

### FEATURES

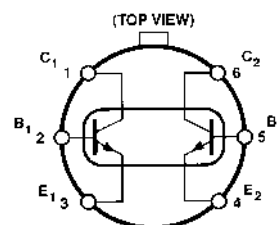
**Low  $V_{OS}$  ( $V_{BE}$  Match):** 40  $\mu\text{V}$  typ, 100  $\mu\text{V}$  max  
**Low  $TCV_{OS}$ :** 0.5  $\mu\text{V}/^\circ\text{C}$  max  
**High  $h_{FE}$ :** 500 min  
**Excellent  $h_{FE}$  Linearity** from 10 nA to 10 mA  
**Low Noise Voltage:** 0.23  $\mu\text{V}$  p-p—0.1 Hz to 10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

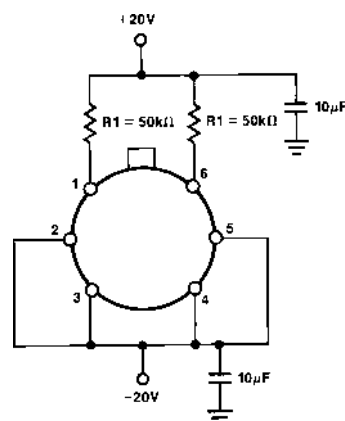
### PIN CONNECTION

TO-78  
(H Suffix)



NOTE: Substrate is connected to case.

### BURN-IN CIRCUIT



REV. A

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# MAT01—SPECIFICATIONS

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

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

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

Parameter	Symbol	Conditions	MAT01AH			MAT01GH			Units
			Min	Typ	Max	Min	Typ	Min	
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	$\mu\text{V}/^\circ\text{C}$
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	$\text{pA}/^\circ\text{C}$
Bias Current	$I_B$			28	60		36	130	nA
Current Gain	$h_{FE}$		167	400		77	300		
Collector-Base	$I_{CBO}$	$T_A = 125^\circ\text{C}$ , $V_{CB} = 30\text{ V}$ , $I_E = 0^4$		15	80		25	200	nA
Collector-Emitter	$I_{CES}$	$T_A = 125^\circ\text{C}$ , $V_{CE} = 30\text{ V}$ , $V_{BE} = 0^{4,6}$		50	300		90	400	nA
Collector-Collector	$I_{CC}$	$T_A = 125^\circ\text{C}$ , $V_{CC} = 30\text{ V}$ , (Note 6)		30	200		50	400	nA

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

Parameter	Symbol	Conditions	MAT01N Typical	Units
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	$\text{pA}$
Collector-Base-Leakage Current	$I_{CBO}$	$V_{CB} = 30\text{ V}$ , $I_E = 0$	25	$\text{pA}$
Gain Bandwidth Product	$f_T$	$V_{CE} = 10\text{ V}$ , $I_C = 10\text{ mA}$	450	$\text{MHz}$
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

<sup>1</sup>Exclude first hour of operation to allow for stabilization.

<sup>2</sup>Parameter describes long-term average drift after first month of operation.

<sup>3</sup>Sample tested.

<sup>4</sup>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.

<sup>5</sup> $I_{CC}$  and  $I_{CES}$  are guaranteed by measurement of  $I_{CBO}$ .

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

<sup>7</sup>Guaranteed by  $I_{OS}$  test limits over temperature.

Specifications subject to change without notice.

## WAFER TEST LIMITS (@ $V_{CB} = 15\text{ V}$ , $I_C = 10\text{ }\mu\text{A}$ , $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

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

### 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.

# MAT01

## ABSOLUTE MAXIMUM RATINGS<sup>1</sup>

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

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

### NOTES

<sup>1</sup>Absolute maximum ratings apply to both DICE and packaged devices.

<sup>2</sup>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  $V_{EBO}$  greater than the 5 V rating shown.

<sup>3</sup>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  $40^\circ\text{C}$ .

<sup>4</sup>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  $70^\circ\text{C}$ .

## ORDERING GUIDE<sup>1</sup>

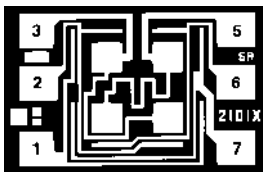
Model	$V_{OS \text{ max}}$ ( $T_A = +25^\circ\text{C}$ )	Temperature Range	Package Option
MAT01AH <sup>2</sup>	0.1 mV	$-55^\circ\text{C}$ to $+125^\circ\text{C}$	TO-78
MAT01GH	0.5 mV	$-55^\circ\text{C}$ to $+125^\circ\text{C}$	TO-78

### NOTES

<sup>1</sup>Burn-in is available on commercial and industrial temperature range parts in TO-can packages.

<sup>2</sup>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  $0.035 \times 0.025 \text{ inch}$ , 875 sq. mils  
( $0.89 \times 0.64 \text{ mm}$ , 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.



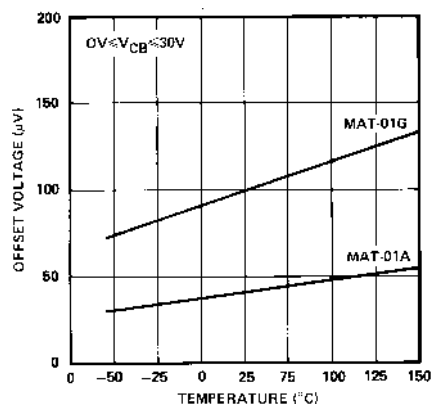


Figure 1. Offset Voltage vs. Temperature

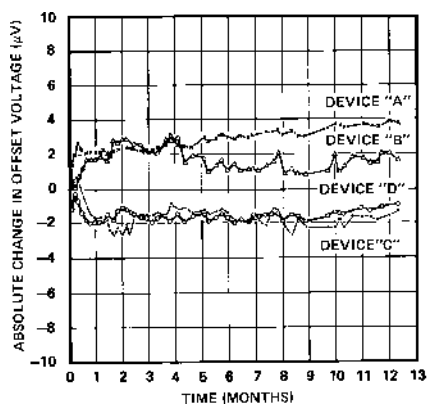


Figure 4. Offset Voltage vs. Time

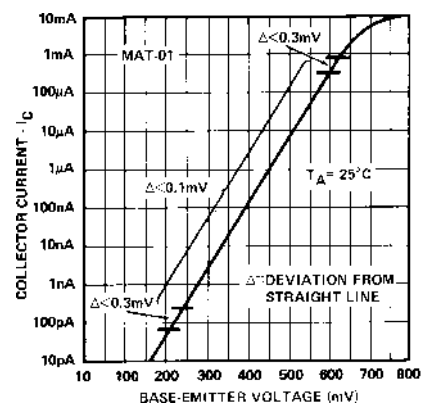


Figure 7. Base-Emitter Voltage vs. Collector Current

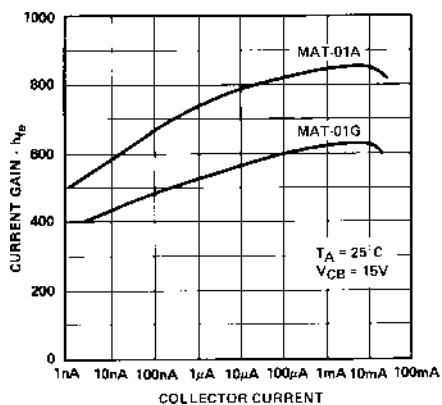


Figure 2. Current Gain vs. Collector Current

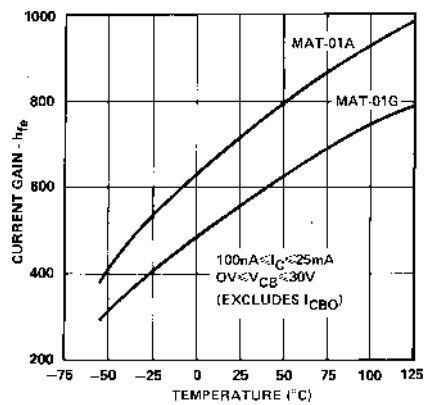


Figure 5. Current Gain vs. Temperature

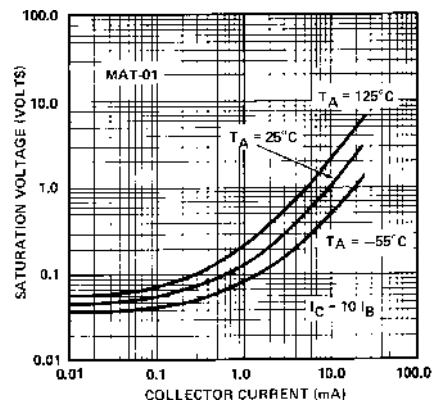


Figure 8. Saturation Voltage vs. Collector Current

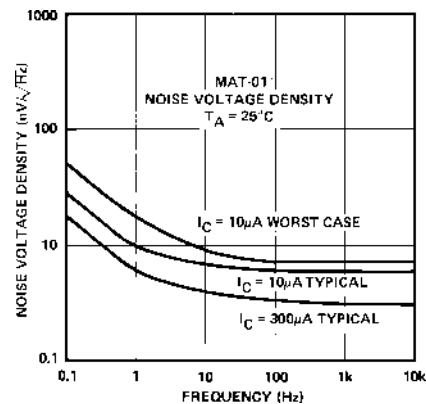


Figure 3. Noise Voltage

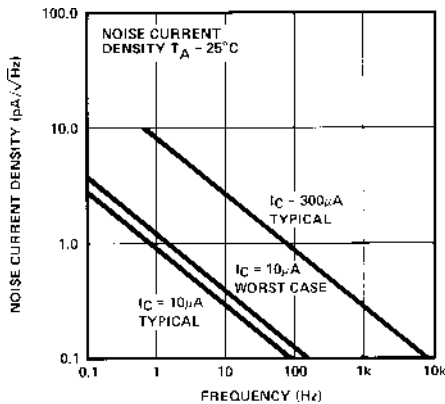


Figure 6. Noise Current Density

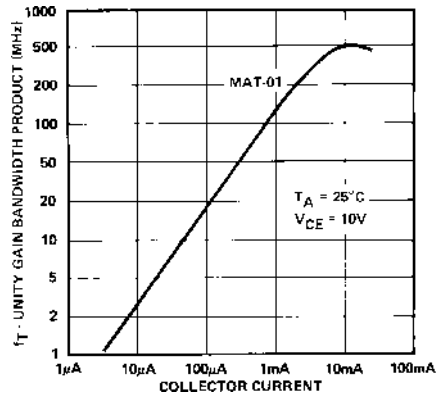


Figure 9. Gain-Bandwidth vs. Collector Current

MAT01

MAT01 TEST CIRCUITS

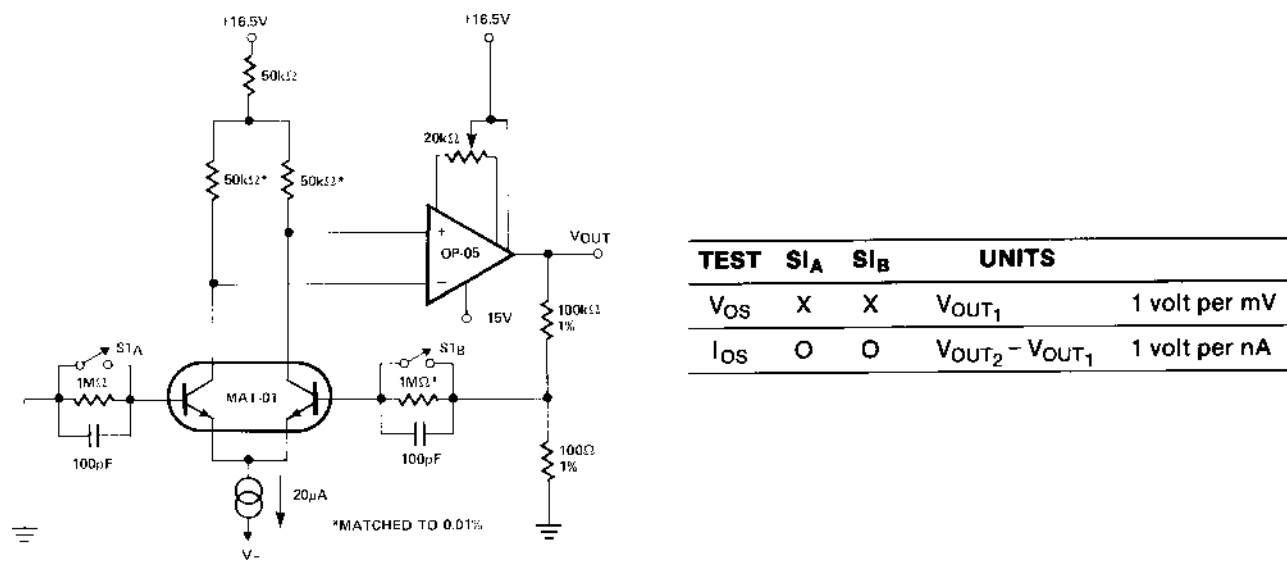


Figure 10. MAT01 Matching Measurement Circuit

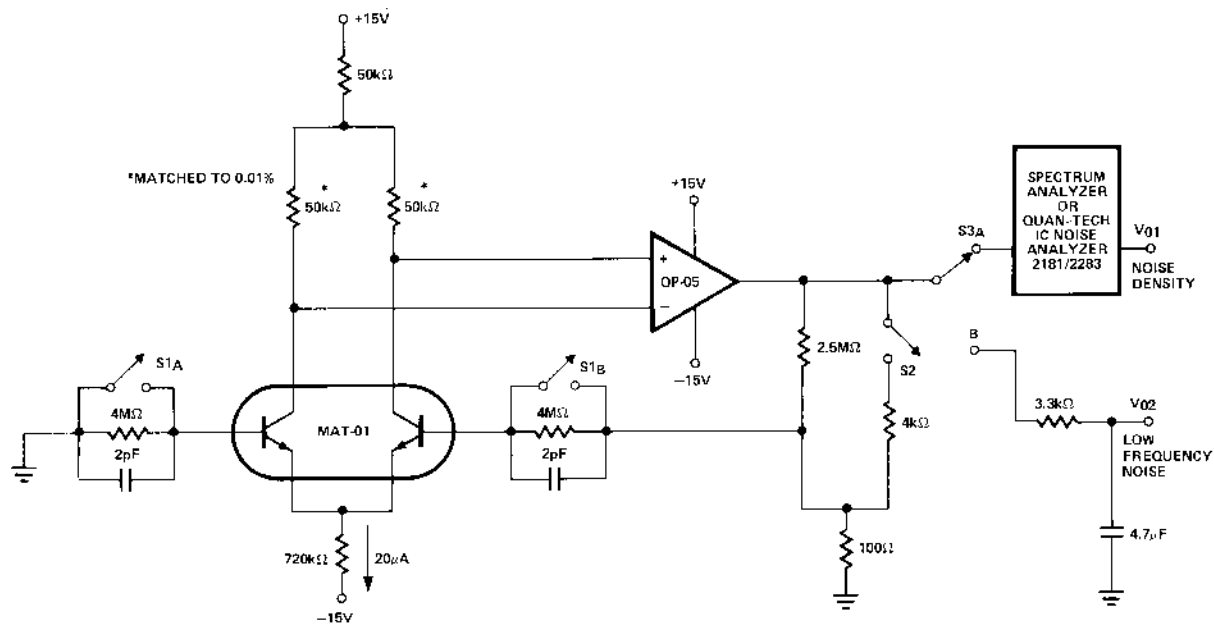


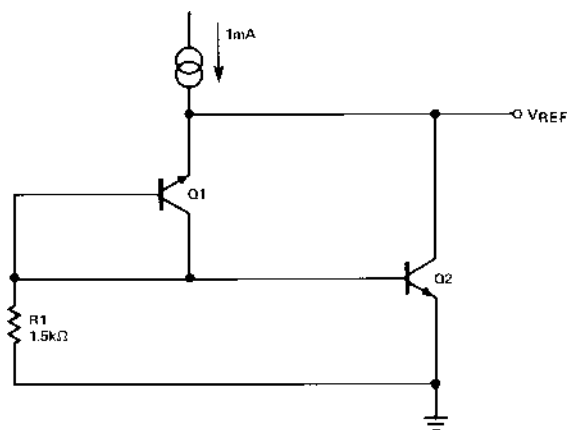
Figure 11. MAT01 Noise Measurement Circuit

## 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



$V_{REF} \sim 7.0V$   
 $TCV_{REF} \sim 10ppm/^{\circ}C$   
 $R_O \sim 40\Omega$   
 $R_1$  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

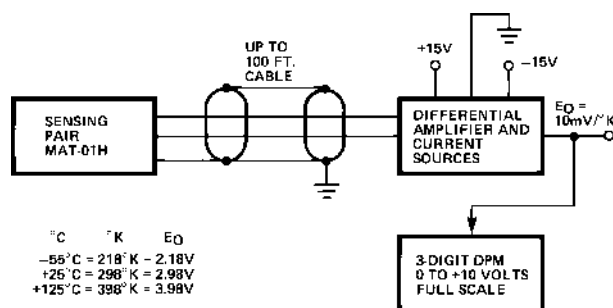
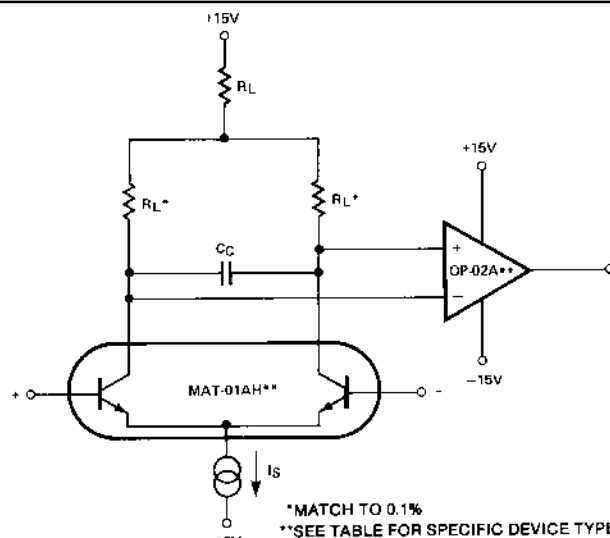


Figure 13. Basic Digital Thermometer Readout in Degrees Kelvin ( $^{\circ}K$ )



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	0.6 $\mu V/^{\circ}C$	1 $\mu V/^{\circ}C$	2 $\mu V/^{\circ}C$	4 $\mu V/^{\circ}C$
$I_{OS}$ 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
$I_S$	20 $\mu A$	2 $\mu A$	20 $\mu A$	2 $\mu A$
$R_L$	100k $\Omega$	1M $\Omega$	100k $\Omega$	1M $\Omega$

Figure 14. Precision Operational Amplifiers

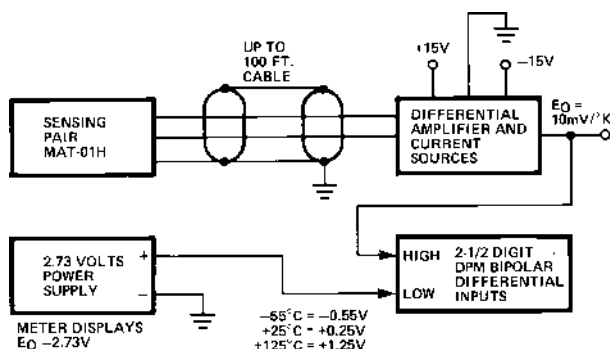
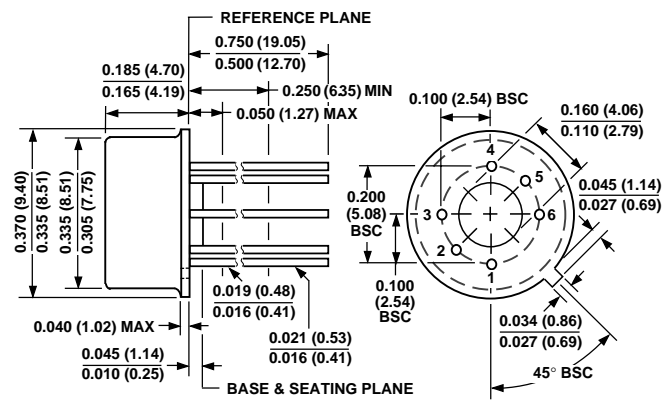


Figure 15. Digital Thermometer with Readout in  $^{\circ}C$

OUTLINE DIMENSIONS  
Dimensions shown in inches and (mm).

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



3127-0-6/97

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