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## FEATURES

- $1.2\mu\text{V}_{\text{P-P}}$  Noise
- $2\mu\text{V}/\sqrt{\text{kHr}}$  Long-Term Stability
- Very Low Hysteresis
- $0.05\text{ppm}/^\circ\text{C}$  Drift
- Temperature Stabilized
- $400^\circ\text{C}/\text{W}$  Thermal Resistance for LTZ1000A Reduces Insulation Requirements
- Specified for  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  Temperature Range
- Offered in TO-99 package

## 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  $0.05\text{ppm}/^\circ\text{C}$ , about  $1.2\mu\text{V}_{\text{P-P}}$  of noise and long-term stability of  $2\mu\text{V}/\sqrt{\text{kHr}}$ .

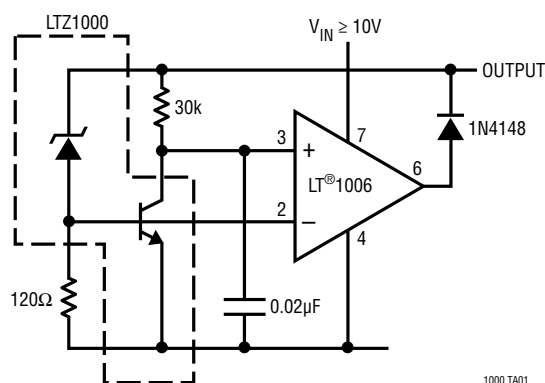
Included on the chip is a subsurface zener reference, a heater resistor for temperature stabilization, and a temperature sensing transistor. External circuitry is used to set operating currents and to temperature stabilize the reference. This allows maximum flexibility and best long-term stability and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

The LTZ1000 and LTZ1000A references can provide superior performance to older devices such as the LM199, provided that the user implements the heater control and properly manages the thermal layout. To simplify thermal insulation, the LTZ1000A uses a proprietary die attach method to provide significantly higher thermal resistance than the LTZ1000.

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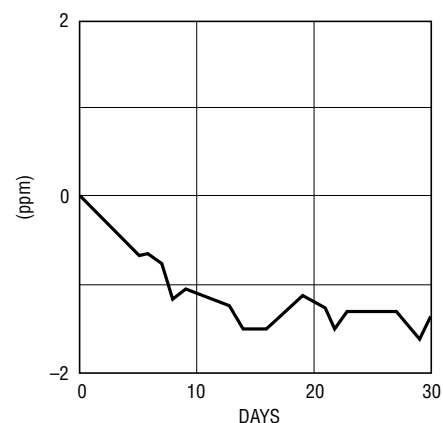
## TYPICAL APPLICATION

Low Noise Reference



1000 TA01

Long-Term Stability



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

1000 TA01b

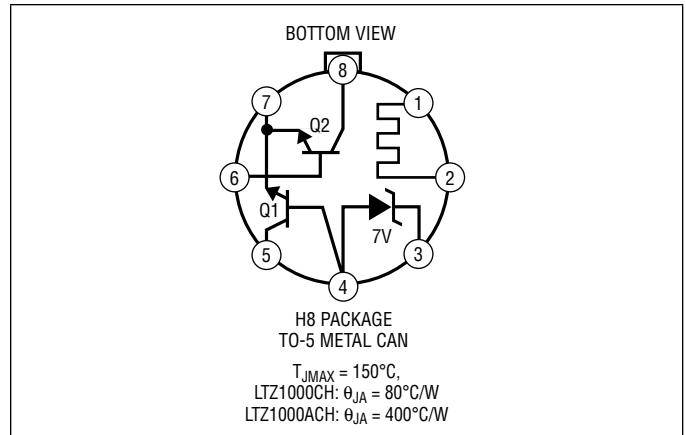
# LTZ1000/LTZ1000A

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                      |   |
|--------------------------------------|---|
| 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  |

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH  | PART MARKING | PACKAGE DESCRIPTION                   | SPECIFIED TEMPERATURE RANGE                    |
|-------------------|--------------|---------------------------------------|--|
| LTZ1000ACH#PBF    | LTZ1000ACH   | 8-Lead TO-5 Metal Can (.200 Inch PCD) | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTZ1000CH#PBF     | LTZ1000CH    | 8-Lead TO-5 Metal Can (.200 Inch PCD) | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LEAD BASED FINISH | PART MARKING | PACKAGE DESCRIPTION                   | SPECIFIED TEMPERATURE RANGE                    |
| LTZ1000ACH        | LTZ1000ACH   | 8-Lead TO-5 Metal Can (.200 Inch PCD) | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |
| LTZ1000CH         | LTZ1000CH    | 8-Lead TO-5 Metal Can (.200 Inch PCD) | $-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$ |

Consult LTC Marketing for parts specified with wider operating temperature ranges.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

This product is only offered in trays. For more information go to: <http://www.linear.com/packaging/>

## ELECTRICAL CHARACTERISTICS (Note 2)

| 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               | $I_Z = 5\text{mA}$ , $0.1\text{Hz} < f < 10\text{Hz}$<br>$I_{Q1} = 100\mu\text{A}$ |     | 1.2  | 2    | $\mu\text{V}_{\text{p-p}}$  |
| Heater Resistance         | $I_L \leq 100\mu\text{A}$  | 200 | 300  | 420  | $\Omega$                    |
| Heater Breakdown Voltage  |  | 35  |      |      | V                           |
| Transistor Q1 Breakdown   | $I_C = 10\mu\text{A}$ , LVCEO  | 15  | 20   |      | V                           |
| Transistor Q2 Breakdown   | $I_C = 10\mu\text{A}$ , LVCEO  | 35  | 50   |      | V                           |
| Q1, Q2 Current Gain       | $I_C = 100\mu\text{A}$   | 80  | 200  | 450  |                             |
| Thermal Resistance        | LTZ1000 Time = 5 Minutes   |     | 80   |      | $^{\circ}\text{C}/\text{W}$ |
|                           | LTZ1000A Time = 5 Minutes  |     | 400  |      | $^{\circ}\text{C}/\text{W}$ |
| Long-Term Stability       | $T = 65^{\circ}\text{C}$   |     | 2    |      | $\mu\text{V}/\text{kHr}$    |

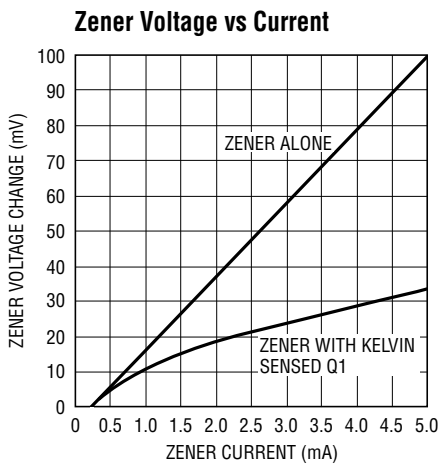
**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** All testing is done at  $25^{\circ}\text{C}$ . 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  $125^{\circ}\text{C}$ .

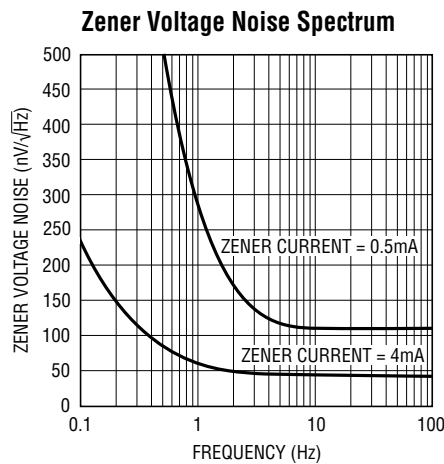
1000afe



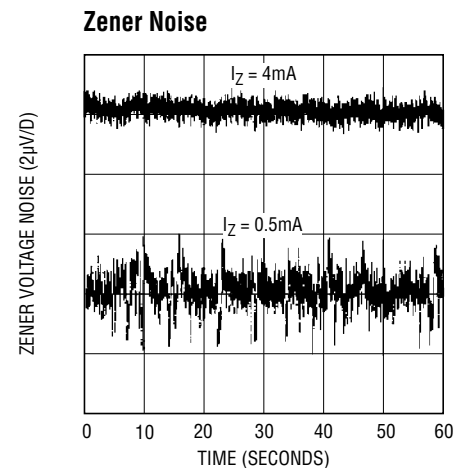
## TYPICAL PERFORMANCE CHARACTERISTICS



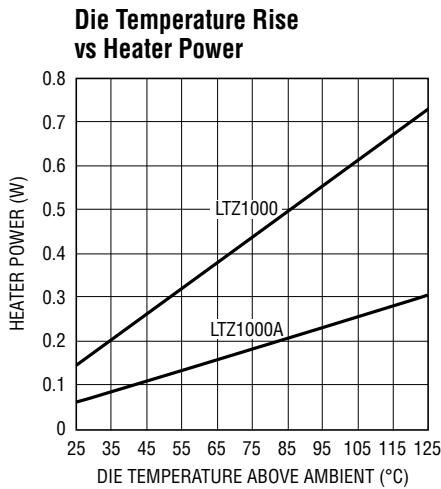
1000 G01



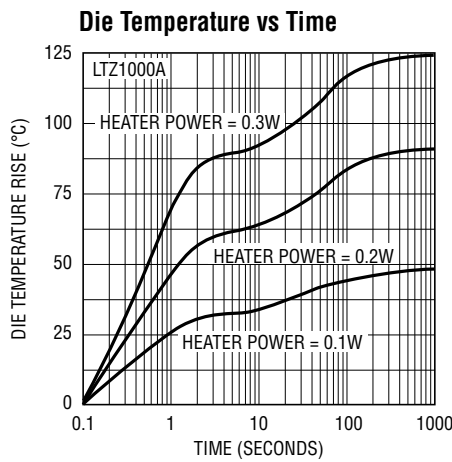
1000 G02



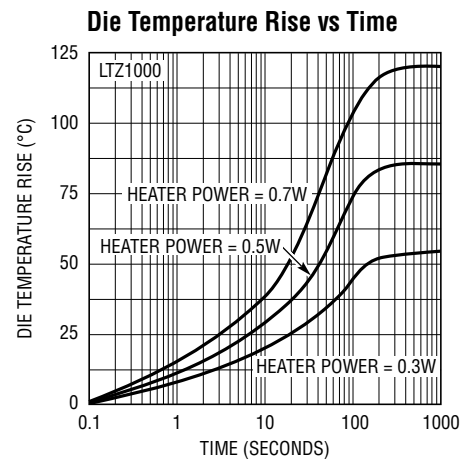
1000 G03



1000 G04



1000 G05



1000 G06

## PIN FUNCTIONS

**Pin 1:** Heater Positive. Must have a higher positive value than Pin 2 and Pin 4.

**Pin 2:** Heater Negative. Must have a higher positive value than Pin 4. Must have equal or lower potential than Pin 1.

**Pin 3:** Zener Positive. Must have a higher positive value than Pin 4.

**Pin 4:** Substrate and Zener Negative. Must have a higher positive value than Pin 7. If Q1 is zenered (about 7V) a permanent degradation in beta will result.

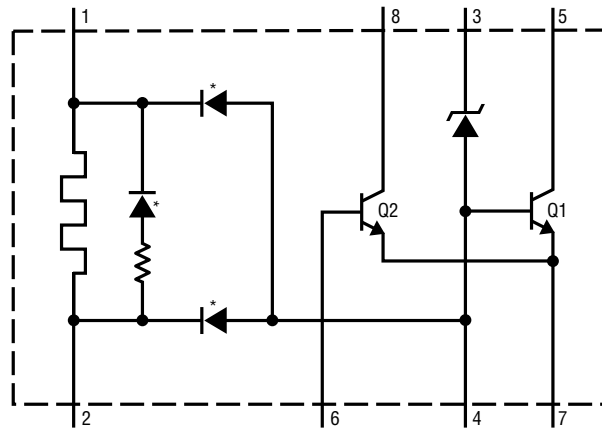
**Pin 5:** Temperature Compensating Transistor Collector.

**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.

## BLOCK DIAGRAM



\*SUBSTRATE DEVICES—DO NOT FORWARD BIAS

1000 TA07

## APPLICATIONS INFORMATION

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 1μV 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 35μV/°C. It is mandatory to keep the zener and transistor leads at the same temperature, otherwise 1ppm 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 1ppm 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.

## APPLICATIONS INFORMATION

### 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. This provides 15°C of margin above a maximum ambient of 45°C, for example. Production variations in emitter-base voltage will typically cause about ±10°C variation. Since the emitter-base voltage changes about 2mV/°C and is very predictable, other temperatures are easily set.

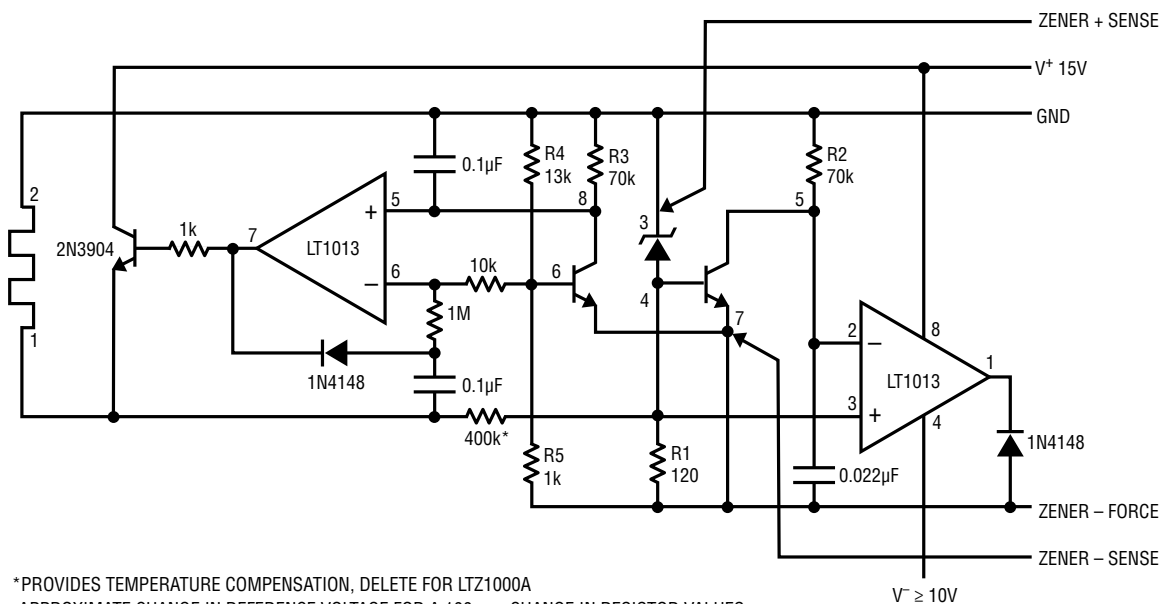
Because higher temperatures accelerate aging and decrease long-term stability, the lowest temperature consistent with the operating environment should be used. The LTZ1000A should be set about 10°C higher than the LTZ1000. This

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. See Application Notes AN-82 and AN-86 for further information. Consult the Linear Technology Applications department for additional help.

## TYPICAL APPLICATIONS

### Negative Voltage Reference



\*PROVIDES TEMPERATURE COMPENSATION, DELETE FOR LTZ1000A

APPROXIMATE CHANGE IN REFERENCE VOLTAGE FOR A 100ppm CHANGE IN RESISTOR VALUES:

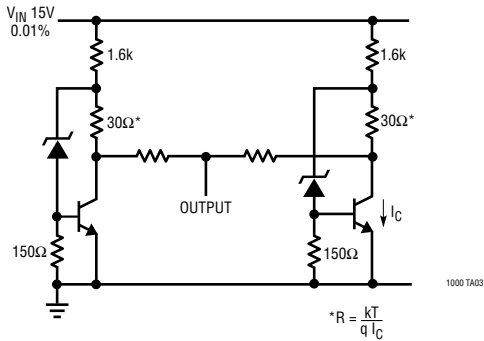
|             | 100ppm = ΔR(Ω) | ΔV <sub>Z</sub> |
|-------------|----------------|-----------------|
| R1          | 0.012Ω         | 1ppm            |
| R2          | 7Ω             | 0.3ppm          |
| R3          | 7Ω             | 0.2ppm          |
| R4/R5 RATIO | ΔR = 0.01%     | 1ppm            |

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

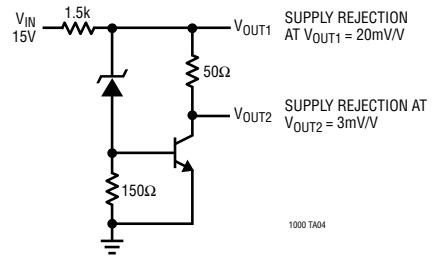
1000 TA02

## TYPICAL APPLICATIONS

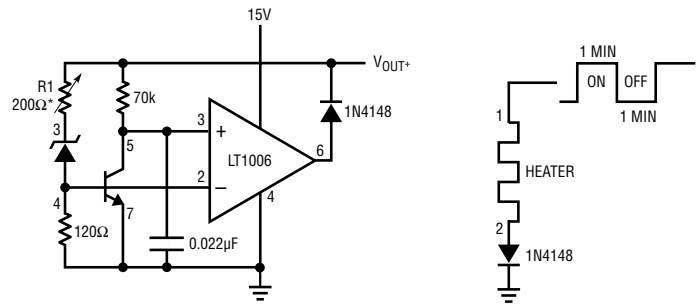
### Averaging Reference Voltage for Lower Noise and Better Stability



### Improving Supply Rejection



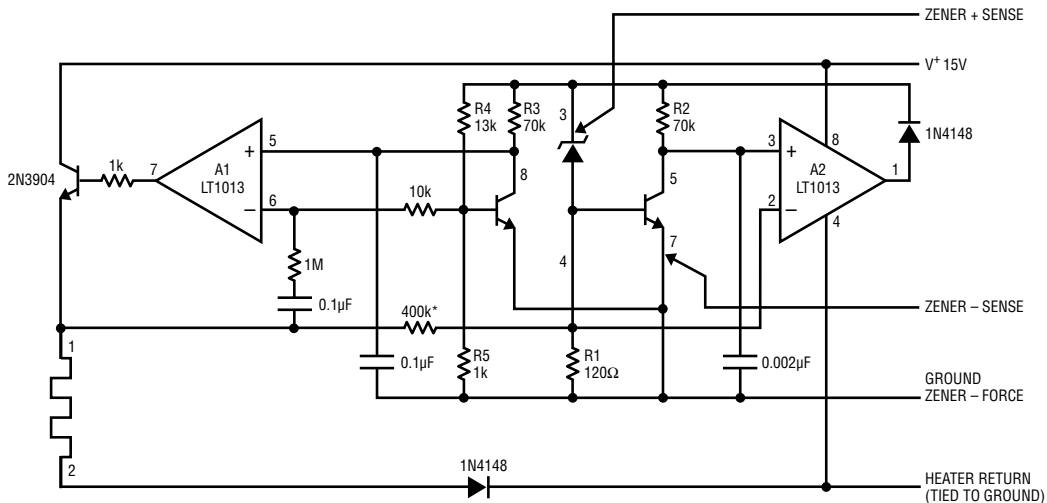
### Adjusting Temperature Coefficient in Unstabilized Applications



\* PULSE HEATER ON AND OFF TO HEAT AND COOL THE REFERENCE. ADJUST R1 FOR MINIMUM VOLTAGE CHANGE THROUGH A TEMPERATURE CYCLE. THE  $-2mV/°C$  TEMPCO OF THE  $V_{BE}$  CANCELS THE  $+2mV/°C$  TEMPCO OF THE ZENER.

1000 TA05

### 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          | 0.012Ω              | 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

1000 TA06

**REVISION HISTORY** (Revision history begins at Rev D)

| REV | DATE  | DESCRIPTION  | PAGE NUMBER |
|-----|-------|--|-------------|
| D   | 4/12  | Corrected thermal information on H8 package drawing            | 2           |
|     |       | Corrected Order Information table                              | 2           |
|     |       | Updated Block Diagram to show substrate diode                  | 4           |
|     |       | Added 1N4148 label to diode in application circuit             | 5           |
|     |       | Added LTC6655 to Related Parts table                           | 8           |
| E   | 11/15 | Web links added  | all         |
|     |       | Correction to Block Diagram, resistor added to substrate diode | 4           |
|     |       | Pin numbers corrected on Negative Voltage Reference diagram    | 5           |

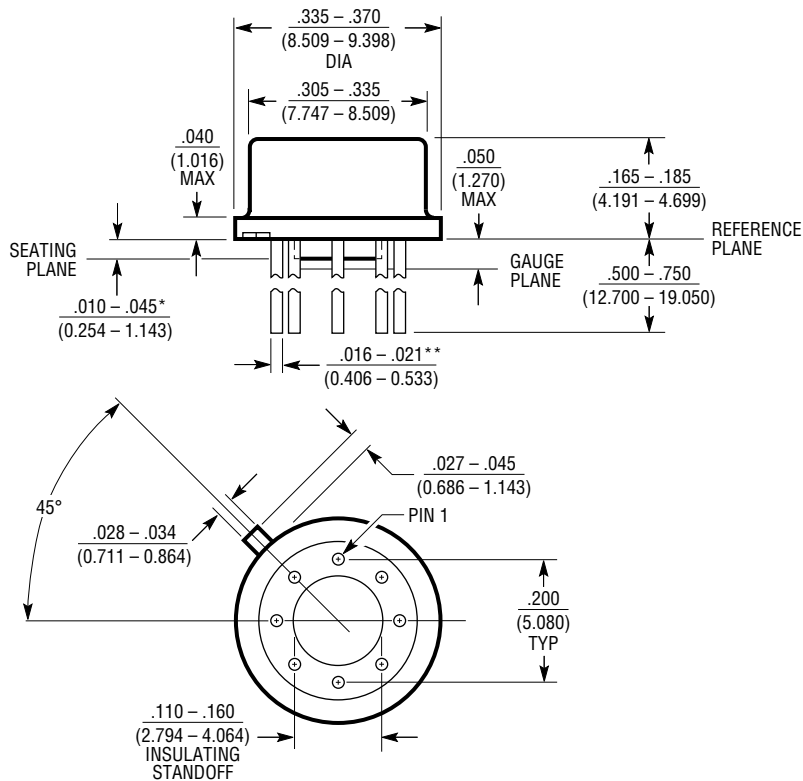


# LTZ1000/LTZ1000A

## PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/product/LTZ1000#packaging> for the most recent package drawings.

### H Package 8-Lead TO-5 Metal Can (.200 Inch PCD) (Reference LTC DWG # 05-08-1320)



\* LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND THE SEATING PLANE

\*\* FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS  $\frac{.016 - .024}{(0.406 - 0.610)}$  H8(TO-5) 0.200 PCD 0204

## RELATED PARTS

| PART NUMBER             | DESCRIPTION                                      | COMMENTS   |
|-------------------------|--|--|
| <a href="#">LM399</a>   | 7V Precision Shunt Reference                     | 0.2% Accuracy, 0.5ppm/°C Drift, 20μV <sub>RMS</sub> Noise          |
| <a href="#">LT1021</a>  | 5V, 7V and 10V Precision Reference               | Available in TO-5, -55°C to 125°C, Series or Shunt Operation       |
| <a href="#">LT1236</a>  | 5V and 10V Low Drift Precision Reference         | 0.05% Accuracy, 5ppm/°C Drift, Series or Shunt Operation           |
| <a href="#">LT1389</a>  | 1.25V, 2.5V, 4V and 5V Nanopower Shunt Reference | 800nA, 0.05% Accuracy, 10ppm/°C Drift                              |
| <a href="#">LT1634</a>  | 1.25V and 2.5V Micropower Shunt Reference        | 0.05%, 10ppm/°C, 10μA Current                                      |
| <a href="#">LTC6655</a> | Precision Low Noise Reference Family             | 2ppm/°C, Maximum Drift, 650nV <sub>P-P</sub> Noise (0.1Hz to 10Hz) |

1000afe



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