

# 10V Precision Voltage Reference

## FEATURES

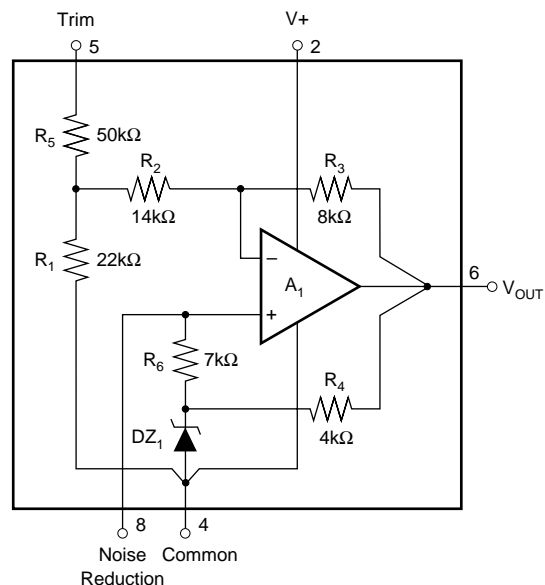
- **+10V  $\pm 0.0025$ V OUTPUT**
- **VERY LOW DRIFT: 2.5ppm/ $^{\circ}$ C max**
- **EXCELLENT STABILITY:**  
5ppm/1000hr typ
- **EXCELLENT LINE REGULATION:**  
1ppm/V max
- **EXCELLENT LOAD REGULATION:**  
10ppm/mA max
- **LOW NOISE: 5 $\mu$ V<sub>PP</sub> typ, 0.1Hz to 10Hz**
- **WIDE SUPPLY RANGE: 11.4VDC to 36VDC**
- **LOW QUIESCENT CURRENT: 1.4mA max**
- **PACKAGE OPTIONS: PLASTIC DIP, SO-8**

## APPLICATIONS

- **PRECISION-CALIBRATED VOLTAGE STANDARD**
- **D/A AND A/D CONVERTER REFERENCE**
- **PRECISION CURRENT REFERENCE**
- **ACCURATE COMPARATOR THRESHOLD REFERENCE**
- **DIGITAL VOLTMETERS**
- **TEST EQUIPMENT**
- **PC-BASED INSTRUMENTATION**

## DESCRIPTION

The REF102 is a precision 10V voltage reference. The drift is laser-trimmed to 2.5ppm/ $^{\circ}$ C max C-grade over the industrial temperature range. The REF102 achieves its precision without a heater. This results in low power, fast warm-up, excellent stability, and low noise. The output voltage is extremely insensitive to both line and load variations and can be externally adjusted with minimal effect on drift and stability. Single supply operation from 11.4V to 36V and excellent overall specifications make the REF102 an ideal choice for demanding instrumentation and system reference applications.



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|  |                 |
|--|-----------------|
| Input Voltage .....                            | +40V            |
| Operating Temperature<br>P, U .....            | -25°C to +85°C  |
| Storage Temperature Range<br>P, U .....        | -40°C to +125°C |
| Lead Temperature (soldering, 10s) .....        | +300°C          |
| (SO, 3s) .....                                 | +260°C          |
| Short-Circuit Protection to Common or V+ ..... | Continuous      |

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

| PRODUCT       | MAX INITIAL<br>ERROR (mV) | MAX DRIFT<br>(PPM/°C) | PACKAGE-LEAD | PACKAGE<br>DESIGNATOR | SPECIFIED<br>TEMPERATURE<br>RANGE | PACKAGE<br>MARKING | ORDERING<br>NUMBER | TRANSPORT<br>MEDIA, QUANTITY |
|---------------|---------------------------|-----------------------|--------------|-----------------------|-----------------------------------|--------------------|--------------------|------------------------------|
| REF102AU<br>" | ±10                       | ±10                   | SO-8         | D                     | −25°C to +85°C                    | REF102AU           | REF102AU           | Tube, 100                    |
|               | ±10                       | ±10                   | SO-8         | D                     | "                                 | REF102AU/2K5       | REF102AU/2K5       | Tape and Reel, 2500          |
| REF102AP      | ±10                       | ±10                   | DIP-8        | P                     | "                                 | REF102AP           | REF102AP           | Tube, 50                     |
| REF102BU<br>" | ±5                        | ±5                    | SO-8         | D                     | "                                 | REF102BU           | REF102BU           | Tube, 100                    |
|               | ±5                        | ±5                    | SO-8         | D                     | "                                 | REF102BU/2K5       | REF102BU/2K5       | Tape and Reel, 2500          |
| REF102BP      | ±5                        | ±5                    | DIP-8        | P                     | "                                 | REF102BP           | REF102BP           | Tube, 50                     |
| REF102CU<br>" | ±2.5                      | ±2.5                  | SO-8         | D                     | "                                 | REF102CU           | REF102CU           | Tube, 100                    |
|               | ±2.5                      | ±2.5                  | SO-8         | D                     | "                                 | REF102CU/2K5       | REF102CU/2K5       | Tape and Reel, 2500          |
| REF102CP      | ±2.5                      | ±2.5                  | DIP-8        | P                     | "                                 | REF102CP           | REF102CP           | Tube, 50                     |

**Top View** **DIP, SO**

NC 1 8 Noise Reduction

V+ 2 7 NC

NC 3 6  $V_{OUT}$

Com 4 5 Trim

NC = Not Connected

# ELECTRICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$  and  $V_S = +15\text{V}$  power supply, unless otherwise noted.

| PARAMETER  | CONDITIONS  | REF102A |     |                              | REF102B |     |                              | REF102C |     |                                 | UNITS  |
|--|---|---------|-----|------------------------------|---------|-----|------------------------------|---------|-----|---------------------------------|--|
|  |   | MIN     | TYP | MAX                          | MIN     | TYP | MAX                          | MIN     | TYP | MAX                             |  |
| <b>OUTPUT VOLTAGE</b><br>Initial<br>vs Temperature <sup>(1)</sup><br>vs Supply<br>(Line Regulation)<br>vs Output Current<br>(Load Regulation)<br>vs Time<br>M Package<br>P, U Packages <sup>(2)</sup><br>Trim Range <sup>(3)</sup><br>Capacitive Load, max | $T_A = 25^\circ\text{C}$<br><br>$V_S = 11.4\text{V to } 36\text{V}$<br><br>$I_L = 0\text{mA to } +10\text{mA}$<br>$I_L = 0\text{mA to } -5\text{mA}$<br>$T_A = +25^\circ\text{C}$ | 9.99    |     | 10.01<br>10<br>2<br>20<br>40 | 9.995   |     | 10.005<br>5<br>1<br>10<br>20 | 9.9975  |     | 10.0025<br>2.5<br>1<br>10<br>20 | V<br>ppm/ $^\circ\text{C}$<br>ppm/V<br>ppm/mA<br>ppm/mA<br>ppm/1000hr<br>ppm/1000hr<br>%<br>pF |
| <b>NOISE</b>   | 0.1Hz to 10Hz   |         | 5   |                              |         | *   |                              |         | *   |                                 | $\mu\text{V}_{PP}$   |
| <b>OUTPUT CURRENT</b>  |   | +10, -5 |     |                              | *       |     |                              | *       |     |                                 | mA   |
| <b>INPUT VOLTAGE RANGE</b>   |   | +11.4   |     | +36                          | *       |     | *                            | *       |     | *                               | V  |
| <b>QUIESCENT CURRENT</b>   | $I_{OUT} = 0$   |         |     | +1.4                         |         |     | *                            |         |     | *                               | mA   |
| <b>WARM-UP TIME</b> <sup>(4)</sup>   | To 0.1%   |         | 15  |                              |         | *   |                              |         | *   |                                 | $\mu\text{s}$  |
| <b>TEMPERATURE RANGE</b><br>Specification<br>REF102A, B, C   |   | -25     |     | +85                          | *       |     | *                            | *       |     | *                               | $^\circ\text{C}$   |

\* Specifications same as REF102A.

NOTES: (1) The "box" method is used to specify output voltage drift vs temperature. See the Discussion of Performance section.

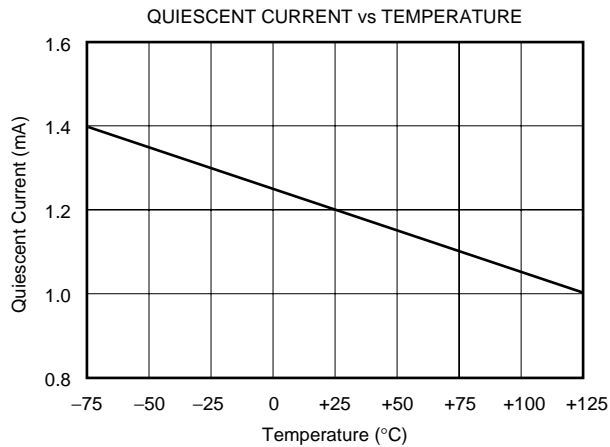
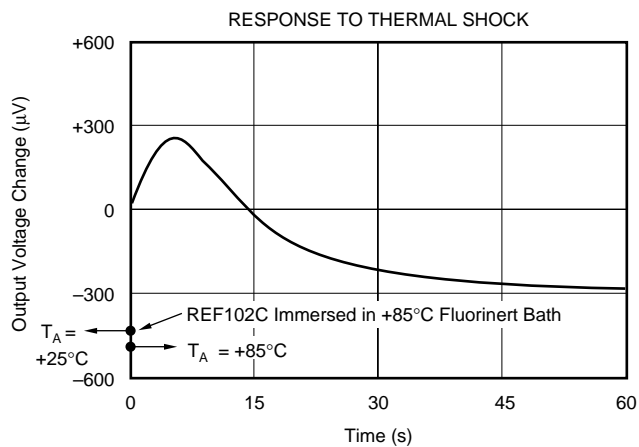
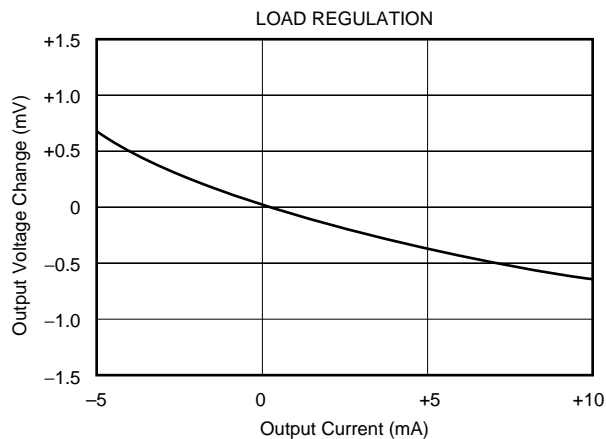
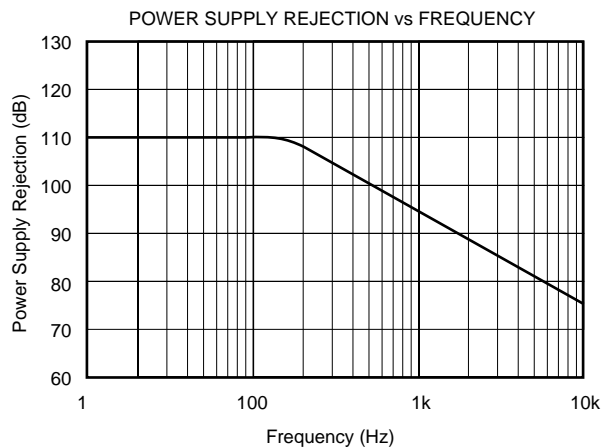
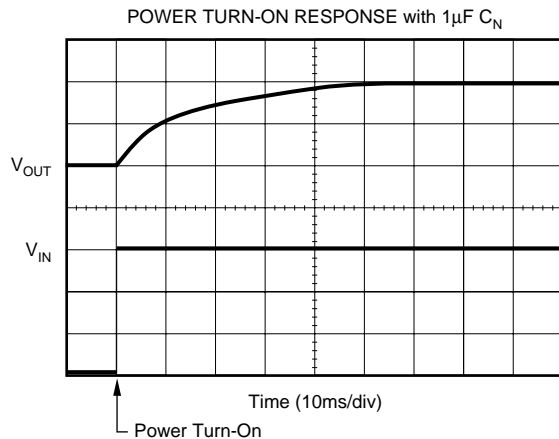
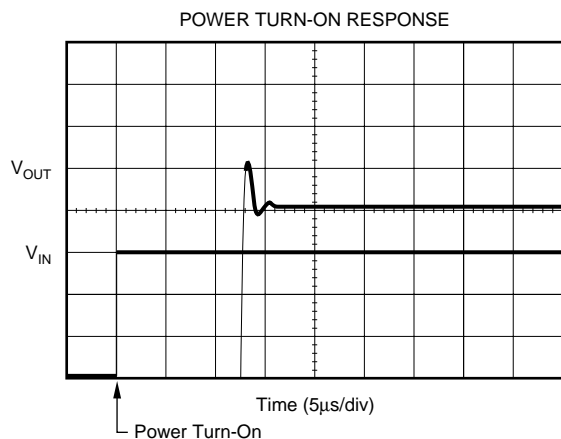
(2) Typically 5ppm/1000hrs after 168hr powered stabilization.

(3) Trimming the offset voltage affects drift slightly. See Installation and Operating Instructions for details.

(4) With noise reduction pin floating. See Typical Characteristics for details.

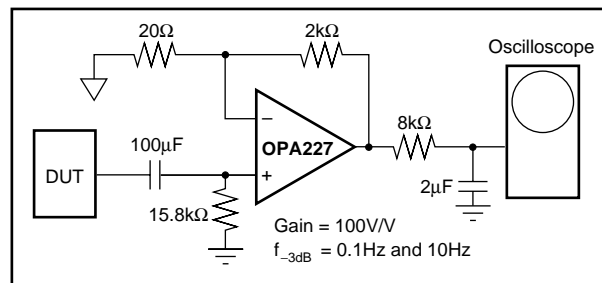
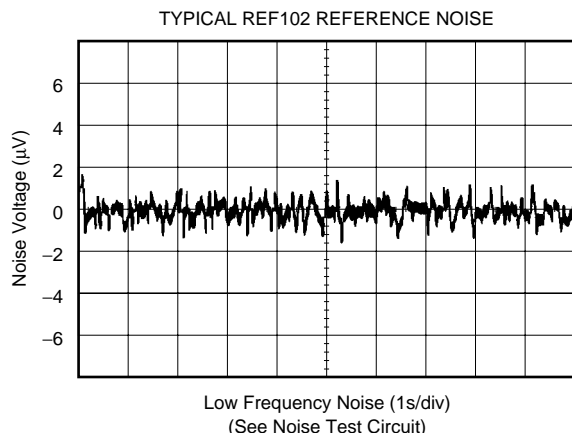
# TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +15\text{V}$ , unless otherwise noted.



# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +15\text{V}$ , unless otherwise noted.



## THEORY OF OPERATION

Refer to the diagram on the first page of this data sheet. The 10V output is derived from a compensated buried zener diode  $DZ_1$ , op amp  $A_1$ , and resistor network  $R_1 - R_6$ .

Approximately 8.2V is applied to the non-inverting input of  $A_1$  by  $DZ_1$ .  $R_1$ ,  $R_2$ , and  $R_3$  are laser-trimmed to produce an exact 10V output. The zener bias current is established from the regulated output voltage through  $R_4$ .  $R_5$  allows user-trimming of the output voltage by providing for small external adjustment of the amplifier gain. Because the temperature coefficient (TCR) of  $R_5$  closely matches the TCR of  $R_1$ ,  $R_2$  and  $R_3$ , the voltage trim has minimal effect on the reference drift. The output voltage noise of the REF102 is dominated by the noise of the zener diode. A capacitor can be connected between the Noise Reduction pin and ground to form a low-pass filter with  $R_6$  and roll off the high-frequency noise of the zener.

## DISCUSSION OF PERFORMANCE

The REF102 is designed for applications requiring a precision voltage reference where both the initial value at room temperature and the drift over temperature are of importance to the user. Two basic methods of specifying voltage reference drift versus temperature are in common usage in the industry—the “butterfly method” and the “box method.” The

REF102 is specified by the more commonly-used “box method.” The “box” is formed by the high and low specification temperatures and a diagonal, the slope of which is equal to the maximum specified drift.

Since the shape of the actual drift curve is not known, the vertical position of the box is not known, either. It is, however, bounded by  $V_{\text{UPPER BOUND}}$  and  $V_{\text{LOWER BOUND}}$  (see Figure 1). Figure 1 uses the REF102CU as an example. It has a drift specification of 2.5ppm/ $^\circ\text{C}$  maximum and a specification temperature range of  $-25^\circ\text{C}$  to  $+85^\circ\text{C}$ . The “box” height,  $V_1$  to  $V_2$ , is 2.75mV.

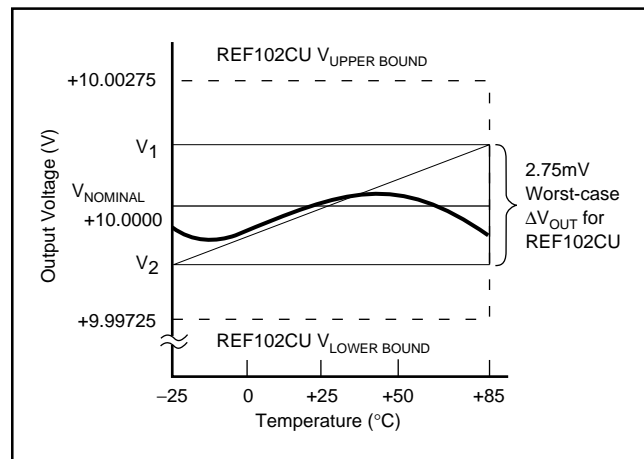


FIGURE 1. REF102CU Output Voltage Drift.

# INSTALLATION AND OPERATING INSTRUCTIONS

## BASIC CIRCUIT CONNECTION

Figure 2 shows the proper connection of the REF102. To achieve the specified performance, pay careful attention to layout. A low resistance star configuration will reduce voltage errors, noise pickup, and noise coupled from the power supply. Commons should be connected as indicated, being sure to minimize interconnection resistances.

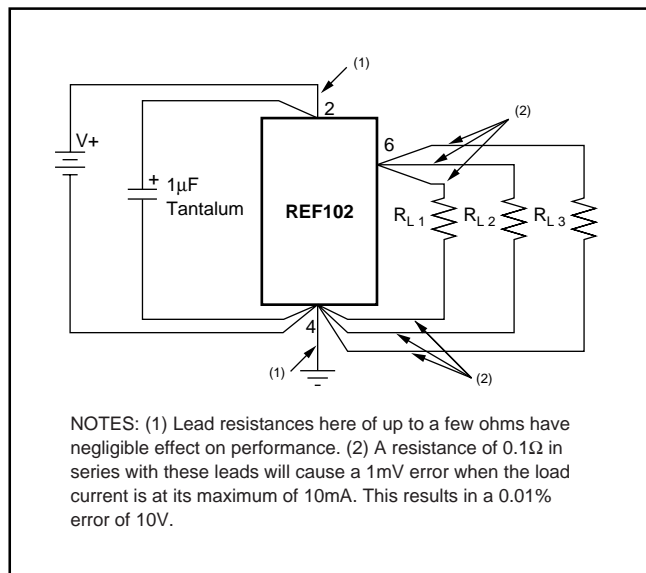


FIGURE 2. REF102 Installation.

## OPTIONAL OUTPUT VOLTAGE ADJUSTMENT

Optional output voltage adjustment circuits are shown in Figures 3 and 4. Trimming the output voltage will change the voltage drift by approximately  $0.008\text{ppm}/^\circ\text{C}$  per mV of trimmed voltage. In the circuit in Figure 3, any mismatch in TCR between the two sections of the potentiometer will also affect drift, but the effect of the  $\Delta\text{TCR}$  is reduced by a factor of five by the internal resistor divider. A high quality potentiometer, with good mechanical stability, such as a cermet, should be

used. The circuit in Figure 3 has a minimum trim range of  $\pm 300\text{mV}$ . The circuit in Figure 4 has less range but provides higher resolution. The mismatch in TCR between  $R_S$  and the internal resistors can introduce some slight drift. This effect is minimized if  $R_S$  is kept significantly larger than the  $50\text{k}\Omega$  internal resistor. A TCR of  $100\text{ppm}/^\circ\text{C}$  is normally sufficient.

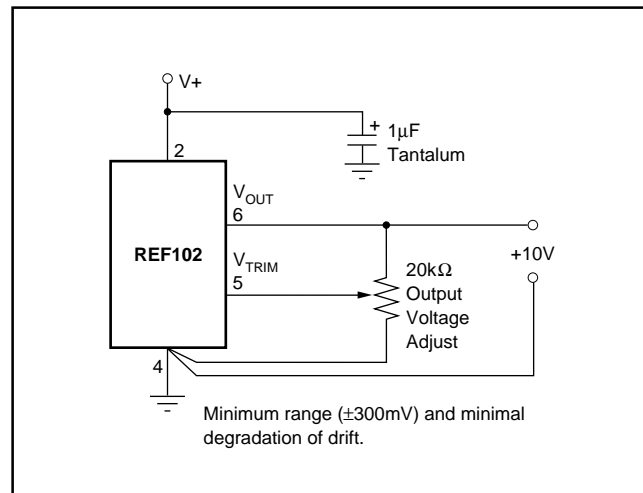


FIGURE 3. REF102 Optional Output Voltage Adjust.

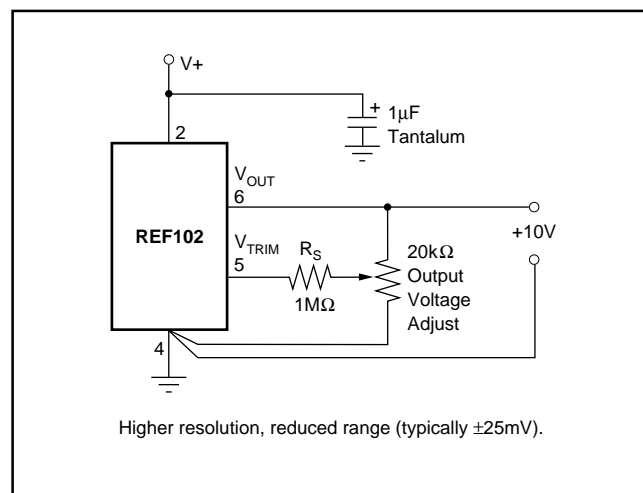


FIGURE 4. REF102 Optional Output Voltage, Fine Adjust.

## OPTIONAL NOISE REDUCTION

The high-frequency noise of the REF102 is dominated by the zener diode noise. This noise can be greatly reduced by connecting a capacitor between the Noise Reduction pin and ground. The capacitor forms a low-pass filter with  $R_6$  (refer to the figure on page 1) and attenuates the high-frequency noise generated by the zener. Figure 5 shows the effect of a  $1\mu\text{F}$  noise reduction capacitor on the high-frequency noise of the REF102.  $R_6$  is typically  $7\text{k}\Omega$  so the filter has a  $-3\text{dB}$  frequency of about  $22\text{Hz}$ . The result is a reduction in noise from about  $800\mu\text{V}_{\text{PP}}$  to under  $200\mu\text{V}_{\text{PP}}$ . If further noise reduction is required, use the circuit in Figure 14.

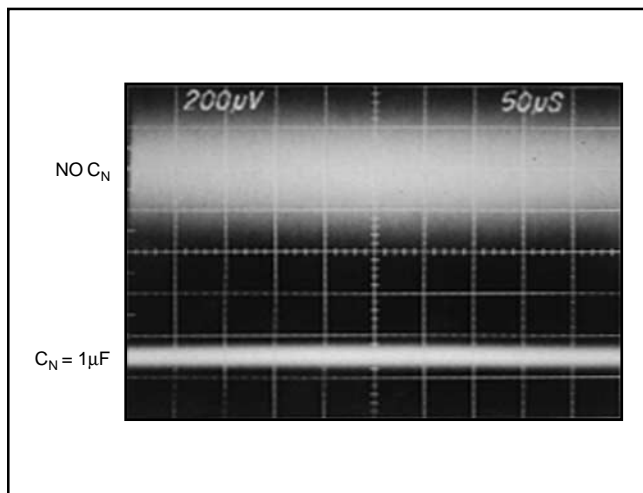


FIGURE 5. Effect of  $1\mu\text{F}$  Noise Reduction Capacitor on Broadband Noise ( $f_{-3\text{dB}} = 1\text{MHz}$ )

## APPLICATIONS INFORMATION

High accuracy, extremely low drift, outstanding stability, and low cost make the REF102 an ideal choice for all instrumentation and system reference applications. Figures 6 through 14 show a variety of useful application circuits.

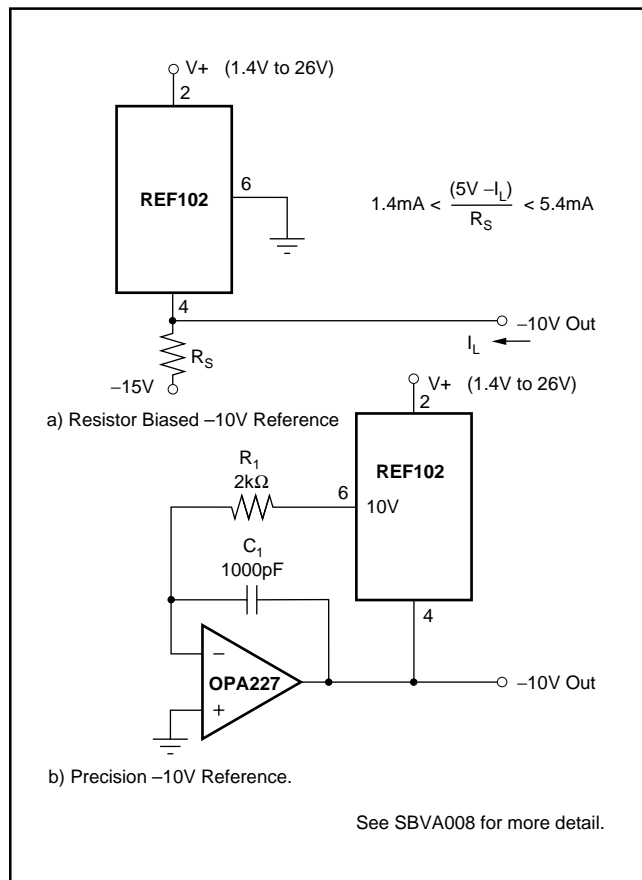


FIGURE 6.  $-10\text{V}$  Reference Using a) Resistor or b) OPA227.

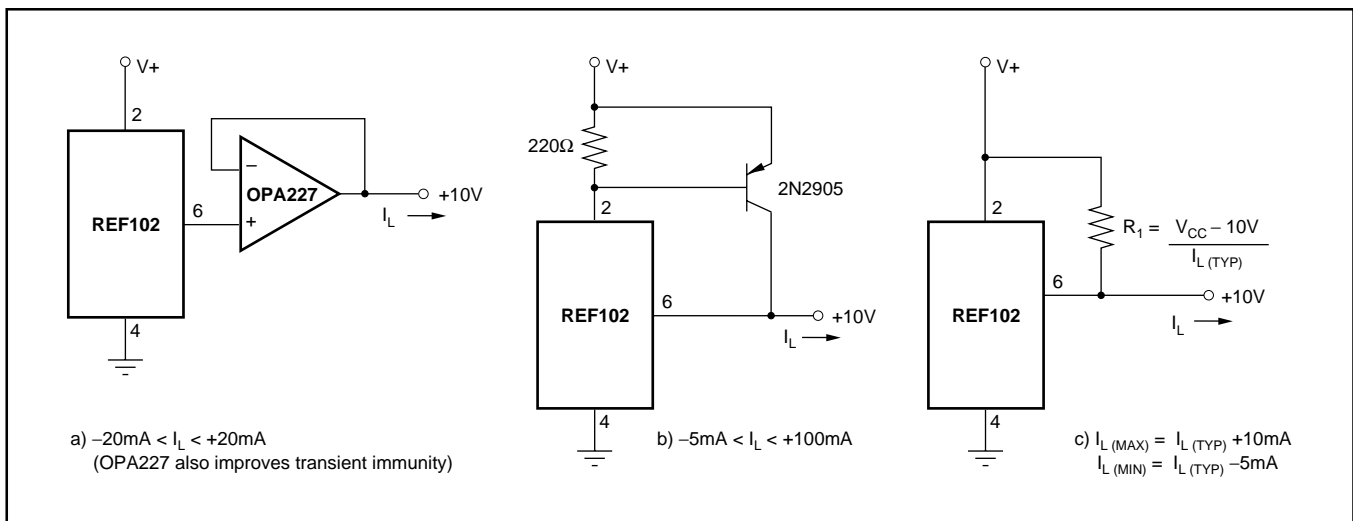


FIGURE 7. +10V Reference With Output Current Boosted to: a)  $\pm 20\text{mA}$ , b)  $+100\text{mA}$ , and c)  $I_{L(\text{TYP})} + 10\text{mA}$ ,  $-5\text{mA}$ .

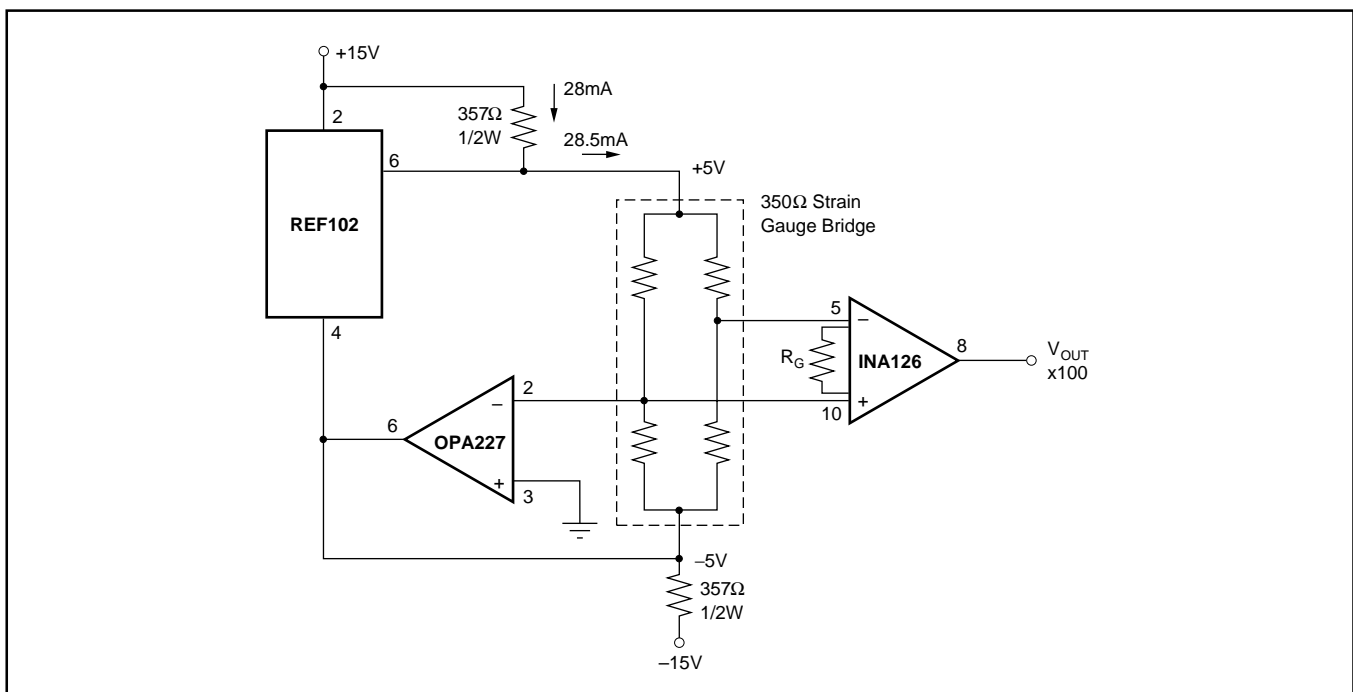


FIGURE 8. Strain Gauge Conditioner for 350Ω Bridge.

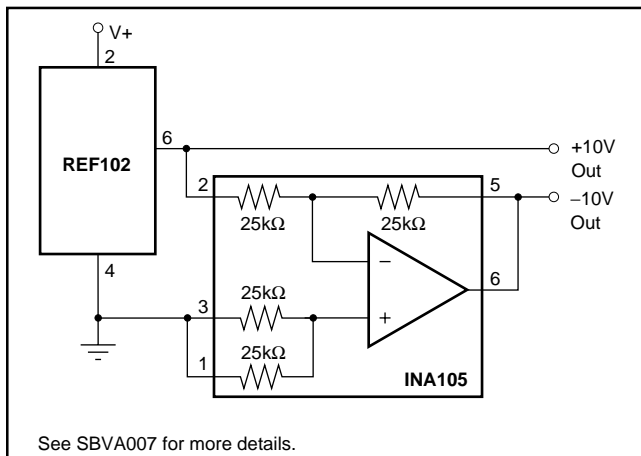


FIGURE 9.  $\pm 10\text{V}$  Reference.

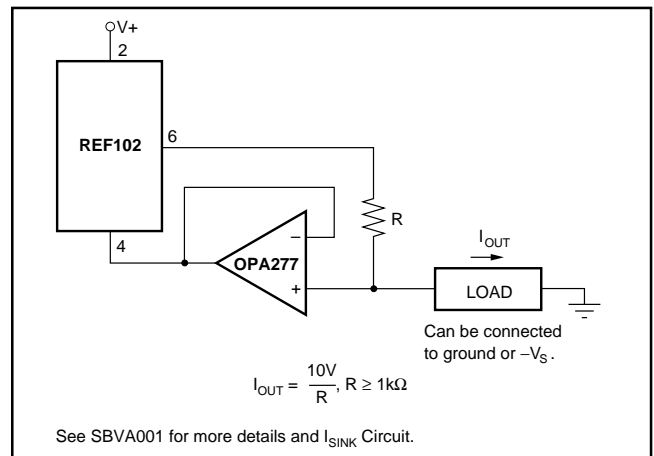


FIGURE 10. Positive Precision Current Source.



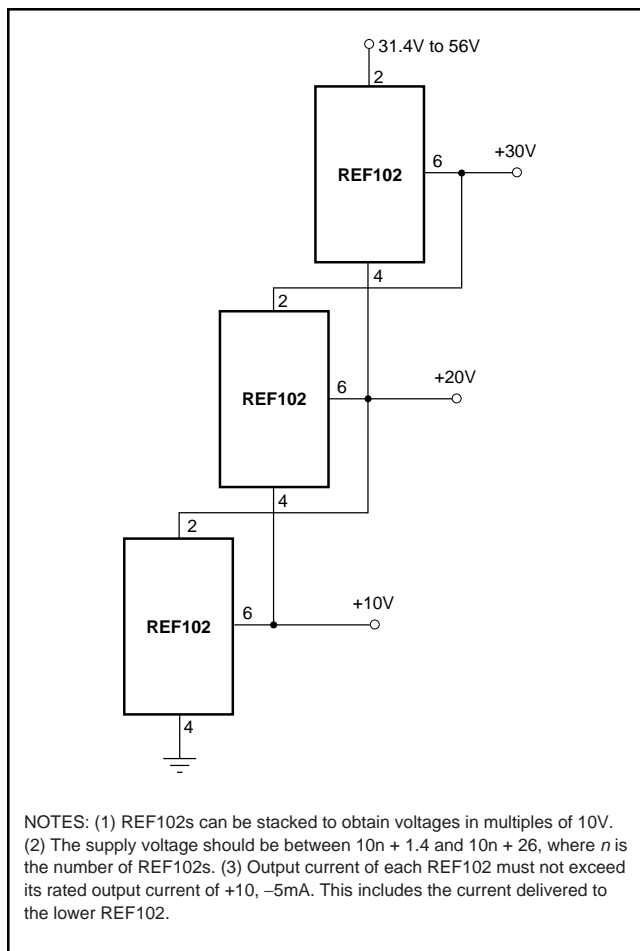


FIGURE 11. Stacked References.

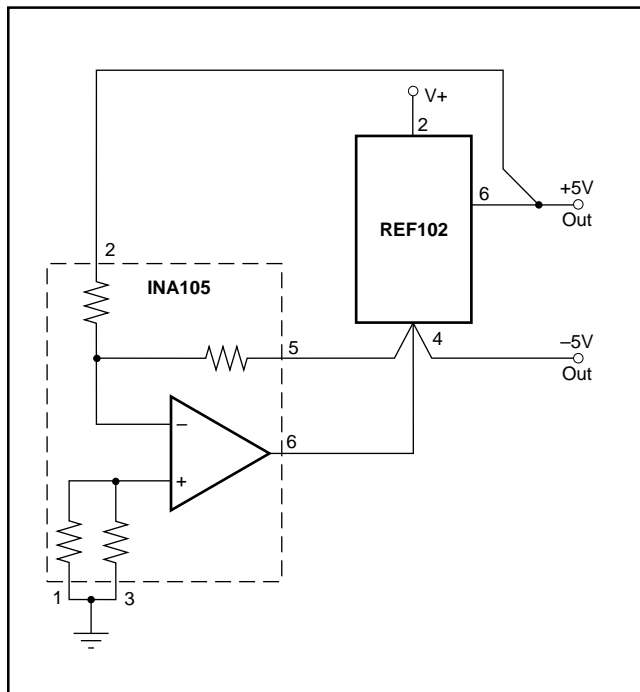


FIGURE 12. ±5V Reference.

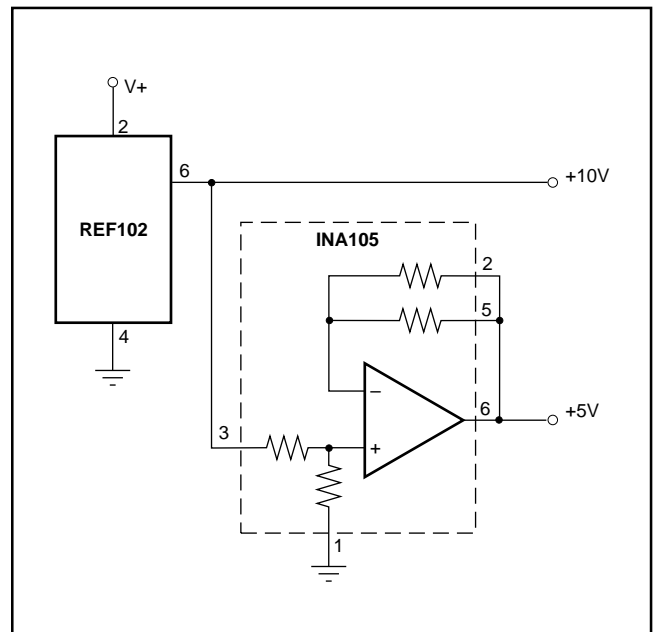


FIGURE 13. +5V and +10V Reference.

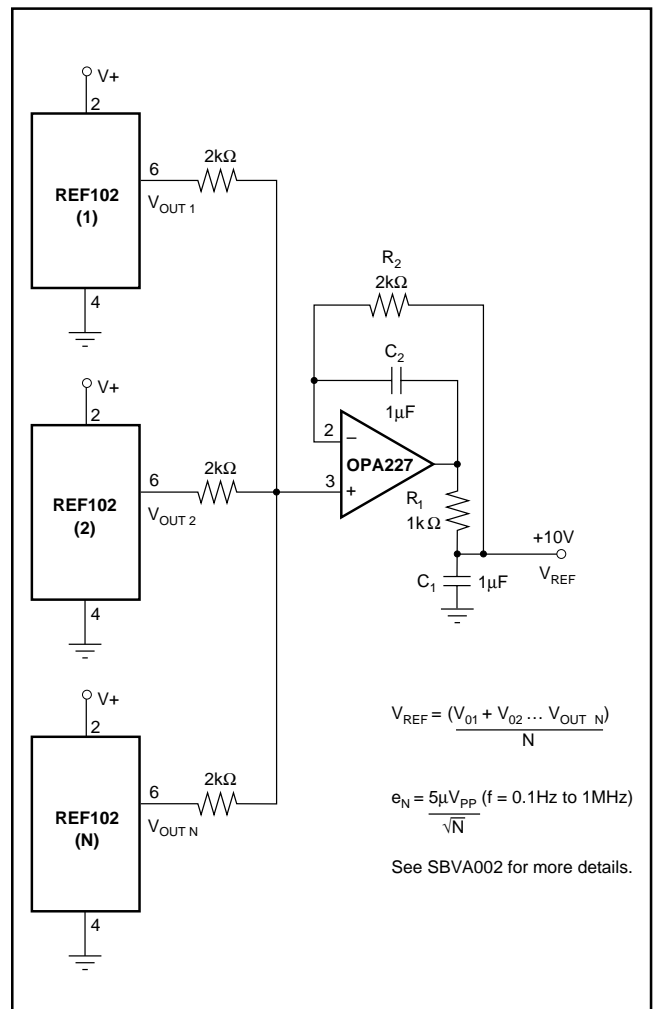


FIGURE 14. Precision Voltage Reference with Extremely Low Noise.

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| REF102AM         | OBSOLETE              | TO-99        | LMC             | 8    |             | TBD                     | Call TI          | Call TI                      |
| REF102AP         | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102APG4       | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102AU         | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102AU/2K5     | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102AU/2K5G4   | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102AUG4       | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102BM         | OBSOLETE              | TO-99        | LMC             | 8    |             | TBD                     | Call TI          | Call TI                      |
| REF102BP         | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102BPG4       | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102BU         | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102BUG4       | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102CM         | OBSOLETE              | TO-99        | LMC             | 8    |             | TBD                     | Call TI          | Call TI                      |
| REF102CP         | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102CPG4       | ACTIVE                | PDIP         | P               | 8    | 50          | Green (RoHS & no Sb/Br) | CU NIPDAU        | N / A for Pkg Type           |
| REF102CU         | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102CUG4       | ACTIVE                | SOIC         | D               | 8    | 100         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| REF102RM         | OBSOLETE              | TO-99        | LMC             | 8    |             | TBD                     | Call TI          | Call TI                      |
| REF102SM         | OBSOLETE              | TO-99        | LMC             | 8    |             | TBD                     | Call TI          | Call TI                      |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame

retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

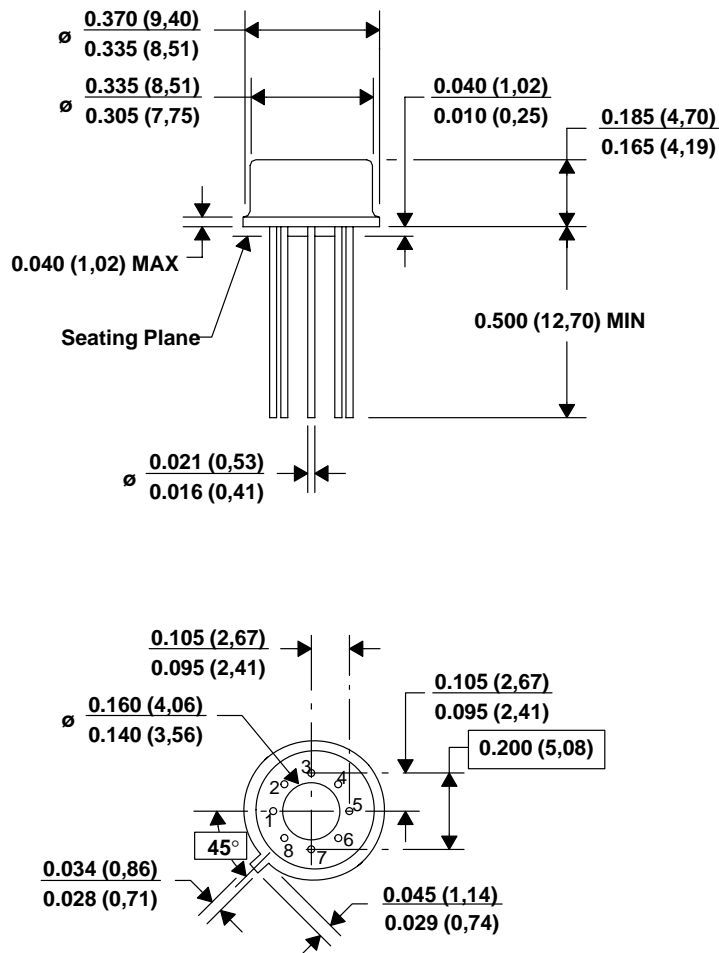
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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## LMC (O-MBCY-W8)

## METAL CYLINDRICAL



4202483/A 03/01

- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
  - Pin numbers shown for reference only. Numbers may not be marked on package.
  - Falls within JEDEC MO-002/TO-99.

## P (R-PDIP-T8)

## PLASTIC DUAL-IN-LINE



NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001

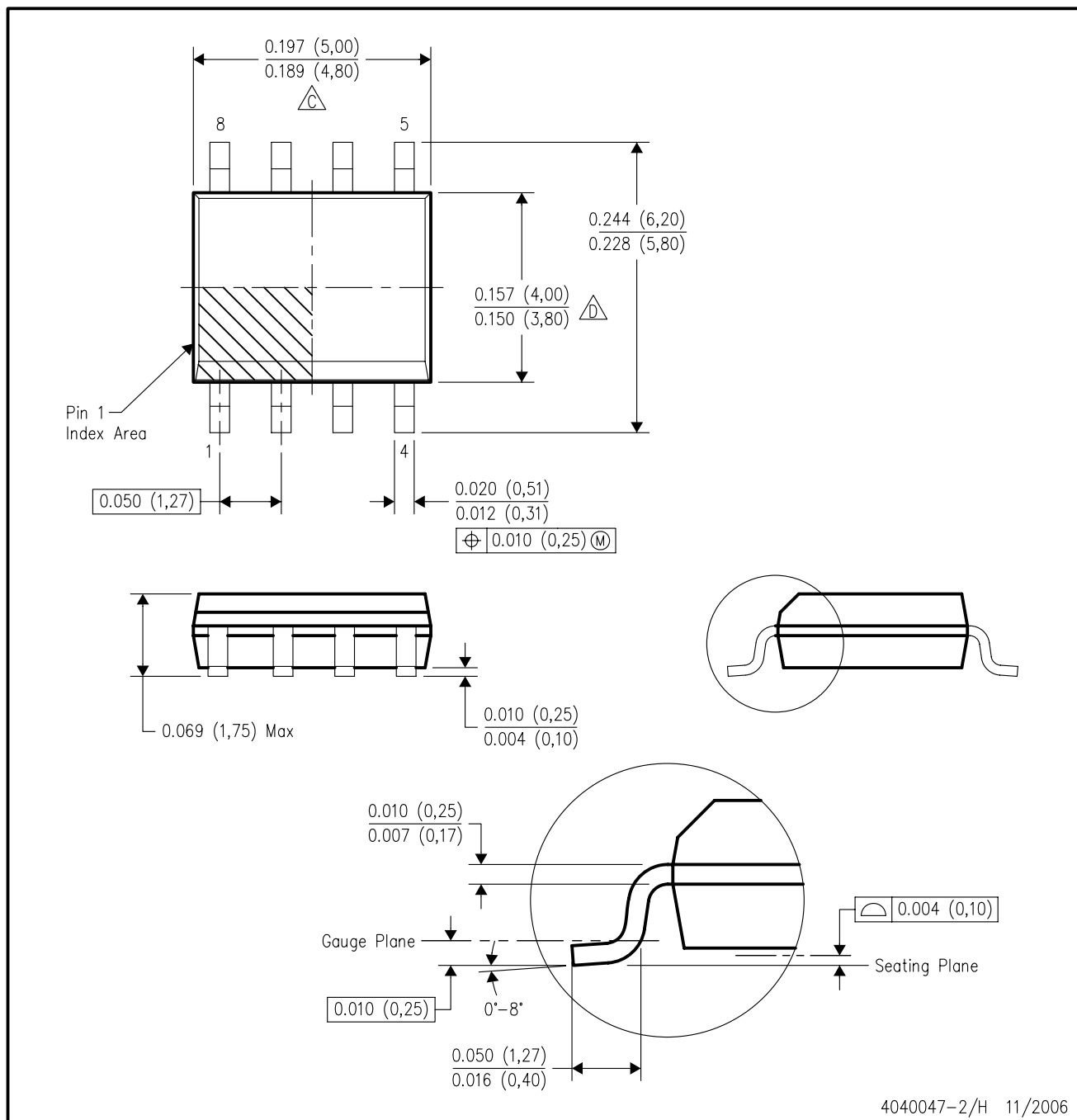
For the latest package information, go to [http://www.ti.com/sc/docs/package/pkg\\_info.htm](http://www.ti.com/sc/docs/package/pkg_info.htm)



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

## D (R-PDSO-G8)

## PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
  - E. Reference JEDEC MS-012 variation AA.

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