

FEATURES

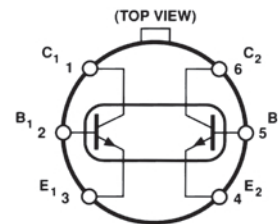
Low V_{OS} (V_{BE} Match): 40 μV typ, 100 μV max
Low TCV_{OS} : 0.5 $\mu\text{V}/^\circ\text{C}$ max
High h_{FE} : 500 min
Excellent h_{FE} Linearity from 10 nA to 10 mA
Low Noise Voltage: 0.23 μV p-p—0.1 Hz to 10 Hz
High Breakdown: 45 V min

PRODUCT DESCRIPTION

The MAT01 is a monolithic dual NPN transistor. An exclusive Silicon Nitride "Triple-Passivation" process provides excellent stability of critical parameters over both temperature and time. Matching characteristics include offset voltage of 40 μV , temperature drift of 0.15 $\mu\text{V}/^\circ\text{C}$, and h_{FE} matching of 0.7%. Very high h_{FE} is provided over a six decade range of collector current, including an exceptional h_{FE} of 590 at a collector current of only 10 nA. The high gain at low collector current makes the MAT01 ideal for use in low power, low level input stages.

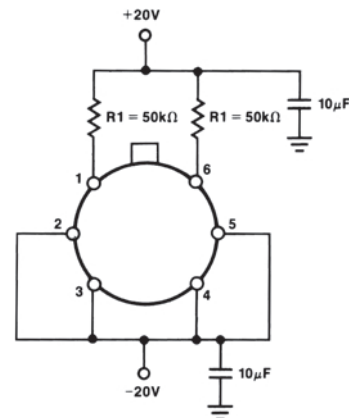
PIN CONNECTION

TO-78
 (H Suffix)



NOTE: Substrate is connected to case.

BURN-IN CIRCUIT



REV. B

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices.

MAT01—SPECIFICATIONS

ELECTRICAL CHARACTERISTICS (@ $V_{CB} = 15\text{ V}$, $I_C = 10\ \mu\text{A}$, $T_A = 25^\circ\text{C}$, unless otherwise noted.)

| Parameter | Symbol | Conditions | MAT01AH | | | MAT01GH | | | Unit | | |
|--------------------------|-------------------------------|---|---------------------------|---|--------------------------|---------|------|-----|---------------------------|------------------------------|------------------------------|
| | | | Min | Typ | Max | Min | Typ | Min | | | |
| Breakdown Voltage | BV_{CEO} | $I_C = 100\ \mu\text{A}$ | 45 | | | 45 | | | V | | |
| Offset Voltage | V_{OS} | | | 0.04 | 0.1 | | 0.10 | 0.5 | mV | | |
| Offset Voltage Stability | V_{OS}/Time | (Note 1) | | 2.0 | | | 2.0 | | $\mu\text{V}/\text{Mo}$ | | |
| First Month | | | (Note 2) | | 0.2 | | | 0.2 | | $\mu\text{V}/\text{Mo}$ | |
| Long Term | | | | | 0.1 | 0.6 | | 0.2 | 3.2 | nA | |
| Offset Current | I_{OS} | | | 13 | 20 | | 18 | 40 | nA | | |
| Bias Current | I_B | | | 590 | | | 430 | | | | |
| Current Gain | h_{FE} | $I_C = 10\ \text{nA}$ | | 500 | 770 | | 250 | 560 | | | |
| | | $I_C = 10\ \mu\text{A}$ | | | 840 | | | 610 | | | |
| | | $I_C = 10\ \text{mA}$ | | | 0.7 | 3.0 | | 1.0 | 8.0 | % | |
| Current Gain Match | Δh_{FE} | $I_C = 10\ \mu\text{A}$ | | | 0.8 | | | 1.2 | % | | |
| | | $100\ \text{nA} \leq I_C \leq 10\ \text{mA}$ | | | | | | | | | |
| Low Frequency Noise | $e_n\ \text{p-p}$ | 0.1 Hz to 10 Hz ³ | | 0.23 | 0.4 | | 0.23 | 0.4 | $\mu\text{V}\ \text{p-p}$ | | |
| Broadband Noise | | | $e_n\ \text{rms}$ | 1 Hz to 10 kHz | | 0.60 | | | 0.60 | | $\mu\text{V}\ \text{rms}$ |
| Voltage | e_n | $f_O = 10\ \text{Hz}^3$ | | | | 7.0 | 9.0 | | 7.0 | 9.0 | $\text{nV}/\sqrt{\text{Hz}}$ |
| Noise Voltage | | | | | $f_O = 100\ \text{Hz}^3$ | | 6.1 | 7.6 | | 6.1 | 7.6 |
| Density | | | $f_O = 1000\ \text{Hz}^3$ | | 6.0 | 7.5 | | 6.0 | 7.5 | $\text{nV}/\sqrt{\text{Hz}}$ | |
| Offset Voltage Change | $\Delta V_{OS}/\Delta V_{CB}$ | $0 \leq V_{CB} \leq 30\ \text{V}$ | | 0.5 | 3.0 | | 0.8 | 8.0 | $\mu\text{V}/\text{V}$ | | |
| Offset Current Change | $\Delta I_{OS}/\Delta V_{CB}$ | $0 \leq V_{CB} \leq 30\ \text{V}$ | | 2 | 15 | | 3 | 70 | pA/V | | |
| Collector-Base | I_{CBO} | $V_{CB} = 30\ \text{V}$, $I_E = 0^4$ | | 15 | 50 | | 25 | 200 | pA | | |
| Leakage Current | | | I_{CES} | $V_{CE} = 30\ \text{V}$, $V_{BE} = 0^{4,5}$ | | 50 | 200 | | 90 | 400 | pA |
| Collector-Emitter | I_{CC} | $V_{CC} = 30\ \text{V}^5$ | | | | 20 | 200 | | 30 | 400 | pA |
| Leakage Current | | | $V_{CE(\text{SAT})}$ | $I_B = 0.1\ \text{mA}$, $I_C = 1\ \text{mA}$ | | 0.12 | 0.20 | | 0.12 | 0.25 | V |
| Collector Saturation | f_T | $V_{CE} = 10\ \text{V}$, $I_C = 10\ \text{mA}$ | | | | 0.8 | | | 0.8 | | V |
| Voltage | | | C_{OB} | $V_{CB} = 15\ \text{V}$, $I_E = 0$ | | 450 | | | 450 | | MHz |
| Gain-Bandwidth Product | C_{CC} | $V_{CC} = 0$ | | | | 2.8 | | | 2.8 | | pF |
| Output Capacitance | | | | | | 8.5 | | | 8.5 | | pF |
| Collector-Collector | | | | | | | | | | | |
| Capacitance | | | | | | | | | | | |

ELECTRICAL CHARACTERISTICS (@ $V_{CB} = 15\ \text{V}$, $I_C = 10\ \mu\text{A}$, $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$, unless otherwise noted.)

| Parameter | Symbol | Conditions | MAT01AH | | | MAT01GH | | | Unit |
|---------------------|------------|---|-----------|--|------|---------|------|------|------------------------------|
| | | | Min | Typ | Max | Min | Typ | Min | |
| Offset Voltage | V_{OS} | | | 0.06 | 0.15 | | 0.14 | 0.70 | mV |
| Average Offset | TCV_{OS} | (Note 6) | | 0.15 | 0.50 | | 0.35 | 1.8 | $\mu\text{V}/^\circ\text{C}$ |
| Voltage Drift | | | I_{OS} | | 0.9 | 8.0 | | 1.5 | 15.0 |
| Offset Current | TCl_{OS} | (Note 7) | | 10 | 90 | | 15 | 150 | $\text{pA}/^\circ\text{C}$ |
| Average Offset | | | I_B | | 28 | 60 | | 36 | 130 |
| Current Drift | I_{CBO} | $T_A = 125^\circ\text{C}$, $V_{CB} = 30\ \text{V}$, $I_E = 0^4$ | | 167 | 400 | | 77 | 300 | |
| Bias Current | | | I_{CES} | $T_A = 125^\circ\text{C}$, $V_{CE} = 30\ \text{V}$, $V_{BE} = 0^{4,6}$ | | 15 | 80 | | 25 |
| Current Gain | I_{CC} | $T_A = 125^\circ\text{C}$, $V_{CC} = 30\ \text{V}$, (Note 6) | | | | 50 | 300 | | 90 |
| Collector-Base | | | | | | 30 | 200 | | 50 |
| Leakage Current | | | | | | | | | |
| Collector-Emitter | | | | | | | | | |
| Leakage Current | | | | | | | | | |
| Collector-Collector | | | | | | | | | |
| Leakage Current | | | | | | | | | |

TYPICAL ELECTRICAL CHARACTERISTICS (@ $V_{CB} = 15\text{ V}$ and $I_C = 10\ \mu\text{A}$, $T_A = +25^\circ\text{C}$, unless otherwise noted.)

| Parameter | Symbol | Conditions | MAT01N Typical | Unit |
|--------------------------------------|-------------------|--|-------------------|------------------------------|
| Average Offset Voltage Drift | TCV_{OS} | | 0.35 | $\mu\text{V}/^\circ\text{C}$ |
| Average Offset Current Drift | TCI_{OS} | | 15 | $\text{pA}/^\circ\text{C}$ |
| Collector-Emitter-Leakage Current | I_{CES} | $V_{CE} = 30\text{ V}, V_{BE} = 0$ | 90 | pA |
| Collector-Base-Leakage Current | I_{CBO} | $V_{CB} = 30\text{ V}, I_E = 0$ | 25 | pA |
| Gain Bandwidth Product | f_T | $V_{CE} = 10\text{ V}, I_C = 10\text{ mA}$ | 450 | MHz |
| Offset Voltage Stability | $\Delta V_{OS}/T$ | First Month (Note 1) | 2.0 | $\mu\text{V}/\text{Mo}$ |
| | | Long-Term (Note 2) | 0.2 | $\mu\text{V}/\text{Mo}$ |

NOTES

¹Exclude first hour of operation to allow for stabilization.

²Parameter describes long-term average drift after first month of operation.

³Sample tested.

⁴The collector-base (I_{CBO}) and collector-emitter (I_{CES}) leakage currents may be reduced by a factor of two to ten times by connecting the substrate (package) to a potential which is lower than either collector voltage.

⁵ I_{CC} and I_{CES} are guaranteed by measurement of I_{CBO} .

⁶Guaranteed by V_{OS} test ($TCV_{OS} \equiv \frac{V_{OS}}{T}$ for $V_{OS} \ll V_{BE}$) $T = 298^\circ\text{K}$ for $T_A = 25^\circ\text{C}$.

⁷Guaranteed by I_{OS} test limits over temperature.

Specifications subject to change without notice.

MAT01

ABSOLUTE MAXIMUM RATINGS¹

| | |
|--|---|
| Collector-Base Voltage (BV_{CBO}) | |
| MAT01AH, GH | 45 V |
| Collector-Emitter Voltage (BV_{CEO}) | |
| MAT01AH, GH | 45 V |
| Collector-Collector Voltage (BV_{CC}) | |
| MAT01AH, GH | 45 V |
| Emitter-Emitter Voltage (BV_{EE}) | |
| MAT01AH, GH | 45 V |
| Emitter-Base Voltage (BV_{EBO}) ² | 5 V |
| Collector Current (I_C) | 25 mA |
| Emitter Current (I_E) | 25 mA |
| Total Power Dissipation | |
| Case Temperature $\leq 40^\circ\text{C}$ ³ | 1.8 W |
| Ambient Temperature $\leq 70^\circ\text{C}$ ⁴ | 500 mW |
| Operating Ambient Temperature | -55°C to $+125^\circ\text{C}$ |
| Operating Junction Temperature | -55°C to $+150^\circ\text{C}$ |

| | |
|--------------------------------------|---|
| Storage Temperature | -65°C to $+150^\circ\text{C}$ |
| Lead Temperature (Soldering, 60 sec) | 300°C |
| DICE Junction Temperature | -65°C to $+150^\circ\text{C}$ |

NOTES

- ¹Absolute maximum ratings apply to both DICE and packaged devices.
- ²Application of reverse bias voltages in excess of rating shown can result in degradation of h_{FE} and h_{FE} matching characteristics. Do not attempt to measure BV_{EBO} greater than the 5 V rating shown.
- ³Rating applies to applications using heat sinking to control case temperature. Derate linearity at $16.4 \text{ mW}/^\circ\text{C}$ for case temperatures above 40°C .
- ⁴Rating applies to applications not using heat sinking; device in free air only. Derate linearity at $6.3 \text{ mW}/^\circ\text{C}$ for ambient temperatures above 70°C .

ORDERING GUIDE¹

| Model | $V_{OS \text{ max}}$ ($T_A = 25^\circ\text{C}$) | Temperature Range | Package Option |
|----------------------|--|---|----------------|
| MAT01AH ² | 0.1 mV | -55°C to $+125^\circ\text{C}$ | TO-78 |
| MAT01GH | 0.5 mV | -55°C to $+125^\circ\text{C}$ | TO-78 |

NOTES

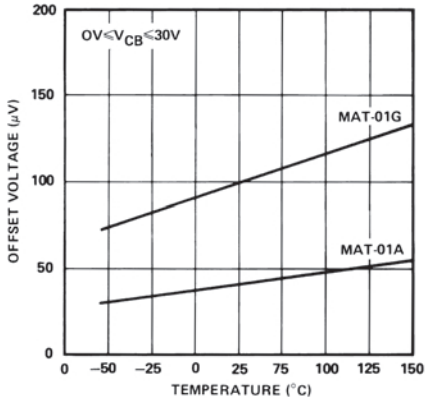
- ¹Burn-in is available on commercial and industrial temperature range parts in TO-can packages.
- ²For devices processed in total compliance to MIL-STD-883, add/883 after part number. Consult factory for 883 data sheet.

CAUTION

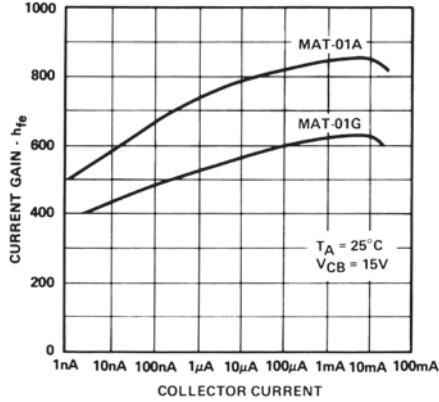
ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the MAT01 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



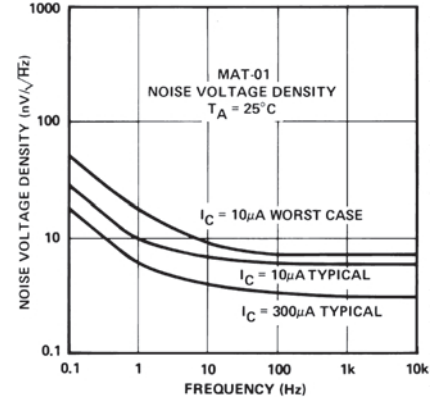
Typical Performance Characteristics—MAT01



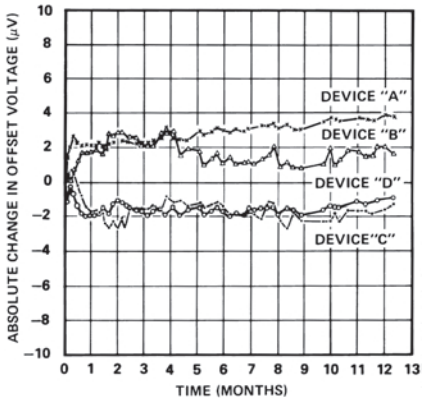
TPC 1. Offset Voltage vs. Temperature



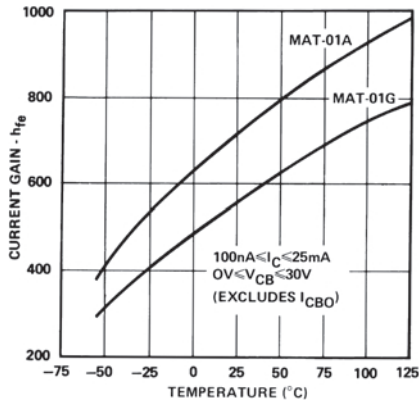
TPC 2. Offset Voltage vs. Time



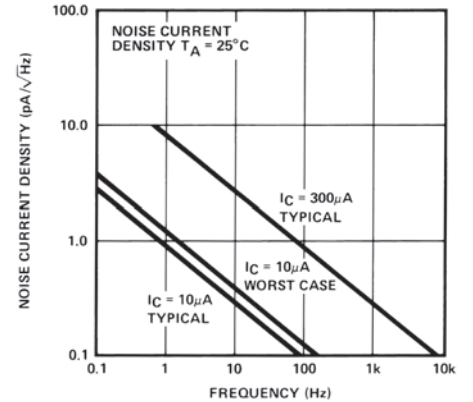
TPC 3. Base-Emitter Voltage vs. Collector Current



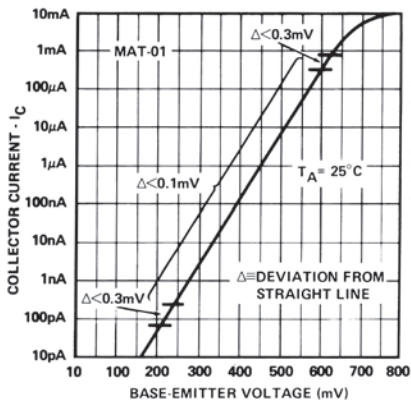
TPC 4. Current Gain vs. Collector Current



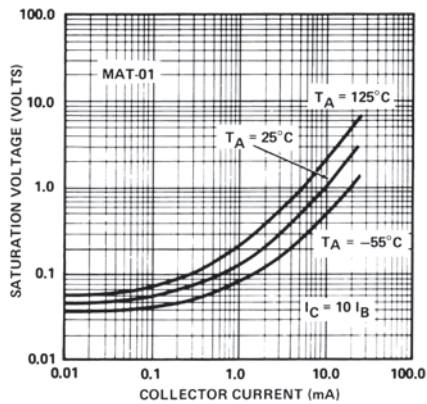
TPC 5. Current Gain vs. Temperature



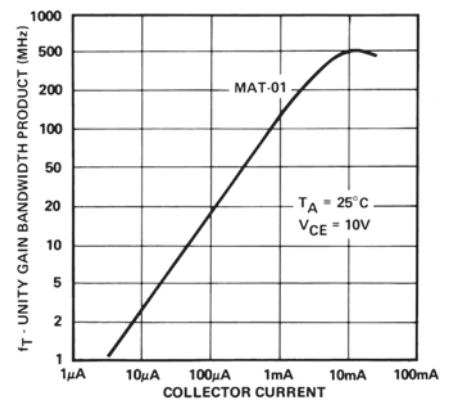
TPC 6. Saturation Voltage vs. Collector Current



TPC 7. Noise Voltage



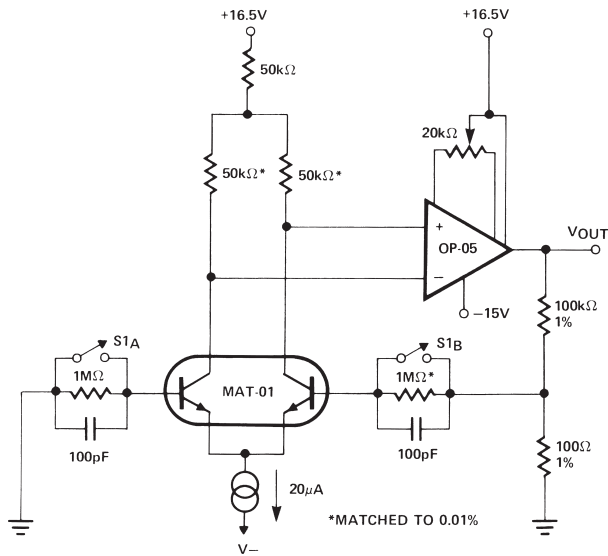
TPC 8. Noise Current Density



TPC 9. Gain-Bandwidth vs. Collector Current

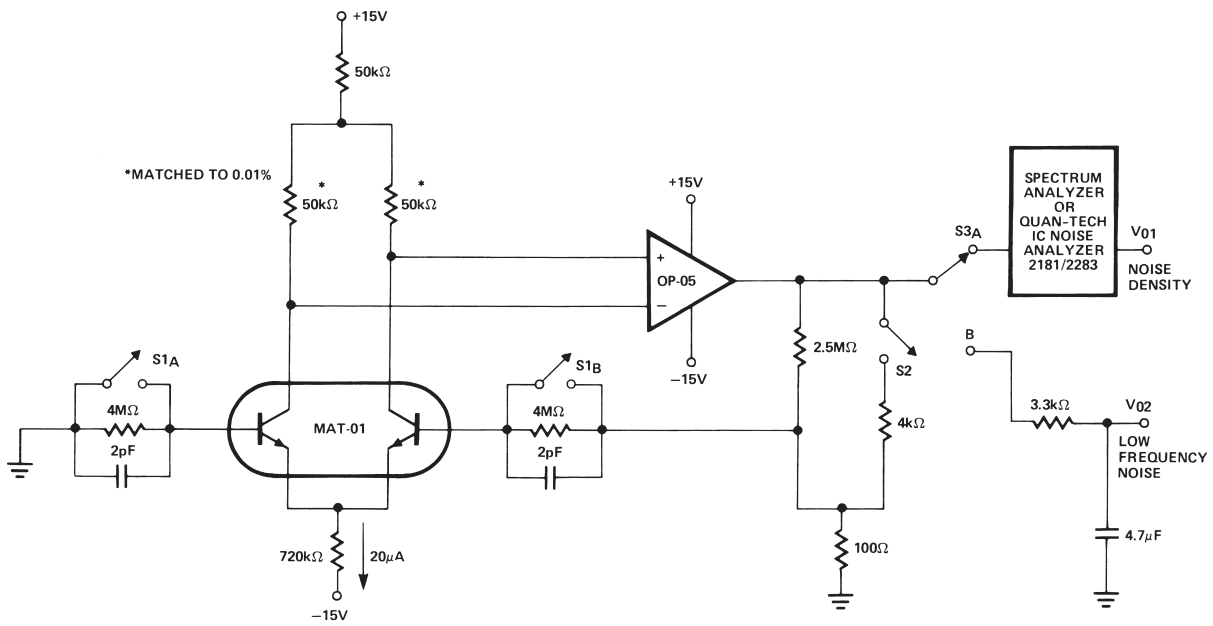
MAT01

MAT01 TEST CIRCUITS



| TEST | SI _A | SI _B | UNITS |
|-----------------|-----------------|-----------------|---|
| V _{OS} | X | X | V _{OUT1} 1 volt per mV |
| I _{OS} | O | O | V _{OUT2} - V _{OUT1} 1 volt per nA |

Figure 1. MAT01 Matching Measurement Circuit



| TEST | SI _A | SI _B | S ₂ | S ₃ | READING |
|--|-----------------|-----------------|----------------|----------------|--|
| Noise Voltage Density (Per Transistor) | X | X | X | A | $V_{01}/\sqrt{2}$ |
| Noise Current Density (Per Transistor) | O | O | X | A | $V_{01}/(\sqrt{2} \times 4M\Omega)$ |
| Low Frequency Noise (Referred to Input) | X | X | O | B | $\frac{V_{02} \text{ PEAK-TO-PEAK}}{25,000}$ |

Figure 2. MAT01 Noise Measurement Circuit

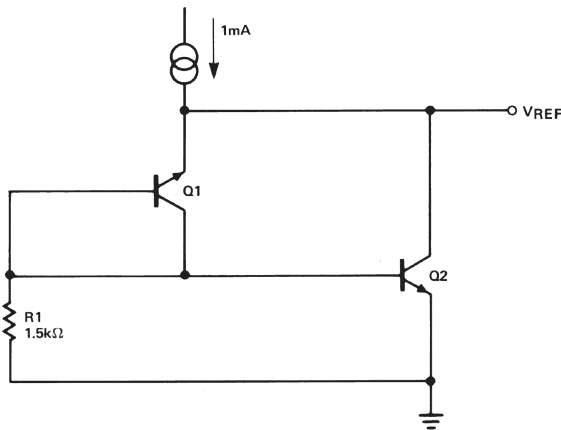
Typical Performance Characteristics—MAT01

APPLICATION NOTES

Application of reverse bias voltages to the emitter-base junctions in excess of ratings (5 V) may result in degradation of h_{FE} and h_{FE} matching characteristics. Circuit designs should be checked to ensure that reverse bias voltages above 5 V cannot be applied during such transient conditions as at circuit turn-on and turn-off.

Stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent realization of the predicted drift performance. Both input terminals should be maintained at the same temperature, preferably close to the temperature of the device's package.

TYPICAL APPLICATIONS



$V_{REF} \approx 7.0V$
 $TCV_{REF} \approx 10ppm/^{\circ}C$
 $R_O \approx 40\Omega$
 R_1 MAY BE ADJUSTED TO MINIMIZE TCV_{REF} . INCREASING R_1 WILL CAUSE A POSITIVE CHANGE IN TCV_{REF} .
 NOTE: h_{FE} OF Q1 WILL BE REDUCED BY OPERATION OF BREAKDOWN MODE.

Figure 3. Precision Reference

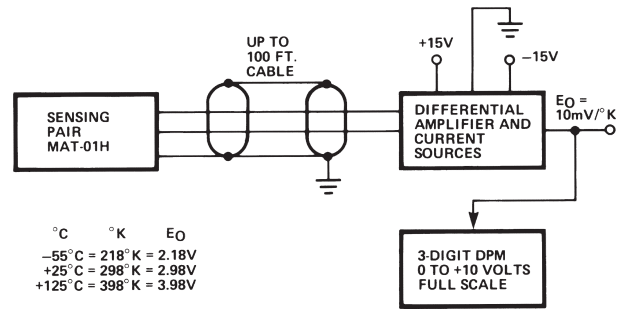


Figure 4. Basic Digital Thermometer Readout in Degrees Kelvin ($^{\circ}K$)

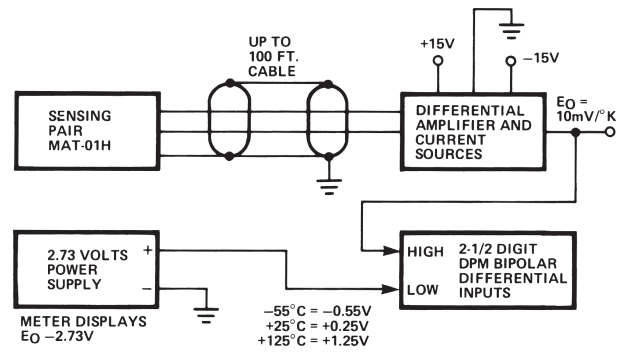
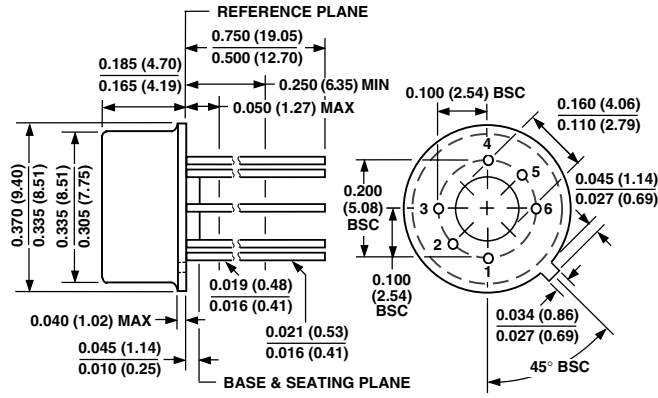


Figure 5. Digital Thermometer with Readout in $^{\circ}C$

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

**H-06A
6-Lead Metal Can (TO-78)**



C00282-0-2/02(B)

Revision History

| Location | Page |
|--|------|
| Data Sheet changed from REV. A to REV. B. | |
| Edits to FEATURES | 1 |
| Deleted WAFER TEST LIMITS | 3 |
| Deleted DICE CHARACTERISTICS | 3 |
| Edits to Table 5 | 7 |

PRINTED IN U.S.A.