-to-peak signal. This allows the device to have good immunity to vibration even when operating at close air gaps,
- immunity to gear run out — the differential-sensor configuration eliminates the base-line variations caused by gear run out, and
- use with stamped-gear configurations — the high-sensitivity switch points allow the use of stamped gears. The shallow mechanical slopes created by the stamping process create an acceptable magnetic gradient down to zero speed. The surface defects caused by stamping the gear are ignored through the use of gain control circuitry.

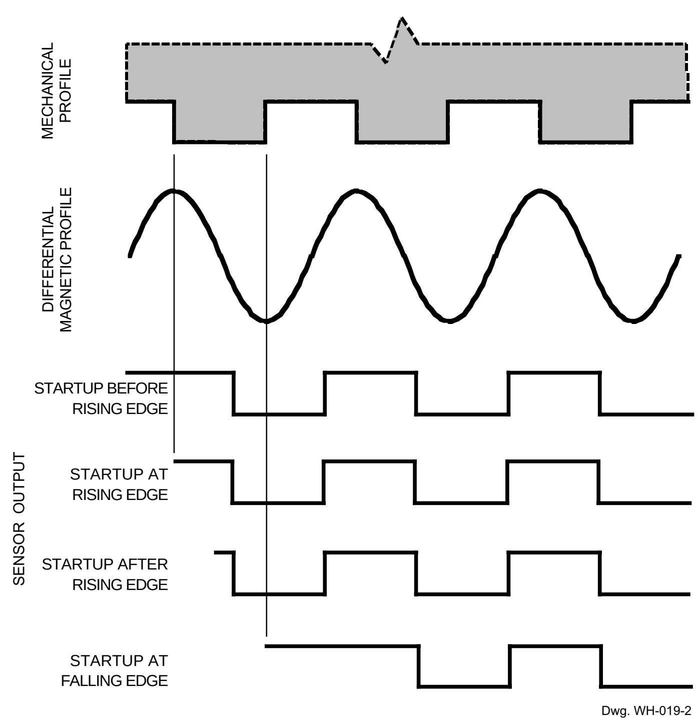
Operation versus air-gap/tooth geometry. Operating specifications are impacted by tooth size, valley size and depth, gear material, and gear thickness. In general, the following guidelines should be followed to achieve greater than 2 mm air gap from the face of unit:

- tooth width (T) > 2 mm;
- valley width (p_C - T) > 2 mm;
- valley depth (h_t) > 2 mm;
- gear thickness (F) > 3 mm; and the
- gear material must be low-carbon steel.

Signal duty cycle. For regular tooth geometry, precise duty cycle is maintained over the operating air-gap and temperature range due to an extremely good symmetry in the magnetic switch points of the device.

Power-on state operation. The device is guaranteed to power on (power up) in the off state (high output voltage) regardless of the presence or absence of a gear tooth.

The first edge seen by the sensor will be missed if the switching caused by that edge reinforces the off state. Therefore, the first edge that can be guaranteed to cause an output transition is the second detected edge. This device has accurate first falling edge detection.



First-edge detection

† Target must be rotating for proper update algorithim operation.

DEVICE DESCRIPTION — Continued

Undervoltage lockout. If the supply voltage falls below the minimum operating voltage ($V_{CC(UV)}$), the device output will turn off (high output voltage) and stay off irrespective of the state of the magnetic field. This prevents false signals caused by undervoltage conditions from propagating through to the output of the sensor.

Output. The output of the sensor is a short-circuit-protected open-collector stage capable of sinking 20 mA. An external pull-up (resistor) to a supply voltage of not more than 26.5 V must be supplied.

Output polarity. The output of the device will switch from low to high (on to off) as the leading edge of the target passes the sensor face in the direction indicated (pin 1 to pin 4), which means that the output voltage will be high when the unit is facing a tooth.

If rotation is in the opposite direction (pin 4 to pin 1), the output of the device will switch from high to low as the leading edge of the target passes the sensor, which means that the output voltage will be low when the unit is facing a tooth.

Power supply protection. The device contains an on-chip regulator and can operate over a wide supply voltage range. For devices that need to operate from an unregulated power supply, transient protection should be added externally. For applications using a regulated line, EMI/RFI protection is still required. Incorrect protection can result in unexplained pulses on the output line, providing inaccurate sensing information to the user.

Internal electronics. The ATS665LSG is a self-calibrating sensor that contains two Hall-effect elements, a temperature-compensated amplifier, and offset cancellation circuitry. Also contained in the device is a voltage regulator to provide supply rejection over the operating voltage range. The Hall transducers and the electronics are integrated on the same silicon substrate using a proprietary BiCMOS process. Changes in temperature do not greatly affect this device due to the stable amplifier design and the offset rejection circuitry.

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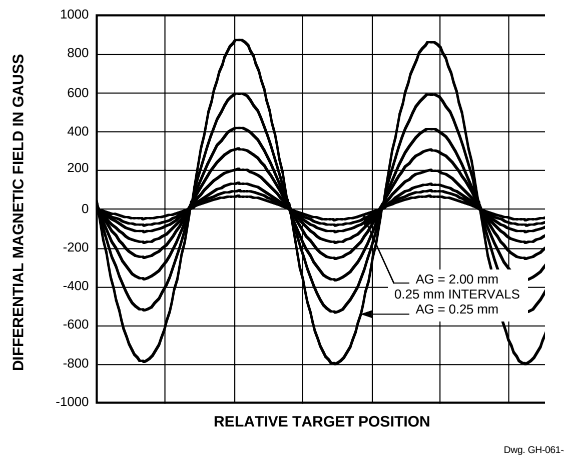
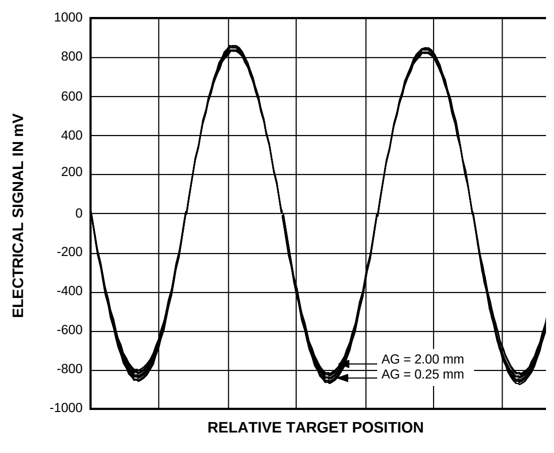
DEVICE DESCRIPTION — Continued

Automatic gain control. The self-calibrating circuitry is unique. After power up, the device measures the peak-to-peak magnetic signal and adjusts the gain using an on-chip D-to-A converter to make the internal signal amplitude constant independent of the installation air gap of the sensor. This feature allows air-gap-independent operational characteristics.

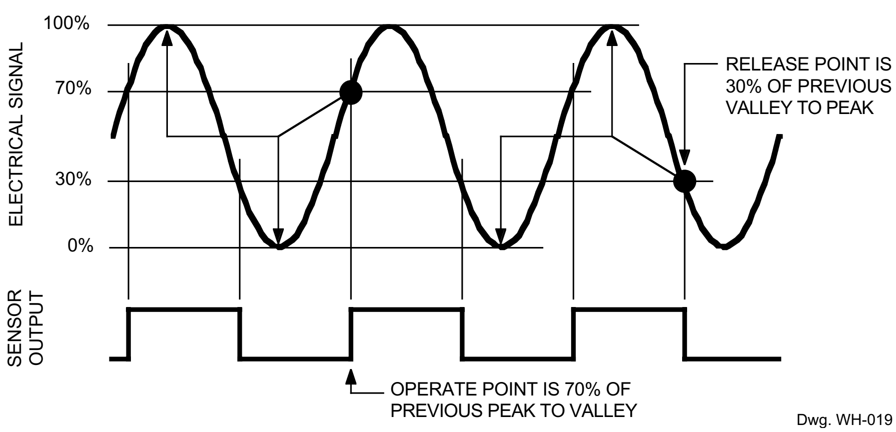
Offset adjust and update. In addition to the gain-control circuitry, the device also has provisions to zero out chip, magnet, and installation offsets. This is accomplished using two D-to-A converters that capture the peak and valley of the signal and use them as a reference for the switching comparator. The switch point for each edge is determined by the previous two edges. Because variations are tracked in real time, the sensor has high immunity to target run-out and retains excellent accuracy and functionality in the presence of both run-out and transient mechanical events. This allows the switch points to be precisely controlled independent of air gap or temperature.



Magnetic signal



Electrical signal after gain control



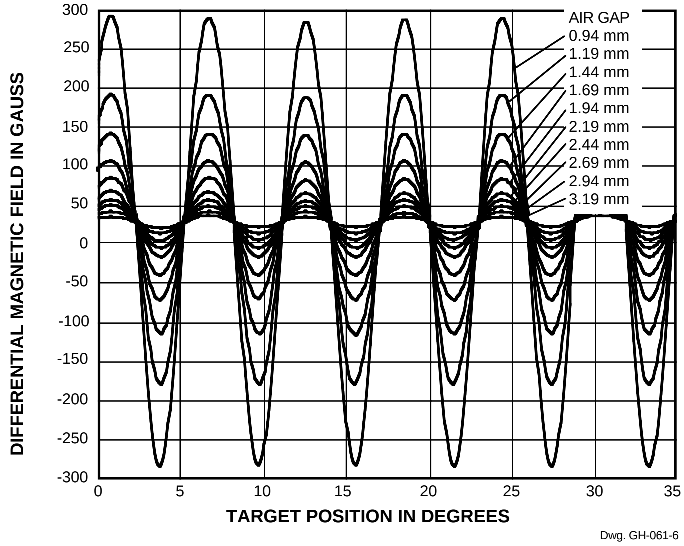
Switching references

SENSOR – TARGET EVALUATION

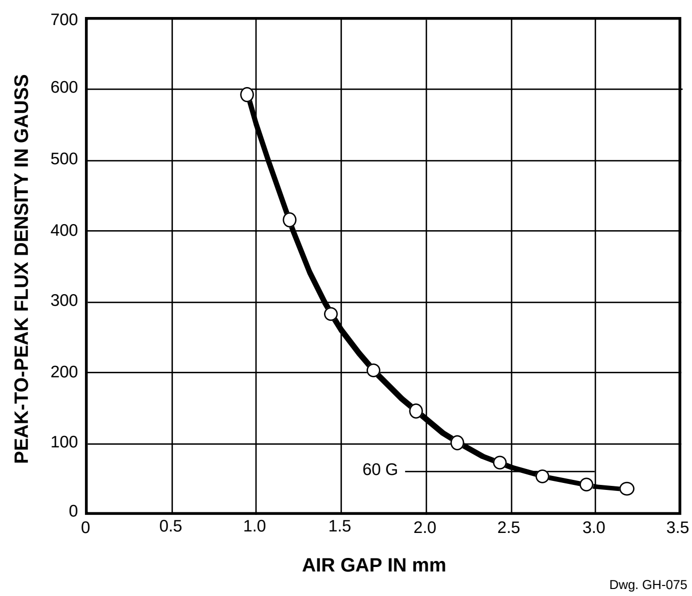
Recommended target evaluation technique. In order to establish the proper operating specification for a particular sensor – target system, a systematic evaluation of the magnetic circuit should be performed. The first step is the generation of a magnetic map of the target. By using a special calibrated version of the ATS665LSG (contact factory), a magnetic signature of the sensor-target system is made.

A single curve is generated from this map data to describe the peak-to-peak magnetic field as a function of the air gap. Knowing the minimum peak-to-peak flux density that guarantees operation of the sensor, one can determine the maximum operational air gap of the sensor-target system. From the target evaluation curve, a minimum peak-to-peak signal of 60 G corresponds to a maximum air gap of approximately 2.5 mm.

Accuracy. While the update algorithm will allow the sensor to adapt to system changes, major changes in air gap can adversely affect switching performance. When characterizing sensor-target performance over a significant air-gap range, be sure to repower the device at each air gap. This ensures that self calibration occurs for each installation condition.



Sensor-target magnetic signature



Target evaluation

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APPLICATIONS INFORMATION

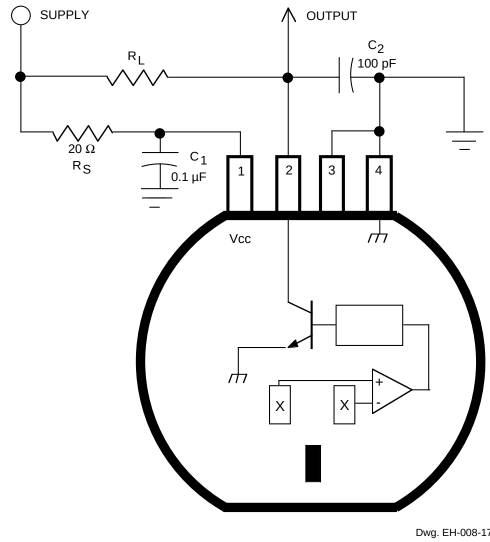
External components. It is strongly recommended that an external bypass capacitor be connected (less than 5 mm from the Hall sensor) between the supply and ground of the device to reduce external noise.

A series resistor (R_S) in combination with the bypass capacitor prevents external EMC pulses from affecting the sensor. The voltage drop across this resistor subtracts from the supply voltage and must be considered.

$$V_{SUPPLY} \geq V_{CC(min)} + (I_{CC} \times R_S)$$

where V_{SUPPLY} is the minimum supply value (including transients), $V_{CC(min)}$ is the specified minimum supply voltage, I_{CC} is the specified maximum supply current and R_S is the maximum series-resistor value (including tolerances). A low operating supply voltage requires a low-value resistor, but noise and other considerations suggest a high-value resistor. Therefore, specify the highest value resistor that will still allow meeting the minimum operating supply voltage requirement. This will also help to minimize package power dissipation (especially under overvoltage conditions).

If not included as part of the load, the output pullup resistor (R_L) should be chosen to limit the current through the output transistor. Do not exceeed the absolute maximum rated output current. Internal current limiting is only intended to protect the device from output short circuits.



Typical application

Power derating. Due to the internal device power dissipation, the junction temperature (T_J) will be higher than the ambient temperature (T_A). To ensure that the absolute maximum junction temperature is not exceeded, the following equations should be applied:

$$T_J = T_A + (P_D \times R_{\theta JA})$$

where P_D is the sum of the supply power

$$I_{CC} \times V_{CC}$$

and the output power

$$I_{OUT} \times V_{OUT(SAT)}$$

and $R_{\theta JA}$ is the package thermal resistance. The specified limits for I_{CC} and $V_{OUT(SAT)}$ should be used to ensure a margin of safety. Note that if an over-voltage condition occurs, I_{CC} will increase, limited only by the internal Zener voltage and the external R_S, and the device will likely be thermally stressed.

Additional applications Information on gear-tooth and other Hall-effect sensors is also available in the "Hall-Effect IC Applications Guide", which can be found in the latest issue of the Allegro MicroSystems Electronic Data Book, AMS-702 or Application Note 27701, or at

www.allegromicro.com

CRITERIA FOR DEVICE QUALIFICATION

All Allegro sensors are subjected to stringent qualification requirements prior to being released to production. To become qualified, except for the destructive ESD tests, no failures are permitted.

Qualification Test	Test Method and Test Conditions	Test Length	Samples Per Lot	Comments
Temperature Humidity Bias Life	JESD22-A101, T_A = 85°C, RH = 85%	1008 hrs	77	Device biased for minimum power
Bias Life	JESD22-A108, T_A = 150°C, $T_J \le$ 165°C	408 hrs	77	Additional hours on agreement of failure rate
(Surge Operating Life)	T_A = 170°C, T_J = 180°C	168 hrs	77	3000 hours on agreement of failure rate
Autoclave, Unbiased	JESD22-A102, T_A = 121°C, 15 psig	96 hrs	77	
High-Temperature (Bake) Storage Life	JESD22-A103, T_A = 170°C	1000 hrs	77	
Temperature Cycle	JESD22-A104, -65°C to +160°C	500 cycles	77	30 s transition, 30 min dwell
Thermal Shock	-40°C to +150°C	100 cycles	77	1 min transition, 10 min dwell
ESD, Human Body Model	CDF-AEC-Q100-002	Pre/Post Reading	3 per test	Test to failure All leads > 4.5 kV*
ESD, Machine Model	CDF-AEC-Q100-003	Pre/Post Reading	3 per test	Test to failure All leads > 200 V
Early Life Failure Rate	CDF-AEC-Q100-008	24 hrs	800	150°C

* With pin 3 tied to pin 4. Isolation of pin 3 may result in reduced ESD performance (2.5 kV).

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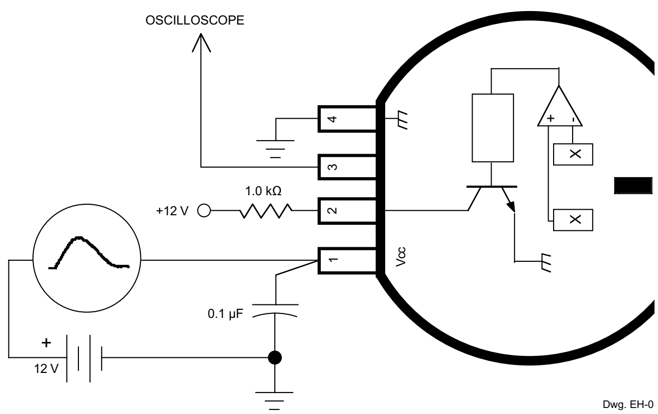
Transient Performance per ISO 7637-1

at T_A = 23 ±5°C, test circuit #1
(Tested at Allegro test facility — for engineering reference only)

Pulse No.	Test	Performance Class at Test Level I	II	III	IV
1	Inductive turn off (negative)	E	–	–	–
2	Inductive turn off (positive)	C	C	E	–
3a	Capacitive/inductive coupling (neg)	–	–	–	A
3b	Capacitive/inductive coupling (pos)	–	–	–	A
4	Reverse battery	–	–	–	A
5	Load dump:	C	E	–	–
6	Ignition coil disconnect	C	E	–	–
7	Field decay (negative)	C	E	–	–



Transient & TEM test circuit #1

Power supply voltage transients, or device output short circuits, may be caused by faulty connectors, crimped wiring harnesses, or service errors. To prevent catastrophic failure, internal protection against overvoltage, reverse voltage, and output overloads have been incorporated to meet the automotive 12 volt system protection requirements of ISO DP7637/1. A series-blocking diode or current-limiting resistor is required in order to survive pulse number six.

Performance Class Definitions

(for transient performance and EMC performance)

A — All functions of a device perform as designed during and after the exposure.

B — All functions of a device perform as designed during exposure; however, one or more of them may go beyond the specified limit tolerance. All functions return automatically to within normal limits afer exposure is removed. Memory must remain Class A.

C — One or more functions of the device do not perform as designed during exposure but return automatically to normal operation after exposure is removed.

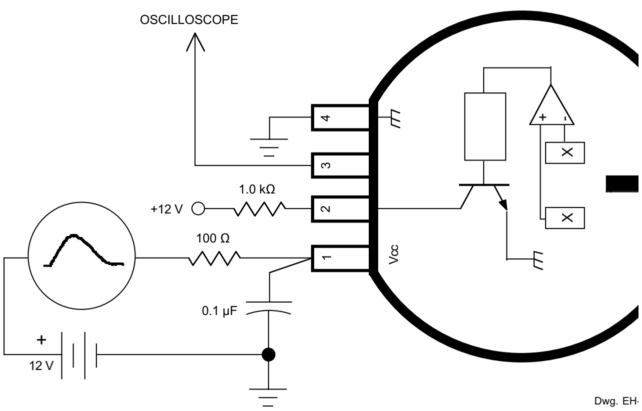
D — One or more functions of the device do not perform as designed during exposure and do not return to normal operation until exposure is removed and the device is reset by simple “operator” action.

E — One or more functions of the device do not operform as designed during and after the exposure and cannot be returned to proper operation without repairing or replacing the device.

Transient Performance per ISO 7637-1

at T_A = 23 ±5°C, test circuit #2
(Tested at Allegro test facility — for engineering reference only)

Pulse No.	Test	Performance Class at Test Level I	II	III	IV
1	Inductive turn off (negative)	C	C	C	C
2	Inductive turn off (positive)	–	–	–	C
3a	Capacitive/inductive coupling (neg)	–	–	–	A
3b	Capacitive/inductive coupling (pos)	–	–	–	A
4	Reverse battery	–	–	–	A
5	Load dump:	A	C	E	–
6	Ignition coil disconnect	C	C	C	C
7	Field decay (negative)	C	C	C	C



Transient test circuit #2

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.

Allegro MicroSystems, Inc. reserves the right to make, from time to time, such departures from the detail specifications as may be required to permit improvements in the performance, reliability, or manufacturability of its products. Before placing an order, the user is cautioned to verify that the information being relied upon is current.

Allegro products are not authorized for use as critical components in life-support appliances, devices, or systems without express written approval.

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ELECTROMAGNETIC COMPATIBILITY (EMC) PERFORMANCE

at T_A = 23 ±5°C, test circuit #1
(Tested at Allegro test facility — for engineering reference only)

Transferse Electro-Magnetic (TEM) Radiation Performance per ISO 11452-3

Test severity level
I = 50 V/m
II = 100 V/m
III = 150 V/m
IV = 200 V/m

Frequency band (MHz)	Performance Class at Test Level			
	I	II	III	IV
F1 (0.01 to 10)	–	–	–	A
F2 (0 to 30)	–	–	–	A
F3 (30 to 80)	–	–	–	A
F4 (80 to 200)	–	–	–	A

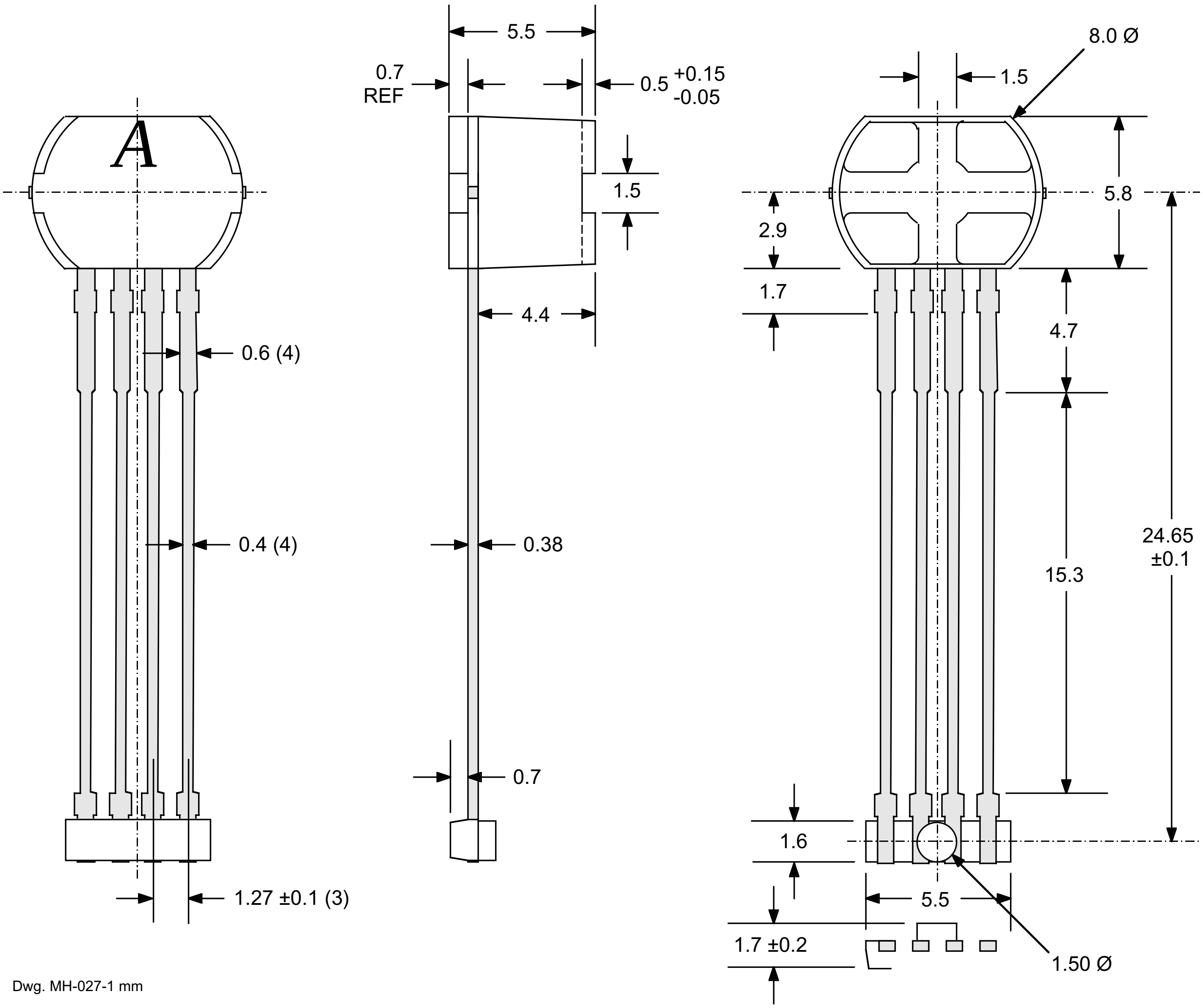
MECHANICAL INFORMATION

Component	Material	Function	Units
Element Spacing			2.2 mm
Sensor Face	Thermoset epoxy	Maximum temperature	170°C*
Sensor Housing	Thermoset epoxy	Maximum temperature	170°C*
Flame Class Rating	—	—	UL94V-0
Leads	Copper	—	—
Lead Finish	90/10 tin/lead solder plate	—	†
Lead Pull	—	—	13 N

*Temperature excursions to 260 °C for 2 minutes or less are permitted (based on delamination studies).
†All industry-accepted soldering techniques are permitted for these modules provided the indicated maximum temperature is not exceeded.

ATS665LSG
TRUE ZERO-SPEED, HALL-EFFECT ADAPTIVE GEAR-TOOTH SENSOR

DIMENSIONS IN MILLIMETERS



Tolerances, unless otherwise specified: 1 place ±0.1 mm, 2 places ±0.05 mm.

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