SGM446
2-Terminal, High-Precision, Current Output Temperature Sensor

GENERAL DESCRIPTION

The SGM446 is a 2-terminal temperature sensor with an output current proportional to absolute temperature. It can be considered as a constant-current and high-impedance regulator passing 1μA/K in the supply voltage range from 4V to 35V. The SGM446 is calibrated to 298.2μA output current at 298.2K (+25℃).

Compared with the traditional electrical temperature sensor, the SGM446 does not need resistance measurement circuit, linearization circuit, precision voltage amplifier and cold junction compensation. It also integrates the compensation of temperature, flow rate measurement, discrete-component correlation, biasing proportional to absolute temperature, level detection of fluids and anemometry.

The high-impedance current output of the SGM446 makes the device insensitive to voltage drops especially on long lines. Therefore, it is particularly suitable for remote sensing applications. The multiplex of the SGM446 is achieved by switching the current through a CMOS multiplexer or switching the supply voltage through the logic gate.

The SGM446 is available in Green UTDFN-2×2-2L and UTDFN-2×2-4L packages. It is specified over a wide temperature range of -55℃ to +150℃.

FEATURES

- **2-Terminal Device: Voltage to Current**
- **Linear Current Output: 1μA/K**
- **Calibration Error: ±2℃**
- **Excellent Linearity: ±0.6℃ over Full Temperature Range**
- **Wide Supply Voltage Range: 4V to 35V**
- **Operating Temperature Range: -55℃ to +150℃**
- **Available in Green UTDFN-2×2-2L and UTDFN-2×2-4L Packages**

APPLICATIONS

Temperature Sensing and Compensation
Industrial Temperature Measurement
Thermocouple Cold Junction Compensation
Remote Temperature Sensing

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM446	UTDFN-2×2-2L	-55℃ to +150℃	SGM446TUEW2G/TR	S00X XXXX	Tape and Reel, 3000
	UTDFN-2×2-4L	-55℃ to +150℃	SGM446TUEX4G/TR	S00Y XXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXX = Date Code, Trace Code and Vendor Code.

XXXX

- Vendor Code
- Trace Code
- Date Code - Year

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Forward Voltage (E+ or E-) 44V
Reverse Voltage (E+ to E-) .... -20V
Package Thermal Resistance
UTDFN-2×2-2L, θ_{JA} .... 206℃/W
UTDFN-2×2-4L, θ_{JA} .... 90℃/W
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃
ESD Susceptibility
HBM 4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Operating Ambient Temperature Range .... -55℃ to +150℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

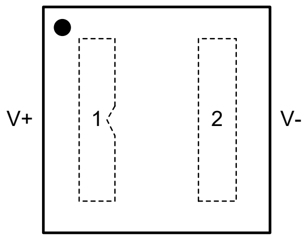
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

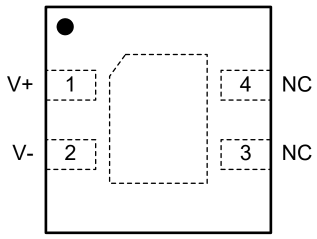
PIN CONFIGURATIONS

(TOP VIEW)



UTDFN-2×2-2L

(TOP VIEW)



UTDFN-2×2-4L

PIN DESCRIPTION

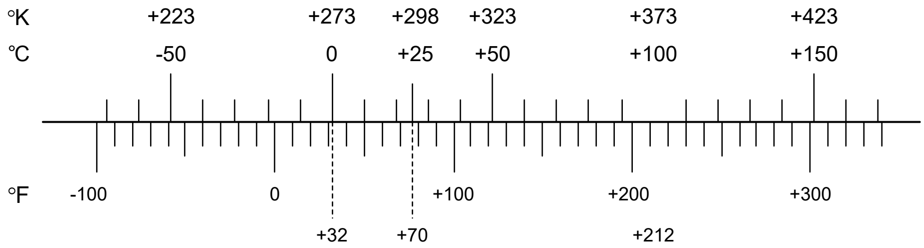
PIN		NAME	FUNCTION
UTDFN-2×2-2L	UTDFN-2×2-4L		
1	1	V+	Sensor (+) and (-) Terminals. Make sure that the V+ terminal is at a higher positive bias voltage than the V- terminal voltage point. The output current changes proportionally with the variation of external temperature.
2	2	V-	
—	3, 4	NC	Not Connected. Leave it floating or connect it to GND.

ELECTRICAL CHARACTERISTICS

(V_S = 5V, T_A = -55℃ to +150℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER		SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply							
Operating Voltage Range		V_S		4		35	V
Sensor Output							
Nominal Current Output		I_{OUT}			298.2		μA
Nominal Temperature Coefficient		I_T			1		μA/K
Calibration Error			T_A = +25℃	-2		2	℃
Absolute Error (Over Rated Performance Temperature Range)	Without External Calibration Adjustment			-5		2	℃
	With +25℃ Calibration Error Set to Zero			-4		1	℃
	Nonlinearity	V_{ONL}			±0.6		℃
	Repeatability [(1)]					0.1	℃
	Long-Term Drift		T_A = +125℃			0.1	℃
Current Noise					1		pA/√Hz
Power Supply Rejection			V_S = 4V to 5V		0.06	0.5	μA/V
			V_S = 5V to 15V		0.02	0.4	
			V_S = 15V to 35V		0.01	0.3	
Case Isolation to Either Lead					2		GΩ
Effective Shunt Capacitance		C_{SHUNT}			10		pF
Electrical Turn-On Time		t_{ON}			200	800	μs
Reverse Bias Leakage Current			Reverse Voltage is 10V		200		nA

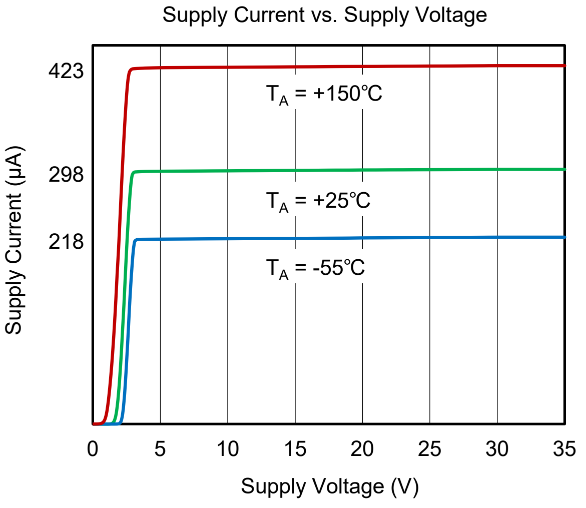
NOTE:
1. The maximum deviation is the difference of +25℃ values measured before and after the temperature cycle of the device from -55℃ to +150℃.

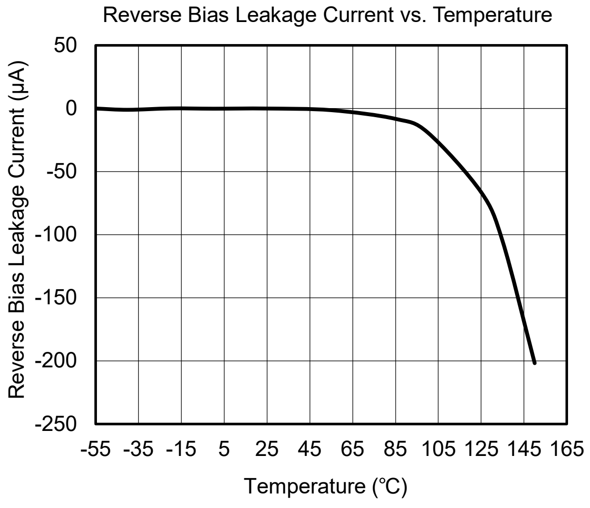


$$℃ = \frac{5}{9} \times (°F - 32) \qquad K = ℃ + 273.15 \qquad °F = \frac{9}{5} \times ℃ + 32 \qquad °R = °F + 459.7$$

Figure 1. Temperature Scale Conversion Equations

TYPICAL PERFORMANCE CHARACTERISTICS





DETAILED DESCRIPTION

The SGM446 can transfer the temperature to the current directly. The silicon transistors are used to operate the transducer through a linear characteristic between output current and temperature. If the collector current density (r) of two transistors is constant, the base-emitter voltage can be calculated by (kT/q) × lnr, where k illustrates Boltzmann constant and q illustrates the quantity of electric charge for one electron. As a result, r, k and q are constant and the only variable in the above equation is temperature T. Therefore, the characteristic is called proportional to absolute temperature (PTAT).

The thin-film with low temperature coefficient plays an important role in converting PTAT voltage to the related PTAT current. Moreover, the scale between PTAT and total current is constant. The internal structure of SGM446 transducer is shown in Figure 2.

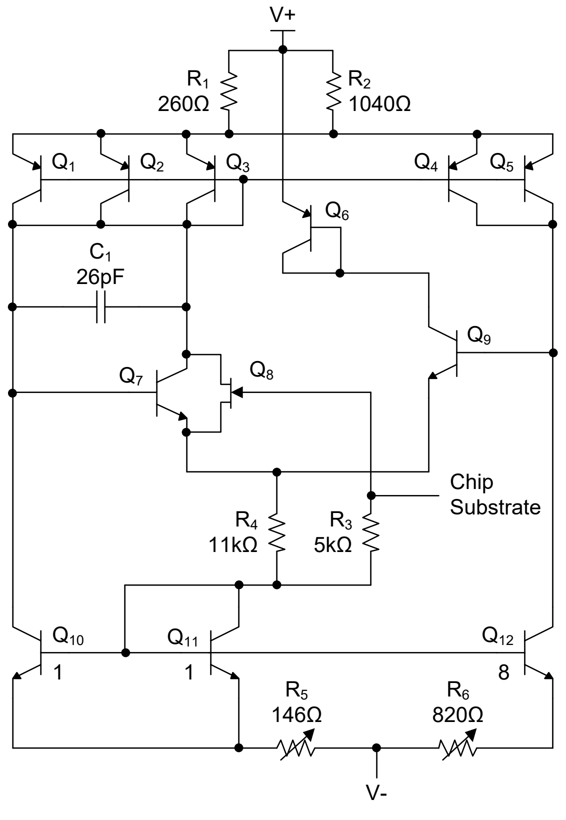


Figure 2. Internal Structure

The corresponding PTAT current can also be calculated and converted with two resistors R_5 and R_6 in Figure 2. Because of the basic of current mirror theory, Q_{11} is used to copy the collector current of Q_{10} and Q_{12}, which is the most important transistor as it can provide bias and leakage current for the rest of the system, so that the total current can be PTAT with the exist of Q_{11}. R_5 and R_6 can be used to calibrate the transducer at the degree of +25℃, and the structure of them is trimmed.

The Explanation of Temperature Sensing

The SGM446 can be easily used in a wide range of applications. Both the environment of temperature and the level of supply voltage can influence the accuracy of the transducer.

The characteristic of SGM446 is PTAT. Because the relationship between Celsius and Kelvin scale is T (℃) = T (K) - 273.2, the absolute 0 degree in Kelvin scale is equal to -273.2 in Celsius scale. This means that the output current of the transducer is equal to the Kelvin temperature multiplied by the scale factor (1μA/K). With this specification, the output current can be automatically adjusted with the temperature change, which means that the output current is equal to 298μA at the temperature level of +25℃ (298K).

Calibration Error

The error of calibration is always set by the factory. It is defined as the difference between the actual temperature and the indicated temperature. The calibration error is also PTAT. For instance, the maximum calibration error can change from +1.6℃ at -55℃ to -2℃ at +150℃. Figure 3 illustrates the change of calibration error within the specified temperature range.

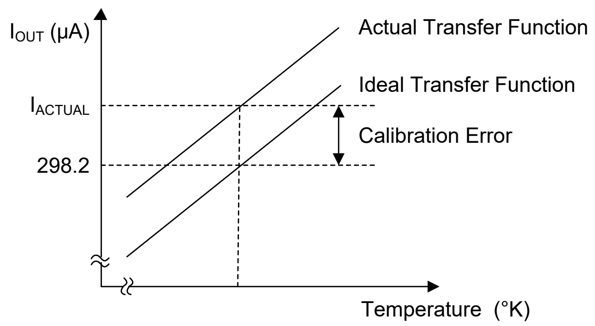


Figure 3. Calibration Error vs. Absolute Temperature

DETAILED DESCRIPTION (Continued)

The calibration error is a significant part within the total error of the device, but it is easy to trim. Figure 4 shows the method about how to trim this calibration error.

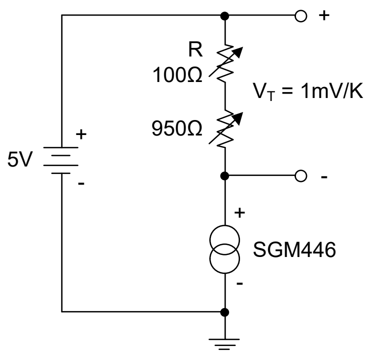


Figure 4. Trim of Temperature

In Figure 4, the temperature can be measured and calculated by the adjustable resistors and the temperature sensor. The principle of this measurement is that if it is trimmed at only one temperature, the calibration error can be zero within the whole temperature range, and the PTAT current can be transferred to voltage with 1mV/K scale factor. Also, this is called an I-V resistor (or a reference of ADC for current input case) which can be trimmed for minimizing the calibration error.

Error vs. Temperature: Trimming out the Calibration Error

The calibration error is tested for each SGM446 when trimming out. From Figure 5, the calibration error of the transducer is also PTAT. In addition, from the figure below, there are curvature and the error of slope at the extreme of temperature. The effect of trimming is shown as below.

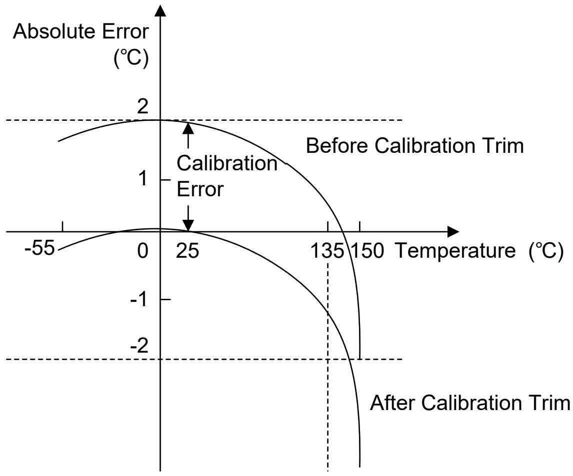


Figure 5. Trimming out the Calibration Error

Error vs. Temperature: No Trimming

When measuring the temperature or output current of the SGM446, the total error consists of the calibration error and the variance of PTAT current. For example, if there is no trimming, the total error can be increased to +1.6℃ at -55℃.

Nonlinearity

The nonlinearity of SGM446 is defined as the maximum offset between the current curve within the specified temperature and its fitted straight line. In addition, the SGM446 has nonlinearity characteristic in its specified temperature range from -55℃ to +150℃. Figure 6 shows the typical values of temperature error for Figure 6.

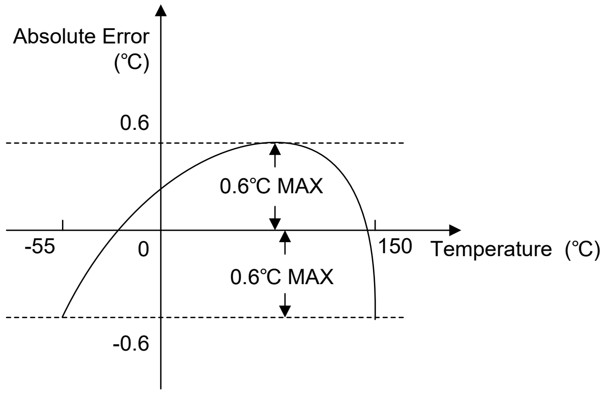


Figure 6. Nonlinearity

DETAILED DESCRIPTION (Continued)

The total temperature error of the following circuit as shown in Figure 7 is contributed by the nonlinearity of the transducer. R_1 can be adjusted to change the output of the circuit to 0V at 0℃, and R_2 can be adjusted to change the output of the circuit to 10V at +100℃. This method can also adjust the output of the circuit accordingly with different temperatures. If the circuit is designed to measure the temperature of +150℃ (15V), the V+ voltage of the amplifier should be greater than 16V. Moreover, the V- voltage should be less than or equal to -4V to guarantee the flow of PTAT current.

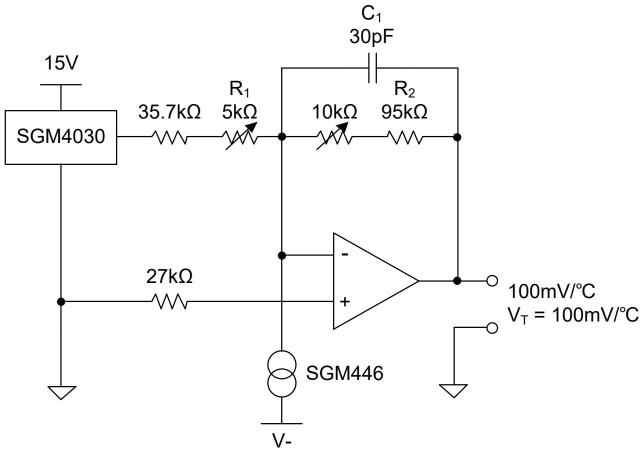


Figure 7. 2 Points Temperature Trim

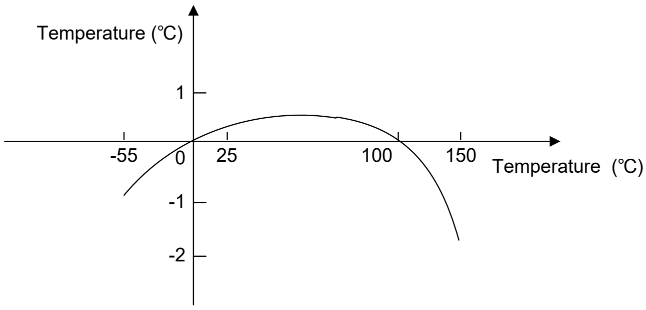


Figure 8. The Accuracy of 2 Points Temperature Trim

Voltage and Thermal Environment Effects

The Power Supply Rejection (PSR) illustrates the maximum change of output current with the variations of input voltage. Under the case of non-ideal power supply, an insensitive output is necessary for the temperature accuracy. This transducer can also be series with a hundreds-ohm resistor (such as the multiplexer made by CMOS).

If the power supply voltage is greater than or equal to 5V, the property of PTAT will not be changed. That is, the error or change can be regarded as a calibration error and be easily trimmed by the scale factor (see Figure 5).

The SGM446 should be used in a low thermal resistance condition with 5V power supply. Any large variations or changes of the thermal resistors would cause self-heating. And the transducer may not work accurately and properly under this environment.

APPLICATION INFORMATION

The SGM446 can be used in the condition of remote sensing of temperature. Figure 9 shows the principle of thermometer, which illustrates that the output current of the transducer can be converted to voltage (1mV/K) by a 1kΩ resistor. If the Celsius degree is required for reading, the output should be offset by 273.2mV as SGM446 only measures the degree in Kelvin.

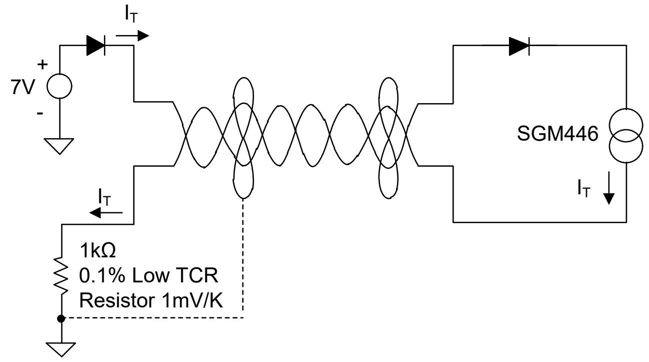


Figure 9. Remote Temperature Sensing

From Figure 10, if the SGM446 is connected in parallel, the average temperature of all the measured temperatures can be indicated. However, the transducers in series illustrate the minimum of all the measured temperatures.

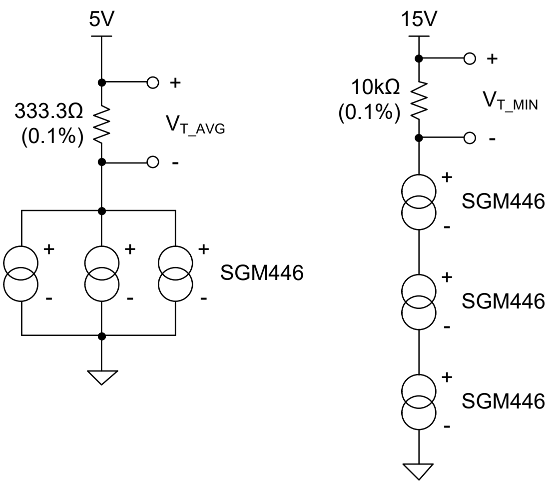


Figure 10. Series and Parallel Connection of SGM446

The following circuit shown in Figure 11 can convert the difference between two PTAT currents into voltages, which can measure the temperature difference. The resistors R_1 and R_2 can trim the output value of the circuit. That is, these two resistors can trim the offset of inherent between two transducers. It will also cause a differential temperature rise due to the internal dissipation if the value of V+ and V- are different. And the application of this circuit can be used in anemometry.

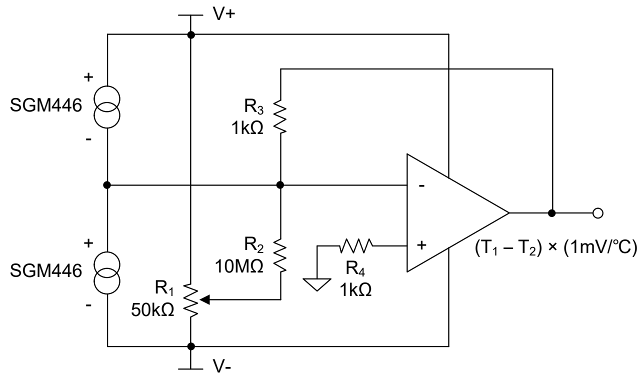


Figure 11. Differential Measurements

Figure 12 can be used to compensate the cold junction from the J-Type thermocouple. The following circuit is used as a reference for the thermocouple (TC) at a temperature range from +15℃ to +35℃. The resistor R_T can calibrate the circuit for the meter of the circuit with known reference temperature. For the Celsius temperature from +15℃ to +35℃, the accuracy can be compensated within the range of ±2℃ if using the specified components with TCs. And different resistor values can fit different types of TCs. If the users attempt to decrease the error, the resistors and voltage reference in TCs should be taken into consideration.

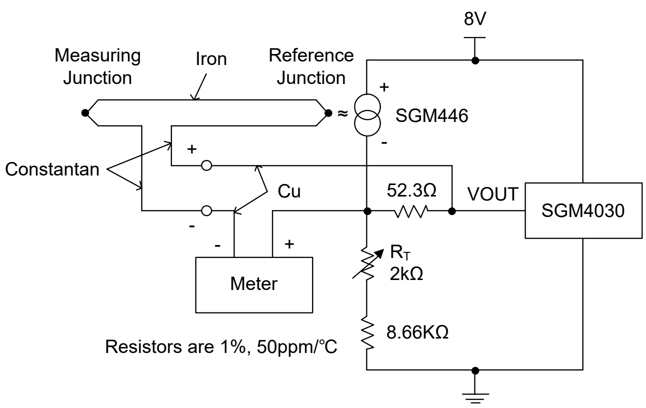


Figure 12. Compensating a Type-J Thermocouple

APPLICATION INFORMATION (Continued)

The current transmitter which is shown in Figure 13 is suitable for using in the system with 40V and 1kΩ. This circuit can be used in the narrow-span temperatures within the output current range from 4mA to 20mA. In this application, the output of SGM446 is amplified from 1μA/K to 1mA/℃, which means that 4mA and 12mA correspond to +17℃ and +25℃ respectively. The adjustable resistor R_T can be used to trim the circuit to a feasible output, so that it can change the measured temperature range which is lower than the current limitation.

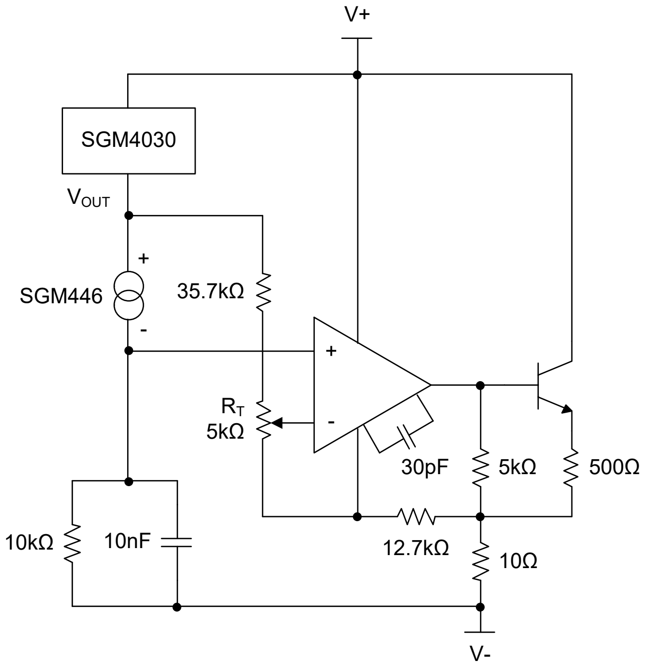


Figure 13. Current Transmitter with 4mA to 20mA output

In Figure 14, the structure of reverse blocking allows the SGM446 to be powered by a CMOS with a voltage level of 5V. This circuit can prevent the heat from dissipation through multiplexing and switching. The transducer can transmit current if it is connected to a logic-high COMS, while there is no current for the transducer connected to a logic-low CMOS. The parasitic capacitance from the SGM446 should be also taken into account.

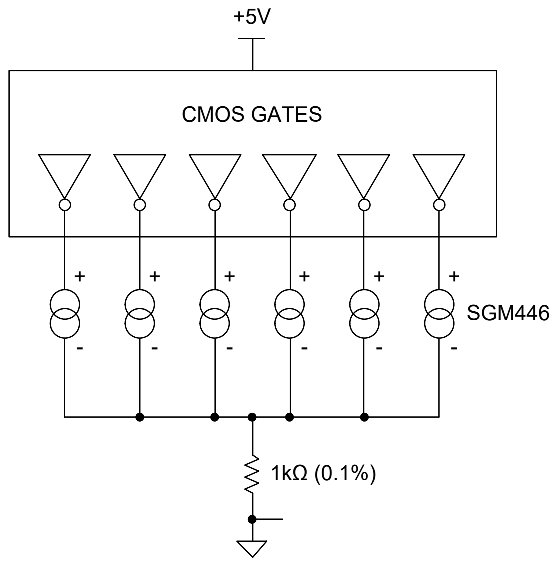


Figure 14. CMOS-Driving Transducer

Figure 15 illustrates that the transducer is multiplexed by an 8-channel multiplexer in the 2-trim mode (see Figure 7 and Figure 8). The additional SGM446s can also be multiplexed with their corresponding resistors with the accuracy of ±2℃ for -55℃ to +125℃. If the circuit is used to test the temperature of +150℃, the supply voltage of the amplifier should be increased to +20℃ to obtain a higher output voltage.

APPLICATION INFORMATION (Continued)

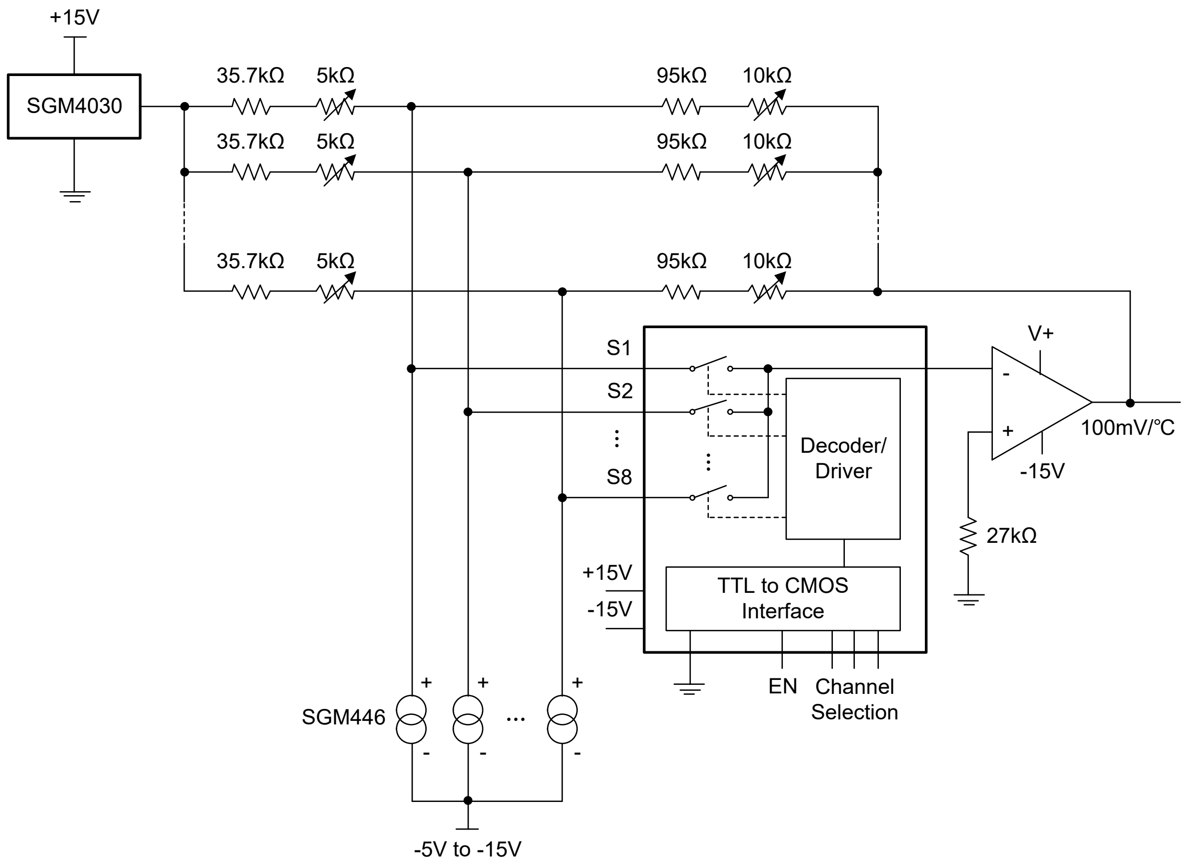


Figure 15. Temperature Sensing with 8-Channel Multiplexer

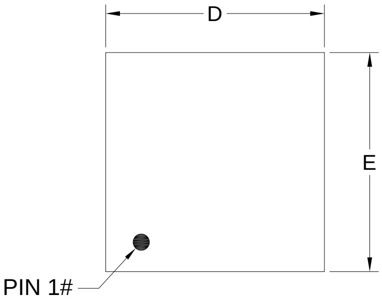
REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

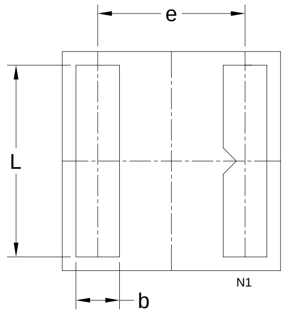
Changes from Original (NOVEMBER 2022) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

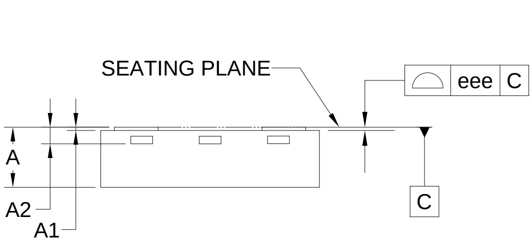
UTDFN-2×2-2L



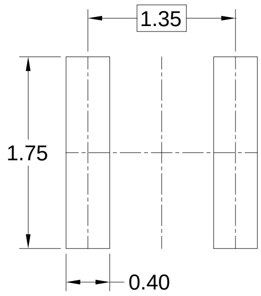
TOP VIEW



BOTTOM VIEW



SIDE VIEW



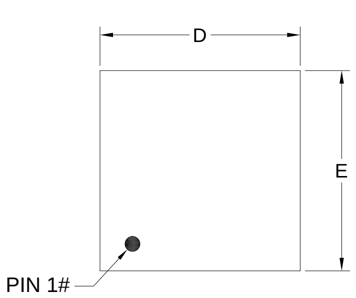
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	**MOD**	**MAX**
A	0.500	0.550	0.600
A1	0.000	-	0.050
A2	0.152 REF		
b	0.350	0.400	0.450
D	1.900	2.000	2.100
E	1.900	2.000	2.100
L	1.700	1.750	1.800
e	1.350 BSC		
eee	0.080		

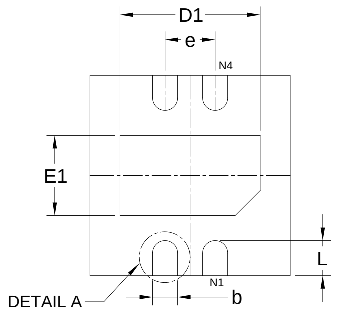
NOTE: This drawing is subject to change without notice.

PACKAGE OUTLINE DIMENSIONS

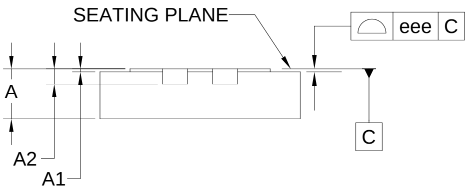
UTDFN-2×2-4L



TOP VIEW

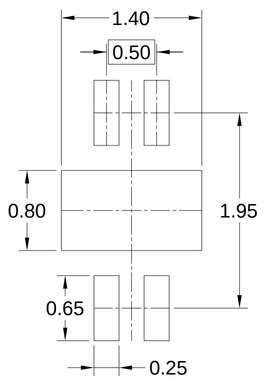


BOTTOM VIEW



SIDE VIEW

DETAIL A
ALTERNATE TERMINAL CONSTRUCTION



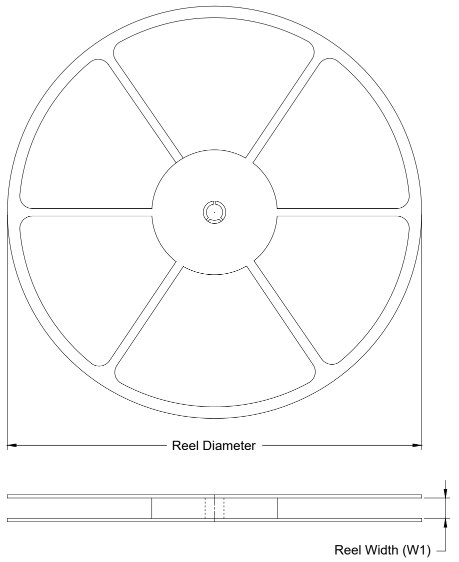
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.450	0.500	0.550
A1	0.000	-	0.050
A2	0.152 REF		
b	0.200	0.250	0.300
D	1.900	2.000	2.100
E	1.900	2.000	2.100
D1	1.350	1.400	1.450
E1	0.750	0.800	0.850
L	0.300	0.350	0.400
e	0.500 BSC		
eee	0.080		

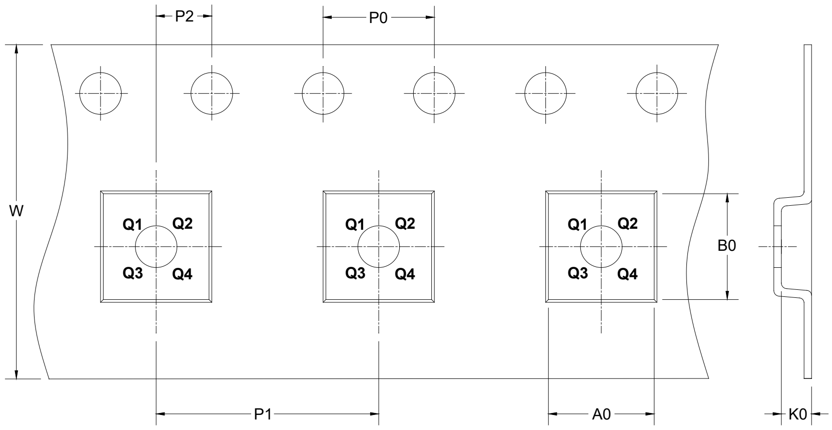
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

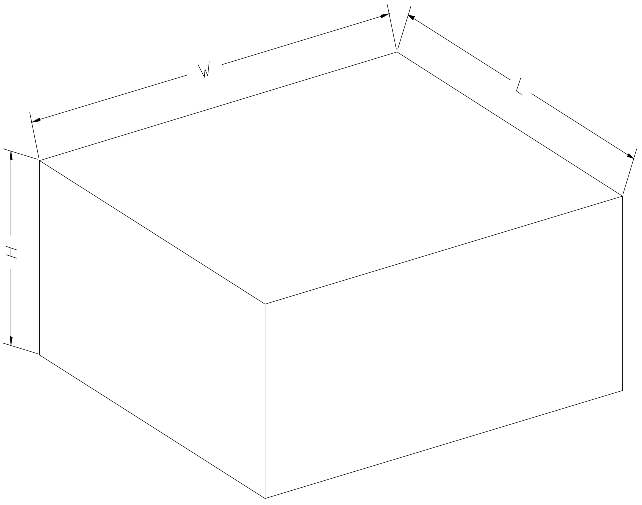
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
UTDFN-2x2-2L	7"	8.6	2.13	2.13	0.88	4.0	4.0	2.0	8.0	Q1
UTDFN-2x2-4L	7"	8.6	2.13	2.13	0.88	4.0	4.0	2.0	8.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002