

## FEATURES

- 1.2 $\mu$ Vp-p Noise
- 2 $\mu$ V Long Term Stability
- Very Low Hysteresis
- 0.05ppm/ $^{\circ}$ C Drift
- Temperature Stabilized

## APPLICATIONS

- Voltmeters
- Calibrators
- Standard Cells
- Scales
- Low Noise RF Oscillators

## DESCRIPTION

The LTZ1000 and LTZ1000A are ultra stable temperature controllable references. They are designed to provide 7V outputs with temperature drifts of 0.05ppm/ $^{\circ}$ C, about 1.2 $\mu$ Vp-p of noise and long term stabilities of 2 $\mu$ V per month.

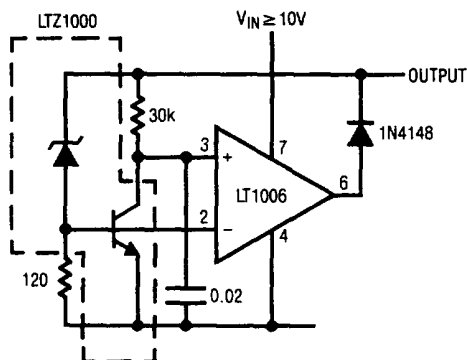
Included on the chip is a subsurface zener reference, heater resistor for temperature stabilization, and a temperature sensing transistor. External circuitry is used to set operating currents and to temperature stabilize the reference. This allows maximum flexibility and best long term stability and noise.

The LTZ1000 and LTZ1000A references can provide superior performance to older references such as the LM199 at the expense of increased circuit complexity and thermal layout considerations. The LTZ1000 is packaged in a standard TO-99 package while the LTZ1000A utilizes a proprietary high thermal resistance die attach which eases thermally insulating the reference.

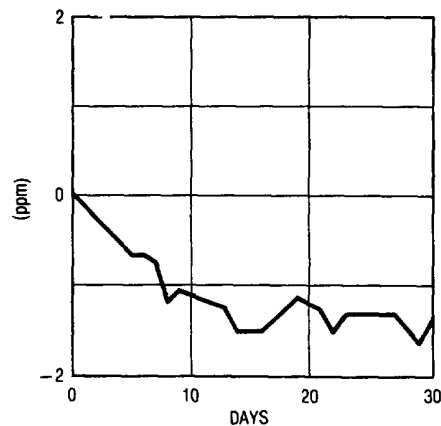
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## TYPICAL APPLICATION

Low Noise Reference



Long Term Stability



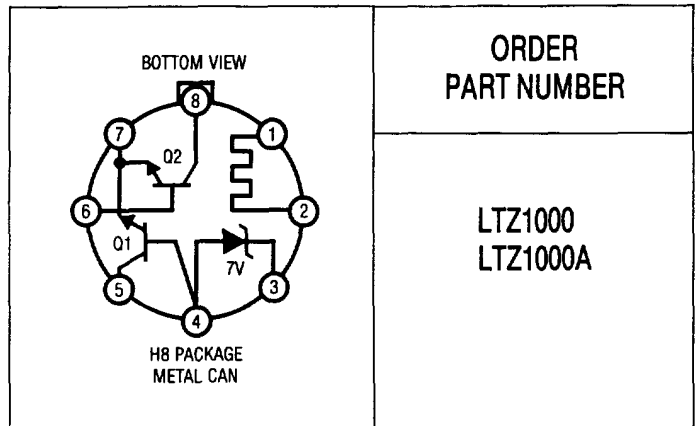
LONG TERM STABILITY OF A TYPICAL DEVICE FROM TIME=0  
 WITH NO PRECONDITIONING OR AGING

# LTZ1000/LTZ1000A

## ABSOLUTE MAXIMUM RATINGS

Heater to Substrate .....	35V
Collector Emitter Breakdown Q1 .....	15V
Collector Emitter Breakdown Q2 .....	35V
Emitter Base Reverse Bias .....	2V
Operating Temperature Range .....	$-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$
Storage Temperature Range .....	$-65^{\circ}\text{C} \leq T_A \leq 150^{\circ}\text{C}$
Substrate Forward Bias .....	0.1V

## PACKAGE/ORDER INFORMATION



## PRECONDITIONING

150°C Burn-In

## ELECTRICAL CHARACTERISTICS (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Zener Voltage	$I_Z = 5\text{mA}, (V_Z + V_{BE_{Q1}}) I_{Q1} = 100\mu\text{A}$	7.0	7.2	7.5	V
	$I_Z = 1\text{mA}, (V_Z + V_{BE_{Q1}}) I_{Q1} = 100\mu\text{A}$	6.9	7.15	7.45	V
Zener Change with Current	$1\text{mA} \leq I_Z < 5\text{mA}$		80	240	mV
Zener Leakage Current	$V_Z = 5\text{V}$		20	200	$\mu\text{A}$
Zener Noise	$I_Z = 5\text{mA}, 0.1\text{Hz} < f < 10\text{Hz}$ $I_{Q1} = 100\mu\text{A}$		1.2	2	$\mu\text{Vp-p}$
Heater Resistance	$I_L \leq 100\mu\text{A}$	200	300	420	$\Omega$
Heater Breakdown Voltage		35			V
Transistor Q1 Breakdown	$I_C = 10\mu\text{A}, \text{LVCEO}$	15	20		V
Transistor Q2 Breakdown	$I_C = 10\mu\text{A}, \text{LVCEO}$	35	50		V
Q1, Q2 Current Gain	$I_C = 100\mu\text{A}$	80	200	450	
Thermal Resistance	LTZ1000 Time = 5 Minutes		80		$^{\circ}\text{C/W}$
	LTZ1000A Time = 5 Minutes		400		$^{\circ}\text{C/W}$
Long Term Stability	$T = 65^{\circ}\text{C}$		2		$\mu\text{V}/\sqrt{\text{KHR}}$

**Note 1:** All testing is done at 25°C. Pulse testing is used for LTZ1000A to minimize temperature rise during testing. LTZ1000 and LTZ1000A devices are QA tested at  $-55^{\circ}\text{C}$  and  $125^{\circ}\text{C}$ .

## PIN FUNCTIONS

**Pin 1:** Heater positive. Must be more positive than Pin 4 and less than 40V.

**Pin 2:** Heater negative. Must be more positive than Pin 4 and less than 40V.

**Pin 3:** Zener positive. Must be more positive than Pin 4.

**Pin 4:** Substrate and Zener negative. Must be more positive than pin 7. If Q1 is Zenered (about 7V) a permanent degradation in beta will result.

**Pin 5:** Temperature compensating transistor collector.

**Pin 6:** Temperature sensing transistor base. If the base emitter junction is Zenered (about 7V) the transistor will suffer permanent beta degradation.

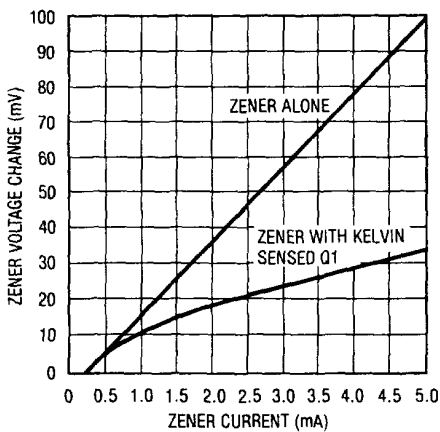
**Pin 7:** Emitter of sensing and compensating transistors.

**Pin 8:** Collector of sensing transistor.

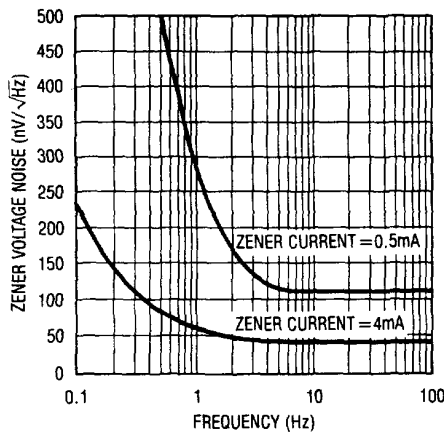
## TYPICAL PERFORMANCE CHARACTERISTICS

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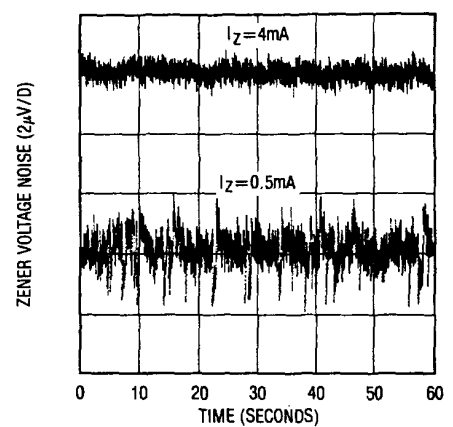
Zener Voltage vs Current



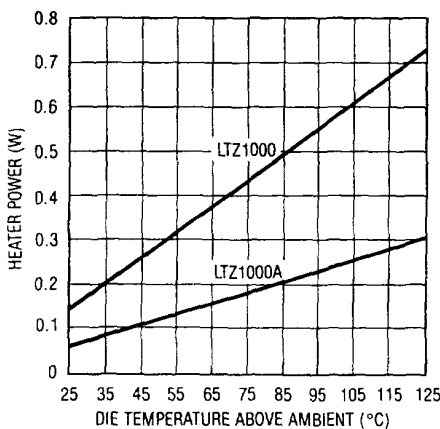
Zener Voltage Noise Spectrum



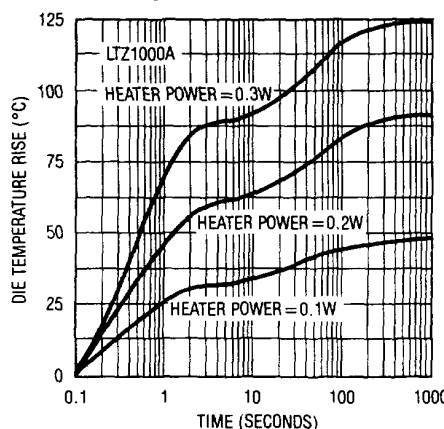
Zener Noise



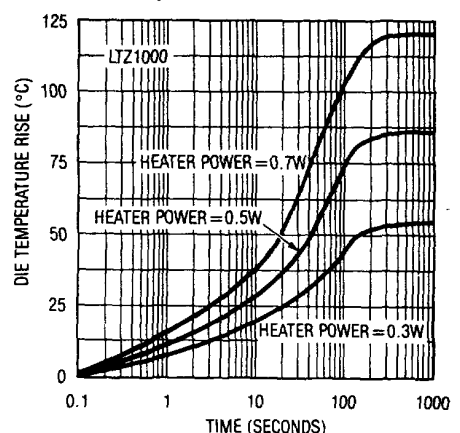
Die Temperature Rise vs Heater Power



Die Temperature Rise vs Time



Die Temperature Rise vs Time



## APPLICATION HINTS

LTZ1000 and LTZ1000A are capable of providing ultimate voltage reference performance. Temperature drifts of better than 0.03ppm/°C and long term stability on the order of 1 $\mu$ V per month can be achieved. Noise of about 0.15ppm can also be obtained. This performance is at the expense of circuit complexity, since external influences can easily cause output voltage shifts of more than 1ppm.

Thermocouple effects are one of the worst problems and can give apparent drifts of many ppm/°C as well as cause low frequency noise. The kovar input leads of the TO-5 package form thermocouples when connected to copper PC boards. These thermocouples generate outputs of 35 $\mu$ V/°C. It is mandatory to keep the zener and transistor leads at the same temperature, otherwise 1 to 5ppm shifts in the output voltage can easily be expected from these thermocouples.

Air currents blowing across the leads can also cause small temperature variations, especially since the package is heated. This will look like 1 to 5ppm of low frequency noise occurring over a several minute period. For best results, the device should be located in an enclosed area and well shielded from air currents.

Certainly, any temperature gradient externally generated, say from a power supply, should not appear across the critical circuitry. The leads to the transistor and zener should be connected to equal size PC traces to equalize the heat loss and maintain them at similar temperatures. The bottom portion of the PC board should be shielded against air currents as well.

Resistors, as well as having resistance temperature coefficients, can generate thermocouple effects. Some types of resistors can generate hundreds of microvolts of thermocouple voltage. These thermocouple effects in the resistor can also interfere with the output voltage. Wire wound resistors usually have the lowest thermocouple voltage, while tin oxide type resistors have very high thermocouple voltage. Film resistors, especially Vishay precision film resistors, can have low thermocouple voltage.

Ordinary breadboarding techniques are not good enough to give stable output voltage with the LTZ1000 family devices. For breadboarding, it is suggested that a small printed circuit board be made up using the reference, the amplifier, and wire wound resistors. Care must be taken to ensure that heater current does not flow through the same ground lead as the negative side of the reference (emitter of Q1). Current changes in the heater could add to or subtract from the reference voltage causing errors with temperature. Single point grounding using low resistance wiring is suggested.

### Setting Control Temperature

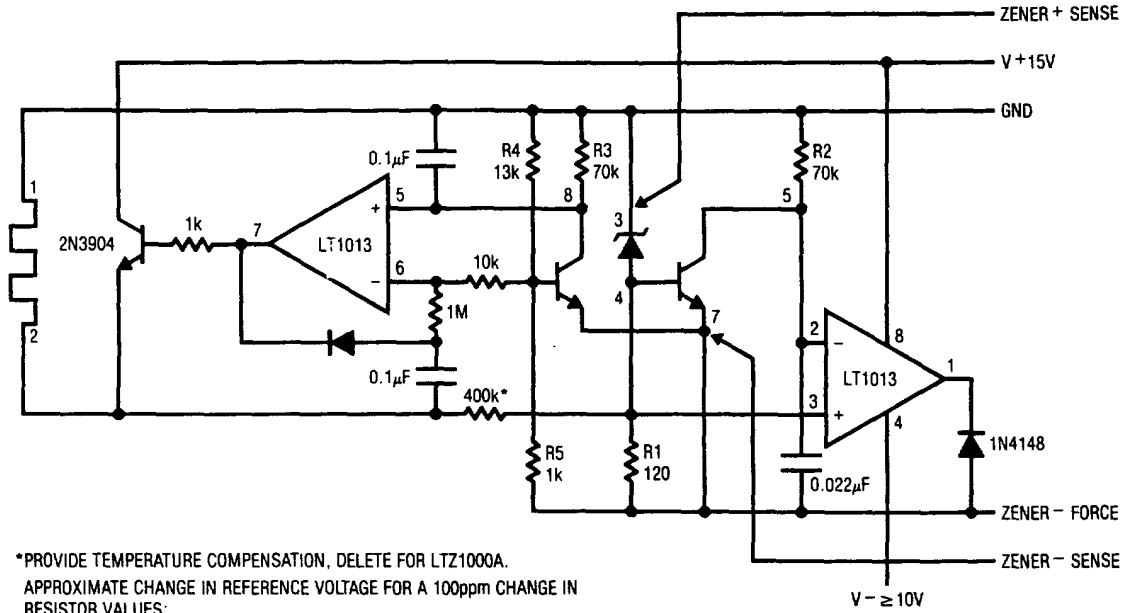
The emitter-base voltage of the control transistor sets the stabilization temperature for the LTZ1000. With the values given in the applications, temperature is normally 60°C. Production variations in emitter-base voltage will typically cause about  $\pm 10^\circ\text{C}$  variation. Since the emitter-base voltage changes about 2mV/°C and is very predictable, other temperatures are easily set.

The lowest temperature consistent with the operating environment should be used. Higher temperatures accelerate aging and decrease long term stability. The LTZ1000A should be set about 10°C higher than the LTZ1000. This is because normal operating power dissipation in the LTZ1000A causes a temperature rise of about 10°C. Of course both types of devices should be insulated from ambient. Several minutes of warm-up is usual.

For applications not requiring the extreme precision or the low noise of the LTZ1000, Linear Technology makes a broad line of voltage references. Devices like the LT1021 can provide drifts as low as 2ppm/°C and devices such as the LM399A can provide drifts of 1ppm/°C. Only applications requiring the very low noise or low drift with time of the LTZ1000 should use this device. Application help is available from Linear Technology.

# TYPICAL APPLICATIONS

## Negative Voltage Reference



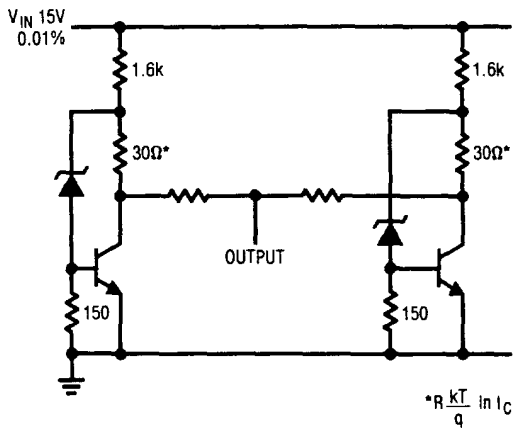
\*PROVIDE TEMPERATURE COMPENSATION, DELETE FOR LTZ1000A.  
APPROXIMATE CHANGE IN REFERENCE VOLTAGE FOR A 100ppm CHANGE IN RESISTOR VALUES:

	$100\text{ppm} = \Delta R(\Omega)$	$\Delta V_Z$
R1	0.012Ω	1ppm
R2	7Ω	0.3ppm
R3	7Ω	0.2ppm
R4/R5 RATIO	$\Delta R = 0.01\%$	1ppm

BOTH A1 AND A2 CONTRIBUTE LESS THAN 2μV OF OUTPUT DRIFT OVER A 50°C RANGE.

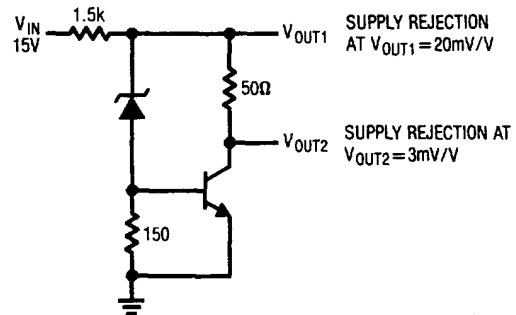
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## Averaging Reference Voltages for Lower Noise and Better Stability



$$*R \frac{kT}{q} \ln I_C$$

## Improving Supply Rejection

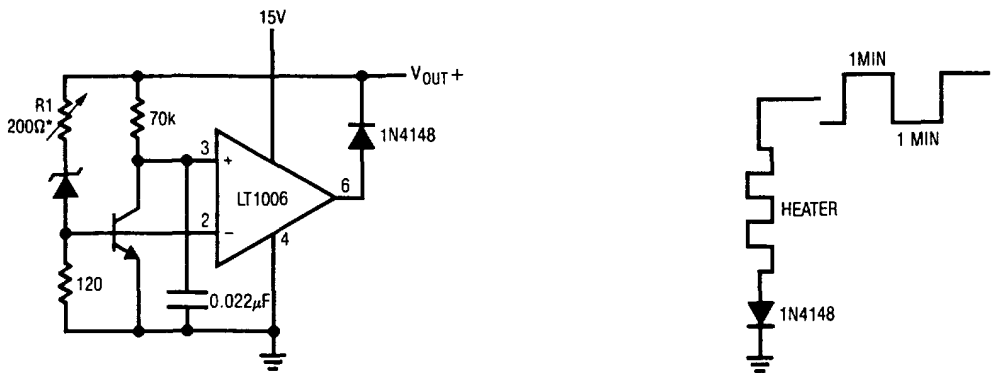


SUPPLY REJECTION  
AT  $V_{OUT1} = 20\text{mV/V}$

SUPPLY REJECTION AT  
 $V_{OUT2} = 3\text{mV/V}$

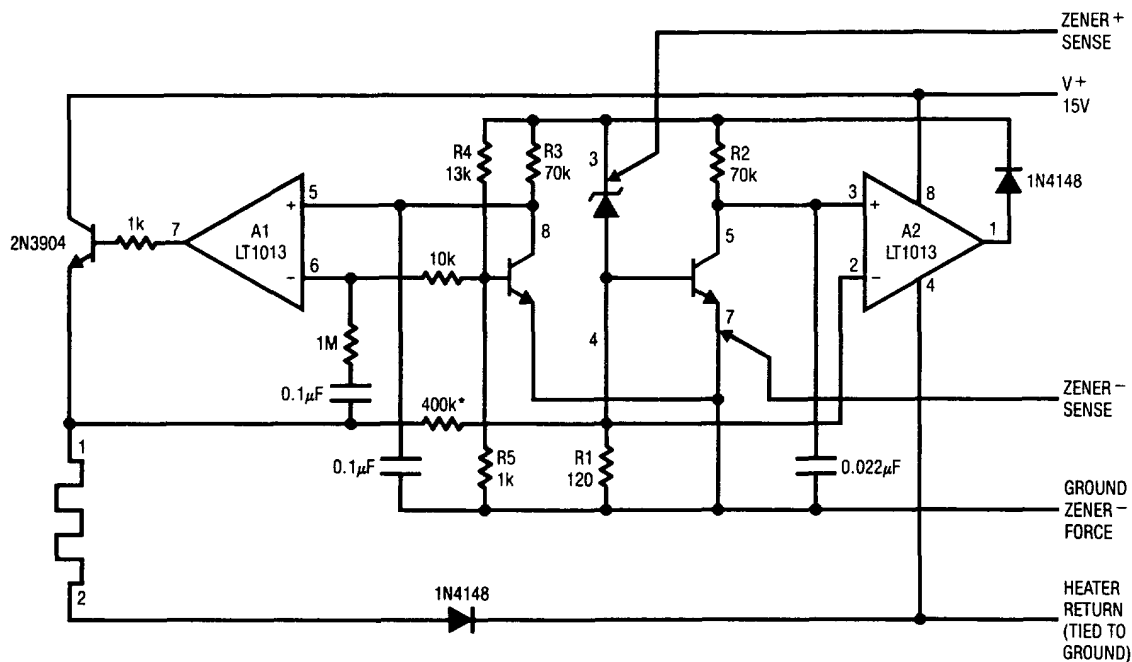
# TYPICAL APPLICATIONS

## Adjusting Temperature Coefficient in Unstabilized Applications



\*PULSE HEATER ON AND OFF TO HEAT AND COOL THE REFERENCE. ADJUST R1 FOR MINIMUM VOLTAGE CHANGE THROUGH A TEMPERATURE CYCLE.

## 7V Positive Reference Circuit

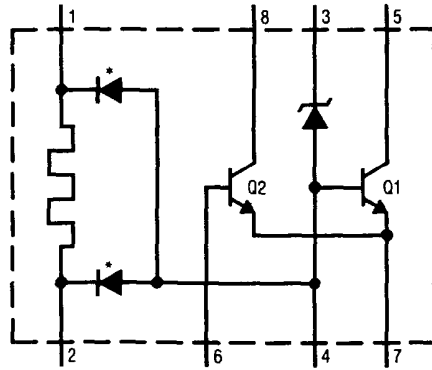


\*PROVIDES TC COMPENSATION, DELETE FOR LTZ1000A.  
 APPROXIMATE CHANGE IN REFERENCE VOLTAGE FOR A 100ppm (0.01%) CHANGE IN RESISTOR VALUES:

	$\Delta R(\Omega)$	$\Delta V_Z$
R1	0.012 $\Omega$	1ppm
R2	7 $\Omega$	0.3ppm
R3	7 $\Omega$	0.2ppm
R4/R5 RATIO	$\Delta R = 0.01\%$	1ppm

BOTH A1 AND A2 CONTRIBUTE LESS THAN 2 $\mu$ V OF OUTPUT DRIFT OVER A 50°C RANGE.

**BLOCK DIAGRAM**

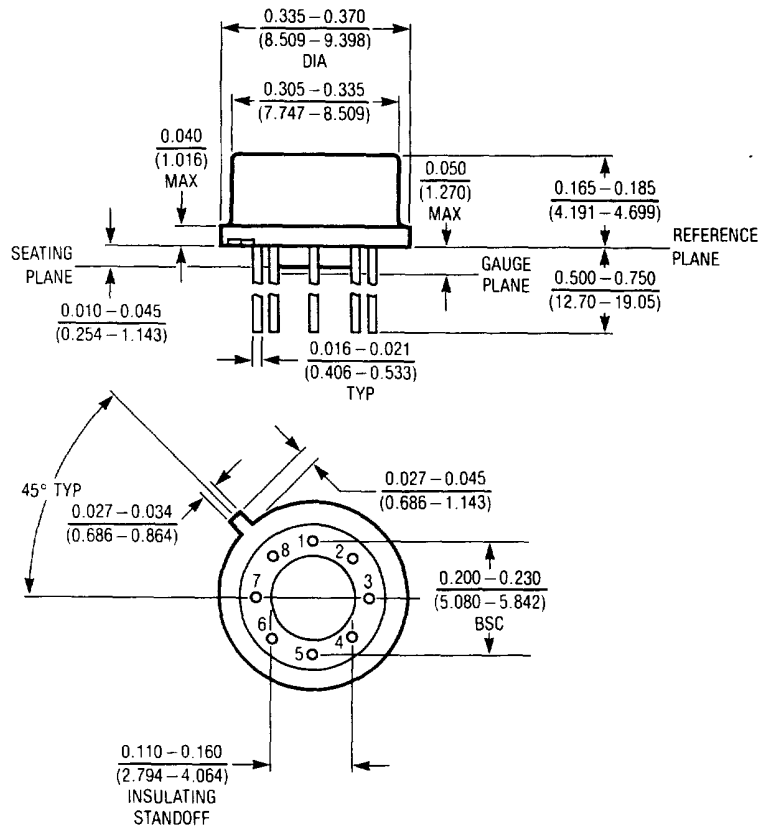


\*SUBSTRATE DIODES-DO NOT FORWARD BIAS

**PACKAGE DESCRIPTION** Dimensions in inches (millimeters) unless otherwise noted.

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**H8 Package  
Metal Can**



NOTE: LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND SEATING PLANE.

H8188

LTZ1000	$\theta_{JA}$ 80°C/W
LTZ1000A	400°C/W