High Accuracy Programmable Camshaft Position Sensor IC

1. Features

- AEC-Q100 qualified
- ISO26262 ASILB
- High Accuracy and High Sensitivity
- Customer-side programming enable
- TPO functionality with optinal Auto-TPO adaption in EEPROM
- Operation Temperature：-40℃～150℃
- Operation Voltage：4V～24V
- 3-pin PCB-less TS-3 package

2. Applications

- Camshaft position detection
- High accuracy gear position detection

3. Description

The SC9388 is an active Hall sensor ideally suited for camshaft applications and similar industrial applications, such as speedometer.

It provides true power on (TPO) functionality from zero speed and maps the mechanical shape of a target wheel, such as either a tooth or a notch into a unique electrical output state.

Variants of self-calibration algorithms are implemented, adaptable to common camshaft targets in order to achieve optimum phase accuracy in operation. TPO capability and cancelation of production spread and assembly tolerance can be achieved by end of line programming.

Each device includes on a single silicon chip a voltage regulator, Hall-voltage generator, small-signal amplifier, chopper stabilization circuits, digital process circuits, EEPROM, diagnostic circuits.

The device is available in a 3-pin package (TS-3) Which integrated with capacitor.

It is lead (Pb) free, with 100% matte tin-plated lead frame.

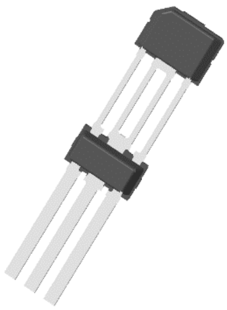

Fig.1 TS-3 Package Outline

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4. Terminal Configuration

TS-3
(Top View)

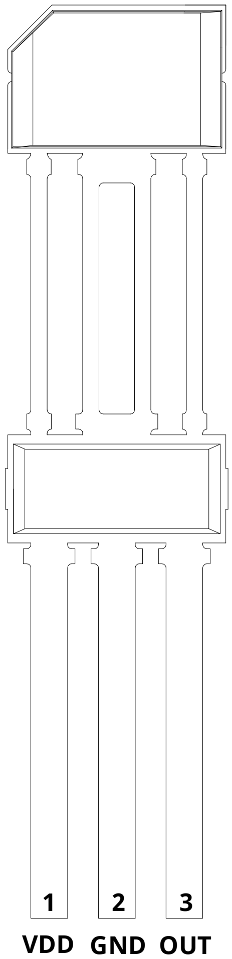


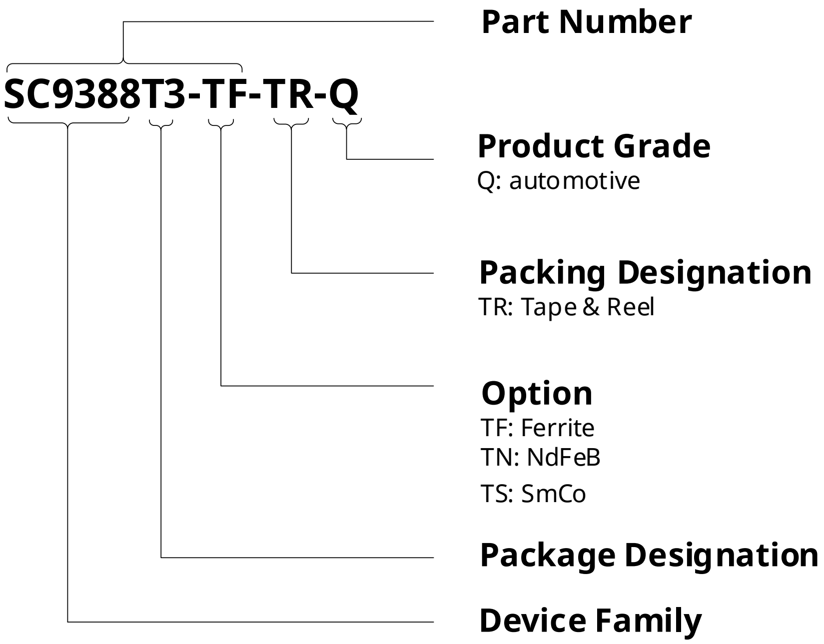
Fig.2 Pin Description

Terminal		Type	Description
Name	Number		
VDD	1	PWR	4V~24V power supply
GND	2	Ground	Ground terminal
OUT	3	Output	Open-drain output. The open drain requires a pull-up resistor

5. Ordering Information

Ordering Information	Marking	Temp.triming	Ambient, T_A(℃)	Package	Packing	Quantity
SC9388T3-TF-TR-Q	9388	Ferrite	-40 ~ 150	TS-3	Tape & reel	1500pcs /reel
SC9388T3-TN-TR-Q	9388	NdFeB	-40 ~ 150	TS-3	Tape & reel	1500pcs /reel
SC9388T3-TS-TR-Q	9388	SmCo	-40 ~ 150	TS-3	Tape & reel	1500pcs/reel

Ordering Information Format



6. Absolute Maximum Ratings

Symbol	Parameter	Test conditions	Min.	Max.	Units
V_{DD}	Power supply voltage (1)	continuous, T_J≤170℃	-16	27	V
		max. 60s, T_J≤170℃	-18	40	V
V_{OUT}	Output Off voltage (1)	continuous, T_J≤170℃	-0.3	27	V
		max. 1h, T_{Amh}≤170℃	-1.0	40	V
T_A	Operating ambient temperature		-40	150	℃
T_J	Maximum junction temperature	exposure time: max. 10×1h, V_{DD}=16V	-40	175	℃
B_Z	Magnetic field induction (2)	magnetic pulse during magnet magnetization. valid with $T_{ambient}$ ≤ 80°C	-4	4	T
N_{PROG}	Maximum No. of EEPROM programming cycles	T_A＜130˚C	-	150	n

Note：
(1) Stresse above those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
(2) Guaranteed by design.

7. ESD Protection

Symbol	Parameter	Test conditions	Min.	Max.	Units
V_{ESD}	ESD-Protection	Refer to AEC-Q100-002E HBM standard,R=1.5kΩ, C=100pF	-8	8	kV

8. Thermal Characteristics

Symbol	Parameter	Test conditions	Min.	Max.	Units
$R_{\theta JA}$	Package thermal resistance	Without PCB, welding process with lead-frame	-	190	℃/W

9. Operating Characteristics

over operating free-air temperature range (V_{DD}=5.0V, unless otherwise noted)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Electrical parameters						
V_{DD}	Supply Voltage		4	5	24	V
V_{OUT}	Continuous Output Off voltage		–	–	27	V
dV_{DD}/dt	Supply voltage power- up/down voltage ramp		3	–	10000	V/ms
V_{sat}	Output saturation voltage	I_{OUT}<15mA	-	-	500	mV
V_{DD_clamp}	Clamping voltage VDD Pin	Leakage current through ESD diode<0.5mA	40	-	-	V
V_{OUT_clamp}	Clamping voltage OUT Pin	leakage current through ESD-diode<0.5mA	40	-	-	V
V_{DD_reset}	Reset voltage		3.0	3.6	-	V
I_{DD}	Supply current		3	4.5–	6	mA
I_{OUT_ON}	Continuous output On current	V_{OUT_LOW}<0.5V	–	–	15	mA
I_{leak}	Output leakage current	V_{OUT}=24V	-	0.1	10	μA
I_{short}	Output current limit during short-circuit condition		30	40	50	mA
Time & Frequency Related						
t_{power_on}	Power on time	During this time the output is locked to high.	0.8	0.9	1	ms
t_{delay}	Delay time between magnetic signal switching point and corresponding output signal falling edge switching event	Falling edge	10	14	19	μs
t_{delay2}	Further options on delay time accessible using EEPROM	Option 2	13	17	22	μs
t_{delay3}		Option 3	16	20	25	μs
t_{delay4}		Option 4	19	23	28	μs
t_{fall}	Output fall time	V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_{OUT}=2.2nF (±10%), valid between 80%-20%	2.0	2.5	3.0	μs
		V_{Pullup}=5V, R_{Pullup}=1.2kΩ (±10%), C_{OUT} =2.2nF (±10%), valid between 90%-10%	3.2	4.5	5.8	μs
t_{rise}	Output rise time	R_{Pullup}=1.2kΩ (±10%), C_{OUT}=2.2nF (±10%),valid between 10%-90%	4	-	11.4	μs
f	Magnetic signal frequency range	Full accuracy	0	–	8000	Hz
C_{VDD}	Capacitance between IC VDD and ground pin		90	100	110	nF
C_{OUT}	Capacitance between IC OUT and ground pin		1.98	2.2	2.42	nF

Operating Characteristics（continued）

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Magnetic parameters						
FSR_{mag_field}	Full scale range of the magnetic field	For magnetic material being NdFeB and SmCo	-31	-	134	mT
		For magnetic material being Frite	-15	-	80	mT
B_{pp_max}	Maximum peak to peak field amplitude in full scale range	For magnetic material being NdFeB and SmCo	-	-	147	mT_{pp}
		For magnetic material being Frrite	-	-	95	mT_{pp}
$B_{threshold}$	Magnetic range for TPO and switching threshold	For magnetic material being NdFeB and SmCoAllowed programmable TPO, Hysteresis not included	-31	-	100	mT
		For magnetic material being Frrite，Allowed programmable TPO, Hysteresis not included	-15	-	45	mT
K_factor	Adjustment range of switching level (k-factor)	6 bit，Programmable step size 0.7936%	25	-	75	%
Accuracy Related						
Jitter	Repeatability accuracy	3 sigma, ΔB_{pkpk}=20mT_{pkpk}	–	–	0.25	°
Phirunning	Phase accuracy	ΔB_{Speed}>9mT_{pkpk} ,signature excluded, accuracy on mentioned wheel in Figure 4	-2	–	3	°
Temperature Cmpensation						
T_C	Pre-programmed (trimmed) temperature coefficient	For magnetic material being SmCo	–	-600	–	ppm/K
		For magnetic material being NdFeB	–	-1200	–	ppm/K
		For magnetic material being Frite	–	-2000	–	ppm/K

10. Block Diagram

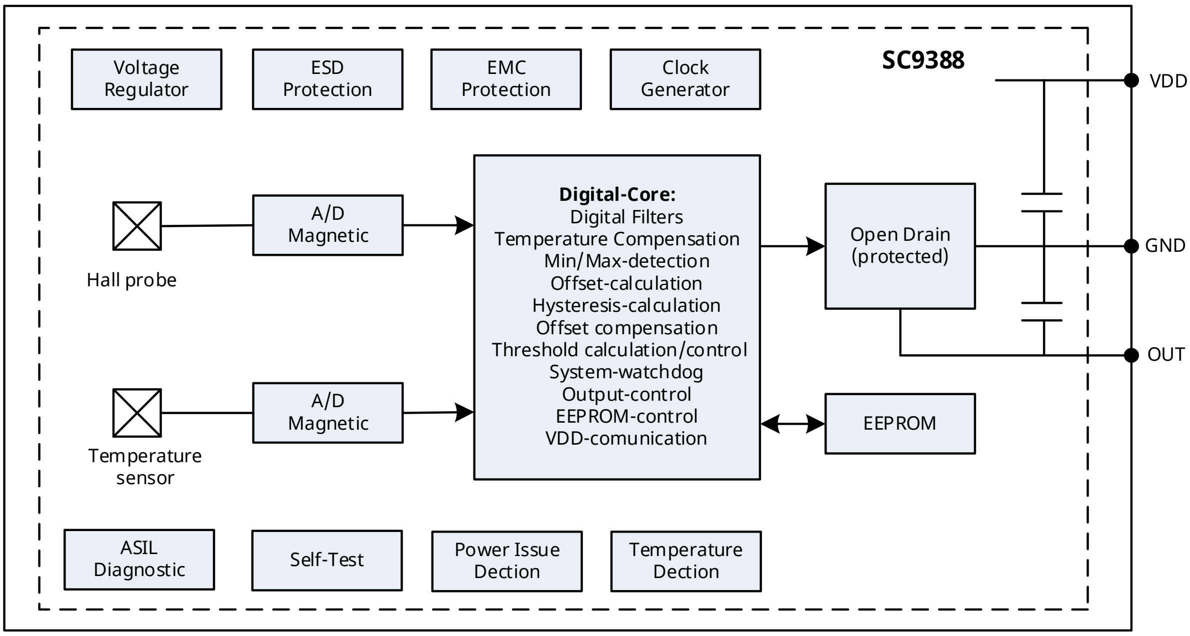


Fig.3 Block Diagram

Contains several circuits:

Chopped Hall Amplifier	Under/Over Voltage Detection
Offset Calibration ADC	POR
PGA + LPF	OSC
Channel ADC(Tracking ADC)	EEPROM programmable
Analog & Digital VDD Regulator	EMC Protection
Current Bias	ASIL / Diagnostic

11 Function Description

- **Working Principle**

The speed detection configuration of SC9388 is shown in the figure below. A cylindrical solid or hollow back-bias magnet is placed behind the IC. As the camshaft rotates, the magnetic flux through the Hall sensing elements differs when the cam tooth peak and tooth valley face the sensor. The signal is processed internally within the chip to accurately output the position information of the tooth peak and tooth valley.

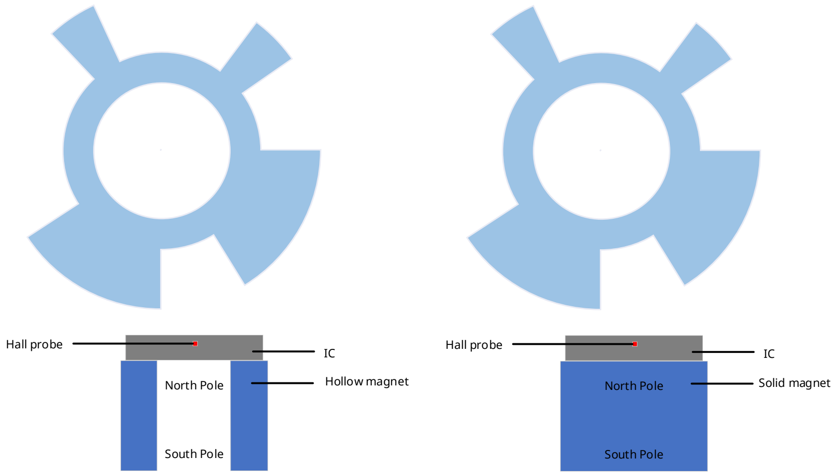


Fig.4 Detection Principle

- **Operation Temperature**

Ambient temperature：-40˚C ~ 150˚C

Peak temperature: 150˚C during 3h

Frequency (peak temperature): 160 times during lifetime

Nominal temperature: T= 80˚C ~ 110˚C

Temperature Profile:

Temperature(℃)	-40	-20	25	80	100	110	125	150
Vehicle lifeti（%）	0.03	0.67	1.5	27	43.9	23	3.5	0.41

- **Operation Steps**

The basic operation of this sensor is to transpose the magnetic field produced by a spinning target wheel into phase information at the output pin. The output voltage indicates forward a teeth or valley and can be adjusted in EEPROM-options.

The correspondence between field polarity and output polarity can be set according to the application needs.

By definition a magnetic field is considered as positive if the magnetic North Pole is placed at the rear side of the sensor.

The operation need to be split to five different phases :

1. Power-on phase

- starts after supply release;
- Lasts tpower-on (power-on time);
- IC loads configuration and settings from EEPROM and initializes state machines and signal path;

2. Initial phase

- starts after Power-on phase;
- lasts one clock cycle;
- IC enables output switching, extrema detection and threshold adaption;
- output remains HIGH or switches to LOW according to direct comparison of field with TPO (true power on functionality)

3. Calibration phase

- starts after Initial phase
- output switches according to the threshold value and according to the selected hysteresis algorithm

4. Running phase

- starts after Calibration Phase;
- The threshold has been calibrated, and the phase accuracy has reached its optimum. Minor adjustments to the threshold are permitted.

- **Averaging Algorithm**

During the running phase, the threshold is calculated by averaging the valid maximum and minimum values to reduce possible offset updates. Each offset update leads to increased jitter, which must be avoided. The algorithm allows selecting a different number of teeth for the averaging calculation. It can also be configured such that once a characteristic signal is captured, the offset calibration value is updated with the result from the previous cycle.

- **Hysteresis Concept**

There are two different hysteresis concepts implemented in the IC, which can be selected in the EEPROM.

Default setting is the hidden hysteresis as seen in Figure5.

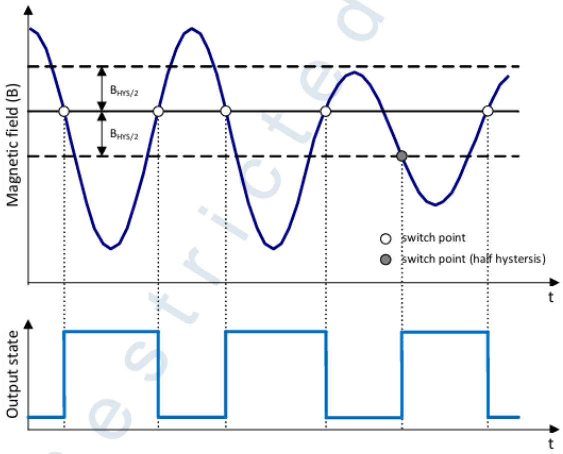


Fig.5 Hidden Hysteresis

This means, that the output always switches at the same level, centered between upper and lower hysteresis. These hysteresis thresholds need to be exceeded and are used to enable the output for the next following switching event. For example, if the magnetic field crosses the lower hysteresis level, then the output is able to switch at the zero crossing. Next following upper hysteresis needs to be exceeded again in order to enable for the next switching. Furthermore the function of half hysteresis maintains switching whenever the upper hysteresis level is not exceeded, but the lower hysteresis level is crossed again, then the output is allowed to switch, so that no edge is lost. However, this causes additional phase error.

In the visible hysteresis mode the output switches on the upper and lower hysteresis levels as indicated with BHYS/2 in Figure6. Five options for half hysteresis can be selected in the EEPROM.

Additionally, the sensor can be set to adaptive hysteresis behavior, with proportional adaption of the hysteresis thresholds according to the magnetic signals amplitude, but not lower than the specified minimumlevel. For more details see Figure7.

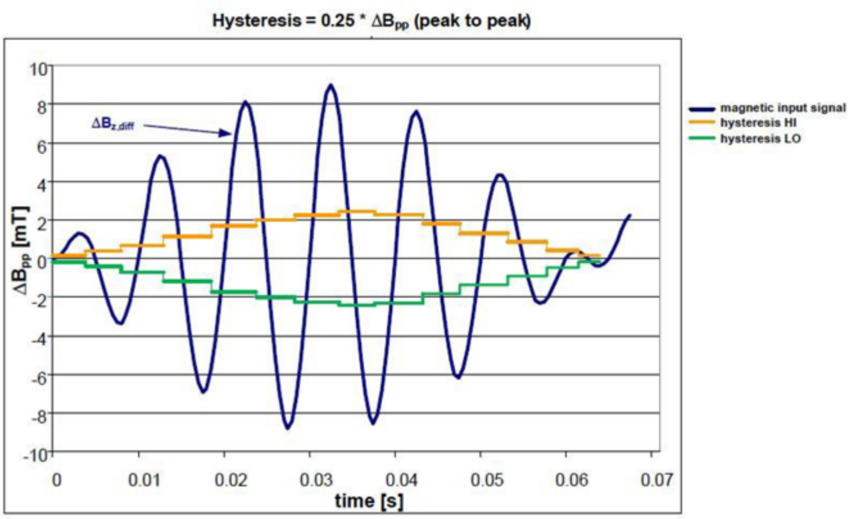


Fig.6 Adaptive Hysteresis

- **Adjust the proper k-factor**

To achieve the optimal switching level under varying air gaps and simultaneously mitigate run-out effects, an adaptive switching level adjustment mechanism is introduced. The core of the algorithm is to adaptively adjust the threshold to a specific percentage of the distance between the extrema (minimum and maximum values), and this percentage is referred to as the k-factor.

The k-factor can be set to a fixed value. Selecting an appropriate value matched to the target wheel reduces the influence of air gap variations on phase accuracy in operating mode. Using a larger k-factor also minimizes hard-edge offset in the application.

However, in some applications, reducing the tooth edge offset is less critical than minimizing the phase accuracy deviation between the initial phase and the running phase. This implies that the k-factor needs to be lowered while maintaining low sensitivity of the phase error to air gap variations.

In this case, the user can set the k-factor to an adaptive value that varies with the magnetic field amplitude. That is, the algorithm targets a specific switching angle and adaptively adjusts the k-factor according to the magnetic field amplitude. By programming B_{min} and B_{max}, a linear relationship between the magnetic field amplitude and the target k-factor can be approximated, as shown in the following formula:

$$\text{Switch threshold} = B_{min} + (B_{max} - B_{min}) * k$$

The fixed portion of the k-factor can be set separately for the calibration phase and the running phase, with a value range of 25%–75% and a step size of 0.7936%.

- **Temperature compensation**

The sensor can continuously measure its own temperature and compensate for the thermal drift of the magnet in the analog signal path based on pre-programmed values, ensuring accurate switching thresholds and thus maintaining high precision.

12. Typical Application

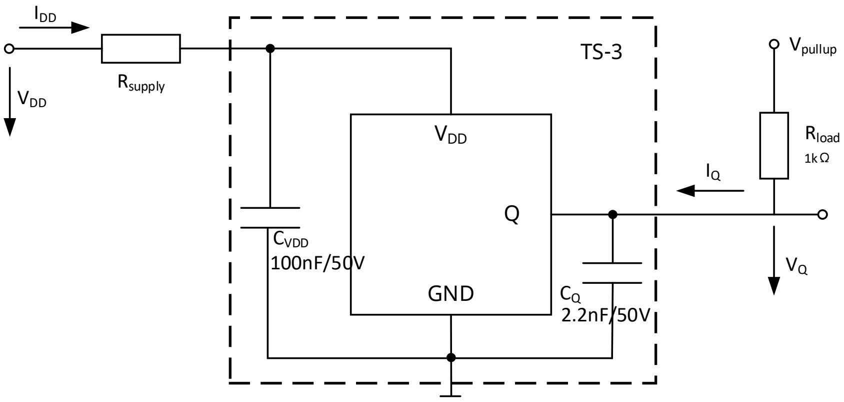
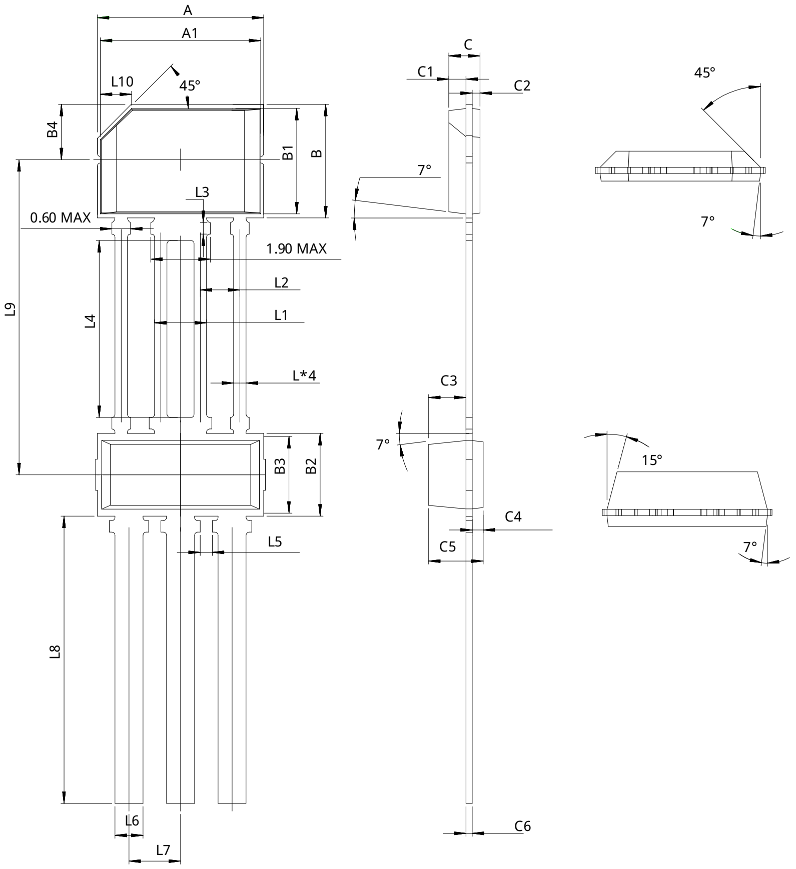


Fig.7 Typical Application Circuit

13. Package Information TS-3



Dimensions in Millimters			
Symbol	MIN	TYP	MAX
A	5.24	5.34	5.44
A1	5.05	5.15	5.25
B	3.52	3.64	3.76
B1	3.28	3.38	3.48
B2	2.40	2.65	2.90
B3	2.10	2.20	2.30
B4	1.68	1.78	1.88
C	0.92	0.96	1.00
C1	0.47	0.52	0.57
C2	0.19	0.24	0.49
C3	1.15	1.20	1.25
C4	0.30	0.35	0.40
C5	1.65	1.75	1.85
C6	—	0.20	—
L	0.35	0.40	0.45
L1	1.62	1.67	1.72
L2	—	1.27	—
L3	0.319	0.369	0.419
L4	5.62	5.67	5.72
L5	0.35	0.39	0.44
L6	0.85	0.90	0.95
L7	1.62	1.665	1.72
L8	9.16	9.21	9.26
L9	9.905	10.105	10.305
L10	—	1.00	—

Notes:
(1) Exact body and lead configuration at vendor's option within limits shown.
(2) Height does not include mold gate flash.Where no tolerance is specified, dimension is nominal.

Fig.8 Package Dimension

14. Packing Information

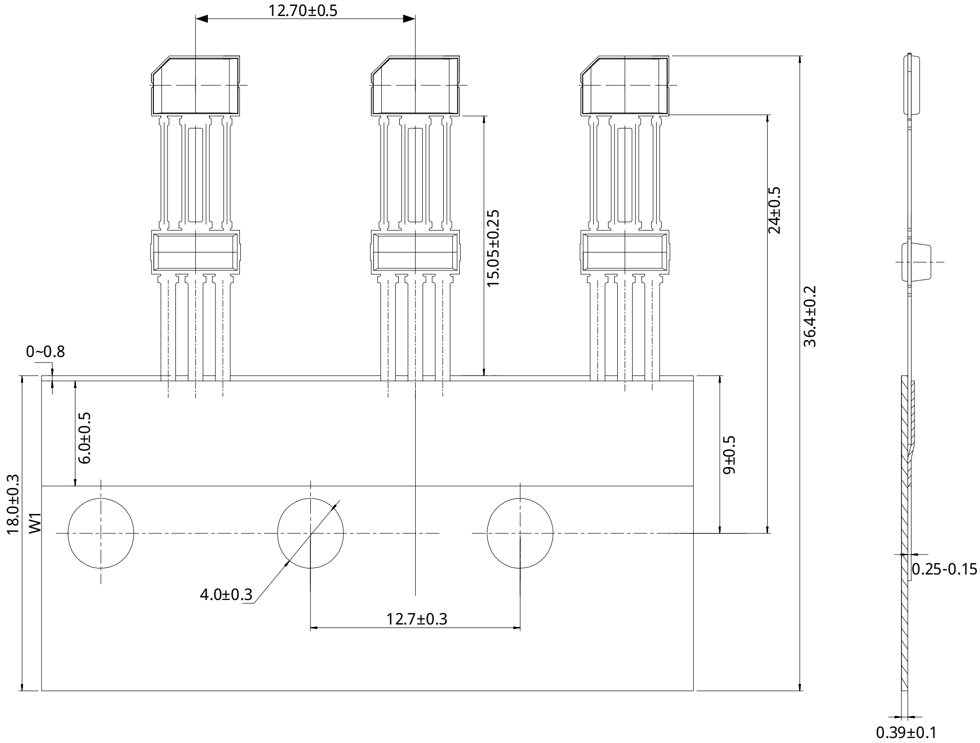


Fig.9 Packing Dimension

15. Revision History

Revision	Date	Description
Rev.E0.1	2024-03-20	Draft Version
Rev.E0.2	2025-06-11	Format Updates，Preliminary Version
Rev.E0.3	2025-12-02	Description update
Rev.A1.0	2026-03-10	Determine the parameter range

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