

SBVS022B – SEPTEMBER 2000 – REVISED JUNE 2009

10V Precision Voltage Reference

FEATURES

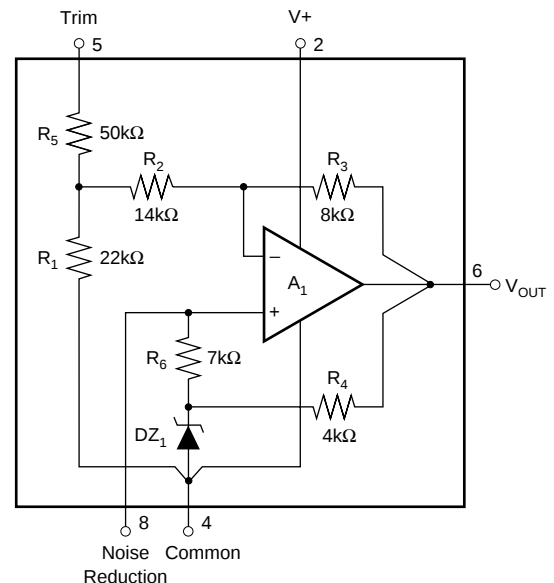
- **+10V ± 0.0025 V OUTPUT**
- **VERY LOW DRIFT: 2.5ppm/ $^{\circ}$ C max**
- **EXCELLENT STABILITY: 5ppm/1000hr typ**
- **EXCELLENT LINE REGULATION: 1ppm/V max**
- **EXCELLENT LOAD REGULATION: 10ppm/mA max**
- **LOW NOISE: 5 μ V_{PP} typ, 0.1Hz to 10Hz**
- **WIDE SUPPLY RANGE: 11.4VDC to 36VDC**
- **LOW 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 VOLTMETER**
- **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.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Input Voltage	+40V
Operating Temperature	
P, U	–25°C to +85°C
Storage Temperature Range	
P, U	–40°C to +125°C
Short-Circuit Protection to Common or V+	Continuous

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.



ELECTROSTATIC
DISCHARGE SENSITIVITY

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.

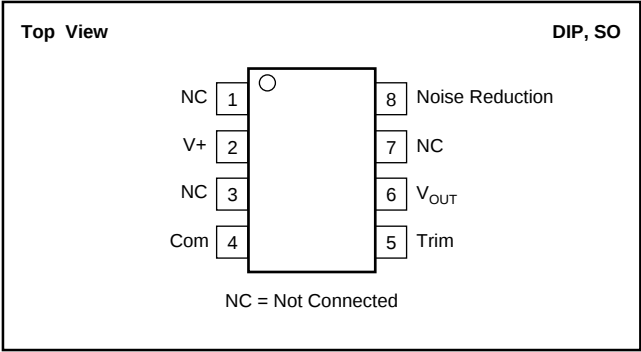
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION⁽¹⁾

PRODUCT	MAX INITIAL ERROR (mV)	MAX DRIFT (PPM/°C)	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
REF102AU	±10	±10	SO-8	D	REF102AU
REF102AP	±10	±10	DIP-8	P	REF102AP
REF102BU	±5	±5	SO-8	D	REF102BU
REF102BP	±5	±5	DIP-8	P	REF102BP
REF102CU	±2.5	±2.5	SO-8	D	REF102CU
REF102CP	±2.5	±2.5	DIP-8	P	REF102CP

NOTE: (1) For the most current package and ordering information, see the Package Option Addendum at the end of this data sheet, or see the TI website at www.ti.com.

PIN CONFIGURATIONS



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	
OUTPUT VOLTAGE Initial vs Temperature ⁽¹⁾ vs Supply (Line Regulation) vs Output Current (Load Regulation) vs Time M Package P, U Packages ⁽²⁾ Trim Range ⁽³⁾ Capacitive Load, max	$T_A = 25^\circ\text{C}$ $V_S = 11.4\text{V to } 36\text{V}$ $I_L = 0\text{mA to } +10\text{mA}$ $I_L = 0\text{mA to } -5\text{mA}$ $T_A = +25^\circ\text{C}$	9.99		10.01 10 2 20 40	9.995		10.005 5 1 10 20	9.9975		10.0025 2.5 1 10 20	V ppm/ $^\circ\text{C}$ ppm/V ppm/mA ppm/mA ppm/1000hr ppm/1000hr % pF
NOISE	0.1Hz to 10Hz		5			*			*		μV_{PP}
OUTPUT CURRENT		+10, -5			*			*			mA
INPUT VOLTAGE RANGE		+11.4		+36	*		*	*		*	V
QUIESCENT CURRENT	$I_{OUT} = 0$			+1.4			*			*	mA
WARM-UP TIME ⁽⁴⁾	To 0.1%		15			*			*		μs
TEMPERATURE RANGE Specification 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.

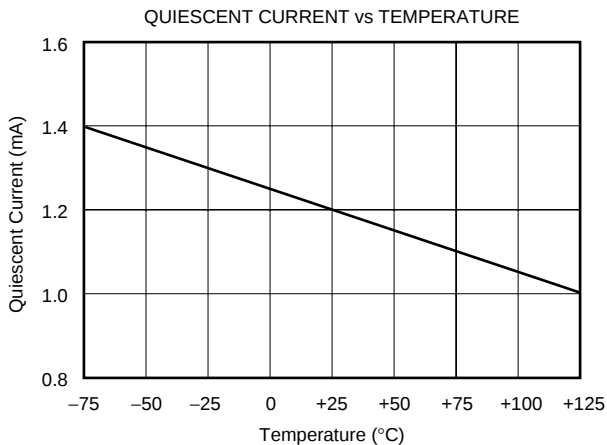
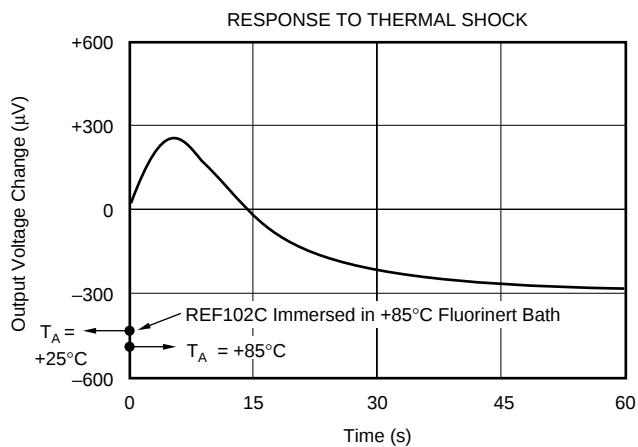
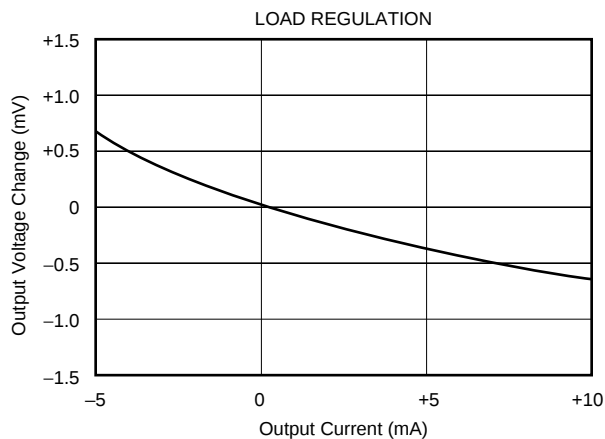
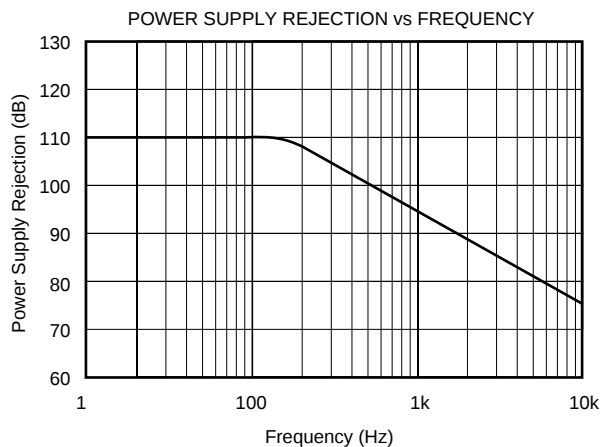
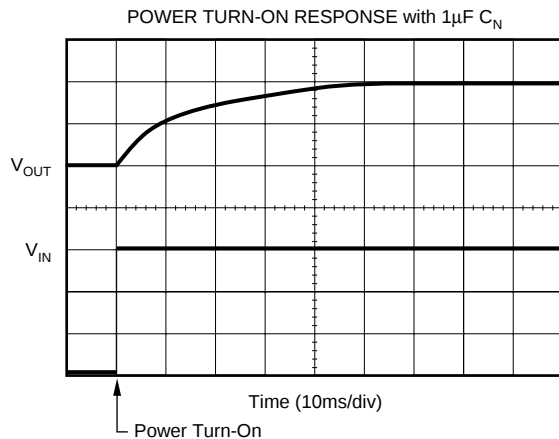
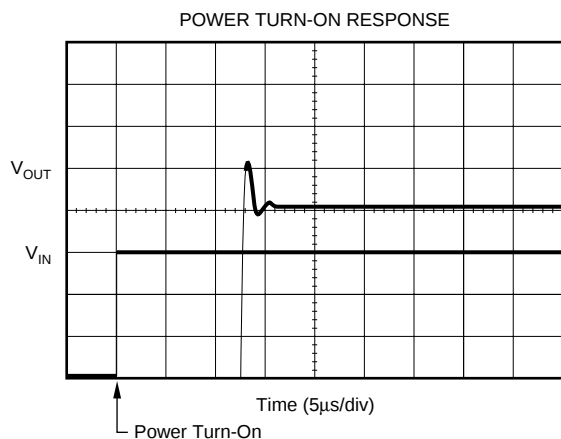
(2) Typically 5ppm/1000hrs after 168hr powered stabilization.

(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.

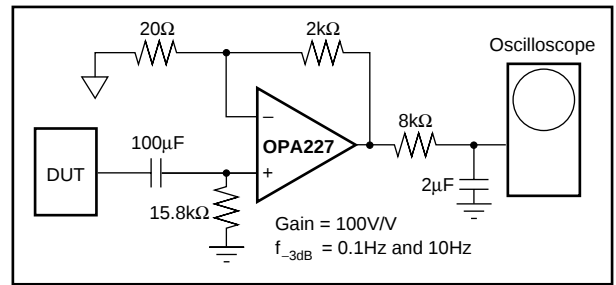
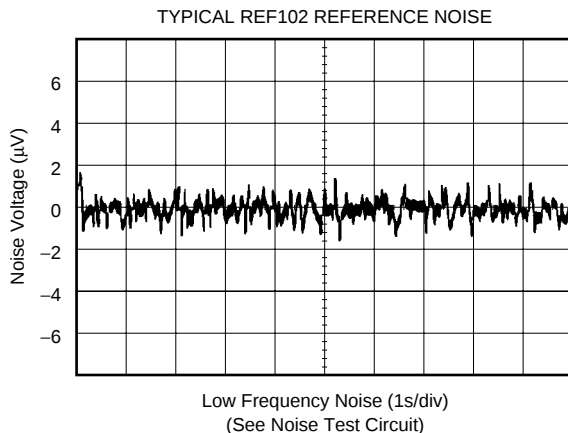
TYPICAL CHARACTERISTICS

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°C to $+85^\circ\text{C}$. The *box* height, V_1 to V_2 , is 2.75mV.

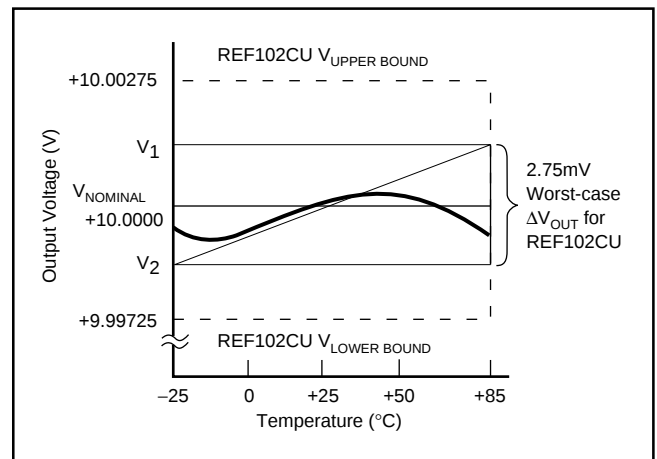


FIGURE 1. REF102CU Output Voltage Drift.

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.

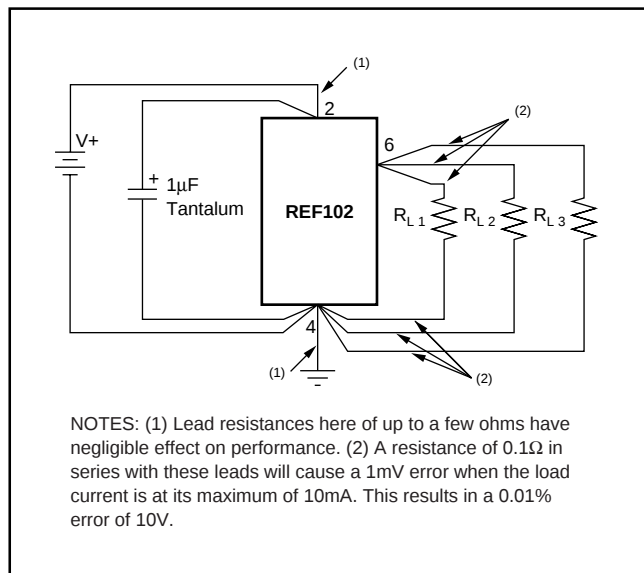


FIGURE 2. REF102 Installation.

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 ΔTCR 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.

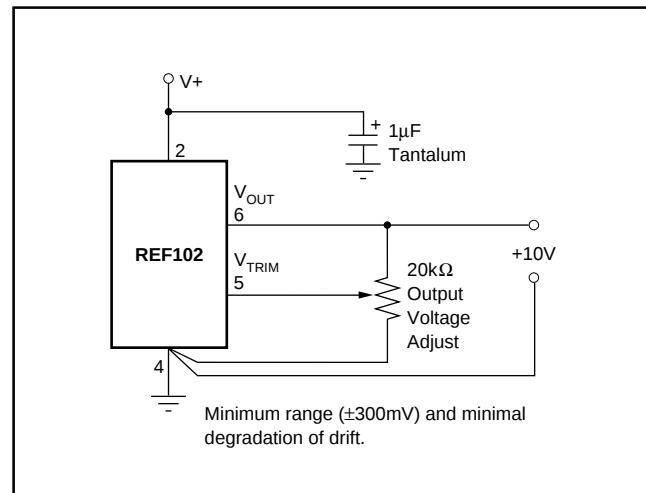


FIGURE 3. REF102 Optional Output Voltage Adjust.

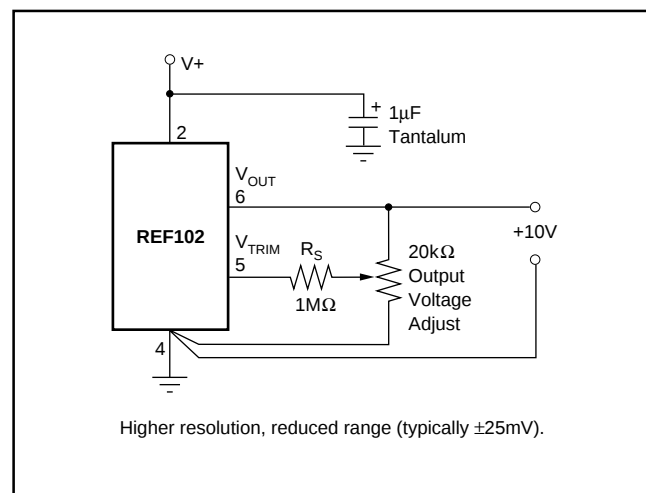


FIGURE 4. REF102 Optional Output Voltage, Fine Adjust.

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 -3dB frequency of about 22Hz . 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.

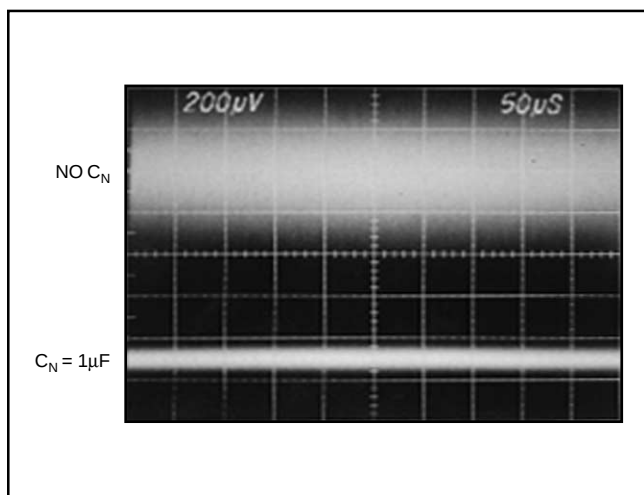


FIGURE 5. Effect of $1\mu\text{F}$ Noise Reduction Capacitor on Broadband Noise ($f_{-3\text{dB}} = 1\text{MHz}$)

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.

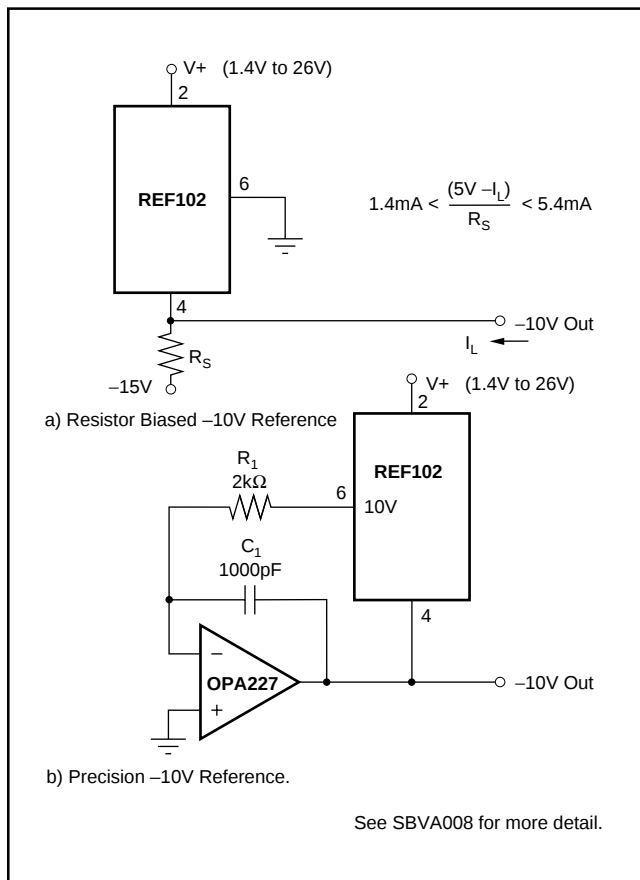


FIGURE 6. -10V Reference Using a) Resistor or b) OPA227.

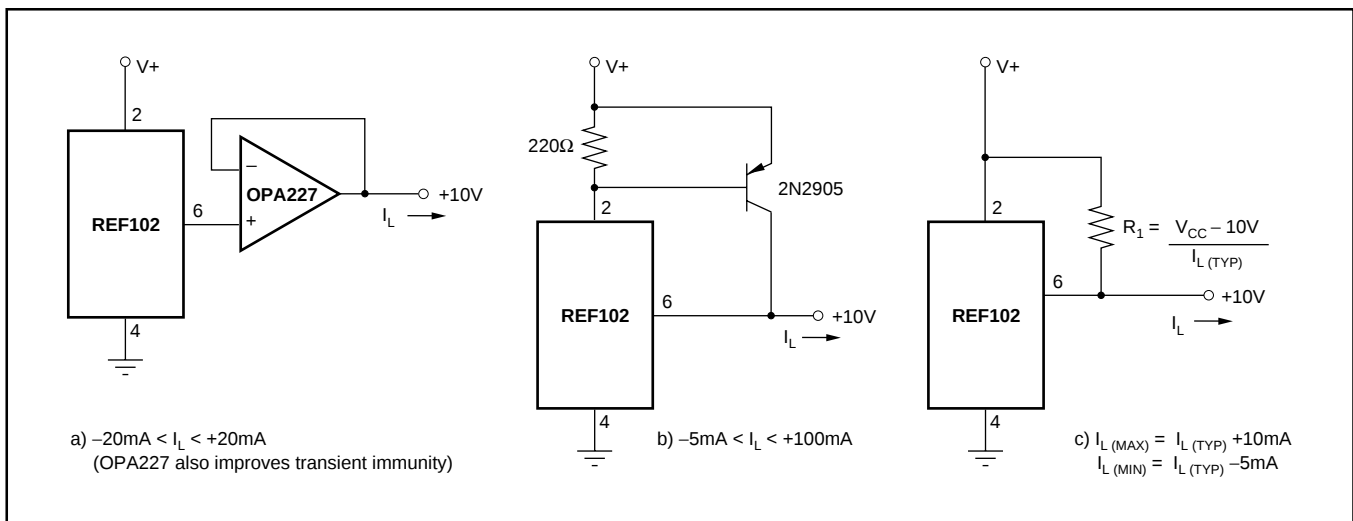


FIGURE 7. +10V Reference With Output Current Boosted to: a) $\pm 20\text{mA}$, b) $+100\text{mA}$, and c) $I_{L(\text{TYP})} + 10\text{mA}$, -5mA .

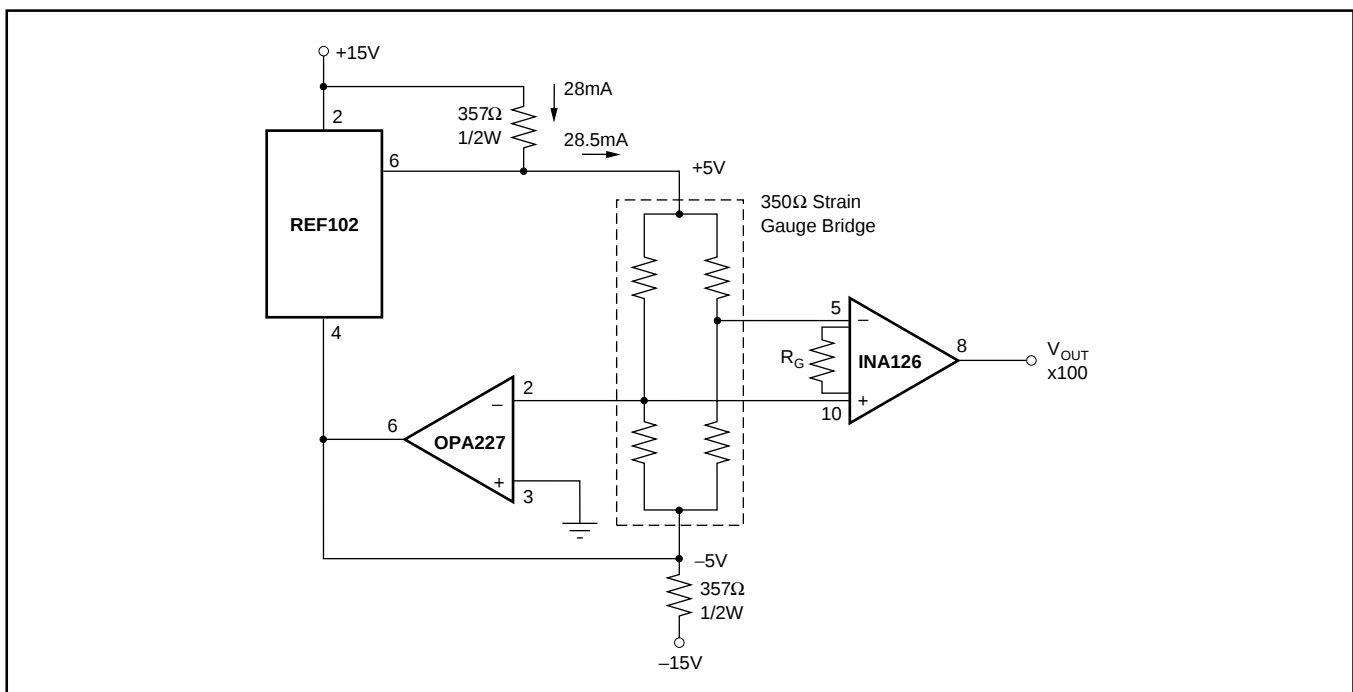


FIGURE 8. Strain Gauge Conditioner for 350Ω Bridge.

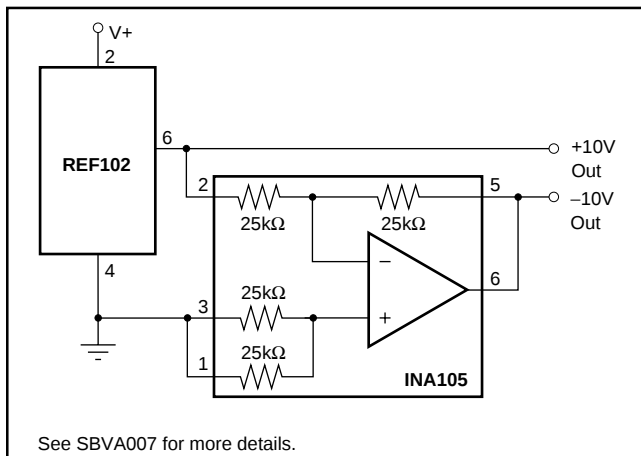


FIGURE 9. $\pm 10\text{V}$ Reference.

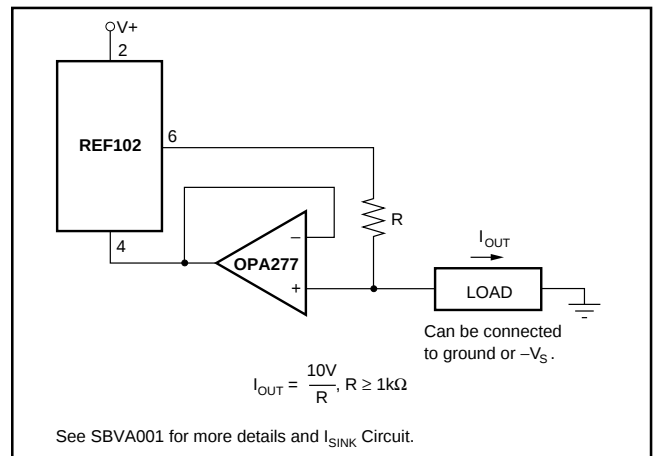


FIGURE 10. Positive Precision Current Source.

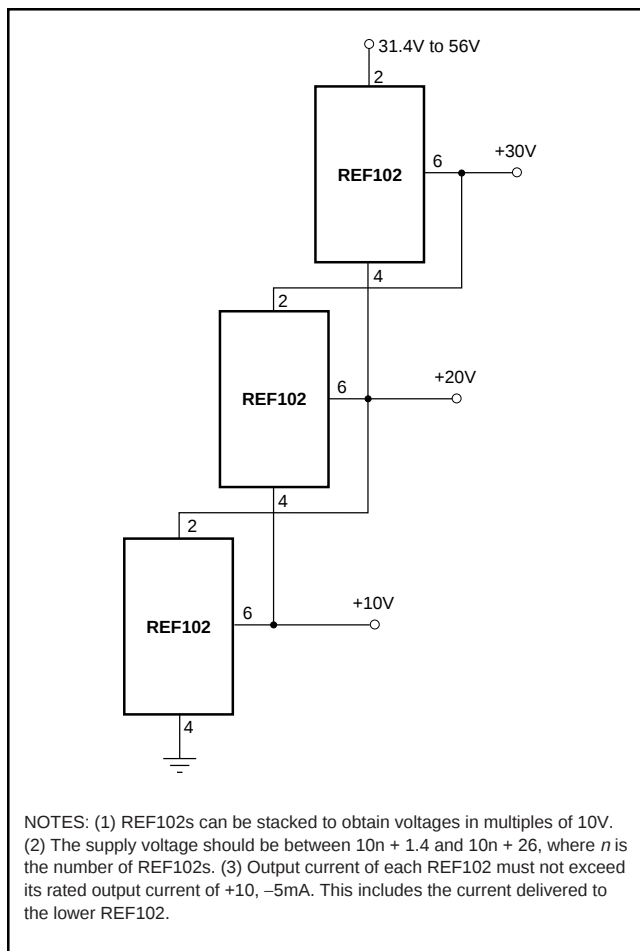


FIGURE 11. Stacked References.

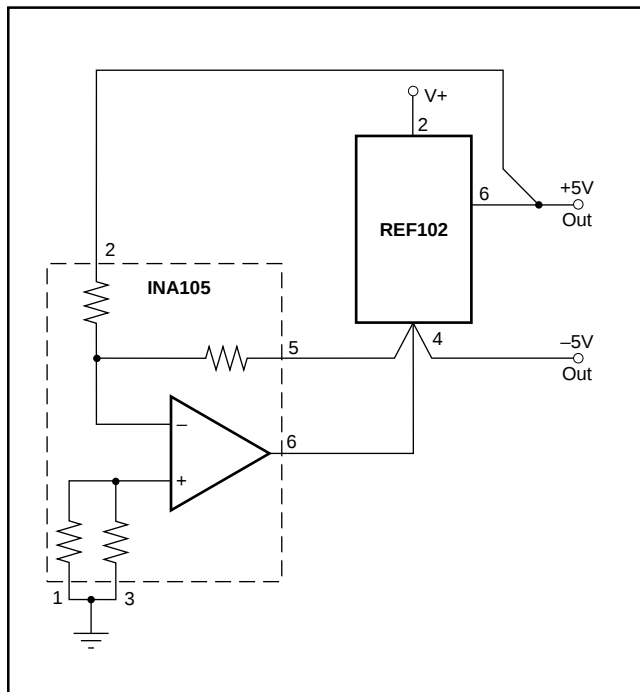


FIGURE 12. ±5V Reference.

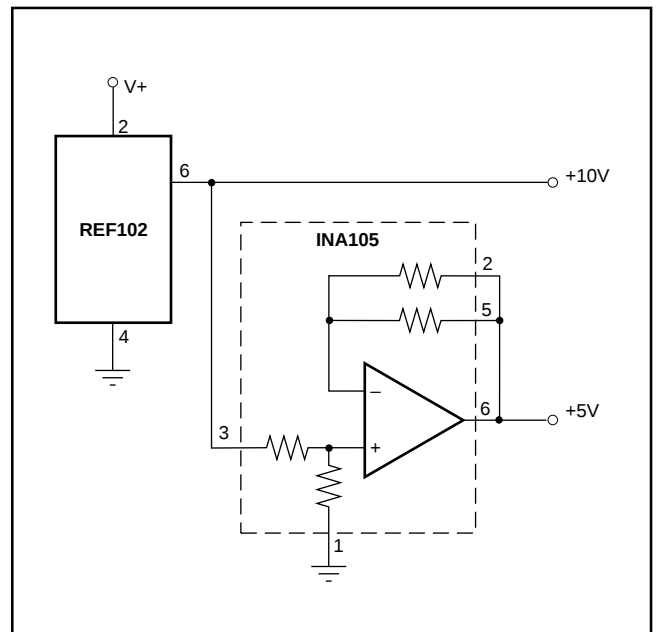


FIGURE 13. +5V and +10V Reference.

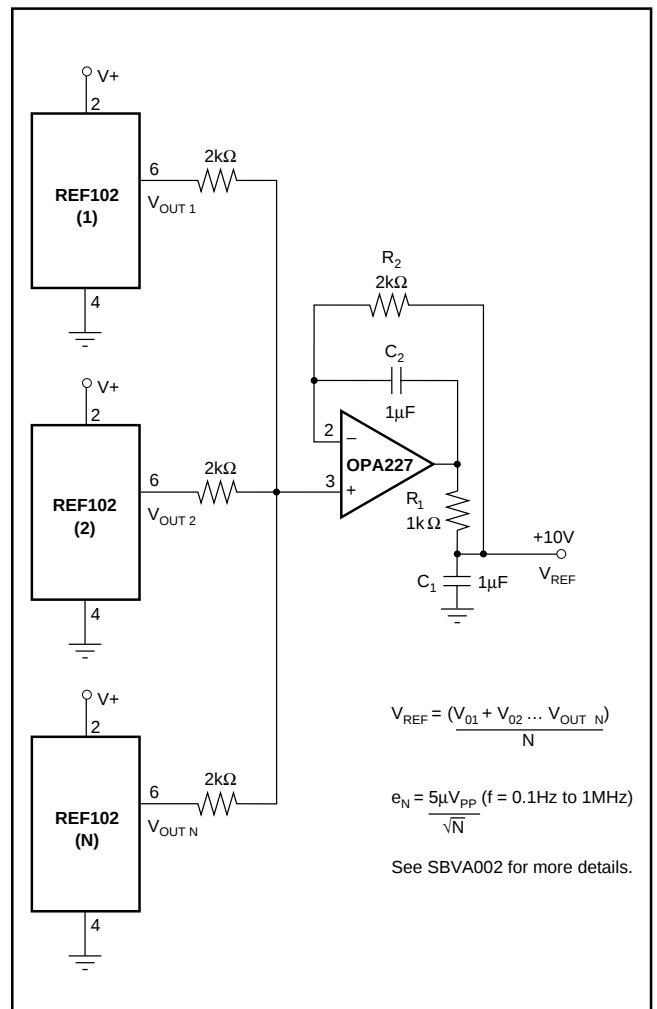


FIGURE 14. Precision Voltage Reference with Extremely Low Noise.

Revision History

DATE	REVISION	PAGE	SECTION	DESCRIPTION
6/09	B	2	Absolute Maximum Ratings	Deleted lead temperature rating.
			Package/Ordering Information	Changed Package Ordering Information table.

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
REF102AP	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type		REF102P A	Samples
REF102APG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type		REF102P A	Samples
REF102AU	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		REF 102U A	Samples
REF102AU/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		REF 102U A	Samples
REF102AUG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR		REF 102U A	Samples
REF102BP	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type		REF102P B	Samples
REF102BPG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type		REF102P B	Samples
REF102BU	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	REF 102U B	Samples
REF102BUG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	REF 102U B	Samples
REF102CP	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	REF102P C	Samples
REF102CPG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	REF102P C	Samples
REF102CU	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	REF 102U C	Samples
REF102CU/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	REF 102U C	Samples
REF102CUG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	REF 102U	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
										C	

⁽¹⁾ 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.

⁽²⁾ 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.

⁽⁴⁾ There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

⁽⁵⁾ Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
REF102AU/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
REF102CU/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

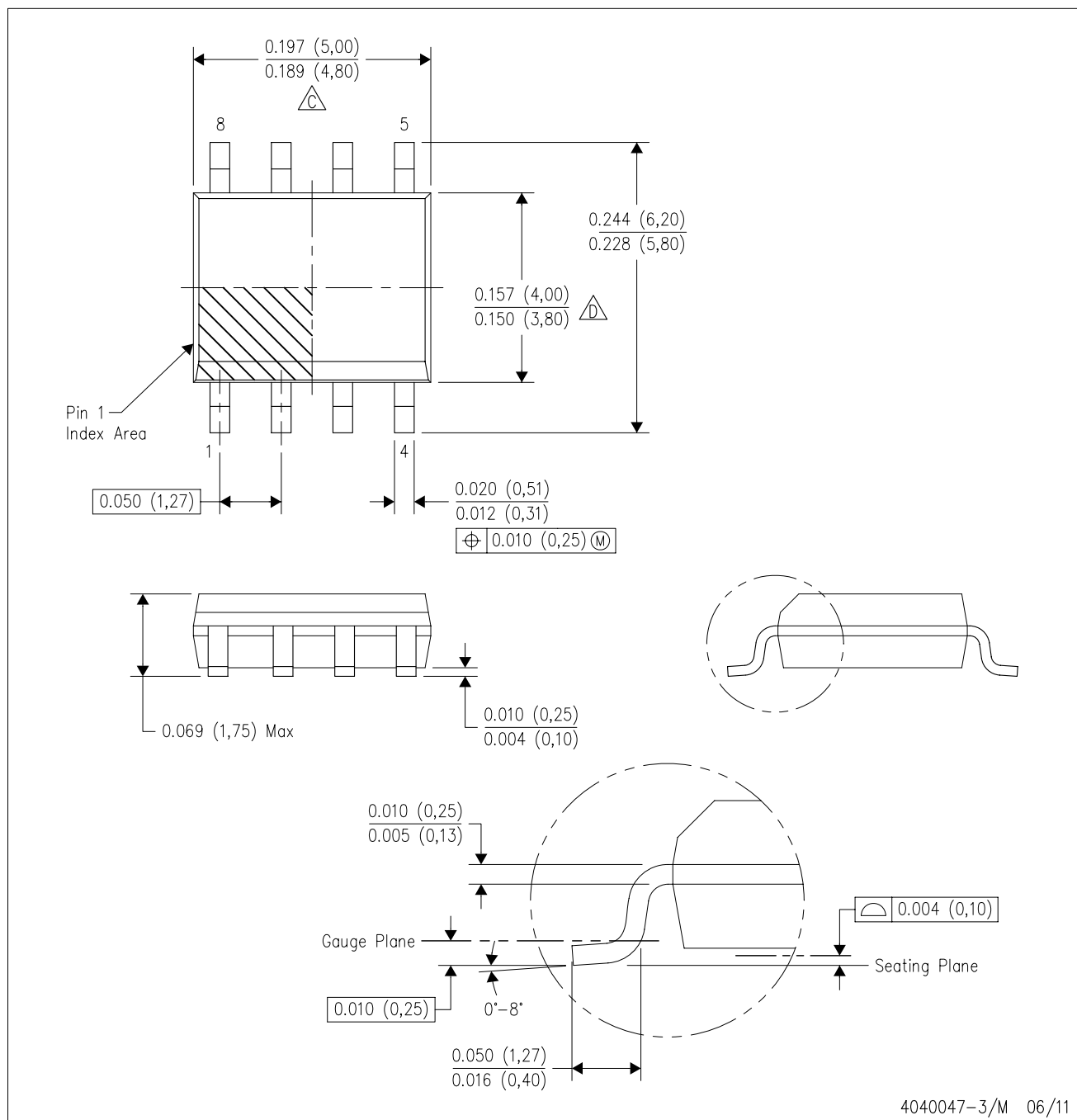


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
REF102AU/2K5	SOIC	D	8	2500	367.0	367.0	35.0
REF102CU/2K5	SOIC	D	8	2500	367.0	367.0	35.0

D (R-PDSO-G8)

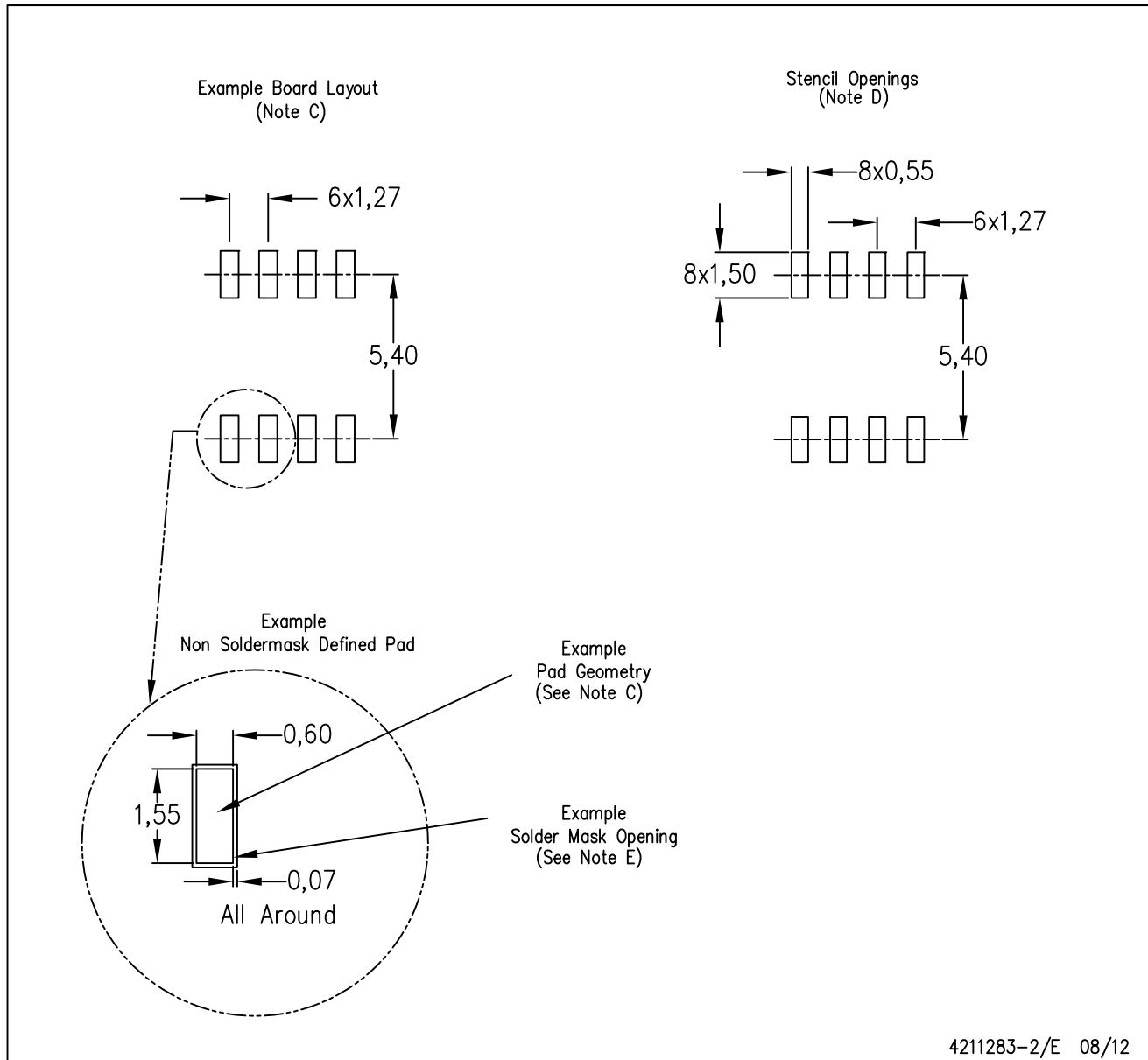
PLASTIC SMALL OUTLINE



- 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 0.006 (0,15) each side.
 - $\triangle D$ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



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

IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.