

Silicon Temperature Sensors

Designed for use in temperature sensing applications in automotive, consumer and industrial products requiring low cost and high accuracy.

- Precise Temperature Accuracy Over Extreme Temperature MTS102: $\pm 2^{\circ}\text{C}$ from -40°C to $+150^{\circ}\text{C}$
- Precise Temperature Coefficient
- Fast Thermal Time Constant
 - 3 Seconds — Liquid
 - 8 Seconds — Air
- Linear V_{BE} versus Temperature Curve Relationship
- Other Packages Available

MTS102
MTS103
MTS105

SILICON
TEMPERATURE
SENSORS



CASE 29-04, STYLE 1
TO-226AA
(TO-92)

Pin Number		
1	2	3
Emitter	Base	Collector

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current — Continuous(5)	I_C	100	mA dc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to $+150$	$^{\circ}\text{C}$

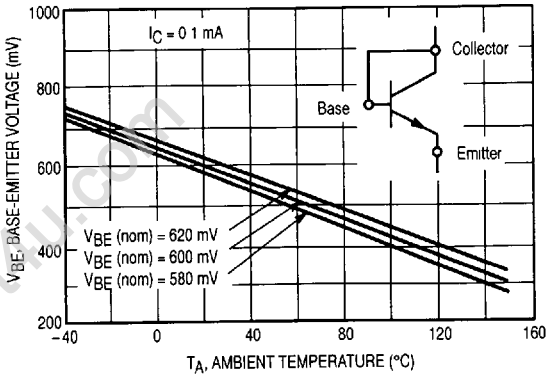


Figure 1. Base-Emitter Voltage versus Ambient Temperature

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Supply Voltage	V_S	-0.2	—	35	Vdc
Output Voltage	V_{out}	-1.0	—	6.0	Vdc
Output Current	I_o	—	—	10	mAdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu\text{Adc}$, $I_C = 0$)	$V_{(BR)EBO}$	4.0	—	—	Vdc
Base-Emitter Voltage ($I_C = 0.1\ \text{mA}$)	V_{BE}	580	595	620	mV
Base-Emitter Voltage Matching ⁽¹⁾ ($I_C = 0.1\ \text{mA}$, $T_A = 25^\circ\text{C} \pm 0.05^\circ\text{C}$)	ΔV_{BE}	MTS102 -3.0 MTS103 -4.0 MTS105 -7.0	— — —	3.0 4.0 7.0	mV
Temperature Matching Accuracy ⁽²⁾ ($T_1 = 40^\circ\text{C}$, $T_2 = +150^\circ\text{C}$, $T_A = 25^\circ\text{C} \pm 0.05^\circ\text{C}$)	ΔT	MTS102 -3.0 MTS103 -3.0 MTS105 -5.0	— — —	3.0 3.0 5.0	$^\circ\text{C}$
Temperature Coefficient ^(3,4) ($V_{BE} = 595\ \text{mV}$, $I_C = 0.1\ \text{mA}$)	T_C	-2.28	-2.265	-2.26	$\text{mV}/^\circ\text{C}$
Thermal Time Constant Liquid Flowing Air	τ_{TH}	— —	3.0 8.0	— —	s
Dependence of T_C on V_{BE} @ 25°C ⁽⁴⁾ (Figure 3)	$\Delta T_C / \Delta V_{BE}$	—	0.0033	—	$\text{mV}/^\circ\text{C}$ mV

THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	—	—	200	$^\circ\text{C}/\text{W}$
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MECHANICAL CHARACTERISTICS

Weight	—	—	87	—	Grams
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NOTES:

1. All devices within any one group or package will be matched for V_{BE} to the tolerance identified in the electrical characteristics table. Each device will be labeled with the mean V_{BE} value for that group.
2. All devices within an individual group, as described in Note 1, will track within the specified temperature accuracy. This includes variations in T_C , V_{BE} , and nonlinearity in the range -40 to $+150^\circ\text{C}$. Nonlinearity is typically less than $\pm 1^\circ\text{C}$ in this range. (See Figure 4)
3. The T_C as defined by a least-square linear regression for V_{BE} versus temperature over the range -40 to $+150^\circ\text{C}$ for a nominal V_{BE} of 595 mV at 25°C . For other nominal V_{BE} values the value of the T_C must be adjusted for the dependence of the T_C on V_{BE} (see Note 4).
4. For nominal V_{BE} at 25°C other than 595 mV, the T_C must be corrected using the equation $T_C = -2.265 + 0.003 (V_{BE} - 595)$ where V_{BE} is in mV and the T_C is in $\text{mV}/^\circ\text{C}$. The accuracy of this T_C is typically $\pm 0.01\ \text{mV}/^\circ\text{C}$.
5. For maximum temperature accuracy, I_C should not exceed 2 mA. (See Figure 2)

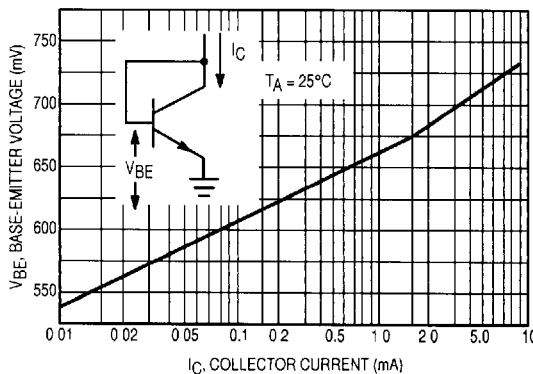


Figure 2. Base-Emitter Voltage versus Collector-Emitter Current

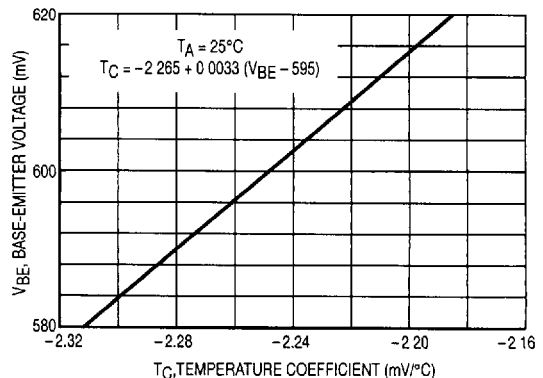


Figure 3. Temperature Coefficient versus Base-Emitter Voltage

MTS102 MTS103 MTS105

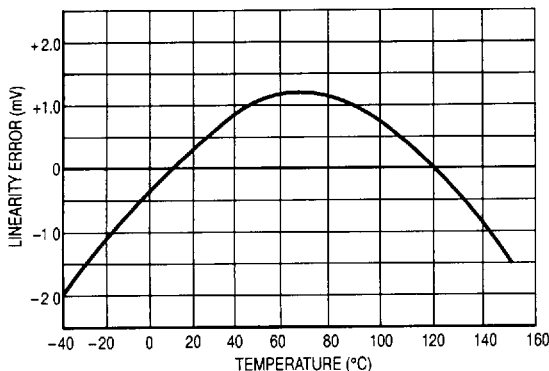


Figure 4. Linearity Error versus Temperature

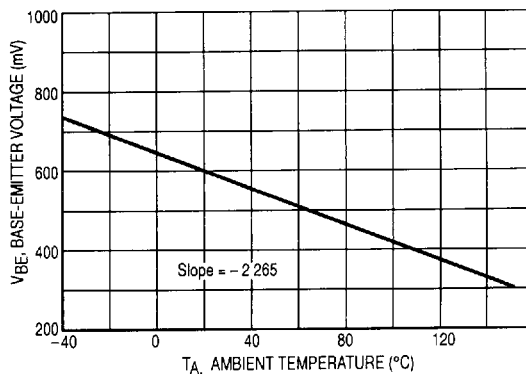
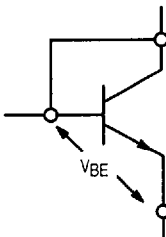


Figure 5. V_{BE} versus Ambient Temperature

APPLICATIONS INFORMATION

The base and collector leads of the device should be connected together in the operating circuit (pins 2 and 3). They are not internally connected.



The following example describes how to determine the V_{BE} versus temperature relationship for a typical shipment of various V_{BE} groups.

EXAMPLE:

Given — Customer receives a shipment of MTS102 devices. The shipment consists of three groups of different nominal V_{BE} values.

Group 1: $V_{BE}(\text{nom}) = 595 \text{ mV}$

Group 2: $V_{BE}(\text{nom}) = 580 \text{ mV}$

Group 3: $V_{BE}(\text{nom}) = 620 \text{ mV}$

Find — V_{BE} versus temperature Relationship.

1. Determine value of T_C :
 - a. If $V_{BE}(\text{nom}) = 595 \text{ mV}$, $T_C = -2.265 \text{ mV}/^\circ\text{C}$ from the Electrical Characteristics table.
 - b. If $V_{BE}(\text{nom})$ is less than or greater than 595 mV determine T_C from the relationship described in Note 4. $T_C = -2.265 + 0.0033 (V_{BE} - 595)$ or see Figure 3.

2. Determine the V_{BE} value at extremes, -40°C and $+150^\circ\text{C}$:

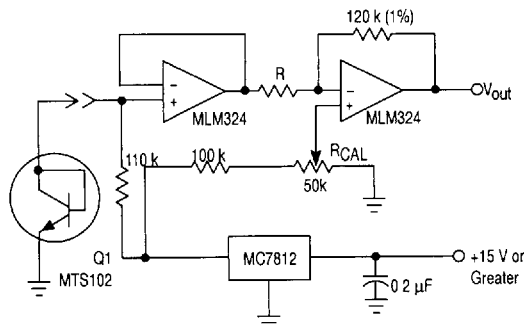
$$V_{BE}(T_A) = V_{BE}(25^\circ\text{C}) + (T_C)(T_A - 25^\circ\text{C}) \text{ where}$$

$$V_{BE}(T_A) = \text{value of } V_{BE} \text{ at desired temperature.}$$

3. Plot the V_{BE} versus T_A curve using two V_{BE} values: $V_{BE}(-40^\circ\text{C})$, $V_{BE}(25^\circ\text{C})$, or $V_{BE}(+150^\circ\text{C})$
4. Given any measured V_{BE} , the value of T_A (to the accuracy value specified: MTS102 — $\pm 2^\circ\text{C}$, MTS103 — $\pm 35^\circ\text{C}$, MTS105 — $\pm 5^\circ\text{C}$) can be read from Figure 5 or calculated from equation 2.
5. Higher temperature accuracies can be achieved if the collector current, I_C , is controlled to react in accordance with and to compensate for the linearity error. Using this concept, practical circuits have been built in which allow these sensors to yield accuracies within $\pm 0.1^\circ\text{C}$ and $\pm 0.01^\circ\text{C}$.

Reference: "Transistors—A Hot Tip for Accurate Temperature Sensing," Pat O'Neil and Carl Derrington, *Electronics* 1979.

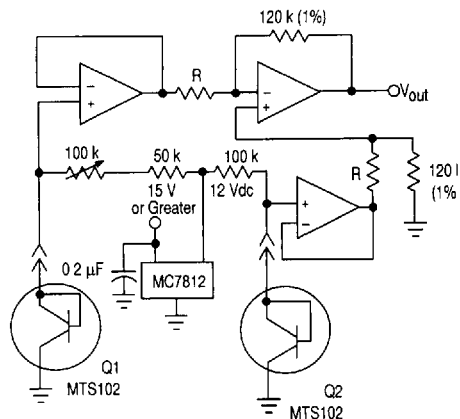
TYPICAL CIRCUITS



NOTE: With Q1 at a known temperature, adjust R_{CAL} to set output voltage to $V_{out} = TEMP \times 10 \text{ mV}$. Output of MTS102, 3, 5 is then converted to $V_{out} = 10 \text{ mV}/^{\circ}\text{C}$ or $^{\circ}\text{K}$

$R = 27 \text{ k}\Omega$ (1%) for $^{\circ}\text{C}$ or $^{\circ}\text{K}$

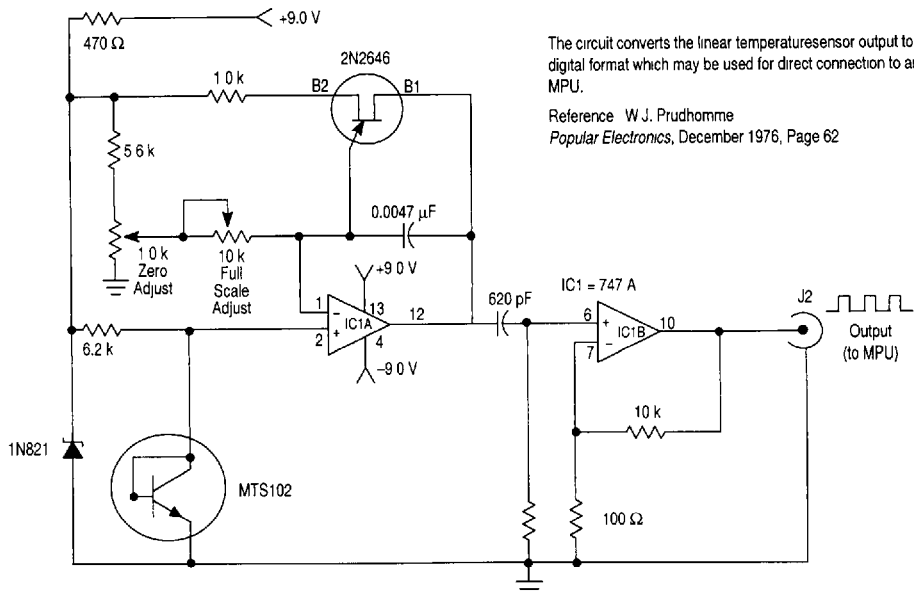
Figure 6. Absolute Temperature Measurement



NOTE: With Q1 and Q2 at identical temperature, adjust R_{CAL} for $V_{out} = 0.000 \text{ V}$

$R = 15 \text{ k}\Omega$ (1%) for $^{\circ}\text{F}$

Figure 7. Differential Temperature Measurement 0 To 150°C



The circuit converts the linear temperature sensor output to a digital format which may be used for direct connection to an MPU.

Reference: W.J. Prudhomme
Popular Electronics, December 1976, Page 62

All resistors are 10% 1/4 watt except 6.2 k which is 5% 1/4 watt

Figure 8. Temperature Sensor to Digital MPU Circuit