

## 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  $-40^{\circ}\text{C}$  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 <sup>(5)</sup>	$I_C$	100	mAdc
Operating and Storage Junction Temperature Range	$T_J, T_{stg}$	$-55$ to $+150$	$^{\circ}\text{C}$

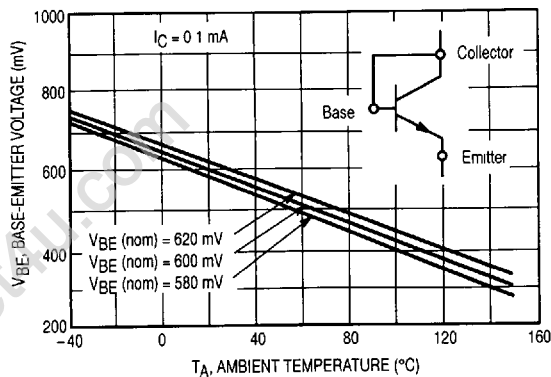


Figure 1. Base-Emitter Voltage versus Ambient Temperature

**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 <sup>(1)</sup> ( $I_C = 0.1 \text{ mA}$ , $T_A = 25^\circ\text{C} \pm 0.05^\circ\text{C}$ )	$\Delta V_{BE}$				mV
	MTS102	-3.0	—	3.0	
	MTS103	-4.0	—	4.0	
	MTS105	-7.0	—	7.0	
Temperature Matching Accuracy <sup>(2)</sup> ( $T_1 = 40^\circ\text{C}$ , $T_2 = +150^\circ\text{C}$ , $T_A = 25^\circ\text{C} \pm 0.05^\circ\text{C}$ )	$\Delta T$				$^\circ\text{C}$
	MTS102	-3.0	—	3.0	
	MTS103	-3.0	—	3.0	
	MTS105	-5.0	—	5.0	
Temperature Coefficient <sup>(3,4)</sup> ( $V_{BE} = 595 \text{ mV}$ , $I_C = 0.1 \text{ mA}$ )	$T_C$	-2.28	-2.265	-2.26	$\text{mV}/^\circ\text{C}$
Thermal Time Constant Liquid Flowing Air	$\tau_{TH}$	—	3.0 8.0	—	s
Dependence of $T_C$ on $V_{BE}$ @ $25^\circ\text{C}$ <sup>(4)</sup> (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:

- 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.
- 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)
- 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  $25^\circ\text{C}$ . 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).
- For nominal  $V_{BE}$  at  $25^\circ\text{C}$  other than 595 mV, the  $T_C$  must be corrected using the equation  $T_C = -2.265 + 0.0033(V_{BE} - 595)$  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  $\pm 0.01 \text{ mV}/^\circ\text{C}$ .
- For maximum temperature accuracy,  $I_C$  should not exceed 2 mA. (See Figure 2)

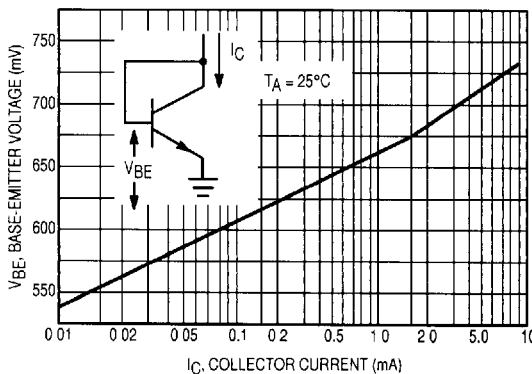


Figure 2. Base-Emitter Voltage versus Collector-Emitter Current

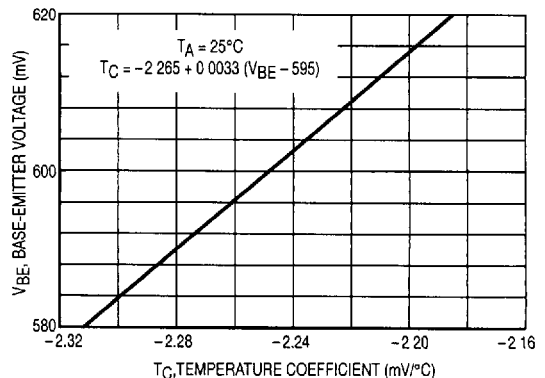
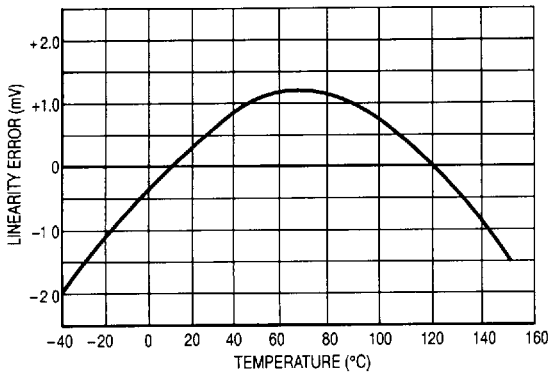
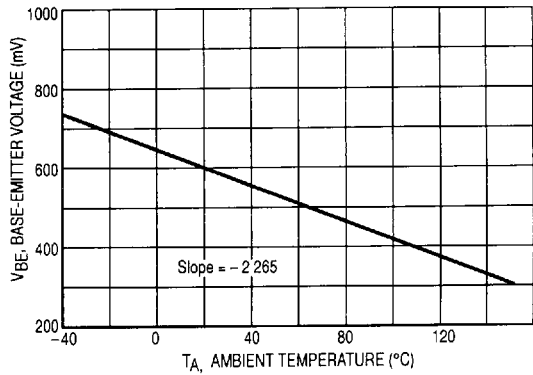


Figure 3. Temperature Coefficient versus Base-Emitter Voltage

**MTS102 MTS103 MTS105**



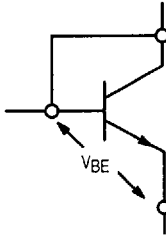
**Figure 4. Linearity Error versus Temperature**



**Figure 5. VBE 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 VBE versus temperature relationship for a typical shipment of various VBE groups.

**EXAMPLE:**

Given — Customer receives a shipment of MTS102 devices. The shipment consists of three groups of different nominal VBE values.

Group 1: VBE (nom) = 595 mV

Group 2: VBE (nom) = 580 mV

Group 3: VBE (nom) = 620 mV

Find — VBE versus temperature Relationship.

1. Determine value of TC:
  - a. If VBE (nom) = 595 mV, TC = -2.265 mV/°C from the Electrical Characteristics table.
  - b. If VBE (nom) is less than or greater than 595 mV determine TC from the relationship described in Note 4. TC = -2.265 + 0.0033 (VBE - 595) or see Figure 3.

2. Determine the VBE value at extremes, -40°C and +150°C:

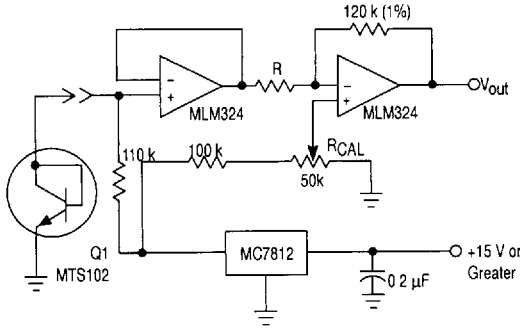
$$V_{BE}(T_A) = V_{BE}(25^\circ\text{C}) + (T_C)(T_A - 25^\circ\text{C})$$

where VBE(TA) = value of VBE at desired temperature.

3. Plot the VBE versus TA curve using two VBE values: VBE (-40°C), VBE(25°C), or VBE(+150°C)
4. Given any measured VBE, the value of TA (to the accuracy value specified: MTS102 - ±2°C, MTS103 - ±35°C, MTS105 - ±5°C) can be read from Figure 5 or calculated from equation 2.
5. Higher temperature accuracies can be achieved if the collector current, IC, 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 ±0.1°C and ±0.01°C.

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

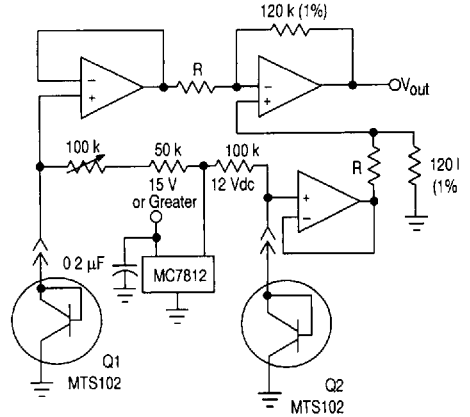
TYPICAL CIRCUITS



NOTE: With Q1 at a known temperature, adjust R<sub>CAL</sub> to set output voltage to V<sub>out</sub> = TEMP x 10 mV. Output of MTS102, 3.5 is then converted to V<sub>out</sub> = 10 mV/° - (°F, °C or °K)

R = 27 kΩ (1%) for °C or °K

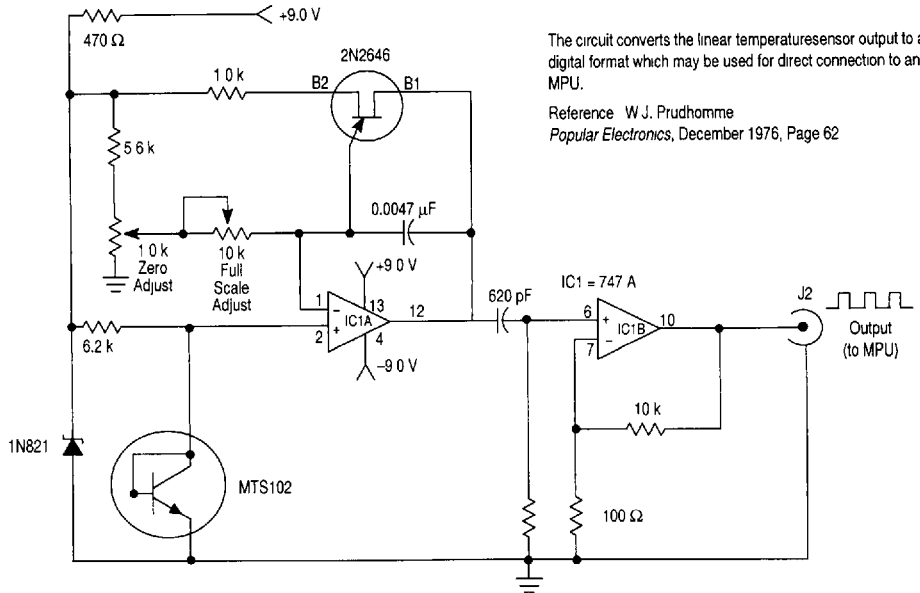
Figure 6. Absolute Temperature Measurement



NOTE: With Q1 and Q2 at identical temperature, adjust R<sub>CAL</sub> for V<sub>out</sub> = 0.000 V

R = 15 kΩ (1%) for °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