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# 1.1nV/ $\sqrt{\text{Hz}}$ NOISE, LOW POWER, PRECISION OPERATIONAL AMPLIFIER

Check for Samples: [OPA211-EP](#)

## 1 FEATURES

- LOW VOLTAGE NOISE: 1.1nV/ $\sqrt{\text{Hz}}$  at 1kHz
- INPUT VOLTAGE NOISE: 80nV<sub>PP</sub> (0.1Hz to 10Hz)
- THD+N: -136dB (G = 1, f = 1kHz)
- OFFSET VOLTAGE: 180 $\mu$ V (max)
- OFFSET VOLTAGE DRIFT: 0.35 $\mu$ V/ $^{\circ}$ C (typ)
- LOW SUPPLY CURRENT: 3.6mA/Ch (typ)
- UNITY-GAIN STABLE
- GAIN BANDWIDTH PRODUCT: 80MHz (G = 100)  
45MHz (G = 1)
- SLEW RATE: 27V/ $\mu$ s
- 16-BIT SETTLING: 700ns
- WIDE SUPPLY RANGE:  $\pm$ 2.25V to  $\pm$ 18V, +4.5V to +36V
- RAIL-TO-RAIL OUTPUT
- OUTPUT CURRENT: 30mA

## 2 APPLICATIONS

- PLL LOOP FILTER
- LOW-NOISE, LOW-POWER SIGNAL PROCESSING
- 16-BIT ADC DRIVERS
- DAC OUTPUT AMPLIFIERS
- ACTIVE FILTERS
- LOW-NOISE INSTRUMENTATION AMPS
- ULTRASOUND AMPLIFIERS
- PROFESSIONAL AUDIO PREAMPLIFIERS
- LOW-NOISE FREQUENCY SYNTHESIZERS
- INFRARED DETECTOR AMPLIFIERS
- HYDROPHONE AMPLIFIERS
- GEOPHONE AMPLIFIERS
- MEDICAL

## 3 SUPPORTS DEFENSE, AEROSPACE, AND MEDICAL APPLICATIONS

- CONTROLLED BASELINE
- ONE ASSEMBLY/TEST SITE
- ONE FABRICATION SITE
- AVAILABLE IN MILITARY (-55 $^{\circ}$ C/125 $^{\circ}$ C) TEMPERATURE RANGE <sup>(1)</sup>
- EXTENDED PRODUCT LIFE CYCLE
- EXTENDED PRODUCT-CHANGE NOTIFICATION
- PRODUCT TRACEABILITY

(1) Additional temperature ranges available - contact factory

## 4 DESCRIPTION

The OPA211 series of precision operational amplifiers achieves very low 1.1nV/ $\sqrt{\text{Hz}}$  noise density with a supply current of only 3.6mA. This series also offers rail-to-rail output swing, which maximizes dynamic range.

The extremely low voltage and low current noise, high speed, and wide output swing of the OPA211 series make these devices an excellent choice as a loop filter amplifier in PLL applications.

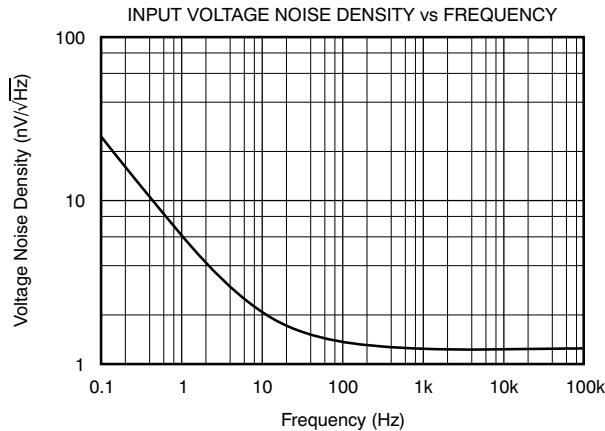
In precision data acquisition applications, the OPA211 series of op amps provides 700ns settling time to 16-bit accuracy throughout 10V output swings. This ac performance, combined with only 125 $\mu$ V of offset and 0.35 $\mu$ V/ $^{\circ}$ C of drift over temperature, makes the OPA211 ideal for driving high-precision 16-bit analog-to-digital converters (ADCs) or buffering the output of high-resolution digital-to-analog converters (DACs).

The OPA211 is specified over a wide dual-power supply range of  $\pm$ 2.25V to  $\pm$ 18V, or for single-supply operation from +4.5V to +36V.

The OPA211 is available in a small MSOP-8 package. This op amp is specified from T<sub>A</sub> = -55 $^{\circ}$ C to +125 $^{\circ}$ C.



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. UNLESS OTHERWISE NOTED, this document contains PRODUCTION DATA.

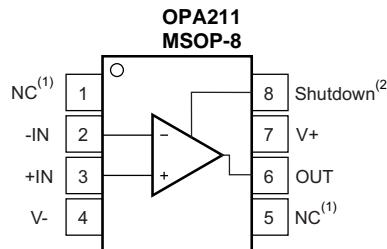


**PACKAGE/ORDERING INFORMATION<sup>(1)</sup>**

T <sub>A</sub>	PACKAGE	ORDERABLE PART NUMBER	PACKAGE MARKING	VID NUMBER
-55°C to 125°C	MSOP-8 - DGK	OPA211MDGKTEP	OBCM	V62/12619-01XE

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at [www.ti.com](http://www.ti.com).

## 5 PIN CONFIGURATIONS



(1) NC denotes no internal connection.

(2) Shutdown function:

- Device enabled:  $(V-) \leq V_{SHUTDOWN} \leq (V+) - 3V$
- Device disabled:  $V_{SHUTDOWN} \geq (V+) - 0.35V$

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.

### 5.1 ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Over operating free-air temperature range (unless otherwise noted).

		VALUE	UNIT
Supply Voltage	$V_S = (V+) - (V-)$	40	V
Input Voltage	$(V-) - 0.5$ to $(V+) + 0.5$		V
Input Current (Any pin except power-supply pins)	$\pm 10$		mA
Output Short-Circuit <sup>(2)</sup>		Continuous	
Operating Temperature	$(T_A)$	-55 to +125	°C
Storage Temperature	$(T_A)$	-65 to +150	°C
Junction Temperature	$(T_J)$	200	°C
ESD Ratings	Human Body Model (HBM)	3000	V
	Charged Device Model (CDM)	1000	V

(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) Short-circuit to  $V_S/2$  (ground in symmetrical dual supply setups), one amplifier per package.

## 6 THERMAL INFORMATION

THERMAL METRIC <sup>(1)</sup>		OPA211	UNITS		
DGK					
8 PINS					
$\theta_{JA}$	Junction-to-ambient thermal resistance <sup>(2)</sup>	184.9	°C/W		
$\theta_{JCtop}$	Junction-to-case (top) thermal resistance <sup>(3)</sup>	71.2			
$\theta_{JB}$	Junction-to-board thermal resistance <sup>(4)</sup>	104.9			
$\psi_{JT}$	Junction-to-top characterization parameter <sup>(5)</sup>	11.5			
$\psi_{JB}$	Junction-to-board characterization parameter <sup>(6)</sup>	103.4			
$\theta_{JCbot}$	Junction-to-case (bottom) thermal resistance <sup>(7)</sup>	N/A			

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, high-K board, as specified in JESD51-7, in an environment described in JESD51-2a.
- (3) The junction-to-case (top) thermal resistance is obtained by simulating a cold plate test on the package top. No specific JEDEC-standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.
- (4) The junction-to-board thermal resistance is obtained by simulating in an environment with a ring cold plate fixture to control the PCB temperature, as described in JESD51-8.
- (5) The junction-to-top characterization parameter,  $\psi_{JT}$ , estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining  $\theta_{JA}$ , using a procedure described in JESD51-2a (sections 6 and 7).
- (6) The junction-to-board characterization parameter,  $\psi_{JB}$ , estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining  $\theta_{JA}$ , using a procedure described in JESD51-2a (sections 6 and 7).
- (7) The junction-to-case (bottom) thermal resistance is obtained by simulating a cold plate test on the exposed (power) pad. No specific JEDEC standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.

## 6.1 ELECTRICAL CHARACTERISTICS: $V_S = \pm 2.25V$ to $\pm 18V$

**BOLDFACE** limits apply over the specified temperature range,  $T_A = -55^\circ C$  to  $+125^\circ C$ .

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

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>					
Input Offset Voltage	$V_{OS}$	$V_S = \pm 15V$		$\pm 20$	$\pm 100$ $\mu V$
Over Temperature				<b><math>\pm 180</math></b>	$\mu V$
Drift	$dV_{OS}/dT$		<b>0.35</b>		$\mu V/^\circ C$
vs Power Supply	$PSRR$	$V_S = \pm 2.25V$ to $\pm 18V$	0.1	0.5	$\mu V/V$
Over Temperature				3	$\mu V/V$
<b>INPUT BIAS CURRENT</b>					
Input Bias Current	$I_B$	$V_{CM} = 0V$	$\pm 50$	$\pm 200$	$nA$
Offset Current	$I_{OS}$	$V_{CM} = 0V$	$\pm 20$	$\pm 150$	$nA$
<b>NOISE</b>					
Input Voltage Noise	$e_n$	$f = 0.1Hz$ to $10Hz$	80		$nV_{PP}$
Input Voltage Noise Density		$f = 10Hz$	2		$nV/\sqrt{Hz}$
		$f = 100Hz$	1.4		$nV/\sqrt{Hz}$
		$f = 1kHz$	1.1		$nV/\sqrt{Hz}$
Input Current Noise Density	$I_n$	$f = 10Hz$	3.2		$pA/\sqrt{Hz}$
		$f = 1kHz$	1.7		$pA/\sqrt{Hz}$
<b>INPUT VOLTAGE RANGE</b>					
Common-Mode Voltage Range	$V_{CM}$	$V_S \geq \pm 5V$	$(V-) + 1.8$		$V$
		$V_S < \pm 5V$	$(V-) + 2$	$(V+) - 1.4$	$V$
Common-Mode Rejection Ratio	$CMRR$	$V_S \geq \pm 5V, (V-) + 2V \leq V_{CM} \leq (V+) - 2V$	114	120	$dB$
		$V_S < \pm 5V, (V-) + 2V \leq V_{CM} \leq (V+) - 2V$	108	120	$dB$
<b>INPUT IMPEDANCE</b>					
Differential			20k $\parallel$ 8		$\Omega \parallel pF$
Common-Mode			10 <sup>9</sup> $\parallel$ 2		$\Omega \parallel pF$
<b>OPEN-LOOP GAIN</b>					
Open-Loop Voltage Gain	$A_{OL}$	$(V-) + 0.2V \leq V_O \leq (V+) - 0.2V, R_L = 10k\Omega$	114	130	$dB$
	$A_{OL}$	$(V-) + 0.6V \leq V_O \leq (V+) - 0.6V, R_L = 600\Omega$	110	114	$dB$
Over Temperature	$A_{OL}$	$(V-) + 0.6V \leq V_O \leq (V+) - 0.6V, I_O \leq 15mA$	110		$dB$
	$A_{OL}$	$(V-) + 0.6V \leq V_O \leq (V+) - 0.6V, 15mA < I_O \leq 30mA$	103		$dB$
<b>FREQUENCY RESPONSE</b>					
Gain-Bandwidth Product	$GBW$	$G = 100$ $G = 1$		80 45	$MHz$
Slew Rate	$SR$			27	$V/\mu s$
Settling Time, 0.01% 0.0015% (16-bit)	$t_S$	$V_S = \pm 15V, G = -1, 10V$ Step, $C_L = 100pF$ $V_S = \pm 15V, G = -1, 10V$ Step, $C_L = 100pF$		400 700	ns
Overload Recovery Time		$G = -10$		500	ns
Total Harmonic Distortion + Noise	$THD+N$	$G = +1, f = 1kHz, V_O = 3V_{RMS}, R_L = 600\Omega$		0.000015 -136	% $dB$

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## ELECTRICAL CHARACTERISTICS: $V_S = \pm 2.25V$ to $\pm 18V$ (continued)

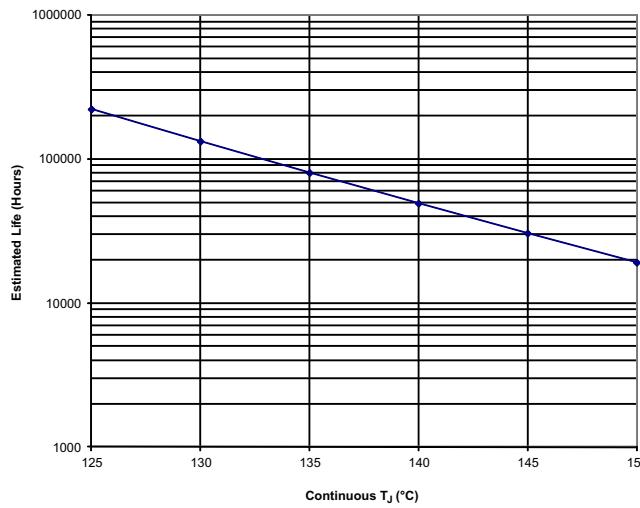
**BOLDFACE** limits apply over the specified temperature range,  $T_A = -55^\circ C$  to  $+125^\circ C$ .

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

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
<b>OUTPUT</b>					
Voltage Output	$V_{OUT}$	$(V-) + 0.2$		$(V+) - 0.2$	V
		$(V-) + 0.6$		$(V+) - 0.6$	V
		$(V-) + 0.6$	+30/-45	$(V+) - 0.6$	V
Short-Circuit Current	$I_{SC}$				mA
Capacitive Load Drive	$C_{LOAD}$		See <a href="#">Typical Characteristics</a>		pF
Open-Loop Output Impedance	$Z_O$	$f = 1MHz$	5		$\Omega$
<b>SHUTDOWN</b>					
Shutdown Pin Input Voltage <sup>(1)</sup>		Device disabled (shutdown)	$(V+) - 0.35$		V
		Device enabled		$(V+) - 3$	V
Shutdown Pin Leakage Current			1		$\mu A$
Turn-On Time <sup>(2)</sup>			2		$\mu s$
Turn-Off Time <sup>(2)</sup>			3		$\mu s$
Shutdown Current		Shutdown (disabled)	1	20	$\mu A$
<b>POWER SUPPLY</b>					
Specified Voltage	$V_S$		$\pm 2.25$	$\pm 18$	V
Quiescent Current (per channel)	$I_Q$	$I_{OUT} = 0A$	3.6	4.5	mA
<b>Over Temperature</b>					
<b>TEMPERATURE RANGE</b>					
Operating Range		$T_A$	-55	+125	$^\circ C$
Thermal Resistance				200	$^\circ C/W$
	$\theta_{JA}$				

(1) When disabled, the output assumes a high-impedance state.

(2) See [Typical Characteristic](#) curves, [Figure 42](#) through [Figure 44](#).



- A. See datasheet for absolute maximum and minimum recommended operating conditions.
- B. Silicon operating life design goal is 10 years at  $105^\circ C$  junction temperature (does not include package interconnect life).

**Figure 1. OPA211-EP Wirebond Life Derating Chart**

## 7 TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

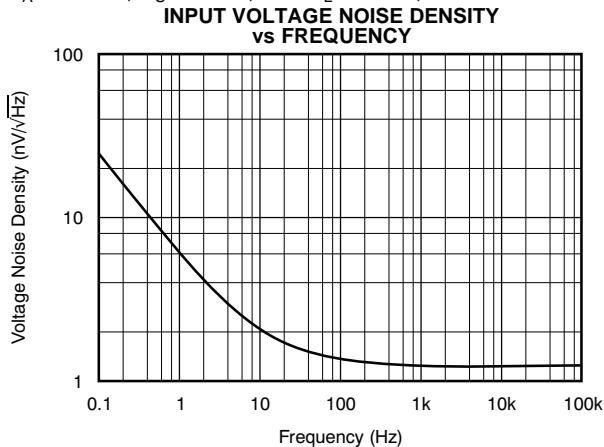


Figure 2.

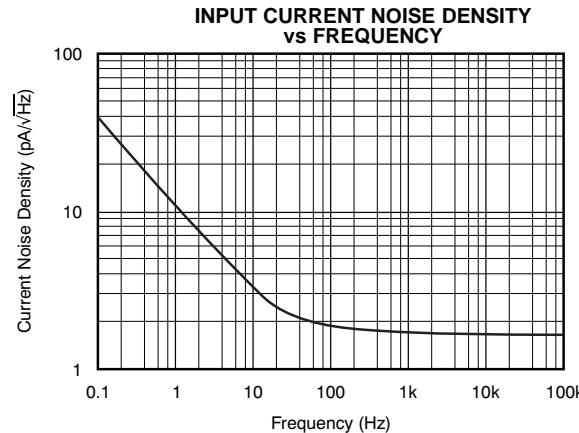


Figure 3.

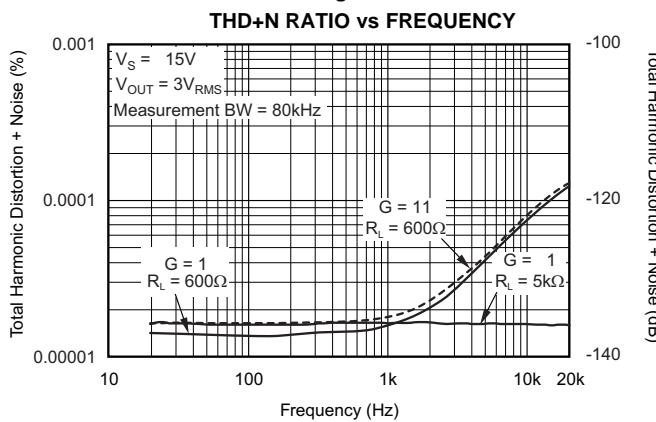


Figure 4.

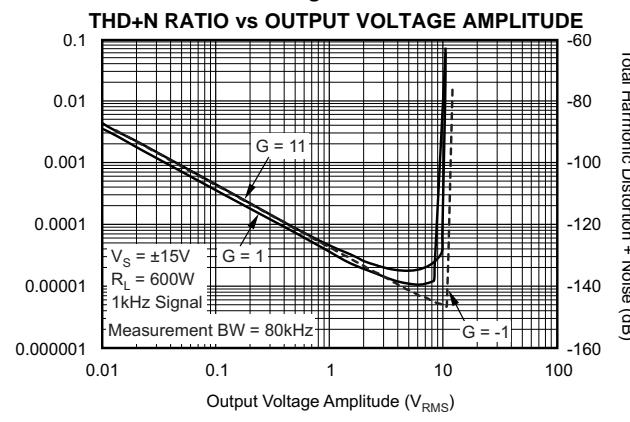


Figure 5.

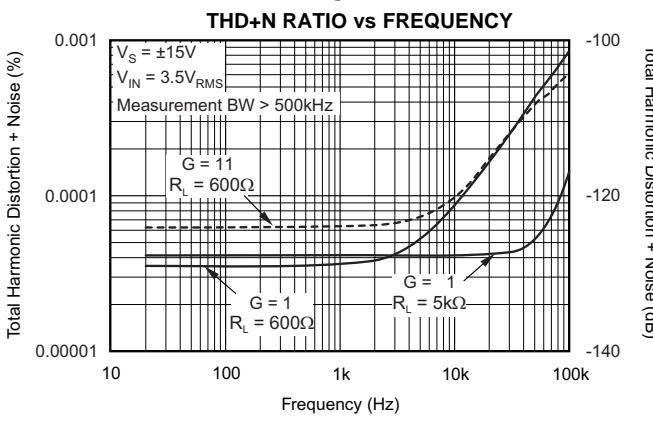


Figure 6.

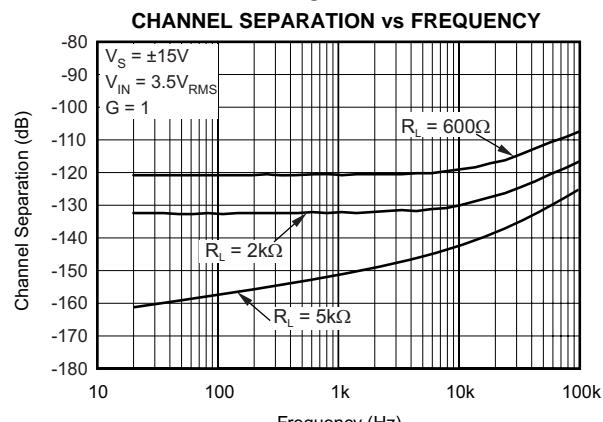


Figure 7.

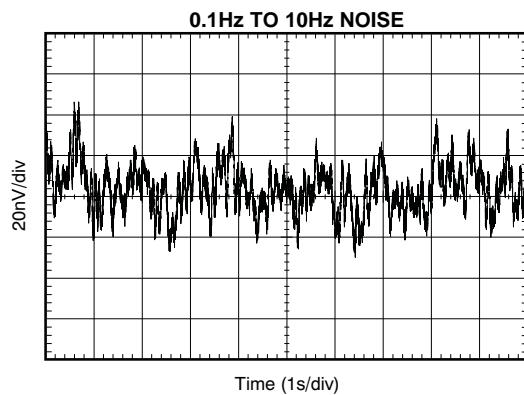
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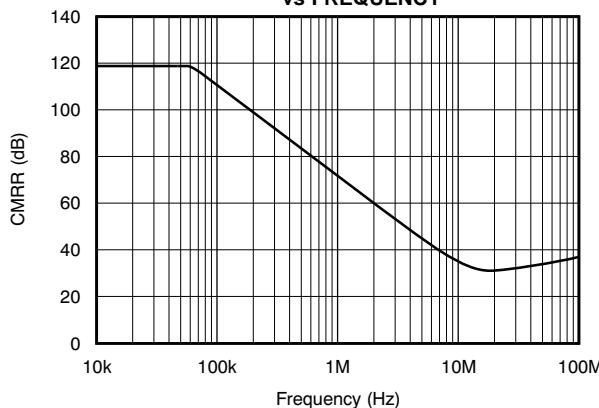
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## TYPICAL CHARACTERISTICS (continued)

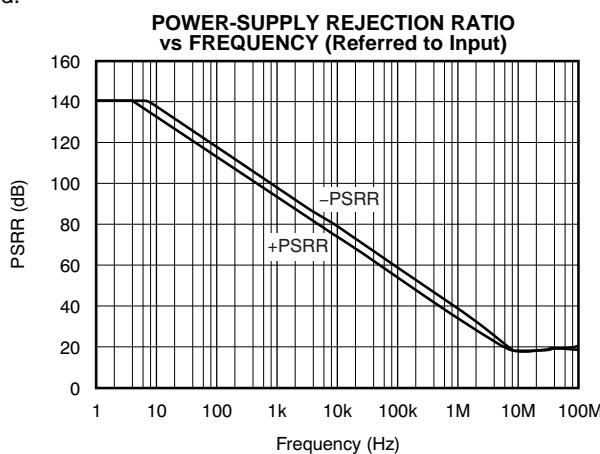
At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.



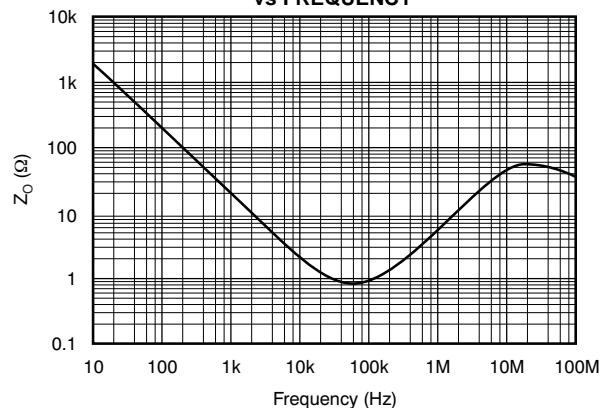
**Figure 8.**  
COMMON-MODE REJECTION RATIO  
vs FREQUENCY



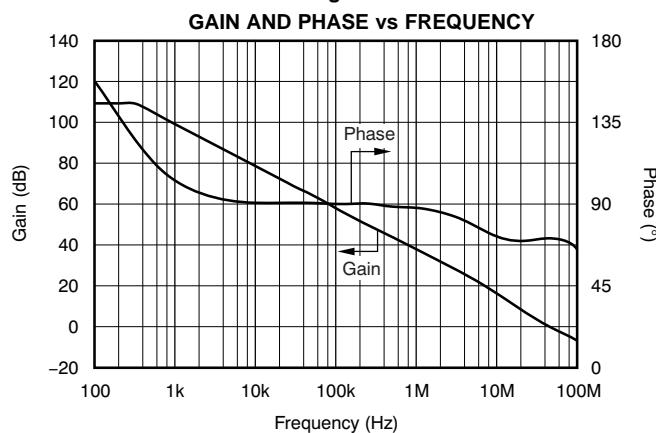
**Figure 10.**



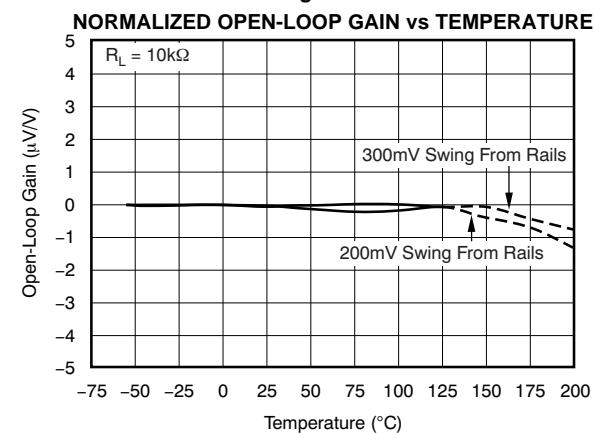
**Figure 9.**  
OPEN-LOOP OUTPUT IMPEDANCE  
vs FREQUENCY



**Figure 11.**



**Figure 12.**



**Figure 13.**

**TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

**OFFSET VOLTAGE PRODUCTION DISTRIBUTION**

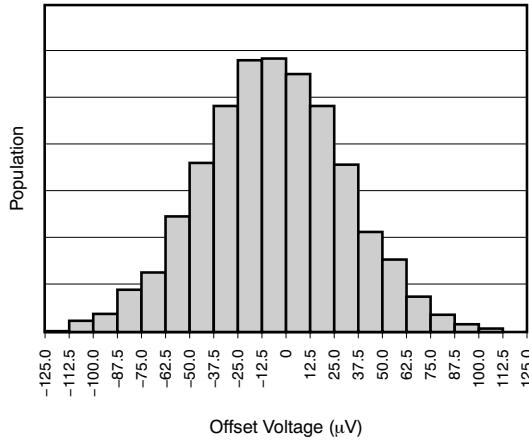


Figure 14.

**OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION**

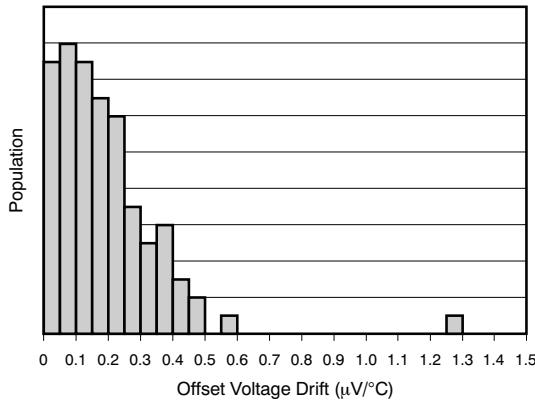


Figure 15.

**$I_B$  AND  $I_{OS}$  CURRENT  
VS  
TEMPERATURE**

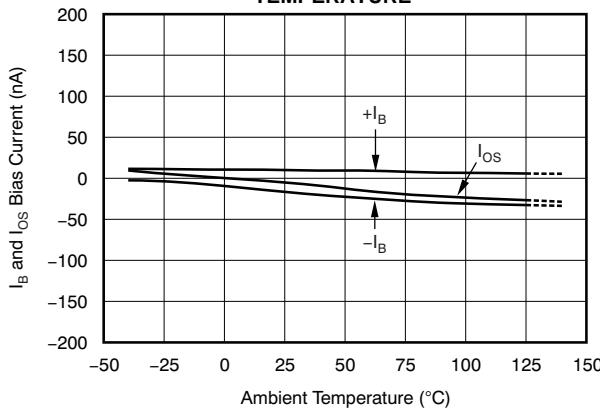


Figure 16.

**$V_{OS}$  WARMUP**

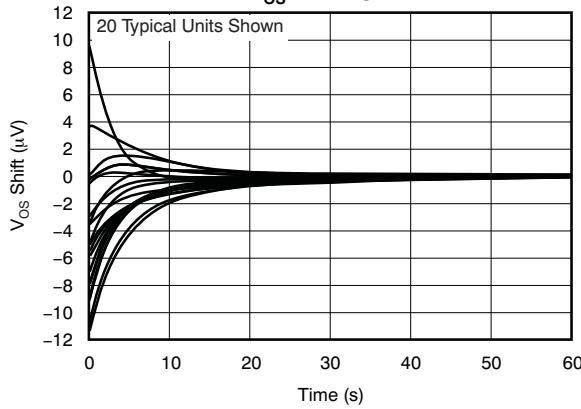


Figure 18.

**OFFSET VOLTAGE vs COMMON-MODE VOLTAGE**

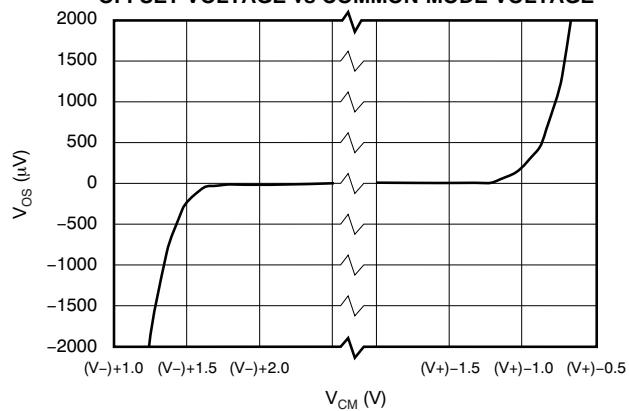


Figure 17.

**INPUT OFFSET CURRENT vs SUPPLY VOLTAGE**

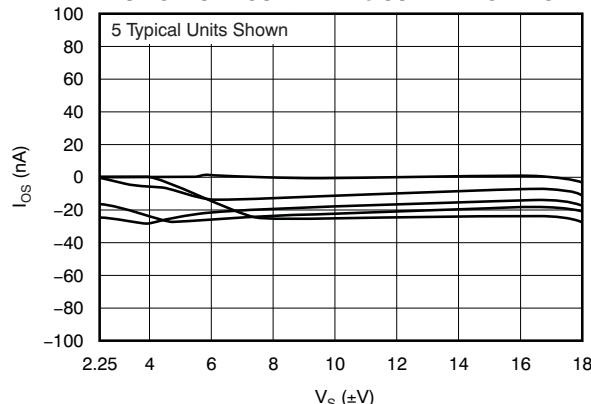


Figure 19.

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## TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

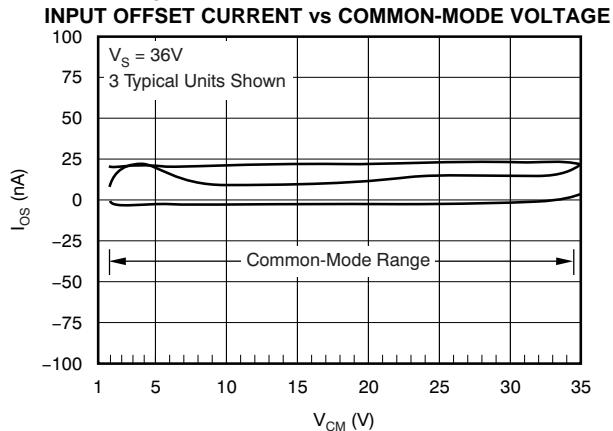


Figure 20.

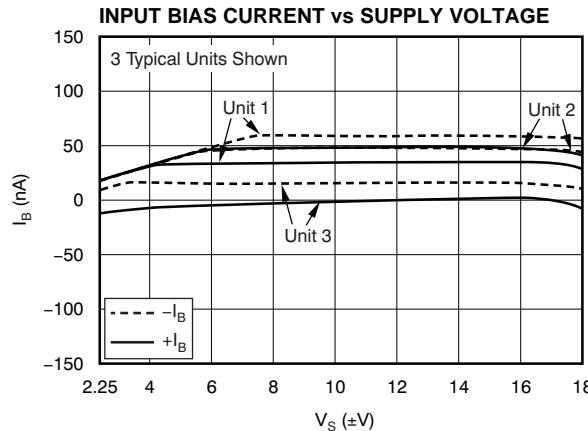


Figure 21.

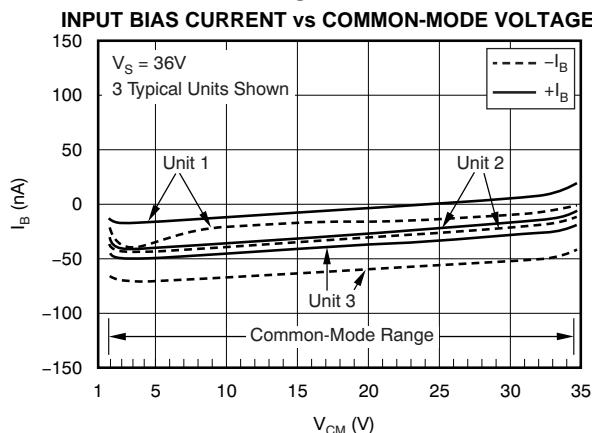


Figure 22.

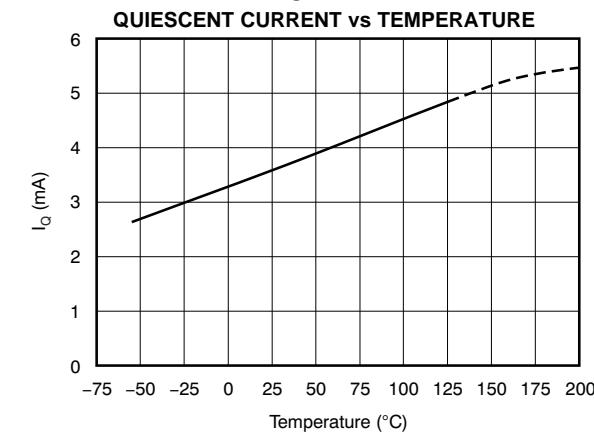


Figure 23.

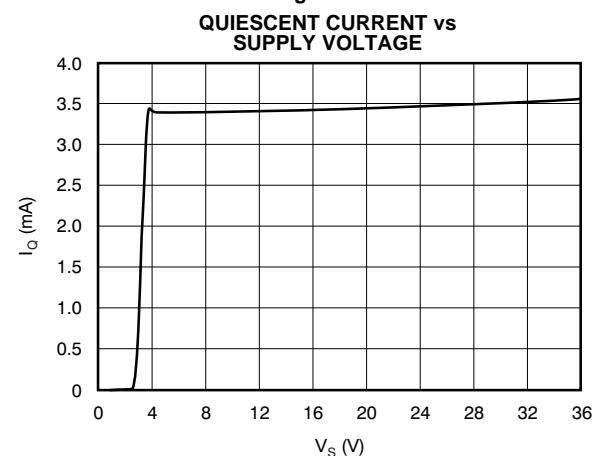


Figure 24.

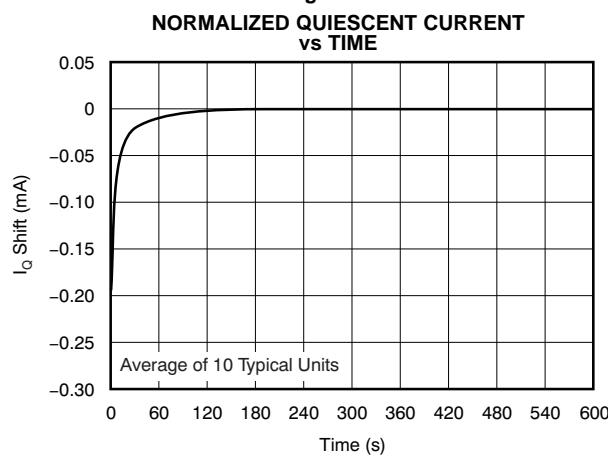


Figure 25.

**TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

**SHORT-CIRCUIT CURRENT  
vs TEMPERATURE**

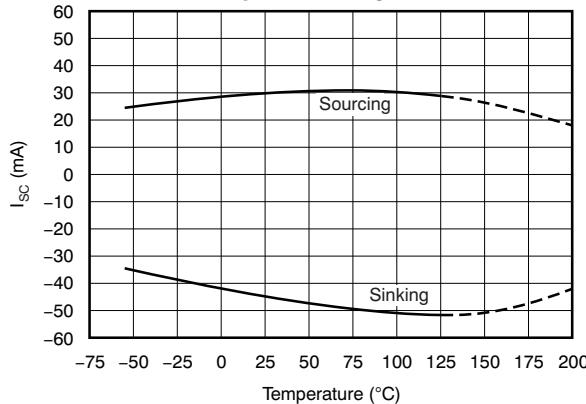


Figure 26.

**SMALL-SIGNAL STEP RESPONSE  
(100mV)**

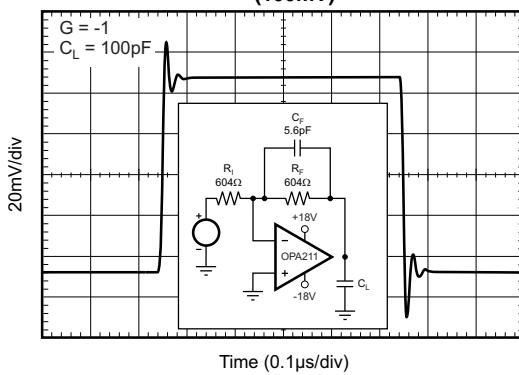


Figure 27.

**SMALL-SIGNAL STEP RESPONSE  
(100mV)**

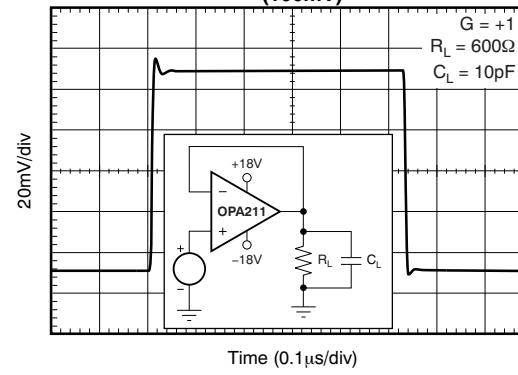


Figure 29.

**SMALL-SIGNAL OVERSHOOT  
vs CAPACITIVE LOAD (100mV Output Step)**

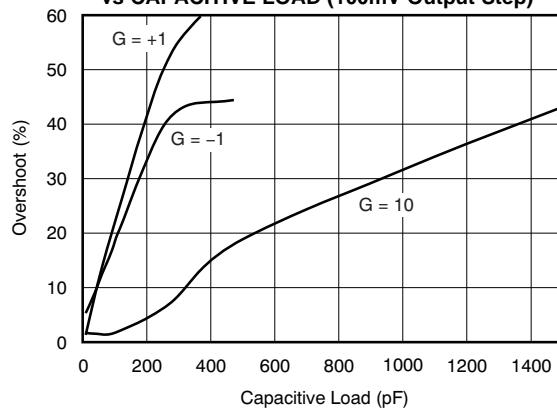


Figure 31.

Figure 28.

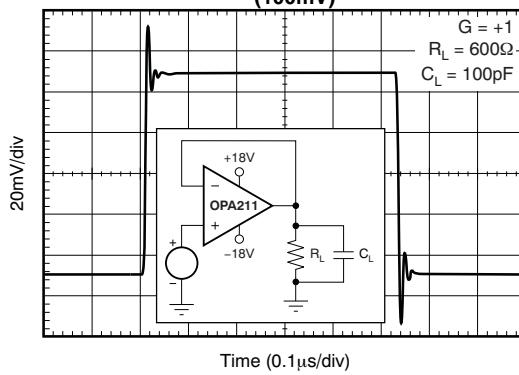


Figure 30.

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## TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

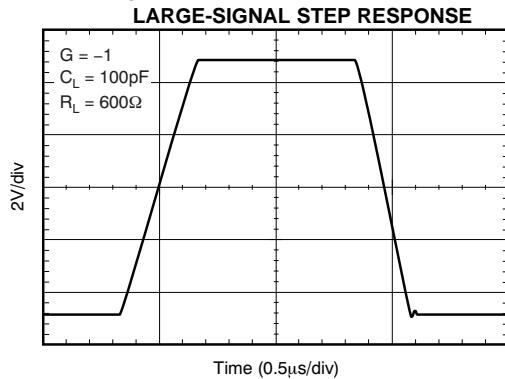


Figure 32.

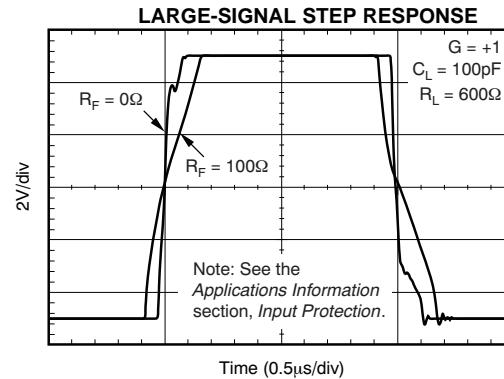


Figure 33.

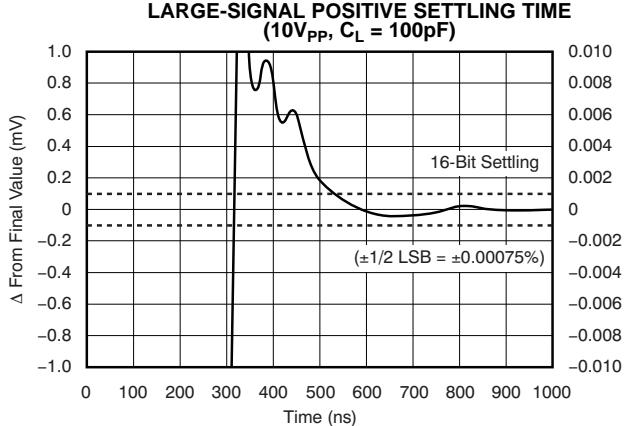


Figure 34.

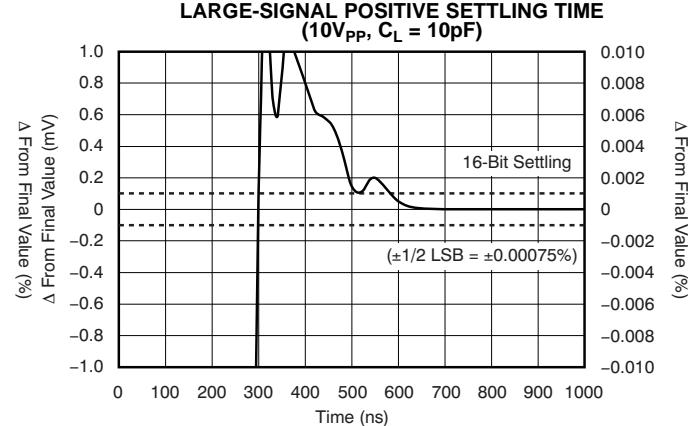


Figure 35.

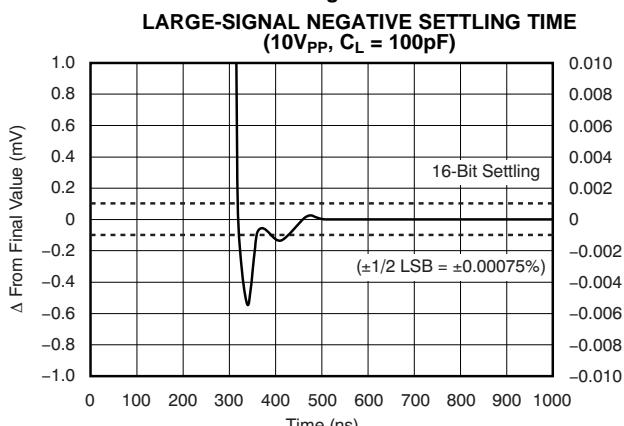


Figure 36.

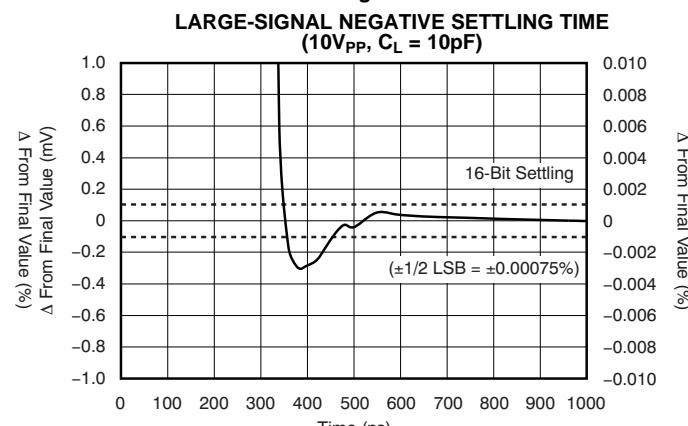


Figure 37.

**TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

**NEGATIVE OVERLOAD RECOVERY**

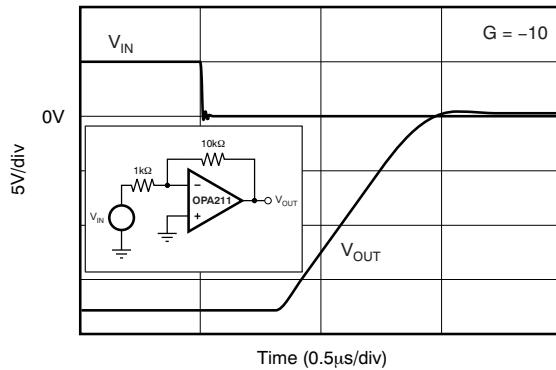


Figure 38.

**POSITIVE OVERLOAD RECOVERY**

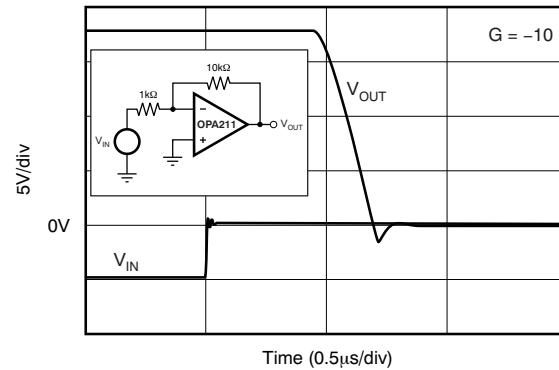


Figure 39.

**OUTPUT VOLTAGE vs OUTPUT CURRENT**

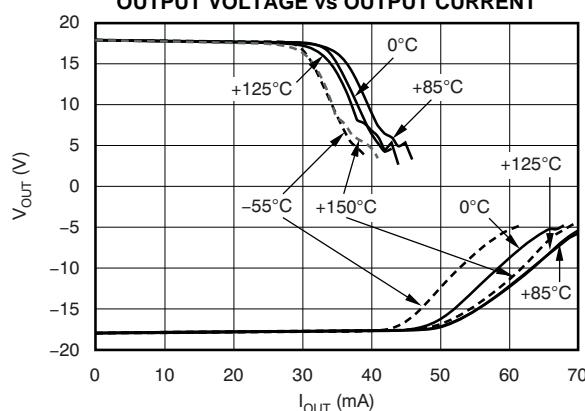


Figure 40.

**TURN-OFF TRANSIENT**

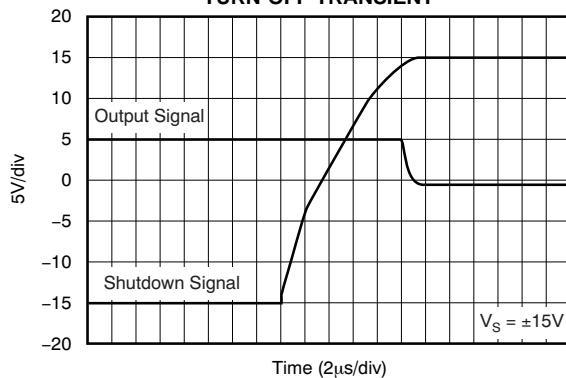


Figure 42.

**NO PHASE REVERSAL**

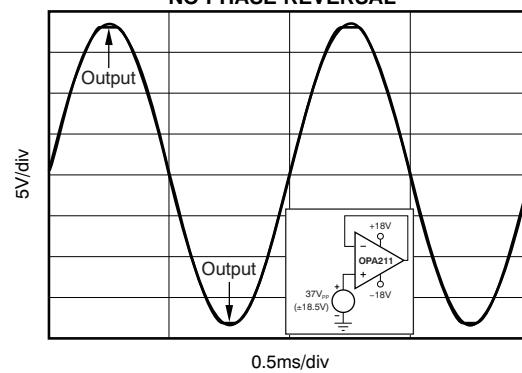


Figure 41.

**TURN-ON TRANSIENT**

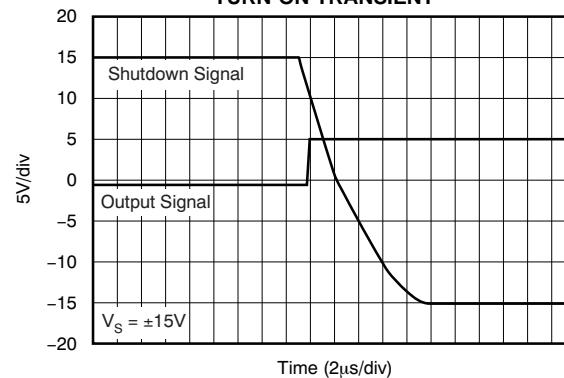
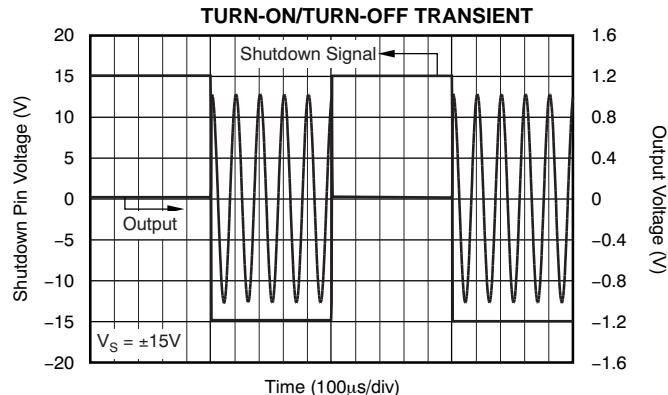


Figure 43.

**TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 18\text{V}$ , and  $R_L = 10\text{k}\Omega$ , unless otherwise noted.

**Figure 44.**

## 8 APPLICATION INFORMATION

The OPA211 is a unity-gain stable, precision op amp with very low noise. Applications with noisy or high-impedance power supplies require decoupling capacitors close to the device pins. In most cases,  $0.1\mu\text{F}$  capacitors are adequate. Figure 45 shows a simplified schematic of the OPA211. This die uses a SiGe bipolar process and contains 180 transistors.

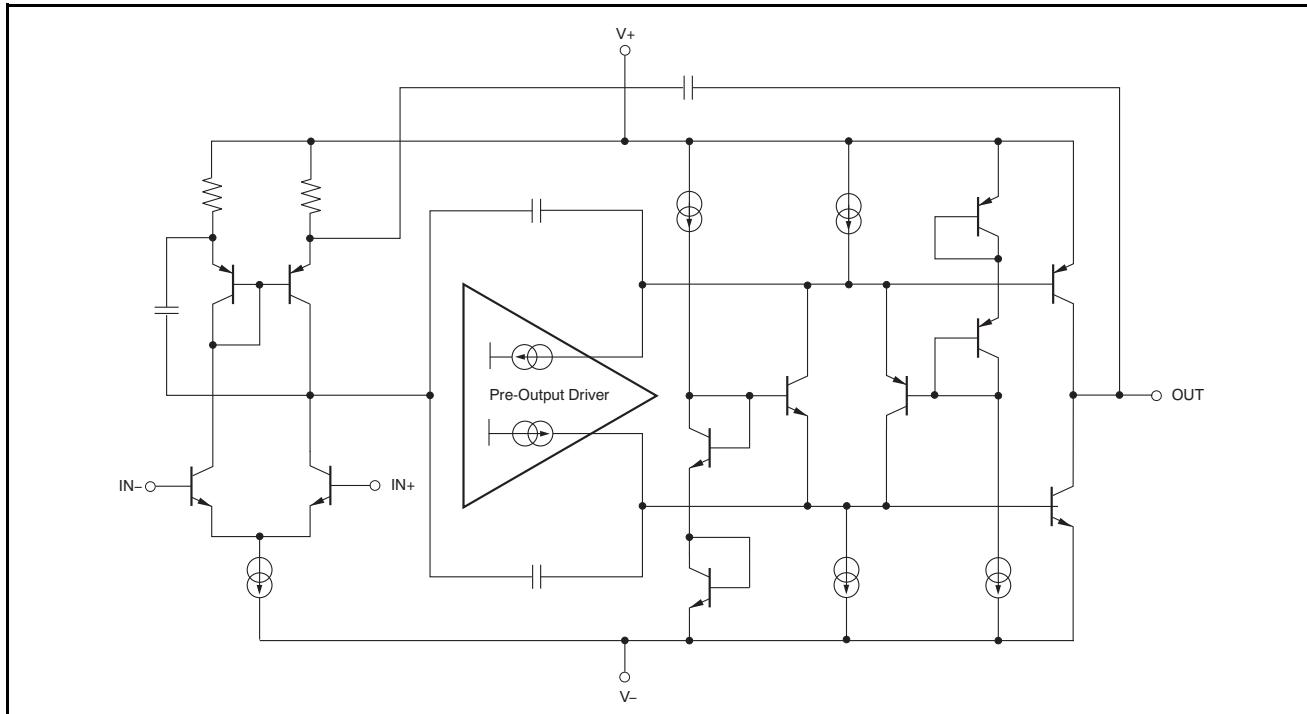
### 8.1 OPERATING VOLTAGE

OPA211 series op amps operate from  $\pm 2.25\text{V}$  to  $\pm 18\text{V}$  supplies while maintaining excellent performance. The OPA211 series can operate with as little as  $+4.5\text{V}$  between the supplies and with up to  $+36\text{V}$  between the supplies. However, some applications do not require equal positive and

### OPERATING VOLTAGE (continued)

negative output voltage swing. With the OPA211 series, power-supply voltages do not need to be equal. For example, the positive supply could be set to  $+25\text{V}$  with the negative supply at  $-5\text{V}$  or vice-versa.

The common-mode voltage must be maintained within the specified range. In addition, key parameters are assured over the specified temperature range,  $T_A = -55^\circ\text{C}$  to  $+125^\circ\text{C}$ . Parameters that vary significantly with operating voltage or temperature are shown in the [Typical Characteristics](#).



**Figure 45. OPA211 Simplified Schematic**

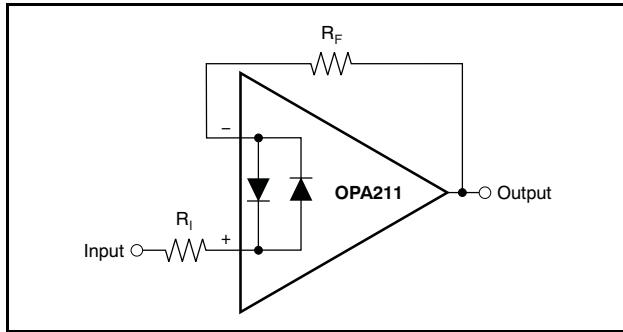
# OPA211-EP

SBOS638 – JUNE 2012

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## 8.2 INPUT PROTECTION

The input terminals of the OPA211 are protected from excessive differential voltage with back-to-back diodes, as shown in [Figure 46](#). In most circuit applications, the input protection circuitry has no consequence. However, in low-gain or  $G = 1$  circuits, fast ramping input signals can forward bias these diodes because the output of the amplifier cannot respond rapidly enough to the input ramp. This effect is illustrated in [Figure 33](#) of the Typical Characteristics. If the input signal is fast enough to create this forward bias condition, the input signal current must be limited to 10mA or less. If the input signal current is not inherently limited, an input series resistor can be used to limit the signal input current. This input series resistor degrades the low-noise performance of the OPA211, and is discussed in the [Noise Performance](#) section of this data sheet. [Figure 46](#) shows an example implementing a current-limiting feedback resistor.

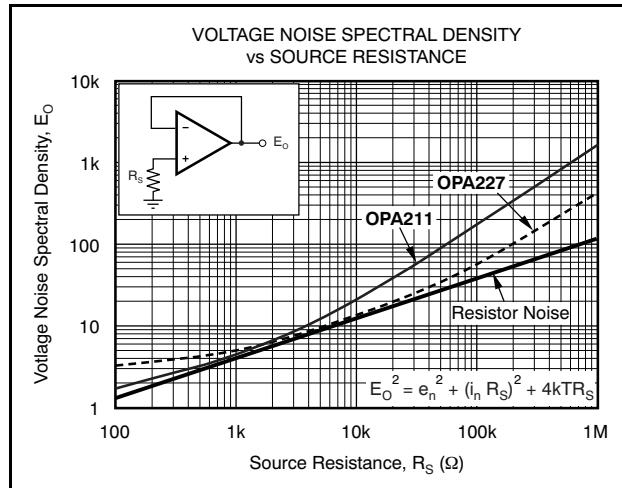


**Figure 46. Pulsed Operation**

## 8.3 NOISE PERFORMANCE

[Figure 47](#) shows total circuit noise for varying source impedances with the op amp in a unity-gain configuration (no feedback resistor network, and therefore no additional noise contributions). Two different op amps are shown with total circuit noise calculated. The OPA211 has very low voltage noise, making it ideal for low source impedances (less than  $2\text{k}\Omega$ ). A similar precision op amp, the [OPA227](#), has somewhat higher voltage noise but lower current noise. It provides excellent noise performance at moderate source impedance ( $10\text{k}\Omega$  to  $100\text{k}\Omega$ ). Above  $100\text{k}\Omega$ , a FET-input op amp such as the [OPA132](#) (very low current noise) may provide improved performance. The equation in [Figure 47](#) is shown for the calculation of the total circuit noise. Note that  $e_n$  = voltage noise,  $I_n$  = current noise,  $R_s$  = source impedance,  $k$  = Boltzmann's constant =  $1.38 \times 10^{-23}$  J/K, and  $T$  is temperature in K.

## NOISE PERFORMANCE (continued)



**Figure 47. Noise Performance of the OPA211 and OPA227 in Unity-Gain Buffer Configuration**

## 8.4 BASIC NOISE CALCULATIONS

Design of low-noise op amp circuits requires careful consideration of a variety of possible noise contributors: noise from the signal source, noise generated in the op amp, and noise from the feedback network resistors. The total noise of the circuit is the root-sum-square combination of all noise components.

The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. This function is plotted in [Figure 47](#). The source impedance is usually fixed; consequently, select the op amp and the feedback resistors to minimize the respective contributions to the total noise.

[Figure 47](#) depicts total noise for varying source impedances with the op amp in a unity-gain configuration (no feedback resistor network, and therefore no additional noise contributions). The operational amplifier itself contributes both a voltage noise component and a current noise component. The voltage noise is commonly modeled as a time-varying component of the offset voltage. The current noise is modeled as the time-varying component of the input bias current and reacts with the source resistance to create a voltage component of noise. Therefore, the lowest noise op amp for a given application depends on the source impedance. For low source impedance, current noise is negligible and voltage noise generally dominates. For high source impedance, current noise may dominate.

## BASIC NOISE CALCULATIONS (continued)

Figure 48 illustrates both inverting and noninverting op amp circuit configurations with gain. In circuit configurations with gain, the feedback network resistors also contribute noise. The current noise of the op amp reacts with the feedback resistors to create additional noise components. The feedback resistor values can generally be chosen to make these noise sources negligible. The equations for total noise are shown for both configurations.

## 8.5 TOTAL HARMONIC DISTORTION MEASUREMENTS

OPA211 series op amps have excellent distortion characteristics. THD + Noise is below 0.0002% ( $G = +1$ ,  $V_{OUT} = 3V_{RMS}$ ) throughout the audio frequency range, 20Hz to 20kHz, with a  $600\Omega$  load.

The distortion produced by OPA211 series op amps is below the measurement limit of many commercially available distortion analyzers. However, a special test circuit illustrated in Figure 49 can be used to extend the measurement capabilities.

Op amp distortion can be considered an internal error source that can be referred to the input. Figure 49 shows a circuit that causes the op amp distortion to be 101 times greater than that normally produced by the op amp. The addition of  $R_3$  to the otherwise standard noninverting amplifier configuration alters the feedback factor or noise gain of the circuit. The closed-loop gain is unchanged, but the feedback available for error correction is reduced by a factor of

## TOTAL HARMONIC DISTORTION MEASUREMENTS (continued)

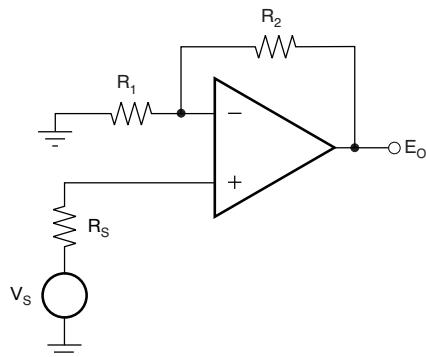
101, thus extending the resolution by 101. Note that the input signal and load applied to the op amp are the same as with conventional feedback without  $R_3$ . The value of  $R_3$  should be kept small to minimize its effect on the distortion measurements.

Validity of this technique can be verified by duplicating measurements at high gain and/or high frequency where the distortion is within the measurement capability of the test equipment. Measurements for this data sheet were made with an Audio Precision System Two distortion/noise analyzer, which greatly simplifies such repetitive measurements. The measurement technique can, however, be performed with manual distortion measurement instruments.

## 8.6 SHUTDOWN

The shutdown (enable) function of the OPA211 is referenced to the positive supply voltage of the operational amplifier. A valid high disables the op amp. A valid high is defined as  $(V+) - 0.35V$  of the positive supply applied to the shutdown pin. A valid low is defined as  $(V+) - 3V$  below the positive supply pin. For example, with  $V_{CC}$  at  $\pm 15V$ , the device is enabled at or below 12V. The device is disabled at or above 14.65V. If dual or split power supplies are used, care should be taken to ensure the valid high or valid low input signals are properly referred to the positive supply voltage. This pin must be connected to a valid high or low voltage or driven, and not left open-circuit. The enable and disable times are provided in the [Typical Characteristics](#) section (see Figure 42 through Figure 44). When disabled, the output assumes a high-impedance state.

**Noise in Noninverting Gain Configuration**



Noise at the output:

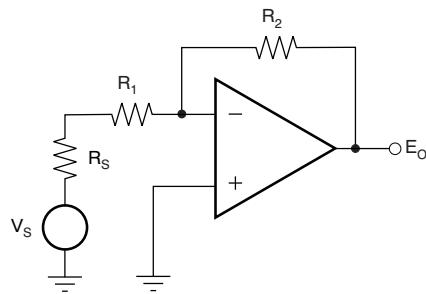
$$E_O^2 = \left[ 1 + \frac{R_2}{R_1} \right]^2 e_n^2 + e_1^2 + e_2^2 + (i_n R_2)^2 + e_S^2 + (i_n R_S)^2 \left[ 1 + \frac{R_2}{R_1} \right]^2$$

$$\text{Where } e_S = \sqrt{4kTR_S} \times \left[ 1 + \frac{R_2}{R_1} \right] = \text{thermal noise of } R_S$$

$$e_1 = \sqrt{4kTR_1} \times \left[ \frac{R_2}{R_1} \right] = \text{thermal noise of } R_1$$

$$e_2 = \sqrt{4kTR_2} = \text{thermal noise of } R_2$$

**Noise in Inverting Gain Configuration**



Noise at the output:

$$E_O^2 = \left[ 1 + \frac{R_2}{R_1 + R_S} \right]^2 e_n^2 + e_1^2 + e_2^2 + (i_n R_2)^2 + e_S^2$$

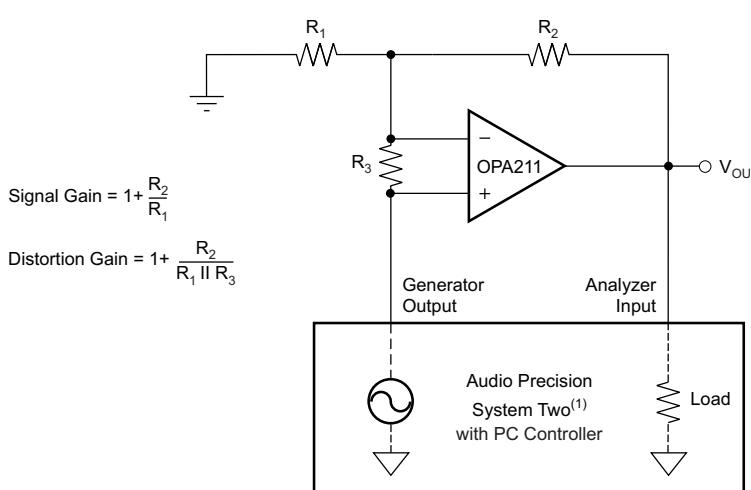
$$\text{Where } e_S = \sqrt{4kTR_S} \times \left[ \frac{R_2}{R_1 + R_S} \right] = \text{thermal noise of } R_S$$

$$e_1 = \sqrt{4kTR_1} \times \left[ \frac{R_2}{R_1 + R_S} \right] = \text{thermal noise of } R_1$$

$$e_2 = \sqrt{4kTR_2} = \text{thermal noise of } R_2$$

For the OPA211 series op amps at 1kHz,  $e_n = 1.1\text{nV}/\sqrt{\text{Hz}}$  and  $i_n = 1.7\text{pA}/\sqrt{\text{Hz}}$ .

**Figure 48. Noise Calculation in Gain Configurations**



(1) For measurement bandwidth, see Figure 4, Figure 5, and Figure 6.

**Figure 49. Distortion Test Circuit**

## 8.7 ELECTRICAL OVERSTRESS

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but may involve the supply voltage pins or even the output pin. Each of these different pin functions have electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect them from accidental ESD events both before and during product assembly.

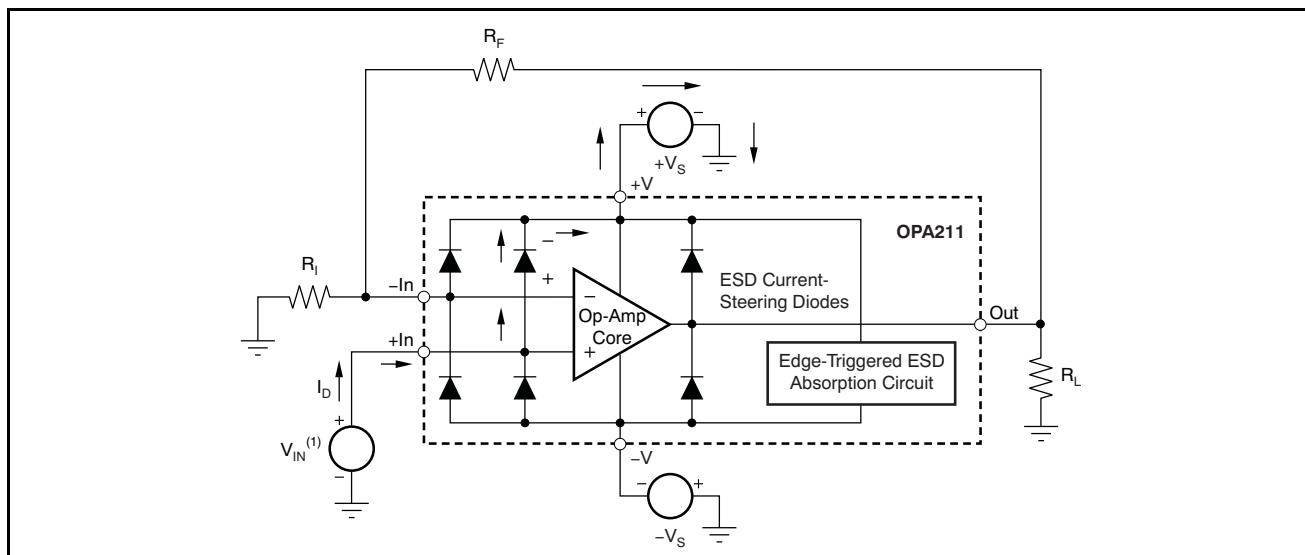
It is helpful to have a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event. [Figure 50](#) illustrates the ESD circuits contained in the OPA211 (indicated by the dashed line area). The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power-supply lines, where they meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

## ELECTRICAL OVERSTRESS (continued)

An ESD event produces a short duration, high-voltage pulse that is transformed into a short duration, high-current pulse as it discharges through a semiconductor device. The ESD protection circuits are designed to provide a current path around the operational amplifier core to prevent it from being damaged. The energy absorbed by the protection circuitry is then dissipated as heat.

When an ESD voltage develops across two or more of the amplifier device pins, current flows through one or more of the steering diodes. Depending on the path that the current takes, the absorption device may activate. The absorption device has a trigger, or threshold voltage, that is above the normal operating voltage of the OPA211 but below the device breakdown voltage level. Once this threshold is exceeded, the absorption device quickly activates and clamps the voltage across the supply rails to a safe level.

When the operational amplifier connects into a circuit such as that illustrated in [Figure 50](#), the ESD protection components are intended to remain inactive and not become involved in the application circuit operation. However, circumstances may arise where an applied voltage exceeds the operating voltage range of a given pin. Should this condition occur, there is a risk that some of the internal ESD protection circuits may be biased on, and conduct current. Any such current flow occurs through steering diode paths and rarely involves the absorption device.



(1)  $V_{IN} = +V_S + 500\text{mV}$ .

**Figure 50. Equivalent Internal ESD Circuitry and Its Relation to a Typical Circuit Application**

**Figure 50** depicts a specific example where the input voltage,  $V_{IN}$ , exceeds the positive supply voltage ( $+V_S$ ) by 500mV or more. Much of what happens in the circuit depends on the supply characteristics. If  $+V_S$  can sink the current, one of the upper input steering diodes conducts and directs current to  $+V_S$ . Excessively high current levels can flow with increasingly higher  $V_{IN}$ . As a result, the datasheet specifications recommend that applications limit the input current to 10mA.

If the supply is not capable of sinking the current,  $V_{IN}$  may begin sourcing current to the operational amplifier, and then take over as the source of positive supply voltage. The danger in this case is that the voltage can rise to levels that exceed the operational amplifier absolute maximum ratings. In extreme but rare cases, the absorption device triggers on while  $+V_S$  and  $-V_S$  are applied. If this event happens, a direct current path is established between the  $+V_S$  and  $-V_S$  supplies. The power dissipation of the absorption device is quickly exceeded, and the extreme internal heating destroys the operational amplifier.

Another common question involves what happens to the amplifier if an input signal is applied to the input while the power supplies  $+V_S$  and/or  $-V_S$  are at 0V. Again, it depends on the supply characteristic while at 0V, or at a level below the input signal amplitude. If

the supplies appear as high impedance, then the operational amplifier supply current may be supplied by the input source via the current steering diodes. This state is not a normal bias condition; the amplifier most likely will not operate normally. If the supplies are low impedance, then the current through the steering diodes can become quite high. The current level depends on the ability of the input source to deliver current, and any resistance in the input path.

## 8.8 THERMAL CONSIDERATIONS

The primary issue with all semiconductor devices is junction temperature ( $T_J$ ). The most obvious consideration is assuring that  $T_J$  never exceeds the absolute maximum rating specified for the device. However, addressing device thermal dissipation has benefits beyond protecting the device from damage. Even modest increases in junction temperature can decrease op amp performance, and temperature-related errors can accumulate. Understanding the power generated by the device within the specific application and assessing the thermal effects on the error tolerance lead to a better understanding of system performance and thermal dissipation needs.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
OPA211MDGKTEP	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	OBCM	<b>Samples</b>
V62/12619-01XE	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-55 to 125	OBCM	<b>Samples</b>

(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) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

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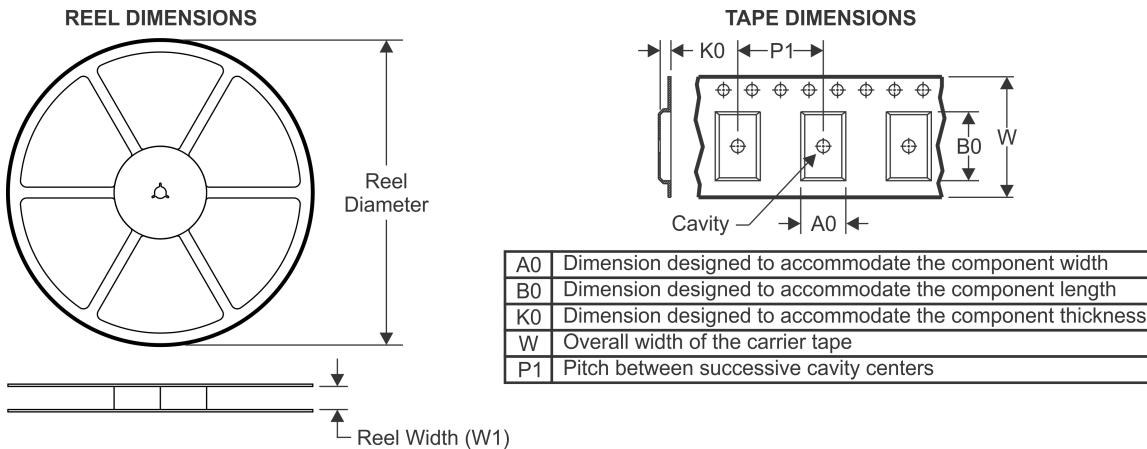
**OTHER QUALIFIED VERSIONS OF OPA211-EP :**

- Catalog: [OPA211](#)

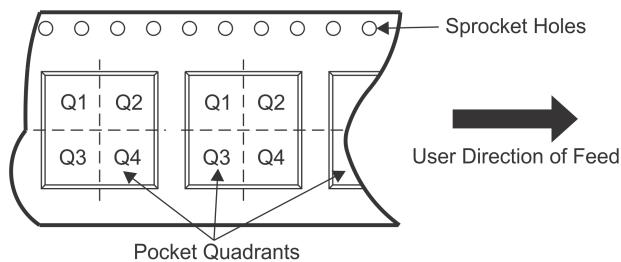
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

**TAPE AND REEL INFORMATION**

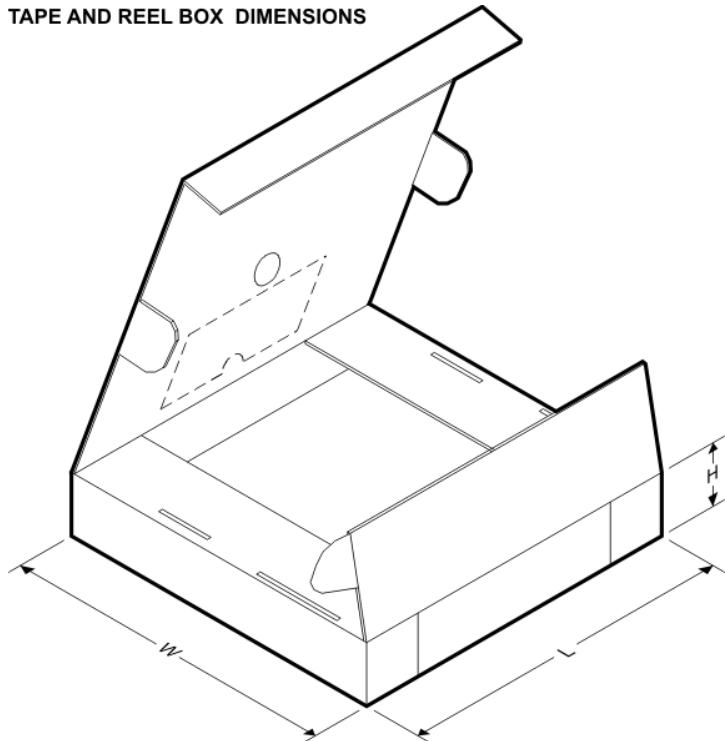


**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**



\*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
OPA211MDGKTEP	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**

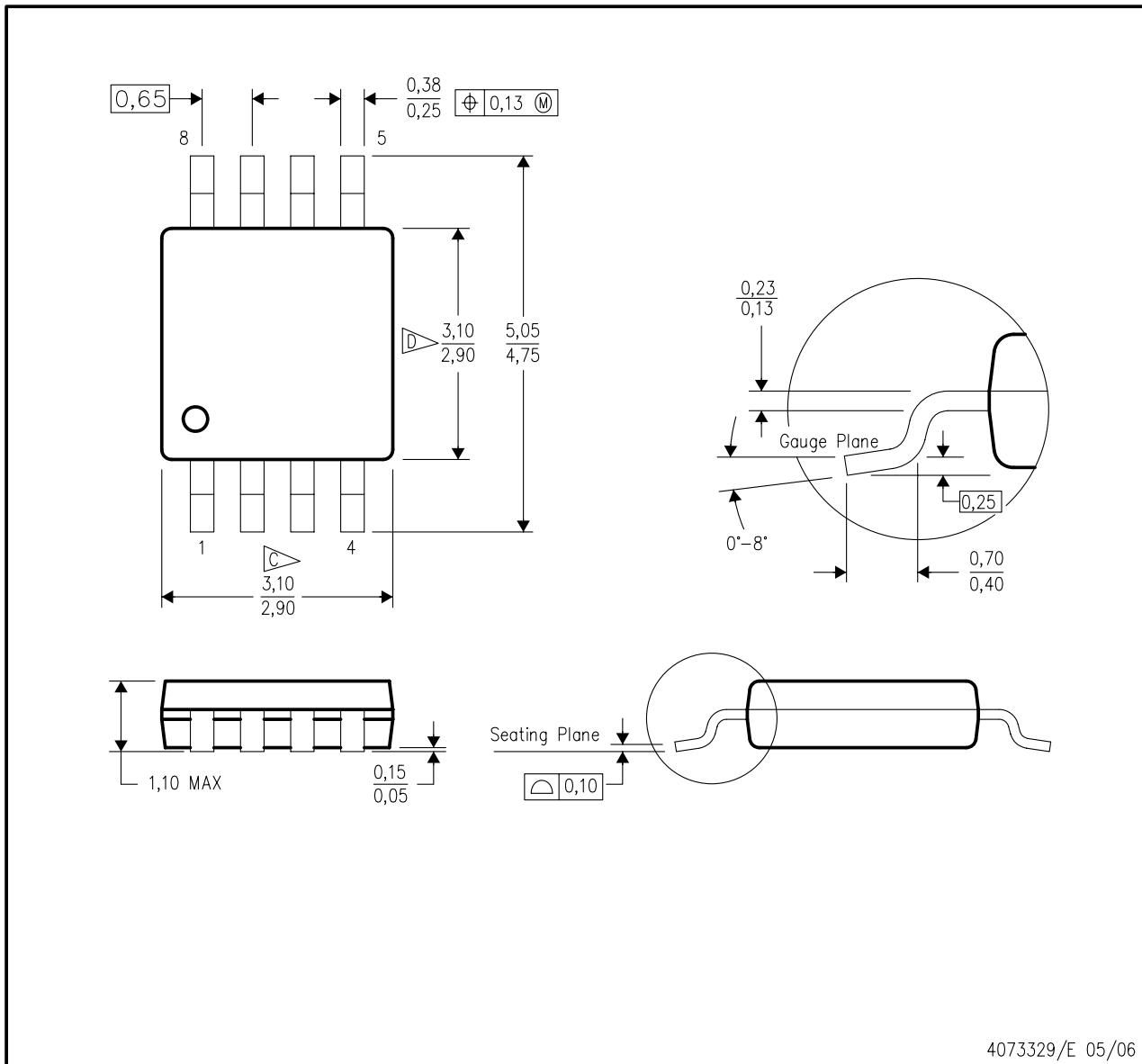
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA211MDGKTEP	VSSOP	DGK	8	250	367.0	367.0	35.0

## MECHANICAL DATA

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

NOTES:

- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0,50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.

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