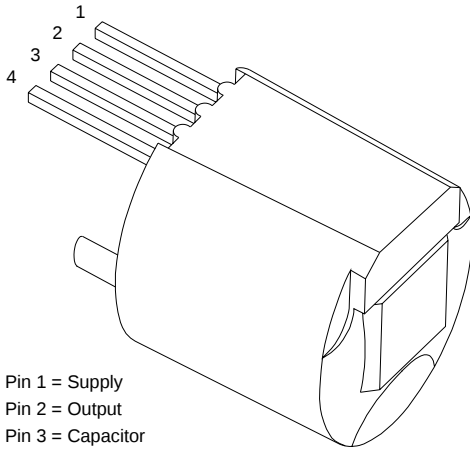


ATS610LSA AND ATS611LSB

Data Sheet
27627.100

DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS



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

Dwg. AH-006

ABSOLUTE MAXIMUM RATINGS over operating temperature range

Supply Voltage, V_{CC} **16 V***
Reverse Supply Voltage, V_{RCC} **-0.5 V**
Output OFF Voltage, V_{OUT} **18 V**
Reverse Output Voltage, V_{OUT} **-0.5 V**
Continuous Output Current, I_{OUT} ... **25 mA**
Minimum External Capacitance,
 C_3 **0.1 μ F**
Package Power Dissipation,
 P_D **See Graph**
Operating Temperature Range,
 T_A **-40°C to +150°C***
Storage Temperature, T_S **+170°C**

* Operation at increased supply voltages with external circuitry is described in Applications Information. Devices for operation at increased temperatures are available on special order.

The ATS610LSA and ATS611LSB gear-tooth sensors are optimized Hall IC plus magnet modules that provide a user-friendly solution for digital gear-tooth sensing applications. Each module combines in a compact high-temperature plastic package, a samarium-cobalt magnet, a pole piece, and a differential Hall-effect IC that has been optimized to the magnetic circuit. These sensors can be easily used in conjunction with a wide variety of gear or target shapes and sizes.

The ATS610LSA is designed to provide increased immunity to false switching in applications that require the sensing of large-tooth gears (e.g., crank angle or cam angle). The ATS611LSB is optimized to sense fine-pitch gears over large working air gaps (e.g., transmission or ABS). These sensors are ideal for use in gathering speed, position, and timing information using gear-tooth-based configurations.

The gear-sensing technology used for these sensor plus magnet modules is Hall-effect based. The sensor incorporates a dual-element Hall IC that switches in response to differential magnetic signals created by the ferrous target. The circuitry contains a patented track-and-hold peak-detecting circuit to eliminate magnet and system offset effects. This circuit has the ability to detect relatively fast changes, such as those caused by gear wobble and eccentricities, and provides stable operation at extremely low rotation speeds.

continued next page...

FEATURES AND BENEFITS

- Fully Optimized Differential Digital Gear-Tooth Sensor
- Single-Chip Sensing IC for High Reliability
- Extremely Low Timing Accuracy Drift with Temperature
- Large Operating Air Gaps
- Small Mechanical Size
- Optimized Magnetic Circuit
- Patented Peak-Detecting Filter:
 - <200 μ s Power-On Time
 - <10 RPM Operation (single-tooth target)
 - Correct First-Edge Detection
 - Uses Small Value Ceramic Capacitors
- Under-Voltage Lockout
- Wide Operating Voltage Range
- Defined Power-Up State

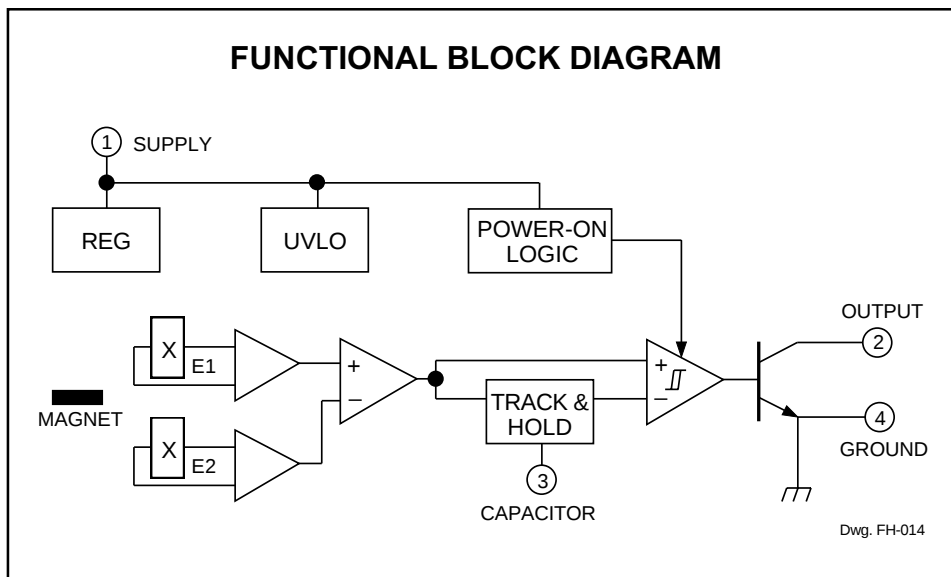
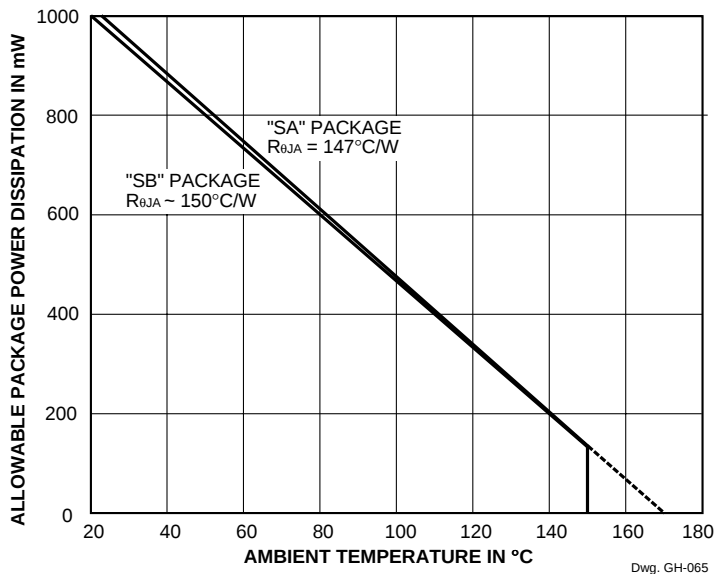
Always order by complete part number, e.g., **ATS610LSA**.

ATS610LSA AND ATS611LSB
DYNAMIC, PEAK-DETECTING,
DIFFERENTIAL HALL-EFFECT
GEAR-TOOTH SENSORS

Both sensors are packaged in miniature plastic housings that have been optimized for size, ease of assembly, and manufacturability. High operating temperature materials are used in all aspects of construction. Devices for operation at increased temperatures are also available on special order.

ATS610LSA: Large-tooth, gear-position sensing — crank angle, cam angle.

ATS611LSB: Fine-pitch, large air gap, gear-speed sensing — transmission, ABS.



ATS610LSA AND ATS611LSB
DYNAMIC, PEAK-DETECTING,
DIFFERENTIAL HALL-EFFECT
GEAR-TOOTH SENSORS

ELECTRICAL CHARACTERISTICS over operating voltage and temperature range,
C₃ = 0.1 μ F to 0.47 μ F.

Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
Supply Voltage	V _{CC}	Operating, T _J < 165°C	V _{CC(UV)}	–	16	V
Power-On State	POS	V _{CC} = 0 → 5 V	HIGH	HIGH	HIGH	–
Under-Voltage Lockout	V _{CC(UV)}	I _{OUT} = 20 mA, V _{CC} = 0 → 5 V	2.5	–	3.5	V
Under-Voltage Hysteresis	V _{CC(hys)}	Lockout (V _{CC(UV)}) – Shutdown	–	0.1	–	V
Output Saturation Voltage	V _{OUT(SAT)}	I _{OUT} = 20 mA	–	90	400	mV
Output Leakage Current	I _{OFF}	V _{OUT} = 16 V	–	0.2	15	μ A
Supply Current	I _{CC}	Output OFF	5.5	7.7	11	mA
		Output ON	8.5	10.5	13	mA
Power-On Delay	t _{on}		–	–	200	μ s
Output Rise Time	t _r	R _L = 500 Ω , C _L = 10 pF	–	0.2	2.0	μ s
Output Fall Time	t _f	R _L = 500 Ω , C _L = 10 pF	–	0.2	2.0	μ s

NOTE: Typical data is at V_{CC} = 5 V and T_A = +25°C and is for design information only.

ATS610LSA AND ATS611LSB **DYNAMIC, PEAK-DETECTING,** **DIFFERENTIAL HALL-EFFECT** **GEAR-TOOTH SENSORS**

ATS610LSA OPERATION over operating voltage and temperature range with reference target (unless otherwise specified).

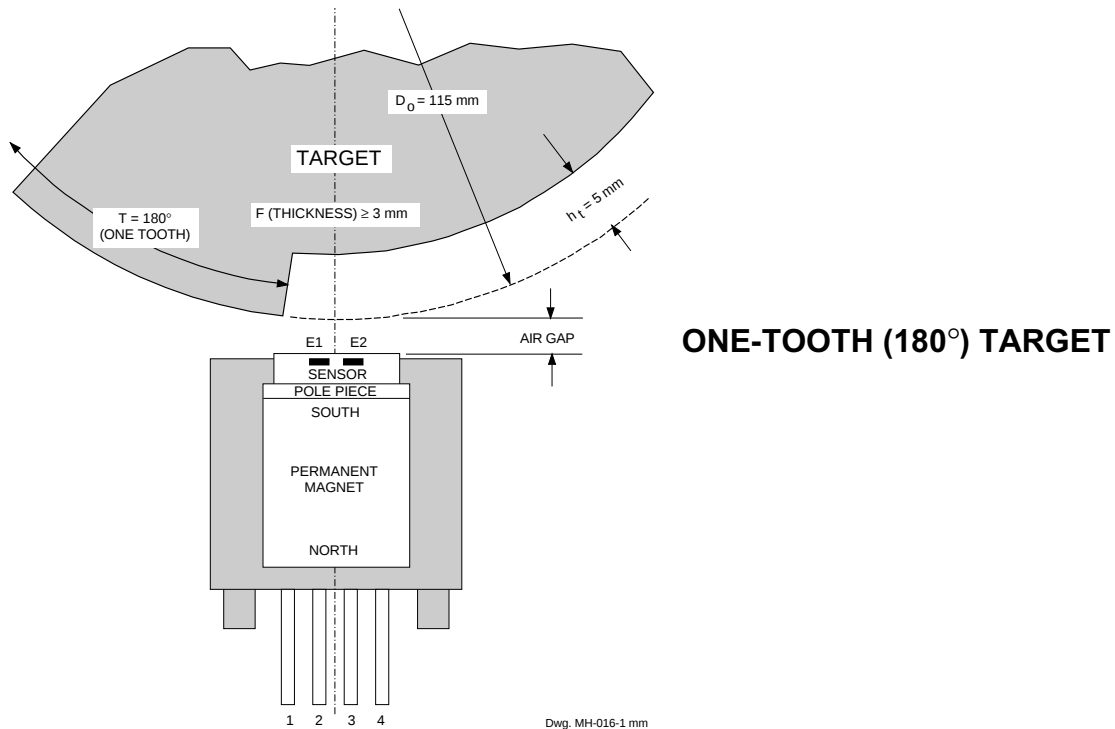
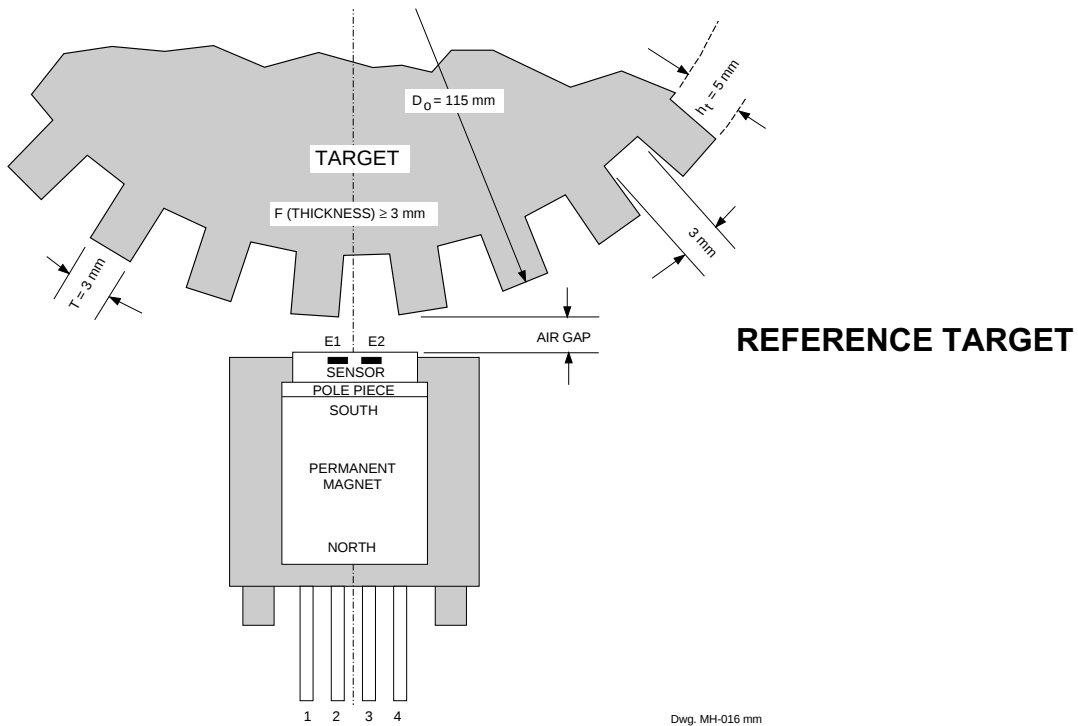
Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
Air Gap Range	AG	Operating, Target Speed > 20 RPM	0.4	–	2.25	mm
Minimum Air Gap	AG _{min}	Operating, One-Tooth (180°) Target, Target Speed = 1000 RPM	–	0.25	–	mm
Maximum Air Gap	AG _{max}	Operating, One-Tooth (180°) Target, Target Speed = 1000 RPM	–	2.75	–	mm
Timing Accuracy	t _θ	Target Speed = 1000 RPM, 0.4 mm ≤ AG ≤ 2 mm	–	±0.5	±1.0	°

ATS611LSB OPERATION over operating voltage and temperature range with reference target (unless otherwise specified).

Characteristic	Symbol	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
Air Gap Range	AG	Operating, Target Speed > 20 RPM	0.4	–	2.5	mm
Minimum Air Gap	AG _{min}	Operating, One-Tooth (180°) Target*, Target Speed = 1000 RPM	–	0.75	–	mm
Maximum Air Gap	AG _{max}	Operating, One-Tooth (180°) Target*, Target Speed = 1000 RPM	–	3.25	–	mm
Timing Accuracy	t _θ	Target Speed = 1000 RPM, 0.4 mm ≤ AG ≤ 2 mm	–	±0.5	±1.0	°

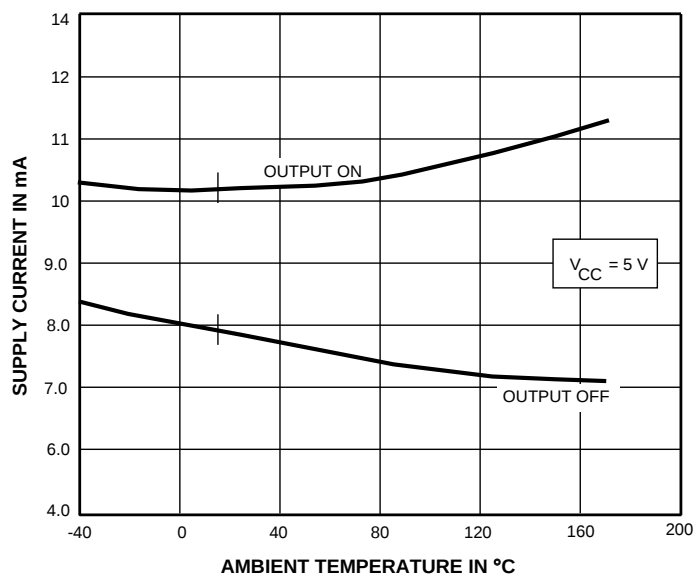
* The one-tooth (180°) target is not recommended for use with the ATS611LSB.

ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

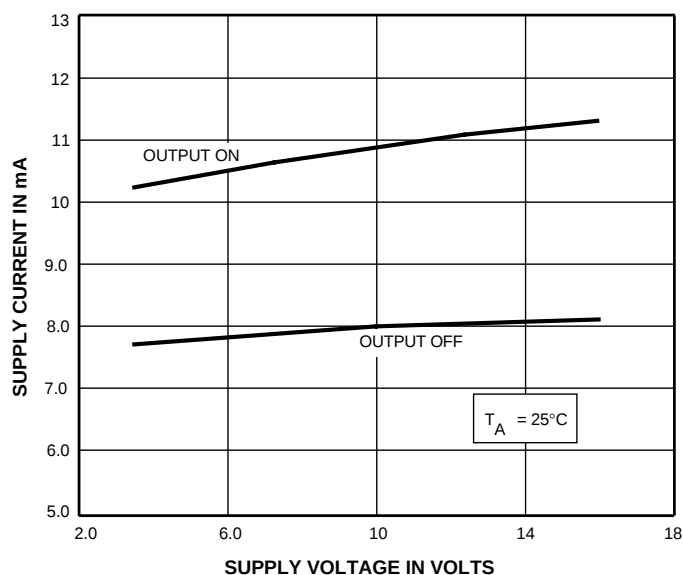


ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

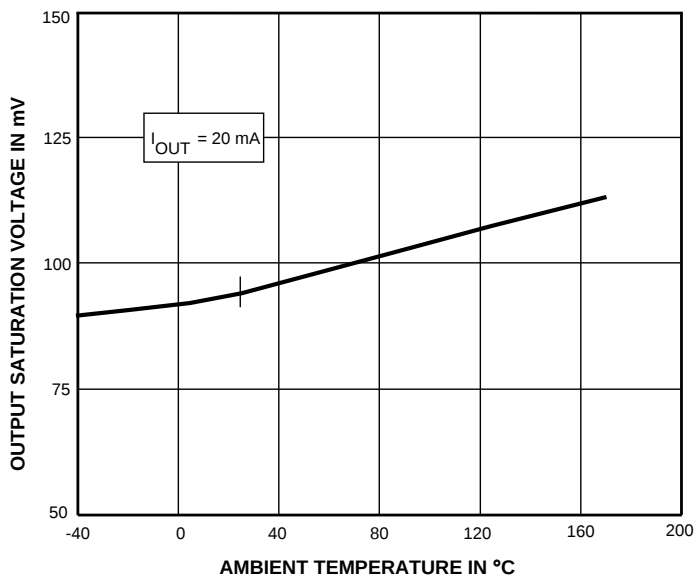
TYPICAL ATS610LSA AND ATS611LSB ELECTRICAL CHARACTERISTICS



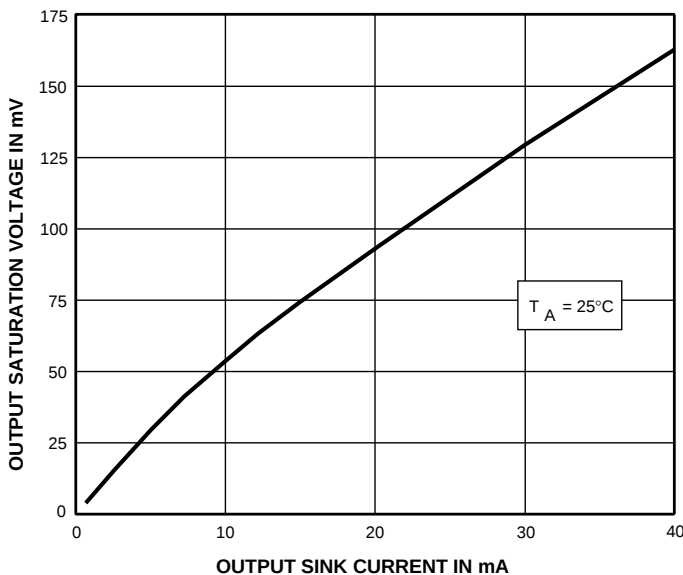
Dwg. GH-014-1



Dwg. GH-058



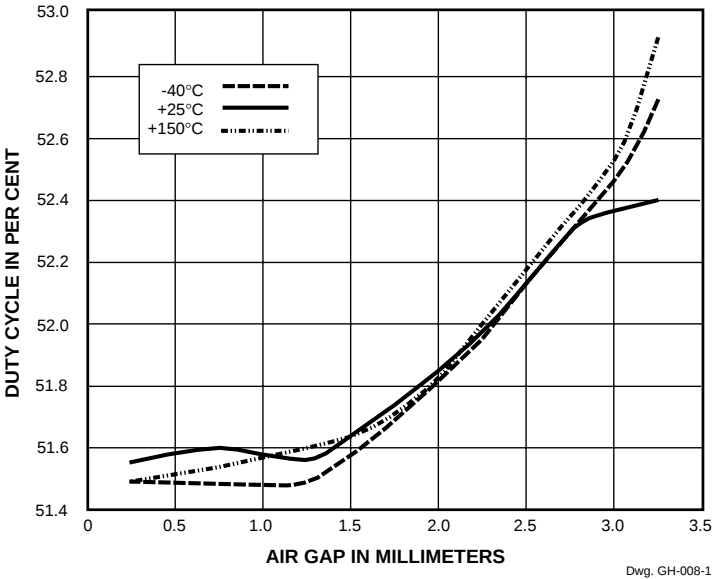
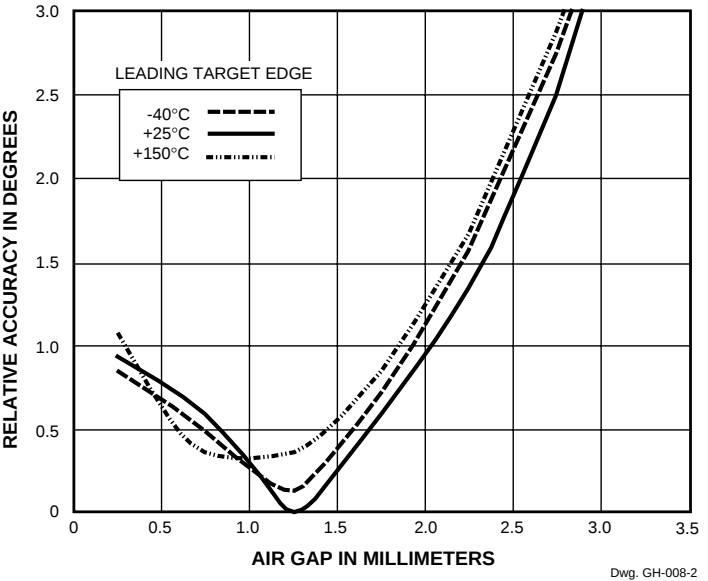
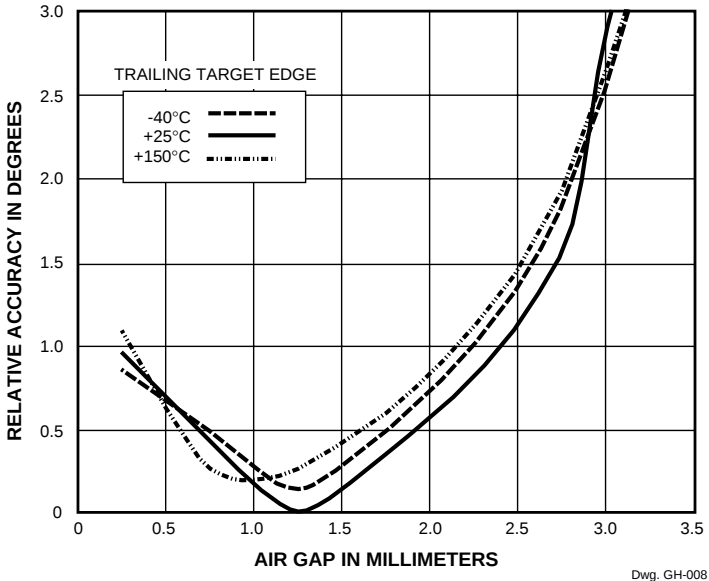
Dwg. GH-013-1



Dwg. GH-059

ATS610LSA AND ATS611LSB
DYNAMIC, PEAK-DETECTING,
DIFFERENTIAL HALL-EFFECT
GEAR-TOOTH SENSORS

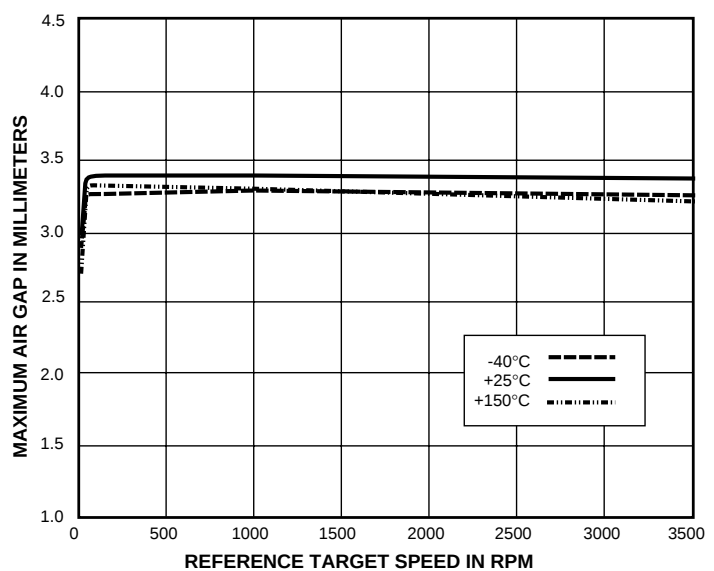
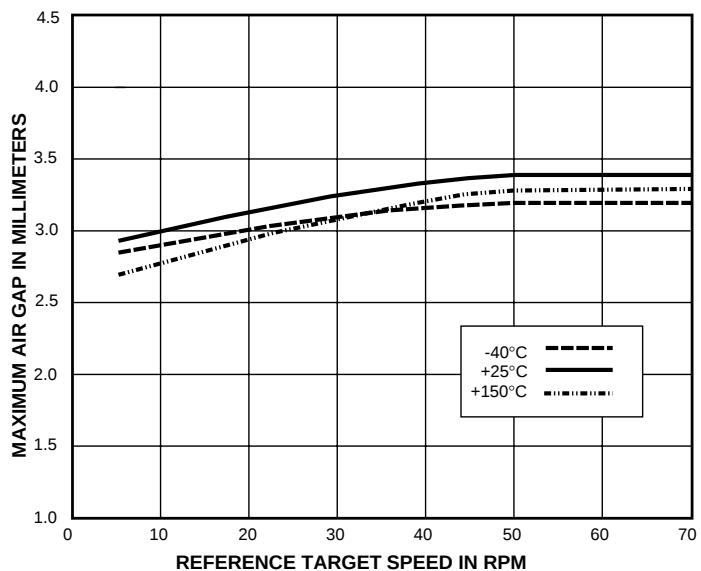
TYPICAL ATS610LSA OPERATING CHARACTERISTICS
(with reference target)



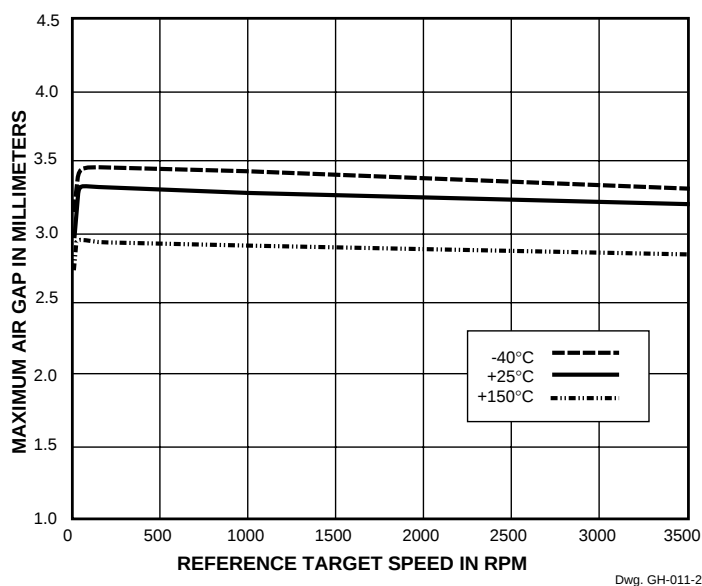
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ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

TYPICAL ATS610LSA OPERATING CHARACTERISTICS (with reference target) — Continued



TYPICAL ATS611LSB OPERATING CHARACTERISTICS (with reference target)



ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

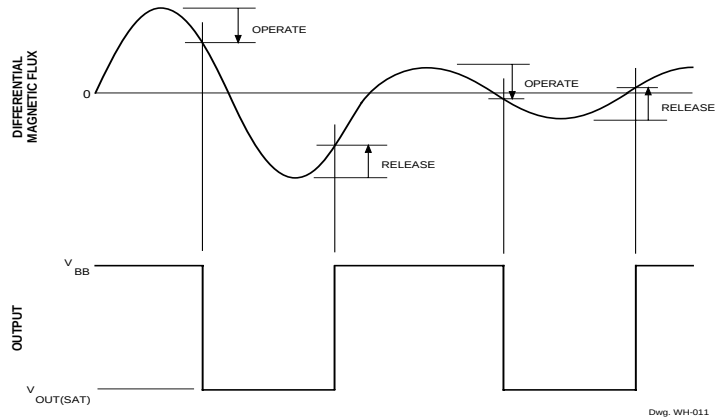
DEVICE DESCRIPTION

The ATS610LSA and ATS611LSB dynamic, peak-detecting, differential Hall-effect gear-tooth sensors are Hall IC plus magnet modules that are fully optimized to provide digital detection of gear-tooth edges in a small package size. Both sensors are packaged in identical miniature plastic housings that have been optimized for size, ease of assembly, and manufacturability. High operating temperature materials are used in all aspects of construction.

The application of these sensors is uncomplicated. After power is applied to the device, they are capable of quickly providing digital information that is representative of a rotating gear or specially designed target. No additional optimization or processing circuitry is required. This ease of use should reduce design time and incremental assembly costs for most applications.

Sensing Technology. Both gear-tooth sensor modules contain 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 2.235 mm (0.088") apart, which sense the magnetic gradient created by the passing of a ferrous object (a gear tooth). The two Hall voltages are compared and the difference is then processed to provide a digital output signal.

The processing circuit uses a patented peak-detection technique to eliminate magnet and system offsets. This technique allows coupling and filtering of offsets without the power-up and settling time disadvantages of classical high-pass filtering schemes. Here, the peak signal of every tooth and valley is detected and is used to provide an instant reference for the operate-point and release-point comparators. In this manner, the thresholds are adapted and referenced to individual signal peaks and valleys, thereby providing immunity to zero-line variation due to installation inaccuracies (tilt, rotation, and off-center placement), as well as for variations caused by target and shaft eccentricities. The peak detection concept also allows extremely low-speed operation when used with small-value capacitors.



Power-On Operation. The device will power on in the OFF state (output high) irrespective of the magnetic field condition. The power-on time of the circuit is no greater than 200 μ s. The circuit is then ready to accurately detect the first target edge that results in a HIGH-to-LOW transition.

Under-Voltage Lockout. When the supply voltage is below the minimum operating voltage ($V_{CC(UV)}$), the device is OFF and stays OFF irrespective of the state of the magnetic field. This prevents false signals, which may be caused by under-voltage conditions (especially during turn on), from appearing at the output.

Output. The device output is an open-collector stage capable of sinking 25 mA. An external pull-up (resistor) to a supply voltage of not more than 18 V must be supplied.

Superior Performance. The ATS610LSA and ATS611LSB peak-detecting differential gear-tooth sensors have several advantages over conventional Hall-effect gear-tooth sensors.

continued next page...

ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

DEVICE DESCRIPTION — Continued

Differential vs. Single-Element Sensing. The differential Hall-element configuration is superior in most applications to the classical single-element gear-tooth sensor. The single-element configuration commonly used (Hall-effect sensor mounted on the face of a simple permanent magnet) requires the detection of a small signal (often <100 G) that is superimposed on a large back-biased field, often 1500 G to 3500 G. For most gear/target configurations, the back-biased field values change due to concentration effects, resulting in a varying baseline with air gap, with valley widths, with eccentricities, and with vibration. The differential configuration cancels the effects of the back-biased field and avoids many of the issues presented by the single Hall element.

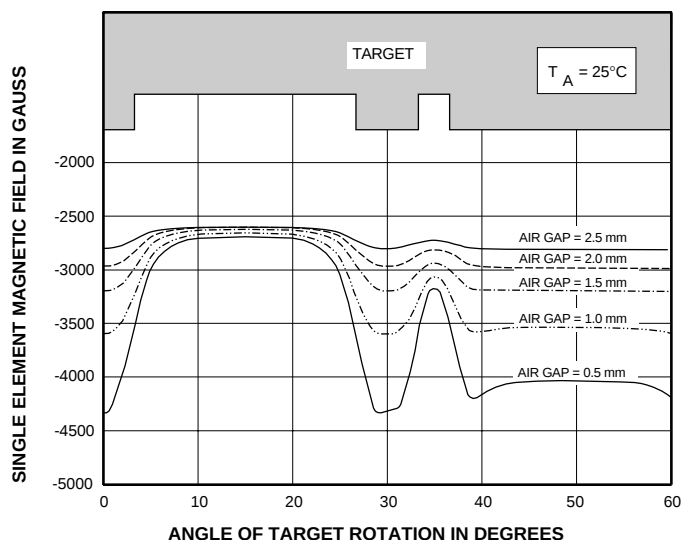
NOTE — 10 G = 1 mT, exactly.

Peak-Detecting vs. AC-Coupled Filters. High-pass filtering (normal ac coupling) is a commonly used technique for eliminating circuit offsets. AC coupling has errors at power up because the filter circuit needs to hold the circuit zero value even though the circuit may power up over a large signal. Such filter techniques can only

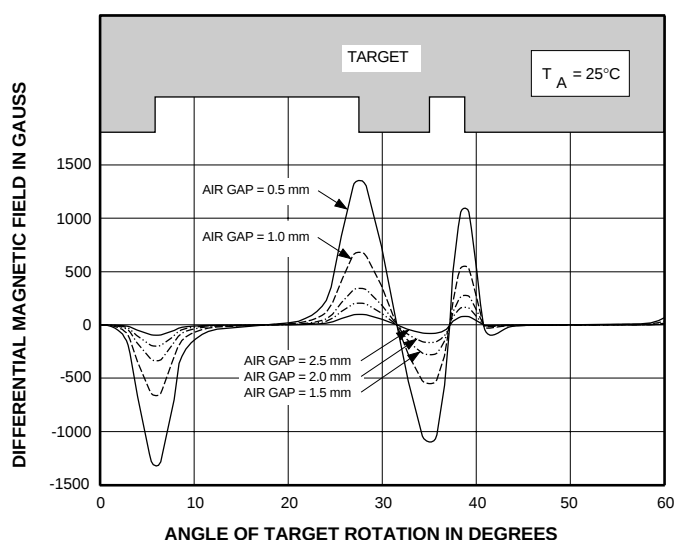
perform properly after the filter has been allowed to settle, which is typically greater than one second. Also, high-pass filter solutions cannot easily track rapidly changing baselines such as those caused by eccentricities. Peak detection switches on the change in slope of the signal and is baseline independent at power up and during running.

Track-and-Hold Peak Detecting vs. Zero-Crossing Reference. The usual differential zero-crossing sensors are susceptible to false switching due to off-center and tilted installations, which result in a shift in baseline that changes with air gap. The track-and-hold peak-detection technique ignores baseline shifts versus air gaps and provides increased immunity to false switching. In addition, using track-and-hold peak-detecting techniques, increased air gap capabilities can be expected because a peak detector utilizes the entire peak-to-peak signal range as compared to zero-crossing detectors that switch on fixed thresholds.

NOTE — “Baseline” refers to the zero-gauss differential where each Hall-effect element is subject to the same magnetic field strength.



Single-element flux maps
showing the impact of varying valley widths



Differential flux maps vs. air gaps

ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

APPLICATIONS INFORMATION

Gear Diameter and Pitch. Signal frequency is a direct function of gear pitch and rotational speed (RPM). The width of the magnetic signal in degrees and, hence, the signal slope created by the tooth is directly proportional to the circumference of the gear (πD_O). Smaller diameters limit the low-speed operation due to the slower rate of change of the magnetic signal per degree of gear rotation (here the limitation is the droop of the capacitor versus the signal change). Larger diameters limit high-speed operation due to the higher rate of change of magnetic signal per degree of rotation (here the limitation is the maximum charge rate of the capacitor versus the rate of signal change). These devices are optimized for a 50 mm gear diameter (signal not limited by tooth width), 0.33 μF capacitor, and speeds of 10 RPM to 8000 RPM. For very large diameter gears (diameter >200 mm), the devices must be configured with a lower value capacitor, but not less than 0.1 μF . This allows for a range of 5:1 in gear diameters.

NOTE — In application, the terms “gear” and “target” are often interchanged. However, “gear” is preferred when motion is transferred.

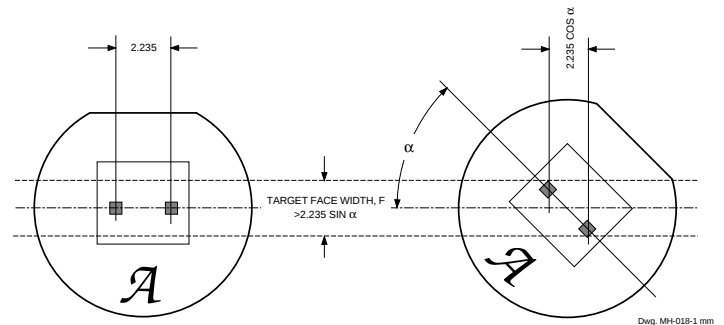
Air Gap and Tooth Geometry. Operating specifications are impacted by tooth width (T), valley width ($p_C - T$) and depth (h_t), gear material, and gear face thickness (F). The target can be a gear or a specially cut shaft-mounted tone wheel made of stamped ferrous metal. In general, the following gear or target guidelines must 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
- (Whole) depth, h_t >3 mm
- Gear material low-carbon steel
- Gear face width (thickness), F >3 mm

Deviation from these guidelines will result in a reduction of air gap and a deterioration in timing accuracy. For applications that require the sensing of large-tooth targets, the optimal sensor choice is the ATS610LSA. Here, the higher switching thresholds provide increased immunity to false switching caused by magnetic overshoot and other

non-uniformities in the gear or target. For applications that require the sensing of a target with a repetitive target structure (valley width less than 5 mm), the optimal sensor choice is the ATS611LSB. Here, the lower switching thresholds make the device more sensitive to magnetic field changes and will provide larger operating air gaps.

Operation with Fine-Pitch Gears. For targets with a circular pitch of less than 4 mm, a performance improvement can be observed by rotating the front face of the sensor module. This sensor rotation decreases the effective sensor-to-sensor spacing and increases the capability of detecting fine tooth or valley configurations, provided that the Hall elements are not rotated beyond the width of the target.



Signal Timing Accuracy. The magnetic field profile width is defined by the sensor element spacing and narrows in degrees as the target diameter increases. This results in improved timing accuracy performance for larger gear diameters (for the same number of gear teeth). The slope of this magnetic profile also changes with air gap, resulting in timing accuracy shift with air gap (refer to typical operating characteristic curves). Valley-to-tooth transitions will generally provide better accuracy than tooth-to-valley transitions for large-tooth or large-valley configurations. For highest accuracy, targets greater than 100 mm in diameter should be used.

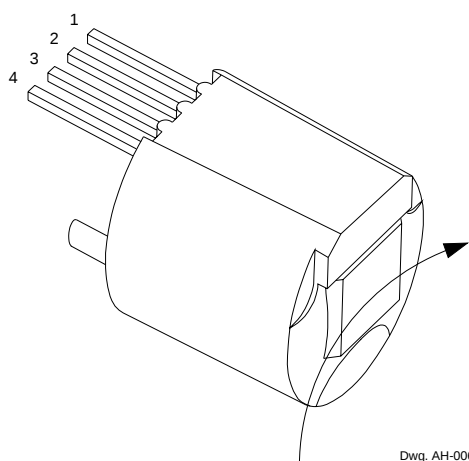
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ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

APPLICATIONS INFORMATION — Continued

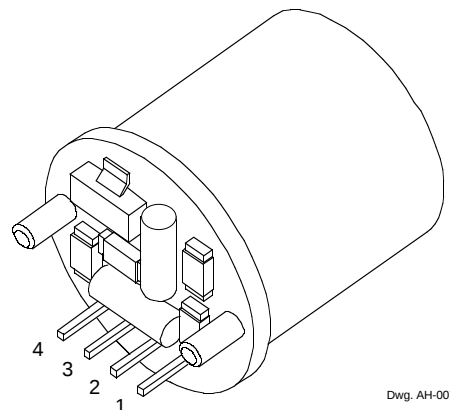
Signal Duty Cycle. For repetitive target structures, precise duty cycle is maintained over the operating air gap and temperature range due to an extremely good symmetry in the magnetic switch points of the device. For nonrepetitive target structures, there will be a small but measureable change in pulse width versus air gap.

Output Polarity. The output of the device will switch from HIGH to LOW as the leading edge of the target passes the module in the direction indicated below (pin 4 to pin 1), which means that the output will be LOW when the unit is facing a tooth. If rotation is in the opposite direction (pin 1 to pin 4), the output of the device will switch from LOW to HIGH as the leading edge of the target passes the module, which means that the output will be HIGH when the unit is facing a tooth.

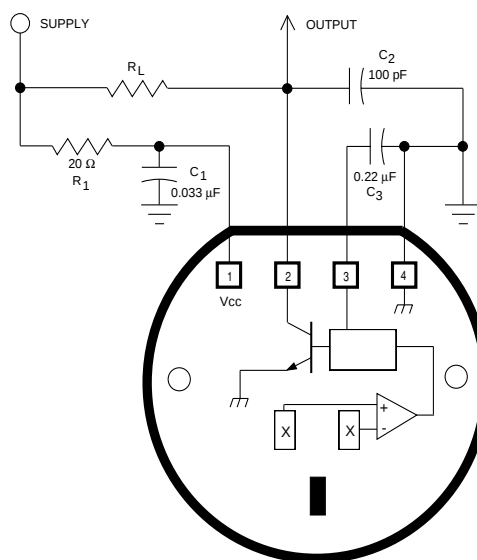


Power Supply Protection. The sensor contains an on-chip voltage regulator and can operate over a wide supply voltage range. For devices that need to operate from an unregulated power supply, transient and double-battery protection should be added externally. For applications using a regulated supply,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

The filter capacitor and EMI protection circuitry can easily be added to a PC board for use with these devices. Provisions have been made for simple mounting of a board on the back of the unit.



Operation From a Regulated Power Supply. These devices require minimal protection circuitry during operation from a low-voltage regulated line. The on-chip voltage regulator provides immunity to power supply variations between 3.5 V and 16 V. However, even while operating from a regulated line, some supply and output filtering is required to provide immunity to coupled and injected noise on the supply line. A basic RC low-pass circuit (R_1C_1) on the supply line and an optional output capacitor (C_2) is recommended for operation in noisy environments. Because the device has an open-collector output, an output pull-up resistor (R_L) must be included either at the sensor output (pin 2) or by the signal processor input.



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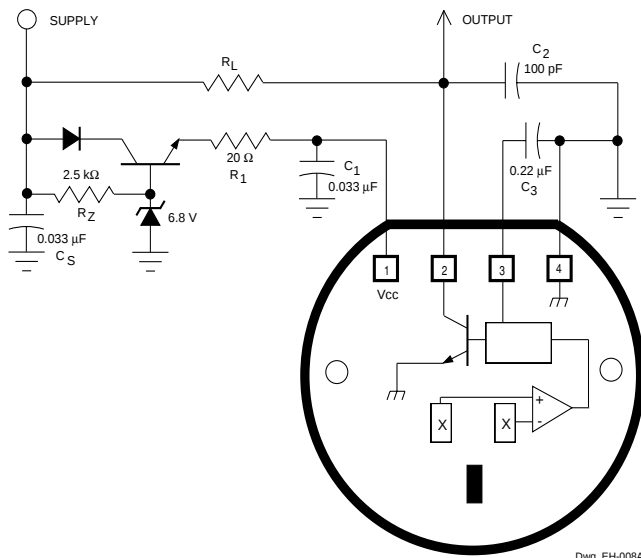
ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

APPLICATIONS INFORMATION — Continued

Operation From an Unregulated Power Supply. In automotive applications, where the device receives its power from an unregulated supply such as the battery, full protection is generally required so that the device can withstand the many supply-side transients. Specifications for such transients vary between car manufacturers, and protection-circuit design should be optimized for each application. In the circuit below, a simple Zener-controlled regulator is constructed using discrete components. The RC low-pass filter on the supply line (R_1C_1) and a low-value supply bypass capacitor (C_S) can be included, if necessary, so as to minimize susceptibility to EMI/RFI. The npn transistor should be chosen with sufficiently high forward breakdown voltage so as to withstand supply-side transients. The series diode should be chosen with sufficiently high reverse breakdown capabilities so as to withstand the most negative transient. The current-limiting resistor (R_Z) and the Zener diode should be sized for power dissipation requirements.

Capacitor Requirements. The choice of the capacitor at pin 3 (C_3) defines the minimum operating speed of the target. This capacitor ($0.1\ \mu\text{F}$ minimum) is required to stabilize the internal amplifiers as well as to eliminate the signal offsets. Typically, a $0.33\ \mu\text{F}$ low-leakage ceramic capacitor is recommended. Values greater than $0.47\ \mu\text{F}$ should not be used as this may cause high-speed performance degradation.

Capacitor leakage current at pin 3 will cause degradation in the low-speed performance of the device. Excess capacitor leakage can result in the sensor changing output state without movement of the gear tooth being sensed. In addition to the capacitor leakage, it is extremely important to minimize the leakage at the PC board and between the pins of the sensor. Up to $50\ \text{nA}$ of external leakage can be tolerated at the capacitor pin node to ground. Choice of low-leakage-current potting compounds and the use of clean PC board techniques are extremely important.



Additional applications Information on gear-tooth and other Hall-effect sensors is provided in the Allegro Electronic Data Book AMS-702 or Application Note 27701.

ATS610LSA AND ATS611LSB **DYNAMIC, PEAK-DETECTING,** **DIFFERENTIAL HALL-EFFECT** **GEAR-TOOTH SENSORS**

MECHANICAL INFORMATION

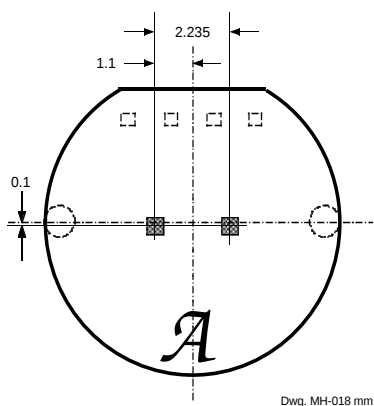
Component	Material	Function	Units
Sensor Face	Thermoset epoxy	Maximum temperature	170°C*
Plastic Housing	Thermoplastic PBT, 30% glass filled	264 psi deflection temp. (DTUL) 66 psi deflection temp. (DTUL) Approximate melting temperature	204°C 216°C 225°C
Leads	Copper	—	—
Lead Integrity	—	—	8 oz.
Lead Finish	90/10 tin/lead solder plate	—	†
Flame Class Rating	—	—	UL94V-0

* Temperature excursions to 225°C for 2 minutes or less are permitted.

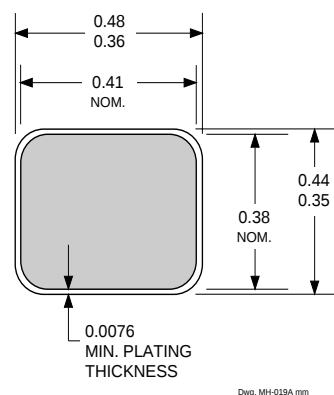
† All industry-accepted soldering techniques are permitted for these modules provided the indicated maximum temperature for each component (e.g., sensor face, plastic housing) is not exceeded. Reasonable dwell times, which do not cause melting of the plastic housing, should be used.

Sensor Location (in millimeters)

(sensor location relative to package center is the design objective)



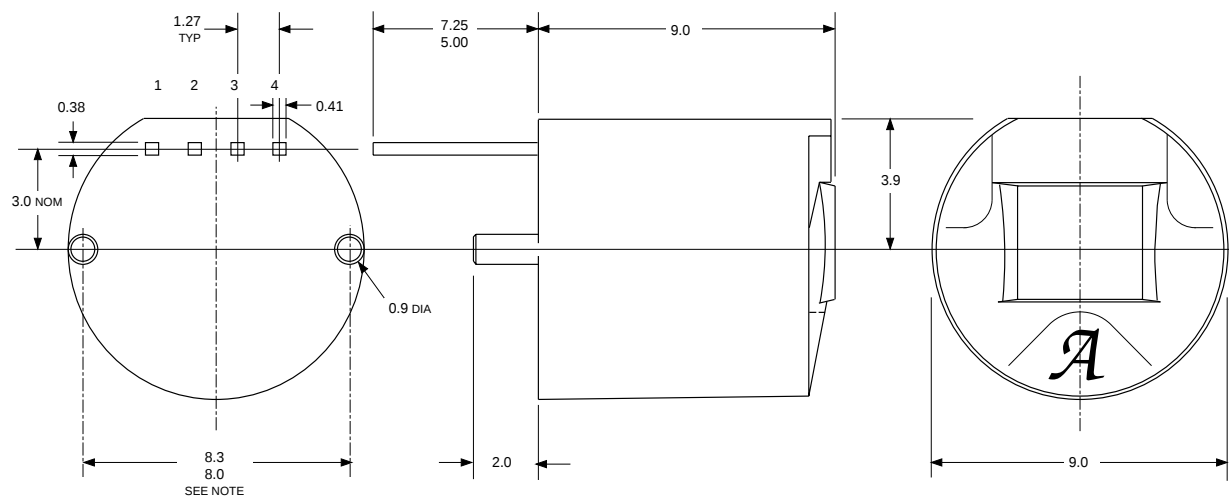
Lead Cross-Section (in millimeters)



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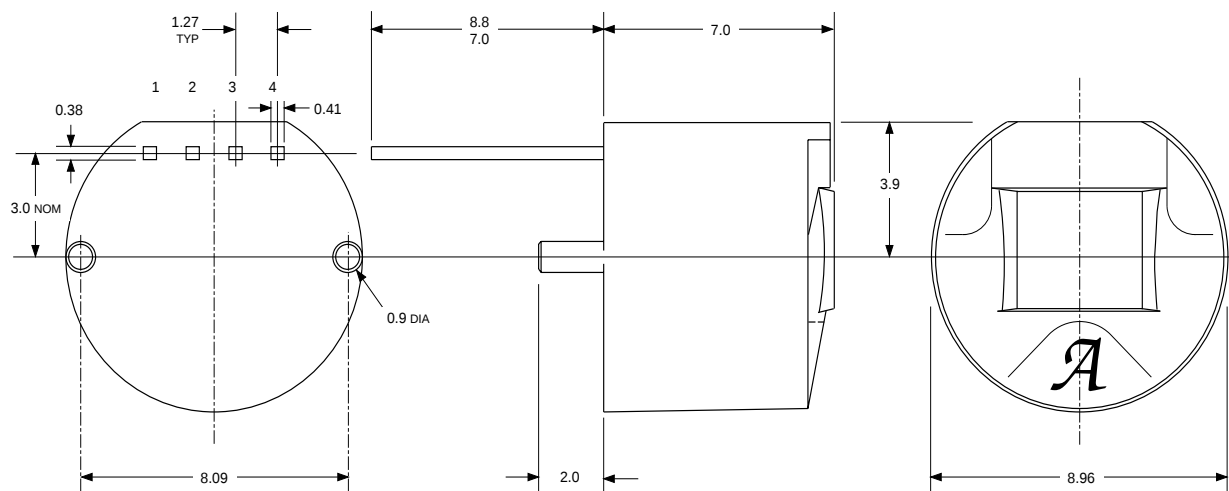
ATS610LSA AND ATS611LSB **DYNAMIC, PEAK-DETECTING,** **DIFFERENTIAL HALL-EFFECT** **GEAR-TOOTH SENSORS**

ATS610LSA DIMENSIONS IN MILLIMETERS



Dwg. MH-017A mm

ATS611LSB DIMENSIONS IN MILLIMETERS



Dwg. MH-017-1B mm

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

NOTE — Nominal dimension and tolerances dependent on package material. Contact factory.

ATS610LSA AND ATS611LSB DYNAMIC, PEAK-DETECTING, DIFFERENTIAL HALL-EFFECT GEAR-TOOTH SENSORS

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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