

# Precision Voltage References

## FEATURES

- Trimmed Output  $\pm 0.3\%$
- Low Drift— $5\text{ppm}/^{\circ}\text{C}$  Typ
- Low Noise— $3\text{ppm}_{(\text{P-P})}$
- High Line Rejection
- Temperature Output—REF-02
- Low Supply Current  $1.4\text{mA}$  Max

## APPLICATIONS

- A/D and D/A Converters
- Precision Regulators
- Constant Current Sources
- V/F Converters
- Bridge Excitation

## DESCRIPTION

The REF-01/REF-02 are precision 10V and 5V bandgap references which provide stable output voltages over a wide range of operating conditions. Output voltage is accurate to  $\pm 0.3\%$  with a low 5ppm/ $^{\circ}\text{C}$  typical temperature coefficient. The REF-01 and REF-02 are excellent choices for applications where low drift, moderate accuracy, low power consumption and low cost are considerations.

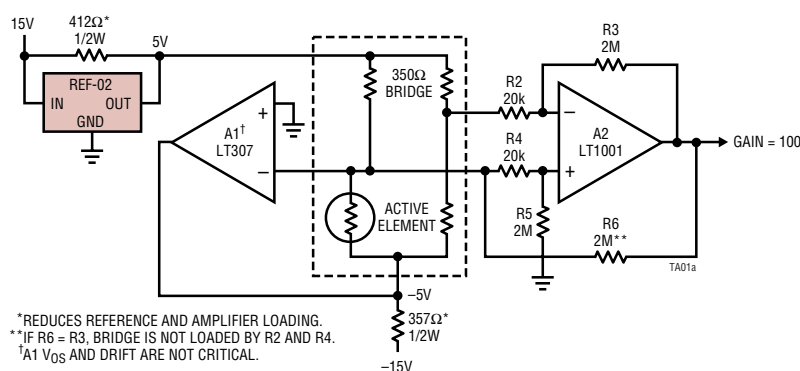
The REF-02 includes a temperature output pin which provides a linear voltage proportional to absolute temperature.

For lower drift and higher accuracy references, please see the LT1019 and LT1021 data sheets.

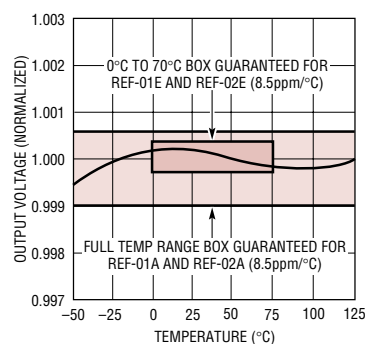
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## TYPICAL APPLICATION

## Ultra Linear Strain Gauge Amplifier



### Output Voltage Temperature Drift



# REF-01/REF-02

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                               |             |
|-------------------------------|-------------|
| REF-01/REF-02 A, E, H .....   | 40V         |
| REF-01C/REF-02C .....         | 30V         |
| Power Dissipation .....       | 500mW       |
| Output Short-Circuit Duration |             |
| To Ground .....               | Indefinite  |
| To $V_{IN} \leq 16V$ .....    | Indefinite  |
| To $V_{IN} > 16V$ .....       | Not Allowed |

|                                            |                |
|--------------------------------------------|----------------|
| Storage Temperature Range .....            | -65°C to 150°C |
| Operating Temperature                      |                |
| REF-01/REF-02, REF-01A/REF-02A ...         | -55°C to 125°C |
| REF-01E/REF-02E, REF-01H/REF-02H,          |                |
| REF-01C/REF-02C, REF-01D/REF-02D ....      | 0°C to 70°C    |
| Lead Temperature (Soldering, 10 sec) ..... | 300°C          |

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                       |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|---------|--------|--------|---------|---------|---------|---------|---------|---------|--|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------|----------|----------|----------|----------|--|----------|
| <p>TOP VIEW</p> <p>NC* 1 2 3 4 5 6 7 8</p> <p>INPUT 2</p> <p>TEMP** 3</p> <p>GND (CASE) 4</p> <p>TRIM 5</p> <p>OUTPUT 6</p> <p>NC* 7</p> <p>NC* 8</p> <p>H PACKAGE<br/>8-LEAD TO-5 METAL CAN<br/><math>T_{JMAX} = 150^{\circ}C</math>, <math>\theta_{JA} = 150^{\circ}C/W</math>, <math>\theta_{JC} = 45^{\circ}C/W</math><br/>* INTERNALLY CONNECTED. DO NOT CONNECT EXTERNALLY.<br/>** DO NOT CONNECT ON REF-01</p> | <p>ORDER PART NUMBER</p> <table><tr><td>REF01AH</td><td>REF02AH</td></tr><tr><td>REF01H</td><td>REF02H</td></tr><tr><td>REF01EH</td><td>REF02EH</td></tr><tr><td>REF01HH</td><td>REF02HH</td></tr><tr><td>REF01CH</td><td>REF02CH</td></tr><tr><td></td><td>REF02DH</td></tr></table> | REF01AH                                                                        | REF02AH | REF01H | REF02H | REF01EH | REF02EH | REF01HH | REF02HH | REF01CH | REF02CH |  | REF02DH | <p>TOP VIEW</p> <p>NC* 1 2 3 4 5 6 7 8</p> <p>INPUT 2</p> <p>TEMP** 3</p> <p>GND 4</p> <p>TRIM 5</p> <p>OUTPUT 6</p> <p>NC* 7</p> <p>NC* 8</p> <p>N8 PACKAGE<br/>8-LEAD PDIP<br/><math>T_{JMAX} = 100^{\circ}C</math>, <math>\theta_{JA} = 130^{\circ}C/W</math><br/>* INTERNALLY CONNECTED. DO NOT CONNECT EXTERNALLY.<br/>** DO NOT CONNECT ON REF-01</p> | <p>ORDER PART NUMBER</p> <table><tr><td>REF01EN8</td><td>REF02EN8</td></tr><tr><td>REF01HN8</td><td>REF02HN8</td></tr><tr><td>REF01CN8</td><td>REF02CN8</td></tr><tr><td></td><td>REF02DN8</td></tr></table> | REF01EN8 | REF02EN8 | REF01HN8 | REF02HN8 | REF01CN8 | REF02CN8 |  | REF02DN8 |
| REF01AH                                                                                                                                                                                                                                                                                                                                                                                                               | REF02AH                                                                                                                                                                                                                                                                               |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01H                                                                                                                                                                                                                                                                                                                                                                                                                | REF02H                                                                                                                                                                                                                                                                                |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01EH                                                                                                                                                                                                                                                                                                                                                                                                               | REF02EH                                                                                                                                                                                                                                                                               |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01HH                                                                                                                                                                                                                                                                                                                                                                                                               | REF02HH                                                                                                                                                                                                                                                                               |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01CH                                                                                                                                                                                                                                                                                                                                                                                                               | REF02CH                                                                                                                                                                                                                                                                               |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                       | REF02DH                                                                                                                                                                                                                                                                               |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01EN8                                                                                                                                                                                                                                                                                                                                                                                                              | REF02EN8                                                                                                                                                                                                                                                                              |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01HN8                                                                                                                                                                                                                                                                                                                                                                                                              | REF02HN8                                                                                                                                                                                                                                                                              |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| REF01CN8                                                                                                                                                                                                                                                                                                                                                                                                              | REF02CN8                                                                                                                                                                                                                                                                              |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                       | REF02DN8                                                                                                                                                                                                                                                                              |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                       |                                                                                |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |
| <p><b>OBSOLETE PACKAGE</b><br/>Consider the N Package for Alternate Source</p>                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                       | <p><b>OBSOLETE PACKAGE</b><br/>Consider the N Package for Alternate Source</p> |         |        |        |         |         |         |         |         |         |  |         |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                              |          |          |          |          |          |          |  |          |

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

## ELECTRICAL CHARACTERISTICS $V_{IN} = 15V$ , $T_A = 25^{\circ}C$ unless otherwise noted.

| SYMBOL                                  | PARAMETER                  | CONDITIONS                            | REF-01A/E, REF-02A/E |             |       | REF-01H, REF-02H |        |       | UNITS         |
|-----------------------------------------|----------------------------|---------------------------------------|----------------------|-------------|-------|------------------|--------|-------|---------------|
|                                         |                            |                                       | MIN                  | TYP         | MAX   | MIN              | TYP    | MAX   |               |
| $V_O$                                   | Output Voltage             | $I_L = 0mA$                           | 9.97                 | 10          | 10.03 | 9.95             | 10     | 10.05 | V             |
|                                         |                            |                                       | 4.985                | 5           | 5.015 | 4.975            | 5      | 5.025 | V             |
|                                         | Output Adjustment Range    | $R_P = 10k\Omega$                     | $\pm 3$              | 5, -27      |       | $\pm 3$          | 5, -27 |       | %             |
|                                         |                            |                                       | $\pm 3$              | 5, -13      |       | $\pm 3$          | 5, -13 |       | %             |
| $e_{nP-P}$                              | Output Voltage Noise       | 0.1Hz to 10Hz (Note 7)                |                      | 20          |       |                  | 20     |       | $\mu V_{P-P}$ |
|                                         |                            |                                       |                      | 10          |       |                  | 10     |       | $\mu V_{P-P}$ |
| $V_{IN}$                                | Input Voltage Range        |                                       | 12                   |             | 40    | 12               |        | 40    | V             |
|                                         |                            |                                       | 7                    |             | 40    | 7                |        | 40    | V             |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$  | Line Regulation (Note 2)   | $(V_{OUT} + 3V) \leq V_{IN} \leq 33V$ |                      | 0.0001      | 0.010 |                  | 0.0001 | 0.010 | %/V           |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation (Note 2)   | $I_L = 0mA$ to 10mA                   |                      | 0.0005      | 0.008 |                  | 0.0005 | 0.010 | %/mA          |
|                                         |                            |                                       |                      | 0.0010      | 0.010 |                  | 0.001  | 0.010 | %/mA          |
| $I_Q$                                   | Quiescent Supply Current   | No Load                               |                      | 0.65        | 1.4   |                  | 0.65   | 1.4   | mA            |
| $I_{OUT}$                               | Load Current Sink Current  |                                       | 10                   | 20          |       | 10               | 20     |       | mA            |
|                                         |                            |                                       | -0.3                 | -20         |       | -0.3             | -20    |       | mA            |
| $I_{SC}$                                | Short-Circuit Current      | $V_O = 0V$                            |                      | 25          |       |                  | 25     |       | mA            |
| $V_T$                                   | Temperature Voltage Output | (Note 3)                              |                      | 620         |       |                  | 620    |       | mV            |
|                                         |                            |                                       |                      | REF-02 Only |       |                  |        |       |               |

**ELECTRICAL CHARACTERISTICS** $V_{IN} = 15V$ ,  $T_A = 25^\circ C$  unless otherwise noted.

| SYMBOL                                  | PARAMETER                    | CONDITIONS                               | REF-01C, REF-02C |          |       | REF-02D   |          |      | UNITS                          |
|-----------------------------------------|------------------------------|------------------------------------------|------------------|----------|-------|-----------|----------|------|--------------------------------|
|                                         |                              |                                          | MIN              | TYP      | MAX   | MIN       | TYP      | MAX  |                                |
| $V_O$                                   | Output Voltage               | $I_L = 0mA$                              | 9.9              | 10       | 10.1  |           |          |      | V                              |
|                                         |                              | REF-01<br>REF-02                         | 4.95             | 5        | 5.05  | 4.9       | 5        | 5.1  | V                              |
|                                         | Output Adjustment Range      | $R_P = 10k\Omega$                        |                  | 5, -27   |       |           |          |      | %                              |
|                                         |                              | REF-01<br>REF-02                         | $\pm 2.7$        | 5, -13   |       | $\pm 2$   | 5, -13   |      | %                              |
| $e_{nP-P}$                              | Output Voltage Noise         | 0.1Hz to 10Hz (Note 7)                   |                  | 30<br>12 |       |           | 12       |      | $\mu V_{P-P}$<br>$\mu V_{P-P}$ |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$  | Line Regulation (Note 2)     | $(V_{OUT} + 3V) \leq V_{IN} \leq 33V$    |                  | 0.0001   | 0.015 |           | 0.0001   | 0.04 | %/V                            |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation (Note 2)     | $I_L = 0mA$ to 8mA<br>$I_L = 0mA$ to 4mA |                  | 0.0005   | 0.015 |           | 0.001    | 0.04 | %/mA<br>%/mA                   |
| $I_Q$                                   | Quiescent Supply Current     | No Load                                  |                  | 0.65     | 1.6   |           | 0.65     | 2    | mA                             |
| $I_{OUT}$                               | Load Current<br>Sink Current |                                          | 8<br>-0.2        | 20<br>20 |       | 8<br>-0.2 | 20<br>20 |      | mA<br>mA                       |
| $I_{SC}$                                | Short-Circuit Current        | $V_O = 0V$                               |                  | 25       |       |           | 25       |      | mA                             |
| $V_T$                                   | Temperature Voltage Output   | (Note 3) REF-02 Only                     |                  | 620      |       |           | 620      |      | mV                             |

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ C$ .  
 $V_{IN} = 15V$ ,  $-55^\circ C \leq T_A \leq \pm 125^\circ C$  for REF-01A/REF-02A and REF-01/REF-02,  $0^\circ C \leq T_A \leq 70^\circ C$  for REF-01E/REF-02E and REF-01H/REF-02H,  $I_L = 0mA$  unless otherwise noted.

| SYMBOL                                 | PARAMETER                                                         | CONDITIONS                                                                      |        | REF-01A/E, REF-02A/E |                  |                | REF-01H/REF-02H |                  |                | UNITS           |
|----------------------------------------|-------------------------------------------------------------------|---------------------------------------------------------------------------------|--------|----------------------|------------------|----------------|-----------------|------------------|----------------|-----------------|
|                                        |                                                                   |                                                                                 |        | MIN                  | TYP              | MAX            | MIN             | TYP              | MAX            |                 |
| $\frac{\Delta V}{\Delta T}$            | Output Voltage Change with Temperature (Notes 4, 5)               | $0^\circ C \leq T_A \leq 70^\circ C$<br>$-55^\circ C \leq T_A \leq 125^\circ C$ | ●<br>● |                      | 0.02<br>0.09     | 0.06<br>0.15   |                 | 0.035<br>0.144   | 0.17<br>0.45   | %<br>%          |
| TC                                     | Output Voltage Temperature Coefficient                            | (Note 6)                                                                        | ●      |                      | 5                | 8.5            |                 | 8                | 25             | ppm/ $^\circ C$ |
|                                        | Change in $V_O$ Temperature Coefficient with Output Adjustment    | $R_P = 10k\Omega$                                                               | ●      |                      | 0.5              |                |                 | 0.5              |                | ppm/%           |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$ | Line Regulation<br>$(V_{OUT} + 3V) \leq V_{IN} \leq 33V$ (Note 2) | $0^\circ C \leq T_A \leq 70^\circ C$<br>$-55^\circ C \leq T_A \leq 125^\circ C$ | ●<br>● |                      | 0.0001<br>0.0001 | 0.012<br>0.015 |                 | 0.0001<br>0.0001 | 0.012<br>0.015 | %/V<br>%/V      |
|                                        | Load Regulation<br>( $I_L = 0mA$ to 8mA) (Note 2)                 | $0^\circ C \leq T_A \leq 70^\circ C$<br>$-55^\circ C \leq T_A \leq 125^\circ C$ | ●<br>● |                      | 0.002<br>0.002   | 0.010<br>0.012 |                 | 0.002<br>0.002   | 0.012<br>0.015 | %/mA<br>%/mA    |
|                                        | Temperature Voltage Output Temperature Coefficient                | (Note 3) REF-02                                                                 | ●      |                      | 2.1              |                |                 | 2.1              |                | mV/ $^\circ C$  |

**ELECTRICAL CHARACTERISTICS**

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_{IN} = 15\text{V}$ ,  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$  and  $I_L = 0\text{mA}$  unless otherwise noted.

| SYMBOL                                  | PARAMETER                                                      | CONDITIONS                          |   | REF-01C, REF-02C |        |       | REF-02D |        |      | UNITS                 |
|-----------------------------------------|----------------------------------------------------------------|-------------------------------------|---|------------------|--------|-------|---------|--------|------|-----------------------|
|                                         |                                                                |                                     |   | MIN              | TYP    | MAX   | MIN     | TYP    | MAX  |                       |
| $\frac{\Delta V}{\Delta T}$             | Output Voltage Change with Temperature                         | (Notes 4, 5)                        | ● |                  |        | 0.45  |         |        | 1.7  | %                     |
| TC                                      | Output Voltage Temperature Coefficient                         | (Note 6)                            | ● |                  | 8      | 65    |         | 8      | 250  | ppm/ $^\circ\text{C}$ |
|                                         | Change in $V_O$ Temperature Coefficient with Output Adjustment | $R_P = 10\text{k}\Omega$            | ● |                  | 0.5    |       |         | 0.5    |      | ppm/%                 |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$  | Line Regulation (Note 2)                                       | $V_{IN} = 8\text{V to } 30\text{V}$ | ● |                  | 0.0001 | 0.018 |         | 0.0001 | 0.05 | %/V                   |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation (Note 2)                                       | $I_L = 0\text{mA to } 5\text{mA}$   | ● |                  | 0.002  | 0.018 |         | 0.002  | 0.05 | %/mA                  |
|                                         | Temperature Voltage Output Temperature Coefficient             | (Note 3) REF-02                     | ● |                  | 2.1    |       |         | 2.1    |      | mV/ $^\circ\text{C}$  |

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** Line and load regulation specifications include the effect of self heating.

**Note 3:** Limit current in or out of Pin 3 to 50nA and capacitance on Pin 3 to 30pF.

**Note 4:**  $\Delta V$  is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of nominal output.

$$\Delta V = \left| \frac{V_{MAX} - V_{MIN}}{V_{OUT}} \right| \cdot 100$$

**Note 5:**  $\Delta V$  specification applies trimmed or untrimmed.

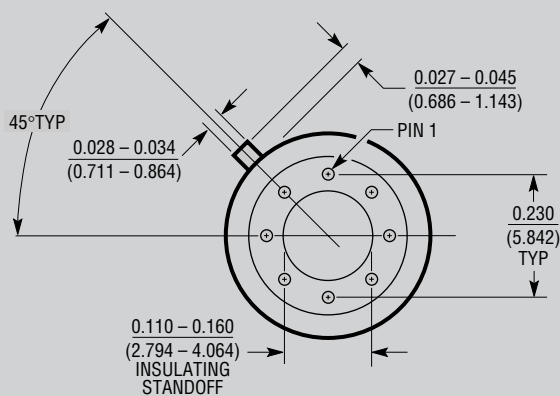
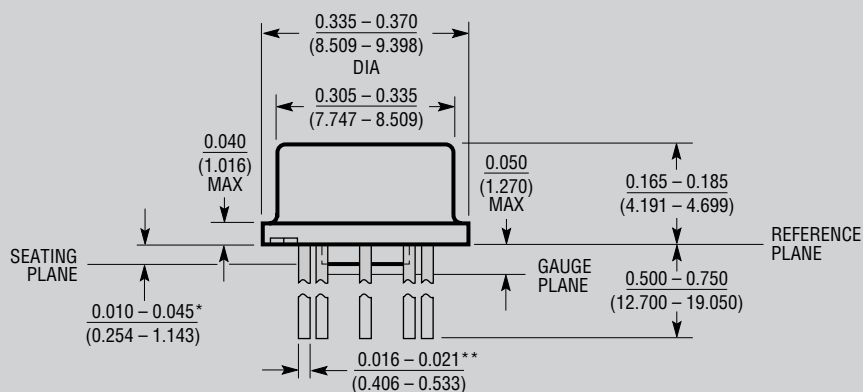
**Note 6:** TC is defined as  $\Delta V$  divided by the temperature range, i.e.,

$$TC = \frac{\Delta V}{T_{MAX} - T_{MIN}}$$

**Note 7:** 0.1Hz to 10Hz noise cannot be 100% tested on modern high speed test equipment, so Linear Technology does not put a guaranteed maximum specification on this parameter for standard units. 100% bench testing of 0.1Hz to 10Hz noise is available on special request. To ensure low output noise, Linear Technology *does* 100% test 10Hz to 1kHz noise. Consult factory for details.

## PACKAGE DESCRIPTION

**H Package**  
**8-Lead TO-5 Metal Can (.230 Inch PCD)**  
 (Reference LTC DWG # 05-08-1321)



\* LEAD DIAMETER IS UNCONTROLLED BETWEEN THE REFERENCE PLANE AND 0.045" BELOW THE REFERENCE PLANE

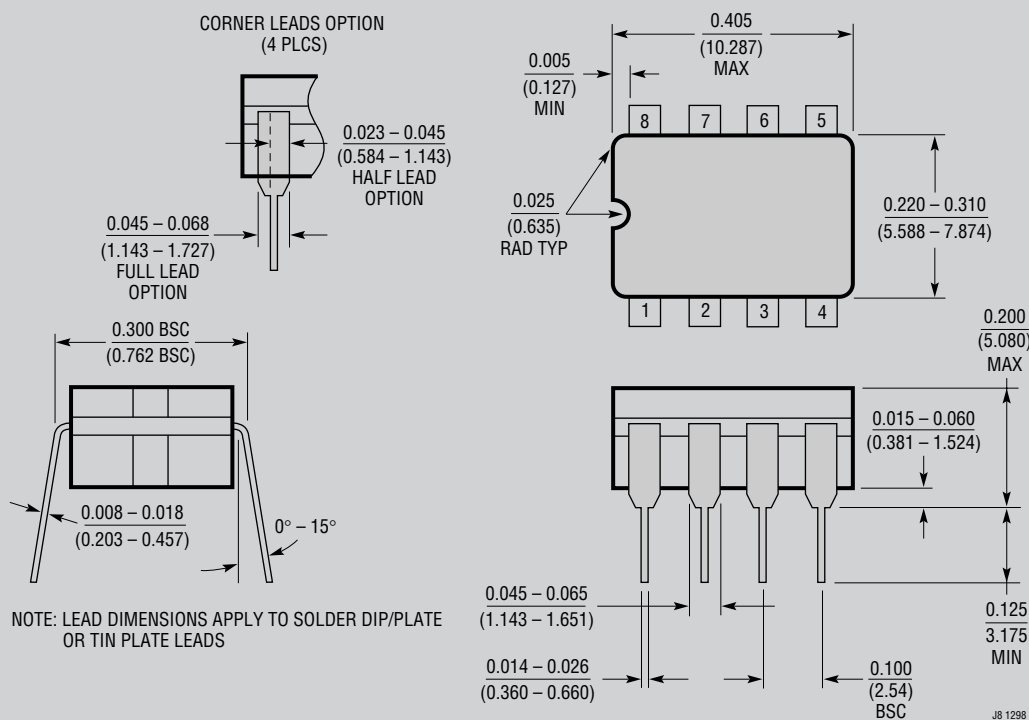
\*\* FOR SOLDER DIP LEAD FINISH, LEAD DIAMETER IS  $0.016 - 0.024$  (0.406 - 0.610)

H8 (TO-5) 0.230 PCD 1197

**OBSOLETE PACKAGE**

PACKAGE DESCRIPTION

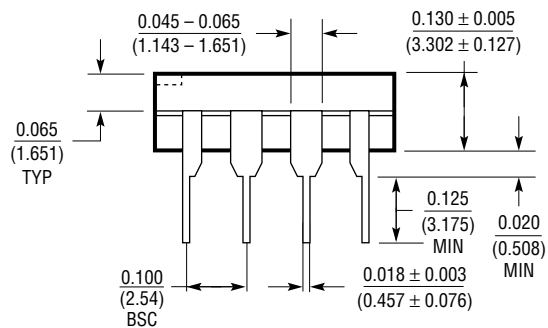
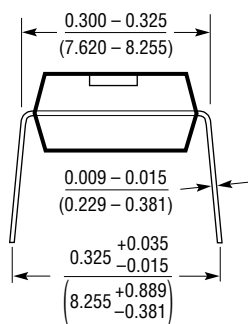
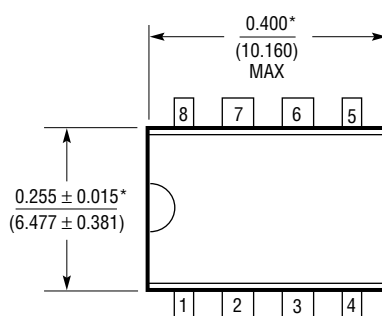
J8 Package  
8-Lead Cerdip (Narrow .300 Inch, Hermetic)  
(Reference LTC DWG # 05-08-1110)



OBSOLETE PACKAGE

## PACKAGE DESCRIPTION

**N8 Package**  
**8-Lead PDIP (Narrow .300 Inch)**  
 (Reference LTC DWG # 05-08-1510)



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

N8 1098

## RELATED PARTS

| PART NUMBER | DESCRIPTION                        | COMMENTS                                               |
|-------------|------------------------------------|--------------------------------------------------------|
| LT1019      | 0.05%, 5ppm/°C Precision Reference | Pin Compatible with the REF-01, REF-02, Improved Specs |