MOTOROLA Semiconductors

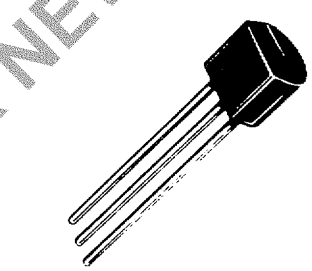
MTS102
MTS103
MTS105

SILICON TEMPERATURE SENSORS

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

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

SILICON TEMPERATURE SENSORS

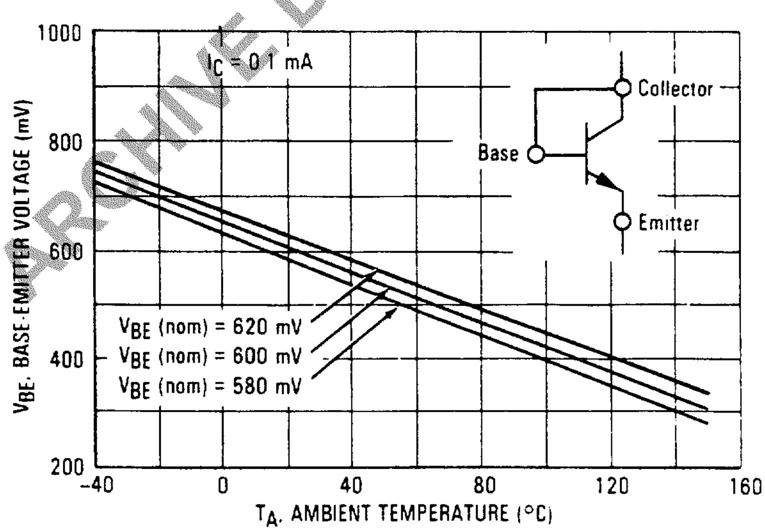


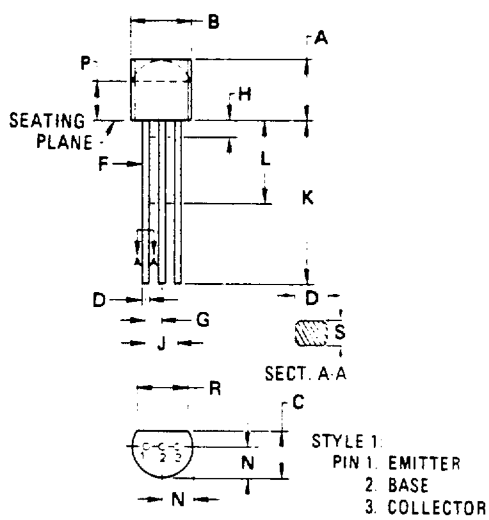
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current — Continuous*	I_C	100	mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

*See Note 5, page 2

FIGURE 1 — BASE-EMITTER VOLTAGE versus AMBIENT TEMPERATURE





DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	4.32	5.33	0.170	0.210
B	4.44	5.21	0.175	0.205
C	3.18	4.19	0.125	0.165
D	0.41	0.56	0.016	0.022
F	0.41	0.48	0.016	0.019
G	1.14	1.40	0.045	0.055
H	–	2.54	–	0.100
J	2.41	2.67	0.095	0.105
K	12.70	–	0.500	–
L	6.35	–	0.250	–
N	2.03	2.92	0.080	0.115
P	2.92	–	0.115	–
R	3.43	–	0.135	–
S	0.36	0.41	0.014	0.016

All JEDEC dimensions and notes apply

CASE 29-02
TO-92

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	$V_{(BR)EBO}$	4.0	—	—	Vdc
Base-Emitter Voltage (I_C = 0.1 mA)	V_{BE}	580	595	620	mV
Base-Emitter Voltage Matching, Note 1 (I_C = 0.1 mA, T_A = 25°C ±0.05°C)	ΔV_{BE}				mV
MTS102		—	—	±3.0	
MTS103		—	—	±4.0	
MTS105		—	—	±7.0	
Temperature Matching Accuracy, Note 2 (T1 = 40°C, T2 = +150°C, T_A = 25°C ±0.05°C)	ΔT				°C
MTS102		—	—	±2.0	
MTS103		—	—	±3.0	
MTS105		—	—	±5.0	
Temperature Coefficient, Notes 3 and 4 (V_{BE} = 595 mV, I_C = 0.1 mA)	TC	-2.28	-2.265	-2.26	mV/°C
Thermal Time Constant	τ_{TH}				s
Liquid		—	3.0	—	
Flowing Air		—	8.0	—	
Dependence of TC on V_{BE} @ 25°C (Note 4, Figure 3)	$\Delta TC/\Delta V_{BE}$	—	0.0033	—	mV/°C / mV

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W

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. Includes variations in TC, V_{BE}, and nonlinearity in the range -40 to +150°C. Nonlinearity is typically less than ±1°C in this range. (See Figure 4)
3. The TC as defined by a least-square linear regression for V_{BE} versus temperature over the range -40 to +150°C for a nominal V_{BE} of 595 mV at 25°C. For other nominal V_{BE} values the value of the TC must be adjusted for the dependence of the TC on V_{BE} (see Note 4)
4. For nominal V_{BE} at 25°C other than 595 mV, the TC must be corrected using the equation TC = -2.265 + 0.003 (V_{BE} - 595) where V_{BE} is in mV and the TC is in mV/°C. The accuracy of this TC is typically ±0.01 mV/°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

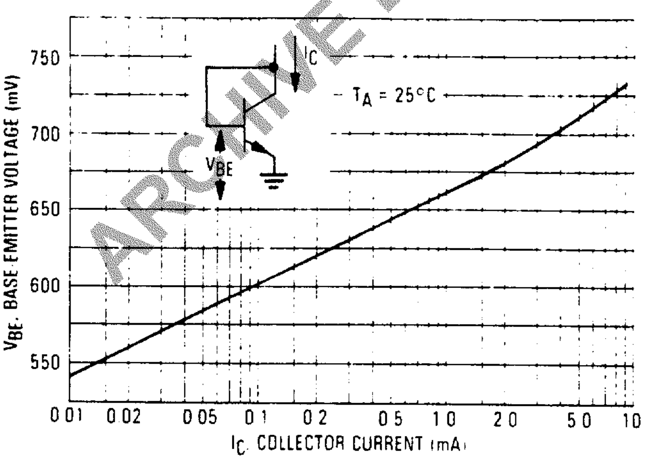


FIGURE 3 — TEMPERATURE COEFFICIENT versus BASE-EMITTER VOLTAGE

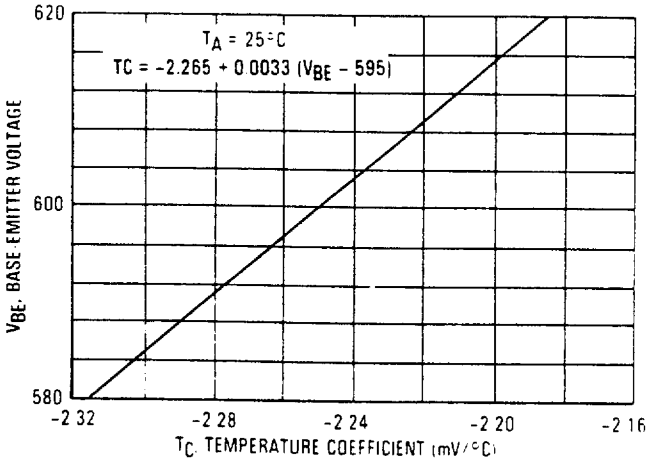
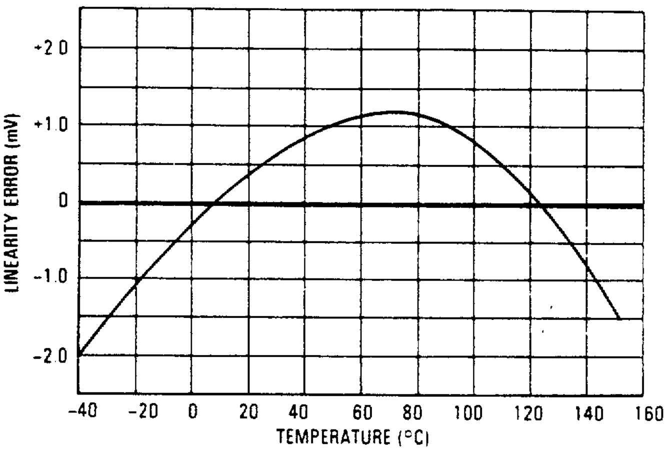
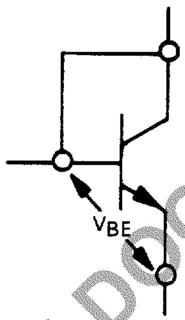


FIGURE 4 — LINEARITY ERROR versus TEMPERATURE



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.

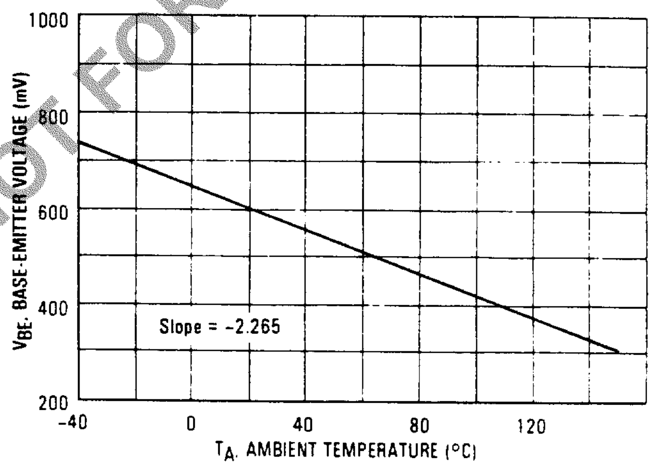
Group 1: V_{BE} (nom) = 595 mV
Group 2: V_{BE} (nom) = 580 mV
Group 3: V_{BE} (nom) = 620 mV

Find — V_{BE} versus Temperature Relationship.

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

2. Determine the V_{BE} value at the extremes, -40°C and +150°C:
   (2) $V_{BE(T_A)} = V_{BE(25°C)} + (TC)(T_A - 25°C)$ 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: $V_{BE(-40°C)}$, $V_{BE(25°C)}$, or $V_{BE(+150°C)}$.

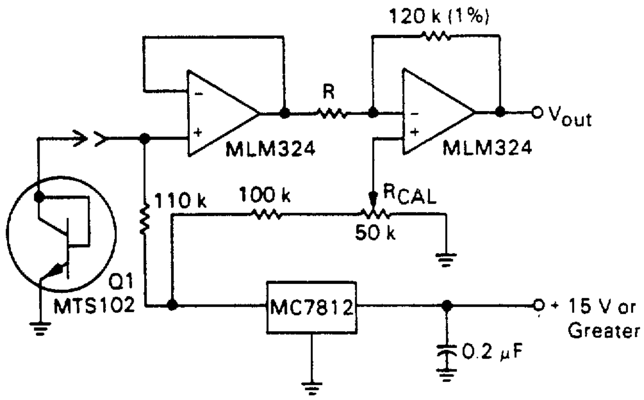


4. Given any measured V_{BE}, the value of T_A (to the accuracy value specified: MTS102 - ±2°C, MTS103 - ±3°C, MTS105 - ±5°C) can be read from the above curve, or calculated from equation 2.

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 these sensors have yielded 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*.

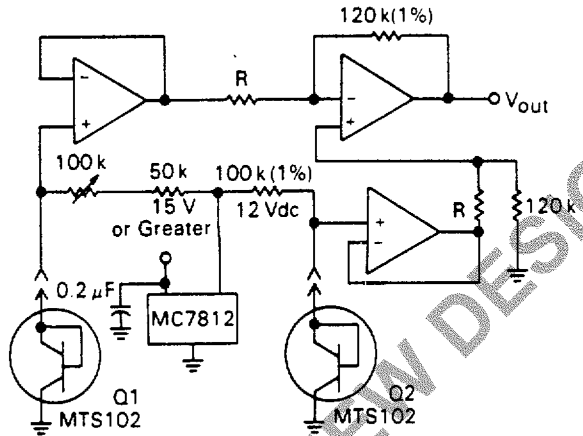
TYPICAL CIRCUITS

FIGURE 5 — ABSOLUTE TEMPERATURE MEASUREMENT



NOTE: With Q1 at a known temperature, adjust R_{CAL} to set output voltage to V_{out} = TEMP × 10 mV. Output of MTS102, 3, 5 is then converted to V_{out} = 10 mV/° - (°F, °C, or °K)

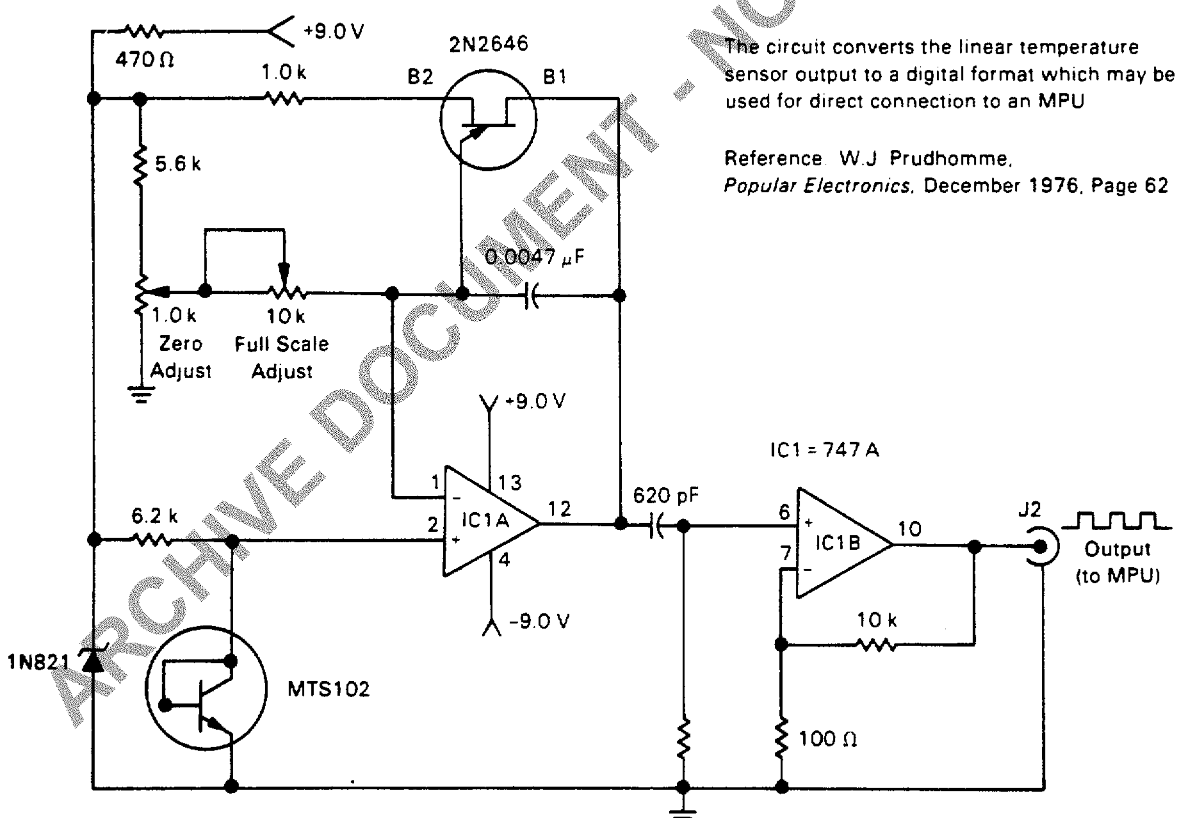
FIGURE 6 — DIFFERENTIAL TEMPERATURE MEASUREMENT 0 to 150°C



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

R = 27 kΩ (1%) for °C or °K R = 15 kΩ (1%) for °F

FIGURE 7 — TEMPERATURE SENSOR TO DIGITAL MPU CIRCUIT



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.

MOTOROLA *Semiconductor Products Inc.*

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