# Matched Monolithic Dual Transistor

# MAT01

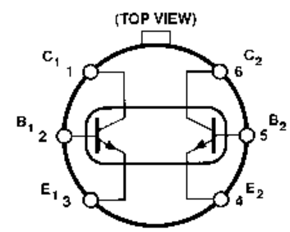
**FEATURES**
**Low $V_{OS}$ ($V_{BE}$ Match): 40 µV typ, 100 µV max**
**Low $TCV_{OS}$: 0.5 µV/°C max**
**High $h_{FE}$: 500 min**
**Excellent $h_{FE}$ Linearity from 10 nA to 10 mA**
**Low Noise Voltage: 0.23 µV p-p—0.1 Hz to 10 Hz**
**High Breakdown: 45 V min**
**Available in Die Form**

## 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 µV/°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.

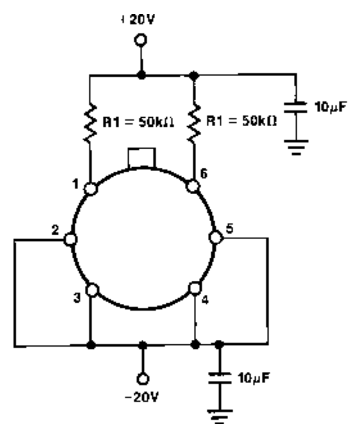
## PIN CONNECTION

**TO-78**
**(H Suffix)**




NOTE: Substrate is connected to case.

## BURN-IN CIRCUIT




REV. A



One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 World Wide Web Site: http://www.analog.com
Fax: 617/326-8703

# MAT01–SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS (@ $V_{CB}$ = 15 V, $I_C$ = 10 μA, $T_A$ = 25°C, unless otherwise noted.)

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

## ELECTRICAL CHARACTERISTICS (@ $V_{CB}$ = 15 V, $I_C$ = 10 μA, –55°C ≤ $T_A$ ≤ +125°C, unless otherwise noted.)

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

## TYPICAL ELECTRICAL CHARACTERISTICS (@ $V_{CB}$ = 15 V and $I_C$ = 10 µA, $T_A$ = +25°C, unless otherwise noted.)

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

NOTES
[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-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 $I_{CBO}$.
[6]Guaranteed by $V_{OS}$ test $(TCV_{OS} \cong \frac{V_{OS}}{T}$ for $V_{OS} \ll V_{BE})$ $T = 298°K$ for $T_A$ = 25°C.
[7]Guaranteed by $I_{OS}$ test limits over temperature.

Specifications subject to change without notice.

## WAFER TEST LIMITS (@ $V_{CB}$ = 15 V, $I_C$ = 10 µA, $T_A$ = +25°C, unless otherwise noted.)

| Parameter | Symbol | Conditions | MAT01N Limits | Units |
|---|---|---|---|---|
| Breakdown Voltage | $BV_{CEO}$ | $I_C$ = 100 µA | 45 | V min |
| Offset Voltage | $V_{OS}$ | | 0.5 | mV max |
| Offset Current | $I_{OS}$ | | 3.2 | nA max |
| Bias Current | $I_B$ | | 40 | nA max |
| Current Gain | $h_{FE}$ | | 250 | min |
| Current Gain Match | $\Delta h_{FE}$ | | 8.0 | % max |
| Offset Voltage Change | $\Delta V_{OS}/\Delta V_{CB}$ | 0 ≤ $V_{CB}$ ≤ 30 V | 8.0 | µV/V max |
| Offset Current Change | $\Delta V_{OS}/\Delta V_{CB}$ | 0 ≤ $V_{CB}$ ≤ 30 V | 70 | pA/V max |
| Collector Saturation Voltage | $V_{CE\,(SAT)}$ | $I_B$ = 0.1 mA, $I_C$ = 1 mA | 0.25 | V max |

NOTE
Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

## ABSOLUTE MAXIMUM RATINGS[1]

Collector-Base Voltage ($BV_{CBO}$)
  MAT01AH, GH, N . . . . . . . . . . . . . . . . . . . . . . . . . . 45 V
Collector-Emitter Voltage ($BV_{CEO}$)
  MAT01AH, GH, N . . . . . . . . . . . . . . . . . . . . . . . . . . 45 V
Collector-Collector Voltage ($BV_{CC}$)
  MAT01AH, GH, N . . . . . . . . . . . . . . . . . . . . . . . . . . 45 V
Emitter-Emitter Voltage ($BV_{EE}$)
  MAT01AH, GH, N . . . . . . . . . . . . . . . . . . . . . . . . . . 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 ≤ 40°C[3] . . . . . . . . . . . . . . . . . . . . 1.8 W
  Ambient Temperature ≤ 70°C[4] . . . . . . . . . . . . . . . 500 mW
Operating Ambient Temperature . . . . . . . . . –55°C to +125°C
Operating Junction Temperature . . . . . . . . . –55°C to +150°C
Storage Temperature . . . . . . . . . . . . . . . . . . –65°C to +150°C
Lead Temperature (Soldering, 60 sec) . . . . . . . . . . . .+300°C
DICE Junction Temperature . . . . . . . . . . . . –65°C to +150°C

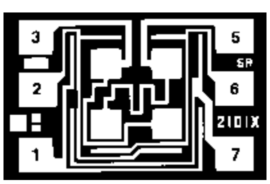
NOTES
[1]Absolute maximum ratings apply to both DICE and packaged devices.
[2]Application of reverse bias voltages in excess of rating shown can result in degradation of $h_{FE}$ and $h_{FE}$ matching characteristics. Do not attempt to measure $BV_{EBO}$ greater than the 5 V rating shown.
[3]Rating applies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

## ORDERING GUIDE[1]

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

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

## DICE CHARACTERISTICS




1. COLLECTOR (1)
2. BASE (1)
3. EMITTER (1)
5. EMITTER (2)
6. BASE (2)
7. COLLECTOR (2)

*DIE SIZE 0.035 × 0.025 inch, 875 sq. mils*
*(0.89 × 0.64 mm, 0.58 sq. mm)*

## 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.

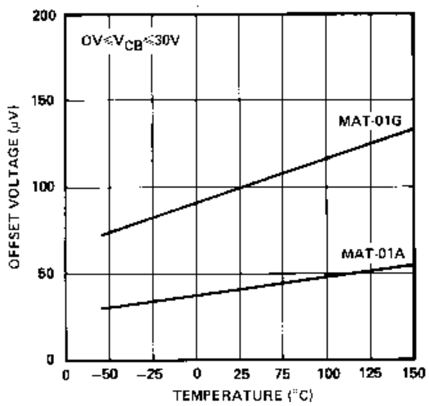



*Figure 1. Offset Voltage vs. Temperature*

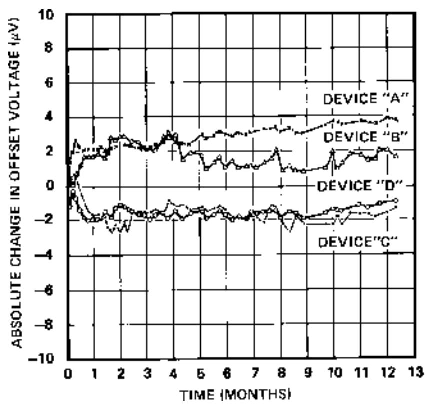



*Figure 4. Offset Voltage vs. Time*

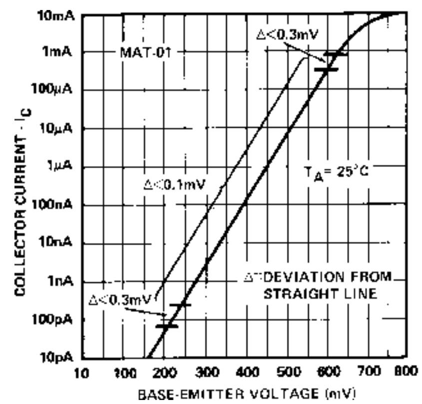



*Figure 7. Base-Emitter Voltage vs. Collector Current*

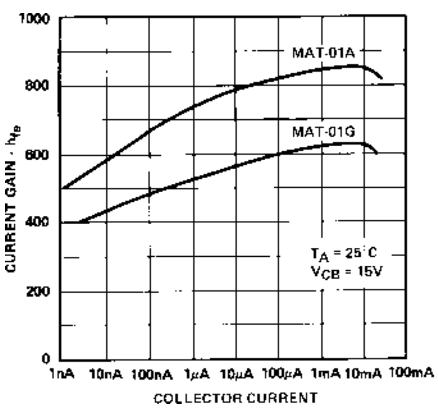



*Figure 2. Current Gain vs. Collector Current*

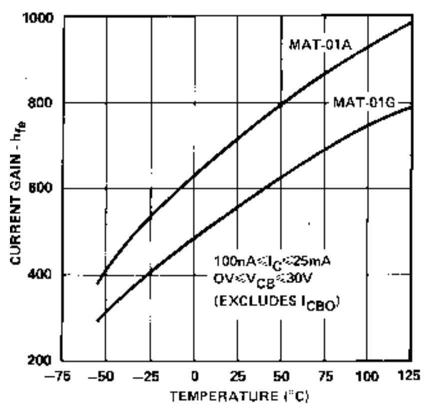



*Figure 5. Current Gain vs. Temperature*

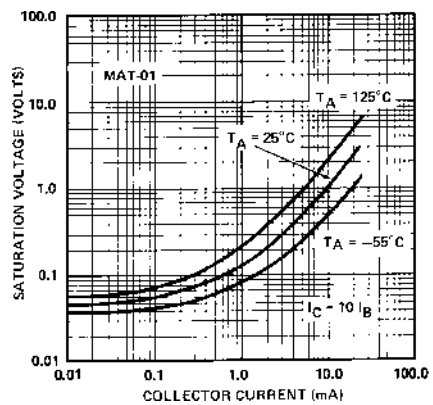



*Figure 8. Saturation Voltage vs. Collector Current*

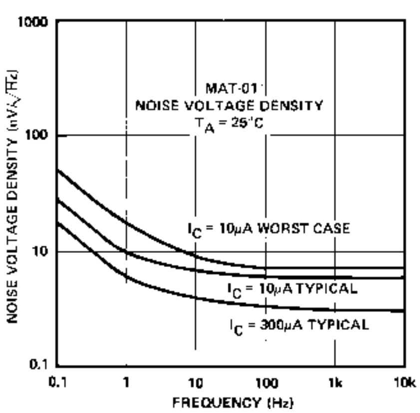



*Figure 3. Noise Voltage*

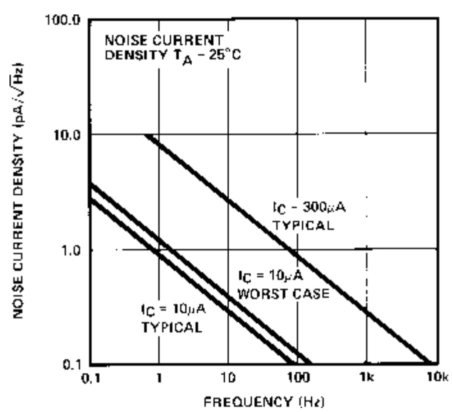



*Figure 6. Noise Current Density*

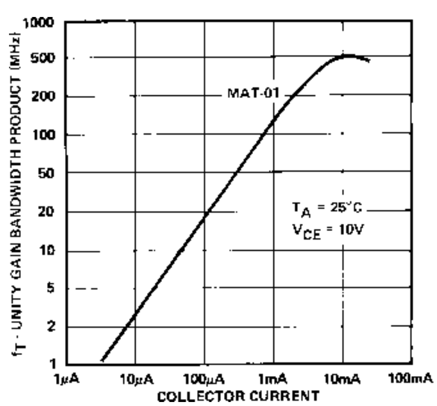
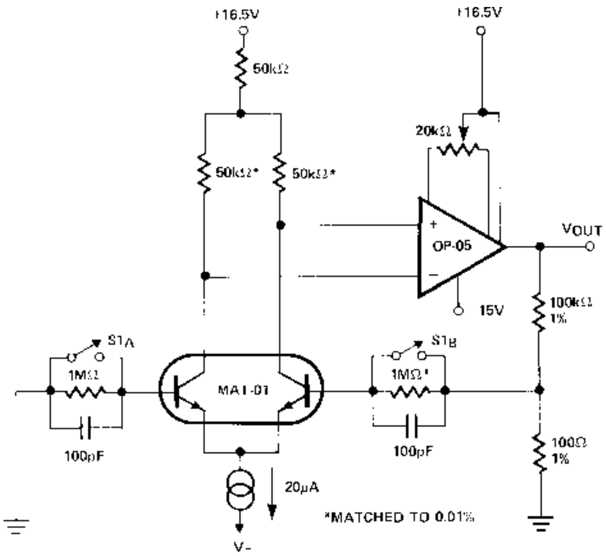


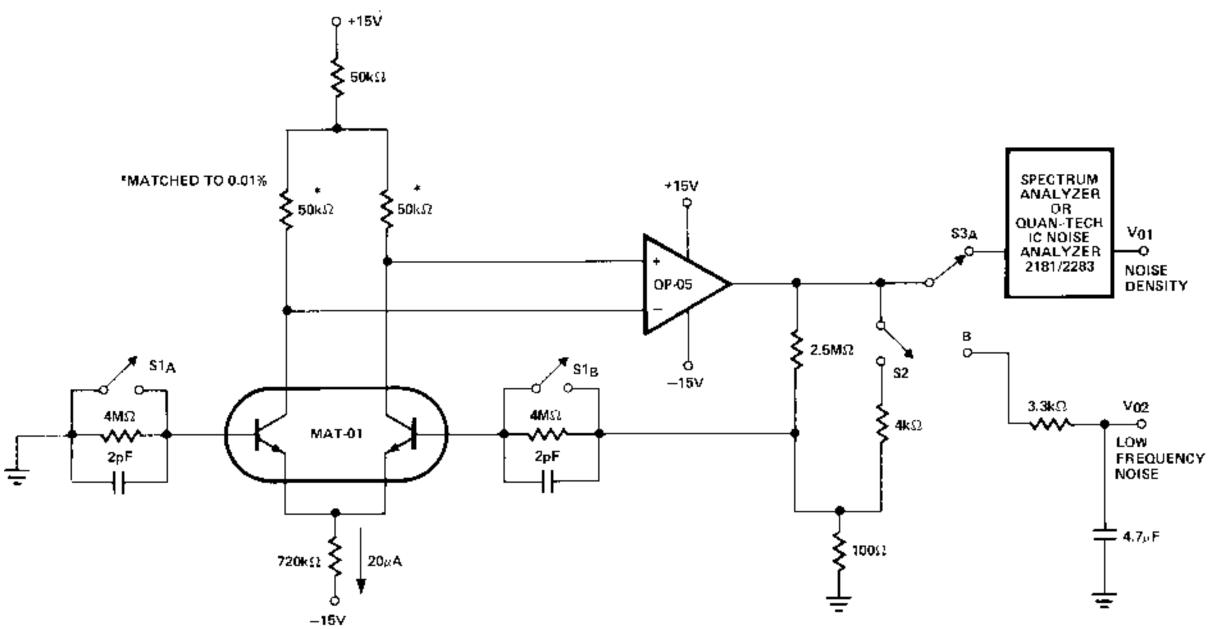

*Figure 9. Gain-Bandwidth vs. Collector Current*

**MAT01 TEST CIRCUITS**




| TEST | $SI_A$ | $SI_B$ | UNITS | |
|---|---|---|---|---|
| $V_{OS}$ | X | X | $V_{OUT_1}$ | 1 volt per mV |
| $I_{OS}$ | O | O | $V_{OUT_2} - V_{OUT_1}$ | 1 volt per nA |

*Figure 10. 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 | $\frac{V_{02}\ \text{PEAK-TO-PEAK}}{25{,}000}$ |

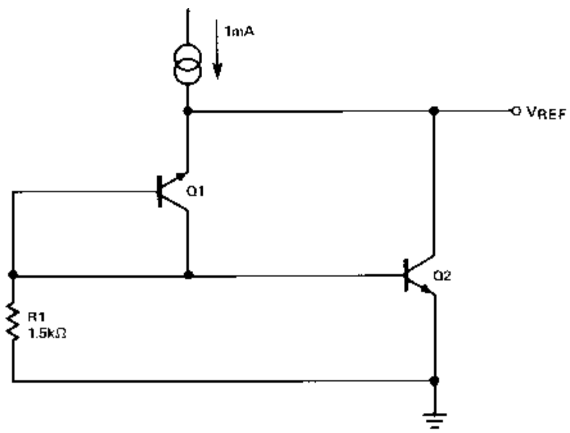
*Figure 11. MAT01 Noise Measurement Circuit*

## 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.

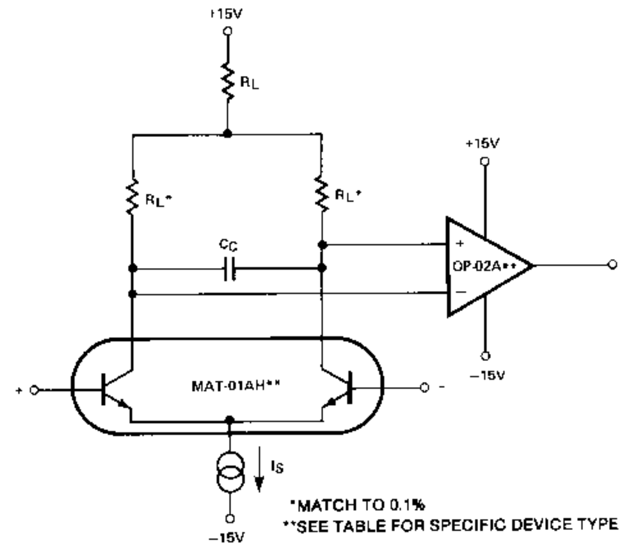
Stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent realization of the predicted drift performance. Both input terminals should be maintained at the same temperature, preferably close to the temperature of the device's package.

## TYPICAL APPLICATIONS




$V_{REF} \approx 7.0V$
$TCV_{REF} \approx 10ppm/°C$
$R_O \approx 40\Omega$
$R_1$ 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 12. Precision Reference*




THIS CONFIGURATION CAN ALSO BE USED WITH THE LOW POWER OP-21 OR MICROPOWER OP-22 TO ACHIEVE A LOW NOISE AND LOW POWER PRECISION OP-AMP.

| | MAT-01AH OP-02A | MAT-01AH OP-02A | MAT-01GH OP-02 | MAT-01GH OP-02 |
|---|---|---|---|---|
| $V_{OS}$ Maximum | 0.15mV | 0.27mV | 0.65mV | 1.2mV |
| $TCV_{OS}$ Maximum | 0.6μV/°C | 1μV/°C | 2μV/°C | 4μV/°C |
| $I_{OS}$ Maximum | 0.8nA | 0.1nA | 3.2nA | 0.32nA |
| $I_B$ Maximum | 20nA | 2nA | 40nA | 4nA |
| Gain Minimum | 2,000,000 | 2,000,000 | 800,000 | 800,000 |
| $I_S$ | 20μA | 2μA | 20μA | 2μA |
| $R_L$ | 100kΩ | 1MΩ | 100kΩ | 1MΩ |

*Figure 14. Precision Operational Amplifiers*

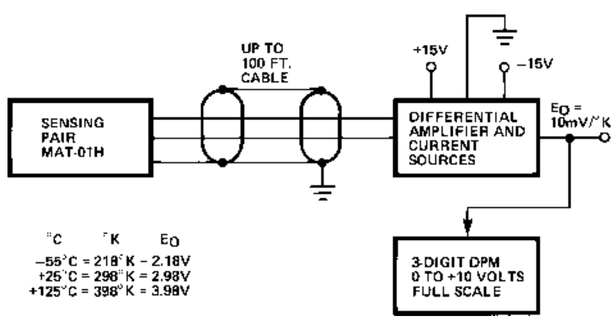



*Figure 13. Basic Digital Thermometer Readout in Degrees Kelvin (°K)*

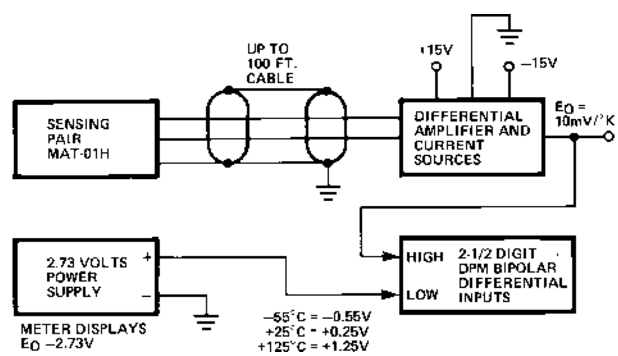
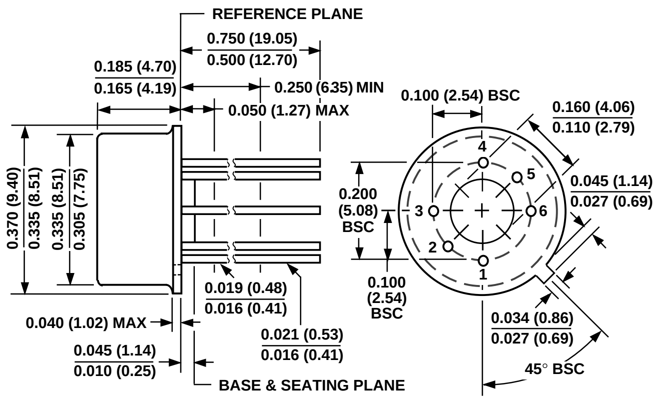



*Figure 15. Digital Thermometer with Readout in °C*

## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

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

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