ATS604

Orientation-Independent Hall Effect Speed and Direction Gear Tooth Sensor IC

FEATURES AND BENEFITS

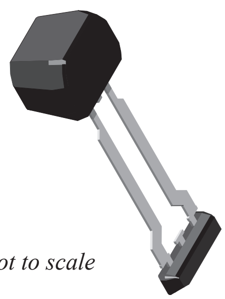
- **Orientation independence** for ease of application installation
- **AK Protocol** output provides speed, direction, air gap, temperature, channel, and standstill information
- **Optimized startup calibration** with automatic channel select
- **Integrated solution** includes back-bias magnet, magnetic sensing IC, and protection capacitor
- **ASIL compliant:** ASIL B(D) safety element out-of-context (SEooC) developed in accordance with ISO 26262, when used as specified in the safety manual
  - □ Integrated diagnostics
  - □ Certified safety design process

ISO 26262 ASIL Compliant

SOLIDSPEED DIGITAL ARCHITECTURE

PACKAGE

3-pin SIP (suffix SN)



Not to scale

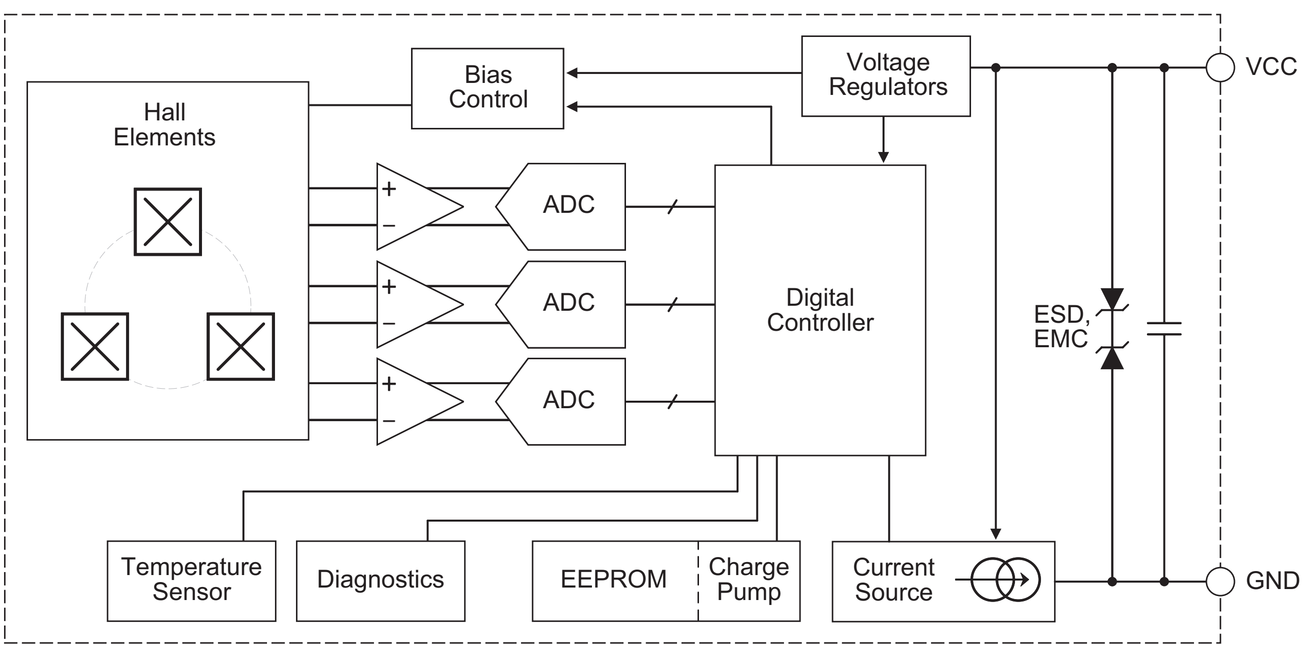
DESCRIPTION

The ATS604 is a Hall-effect integrated circuit (IC) designed for automotive wheel speed sensing applications. Using an integrated back-bias magnet, the IC measures the speed and direction of a rotating ferrous target. With its patented orientation-independent differential magnetic sensing architecture, the face of the IC package can be rotated in plane, allowing for full flexibility in installation angle.

Using the AK Protocol, the ATS604 encodes speed and direction information on a current-modulated two-wire interface. The IC also transmits the measured temperature, air gap information, and selected channels, providing superior system information to the controller. Sophisticated algorithms minimize the amount of rotation until first pulses after power-up through the use of internally writable non-volatile memory.

The ATS604 was developed in accordance with ISO 26262 as a hardware safety element out of context (SEooC) with ASIL B(D) capability for use in automotive safety-related systems when integrated and used in the manner prescribed in the applicable safety manual and datasheet.

The ATS604 is provided in a 3-pin SIP package (suffix SN) that is lead (Pb) free, with tin leadframe plating. The SN package includes an IC, magnet, and capacitor integrated into a single overmold, with an additional molded lead-stabilizing bar for robust shipping and ease of assembly.

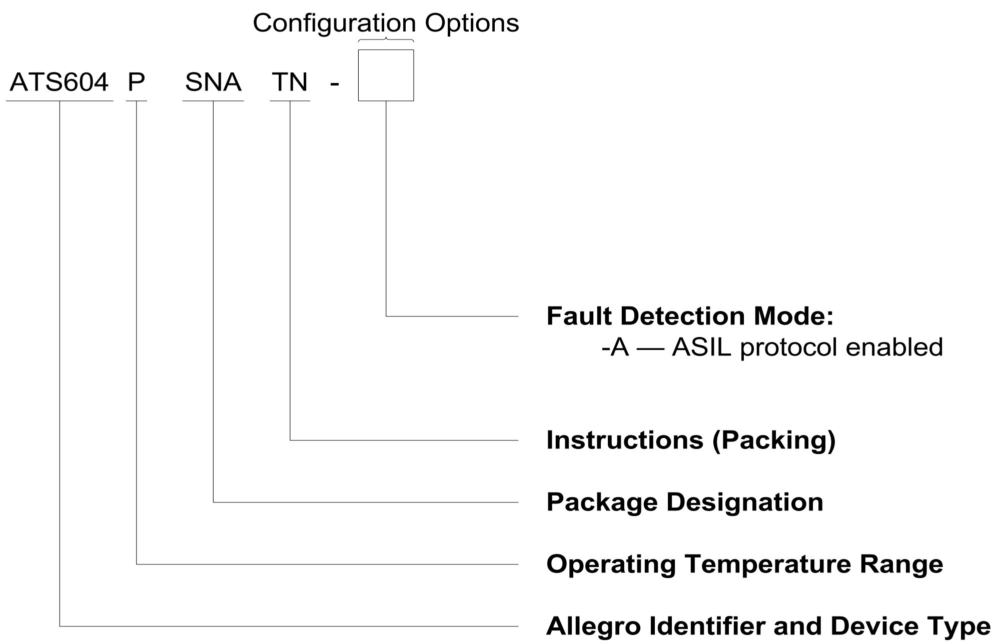


Functional Block Diagram

SELECTION GUIDE

Part Number	Operating Ambient Temperature Range (°C)	Package	Packing [1]	Leadframe Plating
ATS604PSNATN-A	–40 to 160	3-pin SIP	800 pieces per 13-inch reel	Tin

[1] Contact Allegro™ for additional packing options.



ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{CC}		28	V
Reverse Supply Voltage	V_{RCC}		–18	V
Operating Ambient Temperature	T_A	P temperature range	–40 to 160	°C
Operating Junction Temperature	T_J		-40 to 175	°C
Storage Temperature	T_{stg}		–65 to 170	°C

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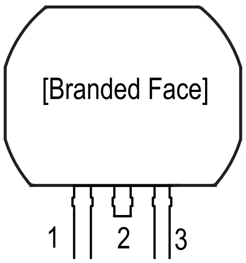


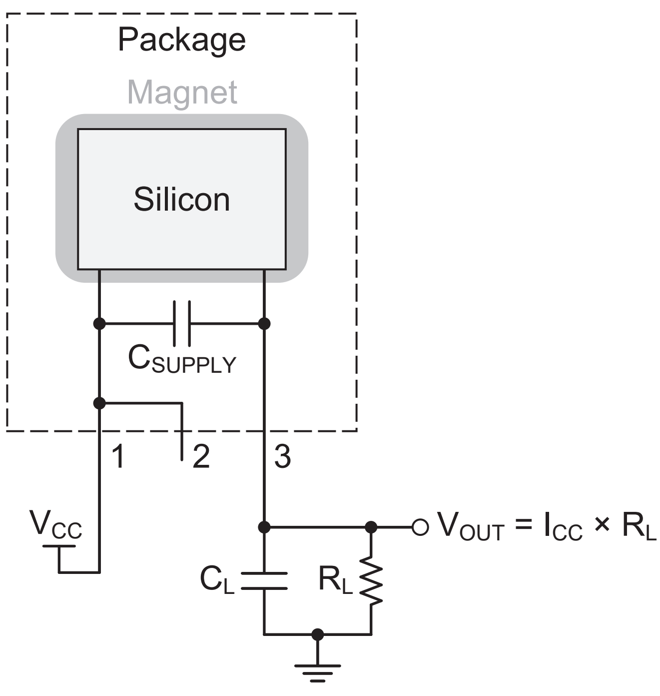
Package SN, 3-Pin SIP Pinout Diagram

Terminal List

Number	Name	Function
1	VCC	Supply voltage
2	VCC	Shorted to pin 1 internally
3	GND	Ground and target data output

INTERNAL COMPONENTS

Characteristic	Symbol	Rating	Unit
Rated Nominal Capacitance	C_{SUPPLY}	2.2	nF



Typical Application Circuit

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OPERATING CHARACTERISTICS: Valid over the full operating voltage and operating ambient temperature ranges, using the Allegro Reference target 60-0, unless otherwise noted

Characteristic	Symbol	Test Conditions	Min.	Typ. [2]	Max.	Unit
ELECTRICAL CHARACTERISTICS						
Supply Voltage [3]	V_{CC}		5.2	–	24	V
Undervoltage Lockout	$V_{CC(UV)}$	V_{CC} from 5.2 V to 0 V	–	3.3	3.7	V
Supply Voltage Hysteresis	$V_{CC(hys)}$	$V_{CC(min)} – V_{CC(UV)}$	1.5	–	–	V
Reverse Supply Current [4]	I_{RCC}	$V_{CC} = V_{RCC}(max)$	–10	–	–	mA
Supply Zener Clamp Voltage	$V_{Zsupply}$	$I_{CC} = I_{CC}(max) + 3$ mA, $T_A = 25°C$	28	–	–	V
Supply Current	$I_{CC(OPEN)}$ [5]	Open safe-current state ($V_{CC} < V_{CC(min)}$)	–	–	3.9	mA
	$I_{CC(LOW)}$ [6]	Low-current state	5.88	7	8.4	mA
	$I_{CC(MID)}$ [6]	Mid-current state	11.76	14	16.8	mA
	$I_{CC(HIGH)}$ [6]	High-current state	23.52	28	33.6	mA
Supply Current Ratio	$I_{CC(MID)}$ / $I_{CC(LOW)}$	Measured as ratio of mid current to low current	1.8	–	–	–
	$I_{CC(HIGH)}$ / $I_{CC(LOW)}$	Measured as ratio of high current to low current	3.6	–	–	–
Power-Up Time			–	–	2	ms
Signal Stabilization After Power-On		Speed < 200 rpm, $V_{CC} > V_{CC(min)}$; time until current level is stabilized	–	–	1	ms
Number of EEPROM Self-Writes Available	$N_{self\text{-}writes}$	Temperature between –40°C and 110°C		250		–
OUTPUT STAGE						
Power-On State	POS		–	$I_{CC(LOW)}$	–	mA
Output Slew Rate	SR_{OUT}	$R_{LOAD} = 50\ \Omega$, $C_{LOAD} = 10$ pF; $I_{CC(HIGH)} \rightarrow I_{CC(LOW)}$, $I_{CC(LOW)} \rightarrow I_{CC(HIGH)}$, 10% to 90% points	8	16	28	mA/µs
AK PROTOCOL CHARACTERISTICS						
Pulse Width for Speed Pulse	$t_{W(SPEED)}$	Trigger level 10.5 mA (middle of 7 to 14 mA)	40	50	60	µs
Pulse Width for Data Bits	$t_{W(DATA)}$		40	50	60	µs
Pulse Width for Initial Bit	$t_{W(INI)}$		20	25	30	µs
Bit Stump Suppression	$t_{W(OFFSET)}$		40	50	60	µs
Message Separation During Stand Still	t_{STOP}		105	150	195	ms
Mid-Level Safe State Pulse Duration [7]	t_{SAFE}	Duration of mid-level safe-state pulse	5	7.5	–	ms
Overtemperature AK Message	T_{over}	Junction temperature	160	190	–	°C
OPERATING CHARACTERISTICS						
Speed Channel	B_{OP_SPD}	% of peak-to-peak V_{PROC} B_{OP}	–	60	–	%
	B_{RP_SPD}	% of peak-to-peak V_{PROC} B_{RP}	–	40	–	%
Direction Channel	B_{OP_DIR}	% of peak-to-peak V_{PROC} B_{OP}	–	50	–	%
	B_{RP_DIR}	% of peak-to-peak V_{PROC} B_{RP}	–	50	–	%
Operating Frequency	f_{ROT}	Input frequency	0	–	3.5	kHz
Delay Time (inital bit + bit stump suppression)	t_{DEL}		60	75	90	µs

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OPERATING CHARACTERISTICS (continued): Valid over the full operating voltage and operating ambient temperature ranges, using the Allegro Reference target 60-0, unless otherwise noted

Characteristic	Symbol	Test Conditions	Min.	Typ. [2]	Max.	Unit
DAC CHARACTERISTICS						
Allowable User-Induced Differential Offset	$B_{dmoffset}$	Magnitude valid for active magnetic channels; see Figure 3	–60	–	60	G
Allowable User-Induced Common Mode Offset	$B_{cmoffset}$	See Figure 3	–120	–	120	G
PERFORMANCE CHARACTERISTICS						
Installation Angle	θ	Angle of Installation (see Figure 5)	0	–	360	degrees
Air Gap Range	AG	Using Allegro Reference Target 60-0	0.5	–	2.5	mm
Angular Vibration Immunity	Vib_{CAL}	Measured across one tooth-valley period (see Figure 2), calibration	0.07 × T_{CYCLE}	–	–	–
	Vib_{RM}	Measured across one tooth-valley period (see Figure 2), Running mode	0.07 × T_{CYCLE}	–	–	–
Direction Change Recognition in Running Mode [8]	N_{CD}	See Figure 11	–	1	–	T_{CYCLE}
Idle Time [9]	t_{IDLE}	Time to enter Idle mode when no output pulse is detected	–	1.5	–	s
Idle Temperature [9]	ΔT_{IDLE}	Temperature change to enter Idle mode when no output pulse is detected	–	10	–	°C
Direction Change Recognition After Idle	N_{CDIDLE}	Device in Idle Mode	–	2	–	T_{CYCLE}
Reorientation [10]	–	Peak-to-peak qualification window to trigger recalibration (SPD channel)	–	3	–	T_{CYCLE}
Recalibration Threshold	Recal_threshold		–	62.5	–	%
First Speed-Only Message	$PULSE_{SPD-ONLY}$	f_{ROT} < 200 Hz	–	1.7	–	T_{CYCLE}
First Speed and Direction Message	$PULSE_{SPD-DIR}$	f_{ROT} < 200 Hz, on device 1st power-on or if self-write counter has been exceeded	–	4	–	T_{CYCLE}
		f_{ROT} < 200 Hz, if correct channel in memory	–	2.5	–	T_{CYCLE}
		f_{ROT} < 200 Hz, if wrong channel in memory [11]	–	4	–	T_{CYCLE}
Tooth-to-Tooth Variation over 1 T_{CYCLE}		Using Reference Target 60-0	–0.2	–	0.2	mm
Total Air Gap Variation During Operation		Momentary interruptions in output sequence permitted; operation within AG range	–0.4	–	0.4	mm
THERMAL CHARACTERISTICS						
Package Thermal Resistance	$R_{\theta JA}$		–	150	–	°C/W

[2] Typical values at V_{CC} = 12 V and T_A = 25°C, unless otherwise specified. Performance may vary for individual units, within the minimum and maximum limits.
[3] Maximum voltage must be adjusted for power dissipation and junction temperature; see Power Derating section.
[4] Negative current is defined as conventional current coming out of (sourced from) the specified terminal.
[5] Open safe state labeled as $I_{CC(open)}$ is entered when diagnostics detect an unsafe state and $V_{CC} < V_{CC(min)}$. Refer to safety manual for further details.
[6] During EEPROM self-writing procedure, this current will be increased by up to 2 mA.
[7] Active safe state is entered for more than t_{SAFE} when diagnostics detect an unsafe state and $V_{CC} > V_{CC(min)}$. Refer to safety manual for further details.
[8] Device can output incorrect direction for up to 1 T_{CYCLE} after direction change. See figure 11.
[9] Both conditions, Idle Time and Idle Temperature, must be met for the device to enter Idle Mode. After entering normal mode, AK messages with direction valid bit set to 0 are output until a valid direction is recognized.
[10] The device recalibrates if the peak-peak value of the active channel falls below Recal_threshold of the peak-peak value of the best speed-channel; refer to Section Normal Operation for additional detail.
[11] When device mounting orientation has changed from last self-memory write.

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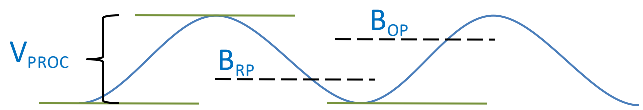

Figure 1: Switch points for differential signal. Representation of an idealized signal.

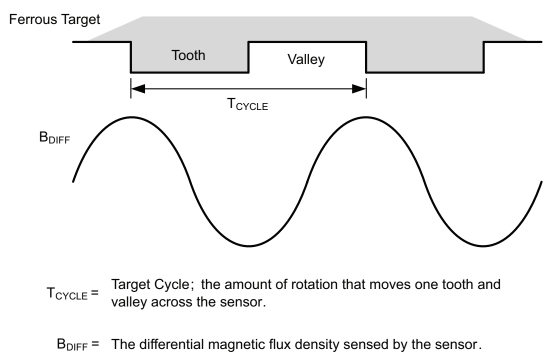

Figure 2: Definition of T_{CYCLE}

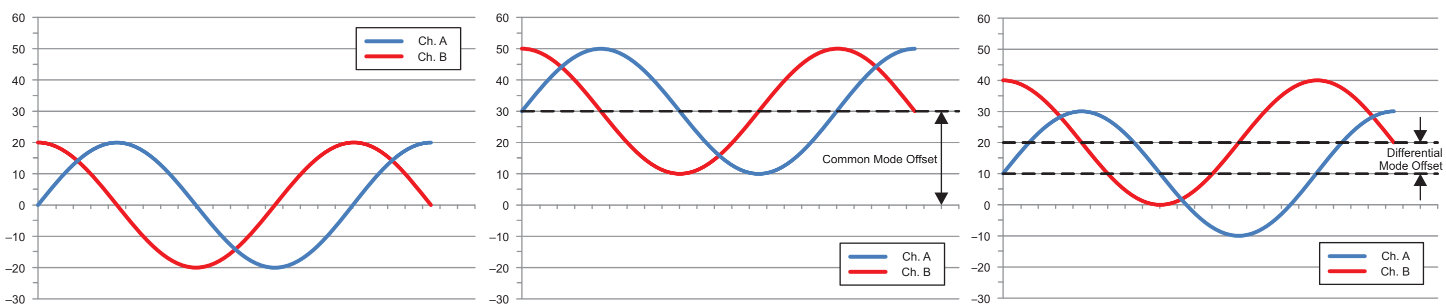

Figure 3 Left: No Offset, Middle: Common Mode Offset, Right: Differential Mode Offset

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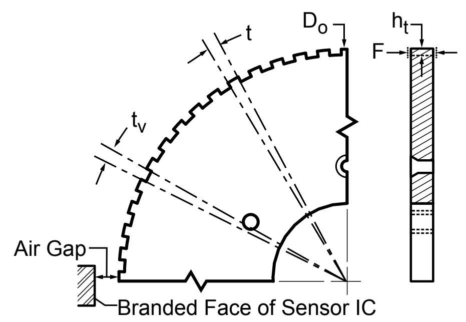
REFERENCE

Reference Target 60-0

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	–	–	

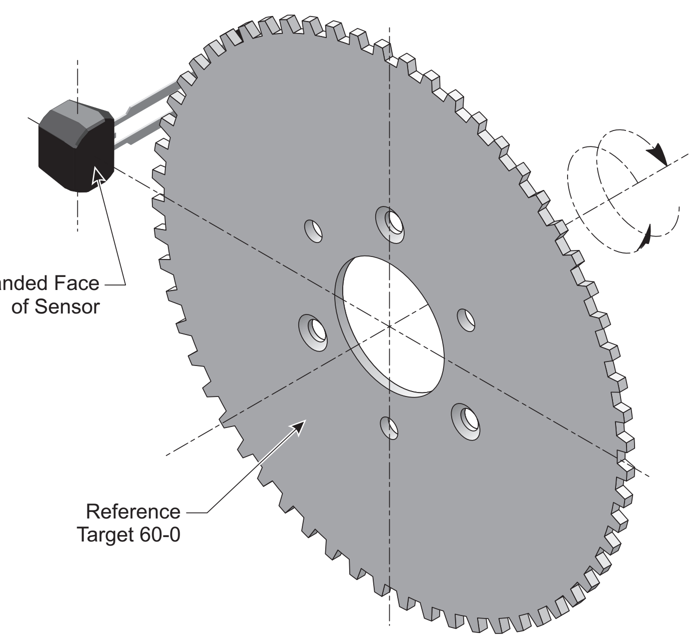


Figure 4: Reference Target 60-0

FUNCTIONAL DESCRIPTION

The ATS604 is intended for use in applications requiring speed and direction information and allows for an installation that is not sensitive to the orientation the device takes up when it is mounted. The assembly is designed to operate with a ferromagnetic gear target due to the magnetic back-bias that is included in the IC package. As shown in Figure 5, the ATS604 can be mounted at any angle in a plane perpendicular to the target rotation.

The ATS604 contains a single-chip Hall-effect sensor IC, a pellet with a flat ferromagnetic pole piece (concentrator) as well as an in-package passive protection component.

To support orientation-insensitive mounting, the IC has three embedded Hall elements (A, B, C) that are located on the edges of an equilateral triangle (Figure 6). The elements sense the magnetic profile of the target simultaneously, but at different locations. To generate the speed signal, three differential signals (A-B, B-C, and A-C) are calculated. With the first pulses detected after power-up, the IC selects the differential signal with the highest peak-to-peak amplitude and uses it as the Speed (SPD) channel. To generate the direction information, the sum of the three Hall signals (A+B+C) is calculated and its phase is compared against the phase of the speed channel according to Table 1. This summed signal is called the Direction (DIR) channel.

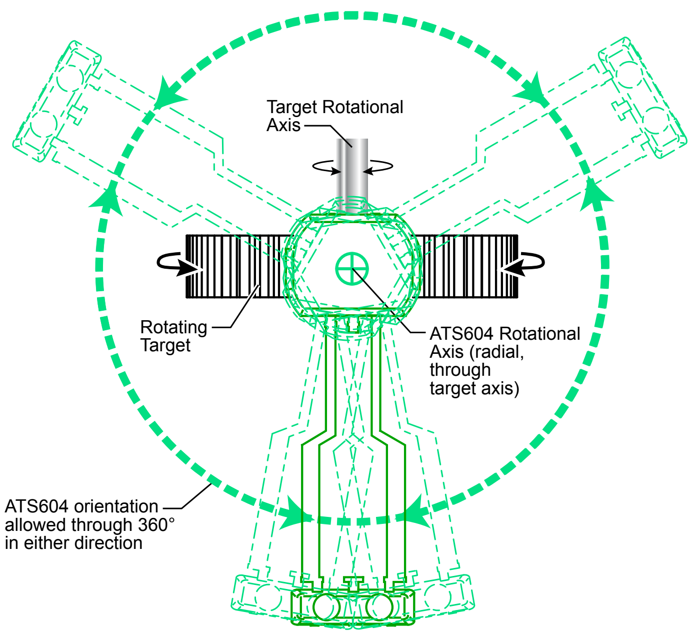


Figure 5: Orientation-Insensitive Mounting

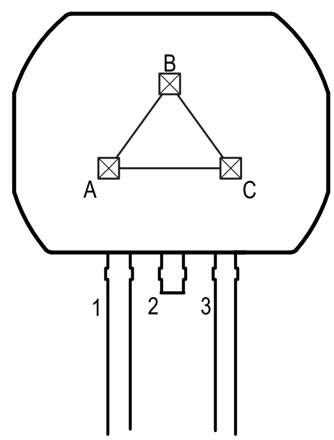


Figure 6: Hall Sensor Configuration

Table 1: Direction Detection Codification

Direction Channel	Speed Channel	
	Rise	**Fall**
High	Negative	Positive
Low	Positive	Negative

Modes of Operation

CALIBRATION

In the calibration mode, only speed-only AK messages (refer to Section Description of AK Protocol) are provided when the target rotates (refer to Figure 7). Pulse accuracy is reduced during calibration. Standstill AK messages are generated when the target does not rotate to indicate that the device is functional.

Typically, speed-only AK messages are transmitted $\text{PULSE}_{\text{SPD-ONLY}}$ after device reset. AK bits are updated, but direction remains invalid.

The calibration mode typically completes after 2.5 T_{CYCLE} (refer to State Description table), and the device proceeds to the Normal operation mode. A signal tracking mechanism enables the update of detection thresholds based on the current signal amplitude and are adapted to the incoming pulses. Time to normal operation mode may vary depending on the speed channel written in memory and device orientation. On the first power-on of its lifetime or if the self-write counter has been exceeded (refer to EEPROM Self-Write of Best Speed Channel section), no speed channel is registered in the EEPROM memory and the device will select the best channel to use. This process takes typically 4 T_{CYCLE}. If the correct speed channel is registered in EEPROM memory, on the next power-on, calibration length is shortened to typically 2.5 T_{CYCLE}. If the wrong speed channel is registered in EEPROM memory, meaning if the device mounting orientation has changed since its last EEPROM self-write, the device must select the correct channel before entering normal operation mode. This step takes typically 4 T_{CYCLE}.

NORMAL OPERATION

The ATS604 generates an AK message for each tooth and valley of the target that passes in front of the device (opposite the branded face of the package case; see Figure 8, Figure 9, and Figure 10).

Target rotational speed information is indicated by the rate of the AK messages. The IC is sensing target rotation in both the positive and negative direction. The direction is indicated by "Direction of rotation" bit in the AK message.

To track the target signal in the presence of imperfections like runout or tooth-to-tooth amplitude variations, a continuous adaptation of offset and detection thresholds according to the positive and negative peak values of the magnetic signals is done.

When no pulses are detected for a time > t_{IDLE} and a temperature change of no less than ΔT, the device transitions into the Idle mode. This ensures that offset and gain drift that could occur during an extended time with no incoming pulses and a significant temperature change during that time do not lead to an operation with inappropriate thresholds.

If the peak-to-peak value of the active channel falls below Recal_threshold of the peak-to-peak value of the best speed-channel, the device initiates a sequence which eventually leads to a transition to Calibration mode. This condition applies if the sensor is turned in its mounting position, ensuring that the appropriate sensor pair for the new position is selected in Calibration mode. The transition is made if the condition is valid for more than three periods. The new channel is then self-written in EEPROM if appropriate conditions

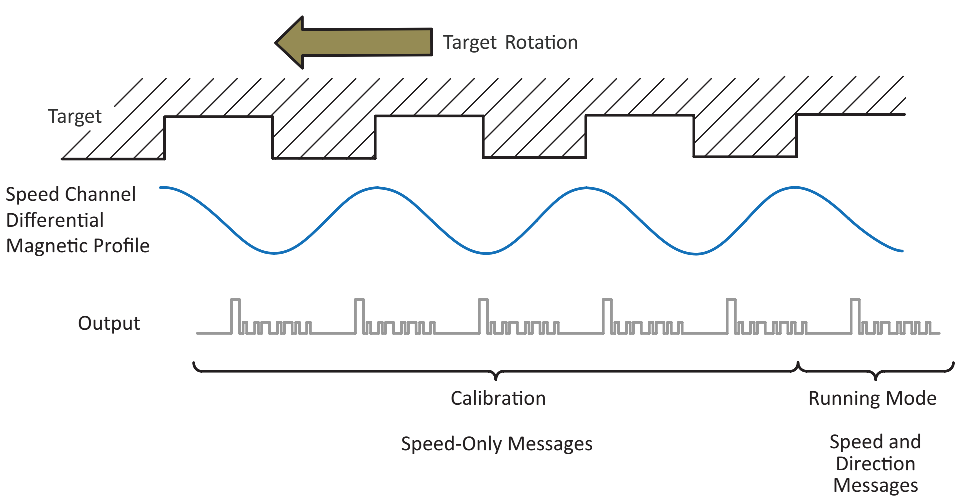


Figure 7: Example of different AK messages order in calibration

apply (see EEPROM Self-Write of Best Channel section below).

The differential sensor architecture of the speed channel provides high immunity to homogenous external magnetic fields. The direction signal is derived by the sum of the three single Hall signals, and it can be sensitive to external magnetic fields. During an external magnet perturbation, rotational vibration, or after a change of direction of rotation, the “Validity of the direction of rotation” may be set to invalid. Due to a rotational vibration, the device may change the currently selected channel and the total sum of messages encoding a positive rotation may differ from the total sum of messages encoding a negative rotation.

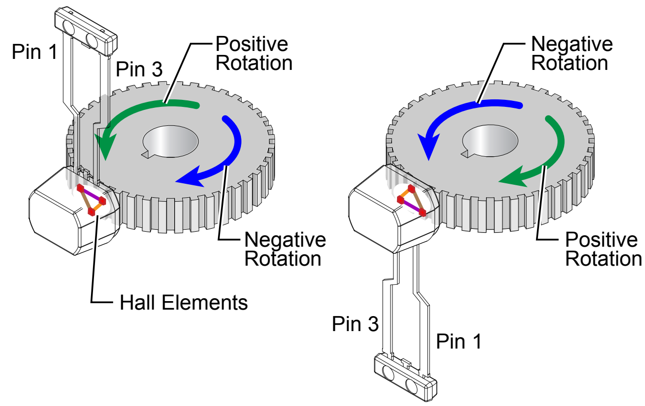


Figure 8: Direction Definition

IDLE MODE

The offset and threshold adaptation that is based on the peak values cannot update the detection thresholds in case of a standstill. However, the signals from the Hall sensors can be subject to drift especially at significant temperature changes during extended standstill time. Therefore, the peak tracking mechanism in the Idle mode uses more aggressive tracking mechanism on the speed channel and direction channel to ensure that all peaks are detected and thresholds correctly updated. As soon as two consecutive pulses with the same direction have been detected the device transition back to Normal mode.

As long as no pulses are detected, standstill AK messages are generated to indicate that the device is functional.

Additionally, in Idle mode, the same condition as in Normal mode applies to trigger recalibration.

The states and their respective actions and transitions are described in Table 2.

SAFE STATE DESCRIPTION

The ATS604 sensor IC contains diagnostic circuitry that will continuously monitor occurrences of failure defects within the IC.

Refer to the ATS604 Safety Manual for additional details.

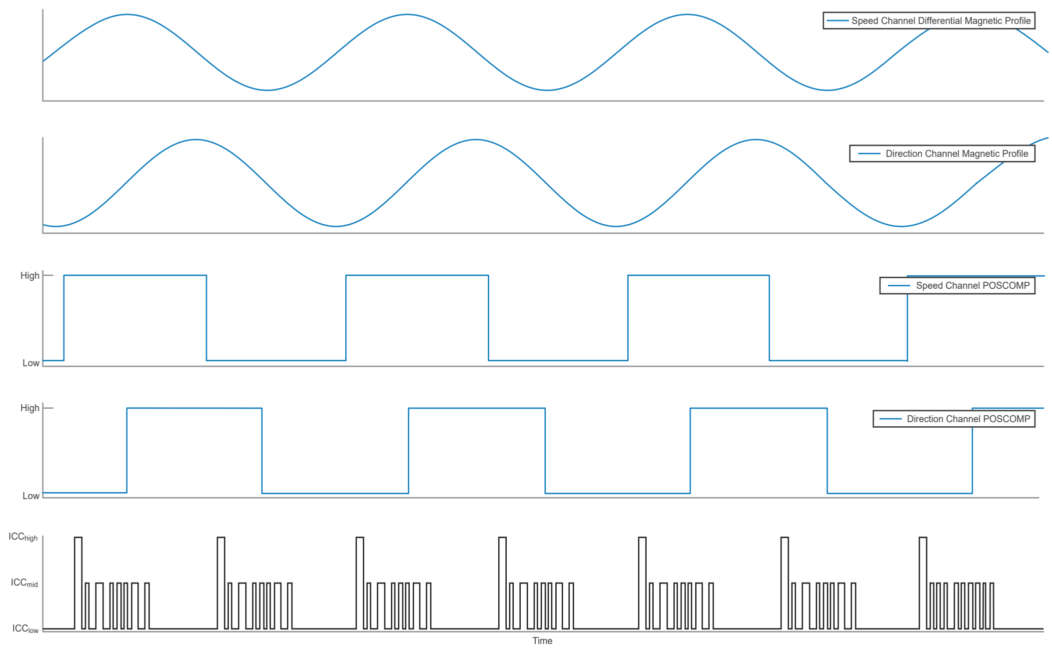


Figure 9: Example of Speed and Direction Output During Normal Operation in Positive Rotation

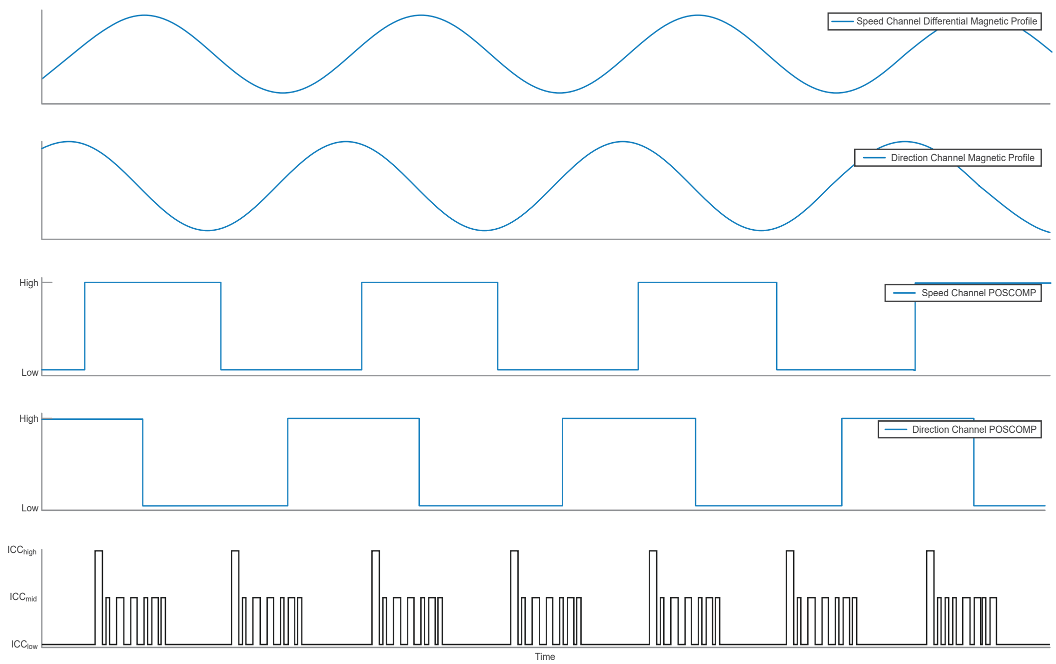


Figure 10: Example of Speed and Direction Output During Normal Operation in Negative Rotation

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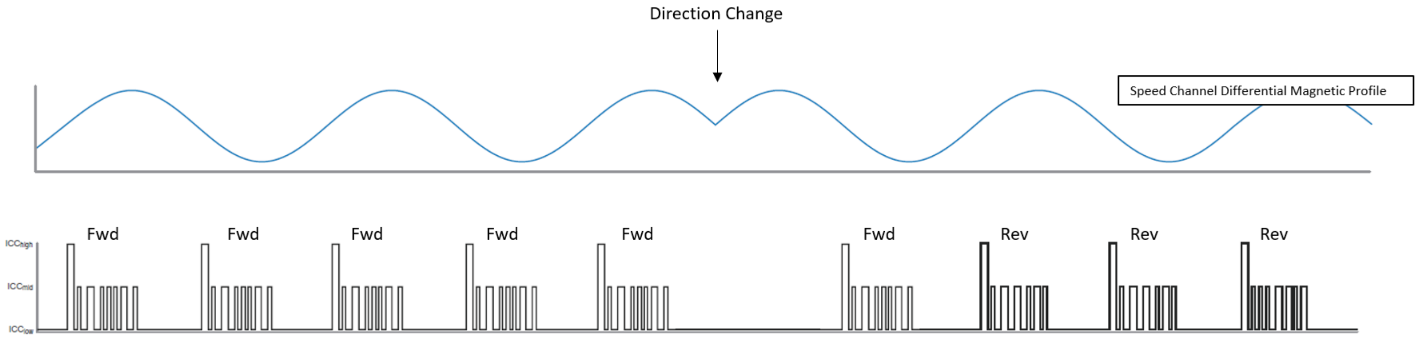

Figure 11: Typical Direction Change Behavior

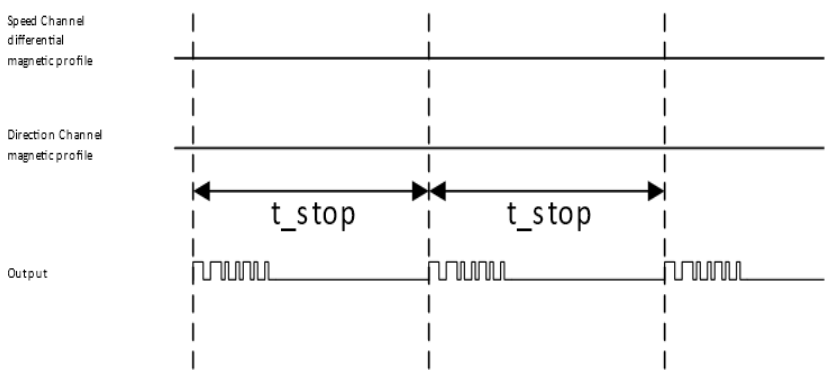

Figure 12: Zero Speed Mode Output

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Table 2: Modes of Operation [14]

#	State	Actions	Output	Transition Conditions	Transition to
1	Reset	Power-up internal circuitry	No output signal	After max. 2 ms	Calibration
				Diagnostic error detected	Safe State
2	Calibration	Selection of Hall plate pair for SPD	Standstill AK message, Speed-only AK message	• After $PULSE_{SPD-DIR}$ [13] • Channels not in lockout • A speed channel has been selected	Normal Mode
				Anomalous speed channel signals detected	Reset
				Diagnostic error detected	Safe State
3	Idle	More aggressive peak detector for optimum threshold detection	Standstill AK message, Speed-only AK message, No direction information	Active speed channel pk-pk < Recal_ threshold pk-pk of best channel	Calibration
				Two consecutive pulses with same direction have been properly detected	Normal Mode
				Diagnostic error detected	Safe State
4	Normal Mode	Detection with adapted thresholds	Speed and direction information, Standstill AK message	No pulses for > t_{IDLE} (typ. 1.5 s) AND temperature change > ΔT_{idle} (10°C)	Idle
				Active speed channel pk-pk < Recal_ threshold pk-pk of best channel	Calibration
				Diagnostic error detected	Safe State
5	Safe State	Detection of diagnostic errors	No output pulse, Refer to safety manual for current level description	If EEPROM error, device remains in this state until new power cycle of device	Remain in Safe State
				After other types of errors	Calibration

[13] Time to normal mode may exceed depending on EEPROM memory status and sensor mounting orientation.
[14] Safe state can be entered in each mode in the case of diagnostic error detection. Vibration messages may be sent as described in Table 7.

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Direction Determination

The ATS604 allows for orientation-insensitive direction detection by automatically selecting one out of three possible Hall pairs during startup. Nevertheless, the direction information is device-referenced and must be converted to vehicle-referenced information before it is processed by the ECU algorithm. The ATS604 provides its device-referenced direction information as positive or negative direction, coded on the “Direction of rotation” bit of the AK message. Mounting tolerance as well as electrical noise can lead to the selection of an adjacent Hall pair during consecutive startup cycles. Therefore, the ATS604 provides the information on the used Hall pair in bit 1:2 and 5:7 of the AK message.

A signal conditioning table in the ECU software must derive the vehicle-referenced direction from the device direction bit, the Sensor Channel bits, and the initial conditions that have been saved during a direction calibration procedure of the vehicle. Because direction information can be easily derived by plausibility algorithms, it is recommended to estimate the initial conditions during normal operation instead of performing a direction calibration procedure. In other words, the sensor channel is encoded in the AK protocol, while the initial bit must be read from the ECU memory.

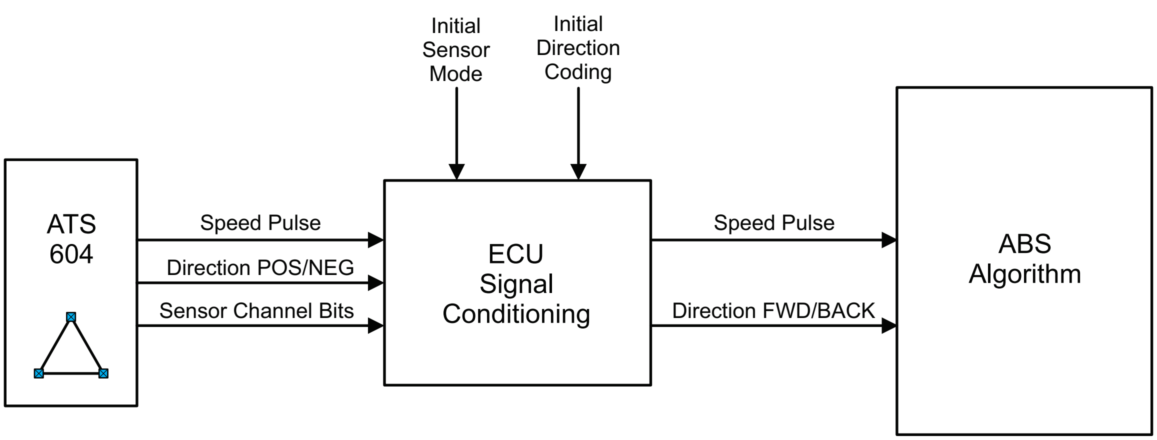

Figure 13: System Block Diagram

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The three Hall pairs that can be selected combined with two respective directions result in six possible mounting positions, as depicted in Figure 14. The arrows indicate the direction of the target movement, revealing that from the sensor's perspective, positions 1 and 4, 2 and 5, as well as 3 and 6 cannot be distinguished. Furthermore, it can be seen that a change in the mounting position from 1 to 2 or from 1 to 6 does not result in a change of the indicated direction, while a change from position 2 to 3 or from 6 to 5 results in a change of the indicated direction. Therefore, the initial position as well as the actual position must be available to determine the vehicle referred direction from the sensor referred direction.

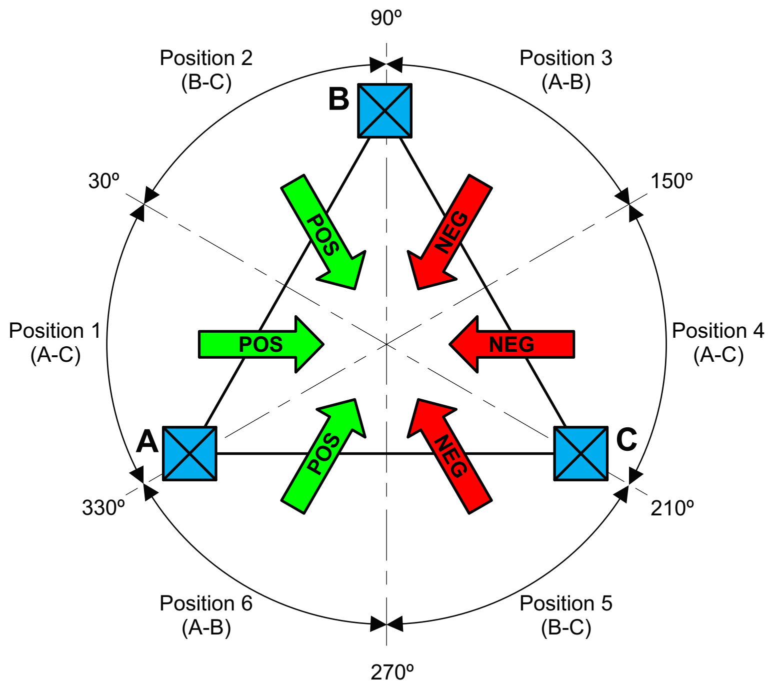

Figure 14: Mounting Positions

Depending on the mounting position, the sensor automatically selects the appropriate Hall pair and does the device direction coding according to Table 3.

Table 3: Mounting Positions and Direction Coding

Position	Installation Angle	Sensors Used for Speed	Direction Coding	Sensor Channel Bit 5:7
1	–30° ... 30°	A-C	A-C leads A+B+C → POS A-C lags A+B+C → NEG	110
2	30° ... 90°	B-C	B-C leads A+B+C → POS B-C lags A+B+C → NEG	010
3	90° ... 150°	A-B	A-B leads A+B+C → NEG A-B lags A+B+C → POS	100
4	150° ... 210°	A-C	A-C leads A+B+C → NEG A-C lags A+B+C → POS	110
5	210° ... 270°	B-C	B-C leads A+B+C → NEG B-C lags A+B+C → POS	010
6	270° ... 330°	A-B	A-B leads A+B+C → POS A-B lags A+B+C → NEG	100

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To get the direction the vehicle is actually moving in, the device direction bit, the sensor mode bits, and the initial conditions must be combined according to Table 4. The device direction bit, as well as the sensor mode bits, are available in the output protocol.

The sensor mode is encoded in the AK-protocol, while the initial condition must be read from the ECU memory.

EEPROM Self-Write of Best Speed Channel

The ATS604 has the capability to self-write in EEPROM the best speed channel under the current sensor orientation. This feature occurs only under certain predefined conditions, including temperature range and the sensor being in run mode. In case reprogramming is required, the sensor does set an internal EEPROM programming flag. If the ATS604 enters stand-still mode and the EEPROM programming flag is set, three consecutive special events messages (refer to Section Description of AK Protocol), EEPROM-write required are sent. Following the third standstill message, the EEPROM write is performed. While writing the EEPROM, the current drawn by the ATS604 will be increased by up to 2 mA. Speed and direction AK messages can be triggered in this time interval and the additional current will be added to all current levels.

In case the device is powered-off with the EEPROM programming flag set but before the actual writing has taken place, the device will experience worse performance at the next power-up event, likely resulting in a device recalibration to determine the best speed channel followed by another attempt to program the EEPROM.

EEPROM self-writes ($N_{self\text{-}writes}$) is only allowed 250 times and occurs only if temperature is within –40°C and 110°C. $N_{self\text{-}writes}$ is monitored by an internal counter. If this counter exceeds the maximum number of write events, the special events message "EEPROM-write counter exceeded" is sent (refer to Section Description of AK Protocol). Furthermore, the startup behavior of the ATS604 is modified in this case, with the device ignoring the last registered speed channel in EEPROM and evaluating the best speed channel with each power-up. This does result in an increased number of non-direction messages after power-up. Devices coming out of the Allegro production process will not have any default channel written in the EEPROM; therefore, on the first power-on after installation, the sensor must evaluate the best speed channel. In this specific case, the sensor startup performance will be similar to the case when "EEPROM-write counter exceeded".

Table 4: Direction Mapping in Case of Changing Mounting Position. Initial Position is the mounting position (refer to Figure 14) at power-up of the device. Actual Position is the current position, which may or may not be different to the initial position at power-up.

Initial Position	Actual Position	Sensor Channel Bits 5:7	ECU Coding when FWD was POS Initially	ECU Encoding when FWD was NEG Initially
1	6	100	POS → FWD	NEG → FWD
	1	110	POS → FWD	NEG → FWD
	2	010	POS → FWD	NEG → FWD
2	1	110	POS → FWD	NEG → FWD
	2	010	POS → FWD	NEG → FWD
	3	100	NEG → FWD	POS → FWD
3	2	010	NEG → FWD	POS → FWD
	3	100	POS → FWD	NEG → FWD
	4	110	POS → FWD	NEG → FWD
4	3	100	POS → FWD	NEG → FWD
	4	110	POS → FWD	NEG → FWD
	5	010	POS → FWD	NEG → FWD
5	4	110	POS → FWD	NEG → FWD
	5	010	POS → FWD	NEG → FWD
	6	100	NEG → FWD	POS → FWD
6	5	010	NEG → FWD	POS → FWD
	6	100	POS → FWD	NEG → FWD
	1	110	POS → FWD	NEG → FWD

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Description of AK Protocol

The ATS604 will fulfill the requirements according to the AK protocol specification “Requirement Specifications for Standardized Interface for Wheel Speed Sensors with Additional Information” (AK-Protokoll), version 4.0, with some extensions as described in this datasheet.

The ATS604 can output several different types of AK messages: Speed-only, Speed and Direction, Special Event, and Standstill messages.

Table 5: AK Messages Types

Message Type	Bit1:2	Bit 3	Bit 5:7
	Identifier Bits		**Data Bits**
Overtemperature	01	0/1	001
Vibration	10	0	001
EEPROM-write required	01	0/1	010
EEPROM-write counter exceeded	01	0/1	100
Speed-only	See sequence below	0	See sequence below
Speed + Direction		1	
Standstill		0/1	

As a standard-compliant extension, the ATS604 encodes additional data in bits 1:2 and 5:7 of each AK message. In the following, each AK message is called a word. Successive AK messages include additional information that are cyclically provided as shown in Figure 15. In the word sequence, channel information is provided 9 times, followed by peak-to-peak information, followed by 9 times channel information, followed by temperature information. The system must receive 20 full AK messages to gather all three types of data at least once. Upon a sensor reset, including a reset due to a channel change, the sequence is restarted. When leaving standstill mode, the sequence is restarted. Vibration in normal mode does not lead to a sequence restart.

During Calibration state, following a device reset or power-up event, the Channel-selected word is output only. Upon entering Normal Mode, the sequence is started with 9 times channel selected followed by 1 times peak-to-peak information.

The information encoded in the data words are channel selected, peak-to-peak information, and temperature.

Channel-Selected Word

The currently selected speed-channel is encoded as a 3-bit value, as shown in Table 7.

Peak-Peak Information Word

Information about the peak-to-peak amplitude of the currently used speed channel is encoded as a 3-bit value. The data represents a measure of the magnitude of the peak-to-peak differential signal as seen by the Hall elements of the currently selected speed channel.

Temperature Information Word

The temperature, as recorded by the device internal temperature sensor, is encoded as a 3-bit value as shown in Table 7.

In addition to this sequence, the device can also output Special Event AK messages in bits 1:2 and 5:7 which modify the default sequence described earlier.

Overtemperature Word

Overtemperature special AK message is sent once a temperature larger than 190°C has been measured by the internal temperature sensor. In this condition, an internal flag is set and the next temperature AK message in the AK sequence is replaced by the overtemperature special AK message. The internal flag remains until at least one overtemperature special AK message is sent, even if the condition is no longer met at the time of the output pulse. After this step, the internal flag resets and the next AK sequence continues using the normal temperature AK message. AK sequence keeps sending the overtemperature special AK message as long as the internal flag is set.

EEPROM-Write Required Word

The ATS604 does store information about the last selected speed channel in EEPROM to speed up the calibration phase. If the device detects that a speed channel other than the one currently stored in EEPROM should be used, an internal flag is set.

If this flag is set and the device starts sending standstill messages, the first 3 standstill messages will contain this word.

After being sent 3 times, the EEPROM self-write will start after transmission of the standstill message. During EEPROM-writing, the current consumption will be increased by up to 2 mA. Standstill and speed + direction messages can be sent while the ATS604 is writing EEPROM.

In case the vehicle starts moving before the third standstill message, the ATS604 will repeat the same sequence of 3 special events messages the next time the sensor enters standstill.

EEPROM self-write is only possible after three consecutive standstill messages.

EEPROM-Write Counter Exceeded Word

If this counter is exceeded and the ATS604 detects that another EEPROM-write is required, an EEPROM-write counter exceeded message will be sent the next time the sensor enters standstill, in place of the EEPROM-write required message.

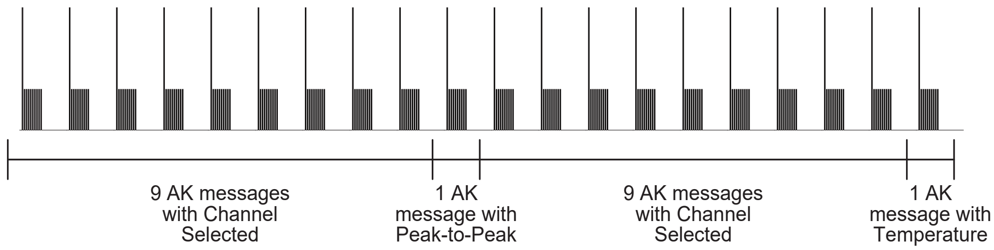

Figure 15: Sequence of additional information encoded in successive AK Messages, default sequence.
Note that the x-axis in this figure does not represent time; there is no delay between messages in the sequence. The time between subsequent messages does only depend on the magnetic input signal.

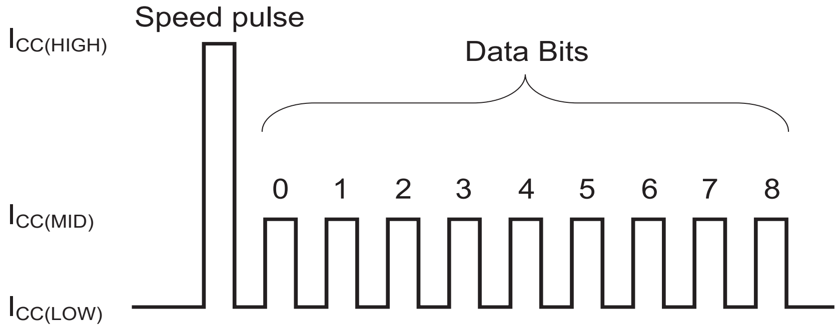

Figure 16: AK Protocol representation

Table 6: Bit Definition of AK Protocol

Bit Number	During Calibration	During Vibration	During Normal Mode	During Standstill
0	Air Gap Reserve	Air Gap Reserve	Air Gap Reserve	Air Gap Reserve [15]
1	AK Meaning Bit 0 (LSB)	AK Meaning Bit 0 (LSB)	AK Meaning Bit 0 (LSB)	AK Meaning Bit 0 (LSB)
2	AK Meaning Bit 1 (MSB)	AK Meaning Bit 1 (MSB)	AK Meaning Bit 1 (MSB)	AK Meaning Bit 1 (MSB)
3	Validity of Direction value = 0	Validity of Direction value = 0	Validity of Direction value = 1	Validity of Direction if standstill message during normal mode, value = 1, else value = 0
4	Direction of Rotation	Direction of Rotation	Direction of Rotation	Direction of Rotation
5	Additional Data Word Bit 0 (LSB)	Additional Data Word Bit 0 (LSB)	Additional Data Word Bit 0 (LSB)	Additional Data Word Bit 0 (LSB)
6	Additional Data Word Bit 1	Additional Data Word Bit 1	Additional Data Word Bit 1	Additional Data Word Bit 1
7	Additional Data Word Bit 2 (MSB)	Additional Data Word Bit 2 (MSB)	Additional Data Word Bit 2 (MSB)	Additional Data Word Bit 2 (MSB)
8	Even Parity Bit	Even Parity Bit	Even Parity Bit	Even Parity Bit

[15] The Air Gap Reserve bit is set to “1” when the magnetic input signal is less than two times the smallest signal the device can detect.

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Table 7: Encoding of data in additional bit-words

Bit 1:2	AK Meaning	Bit 5:7	Content
10	Channel selected	100	1: AB channel selected
		010	2: BC channel selected
		110	3: AC channel selected
		001	4: Vibration
00	Peak-to-Peak	000	0: < LOR [16]
		100	1: 1.00 × LOR to 1.50 × LOR
		010	2: 1.50 × LOR to 1.75 × LOR
		110	3: 1.75 × LOR to 2.25 × LOR
		001	4: 2.25 × LOR to 3.00 × LOR
		101	5: 3.00 × LOR to 4.50 × LOR
		011	6: 4.50 × LOR to 8.00 × LOR
		111	7: > 8.00 × LOR
11	Temperature [17]	000	0: < –10°C
		100	1: –10°C to 20°C
		010	2: 20°C to 60°C
		110	3: 60°C to 100°C
		001	4: 100°C to 130°C
		101	5: 130°C to 150°C
		011	6: 150°C to 170°C
		111	7: >170°C [18]

[16] LOR (Lockout Release) is the threshold of the smallest magnetic signal the device can measure, and it exists beyond the operating Air Gap Range. The LOR air gap is target dependent and should be characterized on individual applications.
[17] Junction temperature: Tolerance is ±20°C from the nominal value except for bit codifications 6 and 7, which have an increased tolerance of ±30°C from nominal value.
[18] Device performance is not guaranteed above the maximum operating junction temperature (T_J).

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EEPROM Programming

EEPROM programming can be done using Allegro dedicated software. Information on how to program EEPROM is given in the software programming guide.

EEPROM Content

The EEPROM does contain multiple areas that can be individually locked. In the state delivered to the customer, the customer scratch area and several parameters can be programmed. It is strongly recommended for the customer to apply the final locks, locking the entire EEPROM prior to installation in a vehicle.

Table 8: EEPROM Content

Name	Description	Bit Width
Customer_Scratch	Customer scratch area.	26
Out_mode	0: Allows for the multiplexer to be on the output pin. 1: Normal output protocol send on the output pin.	1
Lock_o	0: Customer has access to outmode. 1: Locks access to itself and outmode.	1
Lock_s	0: Customer has access to Customer_Scratch. 1: Locks access to itself and 26 bits of Customer_Scratch.	1

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Typical Repeatability Across Air Gap

Repeatability, commonly called jitter, across air gap is shown in Figure 17 and is calculated per-tooth, across all teeth, using the Allegro reference target 60-0.

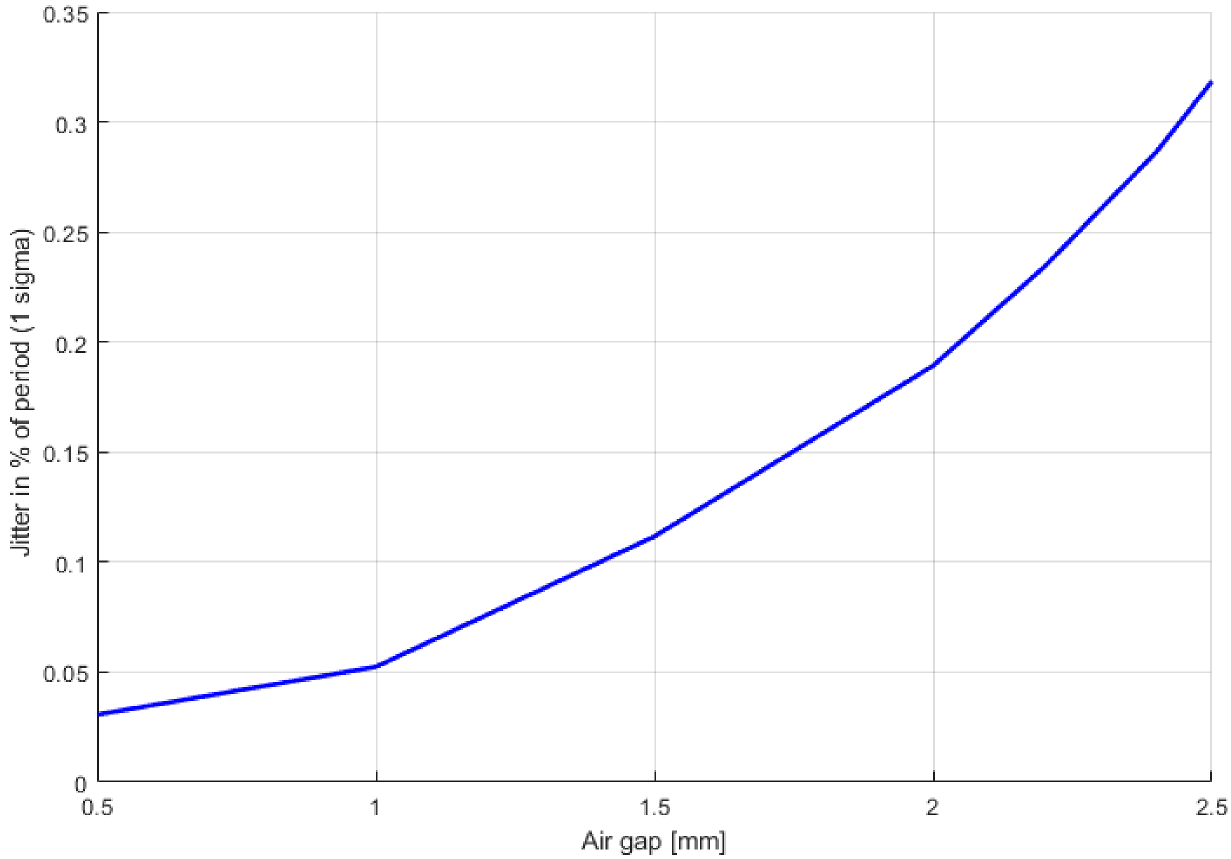

Figure 17: Typical Jitter performance at 25°C across air gap on Allegro reference target 60-0

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POWER DERATING

The device must be operated within the operating junction temperature of the device, T_J. 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 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 a 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 relationship used to estimate T_J, at P_D.

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

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

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

For example, given common conditions such as:

$T_A = 25\ °C$, $V_{CC} = 8\ V$, $R_{\theta JA} = 150°C/W$, and

$I_{CC} = 8.5\ mA$, then:

$$P_D = V_{CC} \times I_{CC} = 8\ V \times 8.5\ mA = 68\ mW$$

$$\Delta T = P_D \times R_{\theta JA} = 68\ mW \times 150°C/W = 10.2°C$$

$$T_J = T_A + \Delta T = 25°C + 10.2°C = 35.2°C$$

With respect to operating conditions, the worst case is given at the maximum input frequency of 3500 Hz. In this case, the average current is calculated to:

- 18.1 mA average current

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 $T_A = 160°C$, package SN, using single-layer PCB.

Observe the worst-case ratings for the device, specifically:

$R_{\theta JA} = 150°C/W$, $T_{J(max)} = 175°C$, $V_{CC(max)} = 24\ V$, and $I_{CC(max)} = 18.1\ mA$.

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

$$\Delta T_{max} = T_{J(max)} - T_A = 175°C - 160°C = 15°C$$

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

$$P_{D(max)} = \Delta T_{max} \div R_{\theta JA} = 15°C \div 150°C/W = 100\ mW$$

Finally, invert equation 1 with respect to voltage:

$$V_{CC(est)} = P_{D(max)} \div I_{CC(max)} = 100\ mW \div 18.1\ mA = 5.5\ V$$

The results indicate 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 $V_{CC(est)} > V_{CC(max)}$, then operation between $V_{CC(est)}$ and $V_{CC(max)}$ is reliable under these conditions.

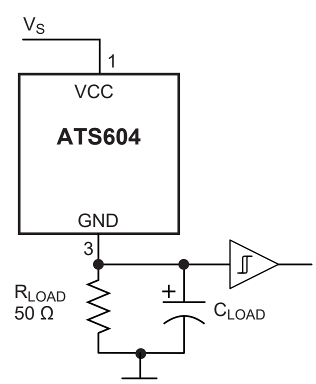

Figure 18: Typical Application Circuit

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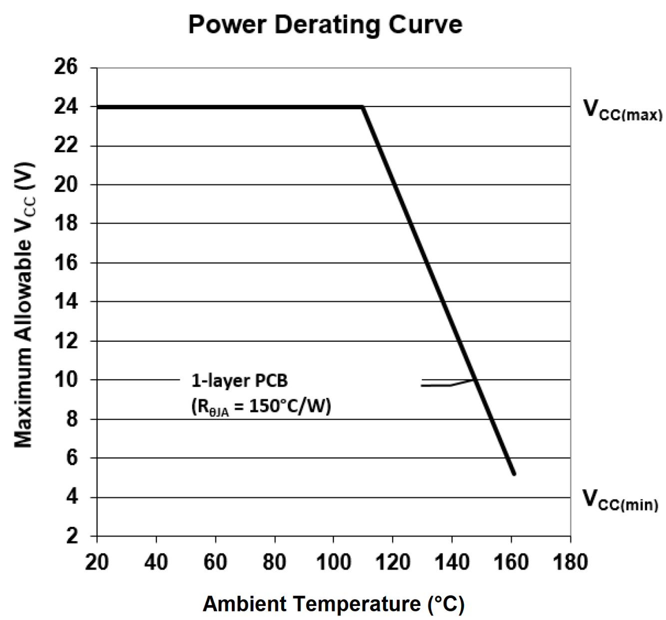


Figure 19: Example graph from the calculations in the Power Derating section

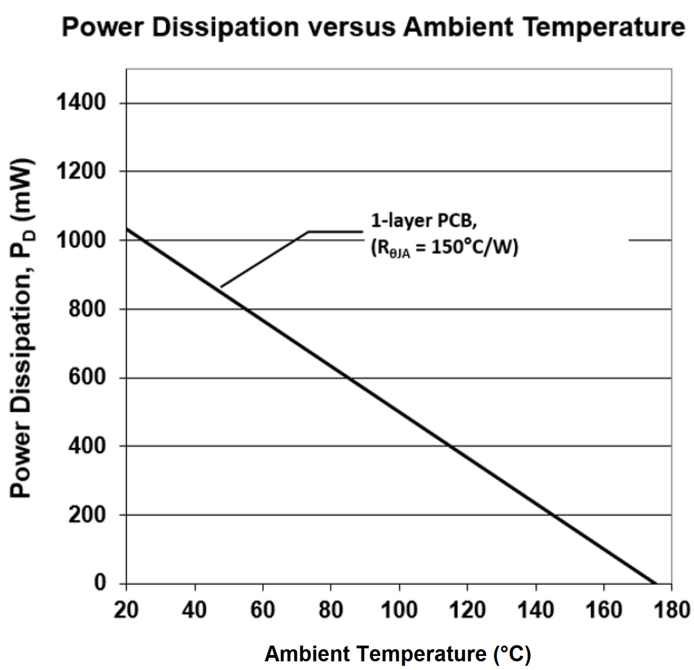
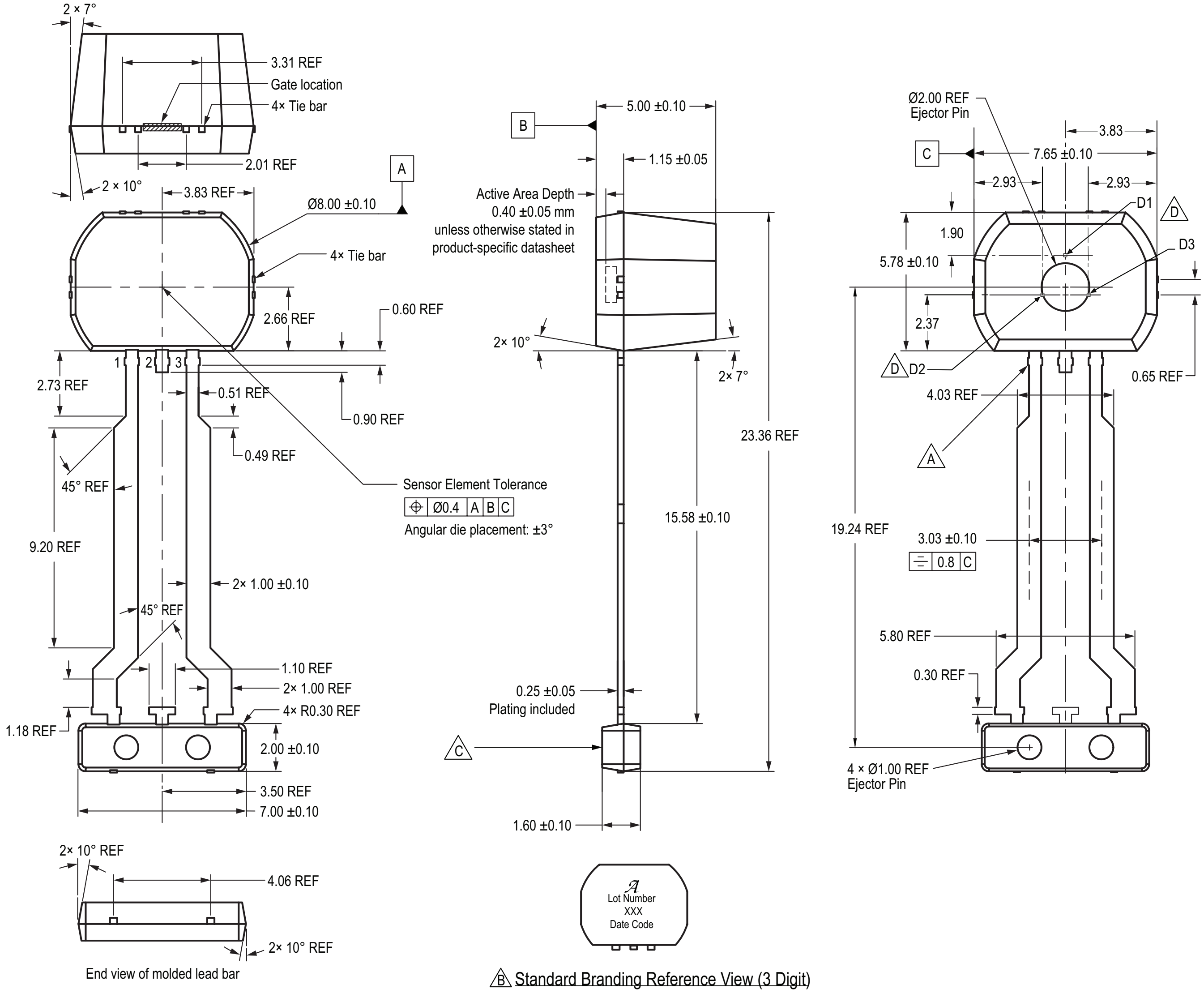


Figure 20: Example graph for Power Dissipation vs. Ambient Temperature

PACKAGE OUTLINE DRAWING

For Reference Only – Not for Tooling Use

(Reference Allegro DWG-0000429, Rev. 5)
Dimensions in millimeters – NOT TO SCALE
Dimensions exclusive of mold flash, gate burs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown



Lines 1, 2, 3, 4: Max. 10 characters per line

Line 1: Logo A
Line 2: Characters 5, 6, 7, 8, 9, 10, 11 of Assembly Lot Number
Line 3: Last 3 digit of Part Number; additional suffixes may be added to Part Number as required
Line 4: 4-digit Date Code

A Dambar removal protrusion (24×)

B Branding scale and appearance at supplier discretion

C Molded lead bar for preventing damage to leads during shipment

D Hall Elements (D1, D2, and D3); not to scale

Figure 21: Package SN, 3-Pin SIP

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REVISION HISTORY

Number	Date	Description
–	November 9, 2022	Initial release
1	June 26, 2026	Updated ASIL branding and description (page 1)

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