



1.8V, *micro*POWER CMOS OPERATIONAL AMPLIFIERS Zero-Drift Series

FEATURES

- **LOW OFFSET VOLTAGE:** 10 μ V (max)
- **ZERO DRIFT:** 0.05 μ V/ $^{\circ}$ C (max)
- **0.01Hz to 10Hz NOISE:** 1.1 μ V_{PP}
- **QUIESCENT CURRENT:** 17 μ A
- **SINGLE-SUPPLY OPERATION**
- **SUPPLY VOLTAGE:** 1.8V to 5.5V
- **RAIL-TO-RAIL INPUT/OUTPUT**
- *micro*SIZE PACKAGES: SC70 and SOT23

APPLICATIONS

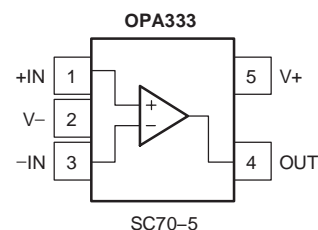
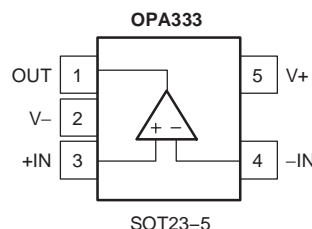
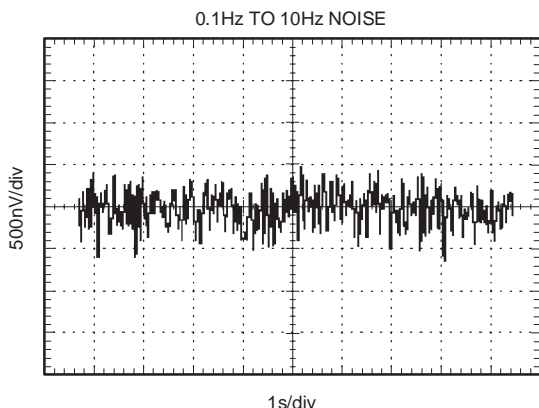
- TRANSDUCER APPLICATIONS
- TEMPERATURE MEASUREMENTS
- ELECTRONIC SCALES
- MEDICAL INSTRUMENTATION
- BATTERY-POWERED INSTRUMENTS
- HANDHELD TEST EQUIPMENT

DESCRIPTION

The OPA333 series of CMOS operational amplifiers uses a proprietary auto-calibration technique to simultaneously provide very low offset voltage (10 μ V max) and near-zero drift over time and temperature. These miniature, high-precision, low quiescent current amplifiers offer high-impedance inputs that have a common-mode range 100mV beyond the rails and rail-to-rail output that swings within 50mV of the rails. Single or dual supplies as low as +1.8V (\pm 0.9V) and up to +5.5V (\pm 2.75V) may be used. They are optimized for low-voltage, single-supply operation.

The OPA333 family offers excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

The OPA333 (single version) is available in the SC70-5, SOT23-5, and SO-8 packages. The OPA2333 (dual version) is offered in DFN-8 (3mm x 3mm, available Q2 '06) and SO-8 packages. All versions are specified for operation from -40° C to $+125^{\circ}$ C.



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.

ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage	+7V
Signal Input Terminals, Voltage ⁽²⁾	-0.3V to (V+) + 0.3V
Signal Input Terminals, Voltage ⁽²⁾	±10mA
Output Short-Circuit ⁽³⁾	Continuous
Operating Temperature	-40°C to +150°C
Storage Temperature	-65°C to +150°C
Junction Temperature	+150°C
ESD Rating	
Human Body Model	4000V
Charged Device Model	1000V



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.

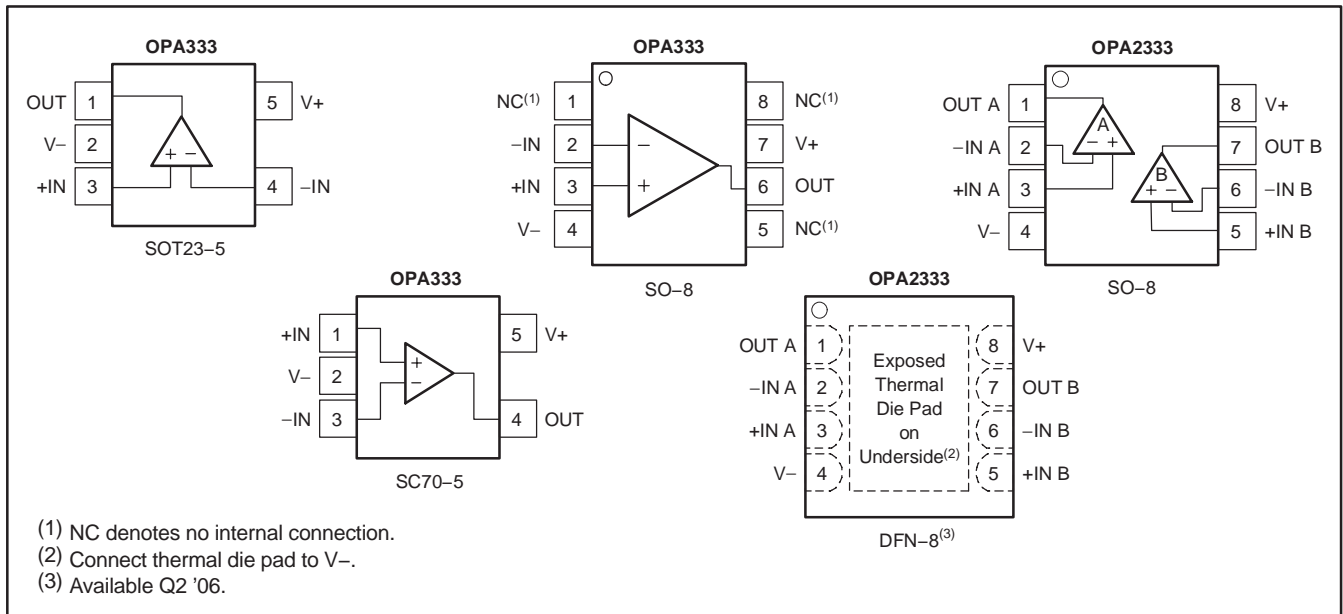
- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.
- (2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond the supply rails should be current limited to 10mA or less.
- (3) Short-circuit to ground, one amplifier per package.

ORDERING INFORMATION(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
OPA333	SOT23-5	DBV	OAXQ
OPA333	SC70-5	DCK	BQY
OPA333	SO-8	D	O333A
OPA2333	SO-8	D	O2333A
OPA2333	DFN-8 ⁽²⁾	DRB	BQZ

- (1) For the most current specification and package information see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
- (2) Available Q2 '06.

PIN CONFIGURATIONS



ELECTRICAL CHARACTERISTICS: $V_S = +1.8V$ to $+5.5V$

Boldface limits apply over the specified temperature range, $T_A = -40^\circ C$ to $+125^\circ C$.

At $T_A = +25^\circ C$, $R_L = 10k\Omega$ connected to $V_S/2$, $V_{CM} = V_S/2$, and $V_{OUT} = V_S/2$, unless otherwise noted.

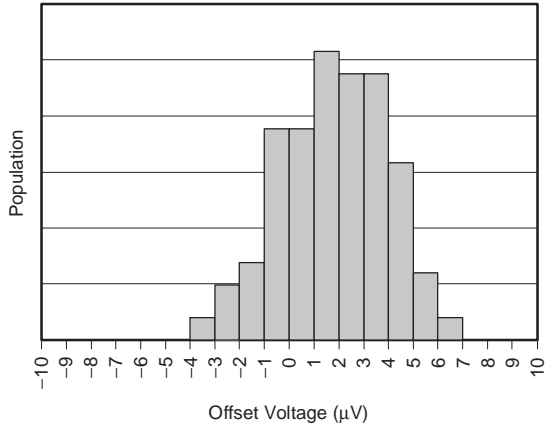
PARAMETER	TEST CONDITIONS	OPA333, OPA2333			UNIT
		MIN	TYP	MAX	
OFFSET VOLTAGE					
Input Offset Voltage	$V_S = +5V$		2	10	μV
vs Temperature			0.02	0.05	$\mu V/^\circ C$
vs Power Supply	$V_S = +1.8V$ to $+5.5V$		1	5	$\mu V/V$
Long-Term Stability ⁽¹⁾			See Note (1)		
Channel Separation, dc			0.1		$\mu V/V$
INPUT BIAS CURRENT					
Input Bias Current			± 70	± 200	pA
over Temperature			± 150		pA
Input Offset Current			± 140	± 400	pA
NOISE					
Input Voltage Noise, $f = 0.01Hz$ to $1Hz$			0.3		μV_{PP}
Input Voltage Noise, $f = 0.1Hz$ to $10Hz$			1.1		μV_{PP}
Input Current Noise, $f = 10Hz$			100		fA/\sqrt{Hz}
INPUT VOLTAGE RANGE					
Common-Mode Voltage Range		$(V-) - 0.1$		$(V+) + 0.1$	V
Common-Mode Rejection Ratio	$(V-) - 0.1V < V_{CM} < (V+) + 0.1V$	106	130		dB
INPUT CAPACITANCE					
Differential			2		pF
Common-Mode			4		pF
OPEN-LOOP GAIN					
Open-Loop Voltage Gain	$(V-) + 100mV < V_O < (V+) - 100mV, R_L = 10k\Omega$	106	130		dB
FREQUENCY RESPONSE					
Gain-Bandwidth Product	$C_L = 100pF$		350		kHz
Slew Rate	$G = +1$		0.16		$V/\mu s$
OUTPUT					
Voltage Output Swing from Rail	$R_L = 10k\Omega$		30	50	mV
over Temperature	$R_L = 10k\Omega$			70	mV
Short-Circuit Current			± 5		mA
Capacitive Load Drive			See Typical Characteristics		
Open-Loop Output Impedance	$f = 350kHz, I_O = 0$		2		k Ω
POWER SUPPLY					
Specified Voltage Range		1.8		5.5	V
Quiescent Current Per Amplifier	$I_O = 0$		17	25	μA
over Temperature				28	μA
Turn-On Time	$V_S = +5V$		100		μs
TEMPERATURE RANGE					
Specified Range		-40		+125	$^\circ C$
Operating Range		-40		+150	$^\circ C$
Storage Range		-65		+150	$^\circ C$
Thermal Resistance	θ_{JA}				$^\circ C/W$
SOT23-5			200		$^\circ C/W$
SO-8			150		$^\circ C/W$
DFN-8			50		$^\circ C/W$
SC70-5			250		$^\circ C/W$

(1) 300-hour life test at $+150^\circ C$ demonstrated randomly distributed variation of approximately $1\mu V$.

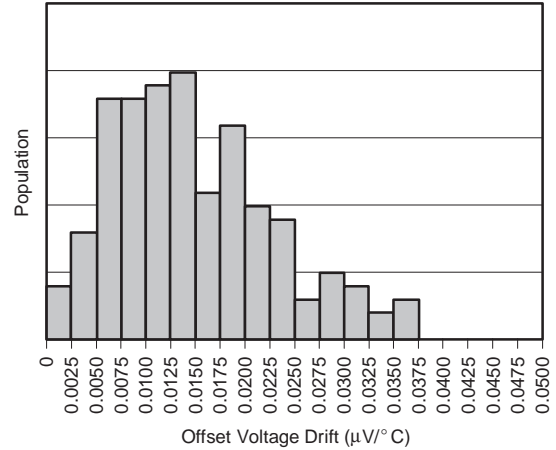
TYPICAL CHARACTERISTICS

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $C_L = 0\text{pF}$, unless otherwise noted.

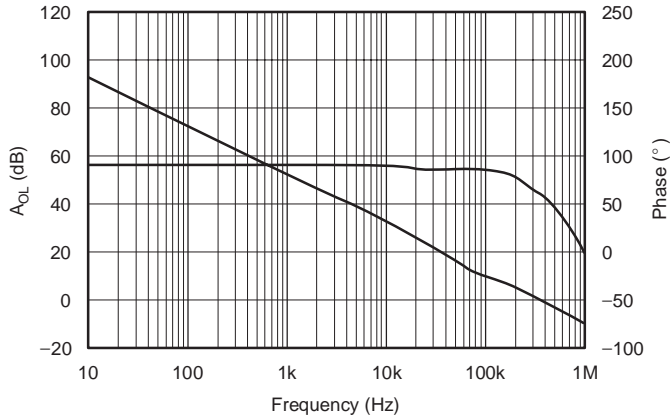
OFFSET VOLTAGE PRODUCTION DISTRIBUTION



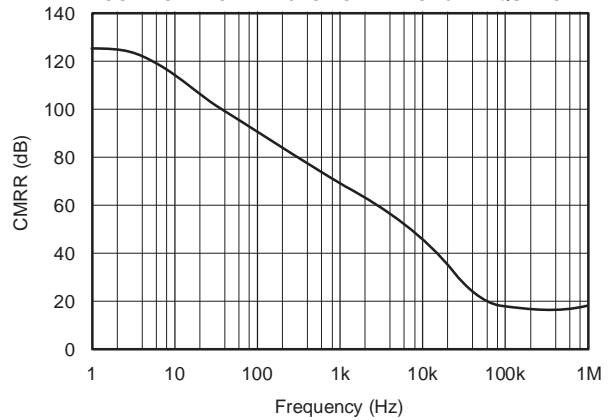
OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION



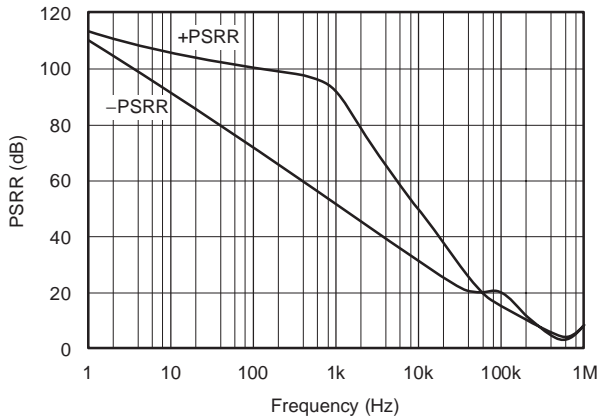
OPEN-LOOP GAIN vs FREQUENCY



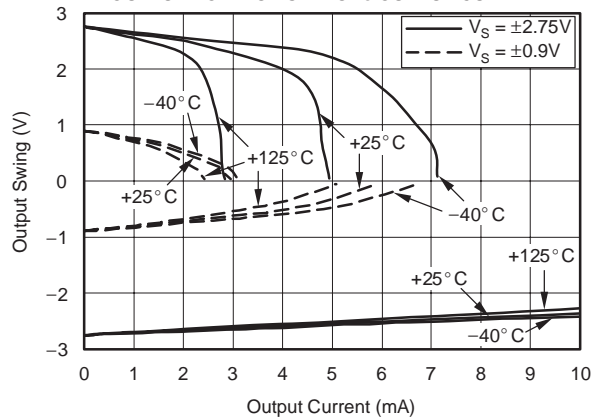
COMMON-MODE REJECTION RATIO vs FREQUENCY



POWER-SUPPLY REJECTION RANGE vs FREQUENCY

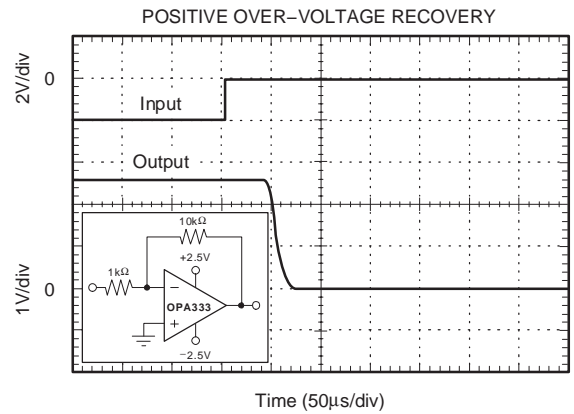
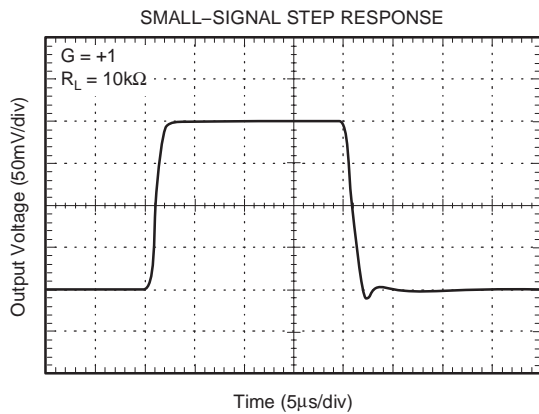
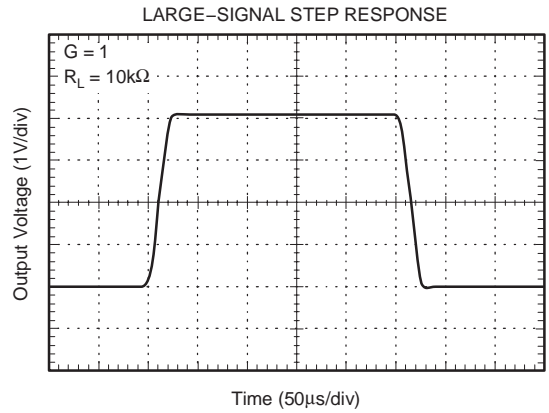
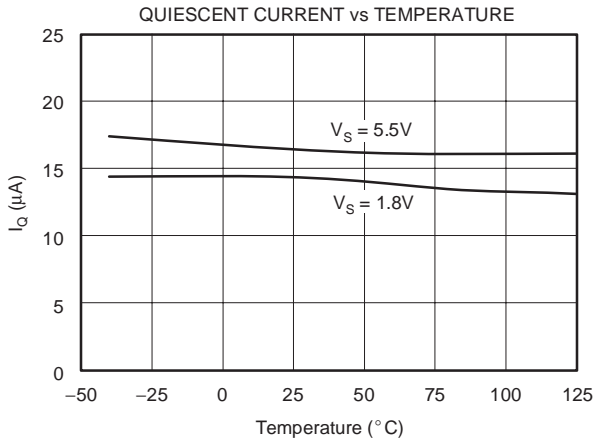
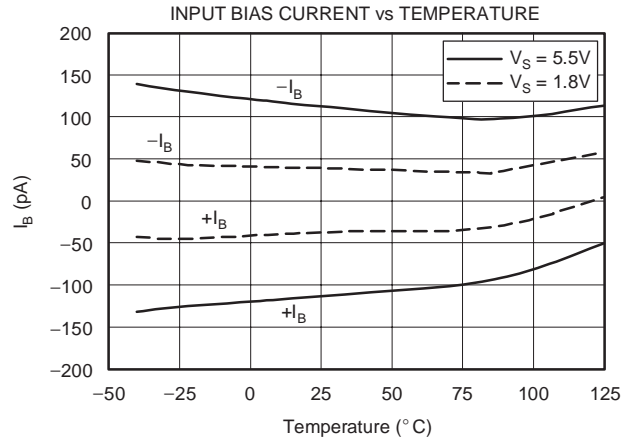
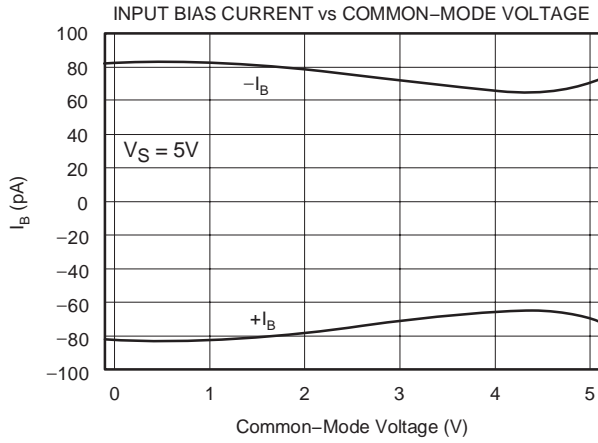


OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



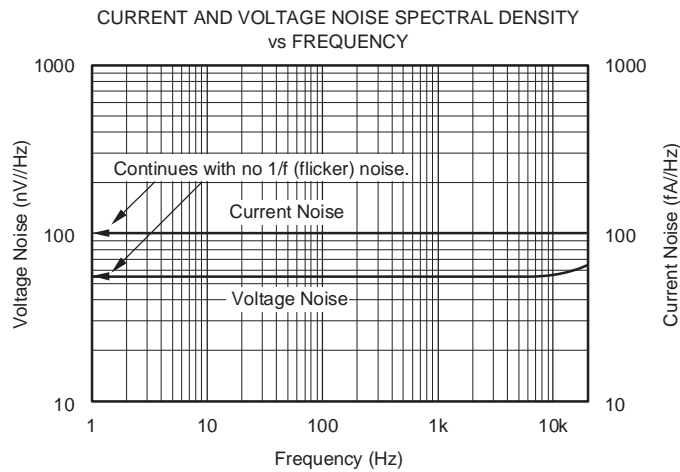
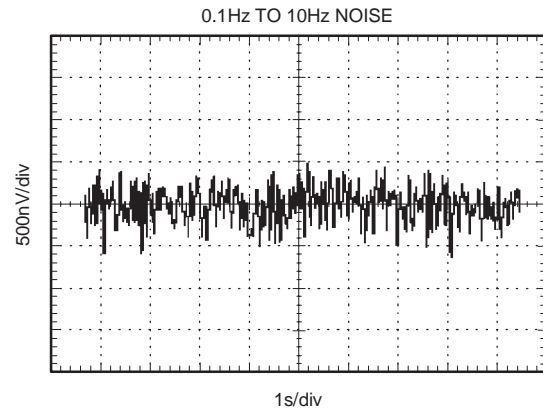
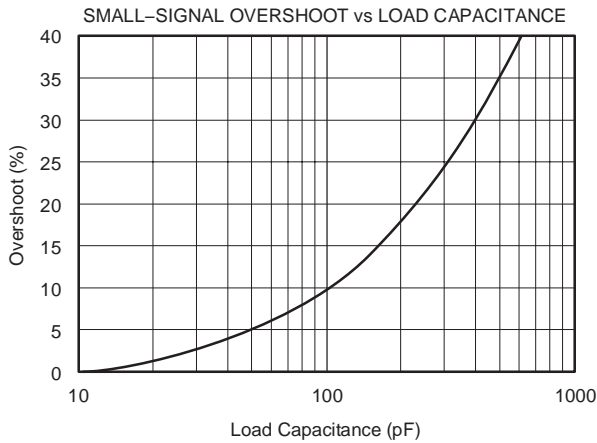
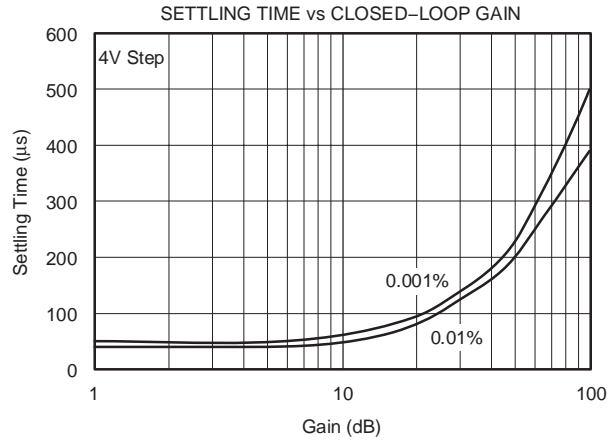
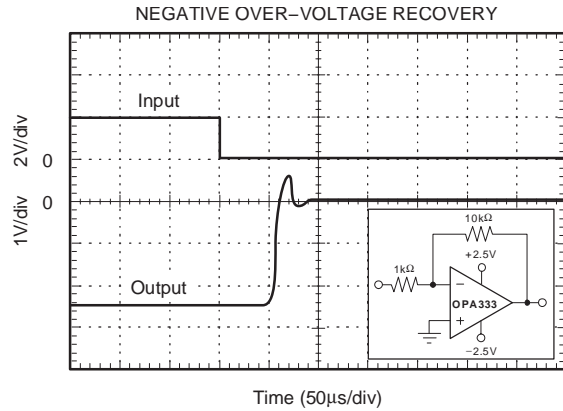
TYPICAL CHARACTERISTICS (continued)

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $C_L = 0\text{pF}$, unless otherwise noted.



TYPICAL CHARACTERISTICS (continued)

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $C_L = 0\text{pF}$, unless otherwise noted.



APPLICATIONS INFORMATION

The OPA333 and OPA2333 are unity-gain stable and free from unexpected output phase reversal. They use a proprietary auto-calibration technique to provide low offset voltage and very low drift over time and temperature. For lowest offset voltage and precision performance, circuit layout and mechanical conditions should be optimized. Avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. These thermally-generated potentials can be made to cancel by assuring they are equal on both input terminals. Other layout and design considerations include:

- Use low thermoelectric-coefficient conditions (avoid dissimilar metals).
- Thermally isolate components from power supplies or other heat sources.
- Shield op amp and input circuitry from air currents, such as cooling fans.

Following these guidelines will reduce the likelihood of junctions being at different temperatures, which can cause thermoelectric voltages of $0.1\mu\text{V}/^\circ\text{C}$ or higher, depending on materials used.

OPERATING VOLTAGE

The OPA333 and OPA2333 op amps operate over a power-supply range of +1.8V to +5.5V ($\pm 0.9\text{V}$ to $\pm 2.75\text{V}$). Supply voltages higher than +7V (absolute maximum) can permanently damage the device. Parameters that vary over supply voltage or temperature are shown in the Typical Characteristics section of this data sheet.

INPUT VOLTAGE

The OPA333 and OPA2333 input common-mode voltage range extends 0.1V beyond the supply rails. The OPA333 is designed to cover the full range without the troublesome transition region found in some other rail-to-rail amplifiers.

Normally, input bias current is about 70pA; however, input voltages exceeding the power supplies can cause excessive current to flow into or out of the input pins. Momentary voltages greater than the power supply can be tolerated if the input current is limited to 10mA. This limitation is easily accomplished with an input resistor, as shown in Figure 1.

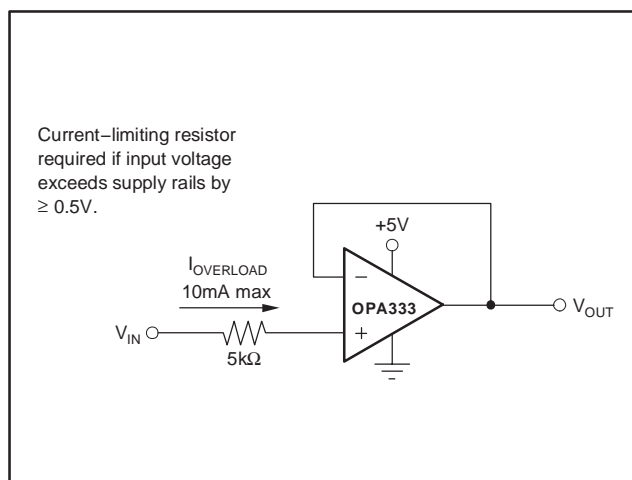


Figure 1. Input Current Protection

INTERNAL OFFSET CORRECTION

The OPA333 and OPA2333 op amps use an auto-calibration technique with a time-continuous 350kHz op amp in the signal path. This amplifier is zero-corrected every $8\mu\text{s}$ using a proprietary technique. Upon power-up, the amplifier requires approximately $100\mu\text{s}$ to achieve specified V_{OS} accuracy. This design has no aliasing or flicker noise.

ACHIEVING OUTPUT SWING TO THE OP AMP NEGATIVE RAIL

Some applications require output voltage swings from 0V to a positive full-scale voltage (such as +2.5V) with excellent accuracy. With most single-supply op amps, problems arise when the output signal approaches 0V, near the lower output swing limit of a single-supply op amp. A good single-supply op amp may swing close to single-supply ground, but will not reach ground. The output of the OPA333 and OPA2333 can be made to swing to ground, or slightly below, on a single-supply power source. To do so requires the use of another resistor and an additional, more negative, power supply than the op amp negative supply. A pull-down resistor may be connected between the output and the additional negative supply to pull the output down below the value that the output would otherwise achieve, as shown in Figure 2.

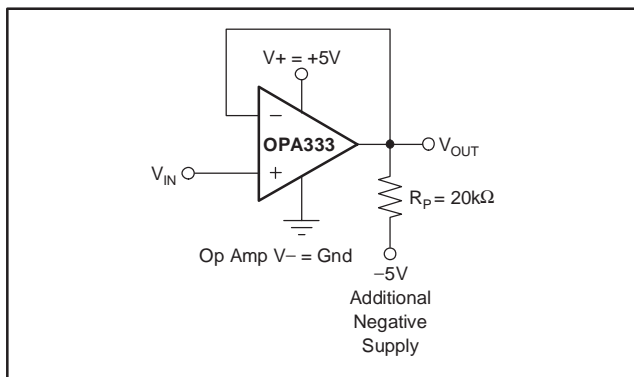


Figure 2. For V_{OUT} Range to Ground

The OPA333 and OPA2333 have an output stage that allows the output voltage to be pulled to its negative supply rail, or slightly below, using the technique previously described. This technique only works with some types of output stages. The OPA333 and OPA2333 have been characterized to perform with this technique; however, the recommended resistor value is approximately 20kΩ. Note that this configuration will increase the current consumption by several hundreds of microamps. Accuracy is excellent down to 0V and as low as -2mV. Limiting and nonlinearity occurs below -2mV, but excellent accuracy returns as the output is again driven above -2mV. Lowering the resistance of the pull-down resistor will allow the op amp to swing even further below the negative rail. Resistances as low as 10kΩ can be used to achieve excellent accuracy down to -10mV.

GENERAL LAYOUT GUIDELINES

Attention to good layout practices is always recommended. Keep traces short and, when possible, use a printed circuit board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1μF capacitor closely across the supply pins. These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI (electromagnetic-interference) susceptibility.

Operational amplifiers vary in their susceptibility to radio frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or dc signal levels with changes in the interfering RF signal. The OPA333 has been specifically designed to minimize susceptibility to RFI and demonstrates remarkably low sensitivity compared to previous generation devices. Strong RF fields may still cause varying offset levels..

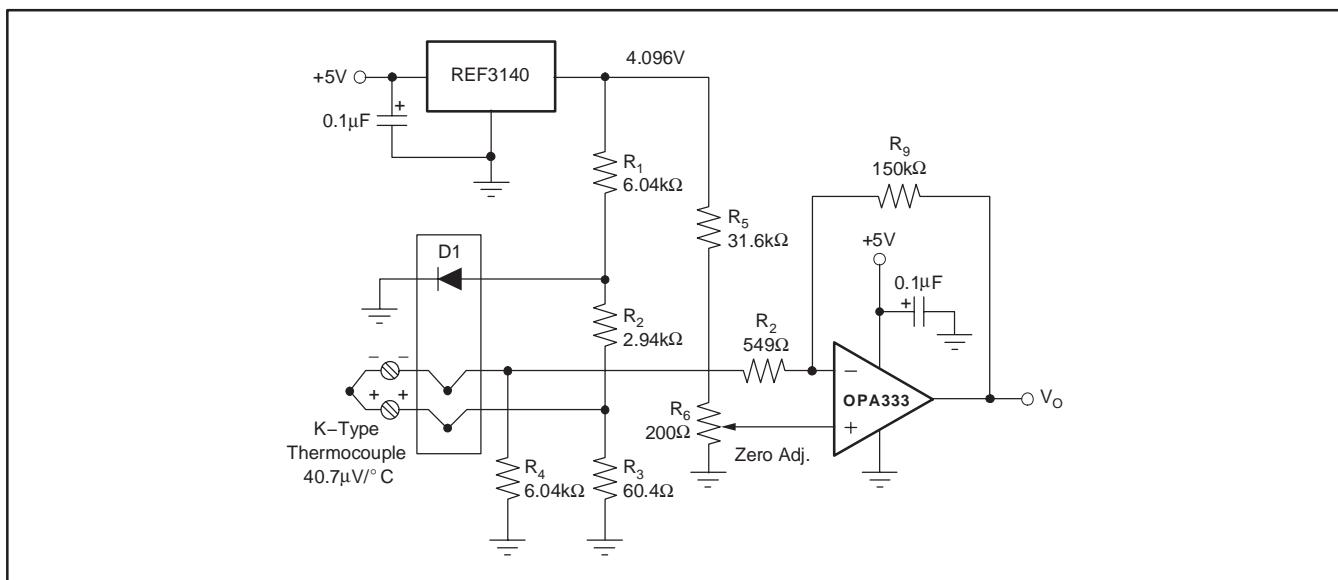


Figure 3. Temperature Measurement

Figure 4 shows the basic configuration for a bridge amplifier.

A low-side current shunt monitor is shown in Figure 5. R_N are operational resistors used to isolate the ADS1100 from the noise of the digital I²C bus. Since the ADS1100 is a 16-bit converter, a precise reference is essential for maximum accuracy. If absolute accuracy is not required, and the 5V power supply is sufficiently stable, the REF3130 may be omitted.

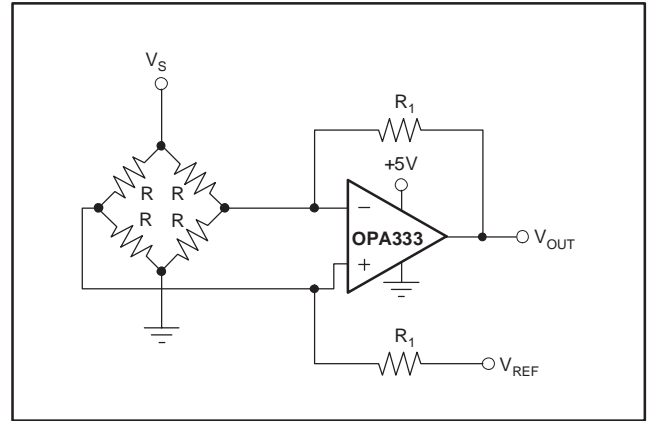


Figure 4. Single Op Amp Bridge Amplifier

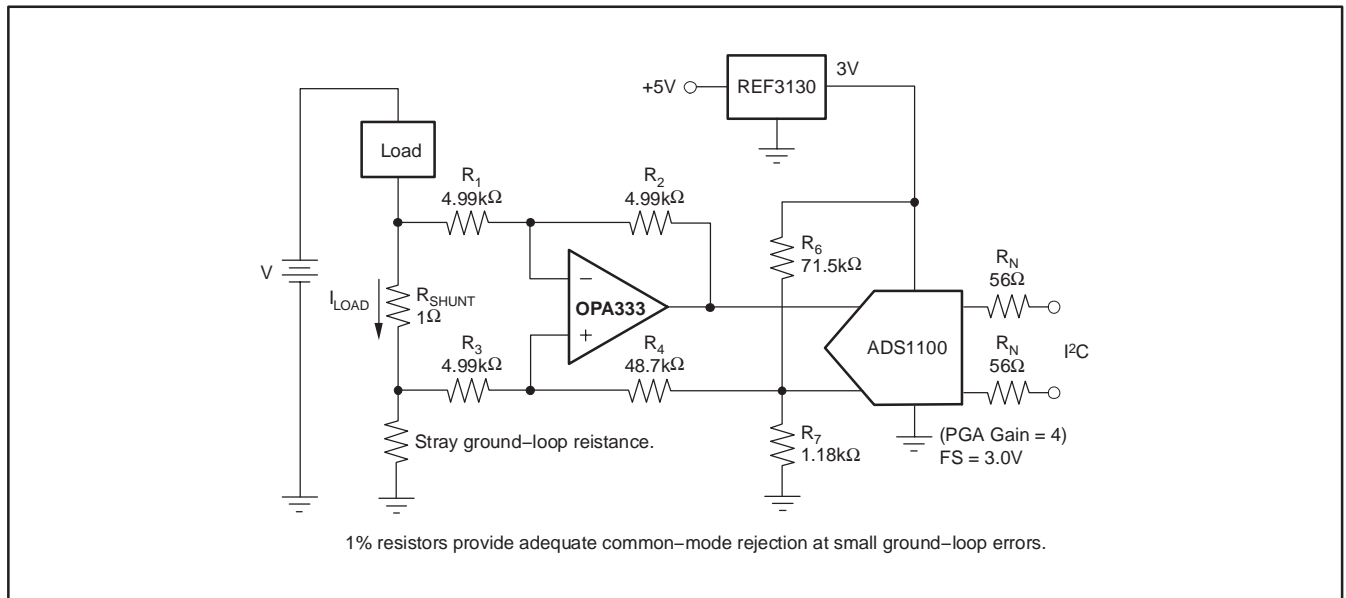


Figure 5. Low-Side Current Monitor

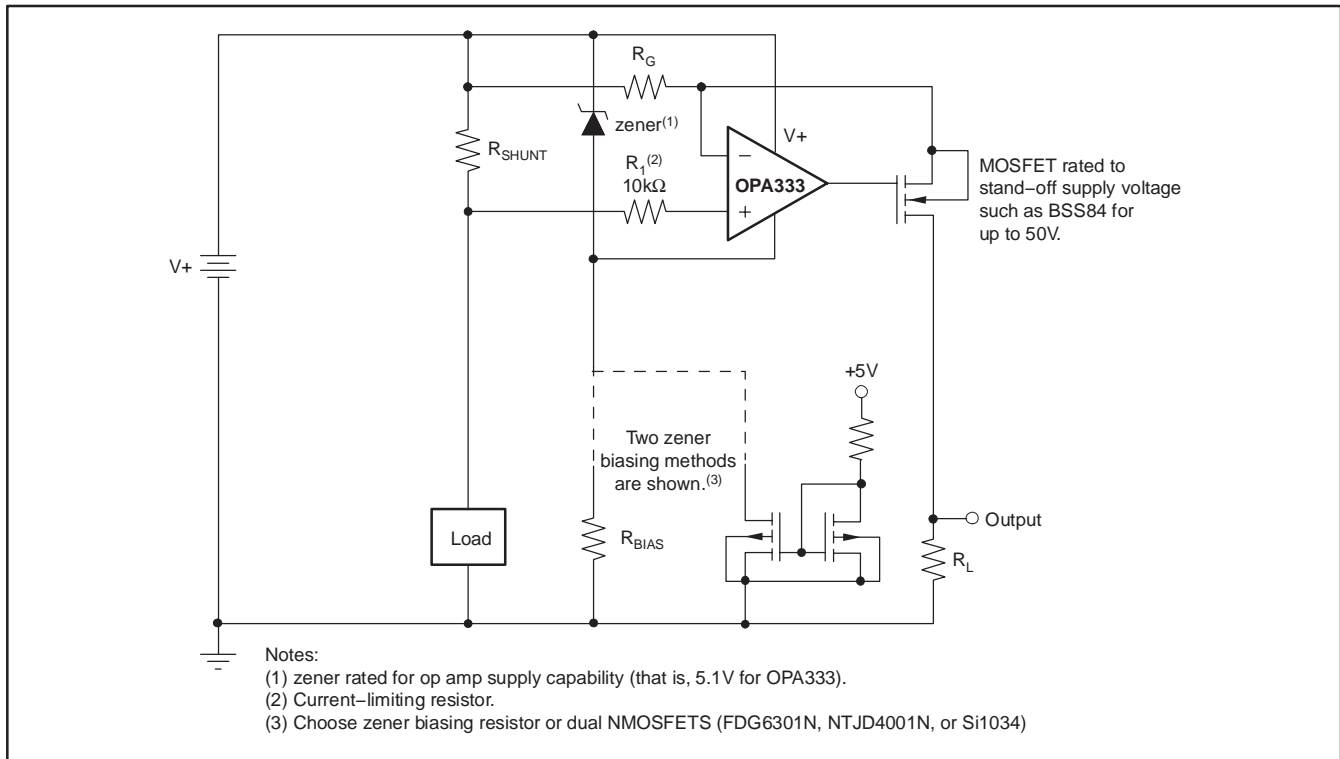


Figure 6. High-Side Current Monitor

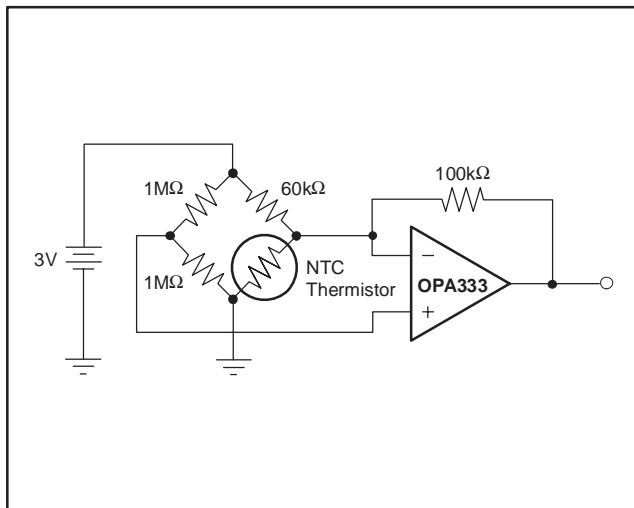


Figure 7. Thermistor Measurement

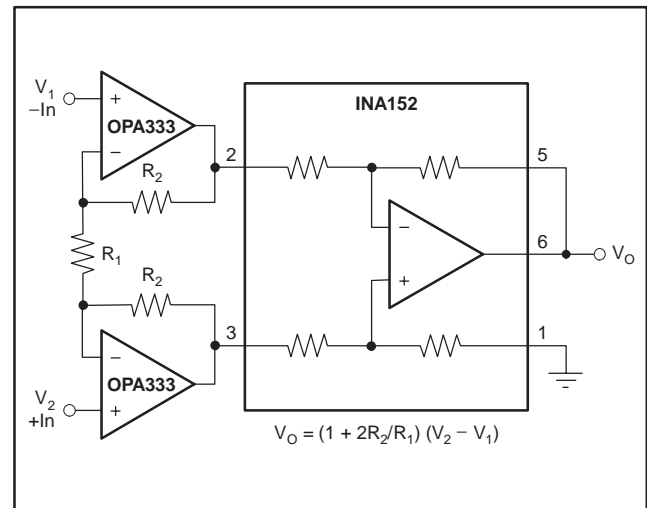


Figure 8. Precision Instrumentation Amplifier

DFN PACKAGE

The OPA2333 is offered in an DFN-8 package (also known as SON). The DFN is a QFN package with lead contacts on only two sides of the bottom of the package. This leadless package maximizes board space and enhances thermal and electrical characteristics through an exposed pad.

DFN packages are physically small, have a smaller routing area, improved thermal performance, and improved electrical parasitics. Additionally, the absence of external leads eliminates bent-lead issues.

The DFN package can be easily mounted using standard printed circuit board (PCB) assembly techniques. See Application Note *QFN/SON PCB Attachment* (SLUA271) and Application Report *Quad Flatpack No-Lead Logic Packages* (SCBA017), both available for download at www.ti.com.

The exposed leadframe die pad on the bottom of the package should be connected to V- or left unconnected.

DFN LAYOUT GUIDELINES

The exposed leadframe die pad on the DFN package should be soldered to a thermal pad on the PCB. A mechanical drawing showing an example layout is attached at the end of this data sheet. Refinements to this layout may be necessary based on assembly process requirements. Mechanical drawings located at the end of this data sheet list the physical dimensions for the package and pad. The five holes in the landing pattern are optional, and are intended for use with thermal vias that connect the leadframe die pad to the heatsink area on the PCB.

Soldering the exposed pad significantly improves board-level reliability during temperature cycling, key push, package shear, and similar board-level tests. Even with applications that have low-power dissipation, the exposed pad must be soldered to the PCB to provide structural integrity and long-term reliability.

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
OPA2333AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA2333AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AIDCKR	ACTIVE	SC70	DCK	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AIDCKT	ACTIVE	SC70	DCK	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
OPA333AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

⁽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.

OBSELETE: 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)

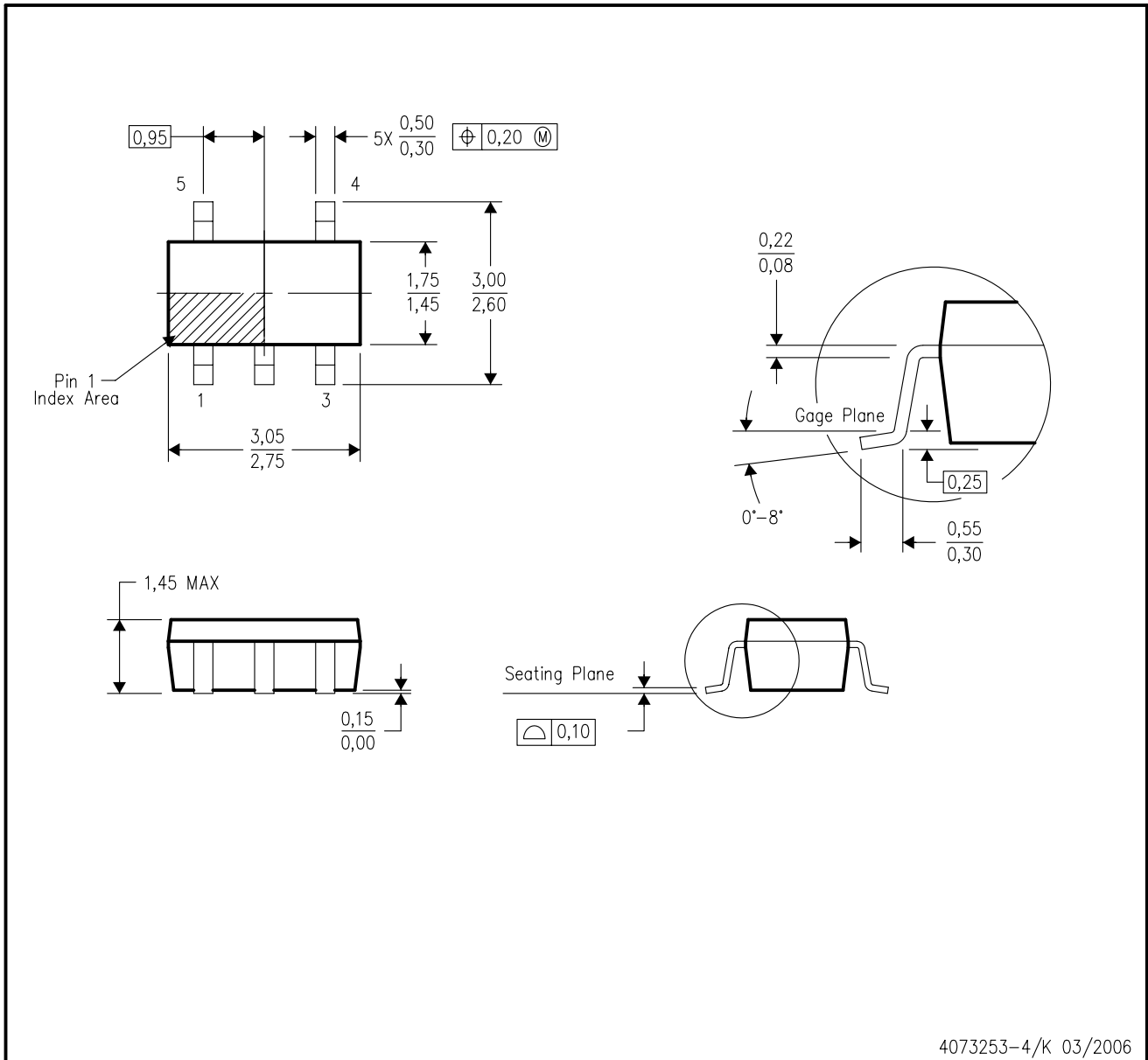
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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.

DBV (R-PDSO-G5)

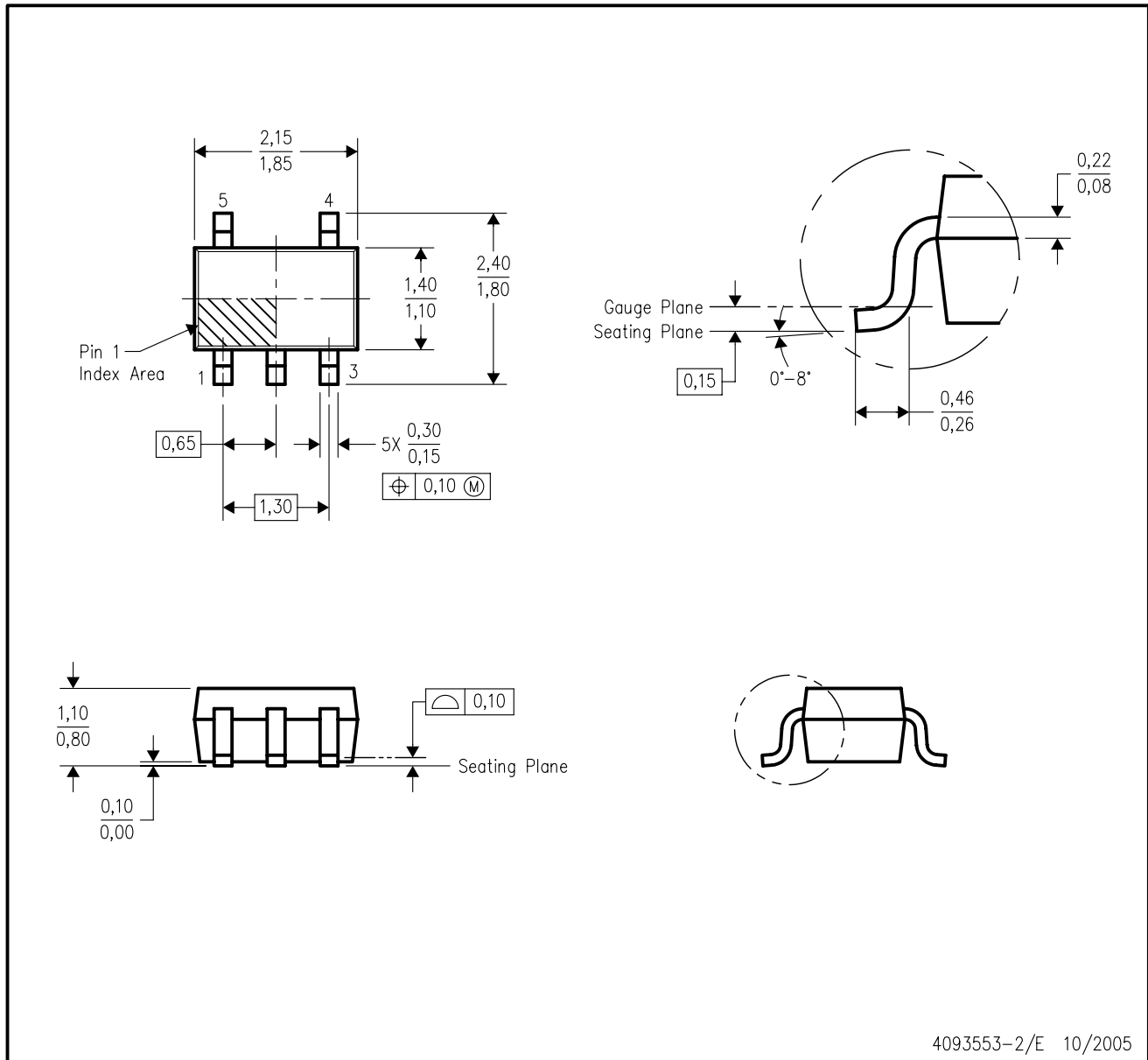
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - Falls within JEDEC MO-178 Variation AA.

DCK (R-PDSO-G5)

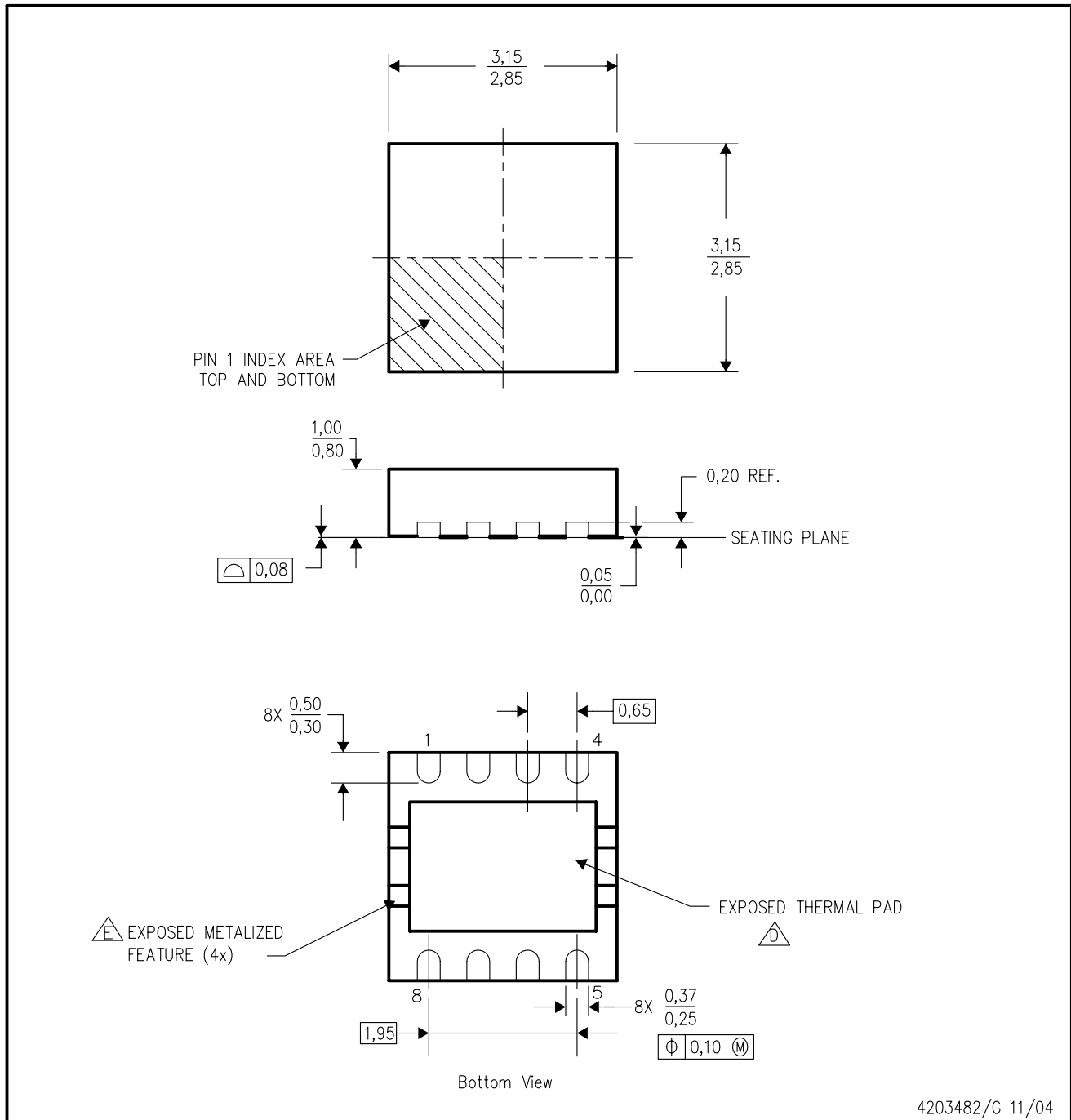
PLASTIC SMALL-OUTLINE PACKAGE





- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. Falls within JEDEC MO-203 variation AA.

DRB (S-PDSO-N8)

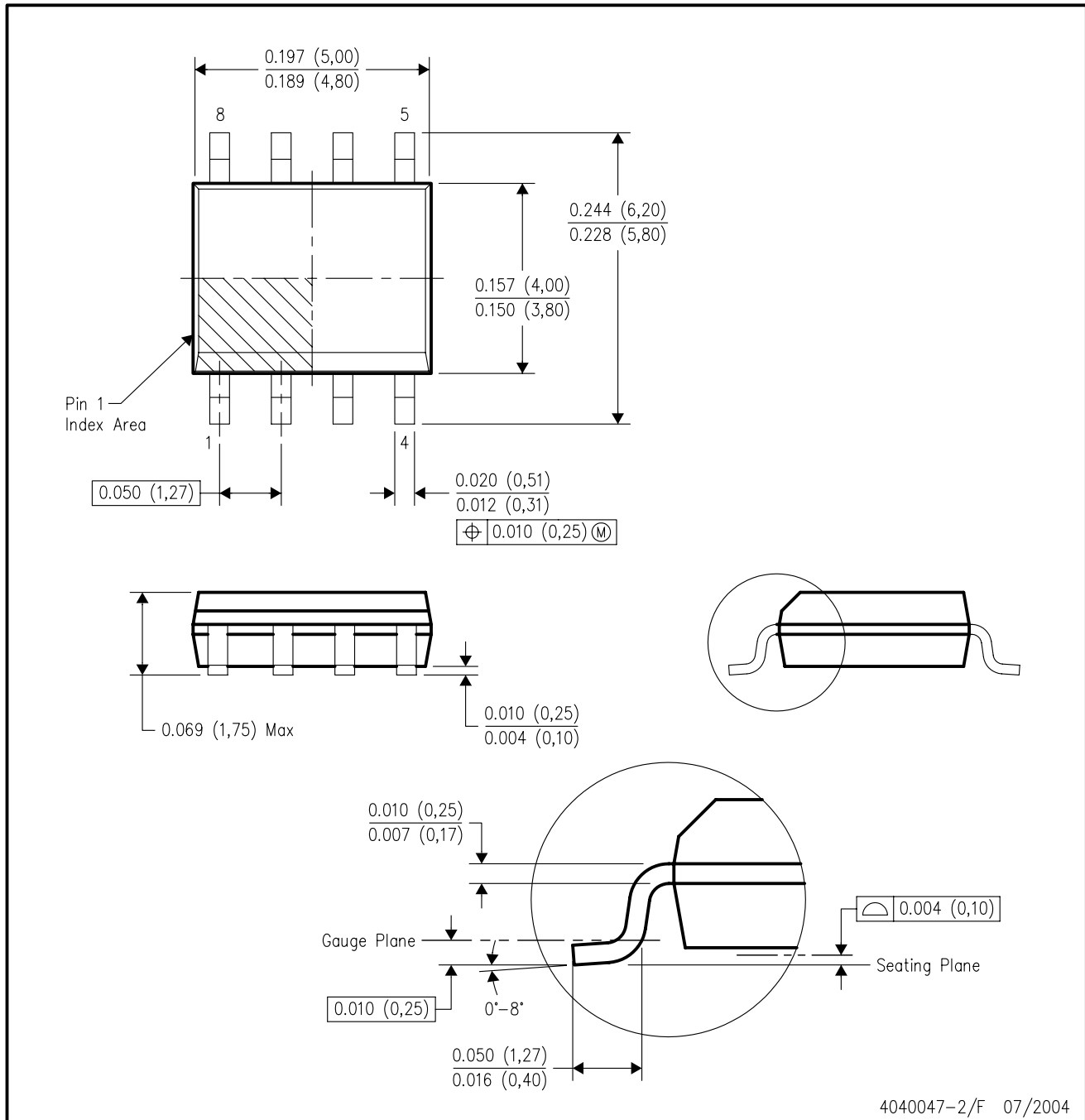
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Small Outline No-Lead (SON) package configuration.
 -  The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
 -  Metalized features are supplier options and may not be on the package.

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.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information 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.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

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.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2006, Texas Instruments Incorporated