

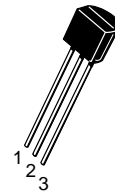
# Silicon Temperature Sensors

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**

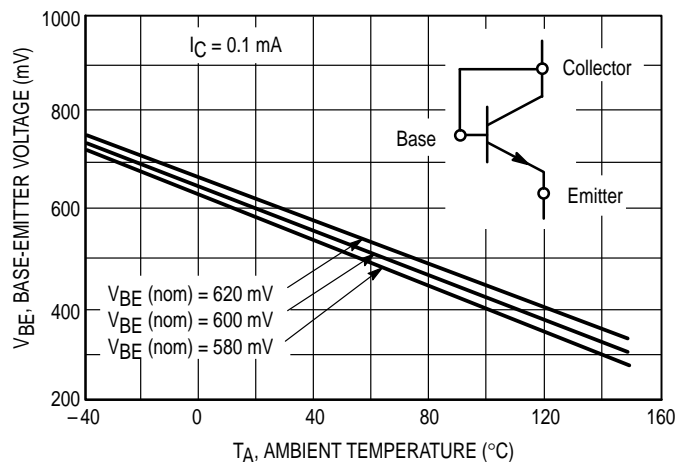


**CASE 29-04, STYLE 1**  
**TO-226AA**  
**(TO-92)**

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**

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# MTS102 MTS103 MTS105

## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Supply Voltage	V <sub>S</sub>	-0.2	—	35	Vdc
Output Voltage	V <sub>out</sub>	-1.0	—	6.0	Vdc
Output Current	I <sub>o</sub>	—	—	10	mAdc
Emitter-Base Breakdown Voltage (I <sub>E</sub> = 100 μAdc, I <sub>C</sub> = 0)	V <sub>(BR)EBO</sub>	4.0	—	—	Vdc
Base-Emitter Voltage (I <sub>C</sub> = 0.1 mA)	V <sub>BE</sub>	580	595	620	mV
Base-Emitter Voltage Matching <sup>(1)</sup> (I <sub>C</sub> = 0.1 mA, T <sub>A</sub> = 25°C ± 0.05°C)	ΔV <sub>BE</sub>	MTS102 -3.0 MTS103 -4.0 MTS105 -7.0	—	3.0 4.0 7.0	mV
Temperature Matching Accuracy <sup>(2)</sup> (T <sub>1</sub> = 40°C, T <sub>2</sub> = +150°C, T <sub>A</sub> = 25°C ± 0.05°C)	ΔT	MTS102 -3.0 MTS103 -3.0 MTS105 -5.0	—	3.0 3.0 5.0	°C
Temperature Coefficient <sup>(3,4)</sup> (V <sub>BE</sub> = 595 mV, I <sub>C</sub> = 0.1 mA)	T <sub>C</sub>	-2.28	-2.265	-2.26	mV/°C
Thermal Time Constant Liquid Flowing Air	τ <sub>TH</sub>	—	3.0 8.0	—	s
Dependence of T <sub>C</sub> on V <sub>BE</sub> @ 25°C <sup>(4)</sup> (Figure 3)	ΔT <sub>C</sub> /ΔV <sub>BE</sub>	—	0.0033	—	mV/°C mV

## THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Ambient	R <sub>θJA</sub>	—	—	200	°C/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<sub>BE</sub> to the tolerance identified in the electrical characteristics table. Each device will be labeled with the mean V<sub>BE</sub> 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<sub>C</sub>, V<sub>BE</sub>, and nonlinearity in the range -40 to +150°C. Nonlinearity is typically less than ±1°C in this range. (See Figure 4)
- The T<sub>C</sub> as defined by a least-square linear regression for V<sub>BE</sub> versus temperature over the range -40 to +150°C for a nominal V<sub>BE</sub> of 595 mV at 25°C. For other nominal V<sub>BE</sub> values the value of the T<sub>C</sub> must be adjusted for the dependence of the T<sub>C</sub> on V<sub>BE</sub> (see Note 4).
- For nominal V<sub>BE</sub> at 25°C other than 595 mV, the T<sub>C</sub> must be corrected using the equation T<sub>C</sub> = -2.265 + 0.003 (V<sub>BE</sub> - 595) where V<sub>BE</sub> is in mV and the T<sub>C</sub> is in mV/°C. The accuracy of this T<sub>C</sub> is typically ±0.01 mV/°C.
- For maximum temperature accuracy, I<sub>C</sub> should not exceed 2 mA. (See Figure 2)

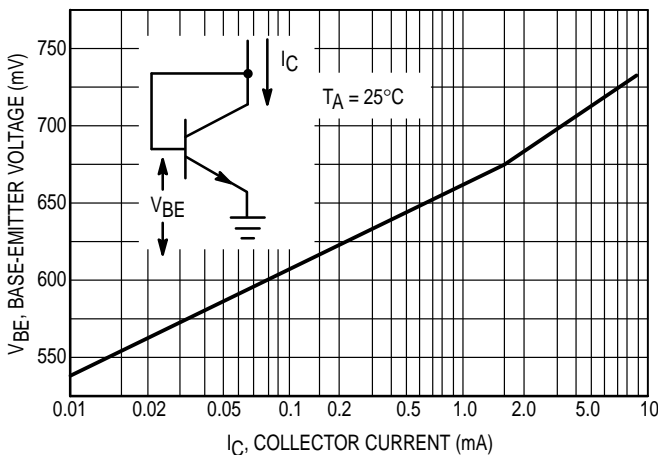


Figure 2. Base-Emitter Voltage versus Collector-Emitter Current

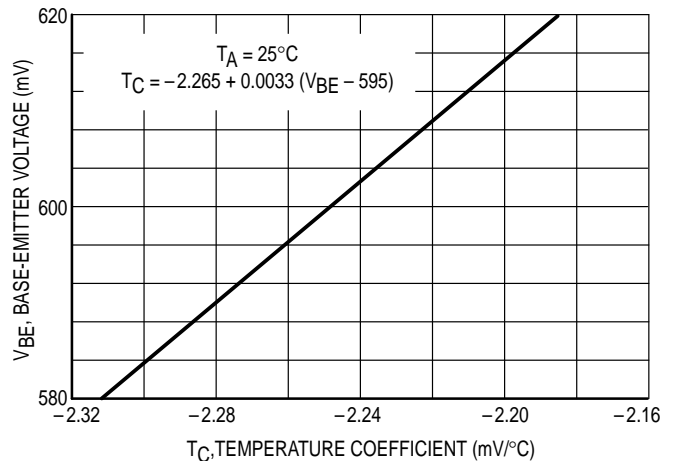


Figure 3. Temperature Coefficient versus Base-Emitter Voltage

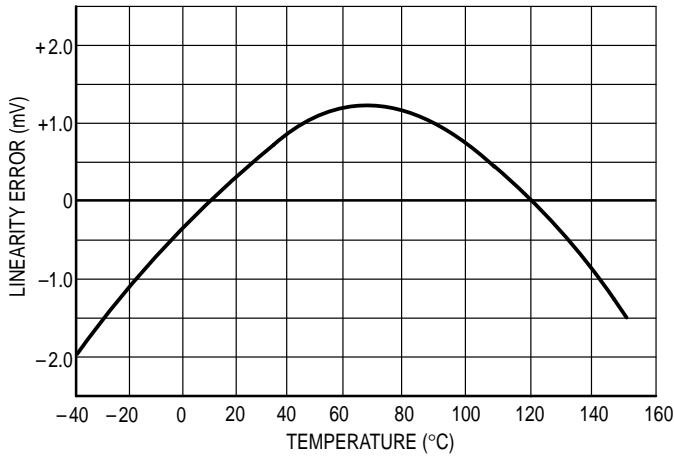


Figure 4. Linearity Error versus Temperature

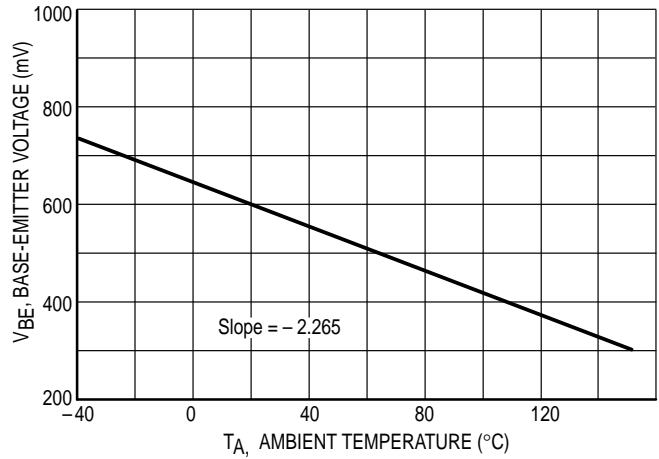
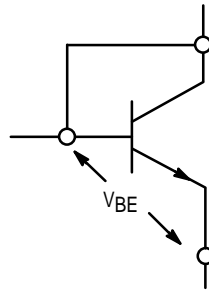


Figure 5.  $V_{BE}$  versus Ambient Temperature

**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:  $V_{BE}$  (nom) = 595 mV

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

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

Find —  $V_{BE}$  versus temperature Relationship.

1. Determine value of  $T_C$ :
  - a. If  $V_{BE}$  (nom) = 595 mV,  $T_C = -2.265$  mV/°C from the Electrical Characteristics table.
  - b. If  $V_{BE}$  (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,  $-40^\circ\text{C}$  and  $+150^\circ\text{C}$ :

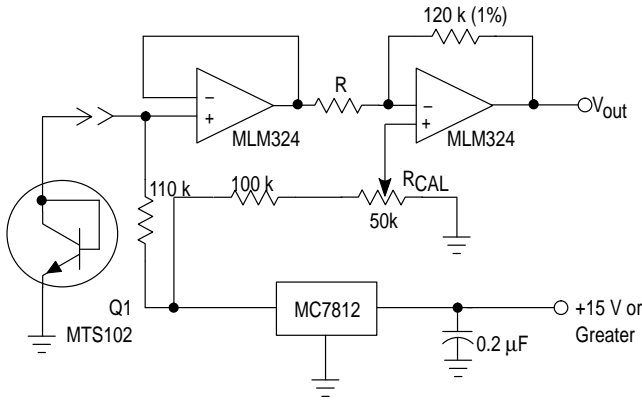
$$V_{BE}(T_A) = V_{BE}(25^\circ\text{C}) + (T_C)(T_A - 25^\circ\text{C})$$

where  $V_{BE}(T_A)$  = value of  $V_{BE}$  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.

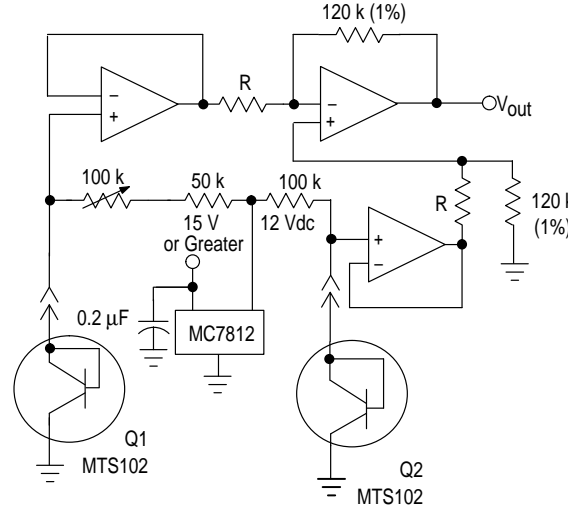
TYPICAL CIRCUITS



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  $V_{out} = 10 \text{ mV}/^\circ - (^\circ\text{F}, ^\circ\text{C} \text{ or } ^\circ\text{K})$

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

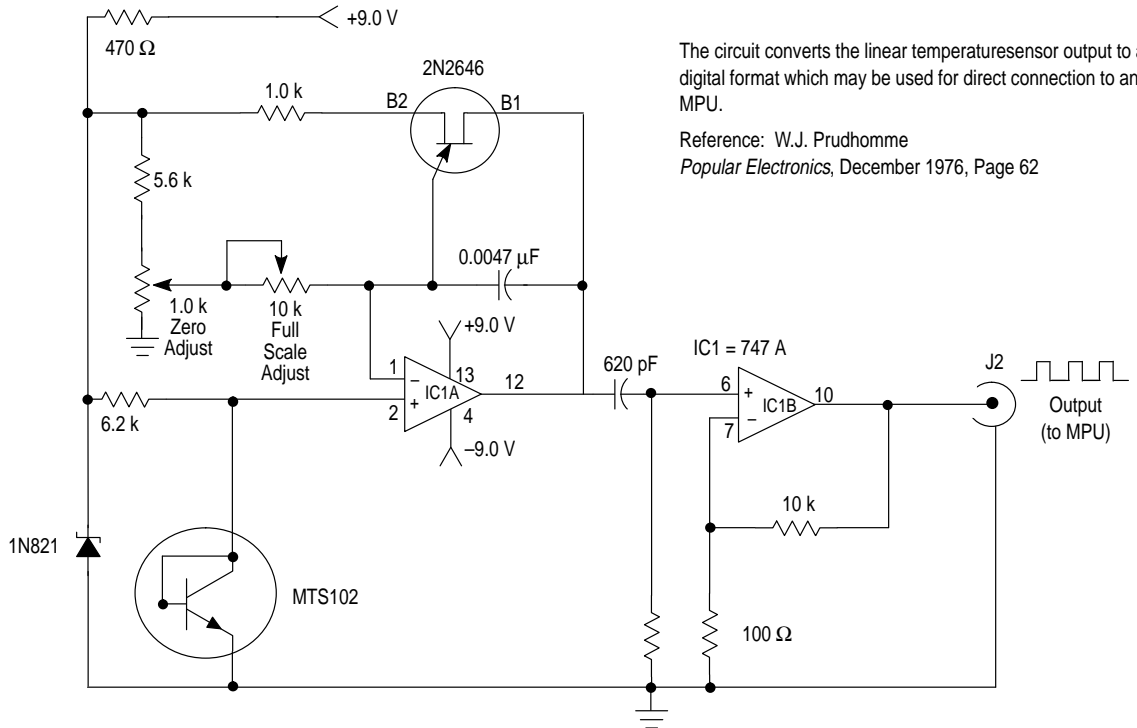
Figure 6. Absolute Temperature Measurement



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



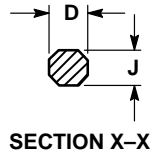
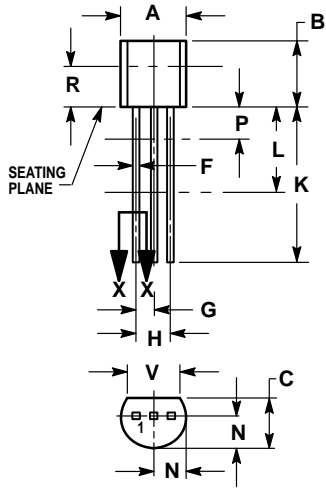
The circuit converts the linear temperature sensor output to a digital format which may be used for direct connection to an MPU.

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

OUTLINE DIMENSIONS




STYLE 1:  
 PIN 1. EMITTER  
 2. BASE  
 3. COLLECTOR

NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K MINIMUM. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.022	0.41	0.55
F	0.016	0.019	0.41	0.48
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	—	12.70	—
L	0.250	—	6.35	—
N	0.080	0.105	2.04	2.66
P	—	0.100	—	2.54
R	0.115	—	2.93	—
V	0.135	—	3.43	—

CASE 029-04  
 (TO-226AA)  
 ISSUE AD

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