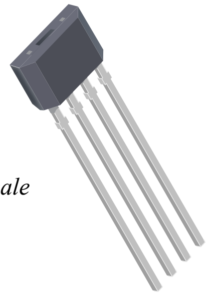
A1694

Chopper-Stabilized Position Sensor IC with Speed and Direction Output

FEATURES AND BENEFITS

- Digital output with speed and direction data provides ferromagnetic target/ring magnet position data
- 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 switchpoints
- Robust test coverage capability using scan-path and IDDQ measurement

PACKAGE: 4-PIN SIP (SUFFIX K)



Not to scale

DESCRIPTION

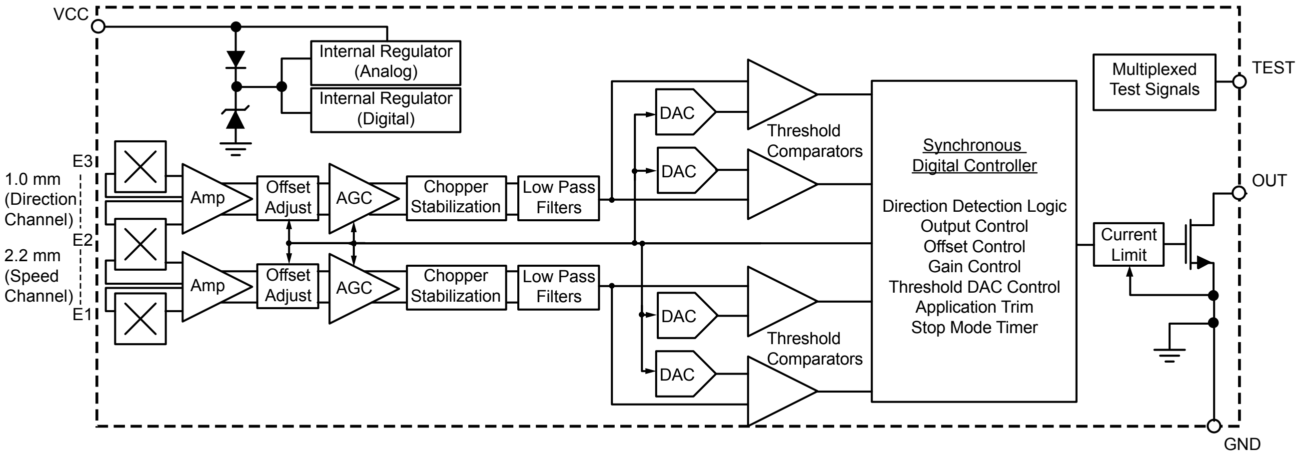
The A1694 provides speed and direction data through a variable-pulse-width output protocol. The device can be used to sense a ring magnet or a ferromagnetic target when back-biased with a proper magnet.

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 data provides absolute position on most crank targets, even in cases of engine backlash.

Advanced calibration techniques are used to optimize signal offset and amplitude. This calibration, combined with the digital tracking of the signal, results in accurate switchpoints 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 A1694 is provided in a 4-pin ultraminiature single in-line package (SIP). The package is lead (Pb) free, with 100% matte tin leadframe plating.

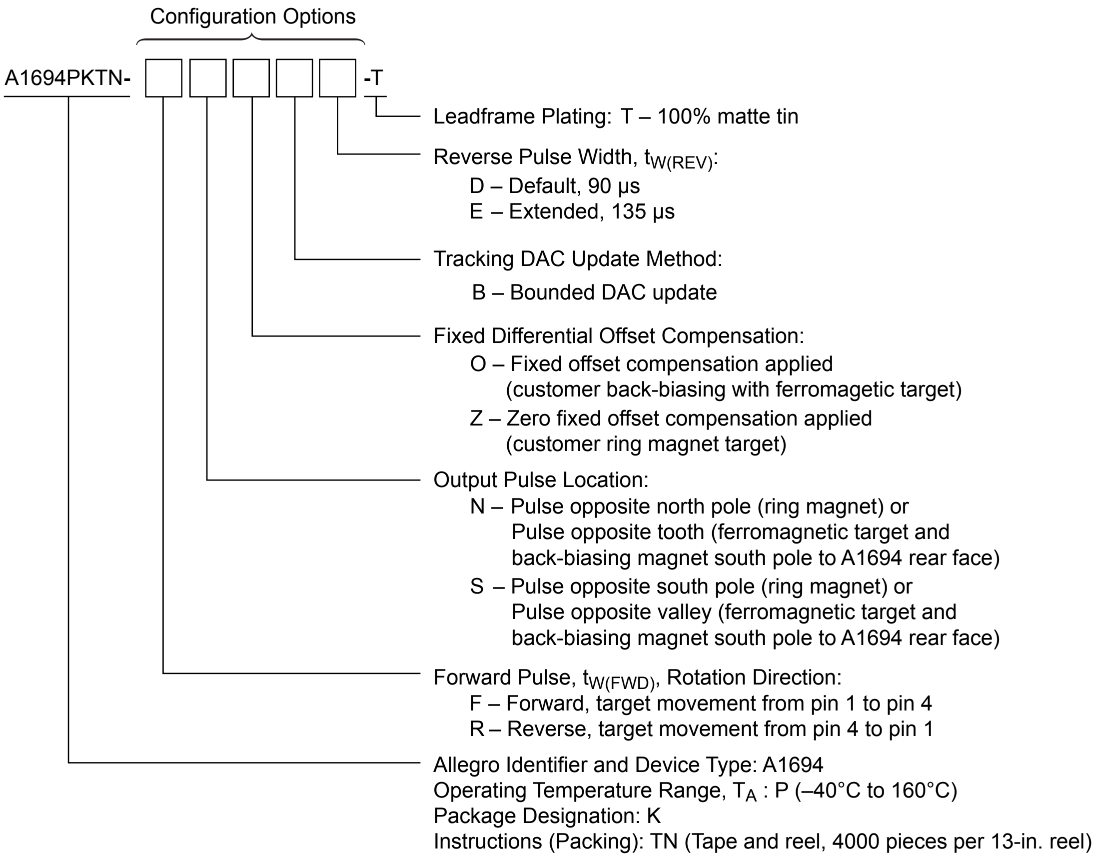
FUNCTIONAL BLOCK DIAGRAM



SELECTION GUIDE

Part Number	Package	Packing [1]	Operating Ambient Temperature Range, T_A (°C)
A1694PKTN-RNOBD-T	4-pin through hole SIP	4000 devices per reel	–40 to 150
A1694PKTN-RNZBD-T			

[1] Not all combinations are available. For availability and pricing of custom programming options, contact Allegro sales.



Leadframe Plating: T – 100% matte tin

Reverse Pulse Width, $t_{W(REV)}$:
- D – Default, 90 µs
- E – Extended, 135 µs

Tracking DAC Update Method:
- B – Bounded DAC update

Fixed Differential Offset Compensation:
- O – Fixed offset compensation applied (customer back-biasing with ferromagetic target)
- Z – Zero fixed offset compensation applied (customer ring magnet target)

Output Pulse Location:
- N – Pulse opposite north pole (ring magnet) or Pulse opposite tooth (ferromagnetic target and back-biasing magnet south pole to A1694 rear face)
- S – Pulse opposite south pole (ring magnet) or Pulse opposite valley (ferromagnetic target and back-biasing magnet south pole to A1694 rear face)

Forward Pulse, $t_{W(FWD)}$, Rotation Direction:
- F – Forward, target movement from pin 1 to pin 4
- R – Reverse, target movement from pin 4 to pin 1

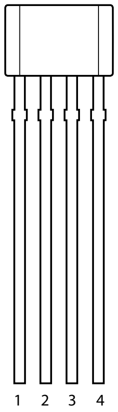
Allegro Identifier and Device Type: A1694
Operating Temperature Range, T_A : P (–40°C to 160°C)
Package Designation: K
Instructions (Packing): TN (Tape and reel, 4000 pieces per 13-in. reel)

ABSOLUTE MAXIUM RATINGS

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{CC}	Refer to the Power Derating section	28	V
Reverse Supply Voltage	V_{RCC}		–18	V
Reverse Output Voltage	V_{ROUT}	R_{PU} > 1000 Ω	–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 P	–40 to 160	°C
Maximum Junction Temperature	T_J(max)	Continuous	165	°C
Storage Temperature	T_{stg}		–60 to 170	°C

PINOUT DIAGRAM AND TERMINAL LIST TABLE

Pinout Diagram



Terminal List

Number	Name	Function
1	VCC	Supply voltage
2	VOUT	Open drain output
3	TEST	Test pin (MUX)
4	GND	Ground

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	–	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	–	–	3.9	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
Test Pin Zener Clamp Voltage	V_{ZTEST}		–	7	–	V
POWER-ON CHARACTERISTICS						
Power-On State	POS	$V_{CC} > V_{CC}$(min), connected as in Figure 9	–	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	–	200	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, C_L = 4.7 nF; 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, C_L = 4.7 nF; 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, C_L = 4.7 nF; 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, C_L = 4.7 nF; 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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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, C_L = 4.7 nF	–	10	–	μs
Output Fall Time	t_f	Measured 90% to 10% of V_{OUT}; see Figure 1; V_{PU} = 5 V, R_{PU} = 1 kΩ, C_L = 4.7 nF	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, C_L = 4.7 nF	–	4.3	–	μs
		Measured 90% to 10% of V_{OUT}; see Figure 1; V_{PU} = 24 V, R_{PU} = 1 kΩ, C_L = 4.7 nF	–	7.6	–	μs
Output Delay Time [5]	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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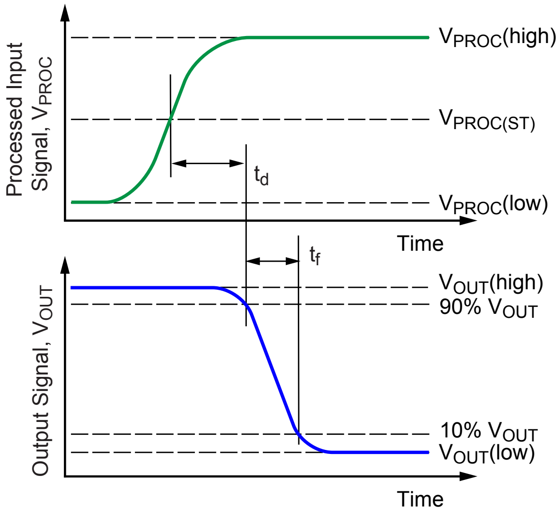

Figure 1: Definitions of Output Delay Time, t_d, and Output Fall Time, t_f

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 Switchpoint	d_{ST}	Distance from target feature center to IC center when V_{PROCST} occurs (becomes 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 [becomes 0.5 × T_{TARGET} (see Figure 3) out of phase if target is rotating in reverse]	–0.25 × T_{TARGET}	–	0.25 × T_{TARGET}	s
Relative Repeatability [6]	$err_{\theta E}$	100 $G_{pk\text{-}pk}$ sinusoidal signal with 6° period; f_{IN} = 1000 Hz	–	–	0.05	deg.
Operating Frequency	$f_{IN(FWD)}$	Correct speed data, forward rotation	0	–	10	kHz
	$f_{IN(REV)}$	Correct speed data, reverse rotation	0	–	5	kHz
Time to First Output Edge	$t_{OUT(init)}$	After t_{PO} elapses, f_{IN} < 600 rpm	–	T_{TARGET}	–	s
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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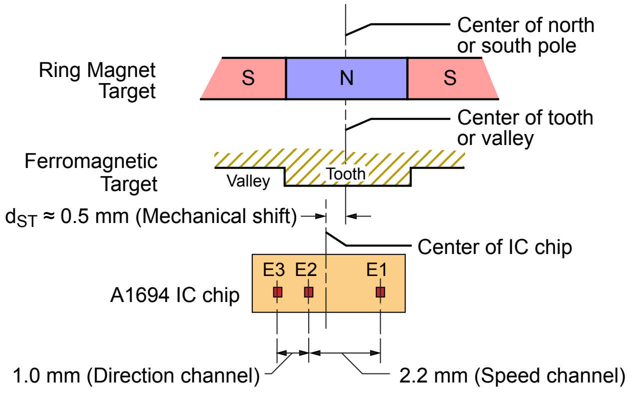
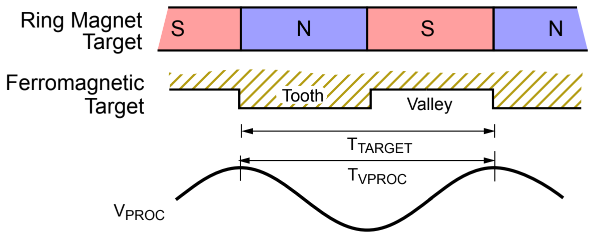


Figure 2: Definition of Mechanical Shift of Switchpoint



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 ring magnet target, both north-to-south or both south-to-north edges; for a ferromagnetic target, both rising or both falling mechanical edges)

Figure 3: Definition of T_{TARGET}

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; magnetic edge not sensed		–	5	–	s
Chopper Frequency	f_C			–	250	–	kHz
Switchpoint	$V_{PROC(ST)}$	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	–	$\%V_{pk\text{-}pk}$
Nominal Sensitivity Temperature Coefficient Programming Range [7]	TC	Sensitivity change relative to temperature	Option O, for use with back-biasing magnet	–	0.04	–	%/°C
			Option Z, for use with ring magnet	–	0.2	–	%/°C
MAGNETIC CHARACTERISTICS							
Differential Magnetic Input Signal	B_{IN}	Speed channel, B_{CHSEP} within specification		50	–	1100	$G_{pk\text{-}pk}$
Back-Biasing Magnetic Field	B_{COMMON}	For ferromagnetic targets		–2500	–	2500	G
Allowable User-Induced Magnetic Offset	B_{OFFSET}	Magnitude valid for both speed and direction channels; magnetic offset between center and outer Hall elements	Option O, for use with back-biasing magnet	–100	–	300	G
			Option Z, for use with ring magnet	–200	–	200	G

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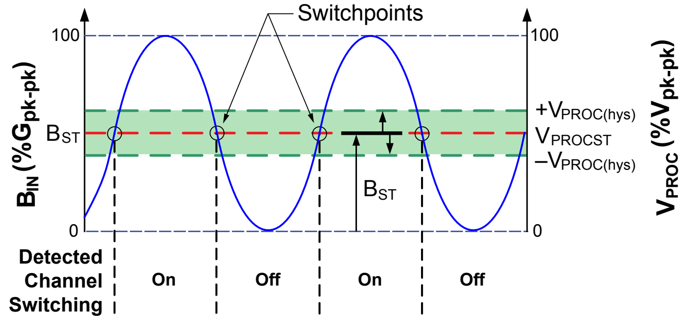


Figure 4: Establishment of Thresholds, Using Internal Hysteresis (Speed Channel)

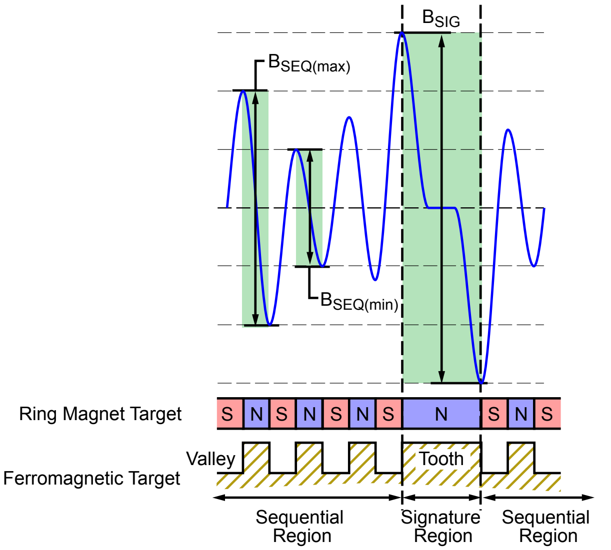


Figure 5: Differential Signature Amplification and Sequential Signal Variation

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

Characteristic	Symbol	Test Conditions		Min.	Typ.	Max.	Unit [1]
MAGNETIC CHARACTERISTICS (continued)							
Allowable Differential Signal Reduction	B_{SEQ}(min)/ B_{SEQ}(max)	Over 60 cycles, excluding signature region, see Figure 5	Option B, for bounded digital-to-analog convertor (DAC) update	0.4	–	–	–
		Over 3 consecutive cycles, excluding signature region, see Figure 5		0.8	–	–	–
	$B_{SEQ(n+1)}$/ $B_{SEQ(n)}$	Single cycle-to-cycle variation, both channels; Includes signature (B_{SIG}) amplification, see Figure 5		0.8	–	2	–
TARGET CHARACTERISTICS							
Required Channel Separation	B_{CHSEP}	Measured between speed and direction channels; measured on normalized (0 to 100%) differential magnetic signals (see the Target Characteristics section)	Opposite switching feature, 0.25 × B_{SEQ} (max) < B_{IN} < 0.75 B_{SEQ} (max)	30	–	–	%
			Opposite non-switching feature, no signal cross-over, 0.25 × B_{SEQ} (max) < B_{IN} < 0.75 B_{SEQ} (max)	0	–	–	%
Safe Signal Inversion Range	$B_{INV(POS)}$	Measured on normalized (0 to 100%) differential magnetic signals (see the Target Design section)		75	–	–	%
	$B_{INV(NEG)}$			–	–	25	%

[1] 1G (gauss) = 0.1 mT (millitesla).
[2] Sustained voltages beyond the clamp voltage might 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.
[5] Time between magnetic signal switchpoint crossing and electrical output signal reaching 90% of $V_{OUT(OFF)}$ = high (see Figure 1).
[6] 6-sigma using 360°-repeatability method on sinusoidal signal over greater than 1000 edges; constant speed, air gap, and temperature.
[7] Option O is targeted for use with a SmCo back-biasing magnet.

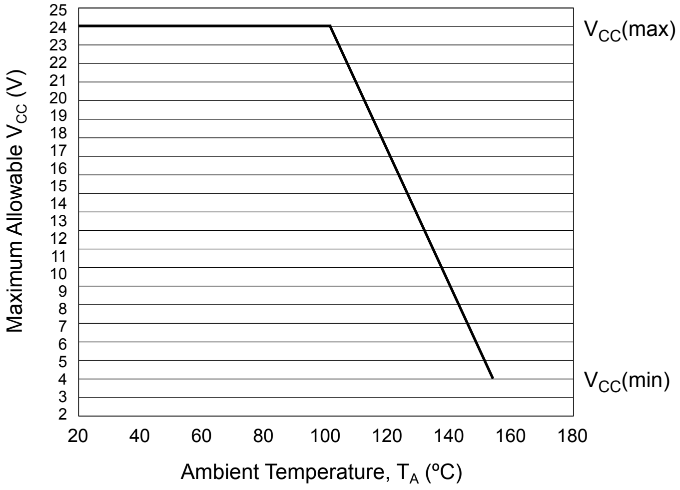
POWER DERATING

THERMAL CHARACTERISTICS: May require derating at maximum conditions, see Application Information

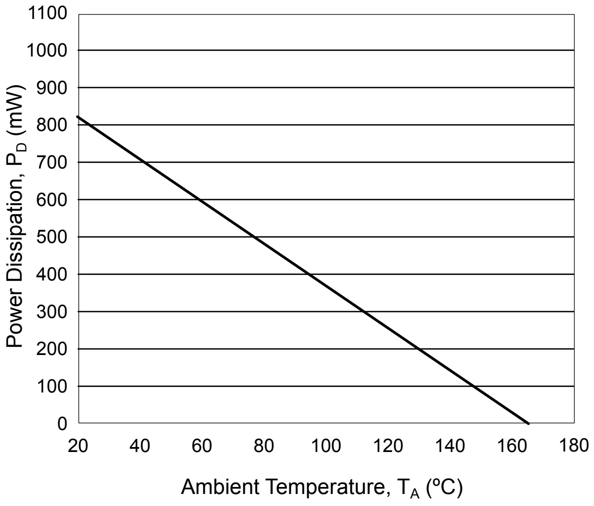
Characteristic	Symbol	Test Conditions [1]	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	On single-layer PCB with copper limited to solder pads	177	°C/W

[1] Additional thermal information available on the Allegro website

Power Derating Curve



Power Dissipation versus Ambient Temperature



FUNCTIONAL DESCRIPTION

Sensing Technology

The sensor integrated circuit (IC) contains a single-chip Hall-effect circuit that supports a trio of Hall elements. These are used in differential pairs to provide an electrical signal containing data regarding edge position and target direction.

Target Profiling

After proper power is applied to the sensor IC, it is capable of providing digital data 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. Additional optimization is not needed and minimal processing circuitry is required. This ease of use reduces design time and incremental assembly costs for most applications.

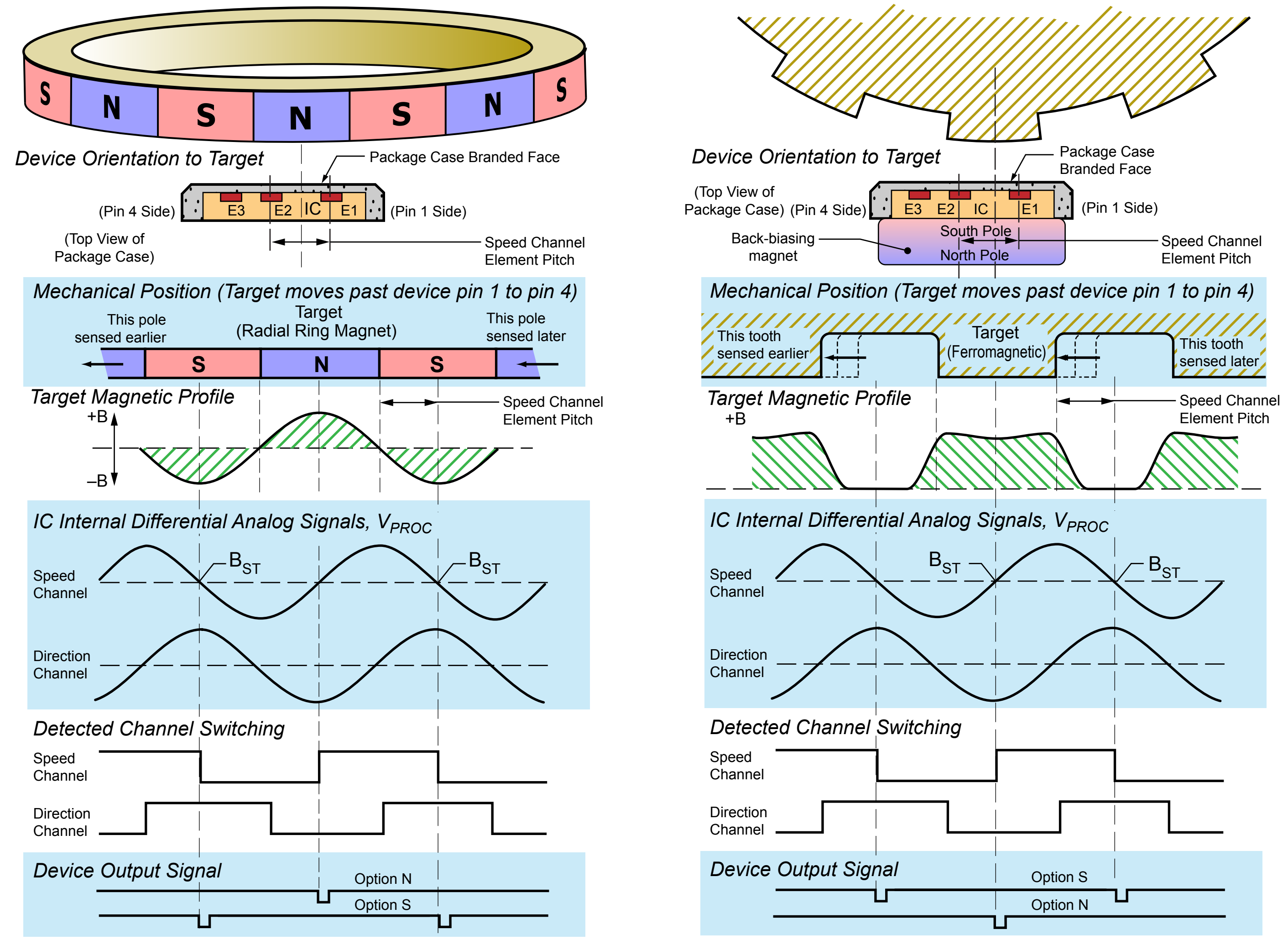


Figure 6: Magnetic Profile Reflects Features of the Target, Allowing the Sensor IC to Present an Accurate Digital Output

Direction Detection

The sensor IC compares the relative phase of its two differential channels to determine in 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), when the target rotation is from pin 1 to pin 4 (option F) or from pin 4 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, and option E, 135 µs).

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

Pulse Occurrence Location

The output pulse can be programmed to occur at the target mechanical features of either polarity. For ring magnet targets, the output pulse can be programmed to occur at the center of a north pole (option N) or at the center of a south pole (option S). For ferromagnetic targets, these options program the output pulse to occur at the center of a tooth (option N) or at the center of a valley (option S) when back-biased with a south pole to the back of the package.

Differential Offset

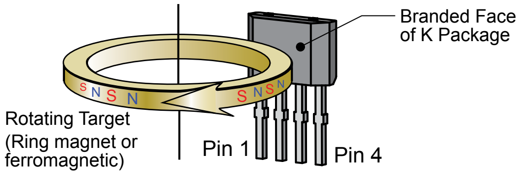
Back-biasing the A1694 (attaching an external magnet on the rear face, for use with ferromagnetic targets) can create uneven magnetic induction on the three Hall elements. This induces a greater static field at the center element than at the two outer elements, resulting in a fixed differential offset on each channel. This is illustrated for the speed channel by the magnetic profile in Figure 8. An offset of equal magnitude is present on the direction channel.

The A1694 can be programmed (option O) to provide a fixed offset that directly counteracts the induced differential offset from a back-biasing magnet. Program a zero offset (option Z) when no back-biasing is used (for ring magnet targets).

Switchpoints

The running mode switchpoints of the A1694 are established dynamically as a percentage of the amplitude of the internal signal, V_{PROC}. Two digital-to-analog converters (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 9), the effect of a signal shift is minimized.

Option F
Forward pulses ($t_{W(FWD)}$) generated for rotation from pin 1 to pin 4



Option R
Forward pulses ($t_{W(FWD)}$) generated for rotation from pin 4 to pin 1

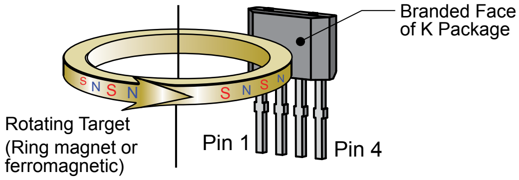


Figure 7: Rotation Direction Definitions

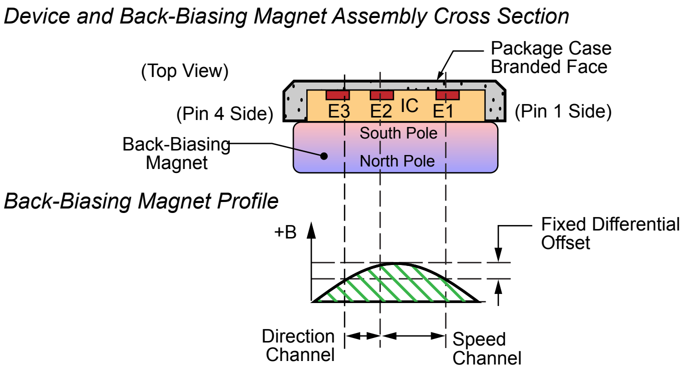


Figure 8: Fixed Differential Offset Resulting from Back-Biasing Magnet

Operating Modes

Calibration Mode

After the power-on time elapses, 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 switchpoint.

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 switchpoints can be accurately computed.

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

Running Mode

After calibration is complete, target-relative rotation-direction data is available. This data 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 might occur 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 A1694 contains an on-chip regulator and can operate across a wide supply-voltage range. For applications using an unregulated power supply, transient protection may be added externally. For applications using a regulated supply line, the need for electromagnetic interference (EMI) and radio-frequency interference (RFI) protection might remain. The minimum circuitry needed for proper operation of the sensor IC is shown in Figure 9. For information about electromagnetic-compatibility (EMC) specification compliance, contact Allegro.

Target Design

The A1694 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 the Functional Description section). Guidelines described here outline differential magnetic signal traits with which the device produces the proper output.

Signal Differentiation at Switching Features

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 10.

For the A1694, a *switching feature* can either be a north or south pole of a ring magnet, or a tooth or valley of a ferromagnetic target, depending on the option of the output pulse location (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.

The differential signal of either channel can lead or lag 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; an example is the repeated magnetic regions on a typical ring magnet. (See Figure 5.)

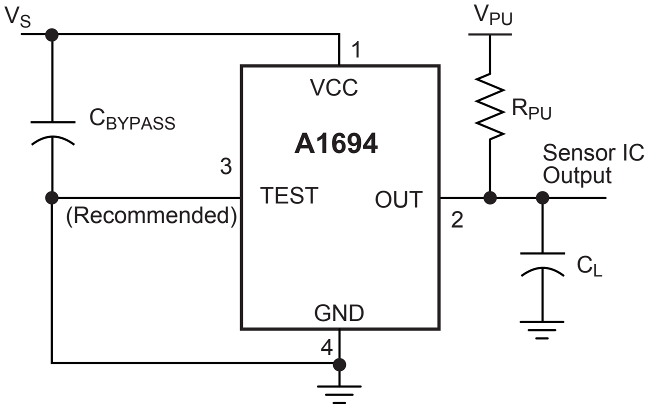


Figure 9: Typical Application Diagram, Showing Minimum Application Circuit Requirements

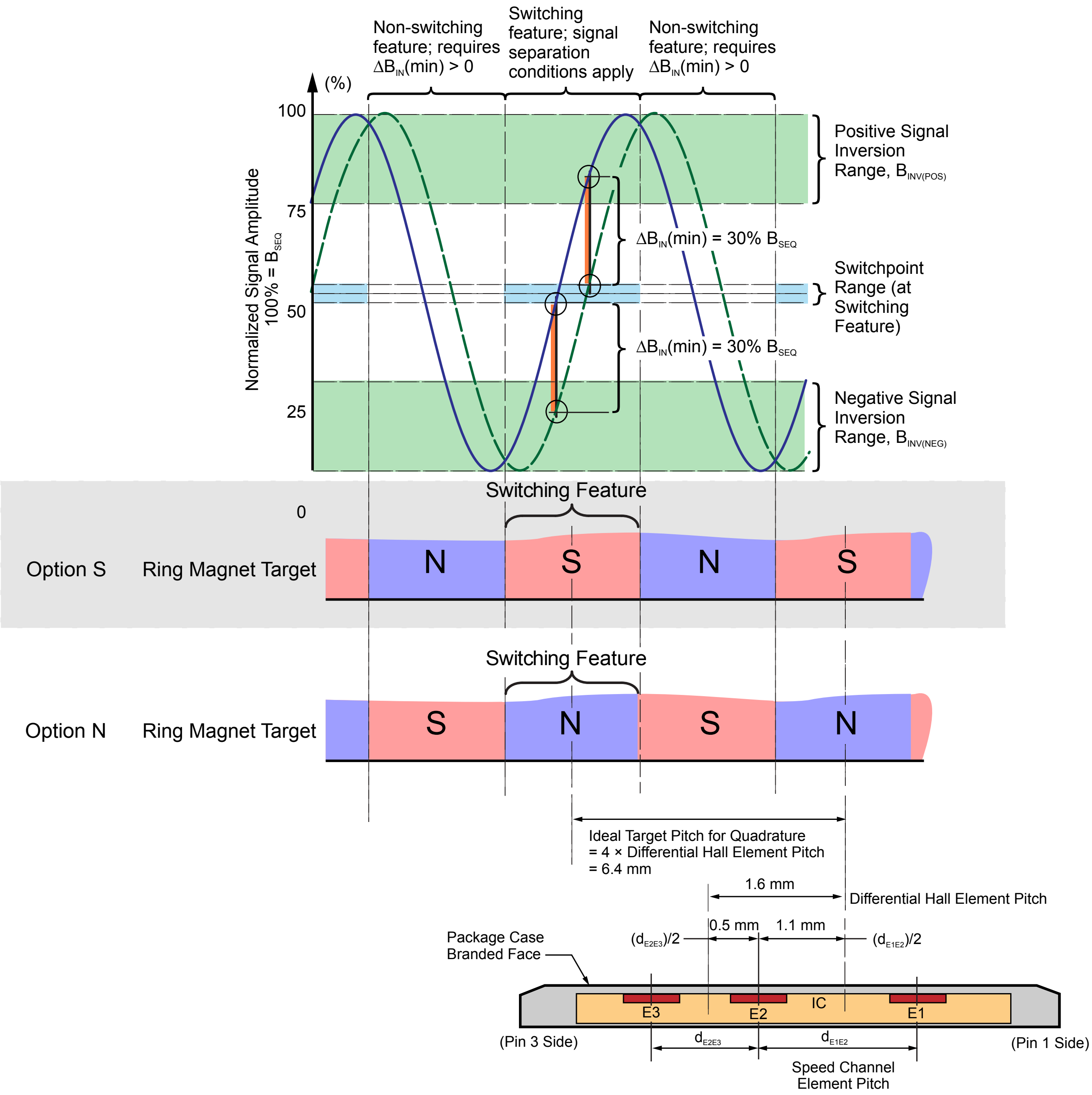


Figure 10: Channel Separation and Signal Inversion Definitions

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 10, two sine waves of equal amplitude 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).

Nonswitching Features

When nonswitching features are adjacent to the device, the constraints on the differential magnetic signals are less stringent, because an output pulse is not 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 switchpoint as on sequential features. The effect of a signature region is a delay in reaching the next switchpoint.

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 those signature features that are nonswitching.

POWER DERATING

The device must be operated below the maximum junction temperature of the device, $T_{J(max)}$. In certain combinations of peak conditions, reliable operation might require derating the 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:

Equation 1:	$P_D = V_{IN} \times I_{IN}$
Equation 2:	$\Delta T = P_D \times R_{\theta JA}$
Equation 3:	$T_J = T_A + \Delta T$

For example, given common conditions such as: T_A= 25°C, V_{CC} = 12 V, I_{CC} = 7 mA, and $R_{\theta JA}$ = 177 °C/W, then:

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

$$\Delta T = P_D \times R_{\theta JA} = 84\ mW \times 156\ °C/W = 13.1°C$$

$$T_J = T_A + \Delta T = 25°C + 13.1°C = 38.1°C$$

A worst-case estimate, $P_{D(max)}$, represents the maximum allowable power level, without exceeding $T_{J(max)}$, at a selected $R_{\theta JA}$ and T_A.

Example: Reliability for V_{CC} at T_A = 150°C.

Observe the worst-case ratings for the device, specifically: $R_{\theta JA}$ = 177 °C/W, T_J(max) = 165°C, V_{CC}(max) = 24 V, and I_{CC}(max) = 15 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:

$$P_D(max) = \Delta T(max) \div R_{\theta JA} = 15°C \div 177\ °C/W = 84.7\ mW$$

Finally, invert Equation 1 with respect to voltage:

$$V_{CC}(est) = P_D(max) \div I_{CC}(max) = 84.7\ mW \div 15\ mA = 5.65\ V$$

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

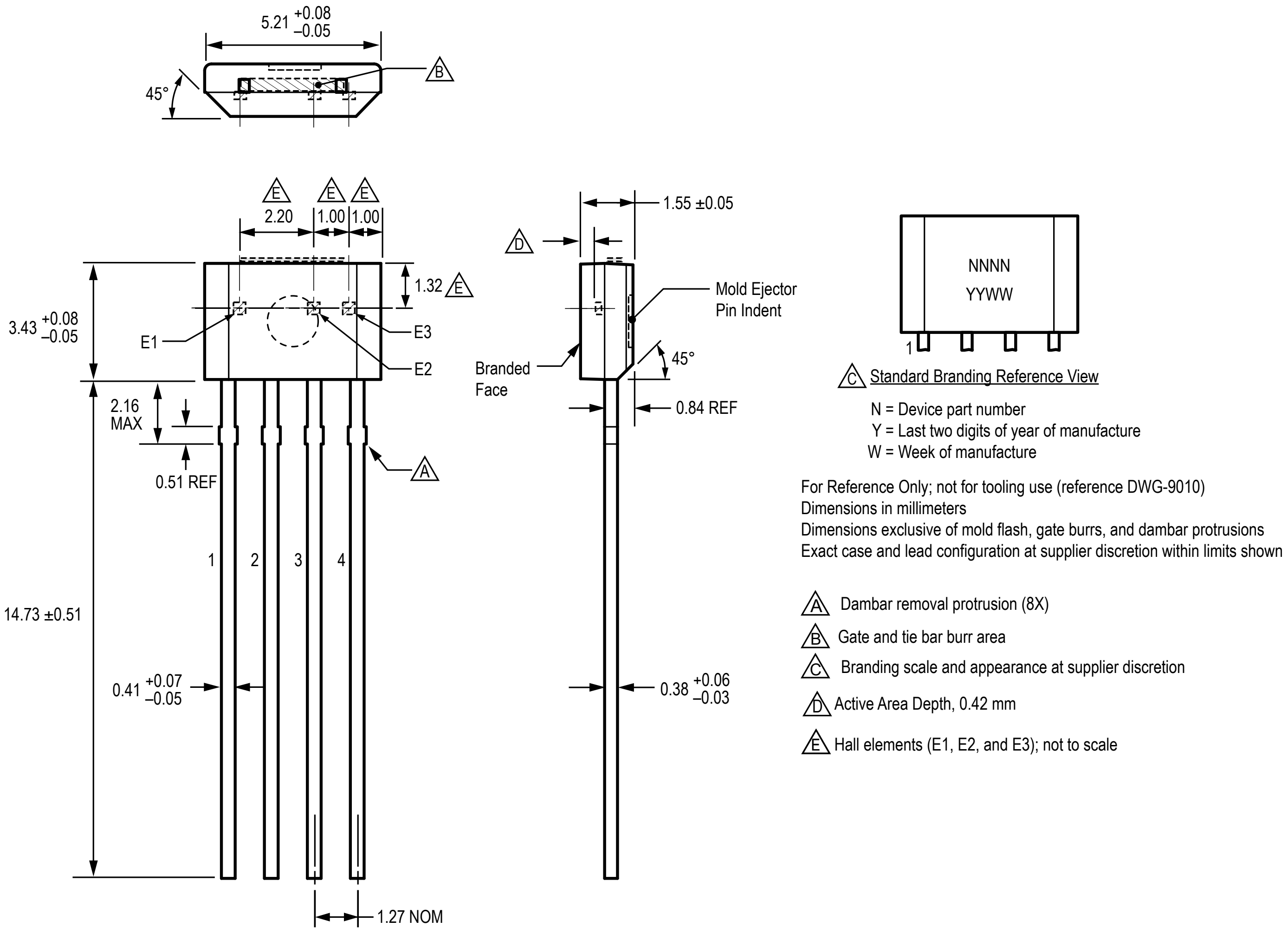
Compare V_{CC}(est) to V_{CC}(max):

- If $V_{CC}(est) \le V_{CC}(max)$, reliable operation between V_{CC}(est) and V_{CC}(max) requires enhanced $R_{\theta JA}$.
- If $V_{CC}(est) \ge V_{CC}(max)$, 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-0000395)
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



N = Device part number
Y = Last two digits of year of manufacture
W = Week of manufacture

For Reference Only; not for tooling use (reference DWG-9010)
Dimensions in millimeters
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown

A Dambar removal protrusion (8X)
B Gate and tie bar burr area
C Branding scale and appearance at supplier discretion
D Active Area Depth, 0.42 mm
E Hall elements (E1, E2, and E3); not to scale

Figure 11: Package K, 4-Pin SIP

Revision History

Number	Description	Pages	Date
– (was 1.0)	Original	All	March 29, 2012
1 (was 1.1)	Increased Allowable User-Induced Magnetic Offset range	7	April 6, 2012
2 (was 1.2)	Correct Output Pulse Location options	misc.	April 13, 2012
3 (was 1.21)	Correct figure 6 polarity	10	April 26, 2012
4	Minor editorial updates	All	May 21, 2019
5	Updated package drawing	17	June 3, 2022
6	Updated selection guide and made minor formatting and editorial changes throughout	All	February 17, 2026
7	Initial release to Allegro website	All	March 24, 2026
	Added A1694PKTN-RNZBD-T part variant to selection guide table	2	

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