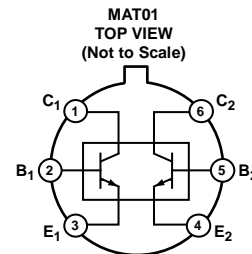


FEATURES**Low V_{OS} (V_{BE} match): 40 μV typical, 100 μV maximum****Low TCV_{OS} : 0.5 $\mu\text{V}/^\circ\text{C}$ maximum****High h_{FE} : 500 minimum****Excellent h_{FE} linearity from 10 nA to 10 mA****Low noise voltage: 0.23 μV p-p from 0.1 Hz to 10 Hz****High breakdown: 45 V min****APPLICATIONS****Weigh scales****Low noise, op amp, front end****Current mirror and current sink/source****Low noise instrumentation amplifiers****Voltage controlled attenuators****Log amplifiers****GENERAL 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%.

PIN CONNECTION DIAGRAM**NOTES**

1. SUBSTRATE IS CONNECTED TO CASE.

Figure 1.

00282-001

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.

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REVISION HISTORY

9/14—Rev. C to Rev. D

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| Changes to Figure 4 and Figure 7 | 6 |
|--|---|

4/13—Rev. B to Rev. C

| | |
|---|-----------|
| Updated Format..... | Universal |
| Added Applications Section, Deleted Figure 2, Renumbered Sequentially..... | 1 |
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| Changes to Table 3 | 5 |
| Changes to Typical Performance Characteristics Section..... | 6 |
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2/02—Rev. A to Rev. B

| | |
|-----------------------------------|---|
| Edits to Features..... | 1 |
| Deleted Wafer Test Limits | 3 |
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| Edits to Table 5..... | 7 |

SPECIFICATIONS

ELECTRICAL CHARACTERISTICS

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

Table 1.

| Parameter | Symbol | Test Conditions/Comments | MAT01AH | | | MAT01GH | | | Unit |
|--|-------------------------------|---|---------|------|------|---------|------|------|------------------------------|
| | | | Min | Typ | Max | Min | Typ | Min | |
| VOLTAGE | | | | | | | | | |
| 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 | | | | | | | | | |
| First Month ¹ | V_{OS}/Time | | | 2.0 | | | 2.0 | | $\mu\text{V}/\text{Mo}$ |
| Long Term ² | | | | 0.2 | | | 0.2 | | $\mu\text{V}/\text{Mo}$ |
| CURRENT | | | | | | | | | |
| Offset Current | I_{OS} | | | 0.1 | 0.6 | | 0.2 | 3.2 | nA |
| Bias Current | I_B | | | 13 | 20 | | 18 | 40 | nA |
| Current Gain | h_{FE} | $I_C = 10\ \text{nA}$ | | 590 | | | 430 | | |
| | | $I_C = 10\ \mu\text{A}$ | 500 | 770 | | 250 | 560 | | |
| | | $I_C = 10\ \text{mA}$ | | 840 | | | 610 | | |
| Current Gain Match | Δh_{FE} | $I_C = 10\ \mu\text{A}$ | | 0.7 | 3.0 | | 1.0 | 8.0 | % |
| | | $100\ \text{nA} \leq I_C \leq 10\ \text{mA}$ | | 0.8 | | | 1.2 | | % |
| NOISE | | | | | | | | | |
| Low Frequency Noise Voltage | $e_n\ \text{p-p}$ | 0.1 Hz to 10 Hz ³ | | 0.23 | 0.4 | | 0.23 | 0.4 | $\mu\text{V p-p}$ |
| Broadband Noise Voltage | $e_n\ \text{rms}$ | 1 Hz to 10 kHz | | 0.60 | | | 0.60 | | $\mu\text{V rms}$ |
| Noise Voltage Density | e_n | $f_0 = 10\ \text{Hz}^3$ | | 7.0 | 9.0 | | 7.0 | 9.0 | $\text{nV}/\sqrt{\text{Hz}}$ |
| | | $f_0 = 100\ \text{Hz}^3$ | | 6.1 | 7.6 | | 6.1 | 7.6 | $\text{nV}/\sqrt{\text{Hz}}$ |
| | | $f_0 = 1000\ \text{Hz}^3$ | | 6.0 | 7.5 | | 6.0 | 7.5 | $\text{nV}/\sqrt{\text{Hz}}$ |
| OFFSET VOLTAGE/CURRENT | | | | | | | | | |
| 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 |
| LEAKAGE | | | | | | | | | |
| Collector to Base Leakage Current | I_{CBO} | $V_{CB} = 30\ \text{V}$, $I_E = 0^4$ | | 15 | 50 | | 25 | 200 | pA |
| Collector to Emitter Leakage Current | I_{CES} | $V_{CE} = 30\ \text{V}$, $V_{BE} = 0^{4,5}$ | | 50 | 200 | | 90 | 400 | pA |
| Collector to Collector Leakage Current | I_{CC} | $V_{CC} = 30\ \text{V}^5$ | | 20 | 200 | | 30 | 400 | pA |
| SATURATION | | | | | | | | | |
| Collector Saturation Voltage | $V_{CE(SAT)}$ | $I_B = 0.1\ \text{mA}$, $I_C = 1\ \text{mA}$ | | 0.12 | 0.20 | | 0.12 | 0.25 | V |
| | | $I_B = 1\ \text{mA}$, $I_C = 10\ \text{mA}$ | | 0.8 | | | 0.8 | | V |
| GAIN BANDWIDTH PRODUCT | | | | | | | | | |
| | f_T | $V_{CE} = 10\ \text{V}$, $I_C = 10\ \text{mA}$ | | 450 | | | 450 | | MHz |
| CAPACITANCE | | | | | | | | | |
| Output Capacitance | C_{OB} | $V_{CB} = 15\ \text{V}$, $I_E = 0$ | | 2.8 | | | 2.8 | | pF |
| Collector to Collector Capacitance | C_{CC} | $V_{CC} = 0$ | | 8.5 | | | 8.5 | | pF |

¹ Exclude first hour of operation to allow for stabilization.

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

³ Sample tested.

⁴ The collector to base (I_{CBO}) and collector to emitter (I_{CES}) leakage currents can be reduced by a factor of 2 to 10 times by connecting the substrate (package) to a potential that is lower than either collector voltage.

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

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

Table 2.

| Parameter | Symbol | Test Conditions/Comments | MAT01AH | | | MAT01GH | | | Unit |
|---|------------|---|---------|------|------|---------|------|------|------------------------------|
| | | | Min | Typ | Max | Min | Typ | Min | |
| OFFSET VOLTAGE/CURRENT | | | | | | | | | |
| Offset Voltage | V_{OS} | | | 0.06 | 0.15 | | 0.14 | 0.70 | mV |
| Average Offset Voltage Drift ¹ | TCV_{OS} | | | 0.15 | 0.50 | | 0.35 | 1.8 | $\mu\text{V}/^\circ\text{C}$ |
| Offset Current | I_{OS} | | | 0.9 | 8.0 | | 1.5 | 15.0 | nA |
| Average Offset Current Drift ² | TCI_{OS} | | | 10 | 90 | | 15 | 150 | $\text{pA}/^\circ\text{C}$ |
| BIAS CURRENT | I_B | | | 28 | 60 | | 36 | 130 | nA |
| CURRENT GAIN | h_{FE} | | | 167 | 400 | | 77 | 300 | |
| LEAKAGE CURRENT | | | | | | | | | |
| Collector to Base Leakage Current | I_{CBO} | $T_A = 125^\circ\text{C}$, $V_{CB} = 30\text{ V}$, $I_E = 0^3$ | | 15 | 80 | | 25 | 200 | nA |
| Collector to Emitter Leakage Current | I_{CES} | $T_A = 125^\circ\text{C}$, $V_{CE} = 30\text{ V}$, $V_{BE} = 0^{1,3}$ | | 50 | 300 | | 90 | 400 | nA |
| Collector to Collector Leakage Current | I_{CC} | $T_A = 125^\circ\text{C}$, $V_{CC} = 30\text{ V}^1$ | | 30 | 200 | | 50 | 400 | nA |

¹ Guaranteed by V_{OS} test $\left(TCV_{OS} \cong \frac{V_{OS}}{T} \text{ for } V_{OS} \ll V_{BE} \right)$, $T = 298\text{ K}$ for $T_A = 25^\circ\text{C}$.

² Guaranteed by I_{OS} test limits over temperature.

³ The collector to base (I_{CBO}) and collector to emitter (I_{CES}) leakage currents can be reduced by a factor of 2 to 10 times by connecting the substrate (package) to a potential that is lower than either collector voltage.

ABSOLUTE MAXIMUM RATINGS

Table 3.

| Parameter ¹ | Rating |
|--|---|
| Breakdown Voltage of | |
| Collector to Base Voltage (BV_{CBO}) | 45 V |
| Collector to Emitter Voltage (BV_{CEO}) | 45 V |
| Collector to Collector Voltage (BV_{CC}) | 45 V |
| Emitter to Emitter Voltage (BV_{EE}) | 45 V |
| Emitter to Base Voltage (BV_{EBO}) ² | 5 V |
| Current | |
| Collector (I_C) | 25 mA |
| Emitter (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 |
| Temperature Range | |
| Operating | -55°C to $+125^\circ\text{C}$ |
| Junction | -55°C to $+150^\circ\text{C}$ |
| Storage | -65°C to $+150^\circ\text{C}$ |
| Lead Temperature (Soldering, 60 sec) | 300°C |

¹ Absolute maximum ratings apply to packaged devices.

² Application 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.

³ Rating 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 .

⁴ Rating 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 .

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

TYPICAL PERFORMANCE CHARACTERISTICS

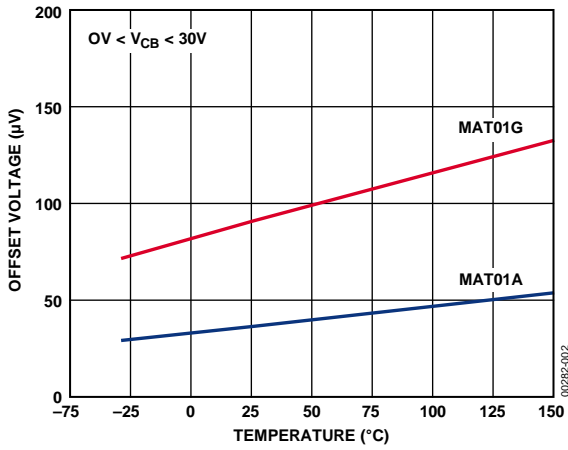


Figure 2. Offset Voltage vs. Temperature

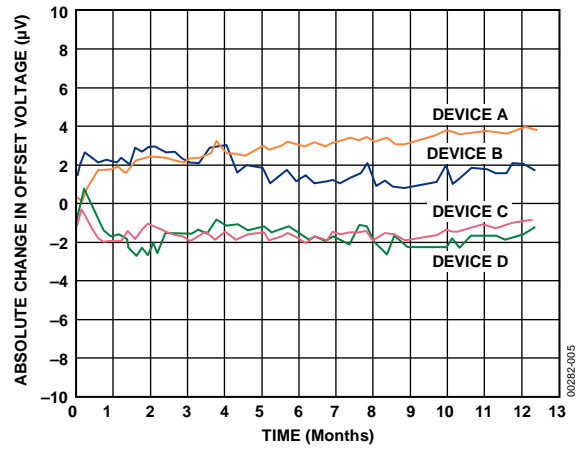


Figure 5. Offset Voltage vs. Time

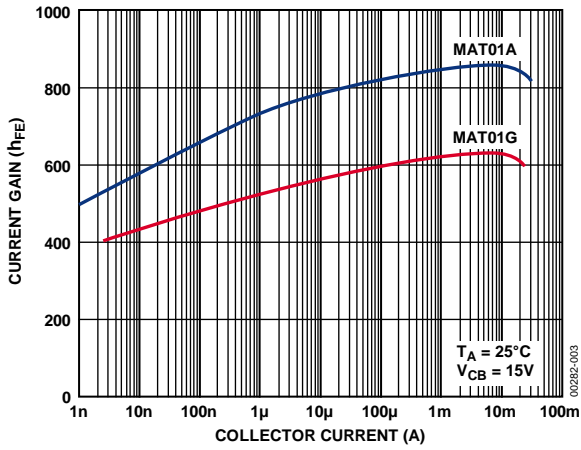


Figure 3. Current Gain vs. Collector Current

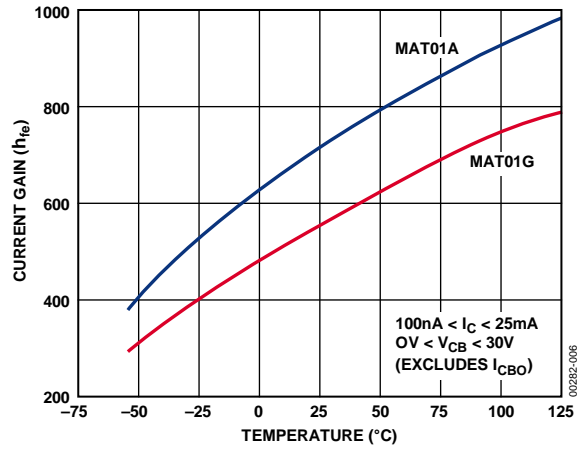


Figure 6. Current Gain vs. Temperature

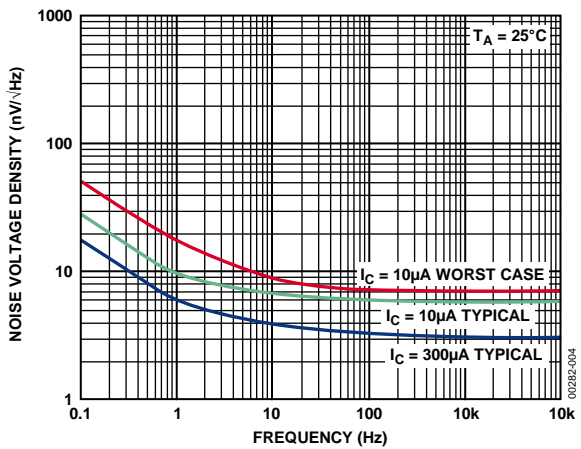


Figure 4. Noise Voltage Density vs. Frequency

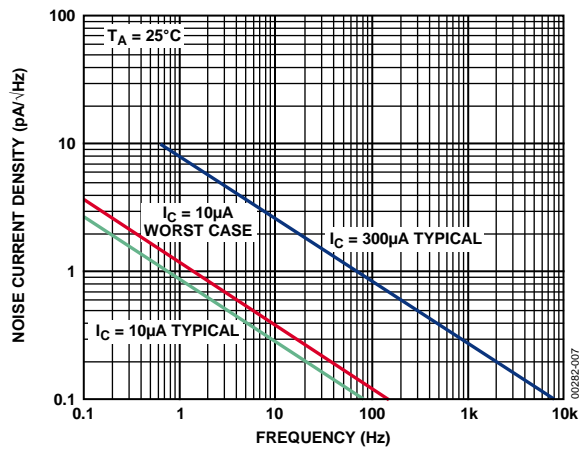


Figure 7. Noise Current Density vs. Frequency

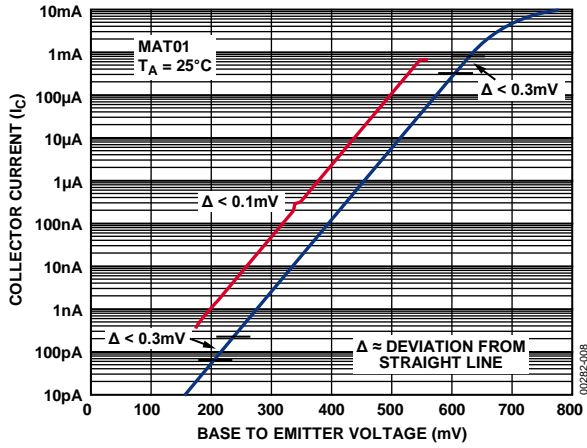


Figure 8. Collector Current vs. Base to Emitter Voltage

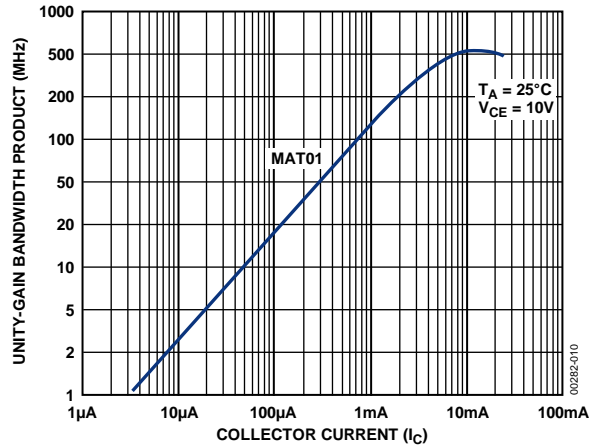


Figure 10. Unity-Gain Bandwidth vs. Collector Current

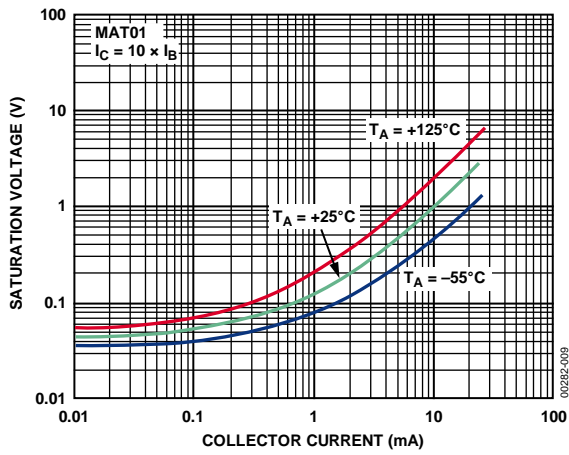


Figure 9. Saturation Voltage vs. Collector Current

TEST CIRCUITS

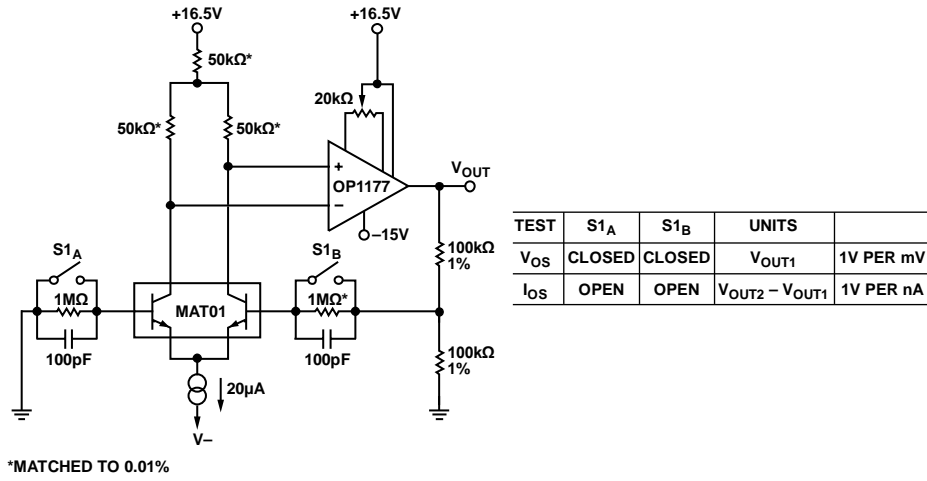
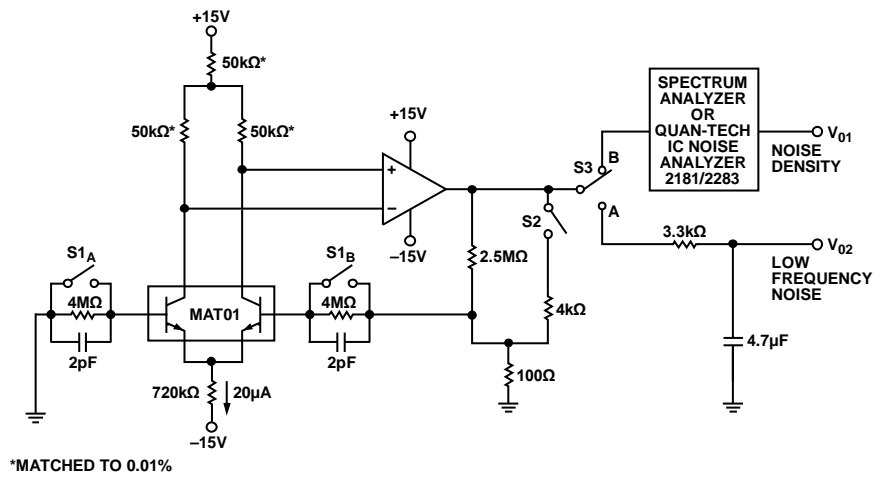


Figure 11. Matching Measurement Circuit



| TEST | S1A | S1B | S2 | S3** | READING |
|---|--------|--------|--------|------|--|
| NOISE VOLTAGE DENSITY (PER TRANSISTOR) | CLOSED | CLOSED | CLOSED | A | $V_{01}/\sqrt{2}$ |
| NOISE CURRENT DENSITY (PER TRANSISTOR) | OPEN | OPEN | CLOSED | A | $V_{01}/(\sqrt{2} \times 4M\Omega)$ |
| LOW FREQUENCY NOISE (REFERRED TO INPUT) | CLOSED | CLOSED | OPEN | B | $\frac{V_{02} \text{ PEAK-TO-PEAK}}{25,000}$ |

**A AND B REFER TO THE THROW POSITION OF THE SWITCH

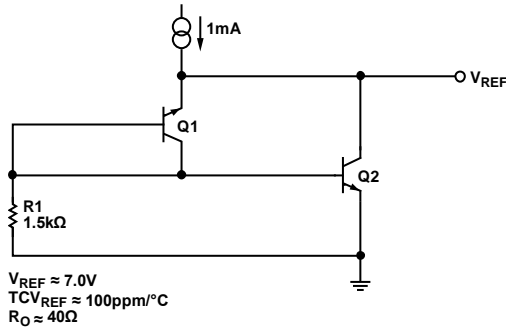
Figure 12. Noise Measurement Circuit

APPLICATIONS INFORMATION

Application of reverse bias voltages to the emitter to base junctions in excess of ratings (5 V) may result in degradation of h_{FE} and h_{FE} matching characteristics. Check circuit designs to ensure that reverse bias voltages above 5 V cannot be applied during transient conditions, such 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. Maintain both input terminals at the same temperature, preferably close to the temperature of the device package.

TYPICAL APPLICATIONS

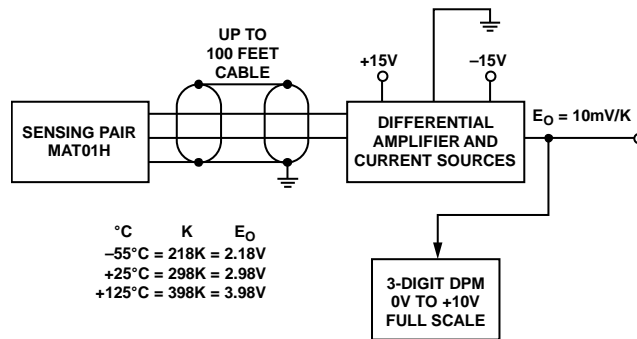


NOTES

1. R1 MAY BE ADJUSTED TO MINIMIZE TCV_{REF} . INCREASING R1 CAUSES A POSITIVE CHANGE IN TCV_{REF} .
2. h_{FE} OF Q1 IS REDUCED BY OPERATION OF BREAKDOWN MODE.

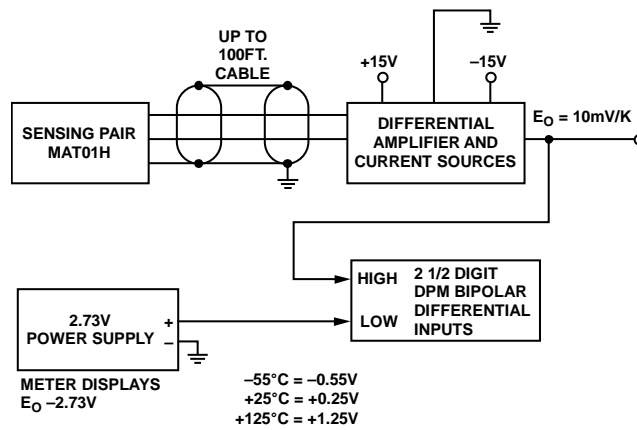
00282-013

Figure 13. Precision Reference



00282-014

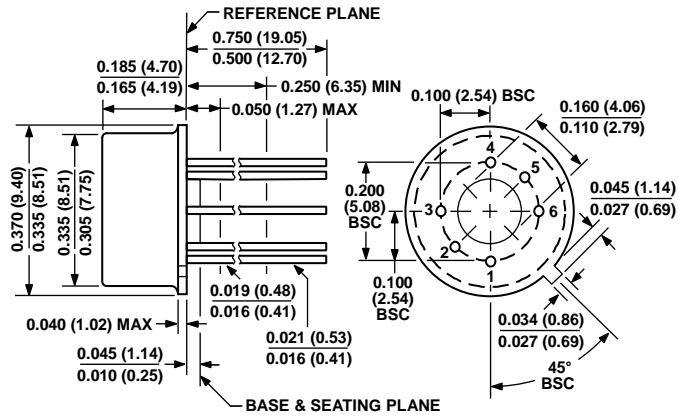
Figure 14. Basic Digital Thermometer Readout in Degrees Kelvin (K)



00282-015

Figure 15. Digital Thermometer with Readout in $^{\circ}C$

OUTLINE DIMENSIONS



CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

022306-A

Figure 16. 6-Pin Metal Header Package [TO-78] (H-06)

Dimensions shown in inches and (millimeters)

ORDERING GUIDE

| Model ¹ | V _{OS} Maximum (T _A = 25°C) | Temperature Range | Package Description | Package Option |
|--------------------|---|-------------------|------------------------------------|----------------|
| MAT01AH | 0.1 mV | -55°C to +125°C | 6-Pin Metal Header Package [TO-78] | H-06 |
| MAT01AHZ | 0.1 mV | -55°C to +125°C | 6-Pin Metal Header Package [TO-78] | H-06 |
| MAT01GH | 0.5 mV | -55°C to +125°C | 6-Pin Metal Header Package [TO-78] | H-06 |
| MAT01GHZ | 0.5 mV | -55°C to +125°C | 6-Pin Metal Header Package [TO-78] | H-06 |

¹ Z = RoHS Compliant Part.

NOTES