10V Precision Voltage Reference

FEATURES
- +10V ±0.0025V OUTPUT
- VERY LOW DRIFT: 2.5ppm/°C max
- EXCELLENT STABILITY: 5ppm/1000hr typ
- EXCELLENT LINE REGULATION: 1ppm/V max
- EXCELLENT LOAD REGULATION: 10ppm/mA max
- LOW NOISE: 5μVpp 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/°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.
**ABSOLUTE MAXIMUM RATINGS**

<table>
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<tr>
<th>PRODUCT</th>
<th>MAX INITIAL ERROR (mV)</th>
<th>MAX DRIFT (PPM/°C)</th>
<th>PACKAGE-LEAD</th>
<th>PACKAGE DESIGNATOR</th>
<th>SPECIFIED TEMPERATURE RANGE</th>
<th>PACKAGE MARKING</th>
<th>ORDERING NUMBER</th>
<th>TRANSPORT MEDIA, QUANTITY</th>
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<tr>
<td>REF102AU</td>
<td>±10</td>
<td>±10</td>
<td>SO-8</td>
<td>D</td>
<td>-25°C to +85°C</td>
<td>REF102AU</td>
<td>REF102AU/2K5</td>
<td>Tube, 100</td>
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<td></td>
<td>*</td>
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<td></td>
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<td></td>
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<tr>
<td>REF102AP</td>
<td>±10</td>
<td>±10</td>
<td>SO-8</td>
<td>D</td>
<td>*</td>
<td>REF102AP</td>
<td>REF102AP/2K5</td>
<td>Tube, 100</td>
</tr>
<tr>
<td>REF102BU</td>
<td>±5</td>
<td>±5</td>
<td>SO-8</td>
<td>D</td>
<td>*</td>
<td>REF102BU</td>
<td>REF102BU/2K5</td>
<td>Tube, 100</td>
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<td>*</td>
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<td></td>
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<tr>
<td>REF102BP</td>
<td>±5</td>
<td>±5</td>
<td>SO-8</td>
<td>D</td>
<td>*</td>
<td>REF102BP</td>
<td>REF102BP/2K5</td>
<td>Tube, 100</td>
</tr>
<tr>
<td>REF102CU</td>
<td>±2.5</td>
<td>±2.5</td>
<td>SO-8</td>
<td>D</td>
<td>*</td>
<td>REF102CU</td>
<td>REF102CU/2K5</td>
<td>Tube, 100</td>
</tr>
<tr>
<td></td>
<td>*</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>REF102CP</td>
<td>±2.5</td>
<td>±2.5</td>
<td>SO-8</td>
<td>D</td>
<td>*</td>
<td>REF102CP</td>
<td>REF102CP/2K5</td>
<td>Tube, 100</td>
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</table>

**NOTE:** (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.

**PACKAGE/ORDERING INFORMATION**

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.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

**PIN CONFIGURATIONS**

<Diagram of pin configurations>

NC = Not Connected
## ELECTRICAL CHARACTERISTICS

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

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<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>REF102A</th>
<th>REF102B</th>
<th>REF102C</th>
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<tr>
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<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>MIN</td>
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<tr>
<td>OUTPUT VOLTAGE</td>
<td>Initial $T_A = 25^\circ C$</td>
<td>9.99</td>
<td>10.01</td>
<td>9.995</td>
</tr>
<tr>
<td></td>
<td>vs Temperature (1) $V_S = 11.4V$ to 36V</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>vs Output Current $I_L = 0mA$ to $+10mA$</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>vs Time $I_L = 0mA$ to $–5mA$</td>
<td>5</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>P, U Packages (2)</td>
<td>20</td>
<td>*</td>
<td>*</td>
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<tr>
<td></td>
<td>Trim Range (3)</td>
<td>±3</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Capacitive Load, max</td>
<td>1000</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>NOISE</td>
<td>0.1Hz to 10Hz</td>
<td>5</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>OUTPUT CURRENT</td>
<td>+10,–5</td>
<td>*</td>
<td>*</td>
<td>mA</td>
</tr>
<tr>
<td>INPUT VOLTAGE RANGE</td>
<td>$I_{OUT} = 0$</td>
<td>+11.4</td>
<td>+36</td>
<td>*</td>
</tr>
<tr>
<td>QUIESCENT CURRENT</td>
<td>$I_{OUT} = 0$</td>
<td>+1.4</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>WARM-UP TIME (4)</td>
<td>To 0.1%</td>
<td>15</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>TEMPERATURE RANGE</td>
<td>Specification</td>
<td>–25</td>
<td>+85</td>
<td>*</td>
</tr>
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</table>

* 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 $T_A = +25^\circ C$, $V_S = +15V$, unless otherwise noted.

POWER TURN-ON RESPONSE

POWER SUPPLY REJECTION vs FREQUENCY

LOAD REGULATION

RESPONSE TO THERMAL SHOCK

QUIESCENT CURRENT vs TEMPERATURE
TYPICAL CHARACTERISTICS (Cont.)

At $T_a = +25^\circ$C, $V_S = +15$V, unless otherwise noted.

TYPICAL REF102 REFERENCE NOISE

![Graph showing noise voltage vs. frequency]

Low Frequency Noise (1s/div)
(See Noise Test Circuit)

TYPICAL REF102 REFERENCE NOISE

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 $DZ_1$, $R_2$, 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 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 $V_{UPPER \ \text{BOUND}}$ and $V_{LOWER \ \text{BOUND}}$ (see Figure 1). Figure 1 uses the REF102CU as an example. It has a drift specification of 2.5ppm/$^\circ$C maximum and a specification temperature range of $-25^\circ$C to $+85^\circ$C. The “box” height, $V_1$ to $V_2$, is 2.75mV.

![Graph showing output voltage vs. temperature]

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.

Optional output voltage adjustment circuits are shown in Figures 3 and 4. Trimming the output voltage will change the voltage drift by approximately 0.008ppm/°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 $\Delta$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 ±300mV. 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 50kΩ internal resistor. A TCR of 100ppm/°C is normally sufficient.

FIGURE 2. REF102 Installation.

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 1μF noise reduction capacitor on the high-frequency noise of the REF102. $R_6$ is typically 7kΩ so the filter has a –3dB frequency of about 22Hz. The result is a reduction in noise from about 800μVPP to under 200μVPP. If further noise reduction is required, use the circuit in Figure 14.

![FIGURE 5. Effect of 1μF Noise Reduction Capacitor on Broadband Noise ($f_{-3dB} = 1MHz$)](image)

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. –10V Reference Using a) Resistor or b) OPA227.](image)

See SBVA008 for more detail.
FIGURE 7. +10V Reference With Output Current Boosted to: a) ±20mA, b) +100mA, and c) $I_L$ (TYP) +10mA, –5A.

FIGURE 8. Strain Gauge Conditioner for 350Ω Bridge.

FIGURE 9. ±10V Reference.

FIGURE 10. Positive Precision Current Source.
NOTES: (1) REF102s can be stacked to obtain voltages in multiples of 10V.
(2) The supply voltage should be between 10n + 1.4 and 10n + 26, where n is
the number of REF102s. (3) Output current of each REF102 must not exceed
its rated output current of ±10, −5mA. This includes the current delivered to
the lower REF102.

FIGURE 11. Stacked References.

FIGURE 12. ±5V Reference.

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

FIGURE 14. Precision Voltage Reference with Extremely
Low Noise.
NOTES:  
A. All linear dimensions are in inches (millimeters).  
B. This drawing is subject to change without notice.  
C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.  
D. Pin numbers shown for reference only. Numbers may not be marked on package.  
E. Falls within JEDEC MO-002/TO-99.
MECHANICAL DATA

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
MECHANICAL DATA

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.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0.15).
D. Falls within JEDEC MS-012 variation AA.
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