ANALOG DEVICES

Matched Monolithic Dual Transistor

MAT01

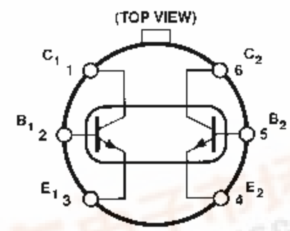
FEATURES
- Low V_{OS} (V_{BE} Match): 40 µV typ, 100 µV max
- Low TCV_{OS}: 0.5 µV/°C max
- High h_{FE}: 500 min
- Excellent h_{FE} Linearity from 10 nA to 10 mA
- Low Noise Voltage: 0.23 µV p-p—0.1 Hz to 10 Hz
- High Breakdown: 45 V min
- Available in Die Form

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.

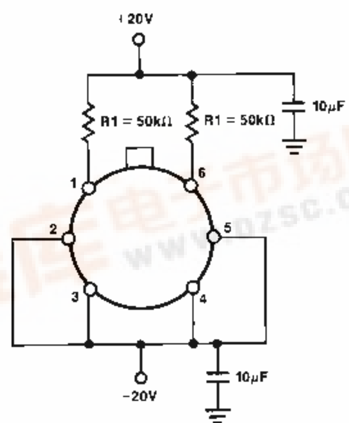
PIN CONNECTION

TO-78
(H Suffix)



NOTE: Substrate is connected to case.

BURN-IN CIRCUIT



REV. A

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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	Δh_{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 Voltage	$V_{CE(SAT)}$	I_B = 0.1 mA, I_C = 1 mA		0.12	0.20		0.12	0.25	V
		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 Leakage Current	I_{CBO}	T_A = 125°C, V_{CB} = 30 V, I_E = 0[4]		15	80		25	200	nA
Collector-Emitter Leakage Current	I_{CES}	T_A = 125°C, V_{CE} = 30 V, V_{BE} = 0[4, 6]		50	300		90	400	nA
Collector-Collector Leakage Current	I_{CC}	T_A = 125°C, V_{CC} = 30 V, (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	Δh_{FE}		8.0	% max
Offset Voltage Change	$\Delta V_{OS}/\Delta V_{CB}$	$0 \leq V_{CB} \leq 30$ V	8.0	µV/V max
Offset Current Change	$\Delta V_{OS}/\Delta V_{CB}$	$0 \leq V_{CB} \leq 30$ 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

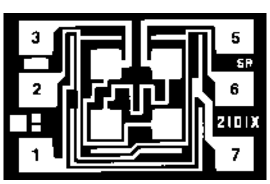
NOTES
[1]Absolute maximum ratings apply to both DICE and packaged devices.
[2]Application of reverse bias voltages in excess of rating shown can result in degradation of h_{FE} and h_{FE} matching characteristics. Do not attempt to measure BV_{EBO} greater than the 5 V rating shown.
[3]Rating applies 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.

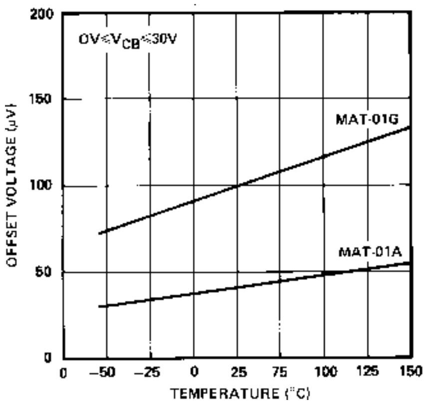


Figure 1. Offset Voltage vs. Temperature

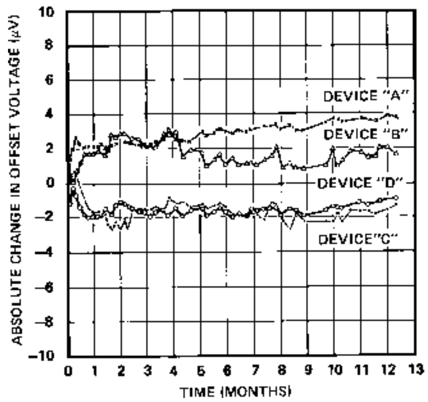


Figure 4. Offset Voltage vs. Time

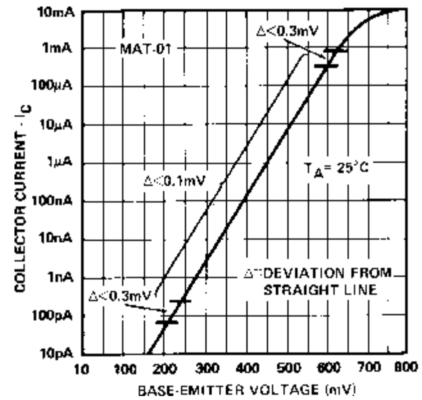


Figure 7. Base-Emitter Voltage vs. Collector Current

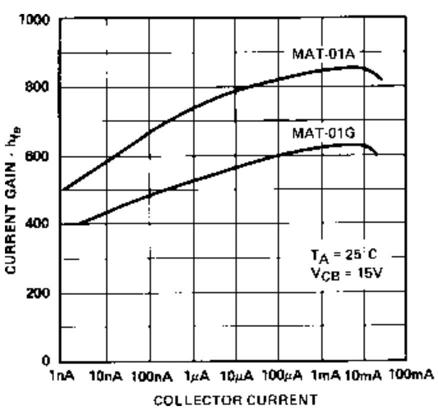


Figure 2. Current Gain vs. Collector Current

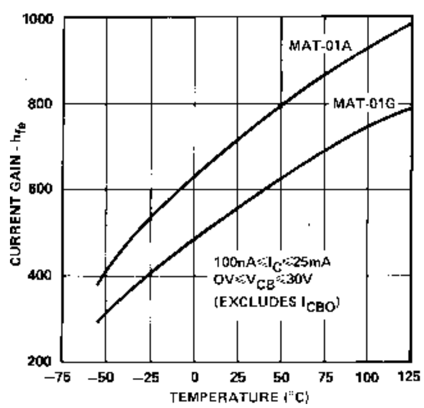


Figure 5. Current Gain vs. Temperature

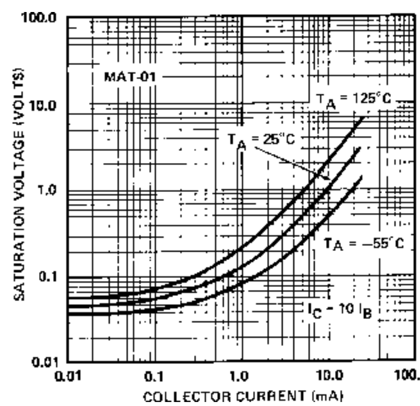


Figure 8. Saturation Voltage vs. Collector Current

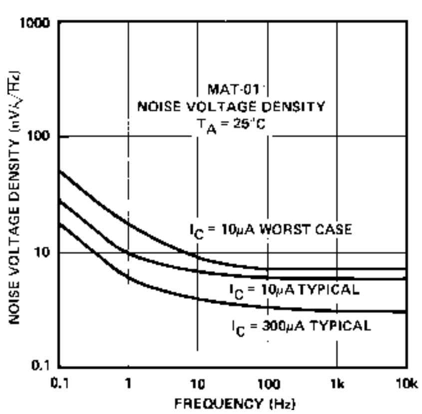


Figure 3. Noise Voltage

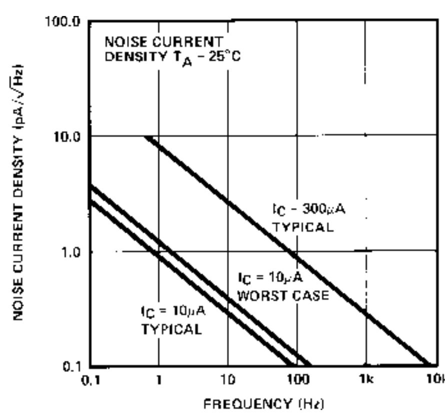


Figure 6. Noise Current Density

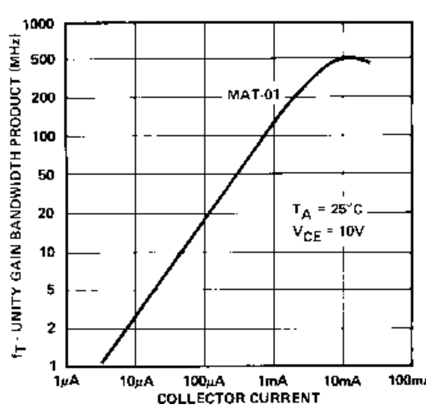
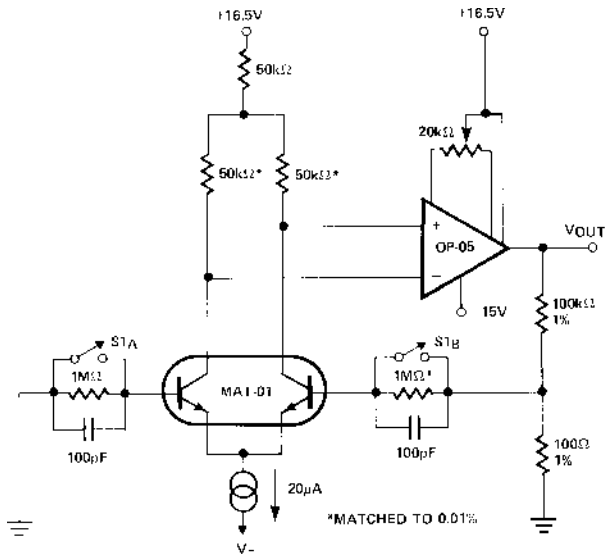


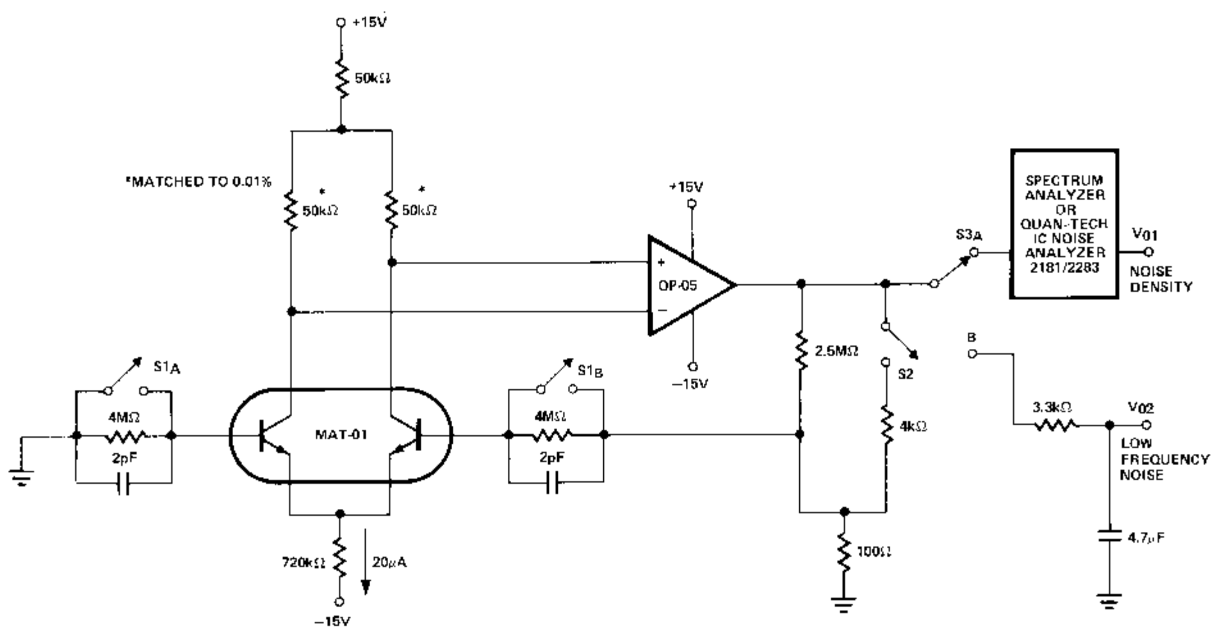
Figure 9. Gain-Bandwidth vs. Collector Current

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	$\frac{V_{02} \text{ PEAK-TO-PEAK}}{25{,}000}$

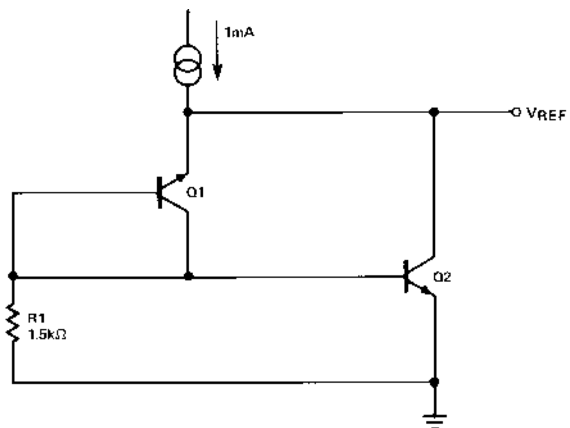
Figure 11. MAT01 Noise Measurement Circuit

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.

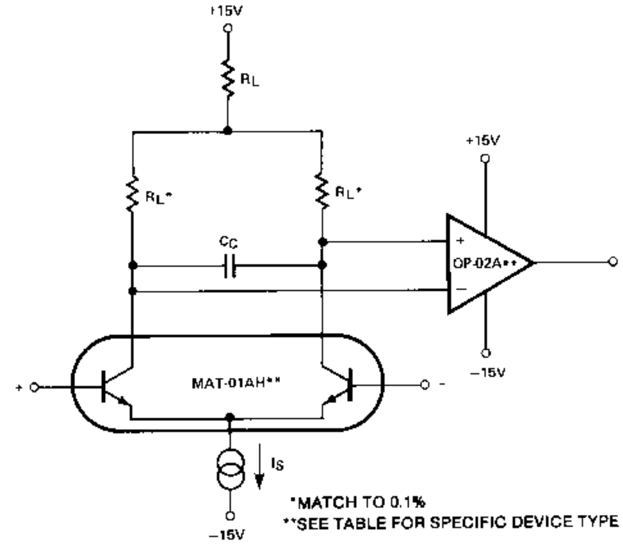
Stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent realization of the predicted drift performance. Both input terminals should be maintained at the same temperature, preferably close to the temperature of the device's package.

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

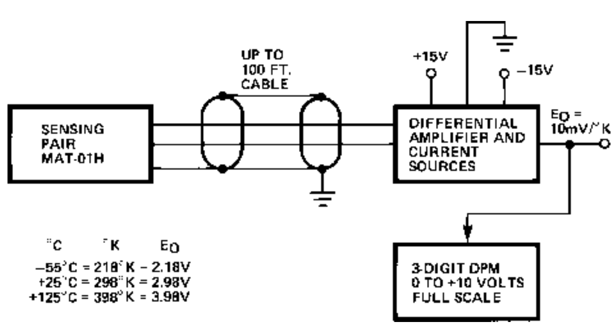


Figure 13. Basic Digital Thermometer Readout in Degrees Kelvin (°K)

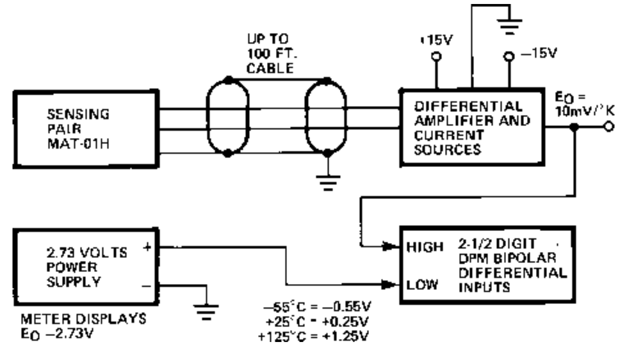
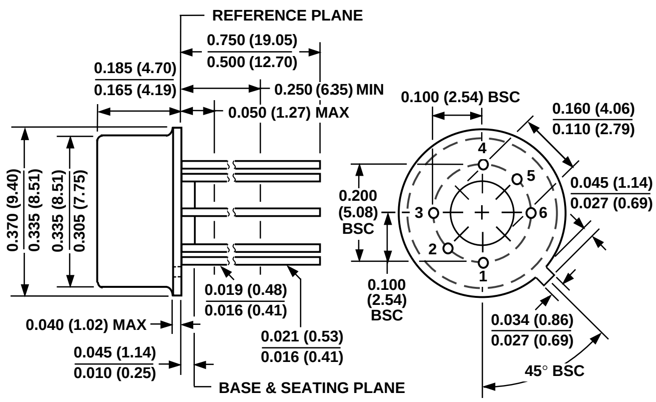


Figure 15. Digital Thermometer with Readout in °C

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

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



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