

## OPA1612-Q1 SoundPlus 高性能、双极输入音频运算放大器

### 1 特性

- 符合汽车应用要求
- 具有符合 AEC-Q100 的下列结果：
  - 器件温度 1 级：-40°C 至 +125°C 的环境运行温度范围
  - 器件人体放电模式 (HBM) 分类等级 2
  - 器件组件充电模式 (CDM) 分类等级 C6
- 出色音质
- 超低噪声：1kHz 时为  $1.1\text{nV}/\sqrt{\text{Hz}}$
- 超低失真：1kHz 时为 0.000015%
- 高压摆率：27V/ $\mu\text{s}$
- 高带宽：40MHz ( $G = +1$ )
- 高开环增益：130dB
- 单位增益稳定
- 低静态电流：每通道 3.6mA
- 轨到轨输出
- 宽电源电压范围：±2.25V 至 ±18V

### 2 应用

- 专业音频设备
- 麦克风前置放大器
- 模数混合控制台
- 播音室设备
- 音频测试和测量
- 高端 A/V 接收器

### 3 概述

OPA1612-Q1 器件是一款双通道、SoundPlus™ 双极输入运算放大器，在 1kHz 频率下可实现很低的噪声密度 ( $1.1\text{nV}/\sqrt{\text{Hz}}$ ) 以及超低失真 (0.000015%)。OPA1612-Q1 器件可在 2k $\Omega$  负载条件下提供摆幅在 600mV 以内的轨到轨输出，这有助于提高余量并实现动态范围的最大化。此外，这些器件还具有 ±30mA 高输出驱动能力。

这些器件支持 ±2.25V 到 ±18V 的宽电源电压范围，每通道电源电流仅为 3.6mA。OPA1612-Q1 运算放大器的单位增益稳定，在宽负载条件范围内可提供出色的动态性能。

双通道型号具有完全独立的电路，即使处于过驱或过载状态也可在通道间实现最低串扰和零交互。

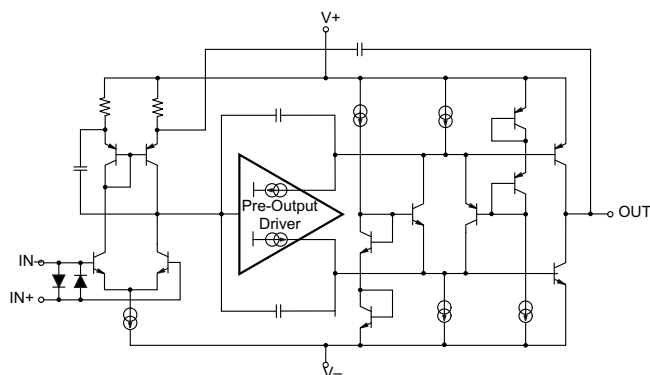
OPA1612-Q1 器件采用小外形尺寸集成电路 (SOIC)-8 封装。该器件的额定工作温度范围为 -40°C 至 +125°C。

器件信息<sup>(1)</sup>

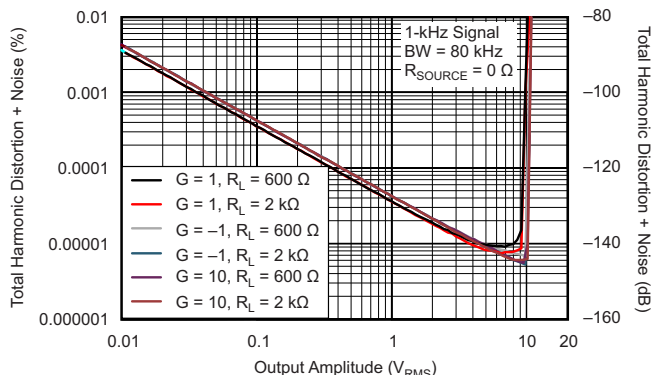
器件型号	封装	封装尺寸 (标称值)
OPA1612-Q1	SOIC (8)	4.90mm x 3.91mm

(1) 如需了解所有可用封装，请见数据表末尾的可订购产品附录。

功能框图



THD+N 比与输出幅值间的关系



## 目录

<b>1</b>	<b>特性</b> .....	<b>1</b>	8.3	Feature Description .....	14
<b>2</b>	<b>应用</b> .....	<b>1</b>	8.4	Device Functional Modes .....	17
<b>3</b>	<b>概述</b> .....	<b>1</b>	<b>9</b>	<b>Application and Implementation</b> .....	<b>18</b>
<b>4</b>	<b>修订历史记录</b> .....	<b>2</b>	9.1	Application Information .....	18
<b>5</b>	<b>Pin Configuration and Functions</b> .....	<b>3</b>	9.2	Typical Application .....	18
<b>6</b>	<b>Specifications</b> .....	<b>4</b>	<b>10</b>	<b>Power-Supply Recommendations</b> .....	<b>22</b>
6.1	Absolute Maximum Ratings .....	4	<b>11</b>	<b>Layout</b> .....	<b>22</b>
6.2	ESD Ratings .....	4	11.1	Layout Guidelines .....	22
6.3	Recommended Operating Conditions .....	4	11.2	Layout Example .....	23
6.4	Thermal Information .....	4	<b>12</b>	<b>器件和文档支持</b> .....	<b>24</b>
6.5	Electrical Characteristics: $V_S = \pm 2.25\text{ V}$ to $\pm 18\text{ V}$ ....	5	12.1	文档支持 .....	24
6.6	Typical Characteristics .....	7	12.2	社区资源 .....	24
<b>7</b>	<b>Parameter Measurement Information</b> .....	<b>11</b>	12.3	商标 .....	24
<b>8</b>	<b>Detailed Description</b> .....	<b>14</b>	12.4	静电放电警告 .....	24
8.1	Overview .....	14	12.5	Glossary .....	24
8.2	Functional Block Diagram .....	14	<b>13</b>	<b>机械、封装和可订购信息</b> .....	<b>24</b>

## 4 修订历史记录

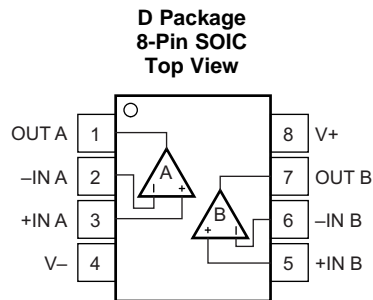
注：之前版本的页码可能与当前版本有所不同。

### Changes from Original (November 2015) to Revision A

Page

• 已更改 器件状态“产品预览”至“量产数据” .....	1
-------------------------------	---

## 5 Pin Configuration and Functions



**Pin Functions**

PIN		I/O	DESCRIPTION
NO.	NAME		
1	OUT A	O	Output, channel A
2	-IN A	I	Inverting input, channel A
3	+IN A	I	Noninverting input, channel A
4	V-	—	Negative (lowest) power supply
5	+IN B	I	Inverting input, channel B
6	-IN B	I	Noninverting input, channel B
7	OUT B	O	Output, channel B
8	V+	—	Positive (highest) power supply

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
$V_S^{(2)}$	Supply voltage		40	V
	Input voltage	(V <sub>-</sub> ) – 0.5	(V <sub>+</sub> ) + 0.5	V
	Input current (all pins except power-supply pins)		±10	mA
	Output short-circuit <sup>(2)</sup>		Continuous	
$T_A$	Operating temperature	–55	125	°C
$T_J$	Junction temperature		200	°C
$T_{stg}$	Storage temperature	–65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Short-circuit to  $V_S / 2$  (ground in symmetrical dual supply setups), one amplifier per package.

### 6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup>	±3000
		Charged-device model (CDM), per AEC Q100-011	±1000

- (1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
Supply voltage (V <sub>+</sub> – V <sub>-</sub> )	4.5 (±2.25)		36 (±18)	V
Specified temperature	–40		85	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		OPA1612-Q1	UNIT
		D (SOIC)	
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	111.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	26.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	0.8	°C/W
$\Psi_{JT}$	Junction-to-top characterization parameter	20.9	°C/W
$\Psi_{JB}$	Junction-to-board characterization parameter	1.6	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.5 Electrical Characteristics: $V_S = \pm 2.25\text{ V}$ to $\pm 18\text{ V}$

At  $T_A = 25^\circ\text{C}$  and  $R_L = 2\text{ k}\Omega$ , unless otherwise noted.  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
AUDIO PERFORMANCE						
THD+N	Total harmonic distortion + noise	G = +1, f = 1 kHz, V <sub>O</sub> = 3 V <sub>RMS</sub>	0.000015%			
			−136			dB
IMD	Intermodulation distortion	SMPTE/DIN two-tone, 4:1 (60 Hz and 7 kHz), G = +1, V <sub>O</sub> = 3 V <sub>RMS</sub>	0.000015%			
			−136			dB
		DIM 30 (3-kHz square wave and 15-kHz sine wave), G = +1, V <sub>O</sub> = 3 V <sub>RMS</sub>	0.000012%			
			−138			dB
		CCIF twin-tone (19 kHz and 20 kHz), G = +1, V <sub>O</sub> = 3 V <sub>RMS</sub>	0.000008%			
			−142			dB
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product	G = 100	80			MHz
		G = 1	40			MHz
SR	Slew rate	G = −1	27			V/μs
	Full-power bandwidth <sup>(1)</sup>	V <sub>O</sub> = 1 V <sub>PP</sub>	4			MHz
	Overload recovery time	G = −10	500			ns
	Channel separation (dual)	f = 1 kHz	−130			dB
NOISE						
	Input voltage noise	f = 20 Hz to 20 kHz	1.2			μV <sub>PP</sub>
e <sub>n</sub>	Input voltage noise density <sup>(2)</sup>	f = 10 Hz	2			nV/√Hz
		f = 100 Hz	1.5			nV/√Hz
		f = 1 kHz	1.1		1.5	nV/√Hz
I <sub>n</sub>	Input current noise density	f = 10 Hz	3			pA/√Hz
		f = 1 kHz	1.7			pA/√Hz
OFFSET VOLTAGE						
V <sub>OS</sub>	Input offset voltage	V <sub>S</sub> = ±15 V	±100	±500		μV
dV <sub>OS</sub> /dT	V <sub>OS</sub> over temperature <sup>(2)</sup>	T <sub>A</sub> = −40°C to +125°C	1	4		μV/°C
PSRR	Power-supply rejection ratio	V <sub>S</sub> = ±2.25 V to ±18 V	0.1	1		μV/V
INPUT BIAS CURRENT						
I <sub>B</sub>	Input bias current	V <sub>CM</sub> = 0 V	±60	±250		nA
		V <sub>CM</sub> = 0 V, DRG package only	±60	±300		nA
	I <sub>B</sub> over temperature <sup>(2)</sup>	T <sub>A</sub> = −40°C to +125°C		350		nA
I <sub>OS</sub>	Input offset current	V <sub>CM</sub> = 0 V	±25	±175		nA
INPUT VOLTAGE RANGE						
V <sub>CM</sub>	Common-mode voltage range		(V−) + 2	(V+) − 2		V
CMRR	Common-mode rejection ratio	(V−) + 2 V ≤ V <sub>CM</sub> ≤ (V+) − 2 V	110	120		dB
INPUT IMPEDANCE						
	Differential		20k    8			Ω    pF
	Common-mode		10 <sup>9</sup>    2			Ω    pF

(1) Full-power bandwidth =  $SR / (2\pi \times V_P)$ , where SR = slew rate.

(2) Specified by design and characterization.

**OPA1612-Q1**

ZHCS07A – NOVEMBER 2015 – REVISED NOVEMBER 2015

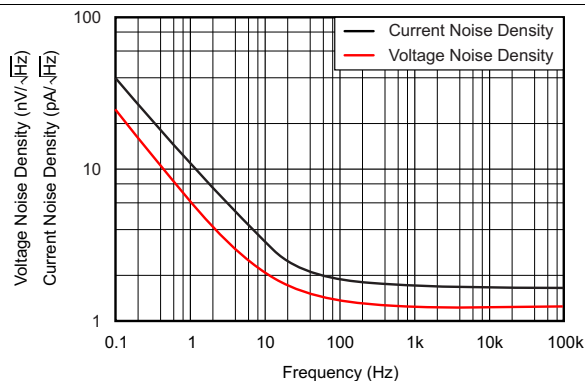
[www.ti.com.cn](http://www.ti.com.cn)
**Electrical Characteristics:  $V_S = \pm 2.25\text{ V}$  to  $\pm 18\text{ V}$  (continued)**

 At  $T_A = 25^\circ\text{C}$  and  $R_L = 2\text{ k}\Omega$ , unless otherwise noted.  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.

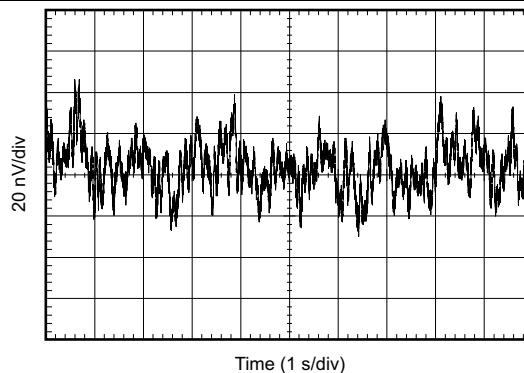
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OPEN-LOOP GAIN						
A <sub>OL</sub>	Open-loop voltage gain	(V <sup>−</sup> ) + 0.2 V ≤ V <sub>O</sub> ≤ (V <sup>+</sup> ) − 0.2 V, R <sub>L</sub> = 10 kΩ	114	130		dB
		(V <sup>−</sup> ) + 0.6 V ≤ V <sub>O</sub> ≤ (V <sup>+</sup> ) − 0.6 V, R <sub>L</sub> = 2 kΩ	110	114		dB
OUTPUT						
V <sub>OUT</sub>	Voltage output	R <sub>L</sub> = 10 kΩ, A <sub>OL</sub> ≥ 114 dB	(V <sup>−</sup> ) + 0.2	(V <sup>+</sup> ) − 0.2		V
		R <sub>L</sub> = 2 kΩ, A <sub>OL</sub> ≥ 110 dB	(V <sup>−</sup> ) + 0.6	(V <sup>+</sup> ) − 0.6		V
I <sub>OUT</sub>	Output current		See <a href="#">Figure 27</a>			mA
Z <sub>O</sub>	Open-loop output impedance		See <a href="#">Figure 28</a>			Ω
I <sub>SC</sub>	Short-circuit current	Source, V <sub>S</sub> = ±18 V	55			mA
		Sink, V <sub>S</sub> = ±18 V	−62			mA
C <sub>LOAD</sub>	Capacitive load drive		See <a href="#">Typical Characteristics</a>			pF
POWER SUPPLY						
V <sub>S</sub>	Specified voltage		±2.25		±18	V
I <sub>Q</sub>	Quiescent current (per channel)	I <sub>OUT</sub> = 0 A		3.6	4.5	mA
	I <sub>Q</sub> over Temperature <sup>(2)</sup>	T <sub>A</sub> = −40°C to +125°C			5.5	mA
TEMPERATURE RANGE						
	Specified range		−40		125	°C
	Operating range		−55		125	°C

## 6.6 Typical Characteristics

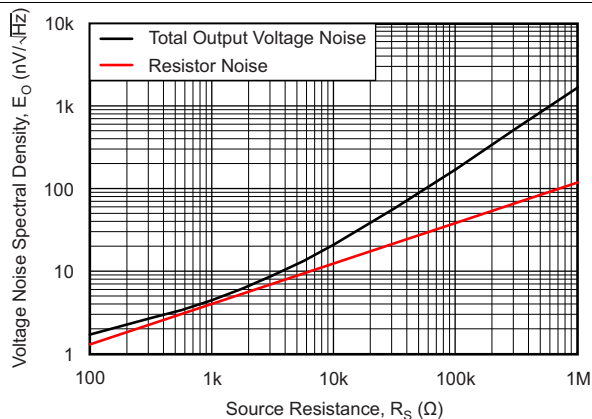
At  $T_A = 25^\circ$ ,  $V_S = \pm 15$  V, and  $R_L = 2$  k $\Omega$ , unless otherwise noted.



**Figure 1. Input Voltage Noise Density and Input Current Noise Density vs Frequency**

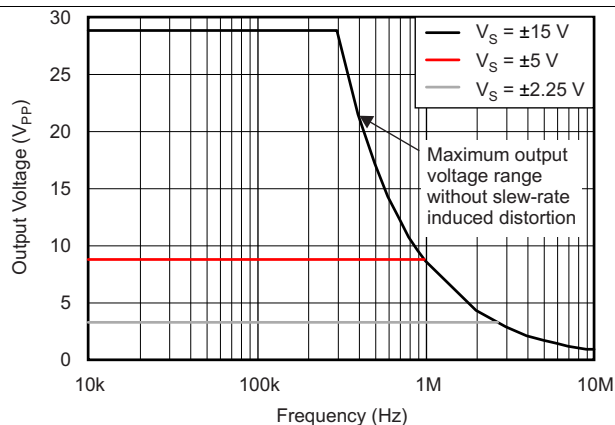


**Figure 2. 0.1-Hz to 10-Hz Noise**

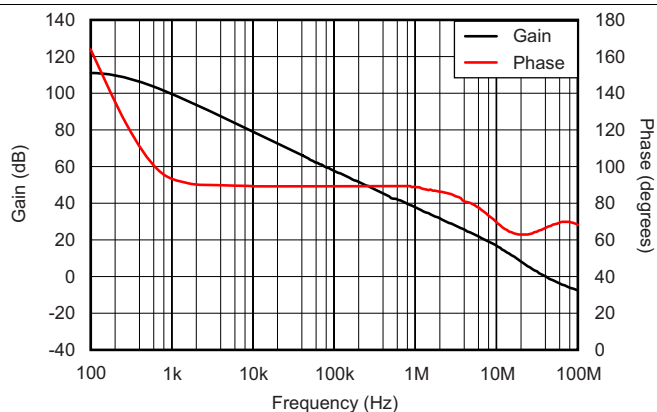


$$E_O^2 = e_n^2 + (i_n \times R_S)^2 + 4kRT_S \quad \text{See Figure 29}$$

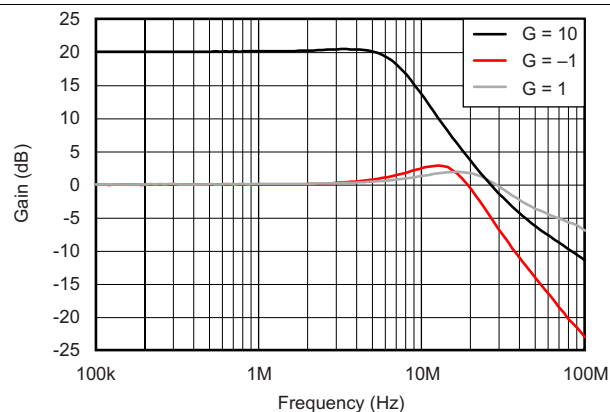
**Figure 3. Voltage Noise vs Source Resistance**



**Figure 4. Maximum Output Voltage vs Frequency**



**Figure 5. Gain and Phase vs Frequency**



**Figure 6. Closed-Loop Gain vs Frequency**

## Typical Characteristics (continued)

At  $T_A = 25^\circ$ ,  $V_S = \pm 15$  V, and  $R_L = 2$  k $\Omega$ , unless otherwise noted.

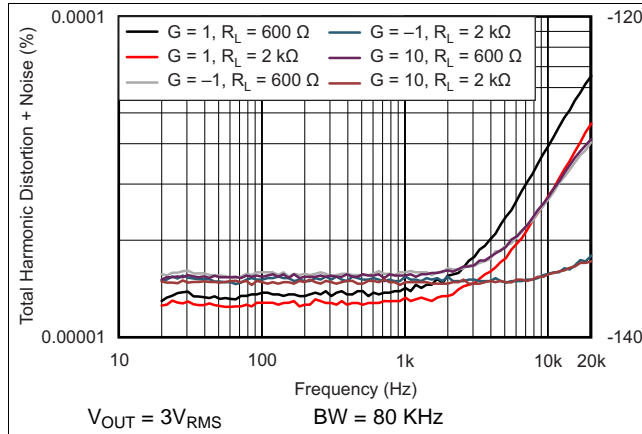


Figure 7. THD+N Ratio vs Frequency

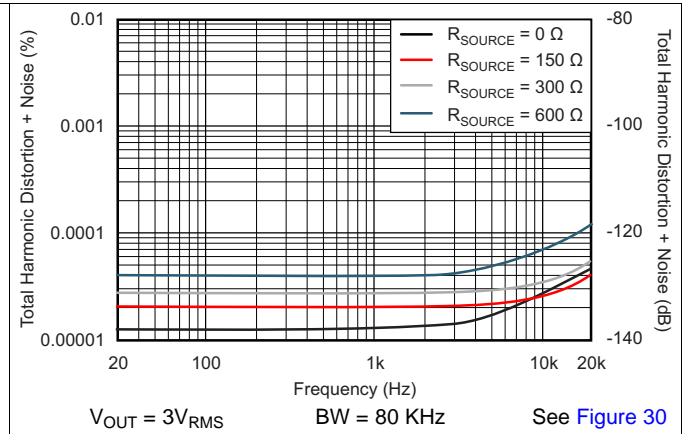


Figure 8. THD+N Ratio vs Frequency

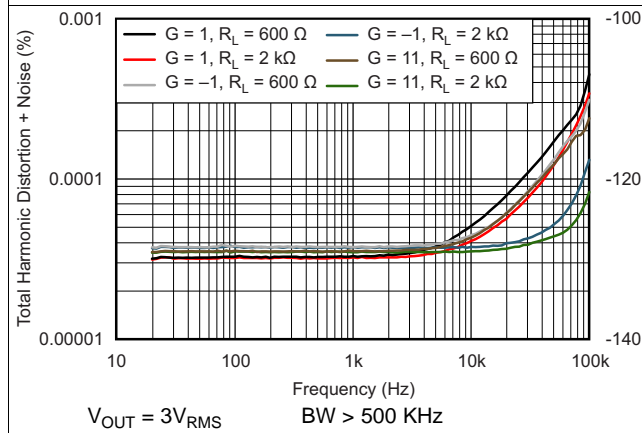


Figure 9. THD+N Ratio vs Frequency

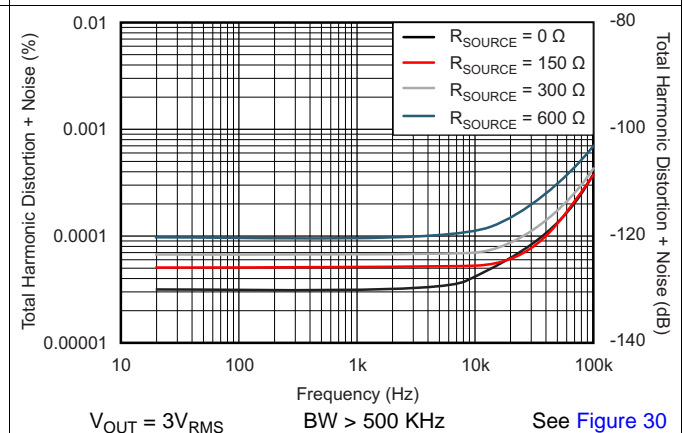


Figure 10. THD+N Ratio vs Frequency

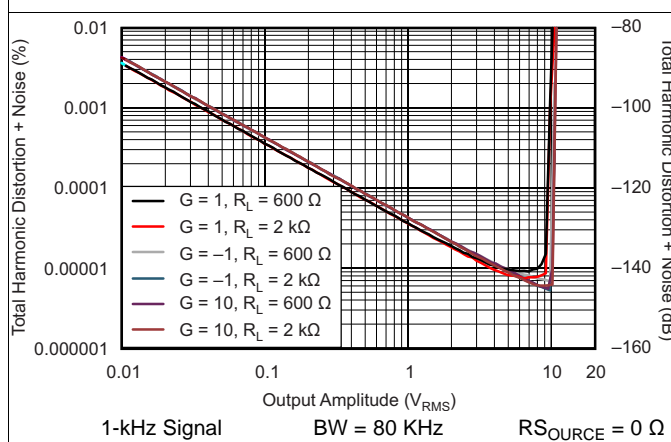


Figure 11. THD+N Ratio vs Output Amplitude

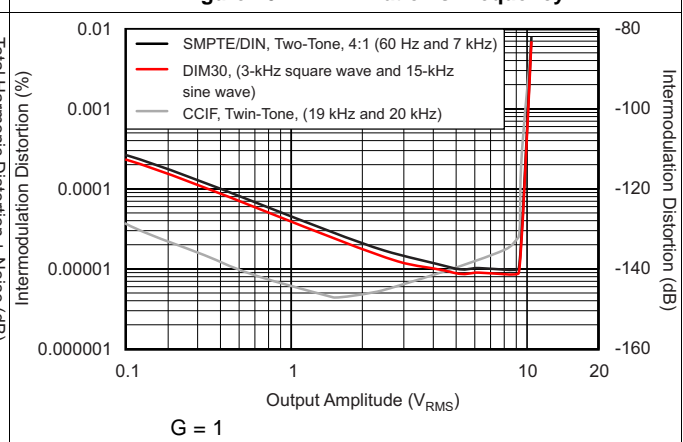
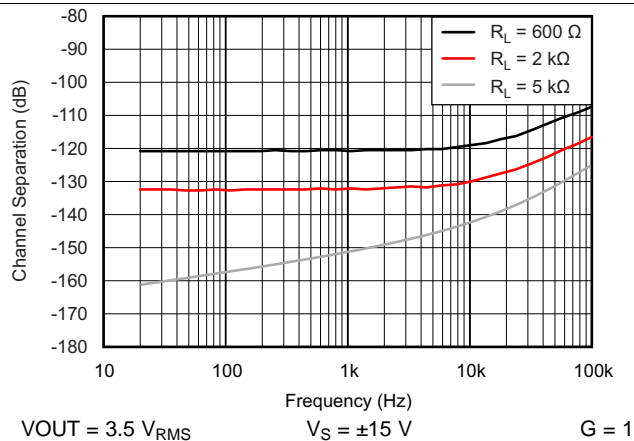


Figure 12. Intermodulation Distortion vs Output Amplitude

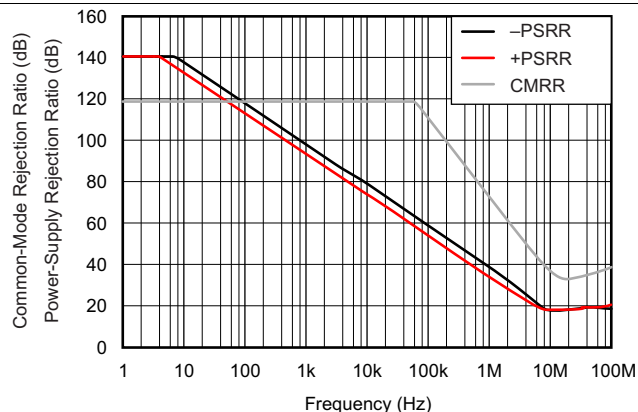


## Typical Characteristics (continued)

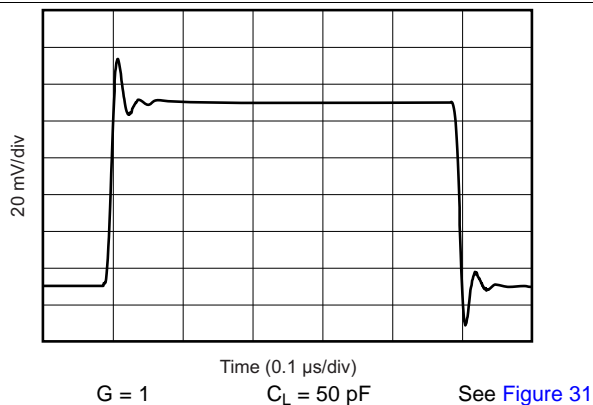
At  $T_A = 25^\circ$ ,  $V_S = \pm 15$  V, and  $R_L = 2$  k $\Omega$ , unless otherwise noted.



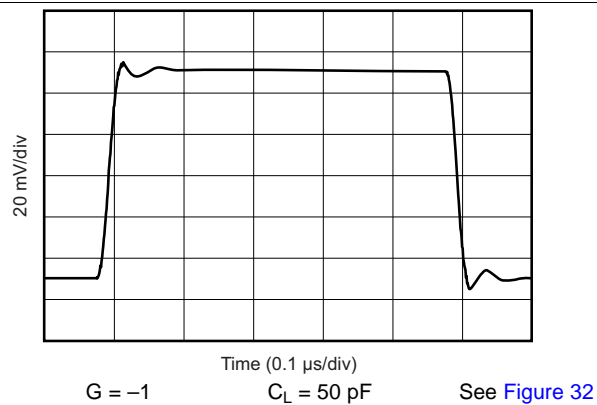
**Figure 13. Channel Separation vs Frequency**



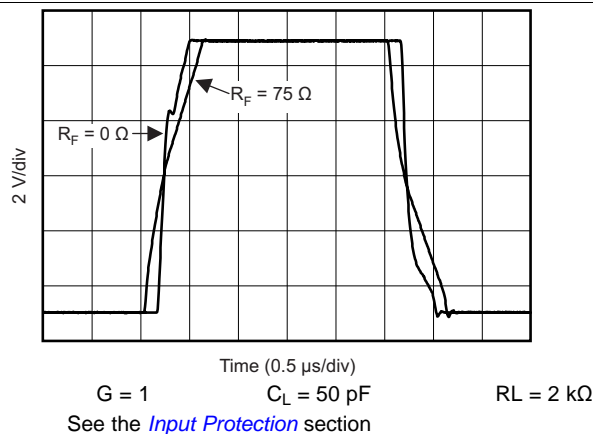
**Figure 14. CMRR and PSRR vs Frequency (Referred to Input)**



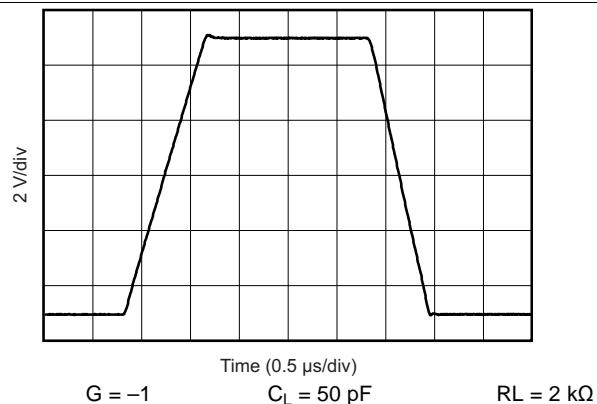
**Figure 15. Small-Signal Step Response (100 mV)**



**Figure 16. Small-Signal Step Response (100 mV)**



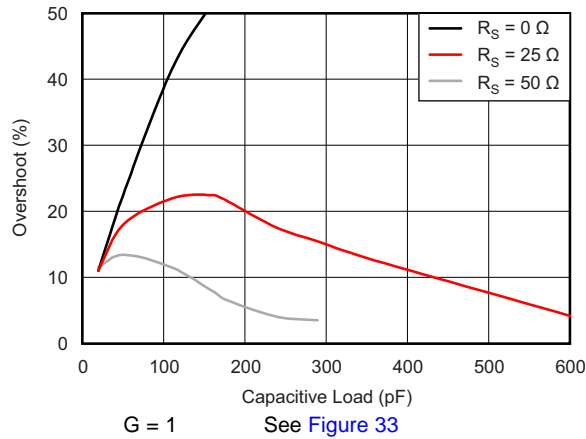
**Figure 17. Large-Signal Step Response**



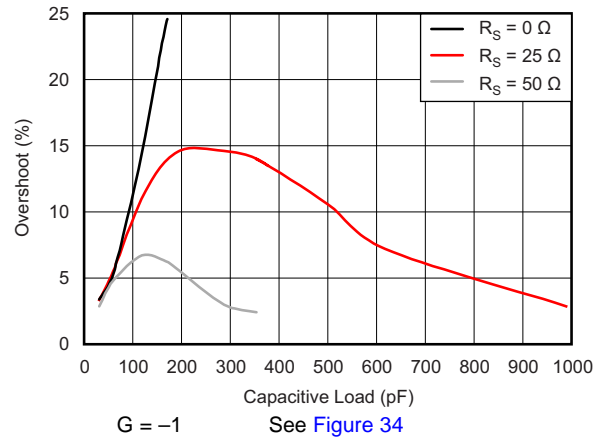
**Figure 18. Large-Signal Step Response**

## Typical Characteristics (continued)

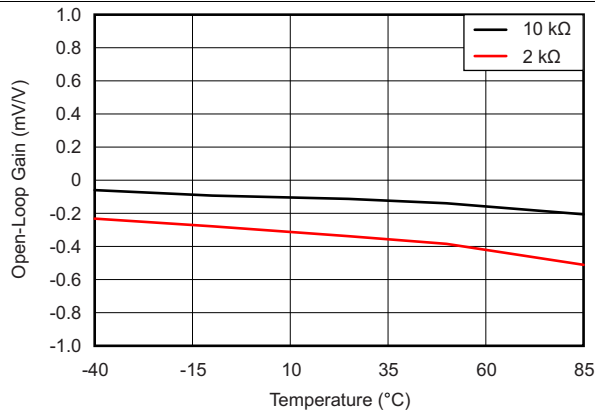
At  $T_A = 25^\circ$ ,  $V_S = \pm 15$  V, and  $R_L = 2$  k $\Omega$ , unless otherwise noted.



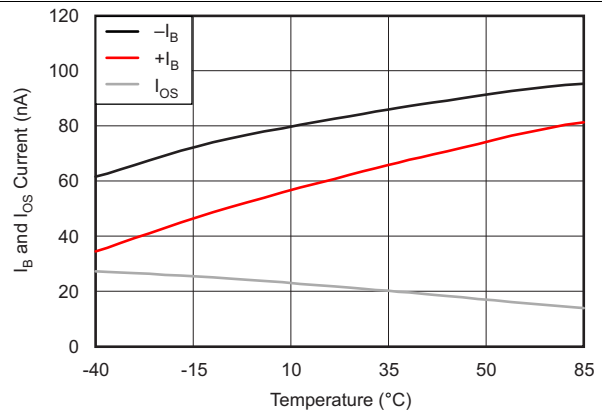
**Figure 19. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**



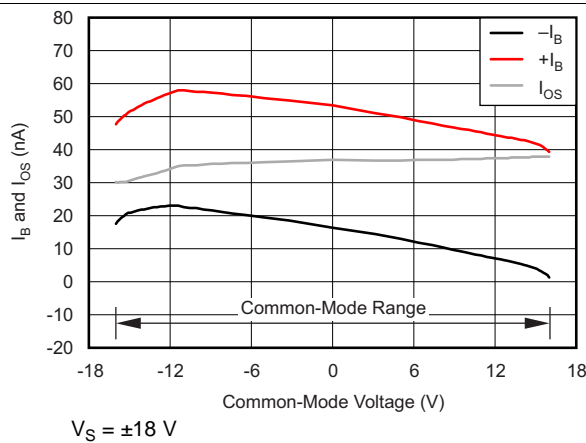
**Figure 20. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**



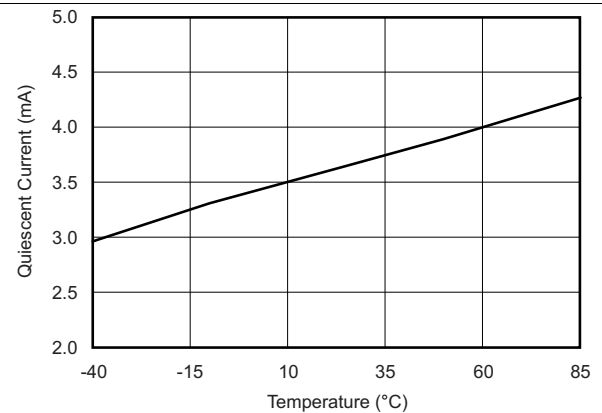
**Figure 21. Open-Loop Gain vs Temperature**



**Figure 22.  $I_B$  and  $I_{OS}$  vs Temperature**



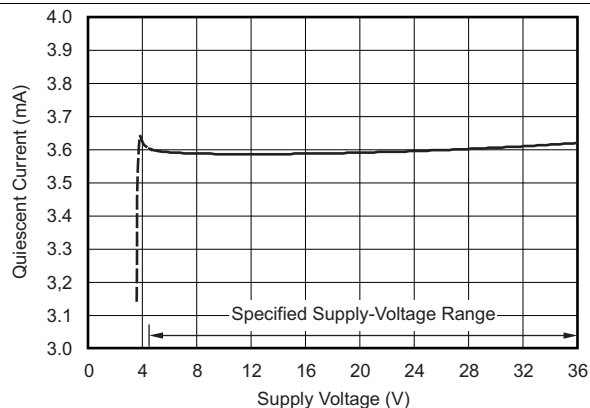
**Figure 23.  $I_B$  and  $I_{OS}$  vs Common-Mode Voltage**



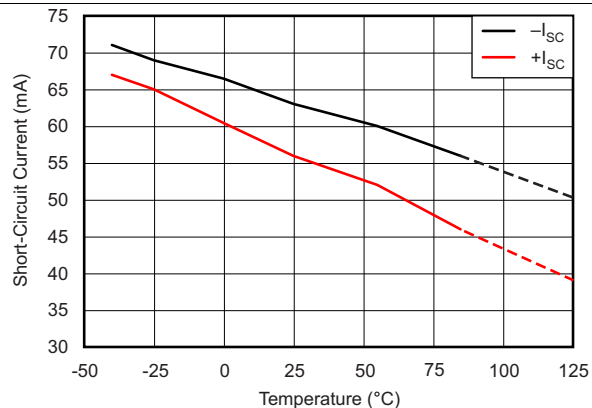
**Figure 24. Quiescent Current vs Temperature**

## Typical Characteristics (continued)

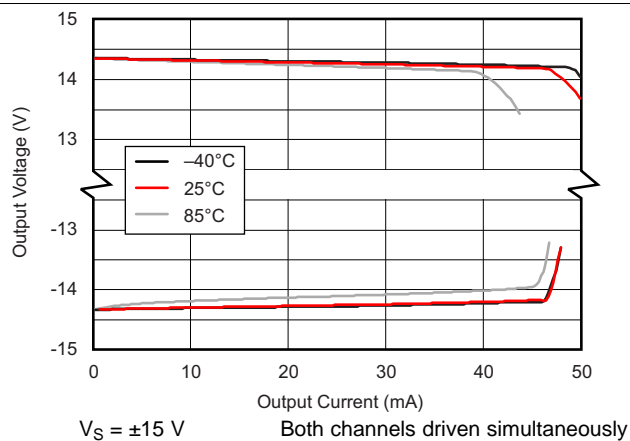
At  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{ V}$ , and  $R_L = 2\text{ k}\Omega$ , unless otherwise noted.



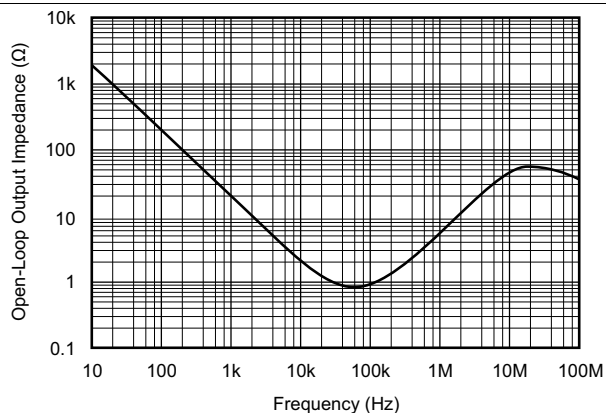
**Figure 25. Quiescent Current vs Supply Voltage**



**Figure 26. Short-Circuit Current vs Temperature**

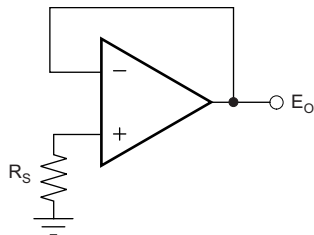


**Figure 27. Output Voltage vs Output Current**

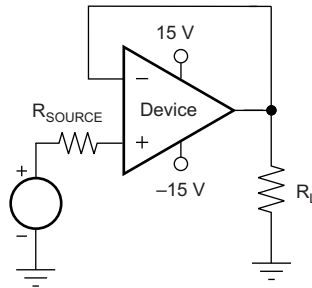
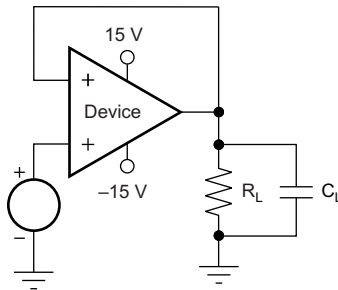
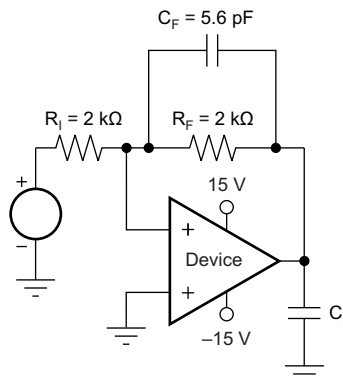
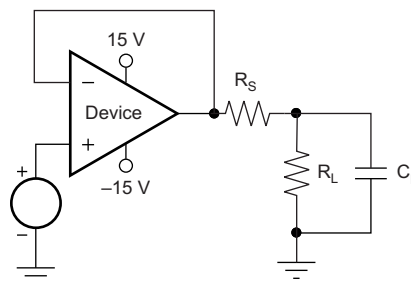


**Figure 28. Open-Loop Output Impedance vs Frequency**

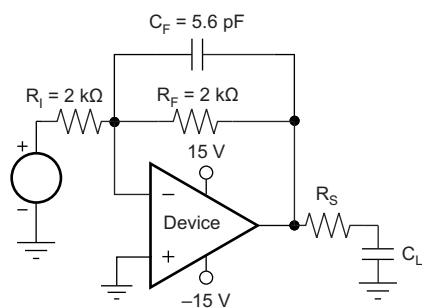
## 7 Parameter Measurement Information



**Figure 29. Circuit for Figure 3—Voltage Noise vs Source Resistance**

**Parameter Measurement Information (continued)**

**Figure 30. Circuit for Figure 8 and Figure 10—THD+N Ratio vs Frequency**

**Figure 31. Circuit for Figure 15—Small-Signal Step Response (100 mV)**

**Figure 32. Circuit for Figure 16—Small-Signal Step Response (100 mV)**

**Figure 33. Circuit for Figure 19—Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**

## Parameter Measurement Information (continued)



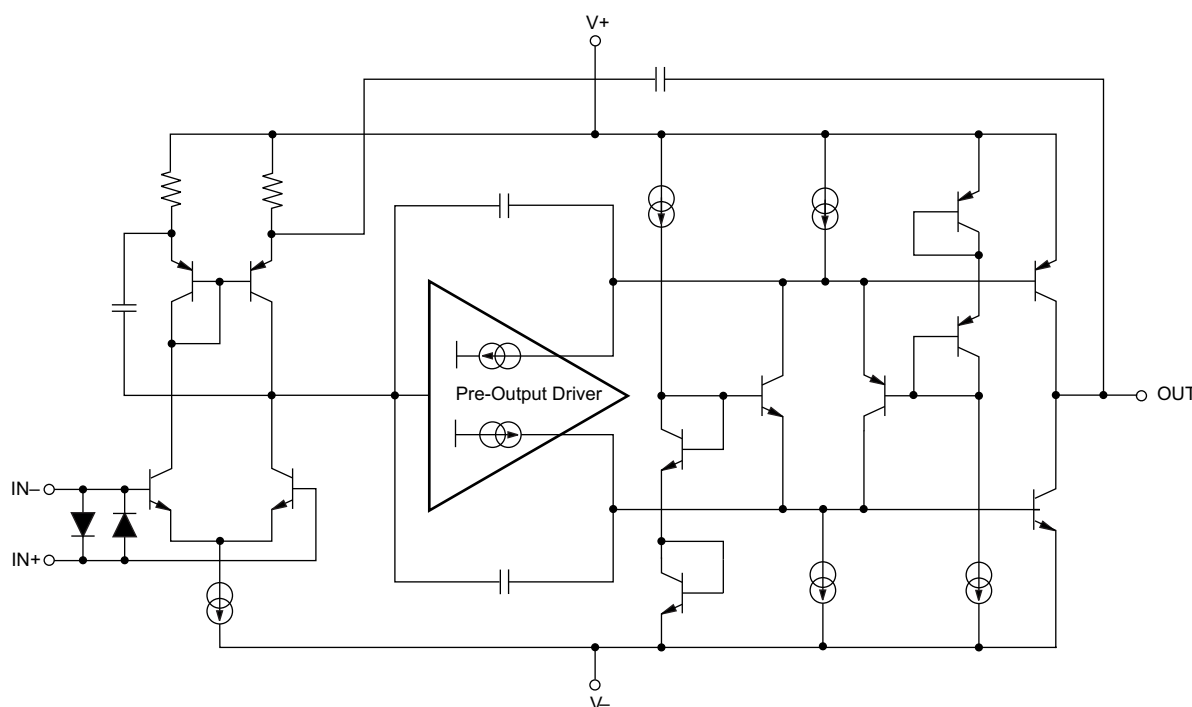
**Figure 34. Circuit for [Figure 20](#)—Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**

## 8 Detailed Description

### 8.1 Overview

The OPA1612-Q1 bipolar-input operational amplifier achieves very low  $1.1\text{-nV}/\sqrt{\text{Hz}}$  noise density with an ultralow distortion of 0.000015% at 1 kHz. The rail-to-rail output swing, within 600 mV with a 2-k $\Omega$  load, increases headroom and maximizes dynamic range. These devices also have a high output drive capability of  $\pm 40\text{ mA}$ . The wide supply range of  $\pm 2.25\text{ V}$  to  $\pm 18\text{ V}$ , on only 3.6 mA of supply current per channel, makes them applicable to both 5-V systems and 36-V audio applications. The OPA1612-Q1 op amp is unity-gain stable and provide excellent dynamic behavior over a wide range of load conditions.

### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 Power Dissipation

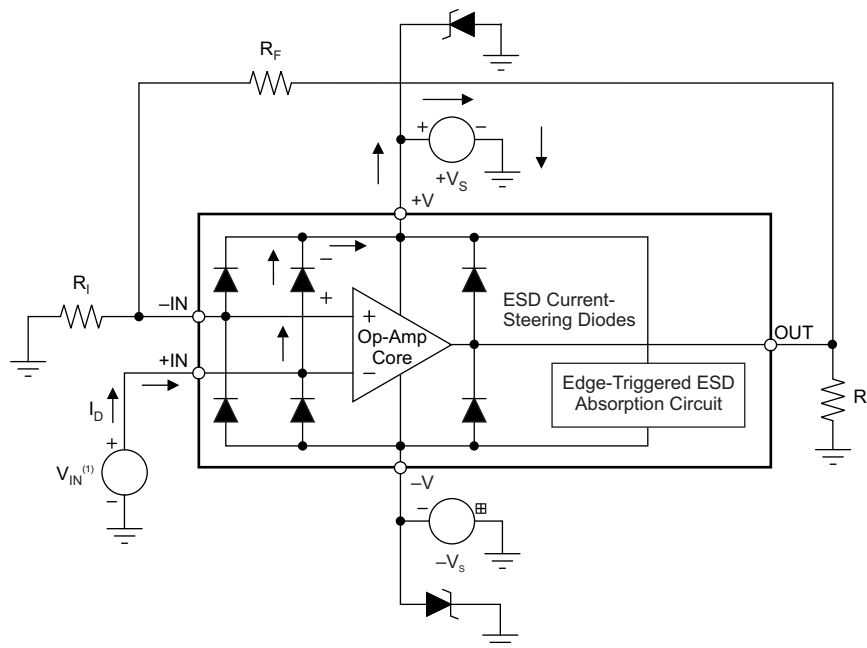
The OPA1612-Q1 op amp is capable of driving 2-k $\Omega$  loads with a power-supply voltage up to  $\pm 18\text{ V}$ . Internal power dissipation increases when operating at high supply voltages. Copper leadframe construction used in the OPA1612-Q1 op amp improves heat dissipation compared to conventional materials. Circuit board layout can also help minimize junction temperature rise. Wide copper traces help dissipate the heat by acting as an additional heat sink. Temperature rise can be further minimized by soldering the devices to the circuit board rather than using a socket.

#### 8.3.2 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.

## Feature Description (continued)

Having a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event is helpful. Figure 35 shows the ESD circuits contained in the OPA1612-Q1 device (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.



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

**Figure 35. Equivalent Internal ESD Circuitry and its Relation to a Typical Circuit Application**

An ESD event produces a short duration, high-voltage pulse that is transformed into a short duration, high-current pulse when discharged through a semiconductor device. The ESD protection circuits are designed to provide a current path around the operational amplifier core to prevent damage to the core. 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 internal to the OPA1612-Q1 device triggers when a fast ESD voltage pulse is impressed across the supply pins. Once triggered, the absorption device quickly activates and clamps the ESD pulse to a safe voltage level.

When the operational amplifier connects into a circuit such as the one Figure 35 shows, 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. If this condition occurs, some of the internal ESD protection circuits may possibly be biased on, and conduct current. Any such current flow occurs through steering diode paths and rarely involves the absorption device.

Figure 35 shows a specific example where the input voltage,  $V_{IN}$ , exceeds the positive supply voltage ( $+V_S$ ) by 500 mV 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 10 mA.

## Feature Description (continued)

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  $+V_S$  or  $-V_S$  are at 0 V. Again, the result depends on the supply characteristic while at 0 V, 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 does 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.

If there is an uncertainty about the ability of the supply to absorb this current, external zener diodes may be added to the supply pins; see [Figure 35](#). The zener voltage must be selected such that the diode does not turn on during normal operation. However, the zener diode voltage must be low enough so that the zener diode conducts if the supply pin begins to rise above the safe operating supply voltage level.

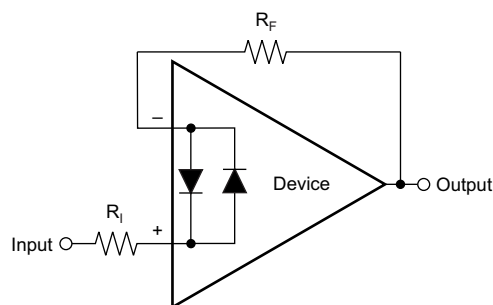
### 8.3.3 Operating Voltage

The OPA1612-Q1 op amp operates from  $\pm 2.25$ -V to  $\pm 18$ -V supplies while maintaining excellent performance. The OPA1612-Q1 device can operate with as little as +4.5 V between the supplies and with up to +36 V between the supplies. However, some applications do not require equal positive and negative output voltage swing. With the OPA1612-Q1 device, power-supply voltages do not need to be equal. For example, the positive supply could be set to +25 V with the negative supply at -5 V.

In all cases, the common-mode voltage must be maintained within the specified range. In addition, key parameters are assured over the specified temperature range of  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ . Parameters that vary with operating voltage or temperature are shown in the [Typical Characteristics](#) section.

### 8.3.4 Input Protection

The input terminals of the OPA1612-Q1 device is protected from excessive differential voltage with back-to-back diodes, as [Figure 36](#) shows. 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 17](#) of the [Typical Characteristics](#) section. If the input signal is fast enough to create this forward bias condition, the input signal current must be limited to 10 mA or less. If the input signal current is not inherently limited, an input series resistor ( $R_I$ ) or a feedback resistor ( $R_F$ ) can be used to limit the signal input current. This input series resistor degrades the low-noise performance of the OPA1612-Q1 device and is examined in the [Noise Performance](#) section. [Figure 36](#) shows an example configuration when both current-limiting input and feedback resistors are used.



**Figure 36. Pulsed Operation**



## 8.4 Device Functional Modes

The OPA1612-Q1 device has a single functional mode. The device is powered on as long as the power supply voltage is between 4.5 V ( $\pm 2.25$  V) and 36 V ( $\pm 18$  V).

## 9 Application and Implementation

### NOTE

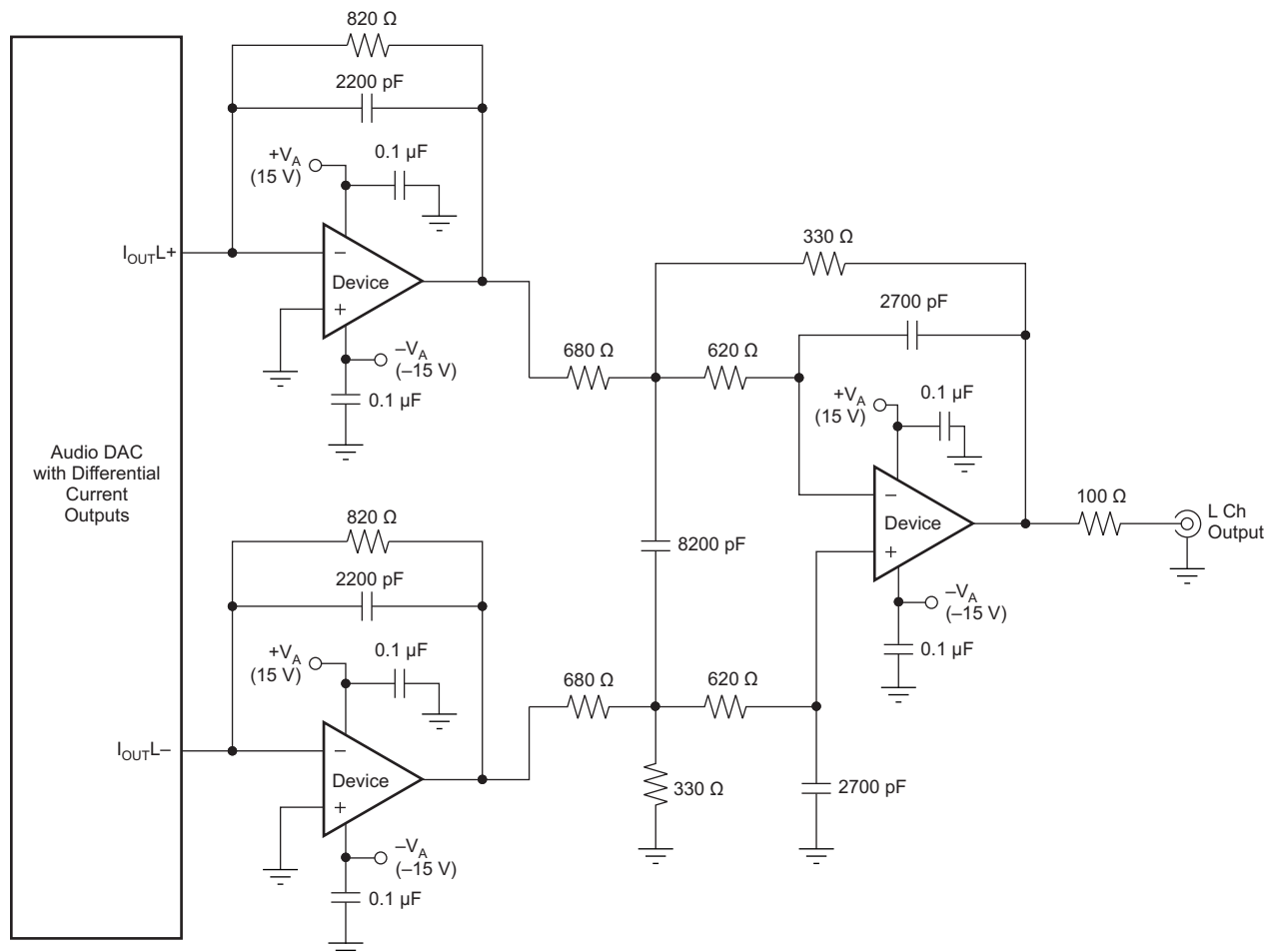
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 9.1 Application Information

The OPA1612-Q1 device is unity-gain stable, precision op amp with very low noise; these devices are also free from output phase reversal. Applications with noisy or high-impedance power supplies require decoupling capacitors close to the device power-supply pins. In most cases, 0.1- $\mu$ F capacitors are adequate.

### 9.2 Typical Application

Figure 37 shows how to use the OPA1612-Q1 device as an amplifier for professional audio headphones. The circuit shows the left side stereo channel. An identical circuit is used to drive the right side stereo channel.



**Figure 37. Audio DAC Post Filter (I/V Converter and Low-Pass Filter)**

## Typical Application (continued)

### 9.2.1 Design Requirements

Use Equation 1 to calculate the total circuit noise.

$$E_O^2 = e_n^2 + (i_n R_S)^2 + 4kTR_S$$

where

- $e_n$  = voltage noise
- $i_n$  = current noise
- $R_S$  = source impedance
- $k$  = Boltzmann's constant =  $1.38 \times 10^{-23}$  J/K
- $T$  = temperature in degrees Kelvin (K)

(1)

### 9.2.2 Detailed Design Procedure

#### 9.2.2.1 Noise Performance

Figure 40 shows the 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).

The OPA1612-Q1 device (GBW = 40 MHz, G = +1) is shown with total circuit noise calculated. The op amp 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. The low voltage noise of the OPA1612-Q1 device makes it a good choice for use in applications where the source impedance is less than 1 kΩ.

##### 9.2.2.1.1 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.

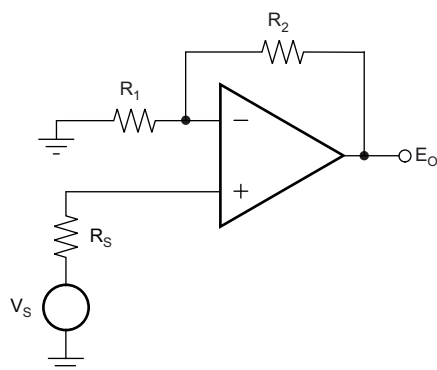
The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. Figure 40 plots this function. The source impedance is usually fixed; consequently, select the op amp and the feedback resistors to minimize the respective contributions to the total noise.

Figure 38 shows 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.

## Typical Application (continued)

### Noise in Noninverting Gain Configuration



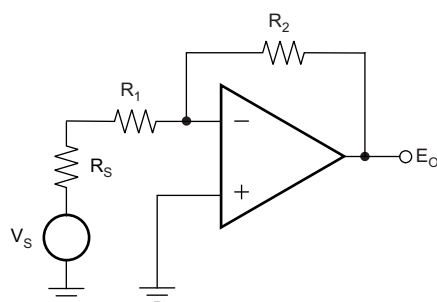
Noise at the output:

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

where

- $e_S = \sqrt{4kTR_S} \times \left[ 1 + \frac{R_2}{R_1} \right]$  = thermal noise of  $R_S$
- $e_1 = \sqrt{4kTR_1} \times \left[ \frac{R_2}{R_1} \right]$  = thermal noise of  $R_1$
- $e_2 = \sqrt{4kTR_2}$  = thermal noise of  $R_2$

### Noise in Inverting Gain Configuration



Noise at the output:

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

where

- $e_S = \sqrt{4kTR_S} \times \left[ \frac{R_2}{R_1 + R_S} \right]$  = thermal noise of  $R_S$
- $e_1 = \sqrt{4kTR_1} \times \left[ \frac{R_2}{R_1 + R_S} \right]$  = thermal noise of  $R_1$
- $e_2 = \sqrt{4kTR_2}$  = thermal noise of  $R_2$

At 1 kHz,  $e_n = 1.1 \text{ nV}/\sqrt{\text{Hz}}$  and  $i_n = 1.7 \text{ pA}/\sqrt{\text{Hz}}$ .

**Figure 38. Noise Calculation in Gain Configurations**

### 9.2.2.2 Total Harmonic Distortion Measurements

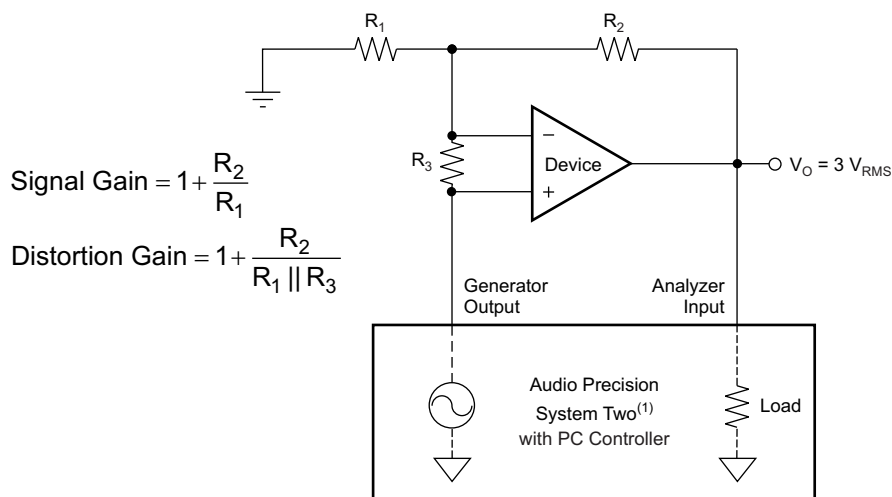
The OPA1612-Q1 op amp has excellent distortion characteristics. THD + noise is below 0.00008% ( $G = +1$ ,  $V_O = 3 V_{\text{RMS}}$ , BW = 80 kHz) throughout the audio frequency range, 20 Hz to 20 kHz, with a 2-k $\Omega$  load (see [Figure 7](#) for characteristic performance).

The distortion produced by OPA1612-Q1 op amp is below the measurement limit of many commercially available distortion analyzers. However, a special test circuit (such as [Figure 39](#) shows) 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 39](#) shows a circuit that causes the op amp distortion to be 101 times (or approximately 40 dB) 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 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  $R_3$ . Keep the value of  $R_3$  small to minimize its effect on the distortion measurements.

## Typical Application (continued)

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 and noise analyzer, which greatly simplifies such repetitive measurements. The measurement technique can, however, be performed with manual distortion measurement instruments.



(1) For measurement bandwidth, see [Figure 7](#) through [Figure 12](#).

SIGNAL GAIN	DISTORTION GAIN	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>
1	101	∞	1 kΩ	10 Ω
–1	101	4.99 kΩ	4.99 kΩ	49.9 kΩ
10	110	549 Ω	4.99 kΩ	49.9 kΩ

**Figure 39. Distortion Test Circuit**

### 9.2.2.3 Capacitive Loads

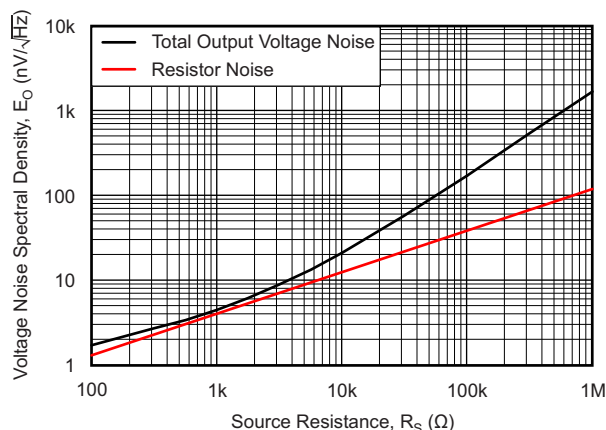
The dynamic characteristics of the OPA1612-Q1 device is optimized for commonly encountered gains, loads, and operating conditions. The combination of low closed-loop gain and high capacitive loads decreases the phase margin of the amplifier and can lead to gain peaking or oscillations. As a result, heavier capacitive loads must be isolated from the output. The simplest way to achieve this isolation is to add a small resistor ( $R_S$  equal to 50 Ω, for example) in series with the output.

This small series resistor also prevents excess power dissipation if the output of the device becomes shorted. [Figure 19](#) and [Figure 20](#) illustrate graphs of *Small-Signal Overshoot vs Capacitive Load* for several values of  $R_S$ . For details of analysis techniques and application circuits, refer to Applications Bulletin AB-028, *Feedback Plots Define Op Amp AC Performance* ([SBOA015](#)).

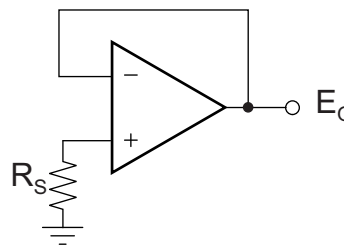
## Typical Application (continued)

### 9.2.3 Application Curves

Equation 1 applies to Figure 40 and Figure 41.



**Figure 40. Noise Performance of the OPA1612-Q1 in Unity-Gain Buffer Configuration**



**Figure 41. Circuit for Figure 40**

## 10 Power-Supply Recommendations

The OPA1612-Q1 device is specified for operation from 4.5 V to 36 V ( $\pm 2.25$  V to  $\pm 18$  V); many specifications apply from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the [Typical Characteristics](#) section.

### CAUTION

Supply voltages larger than 40 V can permanently damage the device; see the [Absolute Maximum Ratings](#) table.

Place 0.1- $\mu\text{F}$  bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, refer to the [Layout](#) section.

## 11 Layout

### 11.1 Layout Guidelines

For best operational performance of the device, use good printed circuit board (PCB) layout practices, including:

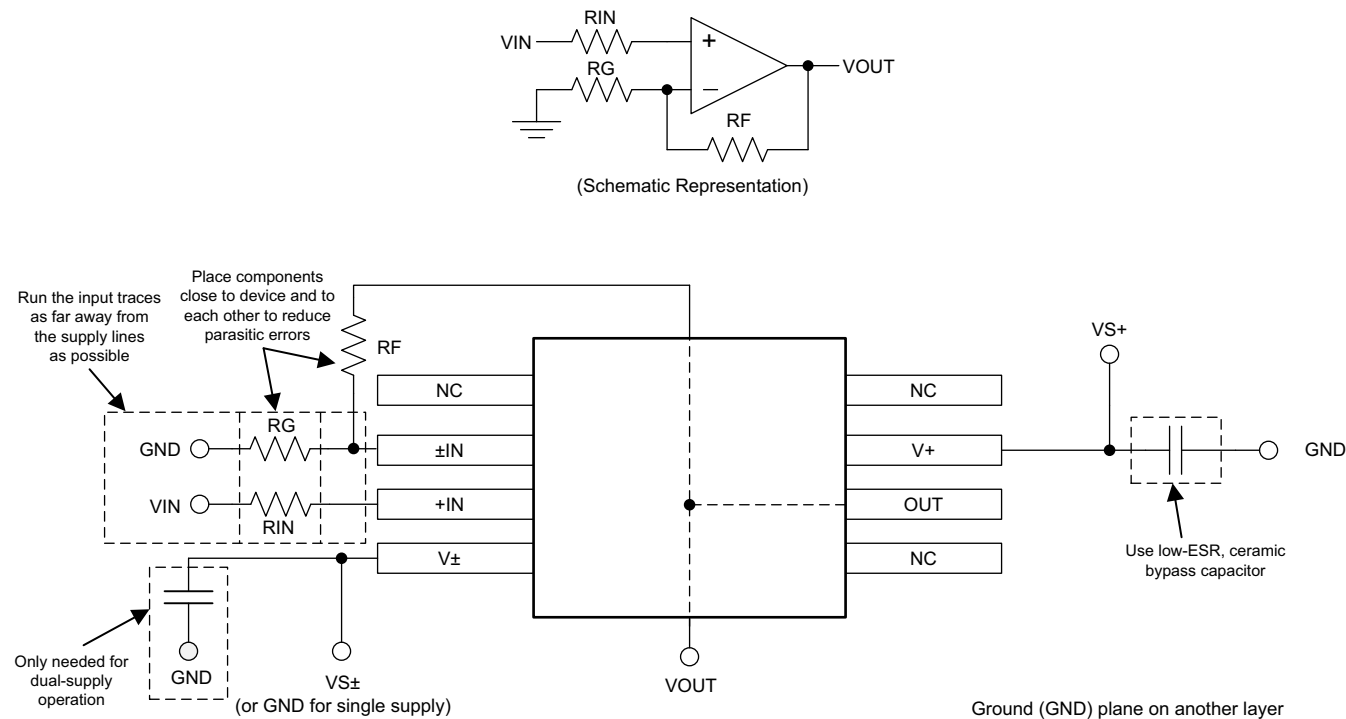
- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and the op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu\text{F}$  ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of the circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds while paying attention to the flow of the ground current. For more detailed information, refer to the application report, *Circuit Board Layout Techniques* (SLOA089).
- In order to reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular as

## Layout Guidelines (continued)

opposed to in parallel with the noisy trace is the preferred method.

- Place the external components as close to the device as possible. As shown in Figure 42, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

## 11.2 Layout Example



**Figure 42. Operational Amplifier Board Layout for a Noninverting Configuration**

## 12 器件和文档支持

### 12.1 文档支持

#### 12.1.1 相关文档

相关文档如下：

- 《反馈曲线图定义运算放大器交流性能》， [SBOA015](#)
- 《电路板布局布线技巧》， [SLOA089](#)

### 12.2 社区资源

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

**TI E2E™ Online Community** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](http://e2e.ti.com), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

### 12.3 商标

E2E is a trademark of Texas Instruments.

SoundPlus is a trademark of Texas Instruments, Inc.

All other trademarks are the property of their respective owners.

### 12.4 静电放电警告



这些装置包含有限的内置 ESD 保护。存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

### 12.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 13 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。 这些信息是针对指定器件可提供的最新数据。 这些数据会在无通知且不对本文档进行修订的情况下发生改变。 欲获得该数据表的浏览器版本，请查阅左侧的导航栏。



## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
OPA1612AQDRQ1	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1612Q1
OPA1612AQDRQ1.B	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1612Q1

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**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.

### OTHER QUALIFIED VERSIONS OF OPA1612-Q1 :

- Catalog : [OPA1612](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

## 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
OPA1612AQDRQ1	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)
OPA1612AQDRQ1	SOIC	D	8	2500	353.0	353.0	32.0



**D0008A**

# PACKAGE OUTLINE

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

## NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

# EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

## 重要通知和免责声明

TI“按原样”提供技术和可靠性数据（包括数据表）、设计资源（包括参考设计）、应用或其他设计建议、网络工具、安全信息和其他资源，不保证没有瑕疵且不做任何明示或暗示的担保，包括但不限于对适销性、与某特定用途的适用性或不侵犯任何第三方知识产权的暗示担保。

这些资源可供使用 TI 产品进行设计的熟练开发人员使用。您将自行承担以下全部责任：(1) 针对您的应用选择合适的 TI 产品，(2) 设计、验证并测试您的应用，(3) 确保您的应用满足相应标准以及任何其他安全、安保法规或其他要求。

这些资源如有变更，恕不另行通知。TI 授权您仅可将这些资源用于研发本资源所述的 TI 产品的相关应用。严禁以其他方式对这些资源进行复制或展示。您无权使用任何其他 TI 知识产权或任何第三方知识产权。对于因您对这些资源的使用而对 TI 及其代表造成的任何索赔、损害、成本、损失和债务，您将全额赔偿，TI 对此概不负责。

TI 提供的产品受 [TI 销售条款](#)、[TI 通用质量指南](#) 或 [ti.com](#) 上其他适用条款或 TI 产品随附的其他适用条款的约束。TI 提供这些资源并不会扩展或以其他方式更改 TI 针对 TI 产品发布的适用的担保或担保免责声明。除非德州仪器 (TI) 明确将某产品指定为定制产品或客户特定产品，否则其产品均为按确定价格收入目录的标准通用器件。

TI 反对并拒绝您可能提出的任何其他或不同的条款。

版权所有 © 2025，德州仪器 (TI) 公司

最后更新日期：2025 年 10 月