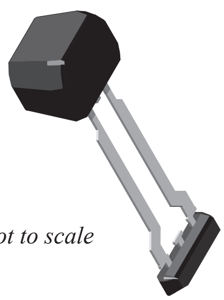
ATS604

Orientation-Independent Back-Bias AK Protocol Wheel Speed and Direction Sensor IC

FEATURES AND BENEFITS

- Orientation-independent mounting
- Two-wire AK Protocol reports speed, direction, temperature, and air gap information
- Fully integrated magnet and bypass capacitor for EMC robustness
- Air-gap-independent switch points
- Large operating air gap capability
- Undervoltage lockout
- True zero-speed operation
- Wide operating voltage range
- Single-chip sensing IC for high reliability
- ISO 26262 ASIL B with integrated diagnostics and certified safety design process (pending assessment)

PACKAGE: 3-pin SIP (suffix SN)



Not to scale

DESCRIPTION

The ATS604 is an advanced gear tooth sensor designed for automotive wheel speed sensing applications. Featuring a patented orientation-independent differential magnetic sensing architecture, the integrated circuit (IC) face can be rotated with any angle, 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 with ASIL B 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.

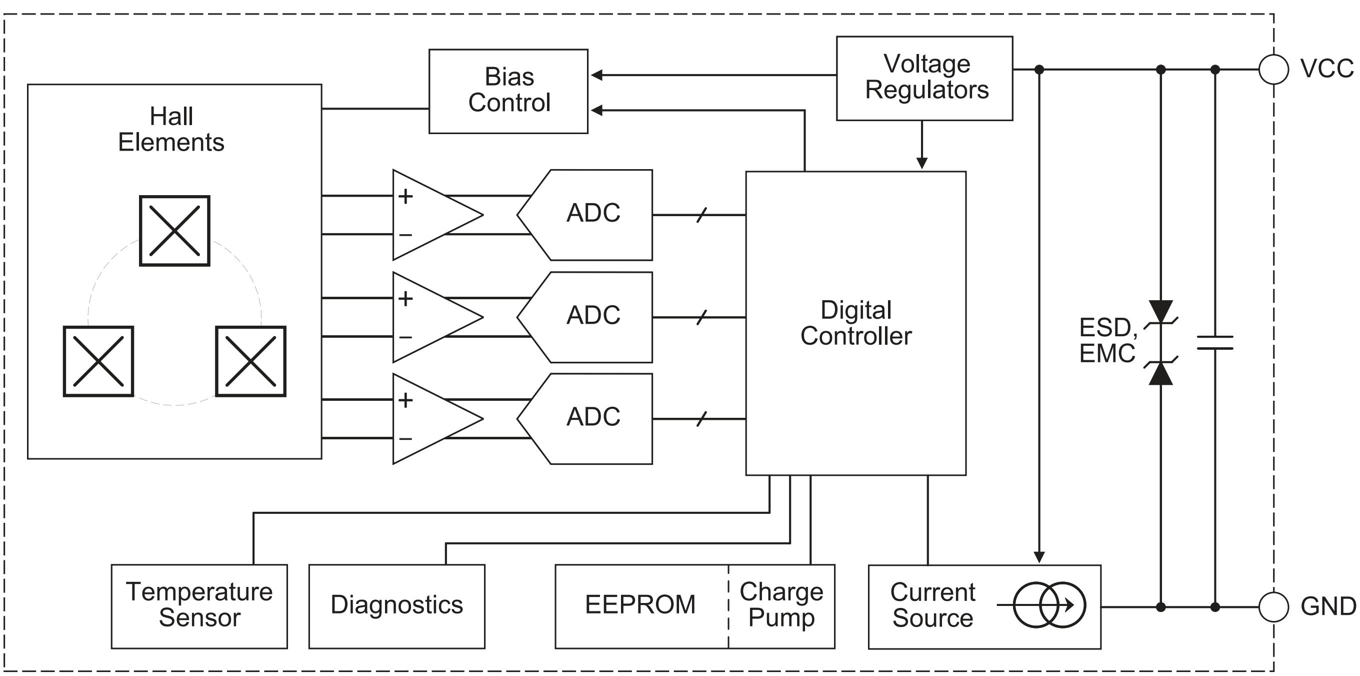
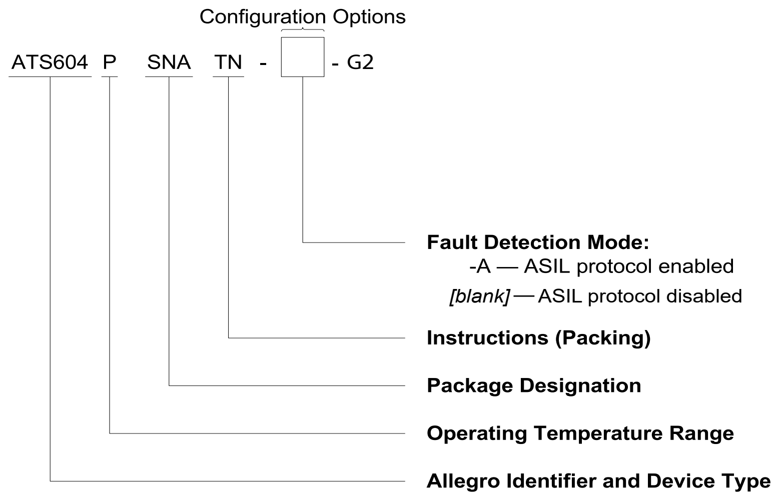


Figure 1: Functional Block Diagram

SELECTION GUIDE

Part Number	Operating Ambient Temperature Range (°C)	Package	Packing [1]	Leadframe Plating
ATS604PSNATN-A-G2	–40 to 160	3-pin SIP	800 pieces per 13-inch reel	Tin

[1] Contact Allegro™ for additional packing options.



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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		–40 to 160	°C
Operating Junction Temperature	T_J		-40 to 175	°C
Maximum Junction Temperature	$T_{J(MAX)}$	5 hours	200	°C
Storage Temperature	T_{stg}		–65 to 170	°C

INTERNAL COMPONENTS

Characteristic	Symbol	Test Conditions	Rating	Unit
Rated Nominal Capacitance	C_{SUPPLY}	Connected between pin 1 and pin 3 (refer to Figure 3)	2.2	nF
Rated Voltage			50	V

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

Characteristic	Symbol	Test Conditions	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	Minimum-K PCB, single-layer, single-sided, with copper limited to solder pads	150	°C/W

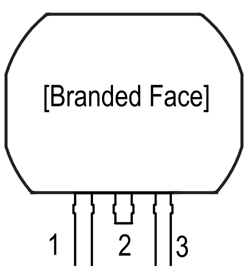

Figure 2: Package SN, 3-Pin SIP Pinout Diagram

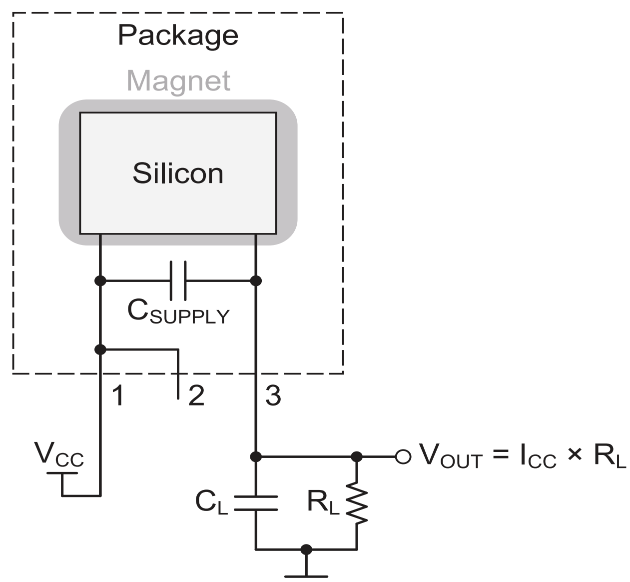

Figure 3: Typical Application Circuit

Terminal List

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

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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. [1]	Max.	Unit
ELECTRICAL CHARACTERISTICS						
Supply Voltage [2]	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 [3]	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	$I_{CC(OPEN)}$ [4]	Open safe-current state ($V_{CC} < V_{CC(min)}$)	–	–	3.9	mA
	$I_{CC(LOW)}$ [5]	Low-current state	5.88	7	8.4	mA
	$I_{CC(MID)}$ [5]	Mid-current state	11.76	14	16.8	mA
	$I_{CC(HIGH)}$ [5]	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	t_{ON}		–	–	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		–
Self-Write Temperature Range	$T_{self\text{-}write}$	Temperature self-writes are allowed	–40	–	110	°C
Self-Write Current Increase	$I_{self\text{-}write}$	Current increase while self-writing	–	2	–	mA
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 [6]	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 B_{DIFF} B_{OP}	–	50	–	%
	B_{RP_SPD}	% of peak-to-peak B_{DIFF} B_{RP}	–	50	–	%
	B_{HYST}	Switch Point Hysteresis	–	15	–	%
Direction Channel	B_{OP_DIR}	% of peak-to-peak B_{DIFF} B_{OP}	–	20	–	%
	B_{RP_DIR}	% of peak-to-peak $B_{DIFF} B_{RP}$	–	80	–	%

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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. [1]	Max.	Unit
Operating Frequency	f_{SIG}	Input frequency	0	–	3.5	kHz
Delay Time	t_{DEL}	Initial bit + bit stump suppression	60	75	90	μs
DAC CHARACTERISTICS						
Allowable User-Induced Differential Offset	$B_{dmoffset}$	See Figure 8	–60	–	60	G
Allowable User-Induced Common Mode Offset	$B_{cmoffset}$	See Figure 8	–120	–	120	G
PERFORMANCE CHARACTERISTICS [7]						
Installation Angle	θ	Angle of installation (see Figure 13)	0	–	360	degrees
Air Gap Range	AG	Using Allegro reference target 60-0	0.5	–	2.5	mm
Standstill Temperature Change	ΔT	Temperature change between speed events to set GDR = 0	–	10	–	°C
Angular Vibration Immunity	Vib	Amount of angular vibration up to which GDR bit is set to 0	0.75	–	–	T_{CYCLE}
		Amount of angular vibration up to which no speed events are output	0.008	–	–	T_{CYCLE}
GDR Recovery	$T_{RECOVER}$	Amount of constant rotation post running mode GDR = 0 scenario before GDR = 1 events resume	–	–	1.75	T_{CYCLE}
Direction Change Recognition in Running Mode	N_{CD}		–	–	1.75	T_{CYCLE}
Reorientation	$T_{RESELECT}$	Peak-to-peak qualification window to trigger recalibration (SPD channel)	–	2	–	T_{CYCLE}
First Message Correct Channel [8]	$PULSE_{MOVEMENT}$	f_{SIG} < 200 Hz	–	–	0.75	T_{CYCLE}
First Message Channel Select [8][9]		f_{SIG} < 200 Hz	–	–	0.75	T_{CYCLE}
First Message Incorrect Channel [8][9]		f_{SIG} < 200 Hz	–	–	1.1	T_{CYCLE}
First Speed-Only Message Correct Channel	$PULSE_{SPD\text{-}ONLY}$	f_{SIG} < 200 Hz	–	–	1.1	T_{CYCLE}
First Speed-Only Message Channel Select [9]		f_{SIG} < 200 Hz	–	–	1.1	T_{CYCLE}
First Speed-Only Message Incorrect Channel [9]		f_{SIG} < 200 Hz	–	–	3.5	T_{CYCLE}
First Speed and Direction Message Correct Channel	$PULSE_{SPD\text{-}DIR}$	f_{SIG} < 200 Hz, if correct channel in memory	–	–	2.25	T_{CYCLE}
First Speed and Direction Message Channel Select [9]	$PULSE_{SELECT}$	f_{SIG} < 200 Hz, on device 1st power-on or if self-write counter has been exceeded	–	–	2.5	T_{CYCLE}
First Speed and Direction Message Incorrect Channel [8][9]	$PULSE_{RESELECT}$	f_{SIG} < 200 Hz, if wrong channel in memory	–	–	3.5	T_{CYCLE}

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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. [1]	Max.	Unit
INPUT MAGNETIC CHARACTERISTICS [7]						
Operating Magnetic Input Signal Variation	$\Delta B_{DIFF(pk-pk)}$	Bounded amplitude ratio within T_{WINDOW} [10]; no missed output transitions or flat line condition; possible incorrect direction information; see Figure 7, Figure 8, and Figure 9	0.6	–	–	–
Operating Magnetic Input Signal Window	T_{WINDOW}	Rolling window where $\Delta B_{DIFF(pk-pk)}$ cannot exceed bounded ratio; see Figure 7, Figure 8, and Figure 9	4	–	–	T_{CYCLE}

[1] 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.
[2] Maximum voltage must be adjusted for power dissipation and junction temperature; see Power Derating section.
[3] Negative current is defined as conventional current coming out of (sourced from) the specified terminal.
[4] 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.
[5] During EEPROM self-writing procedure, this current increases by up to 2 mA.
[6] 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.
[7] Guaranteed by design via simulations.
[8] Movement messages and speed only events can be generated during vibration. Data bits of movement and speed only events can be truncated.
[9] When device mounting orientation has changed from last self-memory write.
[10] Signal variation is defined as the largest amplitude ratio from Bn to Bn + T_{WINDOW}. Signal variation may occur continuously while B_{DIFF} remains in the operating magnetic range.

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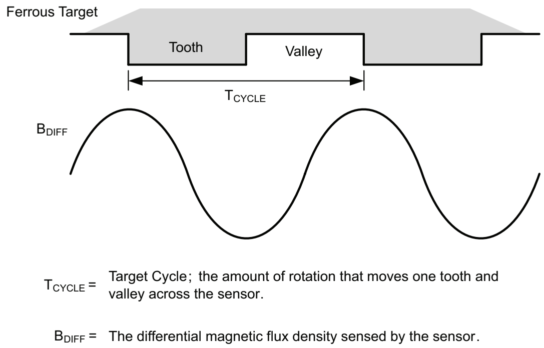

Figure 4: Definition of T_{CYCLE}

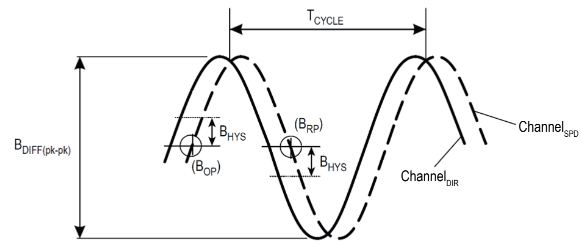

Figure 5: Definition of Switch Point

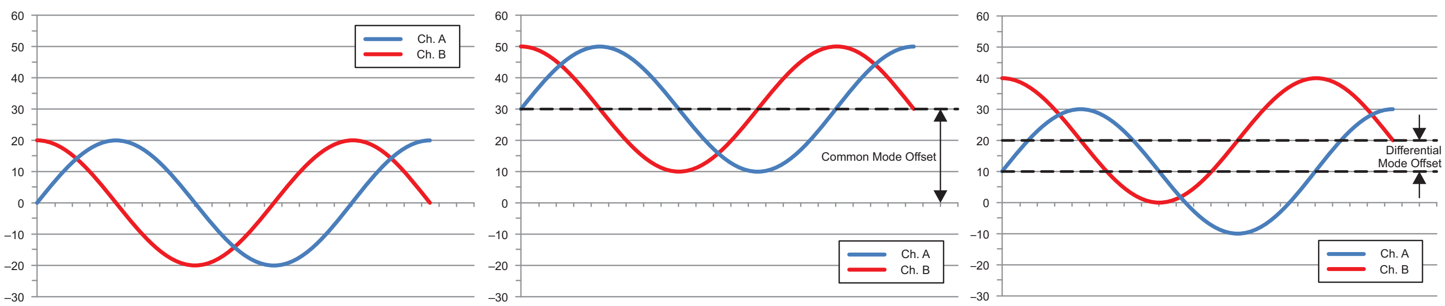

Figure 6 Left: No Offset, Middle: Common Mode Offset; Right: Differential Mode Offset

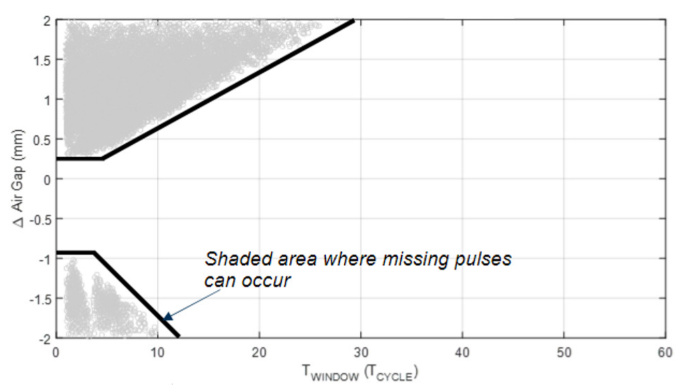

Figure 7: Performance of Differential Sequential Signal Variation

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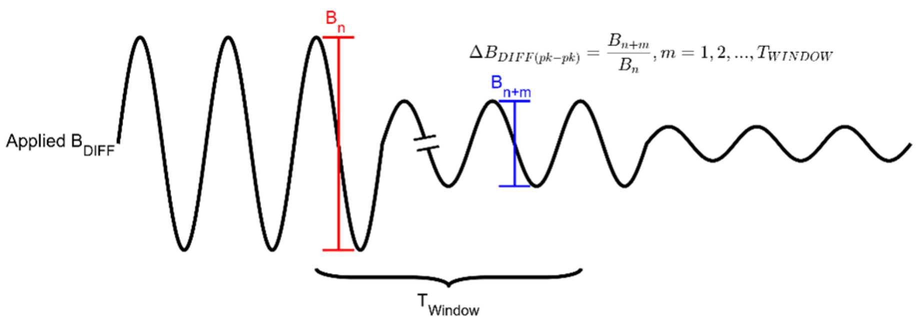

Figure 8: Single Period-to-Period Variation

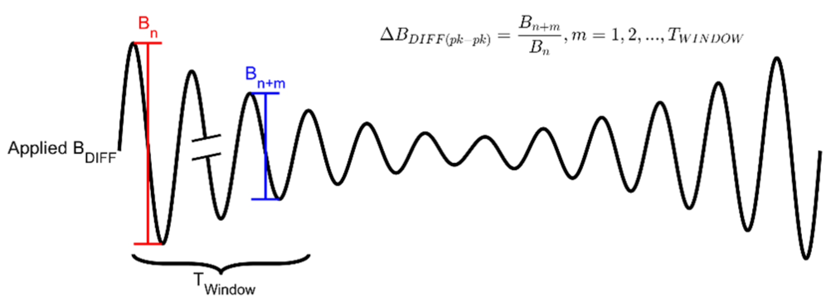

Figure 9: Repeated Period-to-Period Variation

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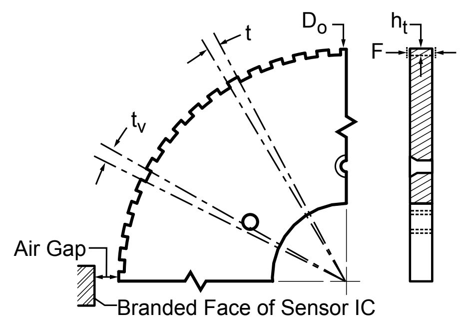
REFERENCE TARGET

Table 1: 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	–	–	

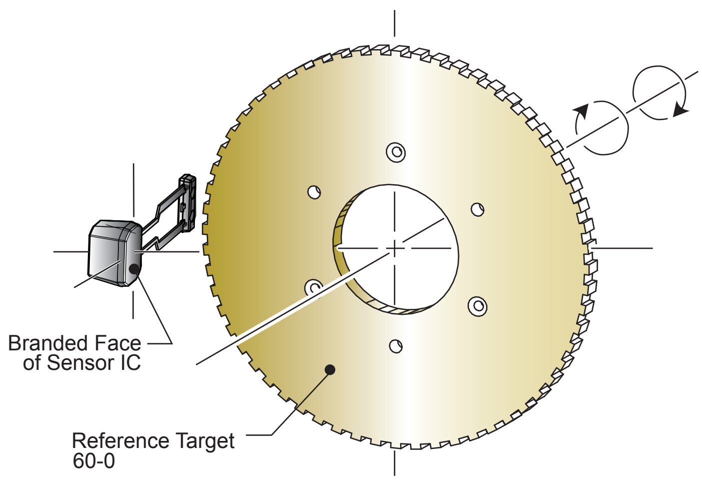


Figure 10: Reference Target 60-0

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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 12, 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 13). Three differential speed (SPD) channels are generated using each pair of sensing elements (A-B, B-C, and A-C). On device power-on, the IC uses the selected speed channel written in EEPROM; if no channel is selected, the IC selects the differential signal with the highest peak-to-peak amplitude and uses it as the speed channel. A single direction (DIR) channel is generated from the sum of the three sensing elements (A+B+C) which is nominally in quadrature with the speed channels. Comparing the speed channel phase with the direction channel phase the target rotation direction can be determined according to Table 2.

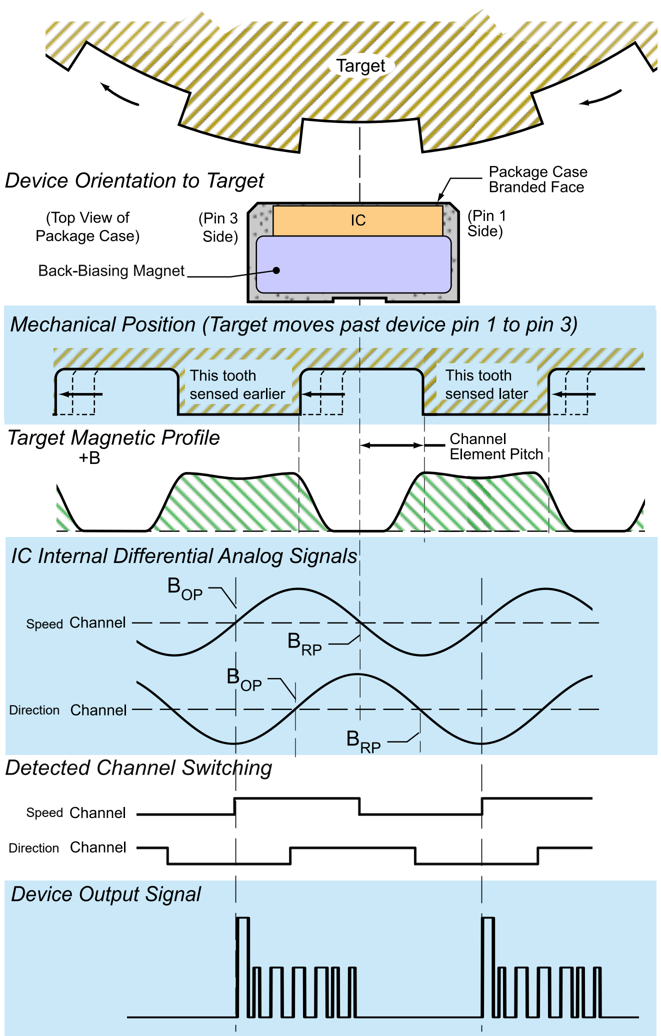

Figure 11: Basic Operation

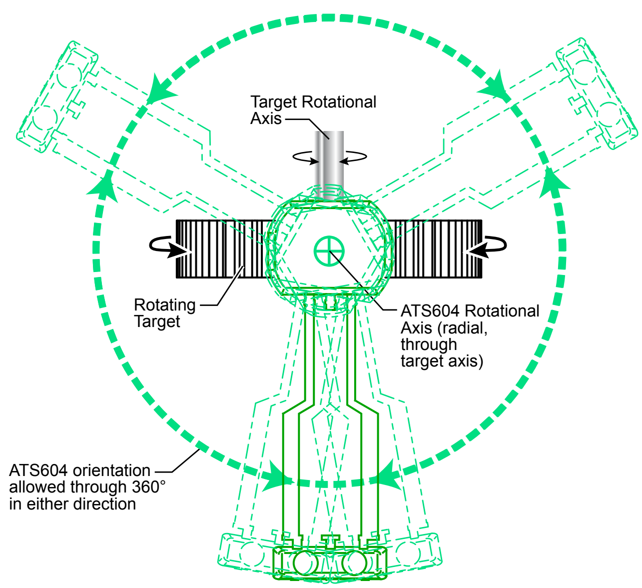

Figure 12: Orientation-Insensitive Mounting

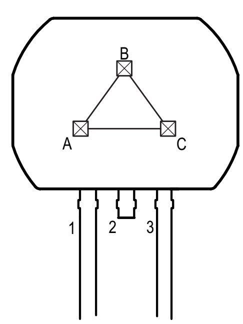

Figure 13: Hall Sensor Configuration

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Modes of Operation

CALIBRATION

In the calibration mode, movement messages and speed-only AK messages (refer to Description of AK Protocol section) are generated when the target rotates. During calibration, pulse accuracy is reduced. Standstill AK messages are generated if no output events are output for a duration of t_{STOP} to indicate that the device is functional.

On device power-on, if the ATS604 detects a peak on the direction channel before a speed channel switching threshold is detected, a movement message is generated. With the direction channel nominally in quadrature with the speed channels, a peak on the direction channel is nominally located at a switching threshold of the speed channel.

If the air gap is larger than the operating air gap range, it is possible that only movement messages are output as they are derived from the direction channel which has a higher magnetic sensitivity. If only movement messages are generated, the IC does not exit calibration due to the magnetic signal amplitude being too small to be tracked by the speed channel.

Speed-only AK messages are transmitted within $PULSE_{SPD\text{-}ONLY}$ of the Operating Characteristics table. AK bits are updated, but direction remains invalid.

The calibration mode is completed within $PULSE_{SELECT}$, $PULSE_{SPD\text{-}DIR}$, or $PULSE_{RESELECT}$ depending on startup conditions once calibration is complete the sensor proceeds to the normal operation mode. 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 stored in the EEPROM, and the device selects the best channel to use. This process takes up to $PULSE_{SELECT}$.

If the correct speed channel is registered in EEPROM memory, on power-on, calibration length is shortened to $PULSE_{SPD\text{-}DIR}$. 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 up to $PULSE_{RESELECT}$.

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.

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 the Direction of Rotation bit in the AK message.

The ATS604 contains tracking algorithms which continuously track the amplitude and offset of the magnetic signals to maintain B_{OP_SPD} and B_{RP_SPD} switch points. The tracking algorithms are used to account for application imperfections such as runout or tooth-to-tooth amplitude variations. In the presence of imperfections, these tracking algorithms result in an increased accuracy of output AK messages.

STANDSTILL

During calibration mode, if no rotation has occurred for t_{STOP}, the IC reports the latest information available. If insufficient rotation has occurred for information to be measured, the IC reports information defined in the post-power-on default values in Table 6. During running mode, if no output events are output for a duration of t_{STOP}, then a standstill output event is output. The AK data bits report the latest information measured by the IC.

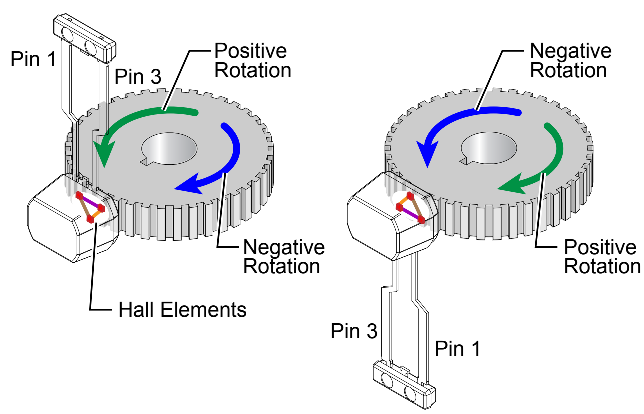

Figure 14: Direction Definition

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CHANNEL RESELECT

If the peak-to-peak value of the active channel is less than that of the peak-to-peak value of the other speed-channels, the device initiates a sequence to reselect the best speed channel. This condition applies if the sensor is turned in its mounting position, ensuring that the appropriate sensor pair for the new position is always selected. The sensor reselects the best channel if the condition is valid for more than $T_{RESELECT}$.

The new channel is then self-written in EEPROM if appropriate conditions apply (see EEPROM Self-Write of Best Speed Channel section).

VALIDITY OF DIRECTION OF ROTATION (GDR)

During calibration, the GDR bit is set to 0. During running mode, if magnetic disturbance detected events occur, the GDR bit is set to 0.

MAGNETIC DISTURBANCE DETECTED

During running mode, if the sensor detects irregular signals which can impact the capability to detect rotation or direction of rotation the sensor outputs bits 5:7 = 001 (magnetic disturbance detected) events. Magnetic disturbance detected events continue to be output until $T_{RECOVER}$ constant rotation occurs. Irregular signals that can lead to magnetic disturbance detected events consist of direction changes, vibration, temperature drifts, offset drifts, and stray field events.

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.

SAFE STATE

All safe state current levels are described in the safety manual, including diagnostics description and transition conditions.

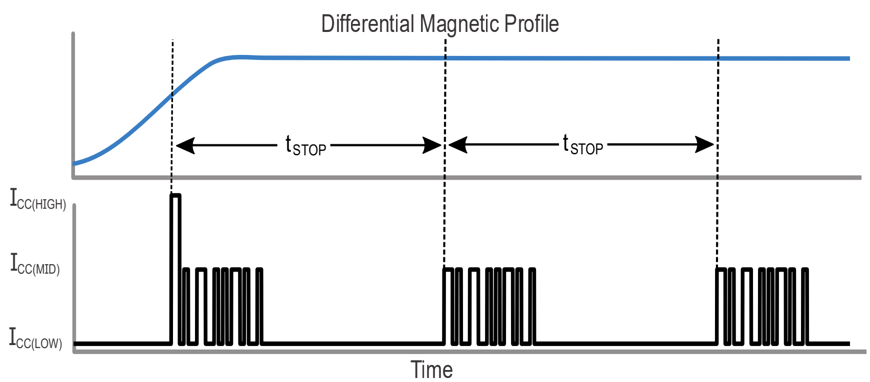

Figure 15: Standstill Output Example

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Table 2: Modes of Operation

Position	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	Movement AK message, Standstill AK message, Speed-only AK message	• After $PULSE_{SELECT}$, $PULSE_{SPD\text{-}DIR}$, or $PULSE_{RESELECT}$ • Channels not in lockout • A speed channel has been selected	Running mode
				Diagnostic error detected	Safe State
3	Running mode	Detection with adapted thresholds	Speed and direction information, Standstill AK message	Diagnostic error detected	Safe State
4	Safe State [1]	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	Safe State
				After other types of errors	Reset

[1] 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 installation and provides direction detection information by automatically selecting one out of three sensing element pairs during first power-on. 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. The ATS604 provides the information on the used Hall pair in bit 1:2 and 5:7 of the AK message.

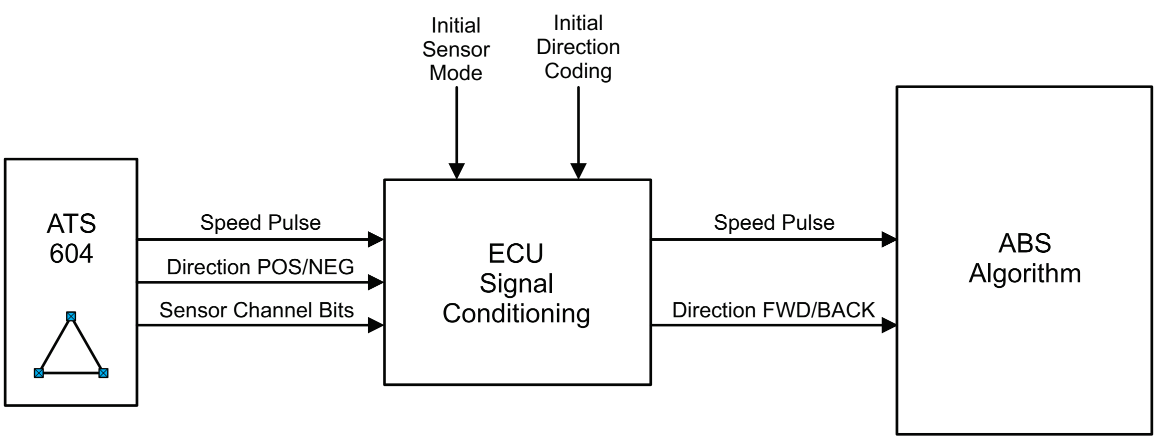

Figure 16: System Block Diagram

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The three sensing element pairs combined with two directions results in six possible mounting positions as depicted in Figure 17. The arrows indicate the direction of the target movement. It is not possible for the sensor to distinguish positions 1 and 4, 2 and 5, as well as 3 and 6. A change in 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.

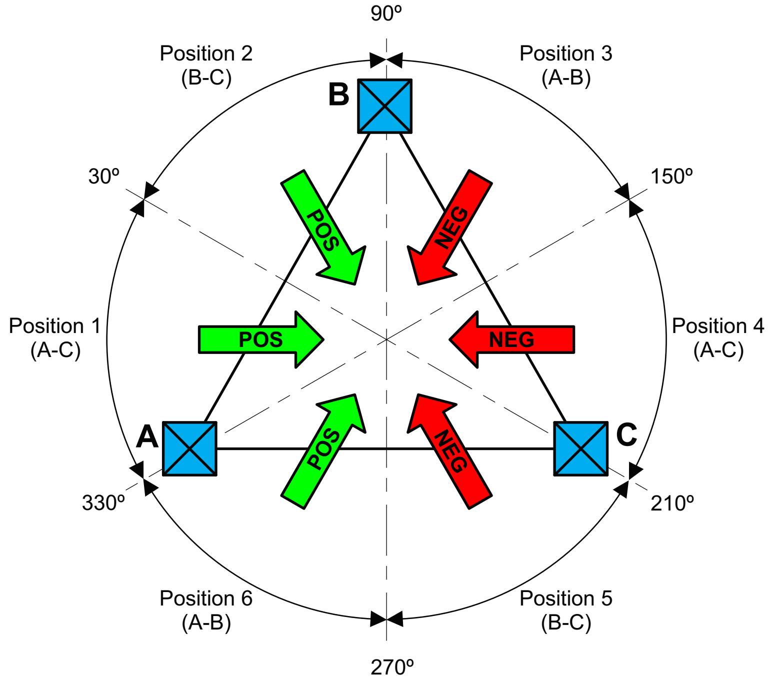

Figure 17: Mounting Positions

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 (Typ.)	Sensors Used for Speed	Target Rotation	Direction Coding
1	–30° to 30°	A – C	A to C C to A	POS NEG
4	150° to 210°			
2	30° to 90°	B – C	B to C C to B	POS NEG
5	210° to 270°			
3	90° to 150°	A – B	A to B B to A	POS NEG
6	270° to 330°			

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To get the direction the vehicle is 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.

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 normal mode. In case reprogramming is required, the sensor does set an internal EEPROM programming flag. If the ATS604 enters standstill mode and the EEPROM programming flag is set, three consecutive special events messages (refer to description of AK Protocol section), 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 is increased by up to $I_{self\text{-}write}$. Speed and direction AK messages can be triggered in this time interval and the additional current is added to all current levels.

In case the device is powered-off with the EEPROM programming flag set before the self-write has occurred, the flag does not persist to the next power-on, resulting in the recalibration procedure needing to be detected and initiated again.

The number of EEPROM self-writes allowed is $N_{self\text{-}writes}$ and self-writes only occur when the junction temperature is within $T_{self\text{-}write}$. $N_{self\text{-}writes}$ 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 Description of AK Protocol section). 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 do not have any default channel written in the EEPROM; therefore, on the first power-on, the sensor must evaluate the best speed channel. In this specific case, the sensor startup performance is 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 17) 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	ECU Coding when FWD was POS Initially	ECU Encoding when FWD was NEG Initially
1	6	POS → FWD	NEG → FWD
	1	POS → FWD	NEG → FWD
	2	POS → FWD	NEG → FWD
2	1	POS → FWD	NEG → FWD
	2	POS → FWD	NEG → FWD
	3	NEG → FWD	POS → FWD
3	2	NEG → FWD	POS → FWD
	3	POS → FWD	NEG → FWD
	4	POS → FWD	NEG → FWD
4	3	POS → FWD	NEG → FWD
	4	POS → FWD	NEG → FWD
	5	POS → FWD	NEG → FWD
5	4	POS → FWD	NEG → FWD
	5	POS → FWD	NEG → FWD
	6	NEG → FWD	POS → FWD
6	5	NEG → FWD	POS → FWD
	6	POS → FWD	NEG → FWD
	1	POS → FWD	NEG → FWD

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Description of AK Protocol

The ATS604 fulfills 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 extensions as described in this datasheet.

The ATS604 can output AK messages with different meanings: movement, speed-only, speed and direction, and standstill messages.

Table 5: AK Message Types

Message Type	Bit 1:2	Bit 3	Bit 5:7
	Identifier Bits	GDR	Data Bits
Movement	See Table 7	0	See Table 7
Speed-only		0	
Speed + Direction		1	
Standstill		0/1	

As a standard-compliant extension, the ATS604 encodes additional data in bits 1:2 and 5:7 of the AK message (word). During calibration, the channel-selected word is generated for all AK messages. During normal mode cyclical AK messages with additional information are generated in a sequence as shown in Figure 18. The word sequence is channel-selected information nine times, peak-to-peak information, channel-selected information nine times, and temperature information. The system must receive twenty complete AK messages to gather all three types of data. This sequence restarts when the sensor powers on.

CHANNEL-SELECTED WORD

The channel that generated the AK message request is encoded as a 3-bit value, as shown in Table 7.

PEAK-TO-PEAK INFORMATION WORD

Peak-to-peak amplitude information of the selected 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 sensing elements of the selected speed channel, as shown in Table 7.

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.

OVERTEMPERATURE WORD

An overtemperature special AK message is generated if a temperature that exceeds T_{OVER} 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 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 stores selected speed channel in EEPROM from the previous power-on to decrease the amount of rotation required to enter normal mode. If the device detects that a speed channel other than the one currently stored in EEPROM should be used, an internal flag is set.

While this flag is set, if the device generates standstill messages, the first three standstill messages are the EEPROM-Write Required Word.

After being sent three consecutive times, the EEPROM self-write starts after transmission of the third standstill message. During EEPROM-writing, the current consumption increases by up to $I_{self\text{-}write}$. Standstill and speed + direction messages can be generated while the ATS604 is writing EEPROM.

In case the vehicle starts moving before the third standstill message, the ATS604 repeats the same sequence of three 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 is sent the next time the sensor enters standstill, in place of the EEPROM-write required message.

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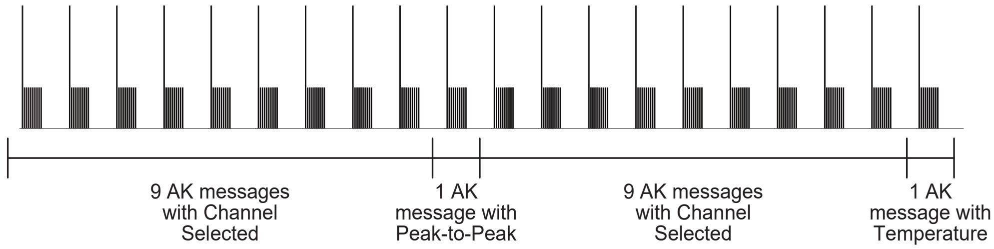

Figure 18: Sequence of additional information encoded in successive AK Messages, default sequence.
Note that the x-axis in this figure does not represent time; there is no delay between messages in the sequence. The time between subsequent messages does only depend on the magnetic input signal.

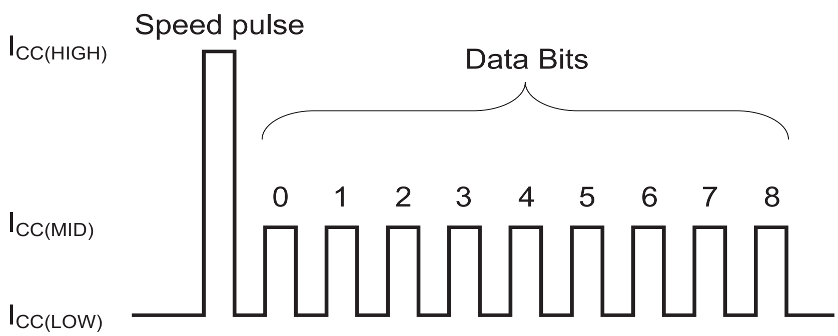

Figure 19: AK Protocol representation

Table 6: Bit Definition of AK Protocol

Bit Number	Field	Abbreviation	Coding	Post-Power-On Default Value
–	Speed Pulse	SP	$I_{CC(HIGH)}$ if speed pulse, $I_{CC(MID)}$ if standstill pulse	–
0	Air Gap Reserve	LR	1 if $G_{pkpk} < B_{LR(pk\text{-}pk)}$, 0 otherwise	0
1	AK Meaning Bit 0 (LSB)	M0	Refer to Table 7	0
2	AK Meaning Bit 1 (MSB)	M1	Refer to Table 7	0
3	Validity of the Direction of Rotation	GDR	1 if direction is valid, 0 otherwise	0
4	Direction	DR	0 if positive rotation, 1 if negative rotation	0
5	Additional Data Word Bit 0 (LSB)	D0	Refer to Table 7	Calculated
6	Additional Data Word Bit 1	D1	Refer to Table 7	Calculated
7	Additional Data Word Bit 2 (MSB)	D2	Refer to Table 7	Calculated
8	Parity	P	1 if parity includes parity bit is even, 0 otherwise	Calculated

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Table 7: Encoding of data in additional bit-words

Bit 1:2	AK Meaning	Bit 5:7	Content
00	Peak-to-Peak	000	0: < LOR[1]
		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
10	Channel selected	000	0: Movement message (Direction channel derived)
		100	1: AB channel selected
		010	2: BC channel selected
		110	3: AC channel selected
		001	4: Magnetic disturbance detected
		101	5: Unused
		011	6: Unused
		111	7: Unused
01	Special Event	000	0: < LOR [18]
		100	1: EEPROM-write counter exceeded
		010	2: EEPROM-write required
		110	3: Unused
		001	4: Over Temperature
		101	5: Unused
		011	6: Unused
		111	7: Unused
11	Temperature [2]	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 [3]

[1] LOR (Lockout Release) is the threshold of the smallest magnetic signal the device can measure, and it exists beyond the operating Air Gap Range.
[2] 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.
[3] Device performance is not guaranteed above the maximum operating junction temperature (T_J).

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Typical Repeatability Across Air Gap

Repeatability, commonly called jitter, across air gap is shown in Figure 20 and is calculated per-tooth across all teeth using the Allegro reference target 60-0.

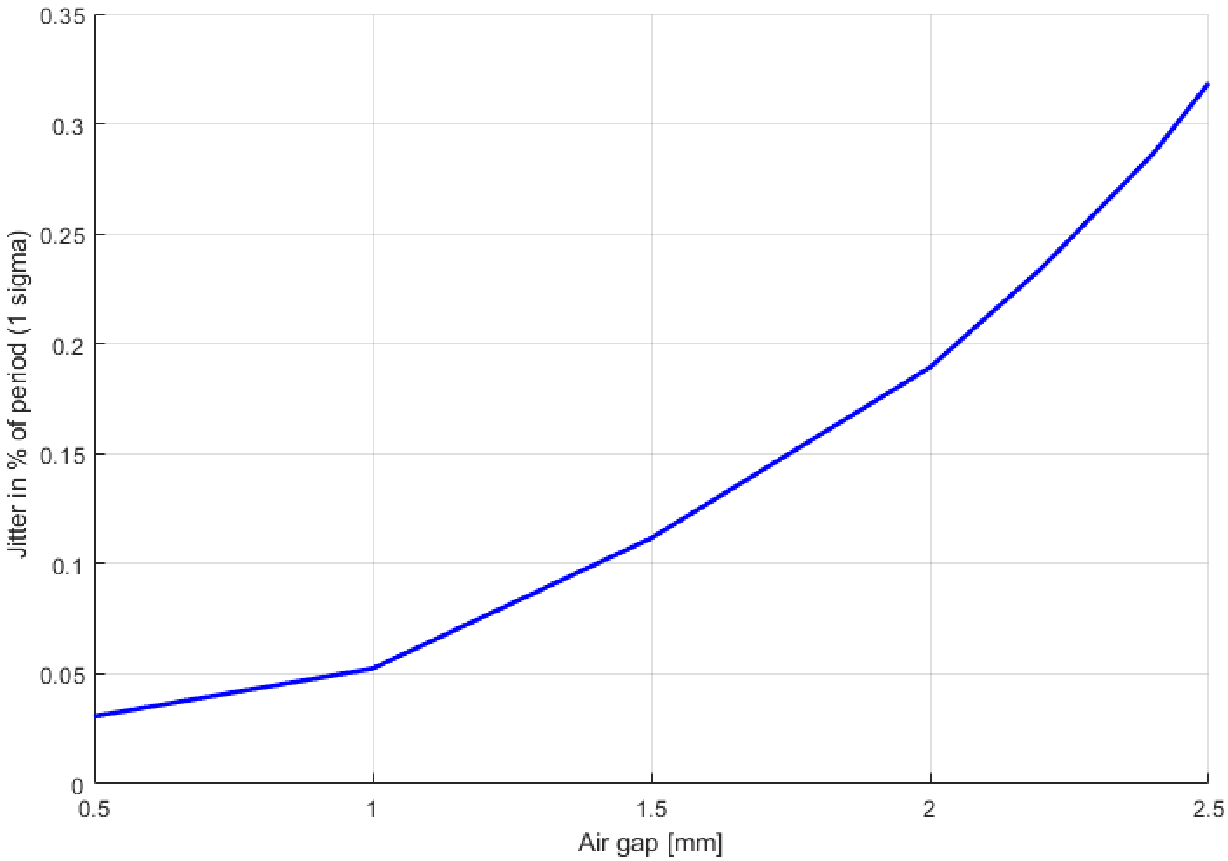

Figure 20: Typical Jitter performance at 25°C across air gap on Allegro reference target 60-0

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POWER DERATING

The device must be operated within the operating junction temperature of the device, $T_{J(max)}$. Under certain combinations of peak conditions, reliable operation may require derating supplied power or improving the heat dissipation properties of the application. This section presents a procedure for correlating factors affecting operating T_J. (Thermal data is also available on the Allegro MicroSystems 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 $I_{CC(max)} = 18.1\ mA$. $I_{CC(MAX)}$ is computed using $I_{CC(HIGH)(max)}$, $I_{CC(MID)(max)}$, and $I_{CC(LOW)(max)}$, with an input signal frequency of $f_{SIG(max)}$.

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.

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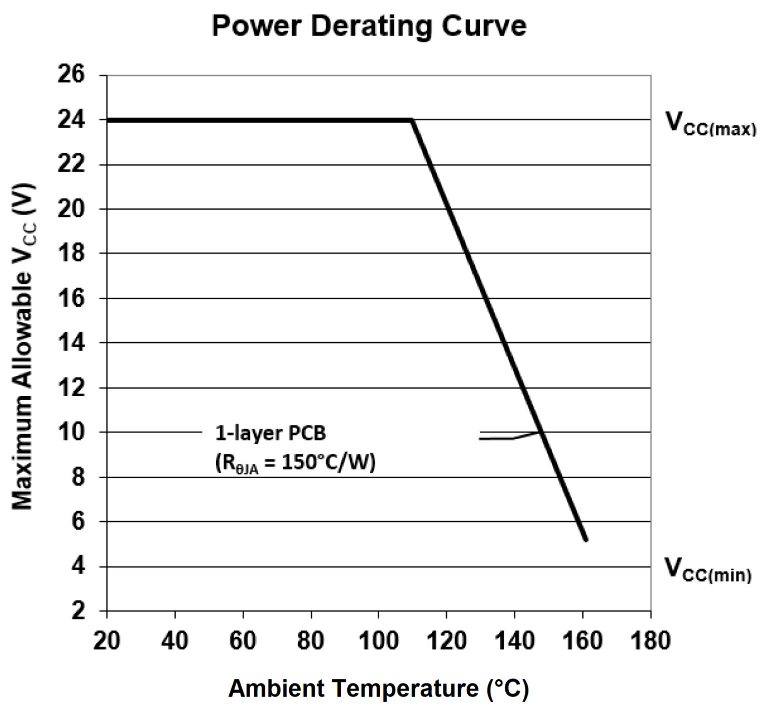

Figure 21: Example graph from the calculations in the Power Derating section

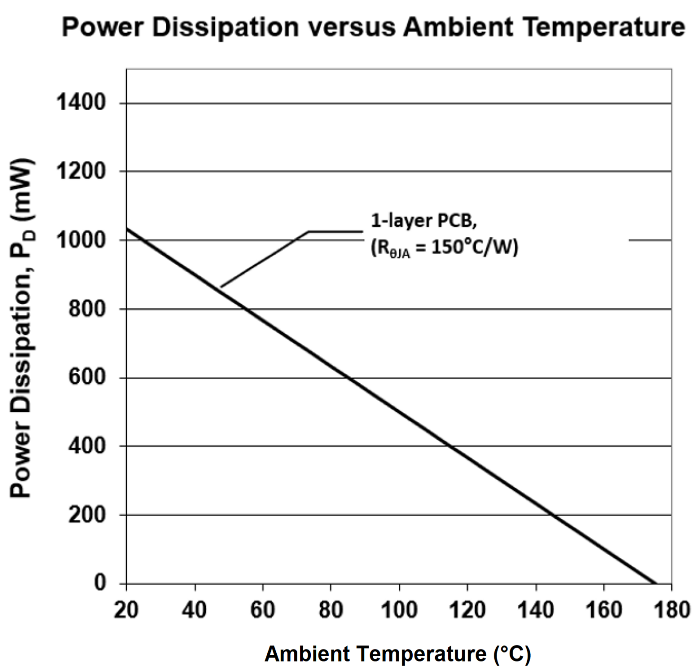

Figure 22: Example graph for Power Dissipation vs. Ambient Temperature

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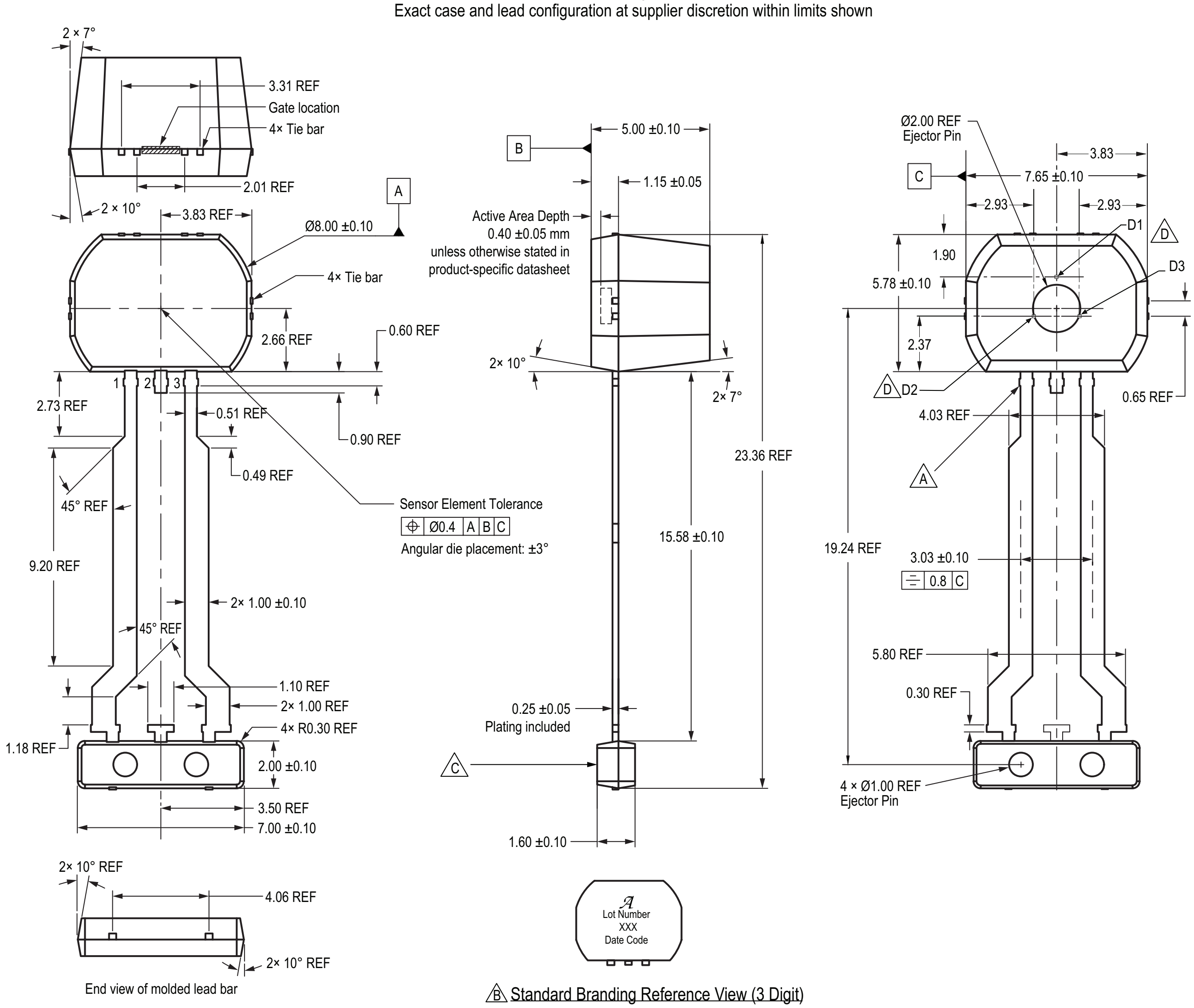
PACKAGE OUTLINE DRAWING

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



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

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

Figure 23: Package SN, 3-Pin SIP

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REVISION HISTORY

Number	Date	Pages	Description
–	December 19, 2024	All	Initial release

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