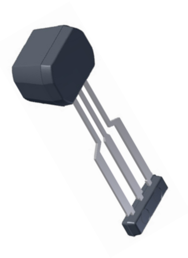
ATS694LSM

Crankshaft Position Sensor IC with Speed and Direction Output

FEATURES AND BENEFITS

- Allegro SM package with integrated EMC components provides robustness to most automotive EMC requirements
- Integrated back-biasing rare-earth pellet
- Digital output with speed and direction information provides ferromagnetic target position information
- Enhanced algorithms provide low jitter and high output accuracy performance
- Electrical offset compensation through chopper stabilization
- Dual zero-crossing with internal hysteresis
- Highly repeatable across operating temperature range
- Automatic Gain Control and Automatic Offset Adjust circuits result in air-gap-independent switch points
- Robust test coverage capability using Scan Path and IDDQ measurement
- Factory-programmable options for application-specific performance optimization

PACKAGE:



3-pin SIP (suffix SM)

Not to scale

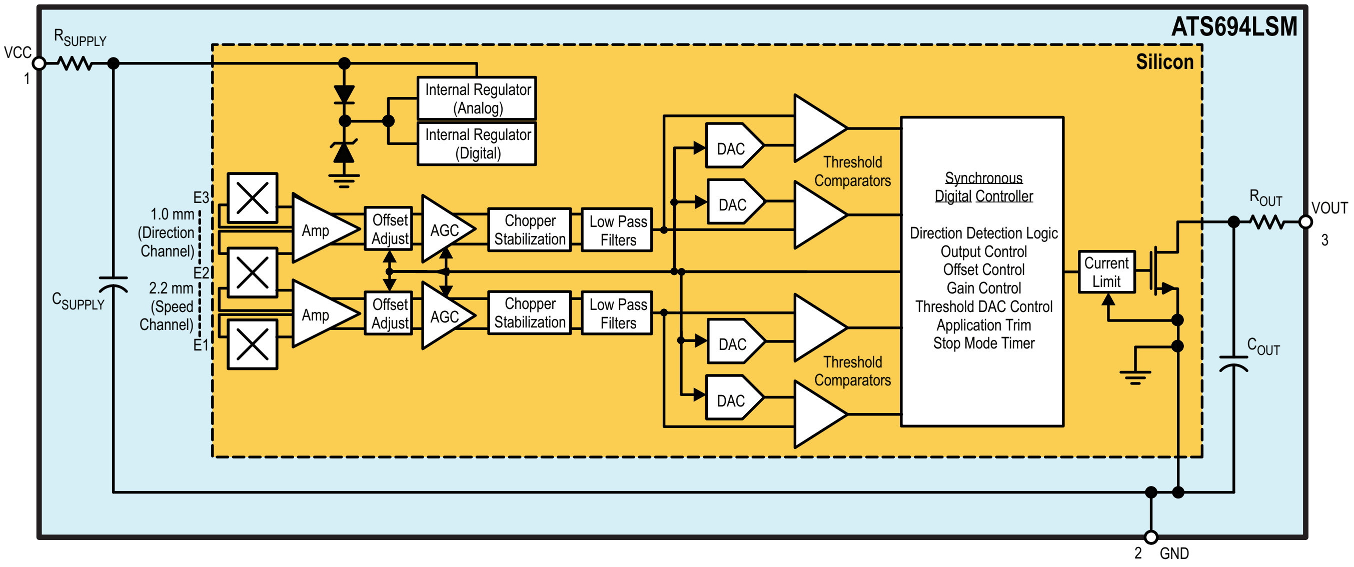
DESCRIPTION

The ATS694LSM is a combined Hall-effect sensing integrated circuit, back-biasing rare-earth pellet, and EMC protection circuit that provides a user-friendly, PCB-less solution for true zero-speed digital crankshaft sensing. The ATS694 provides speed and direction information through a variable pulse-width output protocol. The device can be used to sense rotating ferromagnetic targets.

Three Hall plates are used to create two differential channels. These channels, along with advanced direction detection algorithms, are used to produce a highly accurate speed output. The combination of high accuracy with direction information provides absolute position on most crank targets even in cases of engine backlash, making it ideal for stop/start engine designs.

Advanced calibration techniques are used to optimize signal offset and amplitude. This calibration, combined with the digital tracking of the signal, results in accurate switch points across the full range of air gap and operating temperature. The open-drain output provides a voltage output such that the time between falling electrical edges (period) corresponds to the speed, and the time between a falling edge and corresponding rising edge (pulse width) indicates direction.

The ATS694 is provided in a 3-pin SIP package that is lead (Pb) free, with matte-tin leadframe plating and integrated discrete EMC protection components.



Functional Block Diagram

SELECTION GUIDE

Part Number	Selected Programmable Option					
	Forward Pulse Rotation Direction	**Output Pulse Location**	**Fixed Differential Offset Compensation**	**Tracking DAC Update Method**	**Reverse Pulse Width**	**Target Profiling Diagnostics**
ATS694LSMTN-RNOBD-T	R	N	O	B	D	NA
ATS694LSMTN-RSOBD-T	R	S	O	B	D	NA

PROGRAMMABLE OPTIONS

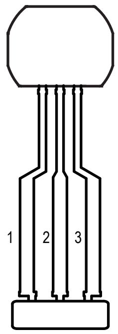
Name	Available Selections [1]	
Forward Pulse, $t_{W(FWD)}$, Rotation Direction	Target movement from pin 1 to pin 3 (F Option)	Target movement from pin 3 to pin 1 (R Option)
Output Pulse Location	Pulse opposite tooth with ferromagnetic target and back-biasing magnet south pole to ATS694 rear face (N Option)	Pulse opposite valley with ferromagnetic target and back-biasing magnet south pole to ATS694 rear face (S Option)
Fixed Differential Offset Compensation	Fixed offset compensation applied for integrated back-biasing rare-earth pellet (O Option)	
Tracking DAC Update Method	Bounded DAC update (B Option)	
Reverse Pulse Width, $t_{W(REV)}$	Default, 90 µs (D Option)	Extended, 135 µs (E Option)
Target Profiling Diagnostics	Diagnostics enabled (-D option)	Diagnostics not available (NA)

[1] Not all combinations are available. Contact Allegro sales for pricing and availability of custom programming options.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

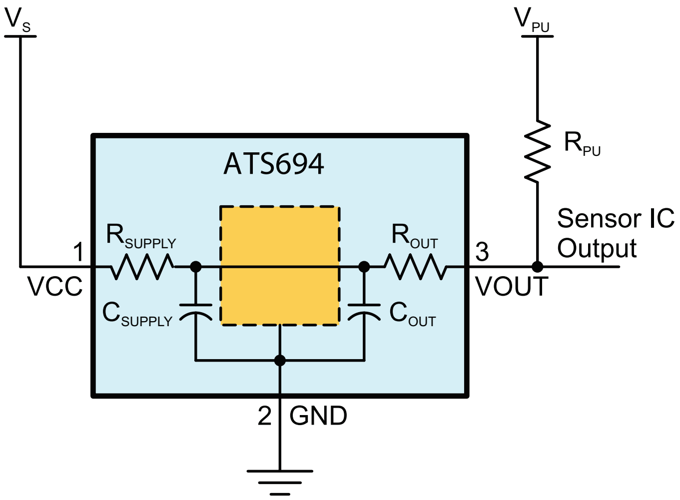
Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{CC}	Refer to Power Derating section	28	V
Reverse Supply Voltage	V_{RCC}		–18	V
Reverse Output Voltage	V_{ROUT}	$R_{PU} > 1000\ \Omega$	–0.5	V
Output Current	$I_{OUTSINK}$	Internal current limiting is intended to protect the device from output short circuits, but is not intended for continuous operation.	25	mA
Reverse Output Current	I_{ROUT}	$V_{OUT} > –0.5$ V, $T_A = 25°C$	–50	mA
Operating Ambient Temperature	T_A	Range L	–40 to 150	°C
Maximum Junction Temperature	T_J(max)	Continuous	165	°C
Storage Temperature	T_{stg}		–60 to 170	°C



Pinout Diagram

Terminal List

Number	Name	Function
1	VCC	Supply Voltage
2	GND	Ground
3	VOUT	Open-Drain Output



Typical Application Circuit

Internal Discrete Component Ratings

Symbol	Characteristic	Rating	Unit
C_{SUPPLY}	Nominal Capacitance	220000	pF
C_{OUT}	Nominal Capacitance	2200	pF
R_{SUPPLY}	Nominal Resistance	20	Ω
R_{OUT}	Nominal Resistance	20	Ω

OPERATING CHARACTERISTICS: Valid at V_{CC} and T_A within specification, unless otherwise specified

Characteristic	Symbol	Test Conditions		Min.	Typ.	Max.	Unit[1]
ELECTRICAL CHARACTERISTICS							
Supply Voltage	V_{CC}	Continuous, $T_J < T_J$(max)		4.4	–	24	V
Reverse Supply Voltage	V_{RCC}	Continuous		–18	–	–	V
Undervoltage Lockout	$V_{CC(UV)}$	V_{CC} 0 → 5 V and V_{CC} 5 → 0 V		–	–	4.3	V
Supply Zener Clamp Voltage	$V_{Zsupply}$	$I_{CC} = I_{CC}$(max) + 3 mA, T_A = 25°C		28	–	–	V
Reverse Supply Zener Clamp Voltage[2]	$V_{RZsupply}$	I_{CC} = –3 mA, T_A = 25°C		–	–	–18	V
Supply Current	I_{CC}	Running mode current		4	–	15	mA
	$I_{CC(CAL)}$	Calibration mode current		–	–	15.7	mA
Supply Zener Current	$I_{Zsupply}$	V_{CC} = 28 V, T_A = 25°C, Running mode		–	–	18	mA
Reverse Supply Current	I_{RCC}	V_{CC} = –18 V		–	–	–3	mA
POWER-ON CHARACTERISTICS							
Power-On State	POS	$V_{CC} > V_{CC}$(min), connected as in Figure 8		–	High	–	V
Power-On Time[3]	t_{PO}			–	–	1	ms
OUTPUT STAGE CHARACTERISTICS							
Output On Voltage	$V_{OUT(SAT)}$	I_{OUT} = 20 mA, output = On state		–	600	1000	mV
		I_{OUT} = 10 mA, output = On state		–	300	500	mV
Output Off Voltage	$V_{OUT(OFF)}$	Continuous		–	–	24	V
Output Zener Clamp Voltage	$V_{Zoutput}$	I_{OUT} = 3 mA, T_A = 25°C		27	–	–	V
Output Zener Current	$I_{Zoutput}$	V_{OUT} = 27 V		–	–	3	mA
Output On Current	$I_{OUT(ON)}$			0	–	25	mA
Output Leakage Current	$I_{OUT(OFF)}$	Output = Off state, V_{OUT} = 24 V		–	0.1	10	μA
Output Current Limit	$I_{OUT(LIM)}$	Output = On state, R_{PU} = 0 Ω, $T_J < T_J$(max)		30	–	80	mA
Pulse Width[4]	$t_{W(CAL)}$	Calibration mode, forward or reverse target rotation; V_{PU} = 5 V, R_{PU} = 1 kΩ; measured on VOUT at 0.5 × V_{PU}		38.25	45	51.75	μs
	$t_{W(FWD)}$	Running mode, forward target rotation; V_{PU} = 5 V, R_{PU} = 1 kΩ; measured on VOUT at 0.5 × V_{PU}		38.25	45	51.75	μs
	$t_{W(REV)}$	Running mode, reverse target rotation; V_{PU} = 5 V, R_{PU} = 1 kΩ; measured on VOUT at 0.5 × V_{PU}	Option D, for default reverse pulse width	76.5	90	103.5	μs
			Option E, for extended reverse pulse width	114.75	135	155.25	μs
Pulse-Width Ratio	$t_{W(REV)}$ / $t_{W(FWD)}$	V_{PU} = 5 V, R_{PU} = 1 kΩ; measured on VOUT at 0.5 × V_{PU}	Option D, for default reverse pulse width	1.7	2	2.4	–
			Option E, for extended reverse pulse width	2.55	3	3.6	–

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[1] 1 G (gauss) = 0.1 mT (millitesla).
[2] Sustained voltages beyond the clamp voltage may cause permanent damage to the IC.
[3] Measured from $V_{CC} \geq V_{CC}$(min) to time when output signal is capable of switching on a magnetic stimulus.
[4] Pulse widths measured at 50% threshold on both rising and falling edges.

OPERATING CHARACTERISTICS (continued): Valid at V_{CC} and T_A within specification, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit[1]
OUTPUT STAGE CHARACTERISTICS (continued)						
Output Rise Time	t_r	Measured 10% to 90% of V_{OUT}; V_{PU} = 5 V, R_{PU} = 1 kΩ	–	5.5	–	µs
Output Fall Time	t_f	Measured 90% to 10% of V_{OUT}; see Figure 1; V_{PU} = 5 V, R_{PU} = 1 kΩ	1.6	2.5	3.8	µs
		Measured 90% to 10% of V_{OUT}; see Figure 1; V_{PU} = 12 V, R_{PU} = 1 kΩ	–	4.3	–	µs
		Measured 90% to 10% of V_{OUT}; see Figure 1; V_{PU} = 24 V, R_{PU} = 1 kΩ	–	7.6	–	µs
Output Delay Time[2]	t_d	1 kHz sinusoidal input signal	12.5	17	21.5	µs
Minimum Separation Between Consecutive Output Pulses	t_{OUTsep}	Includes separation between pulses during a direction change	38.25	45	51.75	µs

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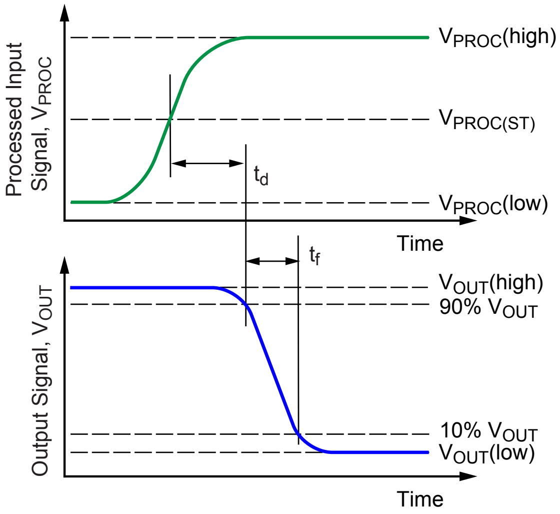

Figure 1: Definitions of Output Delay Time, t_d, and Output Fall Time, t_f

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[1] 1 G (gauss) = 0.1 mT (millitesla).

[2] Time between magnetic signal switch point crossing and electrical output signal reaching 90% of $V_{OUT(OFF)}$ = high (see Figure 1).

OPERATING CHARACTERISTICS (continued): Valid at V_{CC} and T_A within specification, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit[1]
Performance Characteristics						
Mechanical Shift of Switch Point	d_{ST}	Distance from target feature center to IC center when V_{PROCST} occurs (will be shifted an additional 0.5 × T_{TARGET} due to asymmetric Hall elements, see Figure 2)	–	0.5	–	mm
Absolute Phase Error During Calibration	err_{CAL}	Given forward target rotation (will be 0.5 × T_{TARGET} (see Figure 3) out of phase if target is rotating in reverse)	–0.25 × T_{TARGET}	–	0.25 × T_{TARGET}	–
Relative Repeatability[2]	$err_{\theta E}$	100 $G_{pk\text{-}pk}$ sinusoidal signal with 6° period; f_{IN} = 1000 Hz	–	–	0.05	degrees
Operating Frequency	$f_{IN(FWD)}$	Correct speed information, forward rotation	0	–	10	kHz
	$f_{IN(REV)}$	Correct speed information, reverse rotation	0	–	5	kHz
Time to First Output Edge	$t_{OUT(init)}$	After t_{PO} elapses, f_{IN} < 600 rpm	–	T_{TARGET}	–	–
Initial Calibration Interval	CAL_I	f_{IN} < 600 rpm, $B_{IN}(max)/B_{IN}(min) \leq 1.2$ where B_{IN} includes: runout, tooth-to-tooth variation, and signature amplification	–	3	6	output pulse
		f_{IN} < 600 rpm, $B_{IN}(max)/B_{IN}(min) > 1.2$ where B_{IN} includes: runout, tooth-to-tooth variation, and signature amplification	–	7	11	output pulse
Direction Change Recognition	N_{CD}		–	1	–	switch-point

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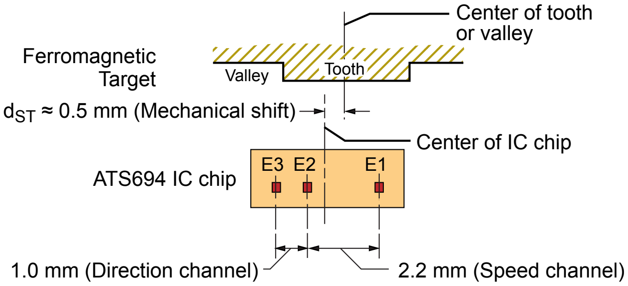
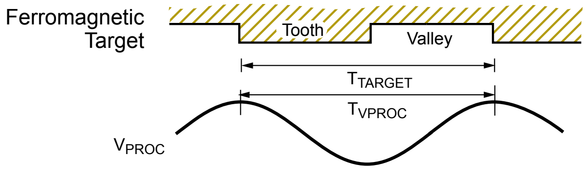


Figure 2: Definition of Mechanical Shift of Switch Point



V_{PROC} = the processed analog signal of the sinusoidal magnetic input (per channel)

T_{TARGET} = period between successive sensed target magnetic edges of the same polarity (for a ferromagnetic target, both rising or both falling mechanical edges)

Figure 3: Definition of T_{TARGET}

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[1] 1 G (gauss) = 0.1 mT (millitesla).

[2] 6-sigma using 360°-repeatability method on sinusoidal signal over greater than 1000 edges; constant speed, air gap, and temperature.

OPERATING CHARACTERISTICS (continued): Valid at V_{CC} and T_A within specification, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit[1]
PERFORMANCE CHARACTERISTICS (continued)						
Missed or Extra Output Pulses in Running Mode	err_{OUT}		–	–	0	output pulse
Stop Mode Timer Period	t_{SM}	Timer interval to initiate Stop mode; no sensed magnetic edges	–	5	–	s
Chopper Frequency	f_C		–	250	–	kHz
Switch Point	$V_{PROC(ST)}$	Speed channel, see Figure 4	45	50	55	$\%V_{pk\text{-}pk}$
Internal Hysteresis	$V_{PROC(hys)}$	Speed channel, one-sided; see Figure 4	–	12.5	–	$\%V_{pk\text{-}pk}$
MAGNETIC CHARACTERISTICS						
Differential Magnetic Input Signal	B_{IN}	Speed channel, B_{CHSEP} within specification	50	–	1100	$G_{pk\text{-}pk}$
Allowable User-Induced Magnetic Offset	B_{OFFSET}	Magnitude valid for both Speed and Direction channels; magnetic offset between center and outer Hall elements	–100	–	100	G

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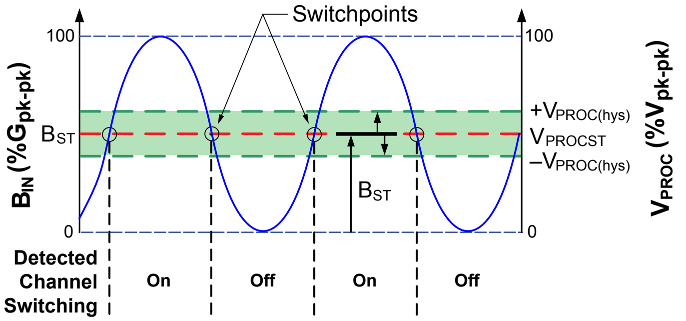

Figure 4: Establishment of Thresholds, Using Internal Hysteresis (Speed Channel)

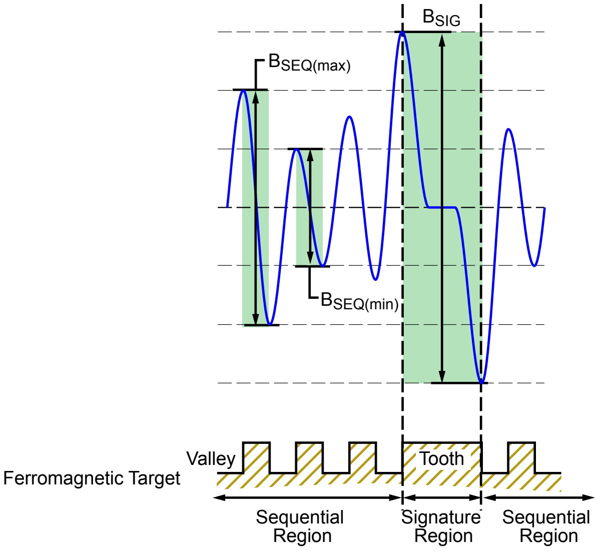

Figure 5: Differential Signature Amplification and Sequential Signal Variation

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[1] 1 G (gauss) = 0.1 mT (millitesla).

OPERATING CHARACTERISTICS (continued): Valid at V_{CC} and T_A within specification, unless otherwise specified

<table>
<tr><th>Characteristic</th><th>Symbol</th><th colspan="2">Test Conditions</th><th>Min.</th><th>Typ.</th><th>Max.</th><th>Unit [1]</th></tr>
<tr><td colspan="8">MAGNETIC CHARACTERISTICS (continued)</td></tr>
<tr><td rowspan="3">Allowable Differential Signal Reduction</td><td rowspan="2">B_{SEQ}(min)/
B_{SEQ}(max)</td><td colspan="2">Over 60 cycles, excluding signature region, see Figure 5</td><td>0.40</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Over 3 consecutive cycles, excluding signature region, see Figure 5</td><td>0.8</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>$B_{SEQ(n+1)}$/
$B_{SEQ(n)}$</td><td colspan="2">Single cycle-to-cycle variation, both channels; Includes signature (B_{SIG}) amplification, see Figure 5</td><td>0.8</td><td>–</td><td>2.0</td><td>–</td></tr>
<tr><td colspan="8">TARGET CHARACTERISTICS</td></tr>
<tr><td rowspan="2">Required Channel Separation</td><td rowspan="2">B_{CHSEP}</td><td rowspan="2">Measured between Speed and Direction channels; measured on normalized (0 to 100%) differential magnetic signals (see Target Definition section)</td><td>Opposite switching feature, measured at B_{ST} on Speed channel</td><td>30</td><td>–</td><td>–</td><td>%</td></tr>
<tr><td>Opposite non-switching feature, no signal cross-over, 0.25 × B_{SEQ} (max)< B_{IN} < 0.75 B_{SEQ} (max)</td><td>0</td><td>–</td><td>–</td><td>%</td></tr>
<tr><td rowspan="2">Safe Signal Inversion Range</td><td>$B_{INV(POS)}$</td><td colspan="2" rowspan="2">Measured on normalized (0 to 100%) differential magnetic signals (see Target Definition section)</td><td>75</td><td>–</td><td>–</td><td>%</td></tr>
<tr><td>$B_{INV(NEG)}$</td><td>–</td><td>–</td><td>25</td><td>%</td></tr>
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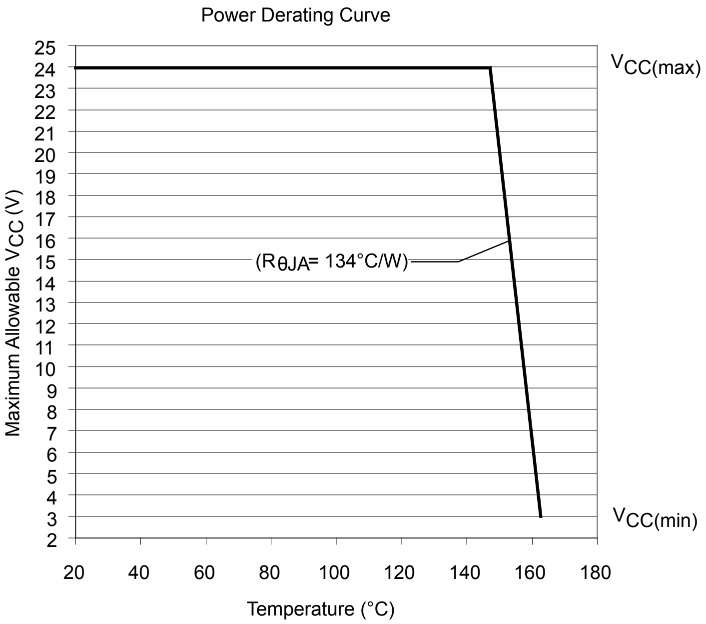
[1] 1 G (gauss) = 0.1 mT (millitesla).

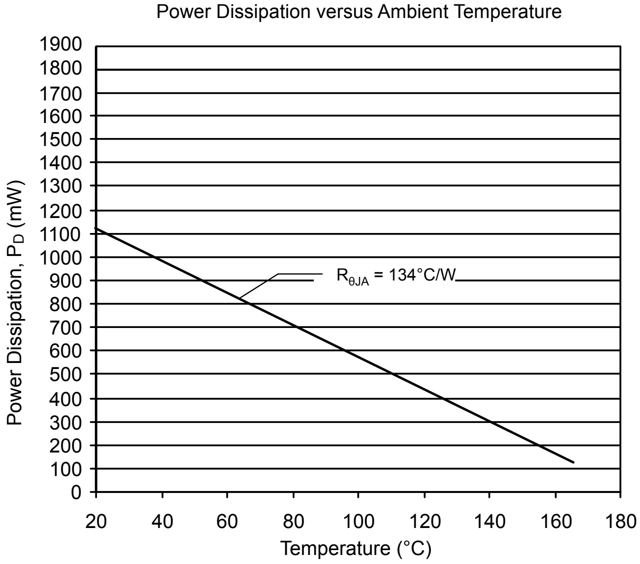
POWER DERATING

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

Characteristic	Symbol	Test Conditions*	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	Single-layer PCB, with copper limited to solder pads	134	°C/W

*Additional thermal information available on the Allegro website





FUNCTIONAL DESCRIPTION

Sensing Technology

The sensor IC contains a single-chip differential Hall-effect sensor IC, a samarium-cobalt magnetic pellet, and a flat ferrous pole piece (concentrator). The Hall-effect circuit supports a trio of Hall elements. These are used in differential pairs to provide an electrical signal containing information regarding edge position and direction of the target.

Target Profiling

After proper power is applied to the sensor IC, it is capable of providing digital information that is representative of the magnetic features of a rotating target. The waveform diagrams in Figure 6 present the automatic translation of the target mechanical profiles, through their induced magnetic profiles, to the digital output signal of the sensor IC. No additional optimization is needed and minimal processing circuitry is required. This ease of use reduces design time and incremental assembly costs for most applications.

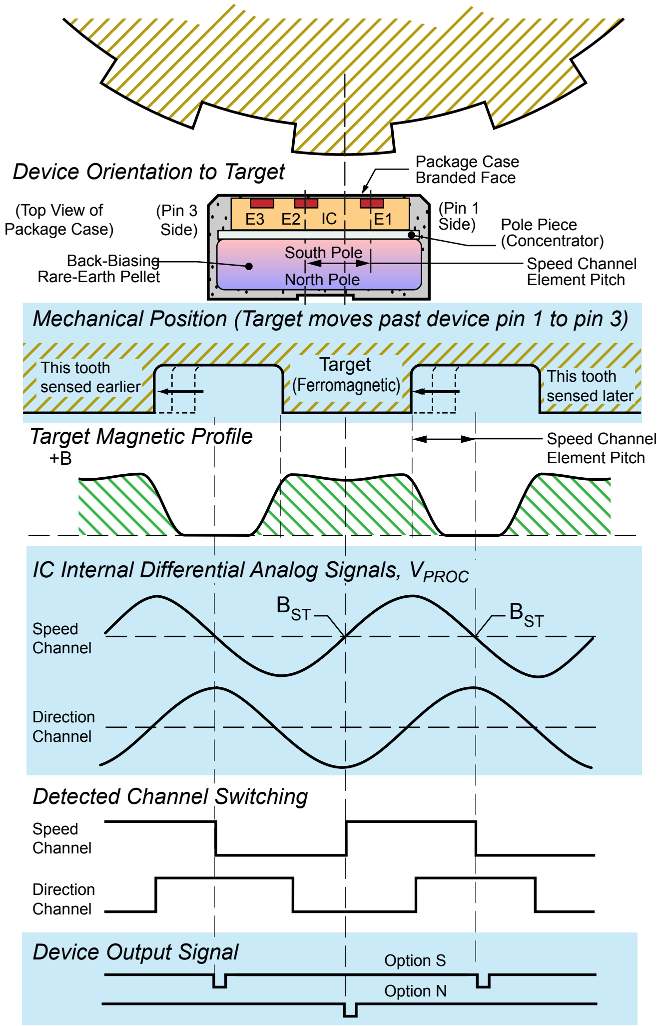


Figure 6: Magnetic Profile

The magnetic profile reflects the features of the target, allowing the sensor IC to present an accurate digital output.

Direction Detection

The sensor IC compares the relative phase of its two differential channels to determine which direction the target is moving. The relative switching order is used to determine the direction, which is communicated through the output.

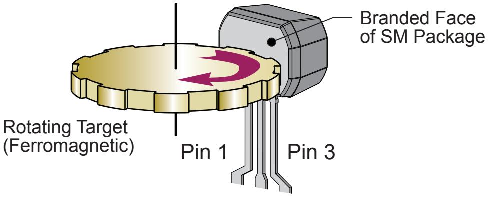
The relative direction of rotation is indicated by the relative pulse widths of the output in Running mode. The output can be programmed to provide the relatively short "forward" pulses, $t_{W(FWD)}$ (45 µs, typ.), when the target rotation is from pin 1 to pin 3 (option F) or from pin 3 to pin 1 (option R), as shown in Figure 7. In addition, two pulse widths are available for the relatively longer "reverse" pulses, $t_{W(REV)}$ (option D, 90 µs, typ., and option E, 135 µs, typ.).

Note:
For proper functionality, the output must be programmed such that the signature region is a non-switching feature (see Application Information section).

Pulse Occurrence Location

The output pulse can be programmed to occur at the target mechanical features of either polarity. The output pulse can be programmed to occur at the center of a tooth (option N) or at the center of a valley (option S).

Option F
Forward pulses ($t_{W(FWD)}$) generated for rotation from pin 1 to pin 3



Option R
Forward pulses ($t_{W(FWD)}$) generated for rotation from pin 3 to pin 1

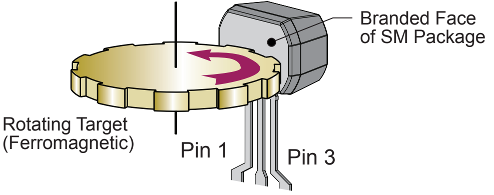


Figure 7: Rotation Direction Definitions

Switch Points

The Running mode switch points of the ATS694 are established dynamically as a percentage of the amplitude of the internal signal, V_{PROC}. Two DACs track the peaks of each V_{PROC} channel. The switching thresholds are established at fixed percentages of the values held in the DACs. The positions of the switching thresholds within these ranges are selected where the most accurate and consistent output switching is ensured, and where direction detection can be achieved in the presence of targets containing signature regions. Because the thresholds are established dynamically as a percentage of the peak-to-peak signal (see Figure 4), the effect of a signal shift is minimized.

Operating Modes

CALIBRATION MODE

After the Power-On Time has elapsed, the Calibration period begins. While calibration is performed, the sensor IC begins to internally detect the magnetic profile of the target. The output becomes active after $t_{OUT(init)}$, at the first detection of a target switching feature generating a switch point.

The gain of the sensor IC is adjusted during the Calibration period, normalizing the internal signal amplitude for the air gap range of the device. This Automatic Gain Control (AGC) feature ensures that operational characteristics are isolated from the effects of installation air gap variation.

Automatic Offset Adjustment (AOA) is circuitry that compensates for the effects of chip, magnet, and installation offsets. (The capability of AOA is indicated by the Allowable User-Induced Magnetic Offset, B_{OFFSET}, in the Operating Characteristics table.) This circuitry works with the AGC during calibration to help center V_{PROC} in the dynamic range to allow for DAC acquisition of signal peaks.

Calibration mode also allows for the peak-detecting DACs to properly acquire the magnetic signal, so that Running mode switch points can be accurately computed.

Output pulses during calibration have a distinct pulse width, $t_{W(CAL)}$. (Target rotation direction information, indicated by output pulse width, is available in Running mode, after calibration is complete.)

RUNNING MODE

After calibration is complete, target relative rotation direction information is available. This information is communicated through the output pulse width.

Peak-tracking DAC algorithms allow tracking of signal drift resulting from temperature changes, as well as tracking of target variations, such as pole-to-pole variation and effective runout. Automatic Offset Adjustment remains active, allowing the IC to compensate for offsets induced by temperature variations over time.

STOP MODE

In certain engine management applications, it is possible for large temperature changes to occur when the target is stationary. These temperature changes can affect the differential magnetic signals. The Stop mode algorithm is engaged to compensate for such shifts in the processed signal that may be seen during stop-and-go conditions. Several observed edges of target rotation are required to leave Stop mode and return to Running mode.

APPLICATION INFORMATION

Power Supply Protection

The ATS694 contains an on-chip regulator and can operate across a wide supply voltage range. Figure 8 shows the minimum circuitry needed for proper operation of the sensor IC. Contact Allegro for information on EMC specification compliance.

Target Design

The ATS694 is designed to provide highly accurate switching at each switching feature detected, including switching at the first switching feature after power-on and at the first switching feature after a reversal in the direction of target rotation. To support this functionality, the target must generate two tandem, differential magnetic profiles with discernible leading/lagging characteristics. The determination of speed and direction are resolved by the device through evaluation of the temporal separation between two differential signals (see Functional Description section). Guidelines described here outline differential magnetic signal traits with which the device will give proper output.

SIGNAL DIFFERENTIATION AT SWITCHING FEATURES

In order to optimize the separation between the profiles from the two differential signals, the sinusoidal waves comprising the magnetic profiles should be in quadrature, as illustrated in Figure 9.

For the ATS694, a *switching feature* can either be a tooth or a valley of a ferromagnetic target, depending on the Output Pulse Location option (N or S). To achieve quadrature, the pitch of the switching features should be approximately twice the distance between (a) the midpoint of Hall elements E1 and E2, and (b) the midpoint of Hall elements E2 and E3. This amounts to a switching feature pitch of 3.2 mm. Output switching occurs at a B_{ST} point (50% of B_{SEQ}) that occurs at a switching feature. The B_{ST} point can be on either a rising or a falling slope of the Speed channel magnetic signal.

Either channel differential signal can be leading or lagging the other, according to the relative direction of target rotation. When a switching feature is adjacent to the device, the difference between the leading differential signal and the lagging differential signal must be at least 30% of the peak-to-peak amplitude in the sequential regions, B_{SEQ}. (Sequential regions are target areas where the switching features are periodic and of uniform configuration, generating a consistent magnetic profile; see Figure 5).

SAFE SIGNAL INVERSION RANGES AT PEAKS

The serial order of the leading and lagging sine waves can be maintained by proper target design, as described here. However, as illustrated in Figure 9, two sine waves of equal amplitude

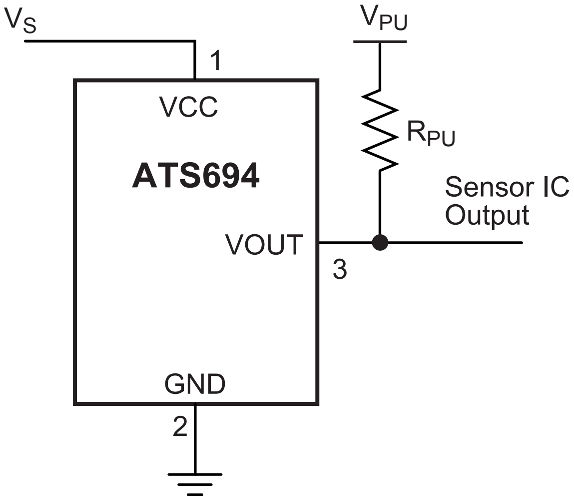


Figure 8: Typical Application Diagram, showing minimum application circuit requirements

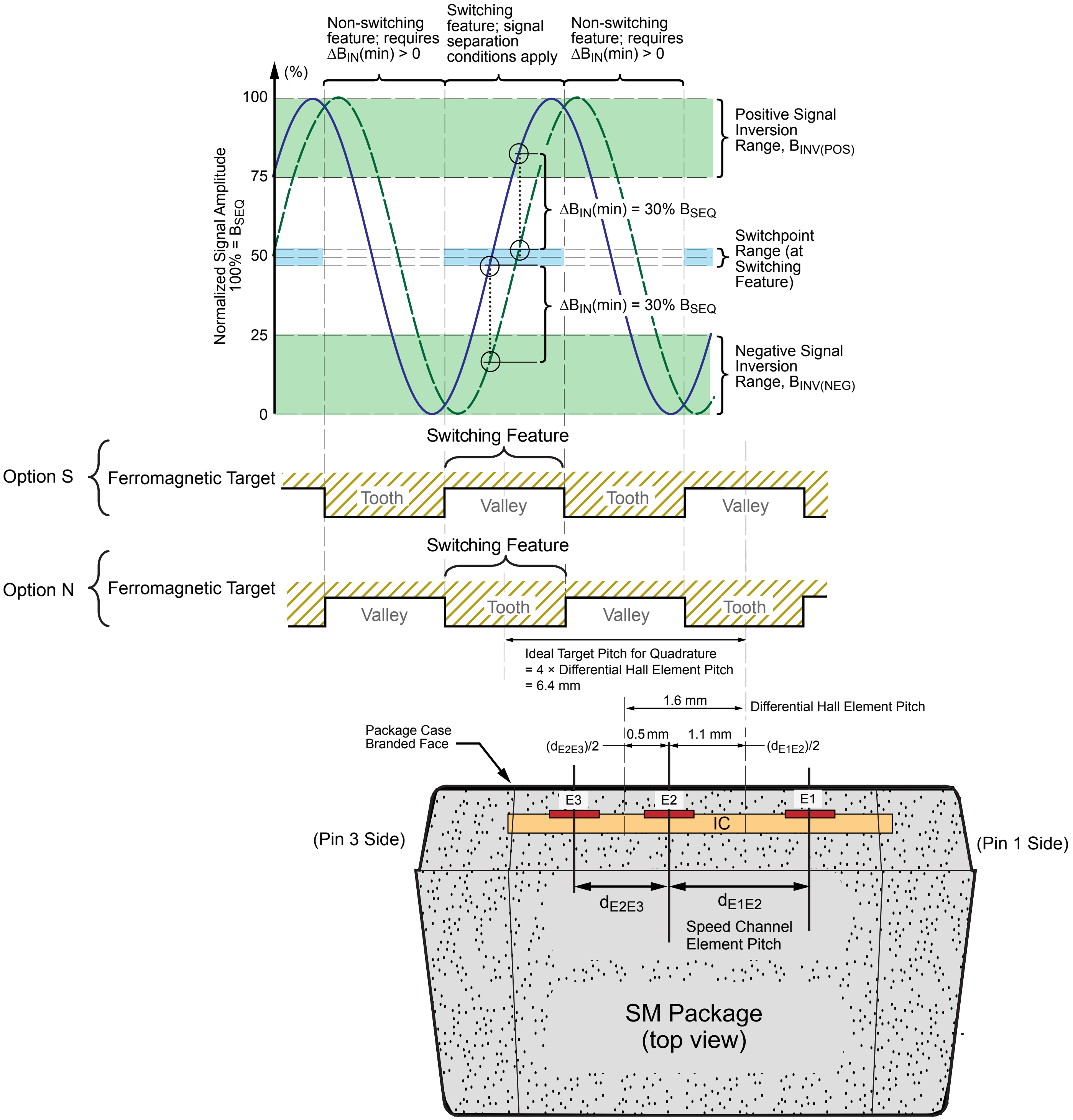


Figure 9: Channel Separation and Signal Inversion Definitions

and period, but phase-shifted, must invert relative amplitudes every half-cycle. To ensure proper switching, the target must be designed so that the cross-over occurs in the Safe Signal Inversion ranges: either in the Negative range, $B_{INV(NEG)}$, at less than 25% of full scale B_{SEQ} (near the negative signal peaks) or in the Positive range, $B_{INV(POS)}$, at more than 75% of full scale (B_{SEQ} near the positive signal peaks).

NON-SWITCHING FEATURES

When non-switching features are adjacent to the device, the constraints on the differential magnetic signals are less stringent, because no output pulses are generated at those intervals. However, channel signal separation greater than zero must be maintained so that the leading/lagging relationship of the signals is not reversed.

USE OF SIGNATURE REGIONS

Signature regions are target features that are disproportionately long relative to the sequential features. As a result, they can generate differential signal peaks that differ from the peaks generated by the sequential regions (see Figure 5). The device accommodates these peaks, and switching occurs at relatively the same switch point as on sequential features. The effect of a signature region would be a delay in reaching the next switch point.

The extension of the signal period significantly reduces the slope of the magnetic gradient around the midpoint of a signature feature. In fact, for relatively large signature features, the magnetic gradient can become nearly flat, as shown in Figure 5. The slack magnetic signal also makes it difficult to maintain the necessary channel separation required for a switching feature. For these reasons, the device accommodates only signature features that are non-switching features.

POWER DERATING

The device must be operated below the maximum junction temperature of the device, T_J(max). Under certain combinations of peak conditions, reliable operation may require derating supplied power or improving the heat dissipation properties of the application. This section presents a procedure for correlating factors affecting operating T_J. (Thermal data is also available on the Allegro MicroSystems 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 relationships used to estimate T_J, at P_D.

$$P_D = V_{IN} \times I_{IN} \tag{1}$$

$$\Delta T = P_D \times R_{\theta JA} \tag{2}$$

$$T_J = T_A + \Delta T \tag{3}$$

For example, given common conditions such as: $T_A = 25°C$, $V_{CC} = 12$ V, $I_{CC} = 7$ mA, and $R_{\theta JA} = 134°C/W$, then:

$$P_D = V_{CC} \times I_{CC} = 12\ V \times 7\ mA = 84\ mW$$

$$\Delta T = P_D \times R_{\theta JA} = 84\ mW \times 134°C/W = 11.3°C$$

$$T_J = T_A + \Delta T = 25°C + 11.3°C = 36.3°C$$

A worst-case estimate, P_D(max), represents the maximum allowable power level (V_{CC}(max), I_{CC}(max)), without exceeding T_J(max), at a selected $R_{\theta JA}$ and T_A.

Example:

Reliability for V_{CC} at $T_A = 150°C$, estimated values based on package SM, using single-layer PCB.

Observe the worst-case ratings for the device, specifically: $R_{\theta JA} = 134°C/W$, $T_J(max) = 165°C$, $V_{CC(absmax)} = 24$ V, and $I_{CC} = 12$ mA.

Calculate the maximum allowable power level, P_D(max). First, invert equation 3:

$$\Delta T(max) = T_J(max) - T_A = 165\,°C - 150\,°C = 15\,°C$$

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

$$P_D(max) = \Delta T(max) \div R_{\theta JA} = 15°C \div 134°C/W = 111.9\ mW$$

Finally, invert equation 1 with respect to voltage:

$$V_{CC(est)} = P_D(max) \div I_{CC} = 111.9\ mW \div 12\ mA = 9.3\ V$$

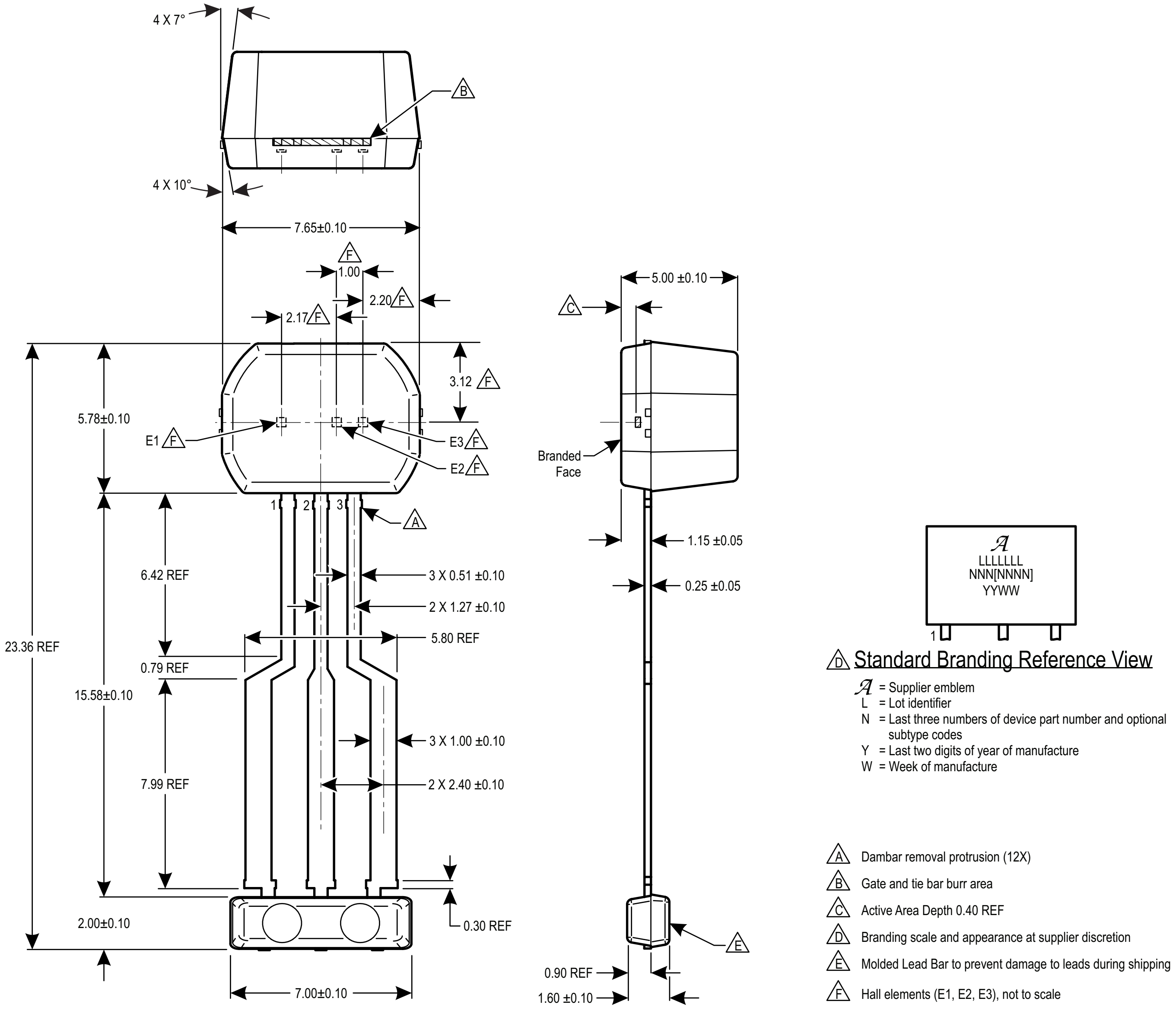
The result indicates that, at T_A, the application and device can dissipate adequate amounts of heat at voltages $\leq V_{CC(est)}$.

Compare $V_{CC(est)}$ to V_{CC}(max). If $V_{CC(est)} \leq V_{CC}$(max), then reliable operation between $V_{CC(est)}$ and V_{CC}(max) requires enhanced $R_{\theta JA}$. If $V_{CC(est)} \geq V_{CC(max)}$, then operation between $V_{CC(est)}$ and V_{CC}(max) is reliable under these conditions.

PACKAGE OUTLINE DRAWING

For Reference Only – Not for Tooling Use

(Reference DWG-9084)
Dimensions in Millimeters – NOT TO SCALE
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown



D Standard Branding Reference View

𝒜 = Supplier emblem
L = Lot identifier
N = Last three numbers of device part number and optional subtype codes
Y = Last two digits of year of manufacture
W = Week of manufacture

A Dambar removal protrusion (12X)
B Gate and tie bar burr area
C Active Area Depth 0.40 REF
D Branding scale and appearance at supplier discretion
E Molded Lead Bar to prevent damage to leads during shipping
F Hall elements (E1, E2, E3), not to scale

Figure 10: Package SM, 3-Pin SIP

Revision History

Number	Date	Description
–	May 10, 2017	Initial release
1	June 29, 2017	Updated Selection Guide and Programmable Options tables
2	February 27, 2019	Minor editorial updates
3	March 6, 2020	Minor editorial updates

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