S-19761 Series

AUTOMOTIVE, 125°C OPERATION, ±0.1%, ±20 ppm/°C, LOW NOISE, HIGH-PRECISION SHUNT VOLTAGE REFERENCE

www.ablic.com

Rev.1.1_00

This IC is high-precision, low temperature coefficient, and low output noise shunt voltage reference developed using CMOS process technologies and is available in SOT-23-3 and compact HSNT-8(1616)B packages. Power can also be supplied from a high input voltage by selecting an appropriate external shunt resistor, making it possible to generate high- precision system reference voltage. The output voltage (reverse breakdown voltage) can be selected from 6 internally fixed voltages of 2.048 V, 2.5 V, 3.0 V, 3.3 V, 4.096 V, or 5.0 V.
This IC is available in 3 accuracy types. A type has an output voltage accuracy of ±0.1% and output voltage temperature coefficient of ±20 ppm/°C max. (Ta = -40°C to +125°C).
The IC is compatible with a wide range of shunt currents with a maximum shunt current of 30 mA.

ABLIC Inc. offers FIT rate calculated based on actual customer usage conditions in order to support customer functional safety design.
For more information regarding our FIT rate calculation, contact our sales representatives.

Caution This product can be used in vehicle equipment and in-vehicle equipment. Before using the product for these purposes, it is imperative to contact our sales representatives.

■ Features

• Output voltage: (Reverse Breakdown Voltage)	2.048 V, 2.5 V, 3.0 V, 3.3 V, 4.096 V, 5.0 V can be selected.
• Output voltage accuracy:	S-19761A: ±0.1% (Ta = +25°C) S-19761B: ±0.2% (Ta = +25°C) S-19761C: ±0.2% (Ta = +25°C)
• Output voltage temperature coefficient:	S-19761A: ±10 ppm/°C max. (Ta = 0°C to +85°C) ±20 ppm/°C max. (Ta = -40°C to +125°C) S-19761B: ±30 ppm/°C max. (Ta = -40°C to +125°C) S-19761C: ±80 ppm/°C max. (Ta = -40°C to +125°C)
• Shunt current range:	80 μA to 30 mA
• Output noise:	28 μV_{RMS} ($V_{z(S)}$ = 2.048 V)
• Output capacitor:	A ceramic capacitor can be used. 0.68 μF or higher
• Operation temperature range:	Ta = -40°C to +125°C
• Lead-free (Sn 100%), halogen-free	
• AEC-Q100 in process*1	

***1.** Contact our sales representatives for details.

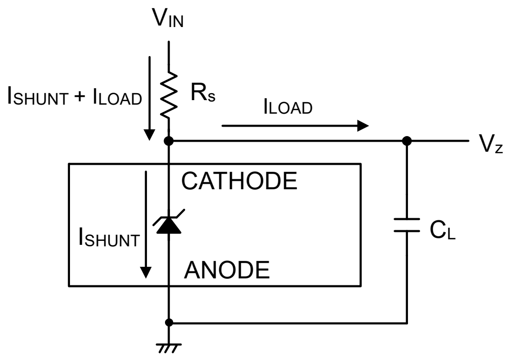
■ Applications

- Reference voltage for automotive A/D converter.
- Reference voltage for automotive comparators.
- Inverter, BMS, OBC, DC-DC converter.
- For automotive use (engine, transmission, suspension, ABS, related devices for EV / HEV / PHEV, etc.)

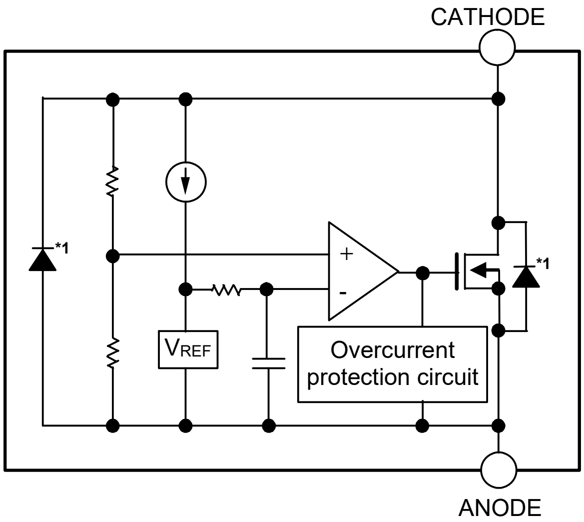
■ Packages

- SOT-23-3
- HSNT-8(1616)B

■ Typical Application Circuit



■ Block Diagram



***1.** Parasitic diode

Figure 1

■ AEC-Q100 in Process

Contact our sales representatives for details of AEC-Q100 reliability specification.

■ Product Name Structure

Users can select output voltage and package type for this IC. Refer to "**1. Product name**" regarding the contents of product name, "**2. Packages**" regarding the package drawings, "**3. Product name list**" regarding details of the product name.

1. Product name

S-19761 x xx A - xxxx U 7

- U: Environmental code
  - U: Lead-free (Sn 100%), halogen-free
- xxxx: Package name abbreviation and packing specification***1**
  - M3T1: SOT-23-3, Tape
  - A8T7: HSNT-8(1616)B, Tape
- A: Operation temperature
  - A: Ta = -40°C to +125°C
- xx: Output voltage
  - 2A :2.048 V, 25 : 2.5 V, 30 : 3.0 V,
  - 33 :3.3 V, 41 : 4.096 V, 50 : 5.0 V
- x: Product type
  - Refer to product name list

***1.** Refer to the tape drawing.

2. Packages

Table 1 Package Drawing Codes

Package Name	Dimension	Tape	Reel	Land
SOT-23-3	MP003-C-P-SD	MP003-C-C-SD	MP003-Z-R-SD	-
HSNT-8(1616)B	PY008-B-P-SD	PY008-B-C-SD	PY008-B-R-SD	PY008-B-L-SD

3. Product name list

3. 1 SOT-23-3

Table 2

Output Voltage	Maximum Shunt Current	A Type ΔV_Z = ±0.1%*1 T_C = ±20 ppm/°C max.*2	B Type ΔV_Z = ±0.2%*1 T_C = ±30 ppm/°C max.*2	C Type ΔV_Z = ±0.2%*1 T_C = ±80 ppm/°C max.*2
2.048 V	25 mA	S-19761A2AA-M3T1U7	S-19761B2AA-M3T1U7	S-19761C2AA-M3T1U7
2.5 V	30 mA	S-19761A25A-M3T1U7	S-19761B25A-M3T1U7	S-19761C25A-M3T1U7
3.0 V	30 mA	S-19761A30A-M3T1U7	S-19761B30A-M3T1U7	S-19761C30A-M3T1U7
3.3 V	30 mA	S-19761A33A-M3T1U7	S-19761B33A-M3T1U7	S-19761C33A-M3T1U7
4.096 V	30 mA	S-19761A41A-M3T1U7	S-19761B41A-M3T1U7	S-19761C41A-M3T1U7
5.0 V	30 mA	S-19761A50A-M3T1U7	S-19761B50A-M3T1U7	S-19761C50A-M3T1U7

3. 2 HSNT-8(1616)B

Table 3

Output Voltage	Maximum Shunt Current	A Type	B Type ΔV_Z = ±0.2%*1 T_C = ±30 ppm/°C max.*2	C Type ΔV_Z = ±0.2%*1 T_C = ±80 ppm/°C max.*2
2.048 V	25 mA	-	S-19761B2AA-A8T7U7	S-19761C2AA-A8T7U7
2.5 V	30 mA	-	S-19761B25A-A8T7U7	S-19761C25A-A8T7U7
3.0 V	30 mA	-	S-19761B30A-A8T7U7	S-19761C30A-A8T7U7
3.3 V	30 mA	-	S-19761B33A-A8T7U7	S-19761C33A-A8T7U7
4.096 V	30 mA	-	S-19761B41A-A8T7U7	S-19761C41A-A8T7U7
5.0 V	30 mA	-	S-19761B50A-A8T7U7	S-19761C50A-A8T7U7

***1.** Ta = +25°C
***2.** Ta = -40°C to +125°C

■ Pin Configurations

1. SOT-23-3

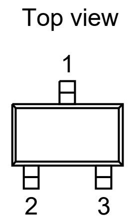


Figure 2

Table 4

Pin No.	Symbol	Description
1	DNU*1	Do not use
2	CATHODE	CATHODE pin
3	ANODE	ANODE pin

***1.** Disconnect the DNU or connect it to the ANODE pin.

2. HSNT-8(1616)B

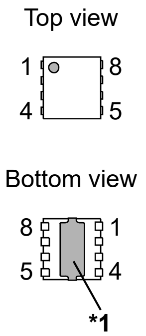


Figure 3

Table 5

Pin No.	Symbol	Description
1	CATHODE	CATHODE pin
2	CATHODE	CATHODE pin
3	NC*2	No connection
4	DNU*3	Do not use
5	NC*2	No connection
6	NC*2	No connection
7	ANODE	ANODE pin
8	ANODE	ANODE pin

***1.** Connect the heat sink of backside at shadowed area to the board, and set electric potential GND (ANODE). However, do not use it as the function of electrode.
***2.** The NC pin is electrically open.
The NC pin can be connected to the CATHODE pin or the ANODE pin.
***3.** Disconnect the DNU or connect it to the ANODE pin.

■ Absolute Maximum Ratings

Table 6

(T_j = -40°C to +150°C unless otherwise specified)

Item	Symbol	Absolute Maximum Rating	Unit
Cathode voltage	$V_{CATHODE}$	V_{ANODE} - 0.3 to V_{ANODE} + 6.0	V
Shunt current*1	I_{SHUNT}	35	mA
Junction temperature	T_j	-40 to +150	°C
Operation ambient temperature	T_{opr}	-40 to +125	°C
Storage temperature	T_{stg}	-40 to +150	°C

***1.** Design and use this IC so that the shunt current which flows through the product during normal operation stays within the ratings.

Caution The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Thermal Resistance Value

Table 7

Item	Symbol	Condition		Min.	Typ.	Max.	Unit
Junction-to-ambient thermal resistance*1	θ_{JA}	SOT-23-3	Board A	-	200	-	°C/W
			Board B	-	165	-	°C/W
			Board C	-	-	-	°C/W
			Board D	-	-	-	°C/W
			Board E	-	-	-	°C/W
		HSNT-8(1616)B	Board A	-	214	-	°C/W
			Board B	-	172	-	°C/W
			Board C	-	52	-	°C/W
			Board D	-	55	-	°C/W
			Board E	-	43	-	°C/W

***1.** Test environment: compliance with JEDEC STANDARD JESD51-2A

Remark Refer to "**■ Power Dissipation**" and "**Test Board**" for details.

■ Recommended Operation Conditions

Table 8

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Cathode voltage*1	$V_{CATHODE}$	-	2.0	V_Z*2	5.5	V
Shunt current	I_{SHUNT}	$V_{CATHODE}$ = 2.048 V	0.08	-	25	mA
		$V_{CATHODE}$ ≥ 2.5 V			30	
Shunt resistor	R_S	-	0.1	-	100	kΩ
Output capacitor	C_L*3	-	0.68	-	100	μF
Operation temperature	Ta	-	-40	-	+125	°C

***1.** Under normal operation the CATHODE pin is used as the output for this IC, however, be careful of the following points when external voltage is applied to the CATHODE pin.
- There is a mode which operates at low voltage conditions if $V_{CATHODE}$ < 2.0 V. Use so that the CATHODE pin voltage $V_{CATHODE}$ ≥ 2.5 V at startup.
- At $V_{CATHODE}$ > V_Z, a large shunt current will flow to the output transistor. The overcurrent protection will be activated and limit voltage to 150 mA typ. ($V_{CATHODE}$ = 5.5 V), however this can lead to deterioration of the product, so avoid continuous use in this status.

***2.** Output voltage (V_Z) (either 2.048 V, 2.5 V, 3.0 V, 3.3 V, 4.096 V, or 5.0 V) is output to $V_{CATHODE}$.

***3.** The recommended CL value is 0.68 μF min. however, in "**■ Reference data**", the data was obtained using 0.22 μF considering the effective capacitance value.

■ Electrical Characteristics

1. $V_{Z(S)}$ = 2.048 V

Table 9

(Ta = -40°C to +125°C unless otherwise specified)

Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse breakdown voltage)[*1]	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	2.046	2.048	2.050	V	1
			S-19761B (0.2%)	2.044	2.048	2.052	V	
			S-19761C (0.2%)	2.044	2.048	2.052	V	
Output voltage tolerance[*2]	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-2.0[*5]	-	2.0[*5]	mV	1
			S-19761B (0.2%)	-4.1[*5]	-	4.1[*5]	mV	
			S-19761C (0.2%)	-4.1[*5]	-	4.1[*5]	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-3.3[*6]	-	3.3[*6]	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-6.1[*5]	-	6.1[*5]	mV	1
			S-19761B	-10.2[*5]	-	10.2[*5]	mV	
			S-19761C	-20.5[*5]	-	20.5[*5]	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.0 V		25	-	-	mA	2
Output voltage temperature coefficient[*3]	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10[*6]	ppm/°C	1
			I_{SHUNT} = 100 μA	-	-	±20[*7]	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±20[*6]		
		S-19761B	I_{SHUNT} = 100 μA	-	-	±30[*7]	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±30[*6]		
		S-19761C	I_{SHUNT} = 100 μA	-	-	±80[*7]	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±80[*6]		
Output voltage load dependence	$\Delta V_{Z(\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	-	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2[*6]	mV	
		1 mA ≤ I_{SHUNT} ≤ 25 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta = -40°C to +125°C	-	-	12[*6]	mV	
Output impedance	Z_Z	I_{SHUNT} = 1 mA, I_{AC} = 0.1 × I_{SHUNT}, f = 120 Hz, Ta = +25°C		-	0.3	1.2[*6]	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10 Hz ≤ f ≤ 10 kHz, Ta = +25°C		-	28	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z(\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis[*4]	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.3	-	mV	1

***1.** In general, output voltage of this IC is also called "Reverse breakdown voltage".

***2.** The output voltage tolerance is defined by the following equation.

$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]

$V_{Z(S)}$: Set output voltage

***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value

***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.

***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.

***6.** The specifications for the applicable items are guaranteed by design.

***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level.
Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "**■ Reference Data**" for details and perform thorough evaluation in the actual application.

2. $V_{Z(S)}$ = 2.500 V

Table 10

(Ta = -40°C to +125°C unless otherwise specified)

Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse breakdown voltage)[*1]	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	2.497	2.500	2.503	V	1
			S-19761B (0.2%)	2.495	2.500	2.505	V	
			S-19761C (0.2%)	2.495	2.500	2.505	V	
Output voltage tolerance[*2]	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-2.5[*5]	-	2.5[*5]	mV	1
			S-19761B (0.2%)	-5.0[*5]	-	5.0[*5]	mV	
			S-19761C (0.2%)	-5.0[*5]	-	5.0[*5]	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-4.0[*6]	-	4.0[*6]	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-7.5[*5]	-	7.5[*5]	mV	1
			S-19761B	-12.5[*5]	-	12.5[*5]	mV	
			S-19761C	-25[*5]	-	25[*5]	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.5 V		30	-	-	mA	2
Output voltage temperature coefficient[*3]	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10[*6]	ppm /°C	1
			I_{SHUNT} = 100 μA	-	-	±20[*7]	ppm /°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±20[*6]		
		S-19761B	I_{SHUNT} = 100 μA	-	-	±30[*7]	ppm /°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±30[*6]		
		S-19761C	I_{SHUNT} = 100 μA	-	-	±80[*7]	ppm /°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±80[*6]		
Output voltage load dependence	$\Delta V_{Z\ (\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	-	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2[*6]	mV	
		1 mA ≤ I_{SHUNT} ≤ 30 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta = -40°C to +125°C	–	-	12[*6]	mV	
Output impedance	Z_Z	I_{SHUNT} = 1mA, I_{AC} = 0.1 × I_{SHUNT}, f = 120Hz, Ta = +25°C		-	0.3	1.2[*6]	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10 Hz ≤ f ≤ 10 kHz, Ta = +25°C		-	35	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z\ (\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis[*4]	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.3	-	mV	1

***1.** In general, output voltage of this IC is also called "Reverse breakdown voltage".

***2.** The output voltage tolerance is defined by the following equation.
$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]
$V_{Z(S)}$: Set output voltage

***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value

***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.

***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.

***6.** The specifications for the applicable items are guaranteed by design.

***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level.
Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "**■ Reference Data**" for details and perform thorough evaluation in the actual application.

3. $V_{Z(S)}$ = 3.000 V

Table 11

(Ta = -40°C to +125°C unless otherwise specified)

Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse reakdown voltage)*1	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	2.997	3.000	3.003	V	1
			S-19761B (0.2%)	2.994	3.000	3.006	V	
			S-19761C (0.2%)	2.994	3.000	3.006	V	
Output voltage tolerance*2	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-3.0*5	-	3.0*5	mV	1
			S-19761B (0.2%)	-6.0*5	-	6.0*5	mV	
			S-19761C (0.2%)	-6.0*5	-	6.0*5	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-4.8*6	-	4.8*6	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-9.0*5	-	9.0*5	mV	1
			S-19761B	-15*5	-	15*5	mV	
			S-19761C	-30*5	-	30*5	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.5 V		30	-	-	mA	2
Output voltage temperature coefficient*3	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10*6	ppm/°C	1
			I_{SHUNT} = 100 μA	-	-	±20*7	ppm/°C	1
			I_{SHUNT} =1 mA, 10 mA	-	-	±20*6		
		S-19761B	I_{SHUNT} = 100 μA	-	-	±30*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±30*6		
		S-19761C	I_{SHUNT} = 100 μA	-	-	±80*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±80*6		
Output voltage load dependence	$\Delta V_{Z\ (\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	-	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2*6	mV	
		1 mA ≤ I_{SHUNT} ≤ 30 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta =-40°C to +125°C	-	-	12*6	mV	
Output impedance	Z_Z	I_{SHUNT} = 1 mA, I_{AC}=0.1 × I_{SHUNT}, f = 120Hz, Ta = +25°C		-	0.3	1.2*6	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10Hz ≤ f ≤ 10 kHz, Ta = +25°C		–	45	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z\ (\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis*4	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.4	-	mV	1

***1.** In general, output voltage of this IC is also called "Reverse breakdown voltage".

***2.** The output voltage tolerance is defined by the following equation.
$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]
$V_{Z(S)}$: Set output voltage

***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value

***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.

***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.

***6.** The specifications for the applicable items are guaranteed by design.

***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level.
Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "■ **Reference Data**" for details and perform thorough evaluation in the actual application.

4. $V_{Z(S)}$ = 3.300 V

Table 12

(Ta = -40°C to +125°C unless otherwise specified)

Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse breakdown voltage)*1	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	3.297	3.300	3.303	V	1
			S-19761B (0.2%)	3.293	3.300	3.307	V	
			S-19761C (0.2%)	3.293	3.300	3.307	V	
Output voltage tolerance*2	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-3.3*5	-	3.3*5	mV	1
			S-19761B (0.2%)	-6.6*5	-	6.6*5	mV	
			S-19761C (0.2%)	-6.6*5	-	6.6*5	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-5.3*6	-	5.3*6	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-9.9*5	-	9.9*5	mV	1
			S-19761B	-16.5*5	-	16.5*5	mV	
			S-19761C	-33*5	-	33*5	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.5 V		30	-	-	mA	2
Output voltage temperature coefficient*3	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10*6	ppm/°C	1
			I_{SHUNT} =100 μA	-	-	±20*7	ppm/°C	1
			I_{SHUNT} =1 mA, 10 mA	-	-	±20*6		
		S-19761B	I_{SHUNT} =100 μA	-	-	±30*7	ppm/°C	1
			I_{SHUNT} =1 mA, 10 mA	-	-	±30*6		
		S-19761C	I_{SHUNT} =100 μA	-	-	±80*7	ppm/°C	1
			I_{SHUNT} =1 mA, 10 mA	-	-	±80*6		
Output voltage load dependence	$\Delta V_{Z(\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	-	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2*6	mV	
		1 mA ≤ I_{SHUNT} ≤ 30 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta = -40°C to +125°C	-	-	12*6	mV	
Output impedance	Z_Z	I_{SHUNT} = 1 mA, I_{AC} = 0.1 × I_{SHUNT}, f = 120 Hz, Ta = +25°C		-	0.3	1.2*6	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10 Hz ≤ f ≤ 10 kHz, Ta = +25°C		-	50	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z(\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis*4	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.4	-	mV	1

***1.** In general, output voltage of this IC is also called "Reverse breakdown voltage".

***2.** The output voltage tolerance is defined by the following equation.

$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]

$V_{Z(S)}$: Set output voltage

***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value

***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.

***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.

***6.** The specifications for the applicable items are guaranteed by design.

***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level. Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "■ **Reference Data**" for details and perform thorough evaluation in the actual application.

5. $V_{Z(S)}$ = 4.096 V

Table 13

(Ta = -40°C to +125°C unless otherwise specified)

Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse breakdown voltage)*1	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	4.092	4.096	4.100	V	1
			S-19761B (0.2%)	4.088	4.096	4.104	V	
			S-19761C (0.2%)	4.088	4.096	4.104	V	
Output voltage tolerance*2	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-4.1*5	-	4.1*5	mV	1
			S-19761B (0.2%)	-8.2*5	-	8.2*5	mV	
			S-19761C (0.2%)	-8.2*5	-	8.2*5	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-6.6*6	-	6.6*6	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-12.3*5	-	12.3*5	mV	1
			S-19761B	-20.5*5	-	20.5*5	mV	
			S-19761C	-41*5	-	41*5	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.5 V		30	-	-	mA	2
Output voltage temperature coefficient*3	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10*6	ppm/°C	1
			I_{SHUNT} = 100 μA	-	-	±20*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±20*6		
		S-19761B	I_{SHUNT} = 100 μA	-	-	±30*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±30*6		
		S-19761C	I_{SHUNT} = 100 μA	-	-	±80*7	ppm/°C	1
			I_{SHUNT} =1 mA, 10 mA	-	-	±80*6		
Output voltage load dependence	$\Delta V_{Z(\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	–	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2*6	mV	
		1 mA ≤ I_{SHUNT} ≤ 30 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta = -40°C to +125°C	-	-	12*6	mV	
Output impedance	Z_Z	I_{SHUNT} = 1 mA, I_{AC} = 0.1 × I_{SHUNT}, f = 120Hz, Ta = +25°C		-	0.3	1.2*6	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10 Hz ≤ f ≤ 10 kHz, Ta = +25°C		-	64	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z(\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis*4	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.5	-	mV	1

***1.** In general, output voltage of this IC is also called "Reverse breakdown voltage".

***2.** The output voltage tolerance is defined by the following equation.

$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]

$V_{Z(S)}$: Set output voltage

***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value

***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.

***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.

***6.** The specifications for the applicable items are guaranteed by design.

***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level.
Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "**■ Reference Data**" for details and perform thorough evaluation in the actual application.

6. $V_{Z(S)}$ = 5.000 V

Table 14

(Ta = -40°C to +125°C unless otherwise specified)

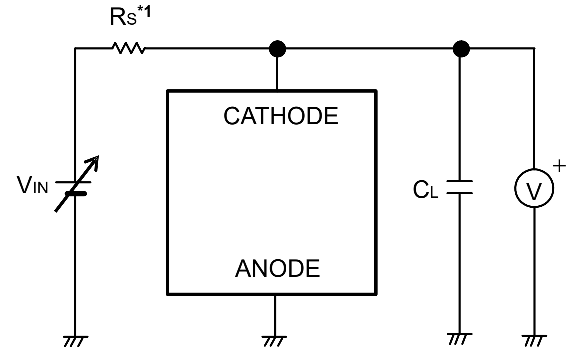
Item	Symbol	Condition		Min.	Typ.	Max.	Unit	Test Circuit
Output voltage (Reverse breakdown voltage)*1	V_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	4.995	5.000	5.005	V	1
			S-19761B (0.2%)	4.990	5.000	5.010	V	
			S-19761C (0.2%)	4.990	5.000	5.010	V	
Output voltage tolerance*2	ΔV_Z	I_{SHUNT} = 100 μA, Ta = +25°C	S-19761A (0.1%)	-5.0*5	-	5.0*5	mV	1
			S-19761B (0.2%)	-10*5	-	10*5	mV	
			S-19761C (0.2%)	-10*5	-	10*5	mV	
		I_{SHUNT} = 100 μA, Ta = 0°C to +85°C	S-19761A	-8.0*6	-	8.0*6	mV	1
		I_{SHUNT} = 100 μA, Ta = -40°C to +125°C	S-19761A	-15*5	-	15*5	mV	1
			S-19761B	-25*5	-	25*5	mV	
			S-19761C	-50*5	-	50*5	mV	
Minimum shunt current	I_{SHUNT_MIN}	I_{SHUNT} (I_{LOAD} = 0 mA)		-	41	80	μA	2
Maximum shunt current	I_{SHUNT_MAX}	$V_{CATHODE}$ ≥ 2.5 V		30	-	-	mA	2
Output voltage temperature coefficient*3	T_C	S-19761A	I_{SHUNT} = 100 μA (Ta = 0°C to +85°C)	-	-	±10*6	ppm/°C	1
			I_{SHUNT} = 100 μA	-	-	±20*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±20*6		
		S-19761B	I_{SHUNT} = 100 μA	-	-	±30*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±30*6		
		S-19761C	I_{SHUNT} = 100 μA	-	-	±80*7	ppm/°C	1
			I_{SHUNT} = 1 mA, 10 mA	-	-	±80*6		
Output voltage load dependence	$\Delta V_{Z(\Delta ISHUNT)}$	I_{SHUNT_MIN} ≤ I_{SHUNT} ≤ 1 mA	Ta = +25°C	-	0.3	0.8	mV	1
			Ta = -40°C to +125°C	-	-	1.2*6	mV	
		1 mA ≤ I_{SHUNT} ≤ 30 mA	Ta = +25°C	-	2.3	8	mV	1
			Ta = -40°C to +125°C	-	-	12*6	mV	
Output impedance	Z_Z	I_{SHUNT} = 1 mA, I_{AC} = 0.1 × I_{SHUNT}, f = 120 Hz, Ta = +25°C		-	0.3	1.2*6	Ω	3
Output noise	e_N	I_{SHUNT} = 100 μA, 10 Hz ≤ f ≤ 10 kHz, Ta = +25°C		-	80	-	μV_{RMS}	1
Long-term stability	$\frac{\Delta V_{Z(\Delta t)}}{V_Z}$	I_{SHUNT} = 100 μA, Δt = 1000 h, Ta = +50°C		-	70	-	ppm	1
Thermal hysteresis*4	$\Delta V_{Z\_HYS(\Delta Ta)}$	Ta = 25°C, ΔTa = -40°C to +125°C		-	0.6	-	mV	1

***1.** Generally, output voltage of this IC is also called "Reverse breakdown voltage".
***2.** The output voltage tolerance is defined by the following equation.
$\Delta V_Z = V_{Z(S)} \times (T_C \times 10^{-6}) \times \Delta Ta$ [V]
$V_{Z(S)}$: Set output voltage
***3.** The output voltage temperature coefficient (T_C) is measured by the butterfly method and is defined by the following equation.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

$V_{Z(E)}$: Output voltage measurement value
***4.** Thermal hysteresis is the difference between the output voltage at the initial value and the output voltage after one low and high temperature cycle, both at 25°C.
***5.** Contact our sales representatives regarding tolerances including output voltage temperature dependence, load dependence, long-term stability, and thermal hysteresis.
***6.** The specifications for the applicable items are guaranteed by design.
***7.** The values listed in the table above for the applicable items are guaranteed at the wafer level.
Since slight variations may occur depending on package assembly and board mounting conditions, please refer to "■ **Reference Data**" for details and perform thorough evaluation in the actual application.

■ Test Circuit



*1. R_S = 2 kΩ

Figure 4 Test Circuit 1

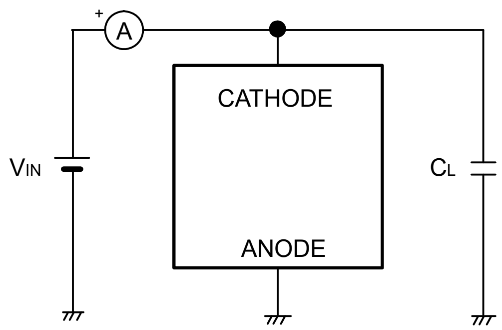
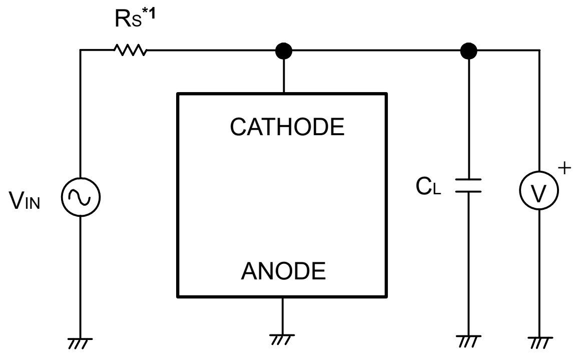


Figure 5 Test Circuit 2



*1. R_S = 2 kΩ

Figure 6 Test Circuit 3

■ Standard Circuits

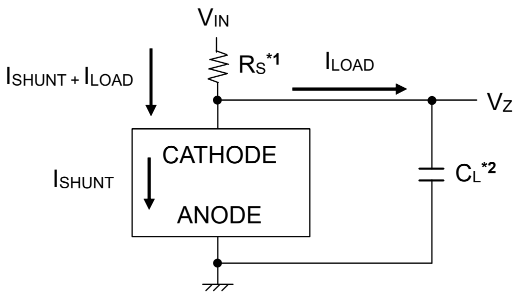


Figure 7

***1.** R_S is a shunt resistor
***2.** C_L is a capacitor for stabilizing the output

Caution The above connection diagram and constants will not guarantee successful operation. Perform thorough evaluation including the temperature characteristics with an actual application to set the constants.

■ External Parts Selection

1. Shunt resistor (R_S)

This IC requires a shunt resistor (R_S) between the external power supply and the CATHODE pin. The IC will operate stably at a resistance value of R_S = 100 Ω to 100 kΩ.
If the external power supply voltage is V_{IN}, the CATHODE pin voltage is V_Z, the shunt current is I_{SHUNT}, and the load current is I_{LOAD}, R_S can be calculated using the following formula.

$$\frac{V_{IN\_MAX}^{*1} - V_Z}{I_{SHUNT\_MAX}^{*3}} \leq R_S \leq \frac{V_{IN\_MIN}^{*2} - V_Z^{*5}}{I_{SHUNT\_MIN}^{*4} + I_{LOAD\_MAX}}$$

For example, if V_{IN} = 12 V to 16 V, V_Z = 4.096 V, and I_{LOAD} = 0 μA to 6.0 mA (I_{SHUNT_MAX} = 15 mA, I_{SHUNT_MIN} = 80 μA), R_S = approximately 800 Ω to 1300 Ω.

***1.** Maximum value of V_{IN} under operation conditions.
***2.** Minimum value of V_{IN} under operation conditions.
***3.** Maximum value of I_{SHUNT} under recommended operation conditions.
***4.** Minimum value of I_{SHUNT} under recommended operation conditions.
***5.** As noted "**1. Basic operation**" in "**■ Operation**", at startup the $V_{CATHODE}$ ≥ 2.5 V condition must be satisfied.
In $V_{Z(S)}$ = 2.048 V products, there is no issue if the left side lower limit value is V_Z = 2.048 V, however it is recommended that V_Z = 2.5 V be substituted for the right side upper limit value for calculation. In this case, the minimum shunt current (I_{SHUNT_MIN}) after start-up can be found by recalculating the R_S calculation value as V_Z = 2.048 V, however note that this value will be larger than the 80 μA specification in "**■ Electrical characteristics**."

2. Output capacitors (C_L)

This IC requires output capacitor (C_L) between the VOUT pin and the VSS pin for phase compensation. Using a ceramic capacitor with the capacitance value (recommended capacitance) listed in "**■ Recommended Operation Conditions**" will ensure stable operation. The capacitance value must be the recommended value, when using an OS capacitor, a tantalum capacitor, or an aluminum electrolytic capacitor. However, oscillation may occur depending on the equivalent series resistance (ESR). Note that the output voltage (V_Z) transient characteristics will vary depending on the capacitance of C_L and the value of ESR.

Caution Perform thorough evaluation including the temperature characteristics with an actual application to select R_S and C_L.

■ Operation

1. Basic operation

Figure 8 shows an equivalent circuit of this IC to describe the basic operation.
This IC functions as a reverse-biased diode. The CATHODE pin is connected to the power supply (V_{IN}) via a shunt resistor (R_S). The R_S must be set appropriately according to the V_{IN}, shunt current (I_{SHUNT}), and load current (I_{LOAD}).
This IC is equipped with an operation mode which limits the start-up voltage (V_{Z_STUP}) when $V_{CATHODE}$ is in a low voltage status. As shown in **Figure 9**, this operation mode is released when $V_{CATHODE}$ ≥ 2.5 V at startup, allowing constant voltage control of the output voltage (V_Z). If VCATHODE < 2.0 V, a low voltage status is detected; after going through this process again, constant voltage control is applied to the output voltage (V_Z). The t_{VREFOK} shown in **Figure 9** is 1 ms typ.. t_{STUP} will be the longer of either the 10 ms typ. required for internal stabilization or the time required for external stabilization (5 times the time constant R_S × C_L).

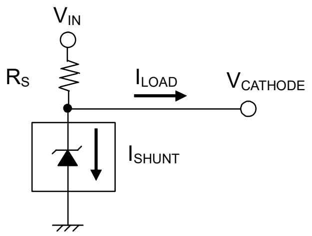


Figure 8 Equivalent Circuit

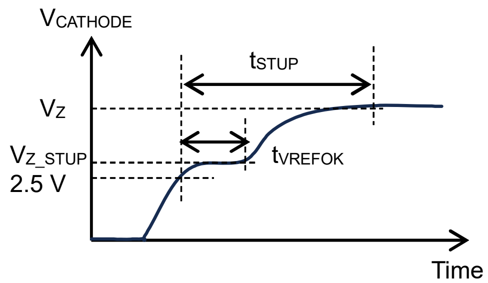
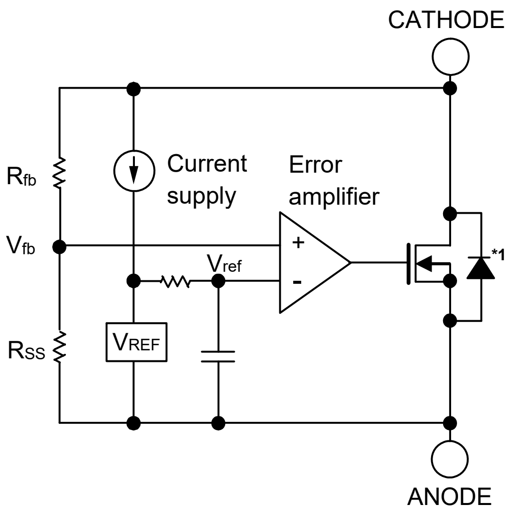


Figure 9 Start-up Waveform and Operating Mode

Figure 10 shows the block diagram of this IC to describe the basic operation.
The error amplifier compares the reference voltage (V_{ref}) with the feedback voltage (V_{fb}). The feedback voltage (V_{fb}) is the output voltage (V_Z), which is also the CATHODE pin voltage, divided by the feedback resistors (R_{fb} and R_{SS}).
The error amplifier controls the output transistor to achieve constant-voltage operation that keeps V_Z constant without any influence from the V_{IN} shown in **Figure 8**. The constant-voltage output voltage has high precision, which makes the product optimal for use as reference voltage for application circuits.



***1.** Parasitic diode

Figure 10 Block Diagram

2. Output transistor

In this IC, a low on-resistance Nch MOS FET transistor is used as an output transistor between the CATHODE pin and ANODE pin. In order to keep V_Z, which is also the CATHODE pin voltage, constant, the output transistor on-resistance varies as necessary based on the difference between the shunt current (I_{SHUNT}) and load current (I_{LOAD}).

Caution Since a parasitic diode exists between the CATHODE pin and the ANODE pin due to the structure of the transistor, the IC may be damaged by a reverse current if $V_{CATHODE}$ becomes lower than V_{ANODE}. Therefore, be sure that $V_{CATHODE}$ is not less than V_{ANODE} - 0.3 V.

3. Overcurrent protection circuit

This IC has a built-in overcurrent protection circuit to limit overcurrent of the output transistor.
In the event some external factor causes the CATHODE pin voltage to exceed V_Z setting value, the overcurrent protection circuit will trigger and limit I_{SHUNT} to 150 mA typ. ($V_{CATHODE}$ = 5.5 V). The IC restarts constant-voltage operation when the output transistor is released from the overcurrent status.

Caution Even if this IC's overcurrent protection circuit limits the shunt current, that current can still be relatively large. Therefore, care must be taken to ensure that the power supply voltage and load current conditions do not exceed the allowable power dissipation if the operation ambient temperature range is high and the output transistor remains in the overcurrent status for an extended period of time.

■ Explanation of Terms

1. Shunt voltage reference

The shunt voltage reference lowers the voltage by having the current flow through the shunt resistor (R_S) in order to maintain a constant voltage. High precision reference voltage is output at the test circuit.

2. Shunt current (I_{SHUNT}), Shunt resistor (R_S)

Shunt current refers to the current which flows between the output transistor CATHODE pin and ANODE pin in this IC. Shunt resistor is the resistor connected between this IC and the power supply. The current (I_{SHUNT} + I_{LOAD}) which flows to the shunt resistor is the sum of the shunt current (I_{SHUNT}) and the current which flows to the load (I_{LOAD}) and is controlled to remain constant via the constant-voltage operation of the shunt voltage reference.

3. Output voltage (V_Z)

Output voltage (V_Z) is the voltage which output within the tolerances indicated in "■ **Electrical Characteristics**" under the specified power supply voltage, load current, and temperature conditions.
When the CATHODE pin voltage increases to the internal set value, the IC will engage constant-voltage operation, and for this reason the voltage which is also generally called "Reverse breakdown voltage" is defined as the output voltage, in likeness of a reverse bias diode.

4. Output voltage temperature coefficient (T_C)

Output voltage temperature coefficient (T_C) is the variation in the set output voltage due to changes in the set temperature. The output voltage temperature coefficient for this IC is calculated using the butterfly method and determined using the following formula.

$$T_C = \frac{\Delta V_Z}{V_{Z(E)}^{*1} \times \Delta Ta} \times 10^6 \text{ [ppm/°C]}$$

A characteristics of output voltage temperature coefficient (T_C) in ±20 ppm/°C (Ta = -40°C to +125°C) will fall within the shaded areas of the operation temperature range shown in **Figure 11**. Furthermore, the output voltage temperature variation [mV/°C] is calculated using the following formula.

$$\frac{\Delta V_Z}{\Delta Ta} \text{ [mV/°C]}^{*2} = V_{Z(S)} \text{ [V]}^{*3} \times T_C \text{ [ppm/°C]}^{*4} \div 1000$$

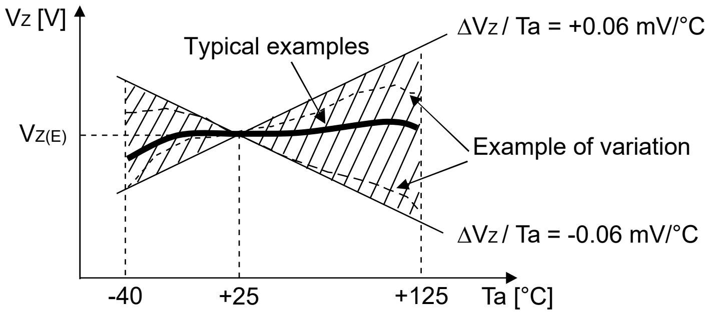


Figure 11 Example of Butterfly Method in $V_{Z(S)}$ = 3.0 V Product Version

***1.** Value of the output voltage measured at Ta = +25°C
***2.** Change in temperature of output voltage
***3.** Set output voltage
***4.** Output voltage temperature coefficient

5. Output voltage load dependence (Load stability), ($\Delta V_{Z(\Delta Ishunt)}$)

When the power supply voltage is constant and I_{LOAD} changes, the I_{SHUNT} also changes so that the total value remains the same. When I_{LOAD} is constant and the power supply voltage changes, I_{SHUNT} also changes by the same amount as the variation in the current flowing to R_S. This shows how much V_Z changes when I_{SHUNT} changes.

6. Long-term stability ($\Delta V_{Z(\Delta t)}$ / V_Z)

This is the amount of variation in V_Z when continuous operation is carried out for 1,000 hours under normal operating conditions. This is not an accelerated test under high temperature, high humidity, and high electrical field conditions like in long-term reliability tests. Please note that the results of long-term reliability tests and long-term stability tests are not included in output voltage tolerance (ΔV_Z) standard ranges.
The figure in the "**■ Reference Data**", "**Long-term stability**" shows characteristics for a sample baked for 24 hours at 125°C after board mounting. Baking or burning-in should also be considered before use for systems which require extremely stable output voltage over long periods of time in order to minimize the amount of drift in the output voltage over time.

7. Thermal hysteresis ($\Delta V_{Z\_HYS(\Delta Ta)}$)

This is the difference between V_Z at the initial value and V_Z after one low and high temperature cycle, both at 25°C. The values shown in "**■ Electrical Characteristics**" are the characteristics of the IC alone at the time of shipping, and do not include the effects of soldering heat drift.
Please note that thermal hysteresis is not included in output voltage tolerance (ΔV_Z) standard ranges.
The formula for calculation of thermal hysteresis is shown below and the temperature profile for measurement of voltage at each term in the formula below is shown in **Figure 12.**

$\Delta V_{Z\_HYS(\Delta Ta)} = V_{Z(25°C\_post(\Delta Ta))} - V_{Z(25°C\_init)}$, ΔTa = -40°C to +125°C

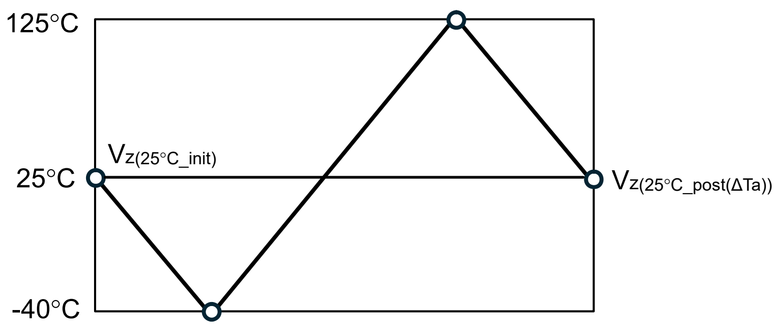


Figure 12 Thermal Hysteresis Temperature Profile

■ Precautions for Use

1. Condition of application, external parts

- In general, a shunt voltage reference requires minimum shunt current to flow as consumption current for operation. Set the shunt resistor (R_S) to flow more than the minimum shunt current as shown in **Table 8**.

- In general, the shunt current (I_{SHUNT}) which the shunt voltage reference sinks is limited by the output transistor drive capability. Set R_S to be equal to or less than the maximum shunt current as shown in **Table 8**.

- In general, if the shunt voltage reference decreases the I_{SHUNT} when the load current (I_{LOAD}) increases, and increases the I_{SHUNT} when I_{LOAD} decreases in order to maintain constant output voltage. Pay attention to the following points when configuring R_S.

  When the load is maximized: Do not fall below the minimum shunt current
  When the load is minimized: Do not exceed the maximum shunt current

- In this IC, an oscillation may occur depending on the selection of the external parts. Perform thorough evaluation including the temperature characteristics with an actual application to select R_S and C_L.

- In general, the shunt voltage reference may cause a problem to the stable operation due to the variation factors of power supply voltage start-up, power supply voltage fluctuation and load fluctuation. In addition, this IC may cause unstable operation due to the different values of the overshoot and undershoot of the output voltage depending on the capacitance of C_L and the value of the equivalent series resistance (ESR).
  Perform thorough evaluation including the temperature characteristics with an actual application to select R_S and C_L. In particular, if R_S or C_L are too small, verify that power supply voltage does not rise to exceed V_Z set value during power supply voltage startup, and that the CATHODE voltage does not momentarily drop below 2.0 V, which would cause the product to reset due to load fluctuation. Also note that if R_S is too large, it can result in increased output noise.

2. Electrical Characteristics

- In general, in addition to initial accuracy and drift performance, other specifications of shunt voltage reference such as long-term stability and thermal hysteresis can affect voltage accuracy particularly over the lifespan of the application.

- The output voltage tolerance (ΔV_Z) and output voltage temperature coefficient (T_C) characteristic items of this IC is the specification standards of the package alone at the time of shipping.
  Changes in characteristics due to "Long-term stability" and "Thermal hysteresis" in "**■ Electrical Characteristics**", as well as "**8. Output voltage (V_Z), Solder thermal drift, Board mounting reflow shift**" and "**9. Solder thermal drift of V_Z vs. Ta characteristics, Board mounting reflow shift**" in "**■ Reference data**" can occur outside of specification standards, so take care to minimize changes in characteristics by mounting and using the product appropriately.
  Perform thorough evaluation using the actual application.

3. Board mounting reflow shift

- When an IC is mounted on a board, thermal expansion and contraction can cause warping and apply stress to the IC. The degree to which this stress is applied varies according to the temperature and warping. If the stress applied to the IC changes, it may no longer satisfy ΔV_Z specification standards.

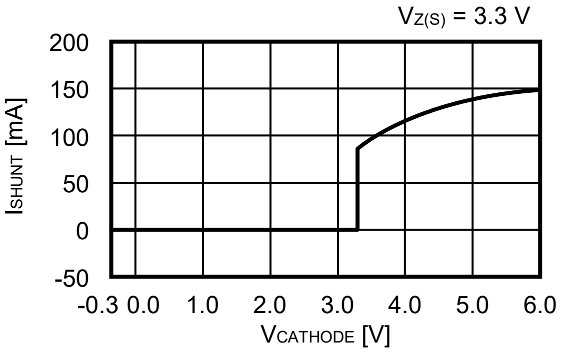
- Note that the output voltage (V_Z), Output voltage temperature coefficient (T_C), and thermal hysteresis may deviate from the values listed in "**■ Electrical Characteristics**" due to the type, shape, or size of the board onto which the IC is mounted, or the mounting conditions.

■ Precautions

- Make sure of the conditions for the power supply voltage, input voltage, output voltage and the load current so that the internal loss does not exceed the power dissipation.
- Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.
- In the package equipped with heat sink of backside, mount the heat sink firmly. Since the heat radiation differs according to the condition of the application, perform thorough evaluation with an actual application to confirm no problems happen.
- ABLIC Inc. claims no responsibility for any disputes arising out of or in connection with any infringement by products including this IC of patents owned by a third party.

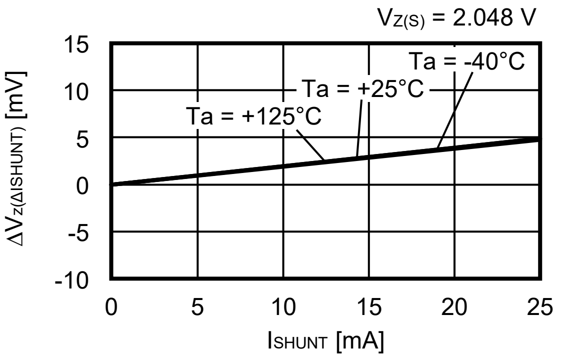
■ Characteristics (Typical Data)

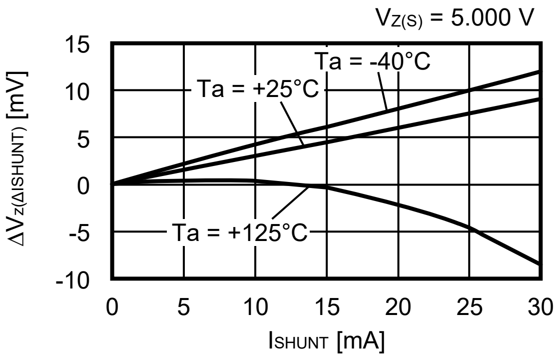
1. Input voltage (reverse voltage) vs. Shunt current



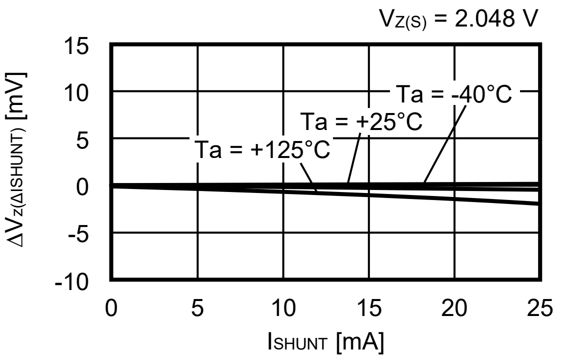
2. Output voltage vs. Shunt current

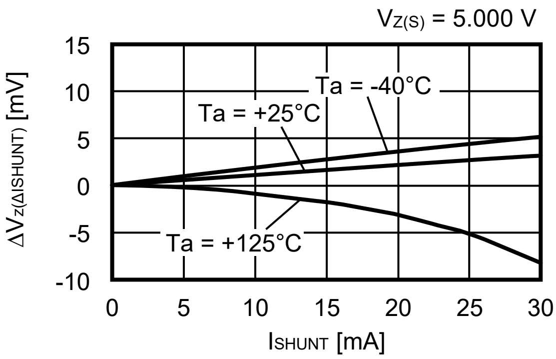
2. 1 SOT-23-3



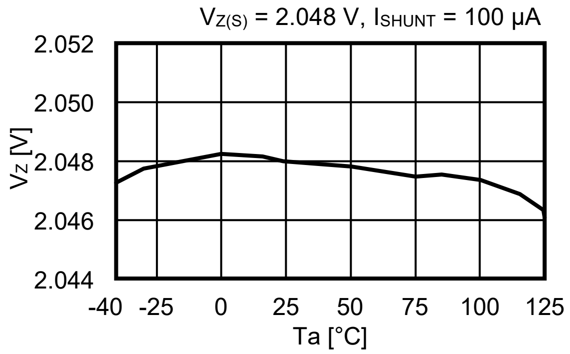


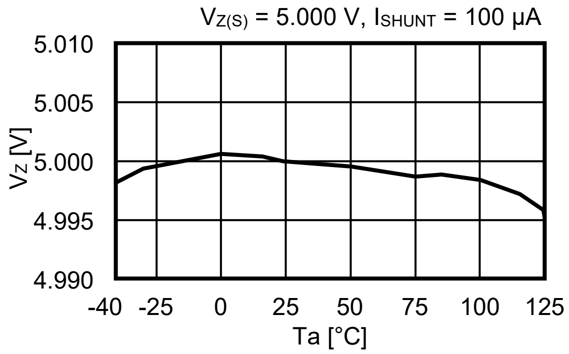
2. 2. HSNT-8(1616)B



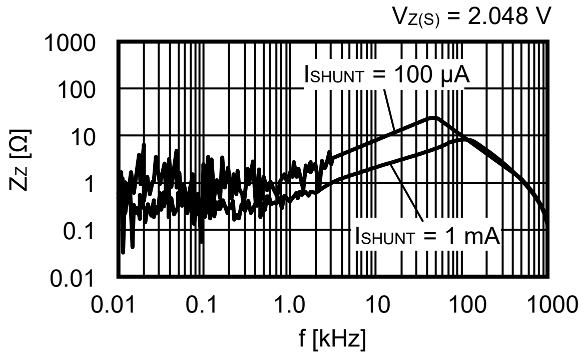


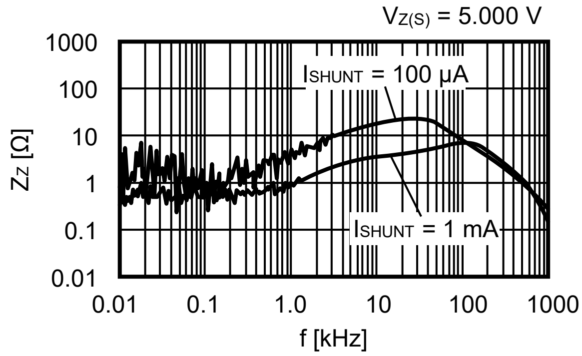
3. Output voltage vs. Ta



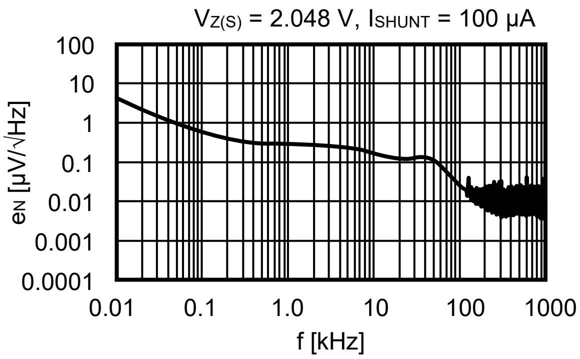


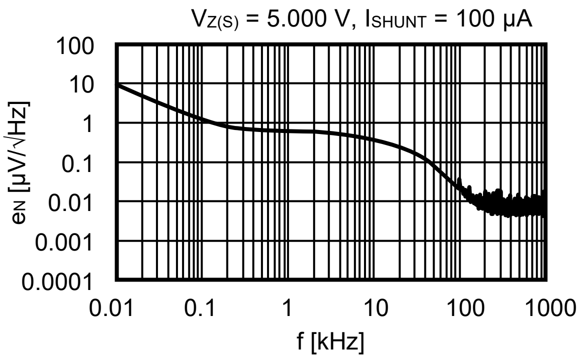
4. Output impedance vs. Frequency characteristic



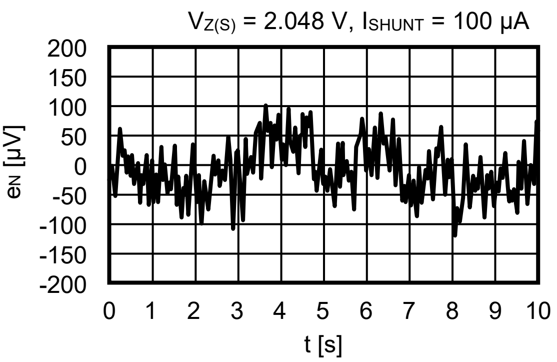


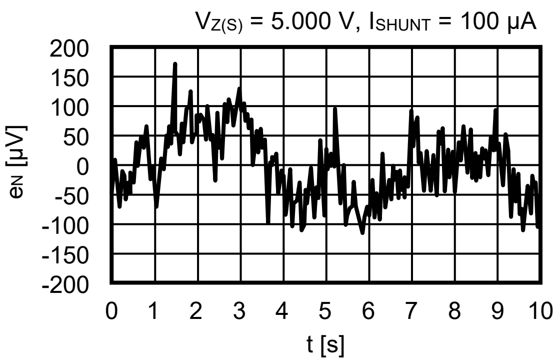
5. Output noise vs. Frequency characteristic (Noise spectrum)





6. Output noise at 0.1 Hz to 10 Hz



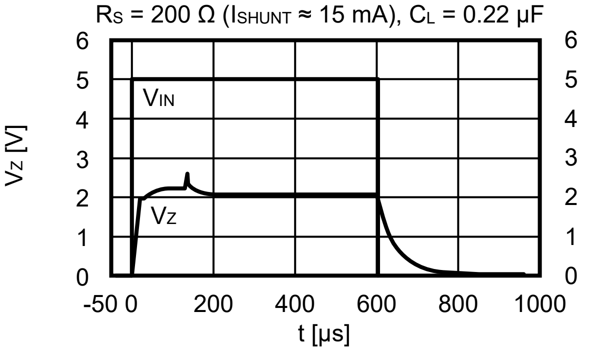


■ Reference Data

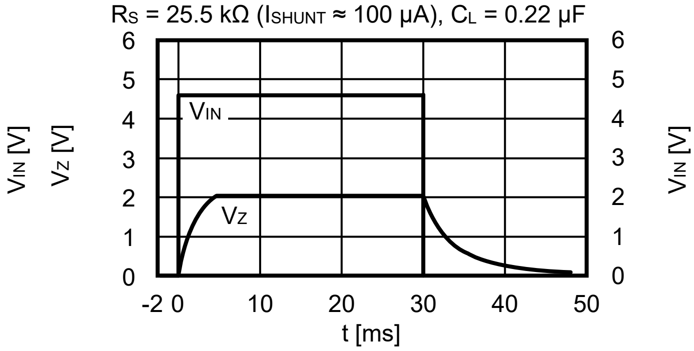
1. Input transient response

1. 1 $V_{Z(S)}$ = 2.048 V

V_{IN} = 0 V → 5.05 V,
R_S = 200 Ω (I_{SHUNT} ≈ 15 mA), C_L = 0.22 μF

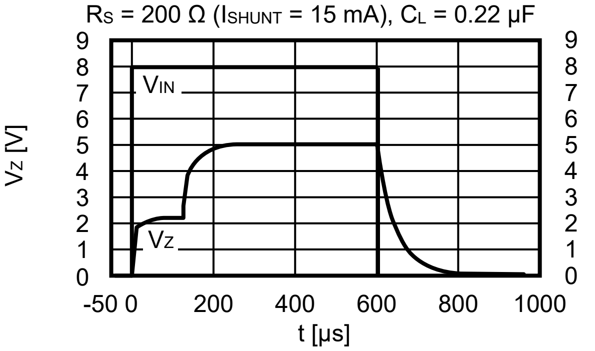


V_{IN} = 0 V → 4.55 V,
R_S = 25.5 kΩ (I_{SHUNT} ≈ 100 μA), C_L = 0.22 μF

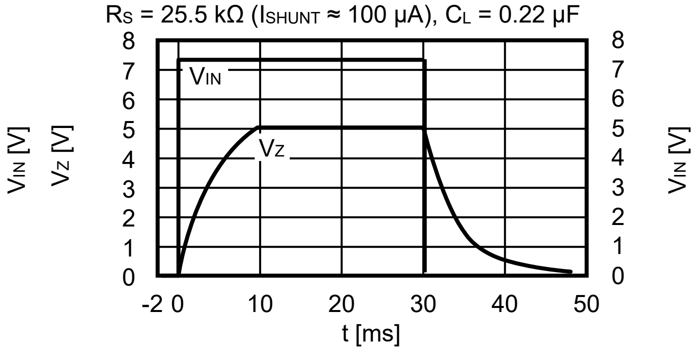


1. 2 $V_{Z(S)}$ = 5.000 V

V_{IN} = 0 V → 8.00 V,
R_S = 200 Ω (I_{SHUNT} = 15 mA), C_L = 0.22 μF



V_{IN} = 0 V → 7.50 V,
R_S = 25.5 kΩ (I_{SHUNT} ≈ 100 μA), C_L = 0.22 μF

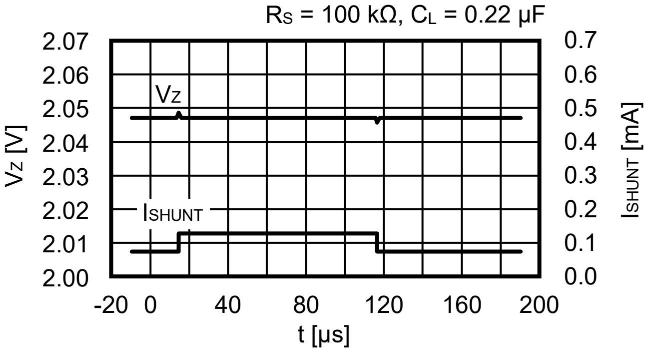


Caution The recommended CL capacitance value is 0.68 μF min. as shown in "■ Recommended Operation Conditions". however, here data was obtained using 0.22 μF, considering the effective capacitance value.

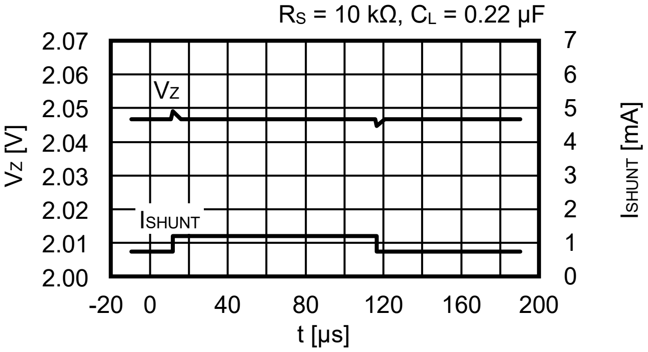
2. Load transient response

2. 1 $V_{Z(S)}$ = 2.048 V

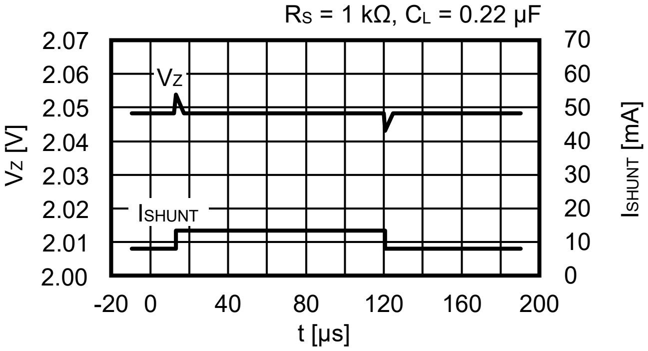
V_{IN} = 14.55 V, I_{LOAD} = 0 μA ↔ 50 μA, R_S = 100 kΩ, C_L = 0.22 μF



V_{IN} = 14.55 V, I_{LOAD} = 0 μA ↔ 0.5 mA, R_S = 10 kΩ, C_L = 0.22 μF

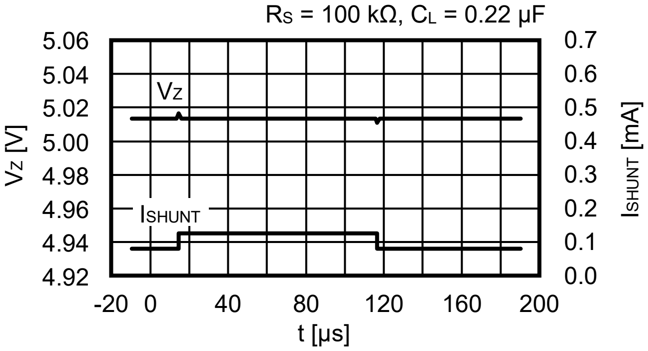


V_{IN} = 14.55 V, I_{LOAD} = 0 μA ↔ 5 mA, R_S = 1 kΩ, C_L = 0.22 μF

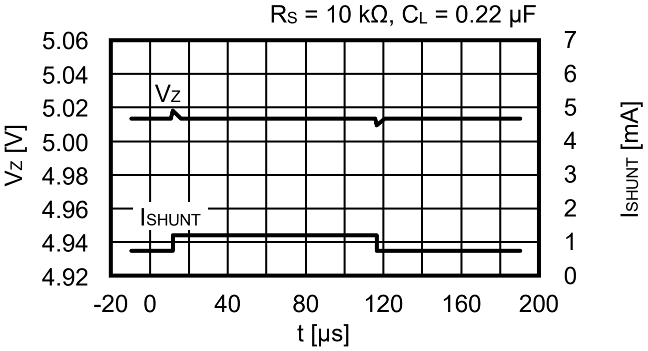


2. 2 $V_{Z(S)}$ = 5.000 V

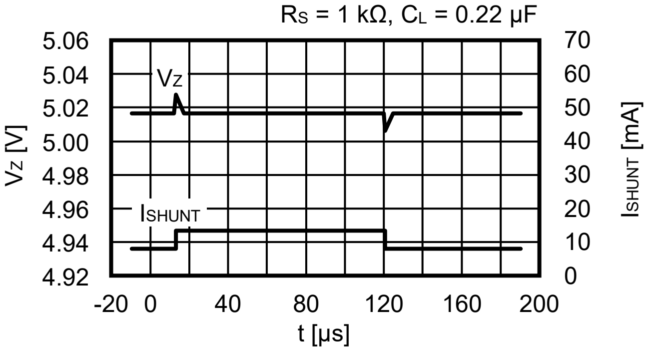
V_{IN} = 17.5 V, I_{LOAD} = 0 μA ↔ 50 μA, R_S = 100 kΩ, C_L = 0.22 μF



V_{IN} = 17.5 V, I_{LOAD} = 0 μA ↔ 0.5 mA, R_S = 10 kΩ, C_L = 0.22 μF

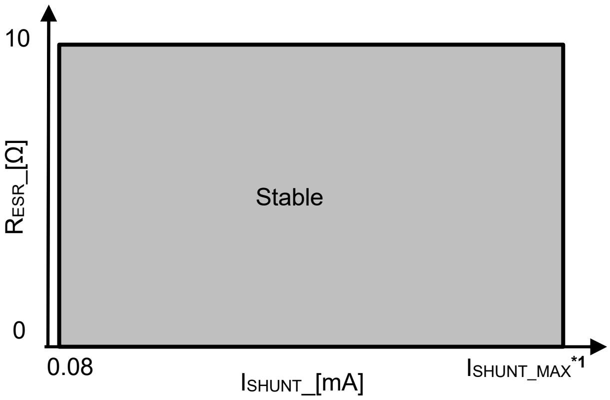


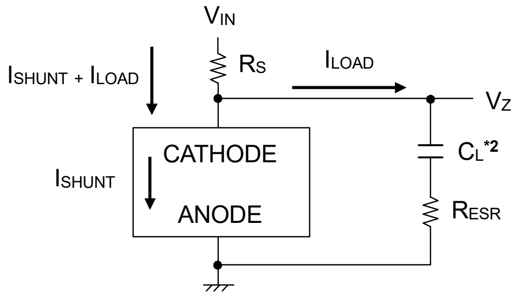
V_{IN} = 17.5 V, I_{LOAD} = 0 μA ↔ 5 mA, R_S = 1 kΩ, C_L = 0.22 μF



Caution **The recommended CL capacitance value is 0.68 μF min. as shown in "■ Recommended Operation Conditions". however, here data was obtained using 0.22 μF, considering the effective capacitance value.**

3. Example of equivalent series resistance vs. Shunt current characteristics (Ta = -40°C to +125°C)

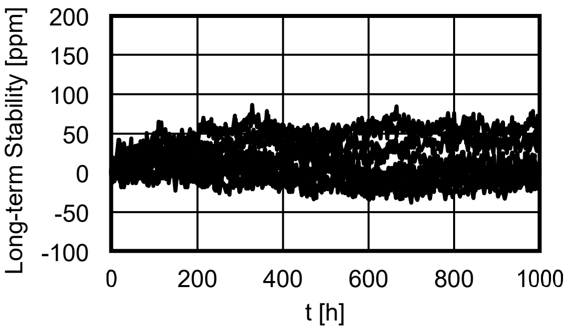




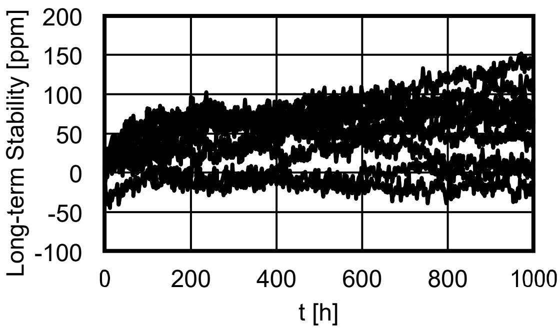
***1.** I_{SHUNT_MAX}: Refer to "■ **Electrical Characteristics**".
***2.** C_L = 0.22 μF, TDK Corporation: C3216X8R1H224K
C_L = 0.68 μF, TDK Corporation: C3216X8R1E684K

4. Long-term stability

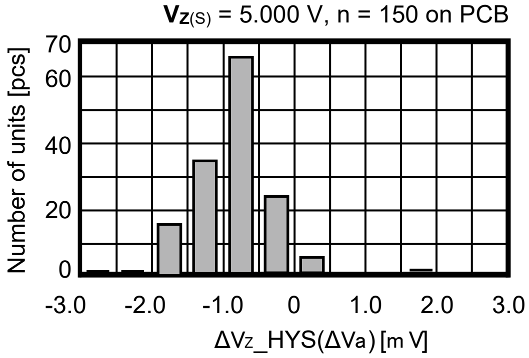
4. 1 SOT-23-3



4. 2 HSNT-8(1616)B



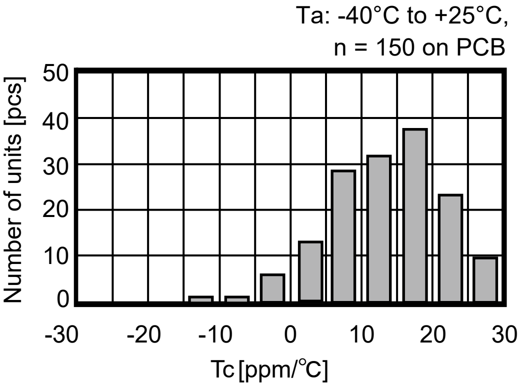
5. Distribution histogram of thermal hysteresis

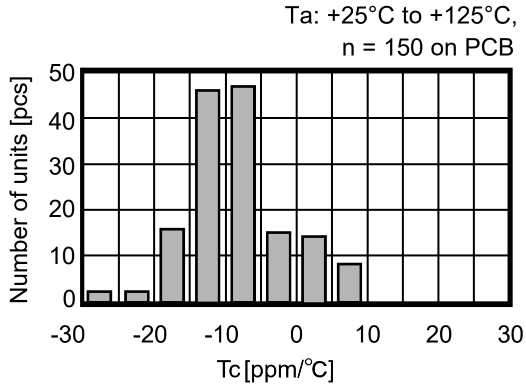


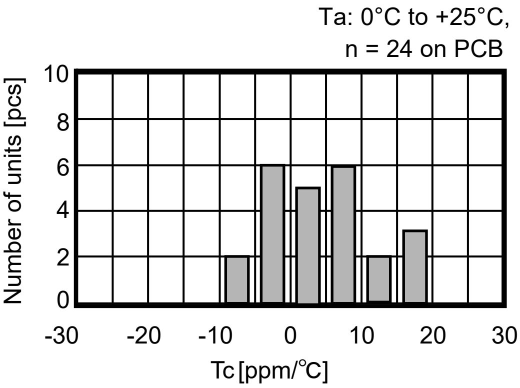
Remark 1. The above shows the thermal hysteresis in one temperature cycle (25°C → -40°C → 125°C → 25°C) for the first time after this IC is mounted on the board following assembly. The thermal hysteresis in the subsequent one temperature cycle will be smaller, which will be closer to the original thermal hysteresis of this IC (specifications in the "■ **Electrical Characteristics**").

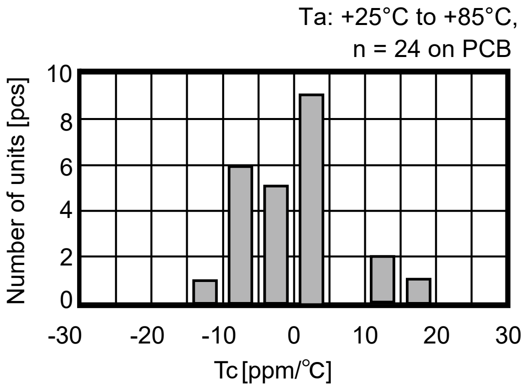
2. The above is the thermal hysteresis in the board mounting status (on PCB). Thermal hysteresis variation and solder thermal drift of this IC are included.

6. Output voltage temperature coefficient (TC) distribution histogram





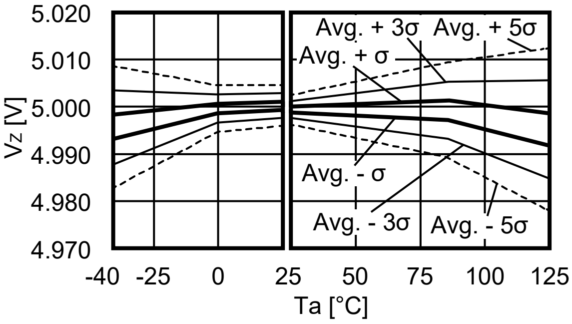




Remark **1.** Variation of the output voltage temperature coefficient of this IC is based on the specifications described in "■ **Electrical Characteristics**". However, note that in actual use, some cases may deviate from IC specifications due to changes in temperature coefficients caused by solder thermal drift during the board mounting.

2. The above includes variation of the output voltage temperature coefficient of this IC. It shows variation of the output voltage temperature coefficient in the board mounting status (on PCB). Thermal hysteresis is not included.

7. Variation of output voltage temperature characteristic

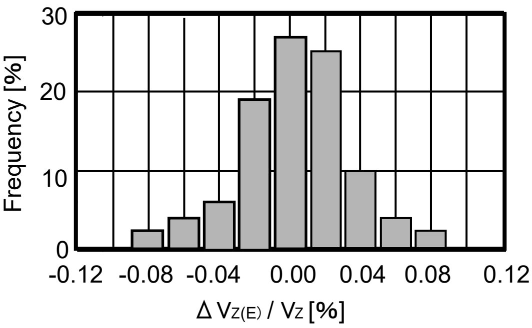


Remark **1.** The above shows variation of the output voltage temperature characteristics in the board mounting status (on PCB).

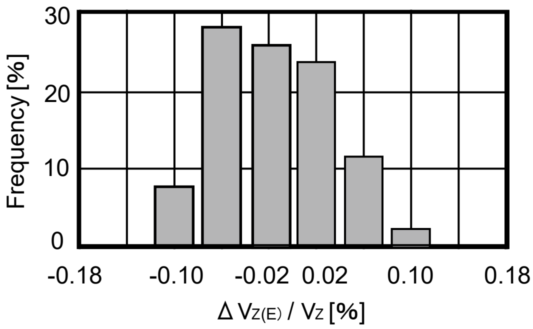
2. It includes output voltage variation, variation of the output voltage temperature coefficient, and thermal hysteresis variation of this IC. Additionally, it includes the solder thermal drift for each of these characteristic variations.

8. Output voltage (V_Z), Solder thermal drift, Board mounting reflow shift

8. 1 SOT-23-3



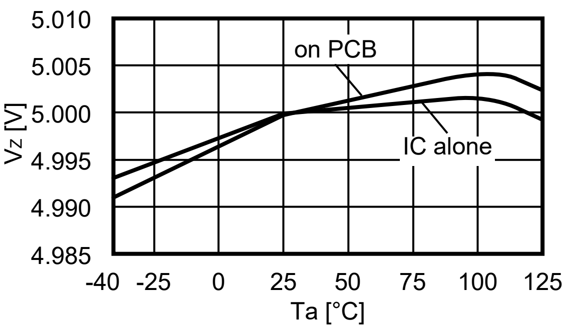
8. 2 HSNT-8(1616)B



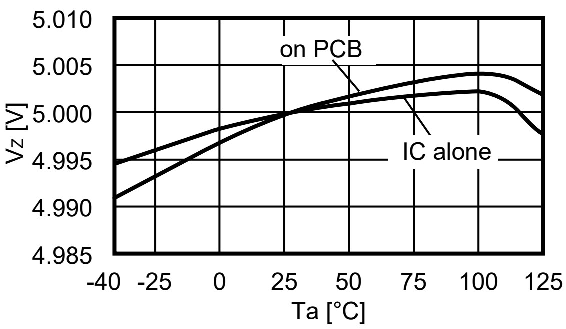
Remark The above shows output voltage variation (Ta = +25°C) in the board mounting status (on PCB) including output voltage variation of this IC. Thermal hysteresis is not included.

9. Solder thermal drift of V_Z vs. Ta characteristics, Board mounting reflow shift

9. 1 SOT-23-3



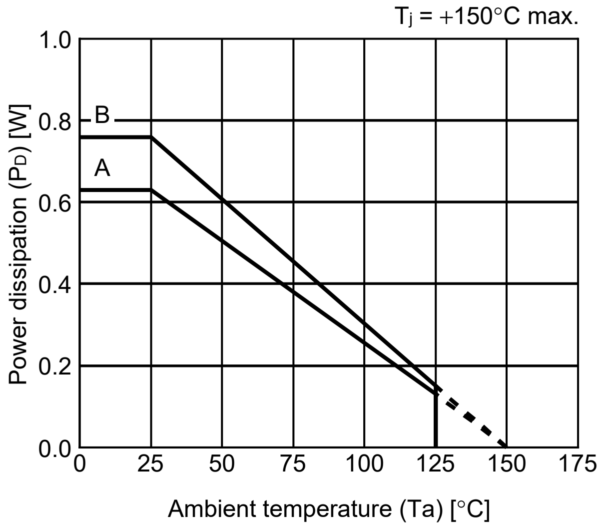
9. 2 HSNT-8(1616)B



Remark The above shows the change in the temperature characteristics of the representative sample due to solder thermal drift and board mounting reflow shift. Thermal hysteresis is not included.

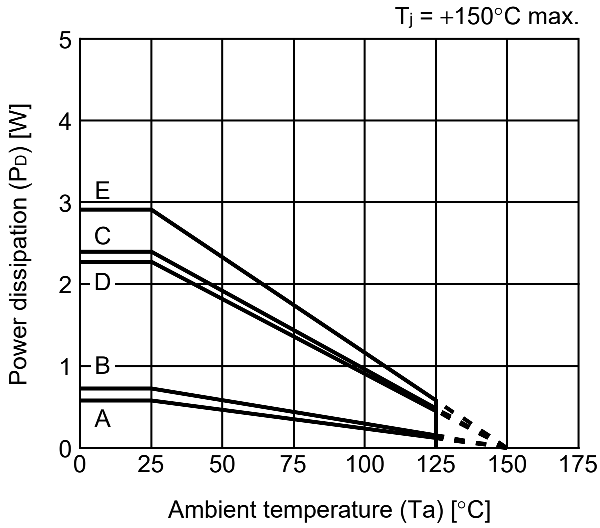
■ Power Dissipation

SOT-23-3



Board	Power Dissipation (P_D)
A	0.63 W
B	0.76 W
C	-
D	-
E	-

HSNT-8(1616)B

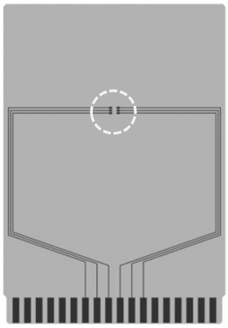


Board	Power Dissipation (P_D)
A	0.58 W
B	0.73 W
C	2.40 W
D	2.27 W
E	2.91 W

SOT-23-3/3S/5/6 Test Board

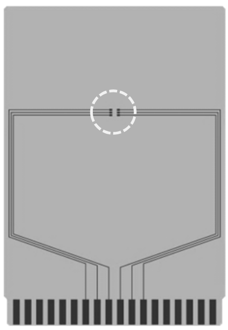
IC Mount Area

(1) Board A



Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		2
Copper foil layer [mm]	1	Land pattern and wiring for testing: t0.070
	2	-
	3	-
	4	74.2 x 74.2 x t0.070
Thermal via		-

(2) Board B



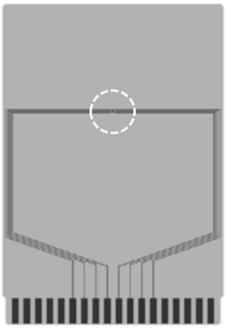
Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		4
Copper foil layer [mm]	1	Land pattern and wiring for testing: t0.070
	2	74.2 x 74.2 x t0.035
	3	74.2 x 74.2 x t0.035
	4	74.2 x 74.2 x t0.070
Thermal via		-

No. SOT23x-A-Board-SD-2.0

HSNT-8(1616)B Test Board

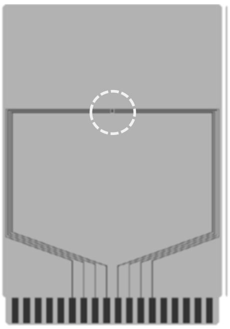
◌ IC Mount Are

(1) Board A



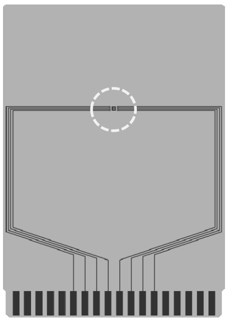
Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		2
Copper foil layer [mm]	1	Land pattern and wiring for testing: t0.070
	2	-
	3	-
	4	74.2 x 74.2 x t0.070
Thermal via		-

(2) Board B

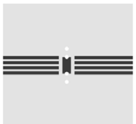


Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		4
Copper foil layer [mm]	1	Land pattern and wiring for testing: t0.070
	2	74.2 x 74.2 x t0.035
	3	74.2 x 74.2 x t0.035
	4	74.2 x 74.2 x t0.070
Thermal via		-

(3) Board C



Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		4
Copper foil layer [mm]	1	Land pattern and wiring for testing: t0.070
	2	74.2 x 74.2 x t0.035
	3	74.2 x 74.2 x t0.035
	4	74.2 x 74.2 x t0.070
Thermal via		Number: 4 Diameter: 0.3 mm



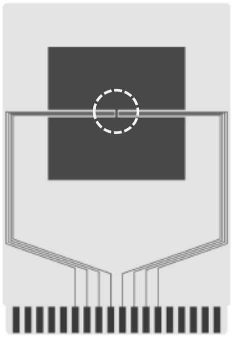
enlarged view

No. HSNT8-C-Board-SD-1.0

HSNT-8(1616)B Test Board

IC Mount Are

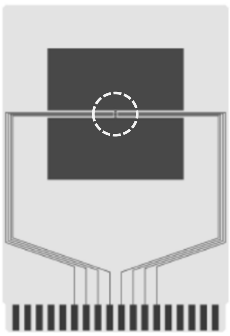
(4) Board D



Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		4
Copper foil layer [mm]	1	Pattern for heat radiation: 2000mm^2 t0.070
	2	74.2 x 74.2 x t0.035
	3	74.2 x 74.2 x t0.035
	4	74.2 x 74.2 x t0.070
Thermal via		-

enlarged view

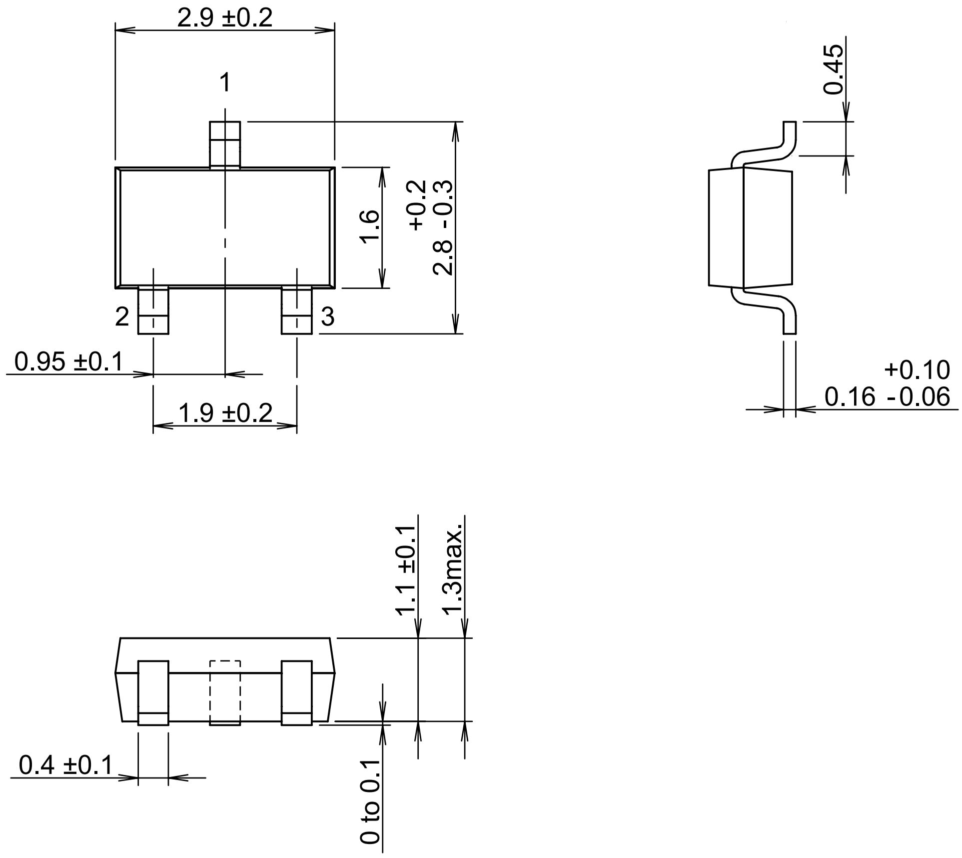
(5) Board E



Item		Specification
Size [mm]		114.3 x 76.2 x t1.6
Material		FR-4
Number of copper foil layer		4
Copper foil layer [mm]	1	Pattern for heat radiation: 2000mm^2 t0.070
	2	74.2 x 74.2 x t0.035
	3	74.2 x 74.2 x t0.035
	4	74.2 x 74.2 x t0.070
Thermal via		Number: 4 Diameter: 0.3 mm

enlarged view

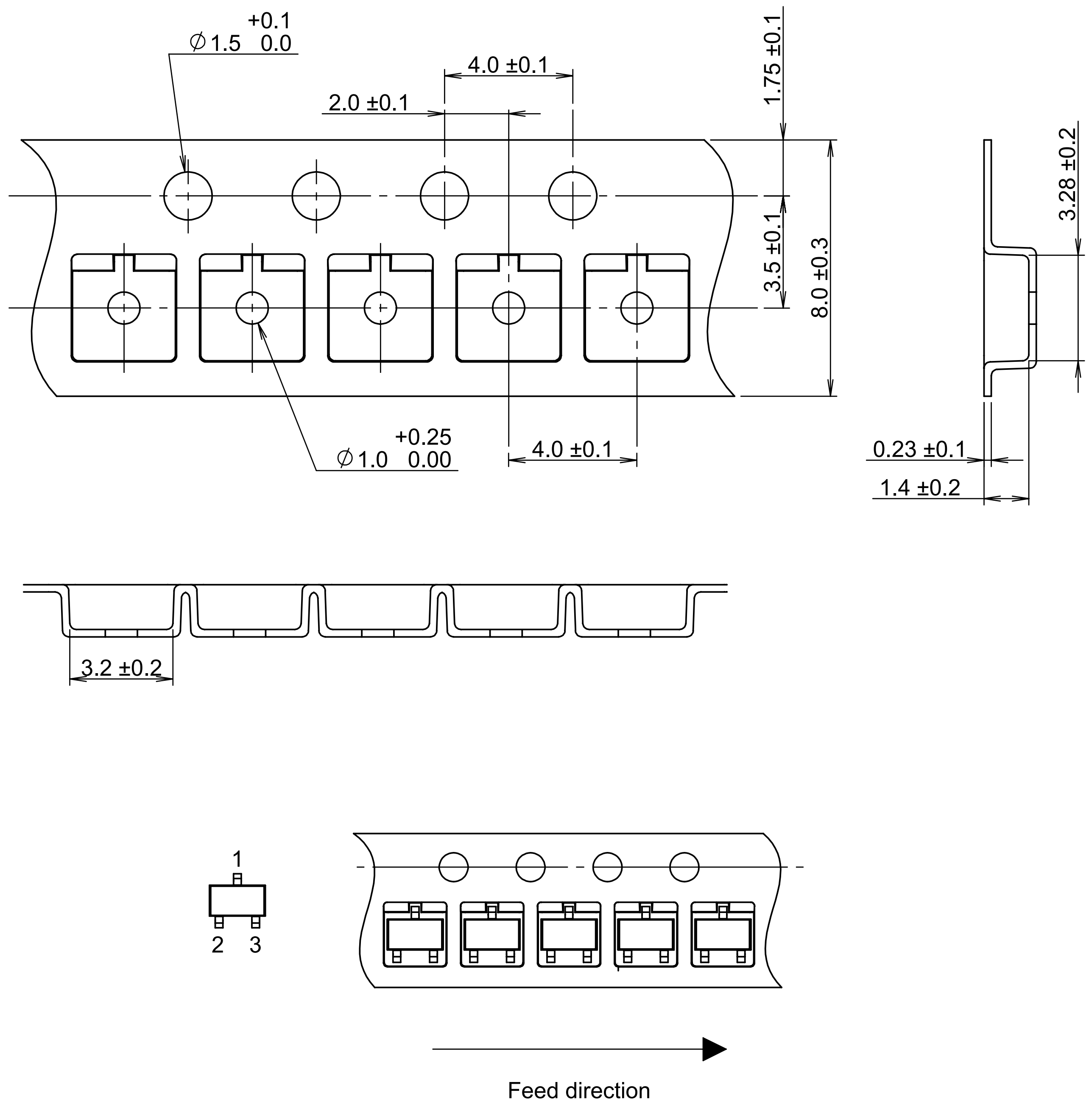
No. HSNT8-C-Board-SD-1.0



No. MP003-C-P-SD-1.1

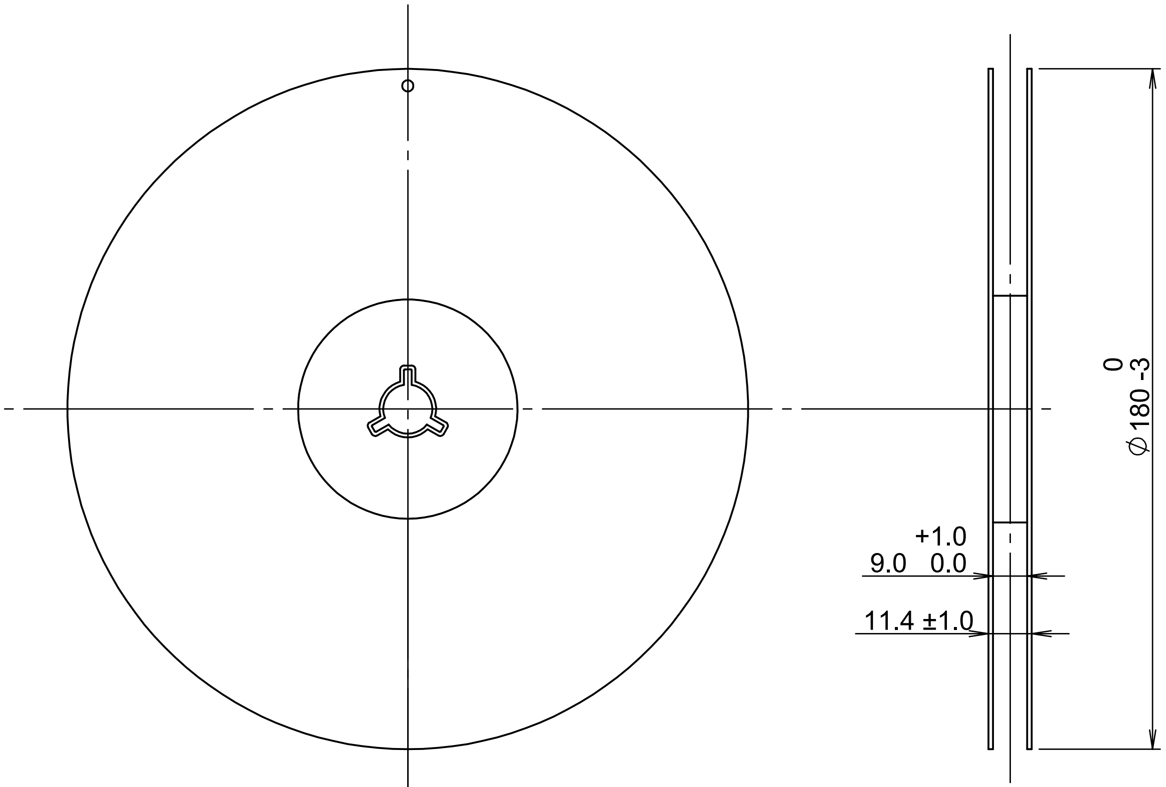
TITLE	SOT233-C-PKG Dimensions
No.	MP003-C-P-SD-1.1
ANGLE	
UNIT	mm

ABLIC Inc.

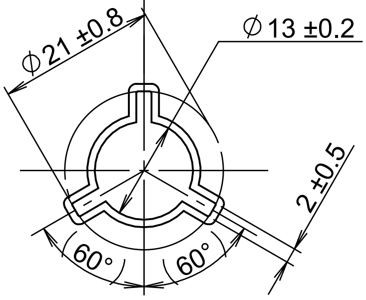


No. MP003-C-C-SD-2.0

TITLE	SOT233-C-Carrier Tape
No.	MP003-C-C-SD-2.0
ANGLE	
UNIT	mm
ABLIC Inc.	

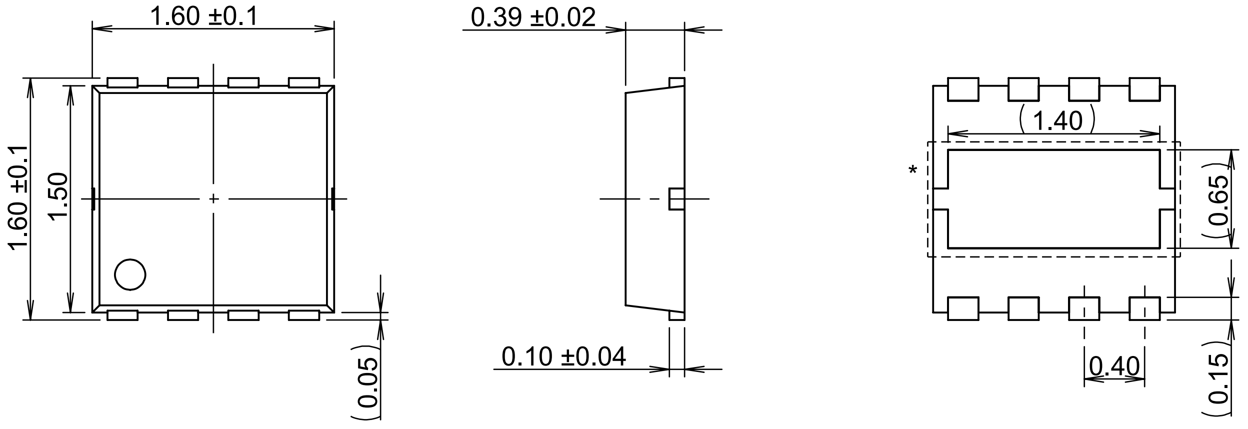


Enlarged drawing in the central part

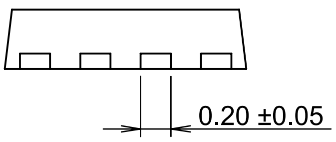


No. MP003-Z-R-SD-2.0

TITLE	SOT233-C-Reel		
No.	MP003-Z-R-SD-2.0		
ANGLE		QTY.	3,000
UNIT	mm		
ABLIC Inc.			



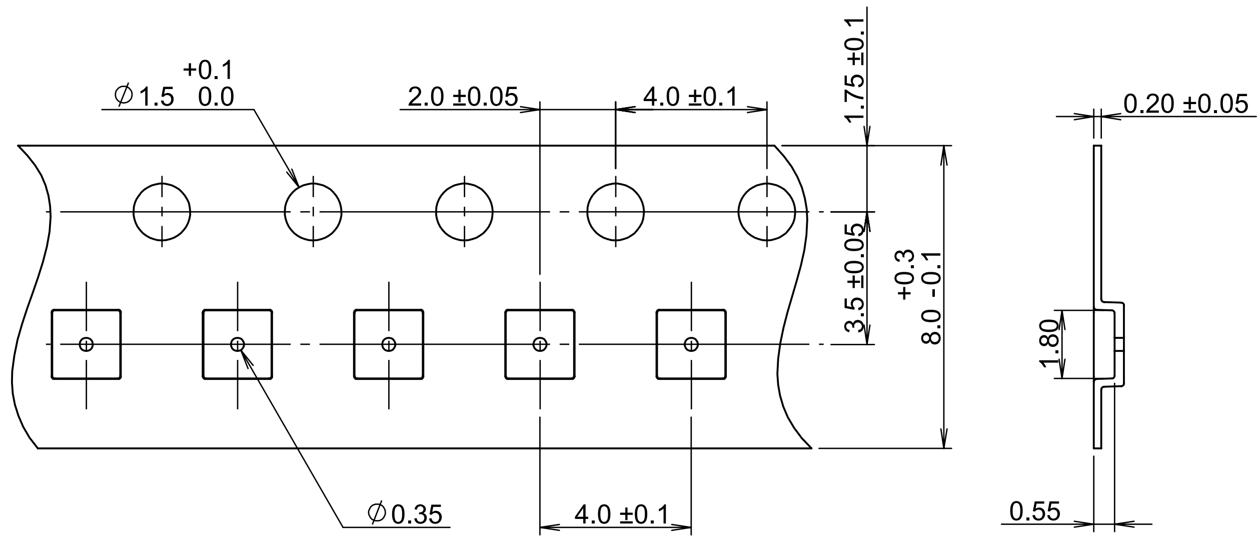
* The heat sink of back side has different electric potential depending on the product.
Confirm specifications of each product.
Do not use it as the function of electrode.

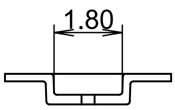


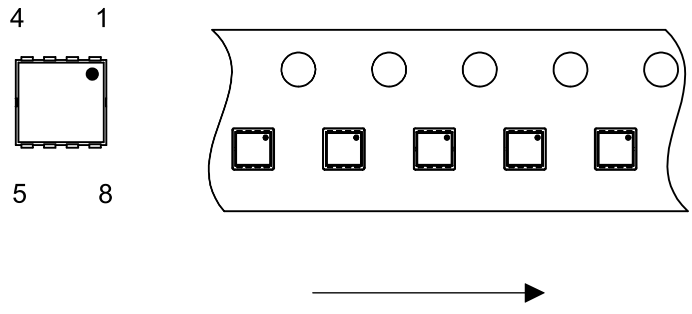
No. PY008-B-P-SD-1.0

TITLE	HSNT-8-C-PKG Dimensions
No.	PY008-B-P-SD-1.0
ANGLE	
UNIT	mm

ABLIC Inc.



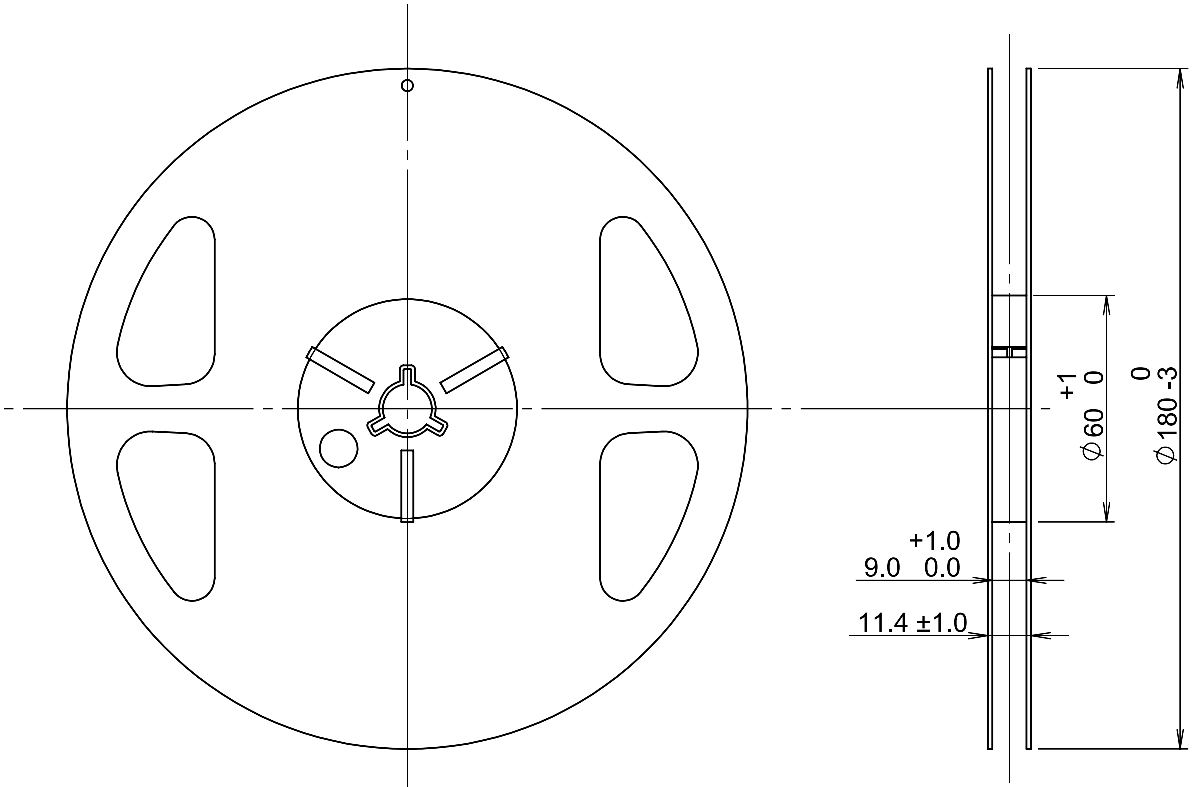




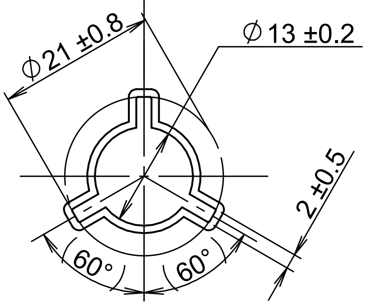
No. PY008-B-C-SD-1.0

TITLE	HSNT-8-C-Carrier Tape
No.	PY008-B-C-SD-1.0
ANGLE	
UNIT	mm

ABLIC Inc.



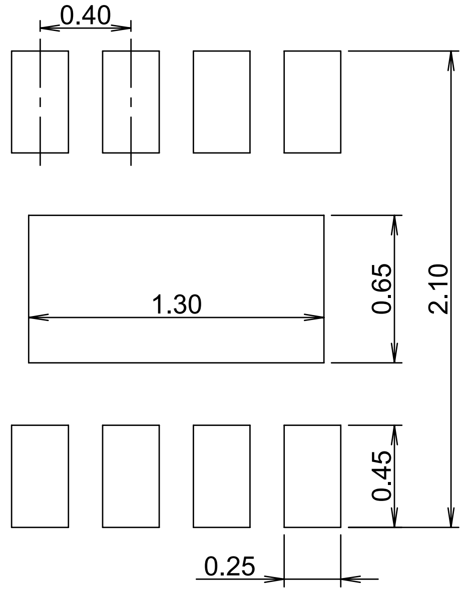
Enlarged drawing in the central part



No. PY008-B-R-SD-1.0

TITLE	HSNT-8-C-Reel		
No.	PY008-B-R-SD-1.0		
ANGLE		QTY.	5,000
UNIT	mm		
ABLIC Inc.			

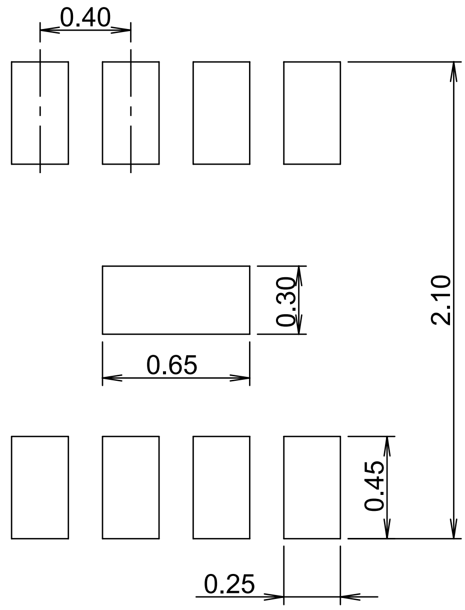
Land Pattern



Caution　It is recommended to solder the heat sink to a board in order to ensure the heat radiation.

注意　放熱性を確保する為に、PKGの裏面放熱板（ヒートシンク）を基板に半田付けすることを推奨いたします。

Metal Mask Pattern



Caution　① Mask aperture ratio of the lead mounting part is 100%.
② Mask aperture ratio of the heat sink mounting part is 20%.
③ Mask thickness: t0.10mm

注意　① リード実装部のマスク開口率は100%です。
② 放熱板実装のマスク開口率は20%です。
③ マスク厚み: t0.10mm

No. PY008-B-L-SD-1.0

TITLE	HSNT-8-C -Land Recommendation
No.	PY008-B-L-SD-1.0
ANGLE	
UNIT	mm
ABLIC Inc.	

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2.4-2019.07