OPA1692 低功耗、低噪声和低失真 SoundPlus™音频运算放大器

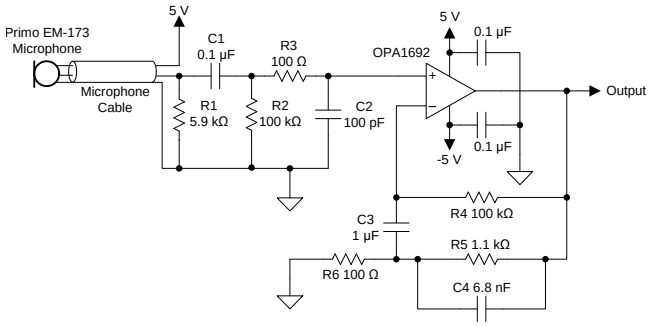
1 特性

- 低噪声：1kHz 时为 4.2nV/√Hz
- 低失真：1kHz 时为 –127dB
- 低静态电流：
  每通道 650μA
- 压摆率： 23V/μs
- 宽增益带宽：5.1MHz
- 单位增益稳定
- 轨至轨输出
- 宽电源电压范围：
  ±1.75V 至 ±18V 或 3.5V 至 36V

2 应用

- 无线耳机
- 无线音频监控系统
- 便携式无线电和耳机
- 便携式音效处理器
- 便携式录音系统
- USB 音频外设

3 线制驻极体麦克风的前置放大器



3 说明

OPA169x 运算放大器将低功耗放大器的性能提高到一个新的层次，实现了 4.2nV/√Hz 的低噪声密度和 –127dB (1kHz) 的低失真。该运算放大器在 2kΩ 负载下还提供 200mV 电源轨范围内的轨至轨输出摆幅，从而增加余量并实现动态范围最大化。这些器件有 ±50mA 的高输出驱动能力。

OPA169x 运算放大器可在 ±1.75V 至 ±18V 或 3.5V 至 36V （每通道的电源电流为 650μA）的宽电源电压范围内工作，具有稳定的单位增益，在各种负载条件下可提供出色的动态行为。

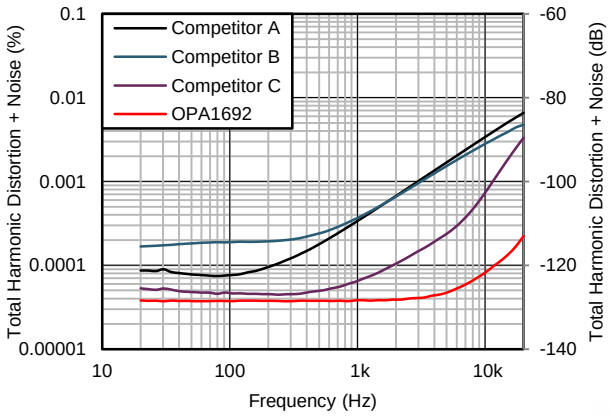
OPA169x 运算放大器的额定工作温度范围为 –40°C 至 125°C。

器件信息(1)

器件编号	封装	封装尺寸（标称值）
OPA1692	VSSOP (8)	3.00mm × 3.00mm
	SOIC (8)	4.90mm × 3.91mm

(1) 如需了解所有可用封装，请参阅数据表末尾的封装选项附录。

THD + N 与频率之间的关系（3 V_{RMS}，2kΩ 负载）



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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 Revision B (September 2018) to Revision C **Page**

- Changed -40℃ to 125℃ Iq to 975 µA ... 6

Changes from Revision A (December 2017) to Revision B **Page**

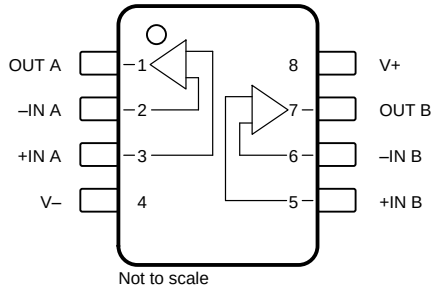
- Changed I_{OS} VCM = 0 MAX from "±10" to "±15" nA ... 5
- Changed I_{OS} TA = –40°C to 125°C MAX from "±15" to "±20" nA ... 5

Changes from Original (June 2017) to Revision A **Page**

- 已更改 将数据表状态从“预告信息”更改成了“生产数据” ... 1

5 Pin Configuration and Functions

OPA1692 D and DGK Packages
8-Pin SOIC and VSSOP
Top View



Not to scale

Pin Functions: OPA1692

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

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Voltage	Supply voltage, V_S = (V+) – (V–)		40	V
	Input	(V–) – 0.5	(V+) + 0.5	
Current	Input (all pins except power-supply pins)	–10	10	mA
	Output short-circuit(2)	Continuous	Continuous	
Temperature	Operating, T_A	–55	125	°C
	Junction, T_J		200	
	Storage, T_{stg}	–65	150	

(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 ANSI/ESDA/JEDEC JS-001(1)	±3000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
V_S	Supply voltage	Single supply	3.5		36	V
		Split supply	±1.75		±18	
T_A	Operating temperature		–40		85	°C

6.4 Thermal Information: OPA1692

THERMAL METRIC(1)		OPA1692		UNIT
		D (SOIC)	DGK (VSSOP)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	123.6	162.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	63.4	56.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	67.0	83.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	16.0	6.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	66.3	81.6	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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

6.5 Electrical Characteristics

at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
AUDIO PERFORMANCE							
THD+N	Total harmonic distortion + noise	G = 1, f = 20 kHz, RL = 2kΩ, VO = 3 VRMS			-118		dB
		G = 1, f = 1 kHz, R_L = 2kΩ, V_O = 3 V_{RMS}			–127		dB
IMD	Intermodulation distortion	G = 1, V_O = 3 V_{RMS}	SMPTE/DIN two-tone, 4:1 (60 Hz and 7 kHz)		0.00005%		
	Intermodulation distortion	G = 1, V_O = 3 V_{RMS}			-126		dB
	Intermodulation distortion	G = 1, V_O = 3 V_{RMS}	CCIF twin-tone (19 kHz and 20 kHz)		0.0002		
	Intermodulation distortion	G = 1, V_O = 3 V_{RMS}	CCIF twin-tone (19 kHz and 20 kHz)		-114		dB
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product	G = 100			5.1		MHz
SR	Slew rate	G = –1			23		V/µs
	Full power bandwidth(1)	V_O = 1 V_P			3.66		MHz
	Overload recovery time	G = –10			250		ns
	Channel separation (dual and quad)	f = 1 kHz			–145		dB
NOISE							
e_n	Input voltage noise	f = 0.1 to 10 Hz			130		nV_{PP}
e_n	Input voltage noise	f = 20 Hz to 20 kHz			3.9		μV_{PP}
	Input voltage noise density	f = 1 kHz			4.2		nV/rtHz
		f = 100 Hz			4.5		
I_n	Input current noise density	f = 1 kHz			0.37		pA/rtHz
		f = 100 Hz			0.4		
OFFSET VOLTAGE							
V_{OS}	Input offset voltage	V_S = ±1.75 V to ±18 V			±0.25	±0.8	mV
V_{OS}	Input offset voltage	V_S = ±1.75 V to ±18 V				±1.0	mV
		V_S = ±1.75 V to ±18 V, T_A = –40°C to +125°C(2)			0.5	5	µV/°C
PSRR	Power-supply rejection ratio	V_S = ±1.75 V to ±18 V			0.1	1.5	µV/V
PSRR	Power-supply rejection ratio	T_A = –40°C to +125°C(2)				2.25	µV/V
INPUT BIAS CURRENT							
I_B	Input bias current	V_{CM} = 0 V			300	550	nA
		T_A = –40°C to +125°C				600	nA
I_{OS}	Input offset current	V_{CM} = 0 V			±2	±15	nA
		TA = –40°C to +125°C				±20	nA
INPUT VOLTAGE RANGE							
V_{CM}	Common-mode voltage range			(V–) + 1.5		(V+) – 0.5	V
CMRR	Common-mode rejection ratio	(V–) + 1.5 V ≤ V_{CM} ≤ (V+) – 0.5 V			0.1	1	uV/V
CMRR	Common-mode rejection ratio	TA = –40°C to +125°C				4	uV/V
INPUT IMPEDANCE							
	Differential Resistance				350		kΩ
	Differential Capacitance				1.5		pF
	Common-Mode Resistance				350		MΩ
	Common-Mode Capacitance				1.6		pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain	TA = –40°C to +125°C		110	140		dB
A_{OL}	Open-loop voltage gain	(V–) + 0.2 V ≤ V_O ≤ (V+) – 0.2 V, R_L = 2 kΩ		120	140		dB

(1) Full-power bandwidth = SR / (2π × V_P), where SR = slew rate.
(2) Specified by design and characterization.

Electrical Characteristics (continued)

at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
V_{OUT}	Voltage output	R_L = 2 kΩ	-17.8		17.8	V
I_{OUT}	Output current			See *Figure 46* , *Figure 47*		mA
Z_O	Open-loop output impedance			See *Figure 14*		Ω
I_{SC}	Short-circuit current(3)			±50		mA
C_{LOAD}	Capacitive load drive			200		pF
POWER SUPPLY						
I_Q	Quiescent current (per channel)	I_{OUT} = 0 A		650	750	µA
		I_{OUT} = 0 A, T_A = –40°C to +125°C(2)		650	975	µA

(3) One channel at a time.

6.6 Typical Characteristics

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

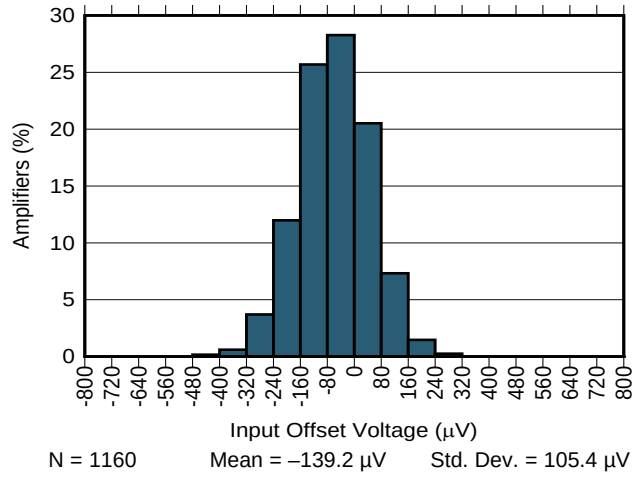


图 1. Input Offset Voltage Distribution

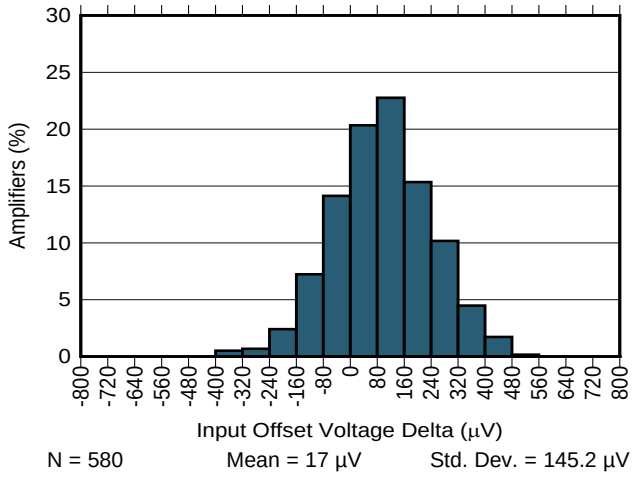


图 2. Input Offset Voltage Matching (Ch. A – Ch. B)

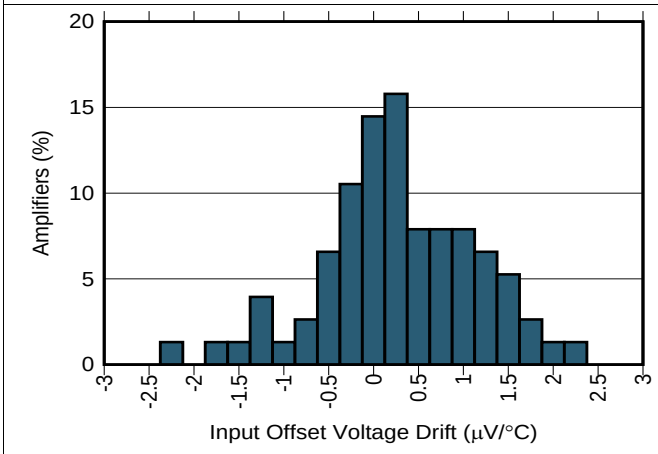


图 3. Offset Voltage Drift Distribution

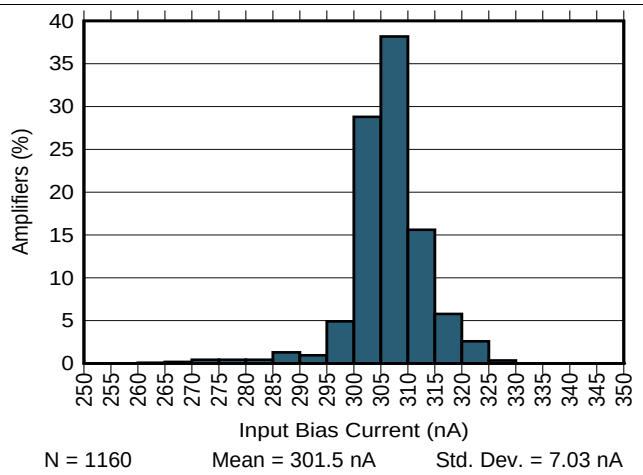


图 4. Input Bias Current Distribution

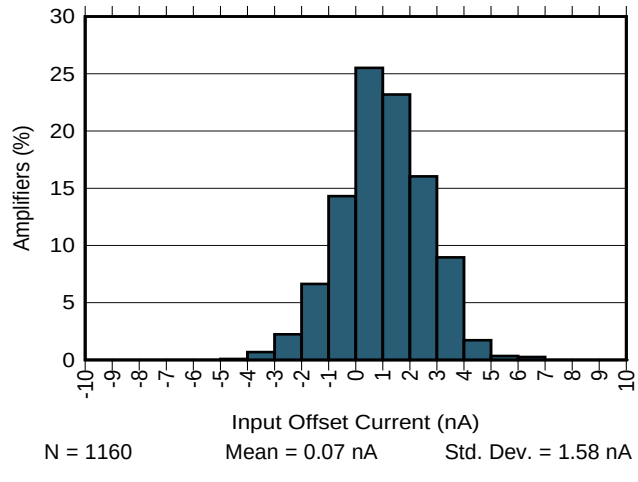


图 5. Input Offset Current Distribution

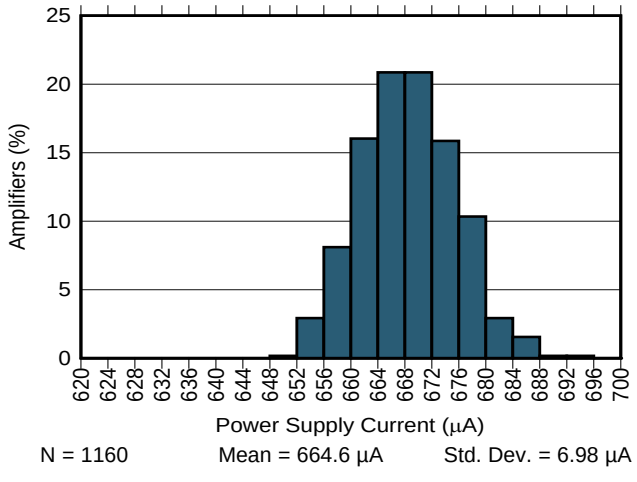


图 6. Power Supply Current Distribution

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

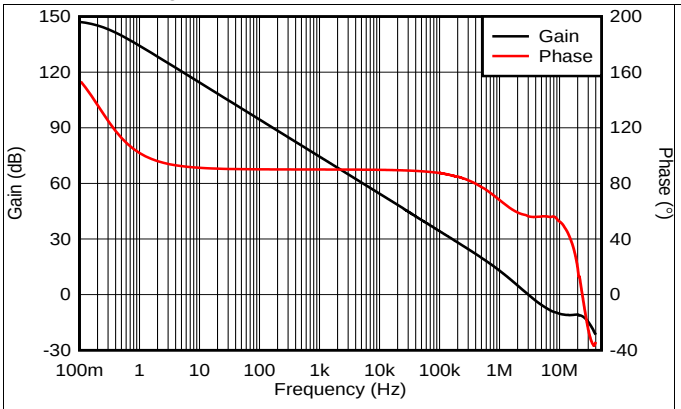


图 7. Open-Loop Gain and Phase vs Frequency

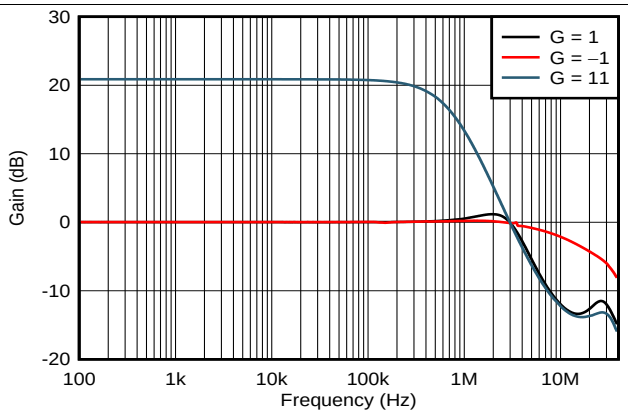


图 8. Closed-Loop Gain vs Frequency

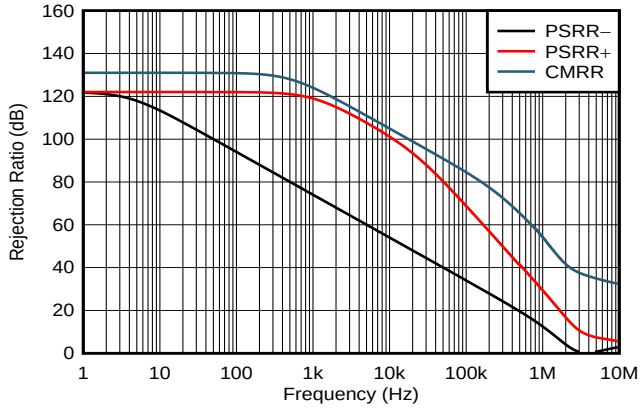


图 9. CMRR and PSRR vs Frequency (Referred to Input)

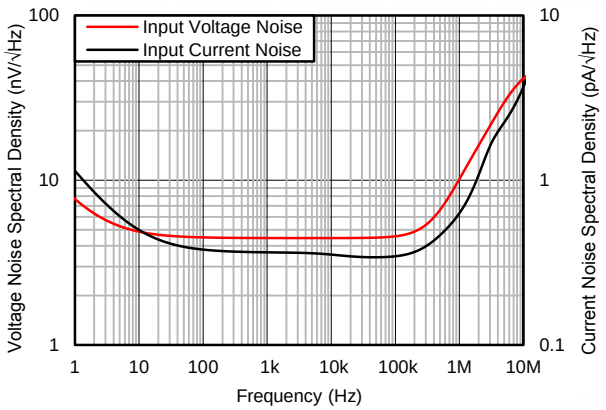


图 10. Input Voltage Noise Spectral Density

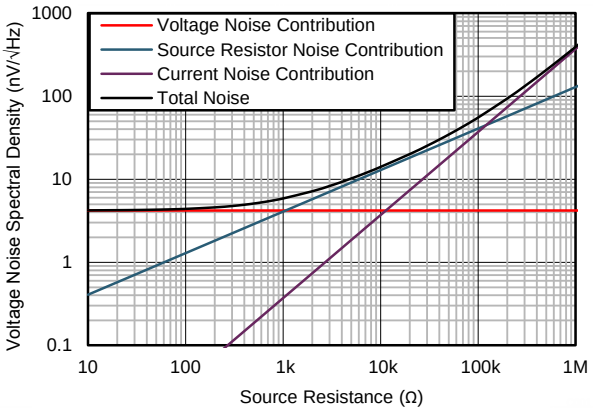


图 11. Voltage Noise vs Source Resistance

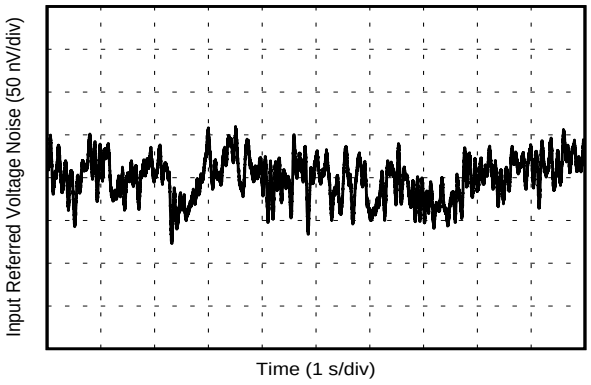


图 12. 0.1-Hz to 10-Hz Voltage Noise

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

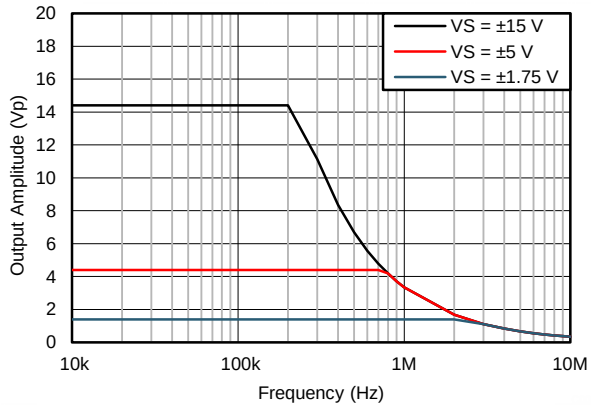


图 13. Maximum Output Voltage vs Frequency

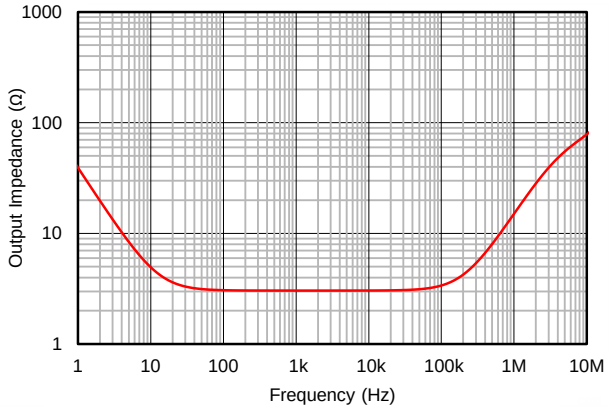


图 14. Open-Loop Output Impedance vs Frequency

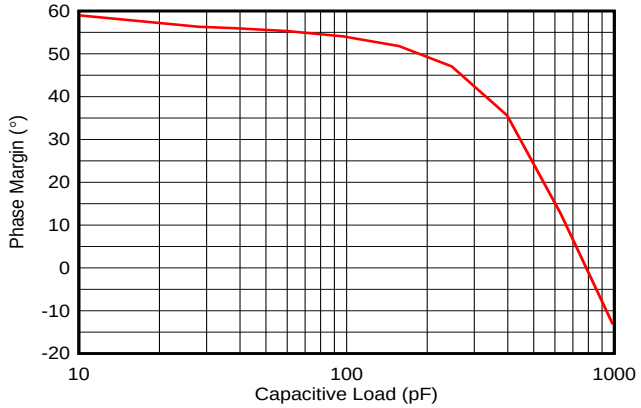


图 15. Phase Margin vs Capacitive Load

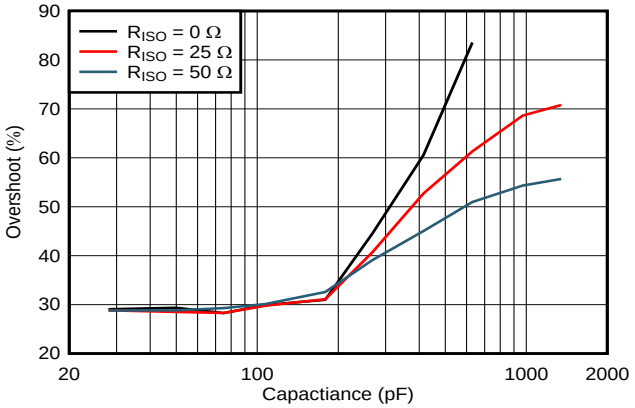


图 16. Overshoot vs Capacitive Load

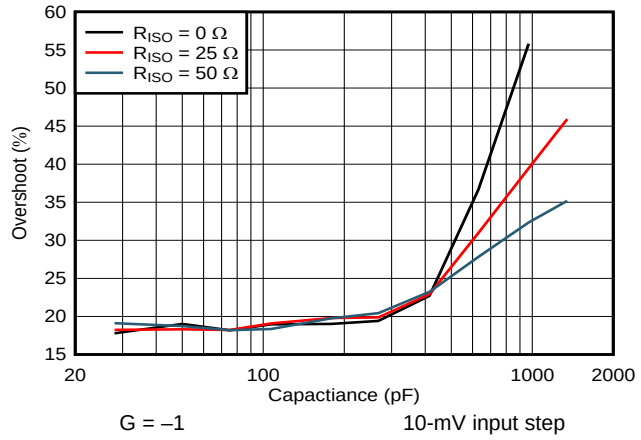


图 17. Overshoot vs Capacitive Load

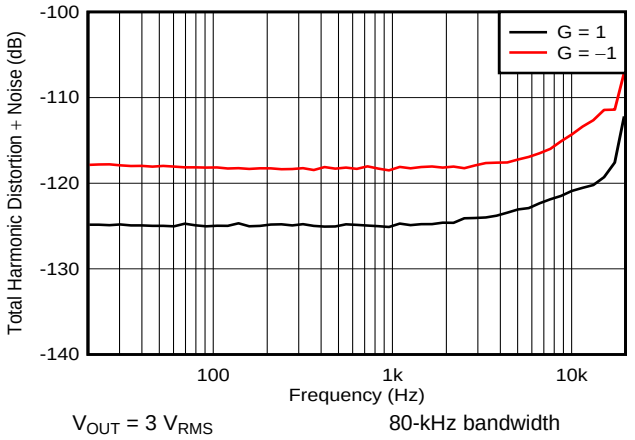
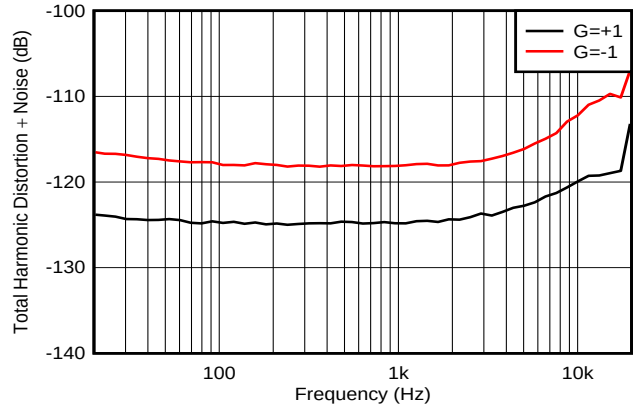


图 18. THD + N Ratio vs Frequency

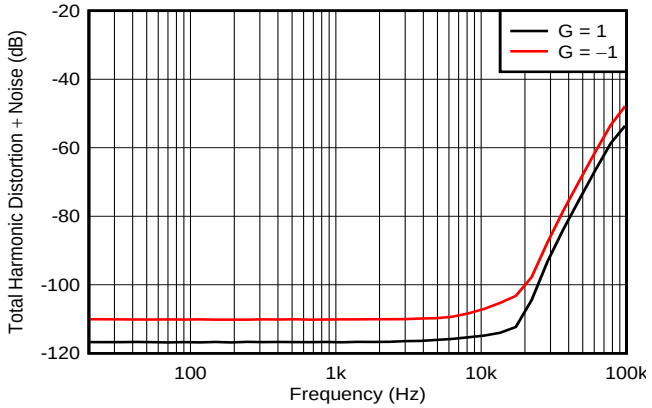
Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)



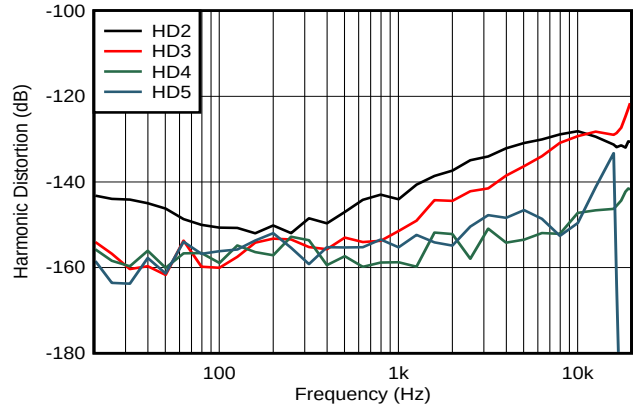
V_{OUT} = 3 V_{RMS} R_L = 600 Ω 80-kHz bandwidth

图 19. THD + N Ratio vs Frequency



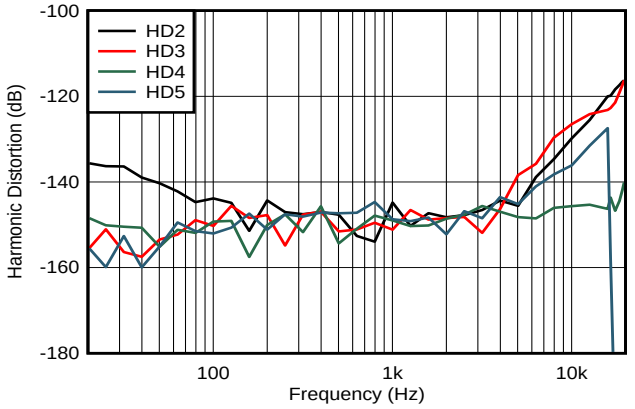
V_{OUT} = 3 V_{RMS} 500-kHz bandwidth

图 20. THD + N Ratio vs Frequency



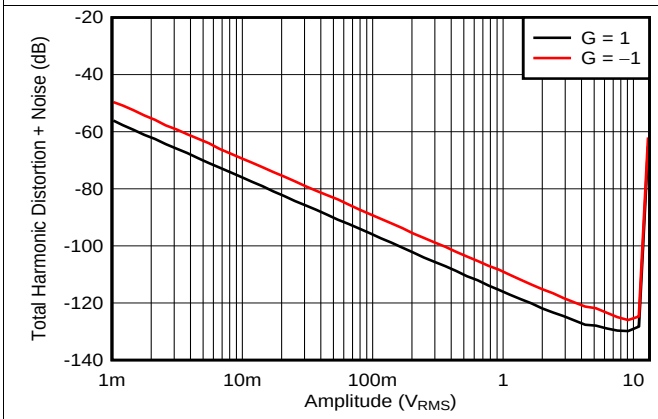
V_{OUT} = 3 V_{RMS} G = 1 80-kHz bandwidth

图 21. Distortion Harmonics vs Frequency



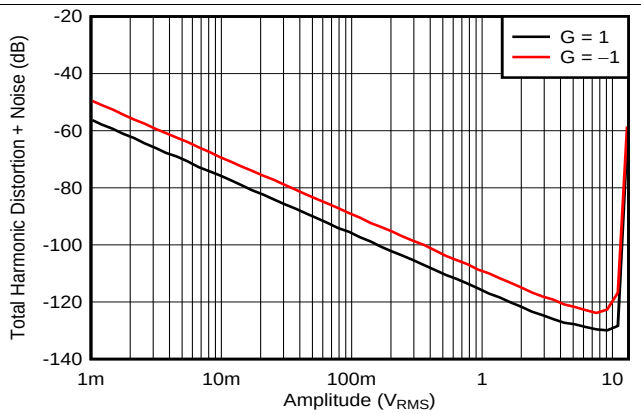
V_{OUT} = 3 V_{RMS} G = –1 80-kHz bandwidth

图 22. Distortion Harmonics vs Frequency



f = 1 kHz 80-kHz bandwidth

图 23. THD + N Ratio vs Output Amplitude



f = 1 kHz R_L = 600 Ω 80-kHz bandwidth

图 24. THD + N Ratio vs Output Amplitude

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

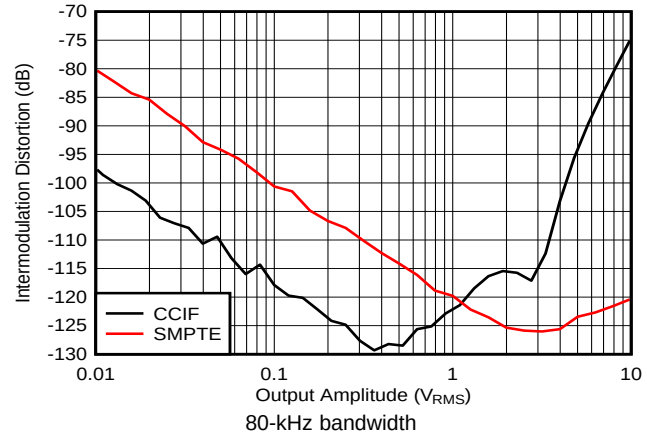


图 25. Intermodulation Distortion vs Output Amplitude

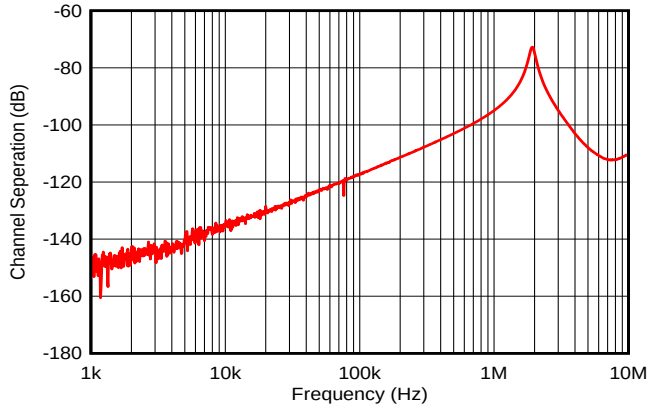


图 26. Channel Separation vs Frequency

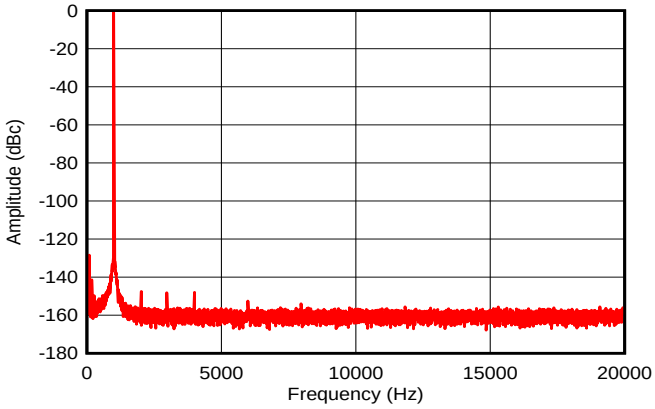


图 27. 1-kHz Output Spectrum

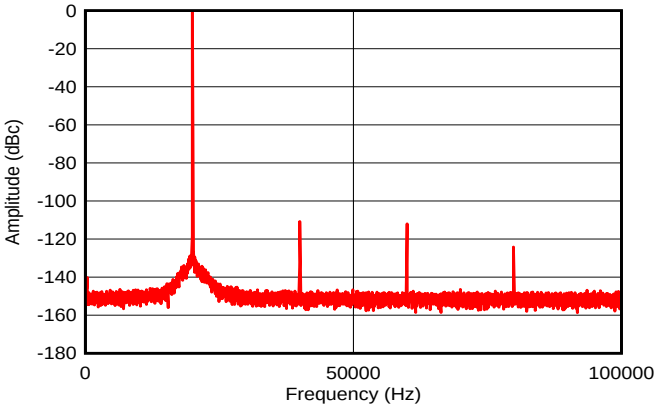


图 28. 20-kHz Output Spectrum

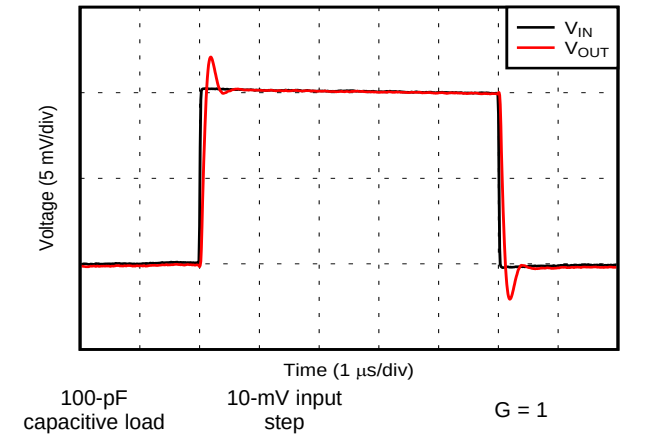


图 29. Small-Signal Step Response

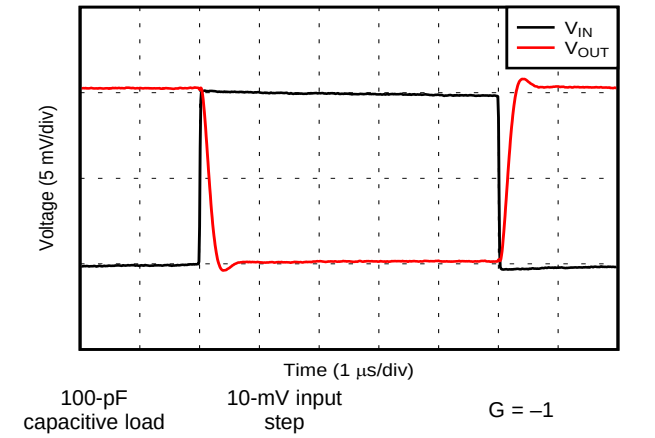


图 30. Small-Signal Step Response

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

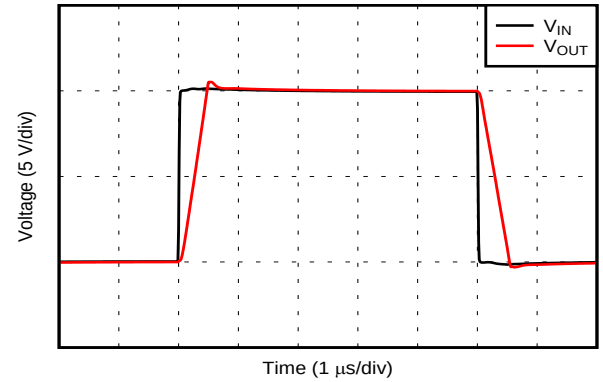


图 31. Large-Signal Step Response

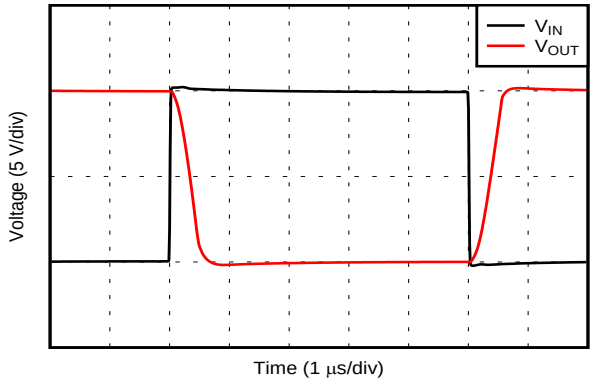


图 32. Large-Signal Step Response

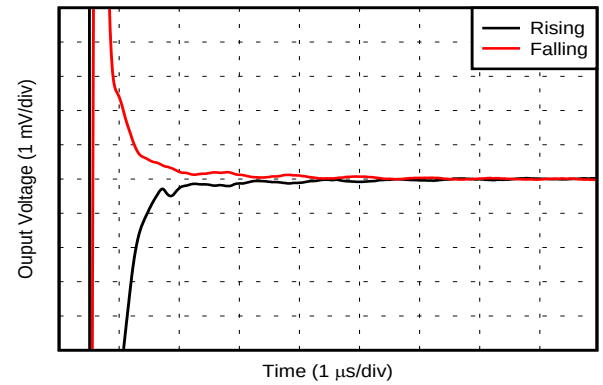


图 33. Settling Time

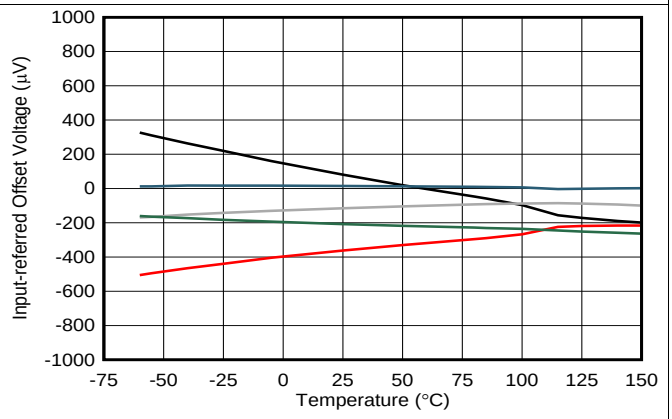


图 34. Input Offset Voltage vs Temperature

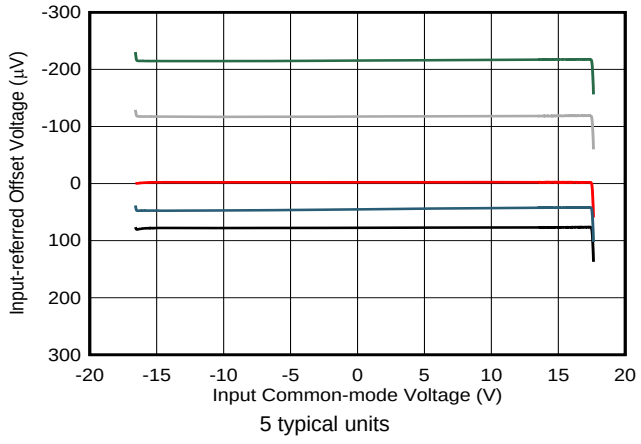


图 35. Input Offset Voltage vs Common-Mode Voltage

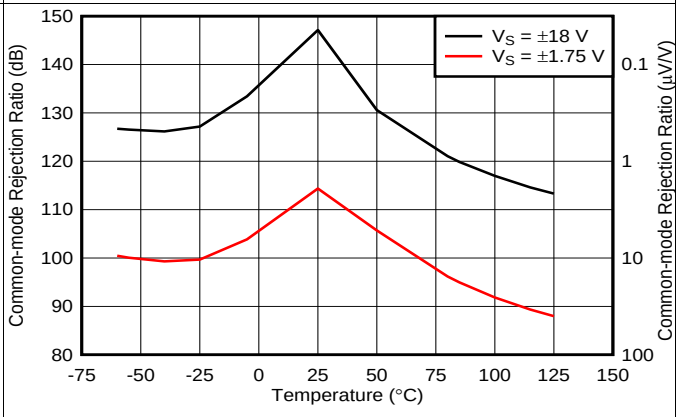


图 36. CMRR vs Temperature

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

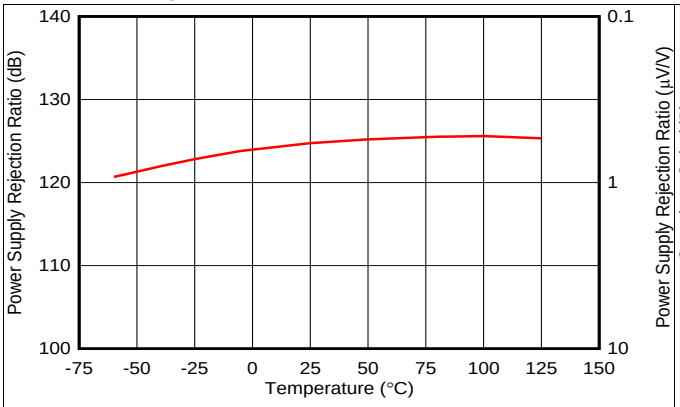


图 37. PSRR vs Temperature

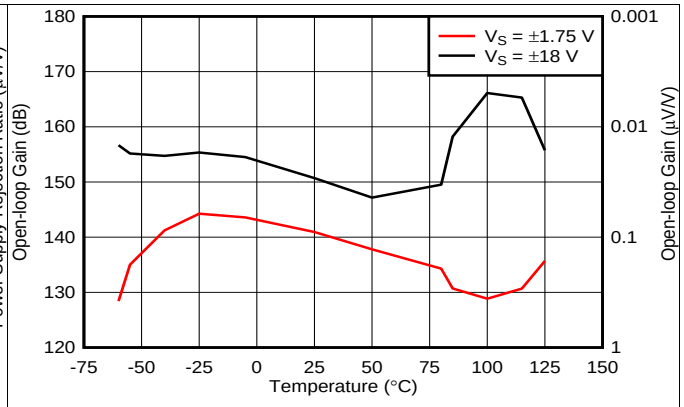


图 38. Open-Loop Gain vs Temperature

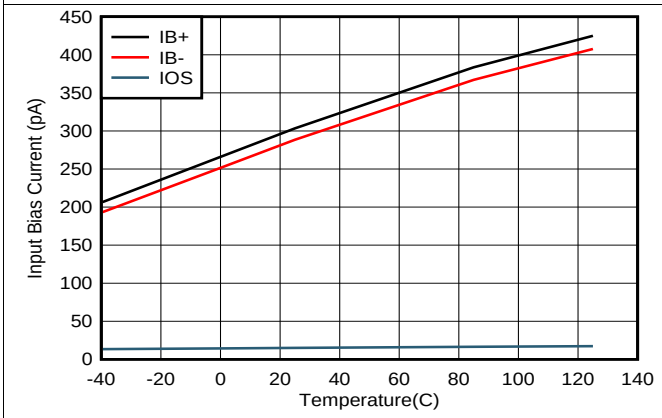


图 39. Input Bias and Offset Current vs Temperature

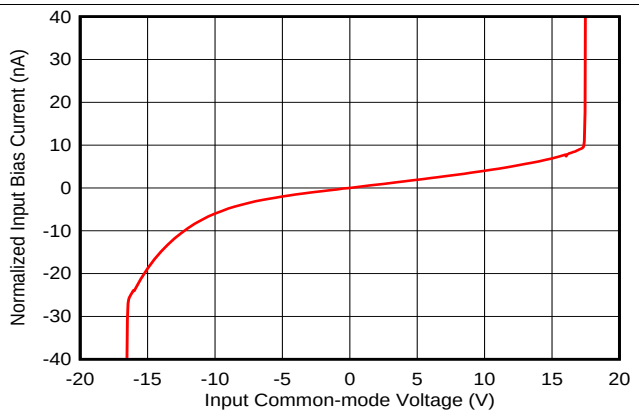


图 40. I_B vs Common-Mode Voltage

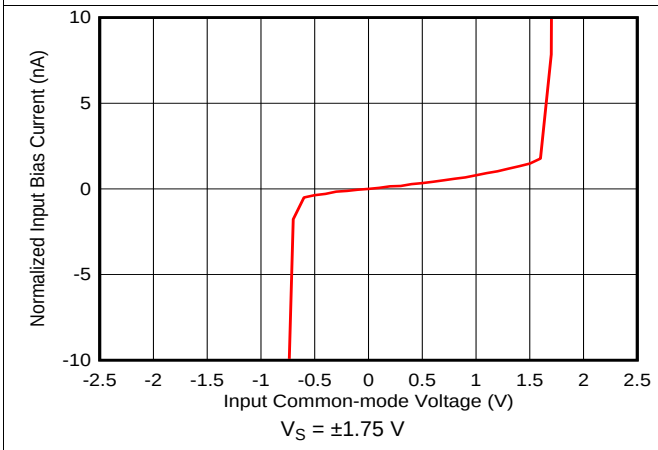


图 41. I_B vs Common-Mode Voltage

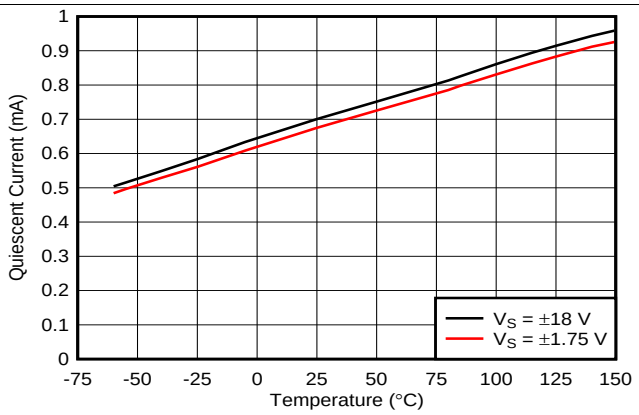


图 42. Supply Current vs Temperature

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

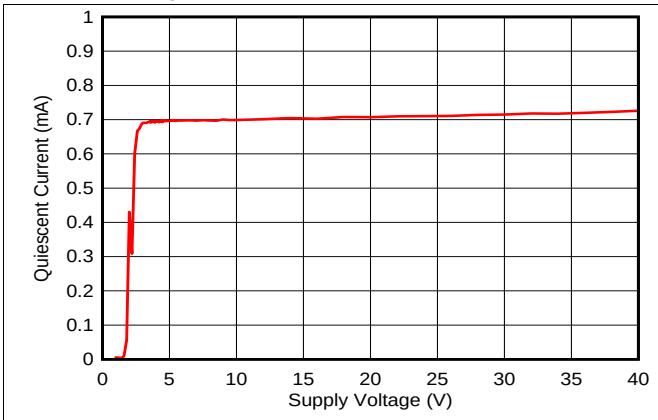


图 43. Supply Current vs Supply Voltage

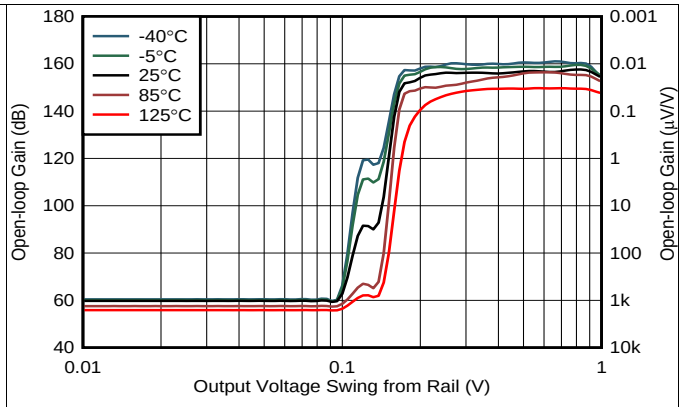


图 44. Open-Loop Gain vs Output Voltage

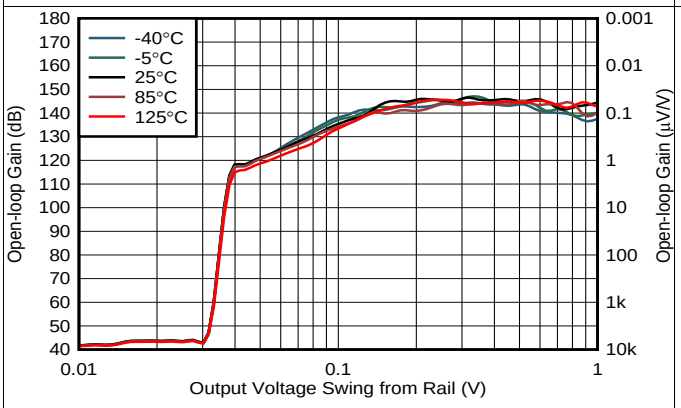


图 45. Open-Loop Gain vs Output Voltage

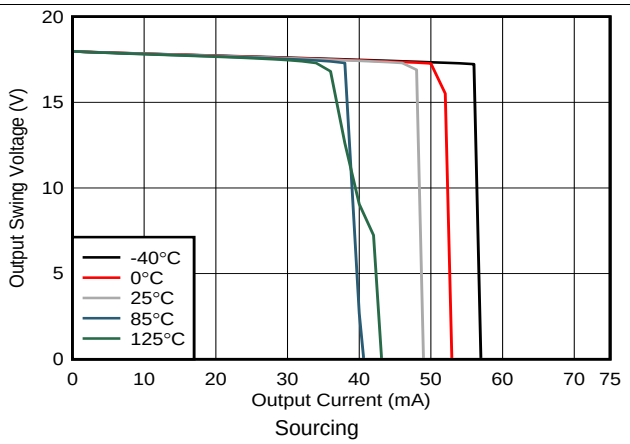


图 46. Output Voltage vs Output Current

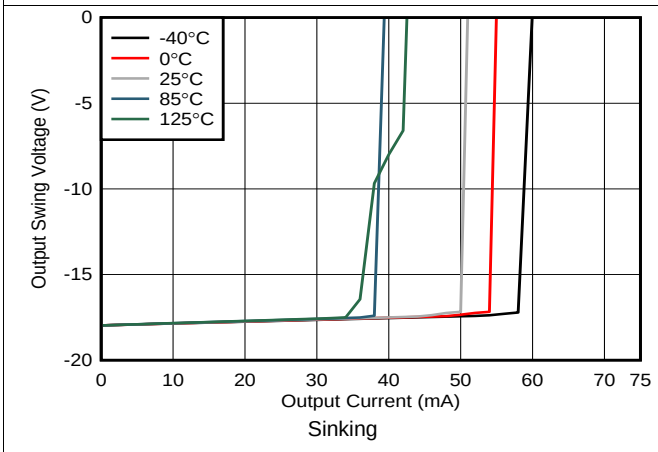


图 47. Output Voltage vs Output Current

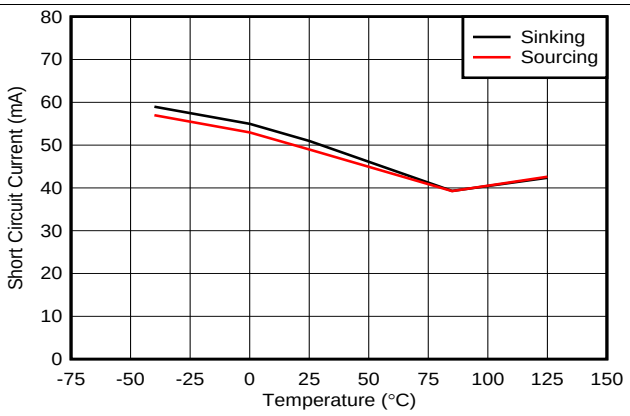


图 48. Short-Circuit Current vs Temperature

Typical Characteristics (接下页)

at T_A = 25°C, V_S = ±18 V, and R_L = 2 kΩ (unless otherwise noted)

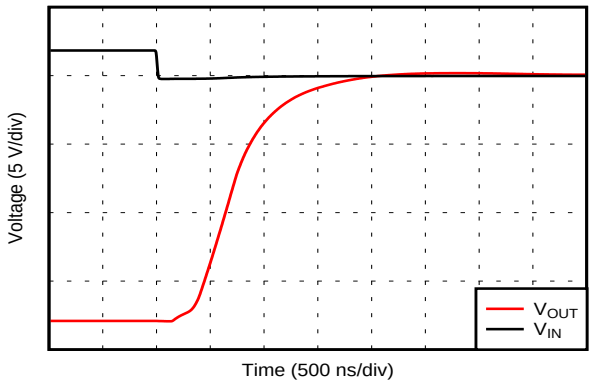


图 49. Negative Overload Recovery

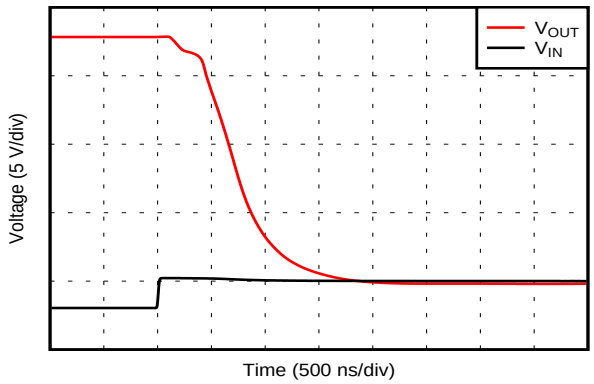


图 50. Positive Overload Recovery

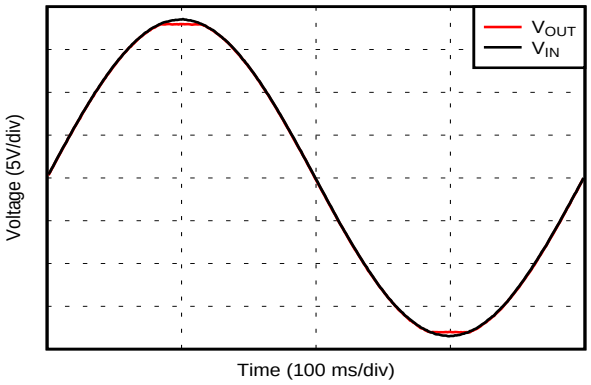


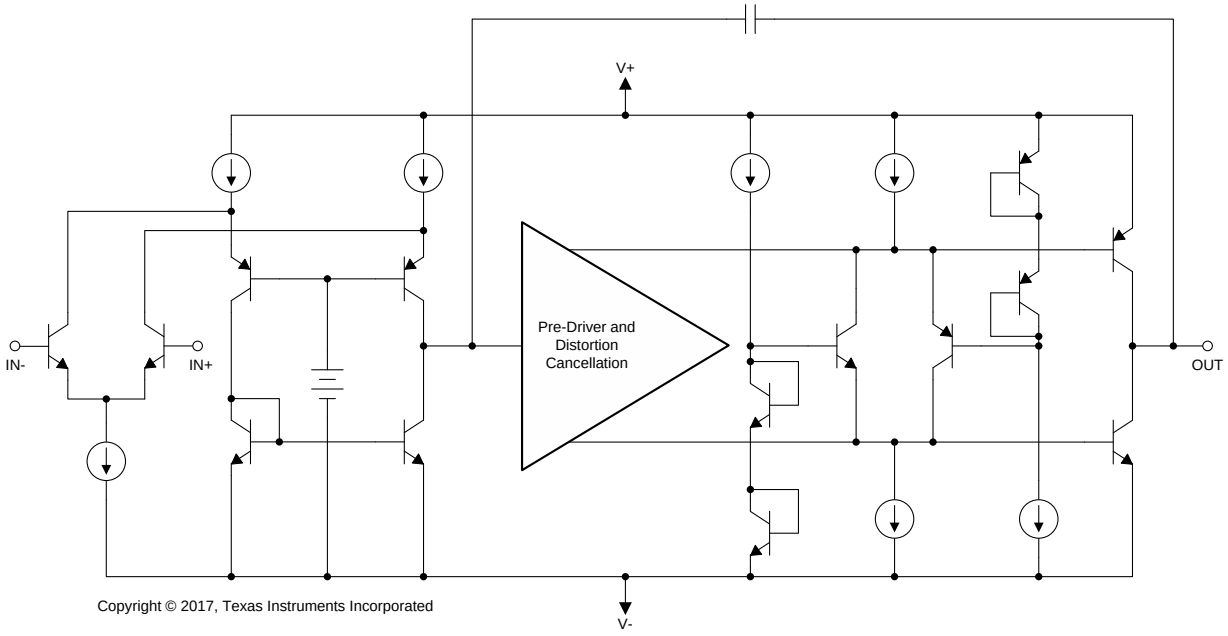
图 51. No Phase Reversal

7 Detailed Description

7.1 Overview

The OPA169x amplifiers are unity-gain stable, dual and quad op amps with low noise. The *Functional Block Diagram* shows a simplified schematic of the OPA169x (one channel shown). The device consists of a very low noise input stage with a folded cascode and a rail-to-rail output stage. A proprietary distortion reduction technology allows the OPA169x family of amplifiers to achieve significantly lower distortion than other op amps that consume the equal or greater power supply current.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Distortion Reduction

Amplifiers use feedback to reduce the amount of distortion they introduce to the signal path. Increasing the amount of feedback available for distortion reduction typically requires an increase in the power supply current of the amplifier. This is not acceptable in low-power amplifiers targeting applications that require low distortion.

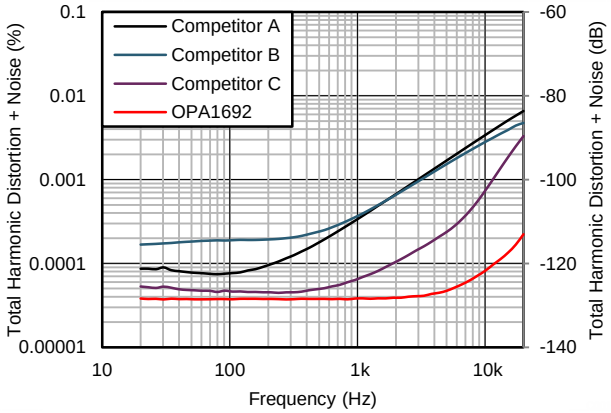


图 53. Comparison of THD + N vs Frequency for Multiple Low-Power Amplifiers

Feature Description (接下页)

The OPA169x family of amplifiers uses a proprietary technology to reduce signal distortion that does not increase the power supply current. The distortion cancellation technique reduces odd-order harmonic distortion, which is produced by the input transistor pair of the amplifier. As 图 53 shows, the impact to THD + N is significant, especially at high frequencies where the OPA169x devices exhibit over 30-dB lower distortion than competitor amplifiers at similar power supply current levels.

7.3.2 Phase Reversal Protection

The OPA169x family has internal phase-reversal protection. Many op amps exhibit phase reversal when the input is driven beyond the linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, reverses the output into the opposite rail. The input of the OPA169x prevents phase reversal with excessive common-mode voltage. Instead, the appropriate rail limits the output voltage. This performance is shown in 图 54.

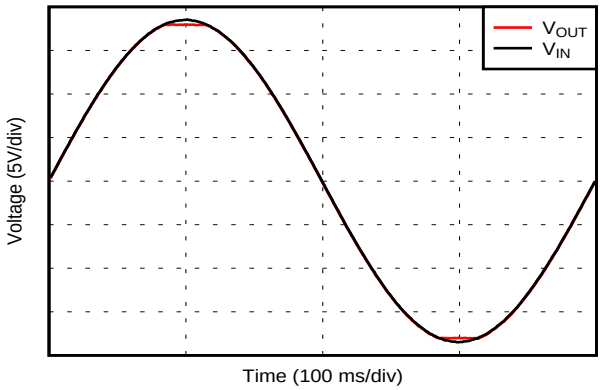


图 54. Output Waveform Devoid of Phase Reversal During an Input Overdrive Condition

7.3.3 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 can 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.

A good understanding of this basic ESD circuitry and the relevance to an electrical overstress event is helpful. 图 55 illustrates the ESD circuits contained in the OPA169x (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 the diodes meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

Feature Description (接下页)

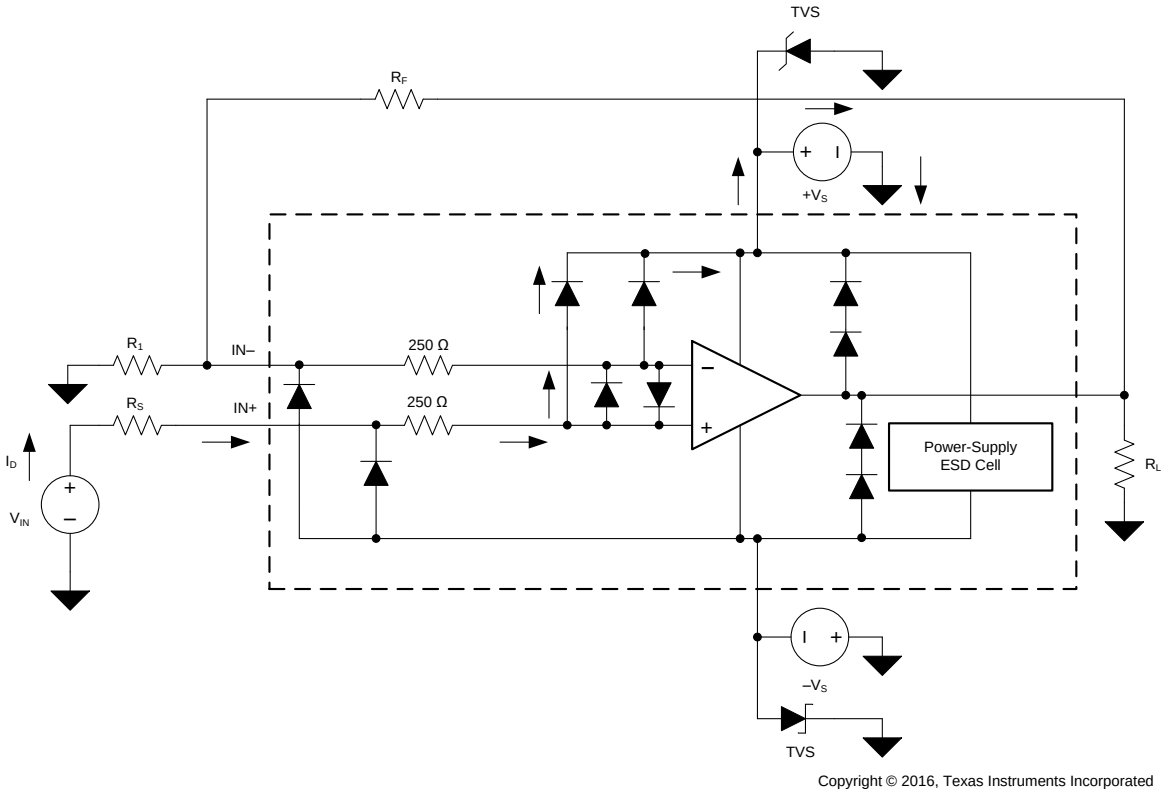


图 55. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

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

When an ESD voltage develops across two or more amplifier device pins, current flows through one or more steering diodes. Depending on the path that the current takes, the absorption device can activate. The absorption device has a trigger, or threshold voltage, that is above the normal operating voltage of the OPA169x but below the device breakdown voltage level. When 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 (see 图 55), the ESD protection components are intended to remain inactive and are not 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, there is a risk that some internal ESD protection circuits can turn on and conduct current. Any such current flow occurs through steering-diode paths and rarely involves the absorption device.

图 55 shows a specific example where the input voltage (V_{IN}) exceeds the positive supply voltage (V+) by 500 mV or more. Much of what happens in the circuit depends on the supply characteristics. If V+ can sink the current, one of the upper input steering diodes conducts and directs current to V+. Excessively high current levels can flow with increasingly higher V_{IN}. As a result, the data sheet specifications recommend that applications limit the input current to 10 mA.

If the supply is not capable of sinking the current, V_{IN} can 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.

Feature Description (接下页)

Another common question involves what happens to the amplifier if an input signal is applied to the input when the power supplies (V+ or V–) are at 0 V. This question depends on the supply characteristic when at 0 V, or at a level below the input signal amplitude. If the supplies appear as high impedance, then the input source supplies the operational amplifier current through the current-steering diodes. This state is not a normal bias condition; most likely, the amplifier 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 any uncertainty about the ability of the supply to absorb this current, add external Zener diodes to the supply pins; see 图 55. Select the Zener voltage so that the diode does not turn on during normal operation. However, the Zener 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.

7.4 Device Functional Modes

7.4.1 Operating Voltage

The OPA169x series op amps operate from ±1.75 V to ±18 V supplies while maintaining excellent performance. The OPA169x series operates with as little as 3.5 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 OPA169x series, power-supply voltages are not required to be equal. For example, the positive supply can 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. Key parameters are assured over the specified temperature range of T_A = –40°C to 125°C. Parameters that vary significantly with operating voltage or temperature are shown in the *Typical Characteristics*.

8 Application and Implementation

注

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.

8.1 Application Information

8.1.1 Capacitive Loads

The dynamic characteristics of the OPA169x amplifiers are 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. Add a small resistor (R_S equal to 50 Ω, for example) in series with the output to isolate heavier capacitive loads.

8.1.2 Noise Performance

图 56 shows the total circuit noise for varying source impedances with the operational amplifier in a unity-gain configuration (with no feedback resistor network and therefore no additional noise contributions). The op amp itself contributes 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 OPA169x has low voltage noise and low current noise. As a result, the current noise contribution of the OPA169x series is negligible for source impedances less than 100 kΩ.

图 56 shows the calculation of the total circuit noise, with these parameters:

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

For more details on calculating noise, see *Basic Noise Calculations*.

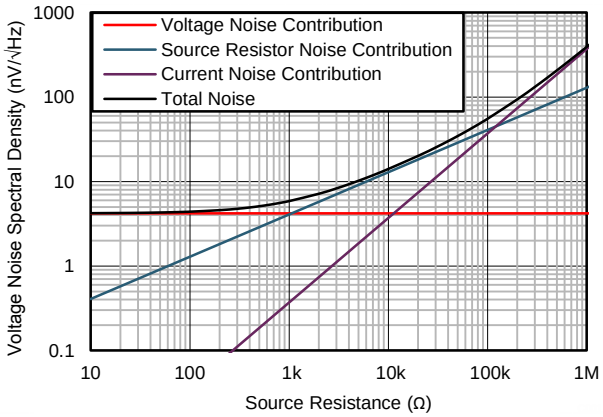


图 56. Noise Performance of the OPA169x in a Unity-Gain Buffer Configuration

Application Information (接下页)

8.1.3 Basic Noise Calculations

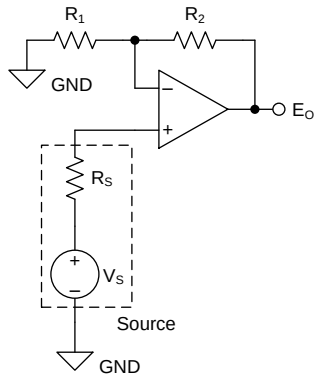
Low-noise circuit design requires careful analysis of all noise sources. External noise sources can dominate in many cases; consider the effect of source resistance on overall op amp noise performance. Total noise of the circuit is the root-sum-square combination of all noise components.

The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. This function is plotted in 图 56. The source impedance is typically fixed; consequently, select the op amp and the feedback resistors to minimize the respective contributions to the total noise.

图 57 shows noninverting **(A)** and inverting **(B)** op amp circuit configurations with gain. In circuit configurations with gain, the feedback network resistors contribute noise. In general, the current noise of the op amp reacts with the feedback resistors to create additional noise components.

The selected feedback resistor values make these noise sources negligible. Low impedance feedback resistors load the output of the amplifier. The equations for total noise are shown for both configurations.

(A) Noise in Noninverting Gain Configuration



Noise at the output is given as E_O, where

$$(1)\quad E_O = \left(1+\frac{R_2}{R_1}\right)\cdot\sqrt{(e_S)^2+(e_N)^2+\left(e_{R_1\|R_2}\right)^2+(i_N\cdot R_S)^2+\left(i_N\cdot\left[\frac{R_1\cdot R_2}{R_1+R_2}\right]\right)^2}\quad [\,V_{RMS}\,]$$

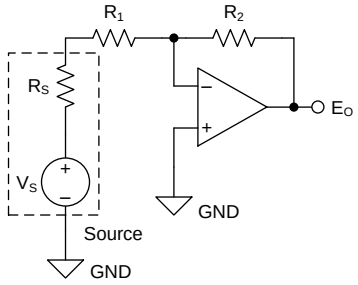
$$(2)\quad e_S = \sqrt{4\cdot k_B\cdot T(K)\cdot R_S}\quad \left[\frac{V}{\sqrt{Hz}}\right]$$ Thermal noise of R_S

$$(3)\quad e_{R_1\|R_2} = \sqrt{4\cdot k_B\cdot T(K)\cdot\left[\frac{R_1\cdot R_2}{R_1+R_2}\right]}\quad \left[\frac{V}{\sqrt{Hz}}\right]$$ Thermal noise of $R_1 \| R_2$

$$(4)\quad k_B = 1.38065\cdot 10^{-23}\quad \left[\frac{J}{K}\right]$$ Boltzmann Constant

$$(5)\quad T(K) = 237.15 + T(°C)\quad [\,K\,]$$ Temperature in kelvins

(B) Noise in Inverting Gain Configuration



Noise at the output is given as E_O, where

$$(6)\quad E_O = \left(1+\frac{R_2}{R_S+R_1}\right)\cdot\sqrt{(e_N)^2+\left(e_{R_1+R_S\|R_2}\right)^2+\left(i_N\cdot\left[\frac{(R_S+R_1)\cdot R_2}{R_S+R_1+R_2}\right]\right)^2}\quad [\,V_{RMS}\,]$$

$$(7)\quad e_{R_1+R_S\|R_2} = \sqrt{4\cdot k_B\cdot T(K)\cdot\left[\frac{(R_S+R_1)\cdot R_2}{R_S+R_1+R_2}\right]}\quad \left[\frac{V}{\sqrt{Hz}}\right]$$ Thermal noise of $(R_1 + R_S) \| R_2$

$$(8)\quad k_B = 1.38065\cdot 10^{-23}\quad \left[\frac{J}{K}\right]$$ Boltzmann Constant

$$(9)\quad T(K) = 237.15 + T(°C)\quad [\,K\,]$$ Temperature in kelvins

(1) e_N is the voltage noise of the amplifier. For the OPAx169x series of operational amplifiers, e_N = 4.2 nV/√Hz at 1 kHz.
(2) i_N is the current noise of the amplifier. For the OPA169x series of operational amplifiers, i_N = 370 fA/√Hz at 1 kHz.
(3) For additional resources on noise calculations, see *TI's Precision Labs Series*.

图 57. Noise Calculation in Gain Configurations

Application Information (接下页)

8.1.4 EMI Rejection

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many op amps is a change in the offset voltage as a result of RF signal rectification. An op amp that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this section provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the op amp. In general, only the noninverting input is tested for EMIRR for the following three reasons:

- Op amp input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
- The noninverting and inverting op amp inputs have symmetrical physical layouts and exhibit approximately matching EMIRR performance
- EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input pin can be isolated on a PCB. This isolation allows the RF signal to be applied directly to the noninverting input terminal with no complex interactions from other components or connecting PCB traces.

  High-frequency signals conducted or radiated to any pin of the operational amplifier result in adverse effects, as the amplifier does not have sufficient loop gain to correct for signals with spectral content outside its bandwidth. Conducted or radiated EMI on inputs, power supply, or output may result in unexpected DC offsets, transient voltages, or other unknown behavior. Take care to properly shield and isolate sensitive analog nodes from noisy radio signals and digital clocks and interfaces.

  The EMIRR IN+ of the OPA169x amplifiers is plotted versus frequency as shown in 图 58. If available, any dual and quad op amp device versions have nearly similar EMIRR IN+ performance. The OPA169x unity-gain bandwidth is 5.1 MHz. EMIRR performance below this frequency denotes interfering signals that fall within the op amp bandwidth.

See *EMI Rejection Ratio of Operational Amplifiers*, available for download from www.ti.com.

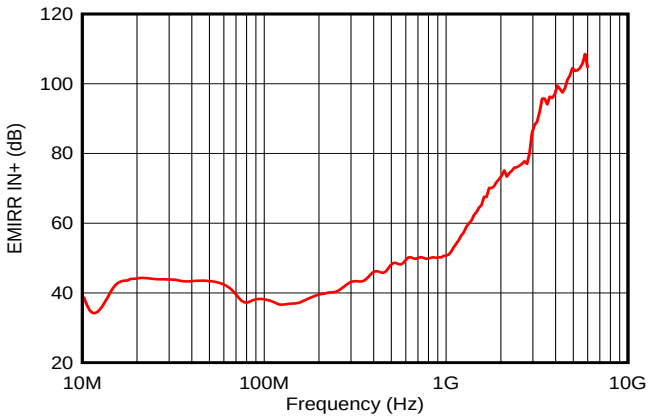


图 58. OPA169x EMIRR IN+

表 1 lists the EMIRR IN+ values for the OPA169x at particular frequencies commonly encountered in real-world applications. Applications listed in 表 1 may be centered on or operated near the particular frequency shown. This information may be of special interest to designers working with these types of applications, or working in other fields likely to encounter RF interference from broad sources, such as the industrial, scientific, and medical (ISM) radio band.

表 1. OPA169x EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION OR ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	45.9 dB
900 MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications	50.2 dB
1.8 GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)	70.7 dB
2.4 GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz)	76.1 dB
3.6 GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	94.1 dB
5 GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)	104.5 dB

8.1.5 EMIRR +IN Test Configuration

图 59 shows the circuit configuration for testing the EMIRR IN+. An RF source connects to the op amp noninverting input pin using a transmission line. The op amp is configured in a unity-gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM). A large impedance mismatch at the op amp input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. A multimeter samples and measures the resulting DC offset voltage. The LPF isolates the multimeter from residual RF signals that may interfere with multimeter accuracy.

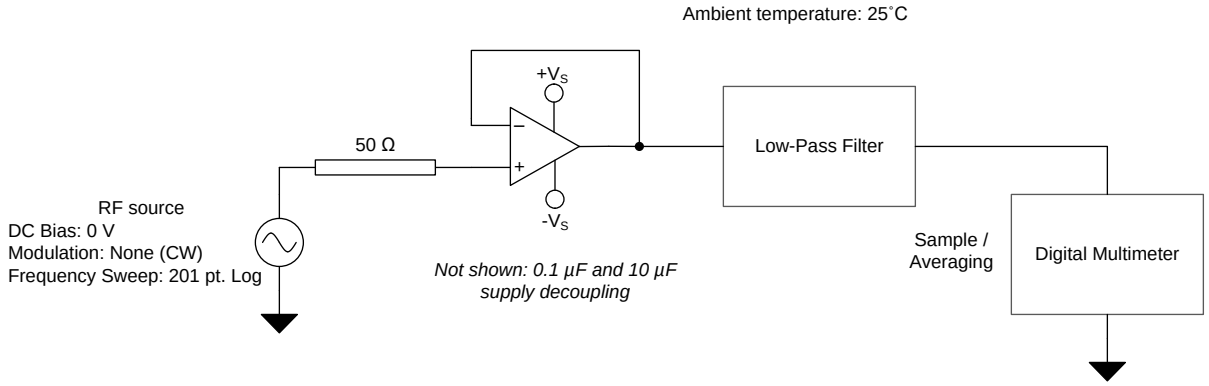


图 59. EMIRR +IN Test Configuration

8.2 Typical Application

The low power consumption, noise, and distortion of the OPA169x family of audio operational amplifiers make the family a viable option for a number of analog audio circuits. 图 60 shows one circuit example, which shows a preamplifier circuit that is designed for high-performance electret microphones that use a 3-wire interface.

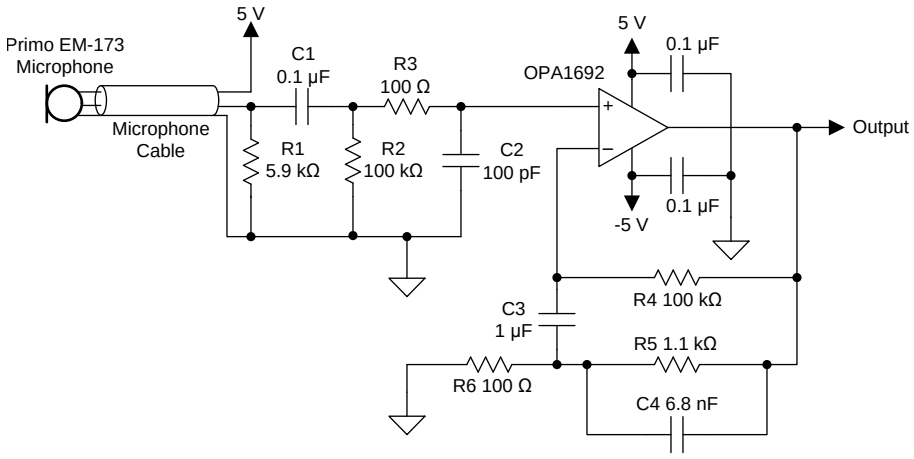


图 60. Low-Noise Preamplifier for 3-Wire Electret Microphones

8.2.1 Design Requirements

- Maximum Input Sound Pressure Level (SPL): 120 dB
- –3-dB Bandwidth: 20 Hz to 20 kHz
- Signal-to-Noise Ratio: > 75 dB
- Power Supply Voltage: ± 5 V
- Power Supply Current: < 1.5 mA

8.2.2 Detailed Design Procedure

The selected design requirements represent a high-performance wireless microphone application. Wireless microphones typically use an electret microphone element, an analog pre-amplifier circuit, and transmit circuitry which may use analog or digital methods of transmission. Because these devices are battery-powered, all circuitry must be designed to consume as little power as possible, while still achieving very high audio performance. The performance specifications for the microphone used in this design are shown in 表 2. This microphone element uses a 3-wire connection scheme with separate connections for power, ground, and signal. The microphone data sheet specifies that the signal line is terminated with a recommended 5.6-kΩ resistance and a 5-V supply.

表 2. Primo EM-173 Microphone Specifications

PARAMETER	VALUE
Sensitivity	–37 dBV
Output impedance	600 Ω
Signal-to-noise ratio (SNR)	80 dB
Maximum input sound pressure level	135 dB
Operating voltage	5 V (3 V – 10 V)
Operating current	600 µA

R1, C1, and R2 provide the correct termination impedance for the microphone and AC-couple the microphone signal to the amplifier input. R2 is selected with a large value (100 kΩ) so that a smaller AC-coupling capacitor can be used (C1). The high-pass corner frequency produced by C1 and R2 must be set to 20 Hz using 公式 1:

$$20\ \text{Hz} = \frac{1}{2 \cdot \pi \cdot R_2 \cdot C_1} = \frac{1}{2 \cdot \pi \cdot 100\ \text{k}\Omega \cdot C_1} \rightarrow C_1 = 79.6\ \text{nF} \rightarrow 100\ \text{nF} \quad (1)$$

R1 and R2 are in parallel for frequencies above 20 Hz. Therefore, select the value of R1 so that when in parallel with R2, the combination results in a 5.6-kΩ resistance as specified in the microphone data sheet. 公式 2 calculates R1.

$$5.6\ \text{k}\Omega = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{R_1 \cdot 100\ \text{k}\Omega}{R_1 + 100\ \text{k}\Omega} \rightarrow R_1 = 5.9\ \text{k}\Omega \tag{2}$$

R3 and C2 form a low-pass filter to prevent the amplification of electromagnetic interference (EMI) signals. 公式 3 shows the corner frequency of this EMI filter.

$$f_{-3\text{dB}} = \frac{1}{2 \cdot \pi \cdot R_3 \cdot C_2} = \frac{1}{2 \cdot \pi \cdot 100\ \Omega \cdot 100\ \text{pF}} = 15.9\ \text{MHz} \tag{3}$$

The input bias current of the OPA1692 through the 100-kΩ input resistor (R2) and can potentially cause a large offset voltage to appear at the output of the amplifier. One solution to this problem is to match the DC resistance of the circuit at each input of the amplifier. R4 and C3 accomplish this goal by providing a DC-feedback path for the amplifier (R4) which has the same resistance as the input resistor (R2). Capacitor C3 serves two functions. First, at low-frequencies this capacitor is effectively an open circuit and therefore the gain of the amplifier is 1, which reduces DC offsets at the output. At high frequencies where the impedance of the capacitor is low, the feedback network of R5, R6, and C4 determine the gain of the amplifier.

The nominal gain of the preamplifier circuit is calculated by considering the output of the microphone at the maximum input SPL. For this design, a maximum input SPL of 120 dB or [20 pascals (Pa)] is specified. The microphone sensitivity is shown as –37 dBV, measured at 1-Pa air pressure. The output signal of the microphone at 20-Pa air pressure can be calculated by converting the –37 dBV sensitivity specification to mV per pascal of air pressure as shown in 公式 4:

$$V_{\text{OUT(MIC)}} = 20\ \text{Pa} \times 10^{\left(\frac{-37\ \text{dBV}}{20}\right)} = 282.5\ \text{mV}_{\text{RMS}} = 399.5\ \text{mVp} \tag{4}$$

The linear output voltage range of the OPA1692 extends to within 200 mV of each power supply. Therefore, on a ±5-V power supply, the linear output voltage range is ±4.8 V. The linear output voltage range of the amplifier and the maximum output signal level of the microphone determine the gain of the amplifier, as shown in 公式 5:

$$G = \frac{V_{\text{OUT(OPA1692)}}}{V_{\text{OUT(MIC)}}} = \frac{4.8\ V_P}{399.5\ \text{mV}_P} = 12.015\ (21.6\ \text{dB}) = 1 + \frac{R_5}{R_6} \tag{5}$$

Selecting values of 1.1 kΩ and 100 Ω for R5 and R6, respectively, produce a nominal gain of 12 for the circuit, allowing the full linear output swing of the amplifier to be used for the maximum input SPL. The feedback capacitor (C4) limits the gain of the circuit at high frequencies beyond the range of human hearing. 公式 6 shows the high-pass corner frequency that capacitor C4 produces:

$$20\ \text{kHz} = \frac{1}{2 \cdot \pi \cdot R_5 \cdot C_4} = \frac{1}{2 \cdot \pi \cdot 1.1\ \text{k}\Omega \cdot C_4} \rightarrow C_4 = 7.23\ \text{nF} \rightarrow 6.8\ \text{nF} \tag{6}$$

Lastly, by the low-frequency bandwidth requirement for the design and the gain determines the value of C3. The high-pass corner frequency produced by this capacitor is affected by resistors R5 and R6 as shown in 公式 7:

$$C_3 = \left(1 + \frac{R_5}{R_6}\right) \frac{1}{2 \cdot \pi \cdot R_4 \cdot f_{-3\text{dB}}} = (12) \frac{1}{2 \cdot \pi \cdot 100\ \text{k}\Omega \cdot 20\ \text{Hz}} \rightarrow C_3 = 955\ \text{nF} \rightarrow 1\ \mu\text{F} \tag{7}$$

8.2.3 Application Curves

表 3 lists the performance of the preamplifier circuit in 图 60. The total power supply current of the circuit is a combination of the 600 µA consumed by the microphone element itself and the 650 µA power-supply current of the OPA1692. 图 61 shows the frequency response of the circuit. Comparing the output signal level of the microphone for a 1-Pa input signal level to the A-weighted noise of the preamplifier circuit and microphone determines the SNR of the circuit. For a 1-Pa input sound level, the microphone produces a 14.13 mV_{RMS} signal. The microphone has an SNR of 80 dB, which results in a RMS noise voltage of 1.41 μV_{RMS}. The input-referred A-weighted noise voltage of the preamplifier circuit is 600.6 nV_{RMS}. The microphone and preamplifier noise must be combined as a root sum of squares, which results in a total RMS noise voltage of 1.53 μV_{RMS} and a total circuit SNR of 79.3 dB. By selecting the OPA1692 for this design, this circuit achieves a high level of performance with low power consumption.

表 3. Comparison of Design Requirements and Results

SPECIFICATION	DESIGN REQUIREMENT	DESIGN RESULT
Gain	12 V/V or 21.6 dB (120 dB Maximum Input SPL)	11.79 V/V or 21.43 dB
–3-dB bandwidth	20 Hz to 20 kHz	24 Hz to 21 kHz
Signal-to-noise ratio	> 75 dB	79.3 dB
Power supply current (microphone and amplifier circuit)	< 1.5 mA	1.25 mA

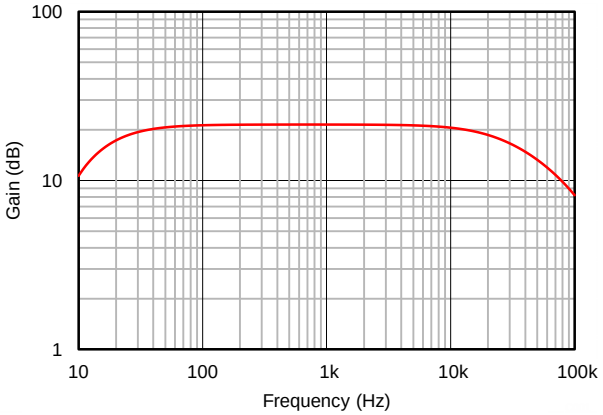


图 61. Frequency Response of the Low-Noise Preamplifier for 3-Wire Electret Microphones

8.3 Other Application Examples

8.3.1 Two-Wire Electret Microphone Preamplifier

The circuit in 图 60 can be modified to accommodate two-wire electret microphones, as shown in 图 62. In two-wire configurations, there is no resistor in series with the source of the internal JFET of the microphone. The audio signal is output as a varying voltage across the biasing resistor (2.2 kΩ in 图 62) of the capsule. The preamplifier input is AC-coupled to the biasing resistor through a 0.1-µF capacitor and 47-kΩ input resistor.

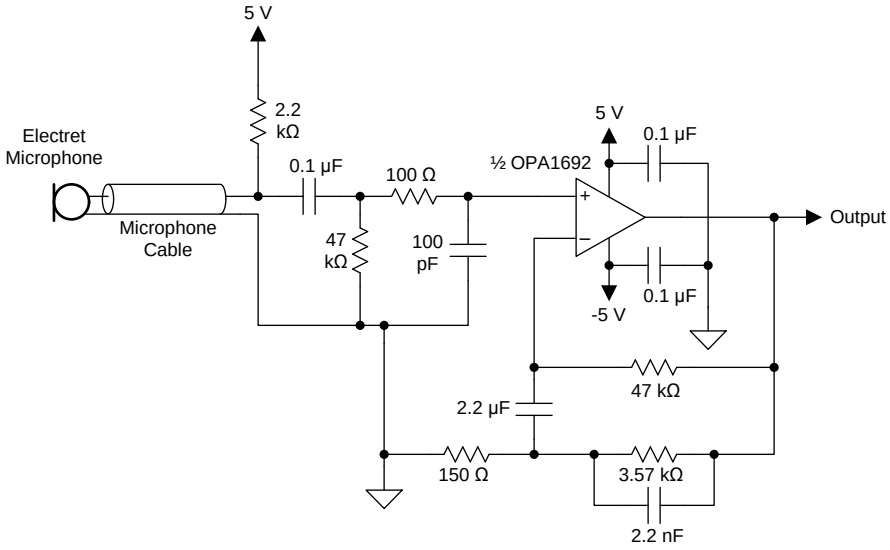


图 62. Two-Wire Electret Microphone Preamplifier

Other Application Examples (接下页)

8.3.2 Battery-Powered Preamplifier for Professional Microphones

图 63 shows a preamplifier designed for portable applications that require low-noise, high common-mode rejection, and long battery life. Both channels of the OPA1692 are configured as a two-op amp instrumentation amplifier with a variable gain from 6 to 40 dB. An array of 1-kΩ resistors is recommended for the feedback network because the excellent matching of these resistors ensure high common-mode rejection in the circuit. An OPA171 is configured as a buffered power supply divider to provide a biasing voltage to the circuit, allowing the system to operate properly on a single 9-V battery. The additional components at the OPA1692 inputs are for phantom power, EMI, and ESD protection. The circuit consumes approximately 2 mA of quiescent power supply current.

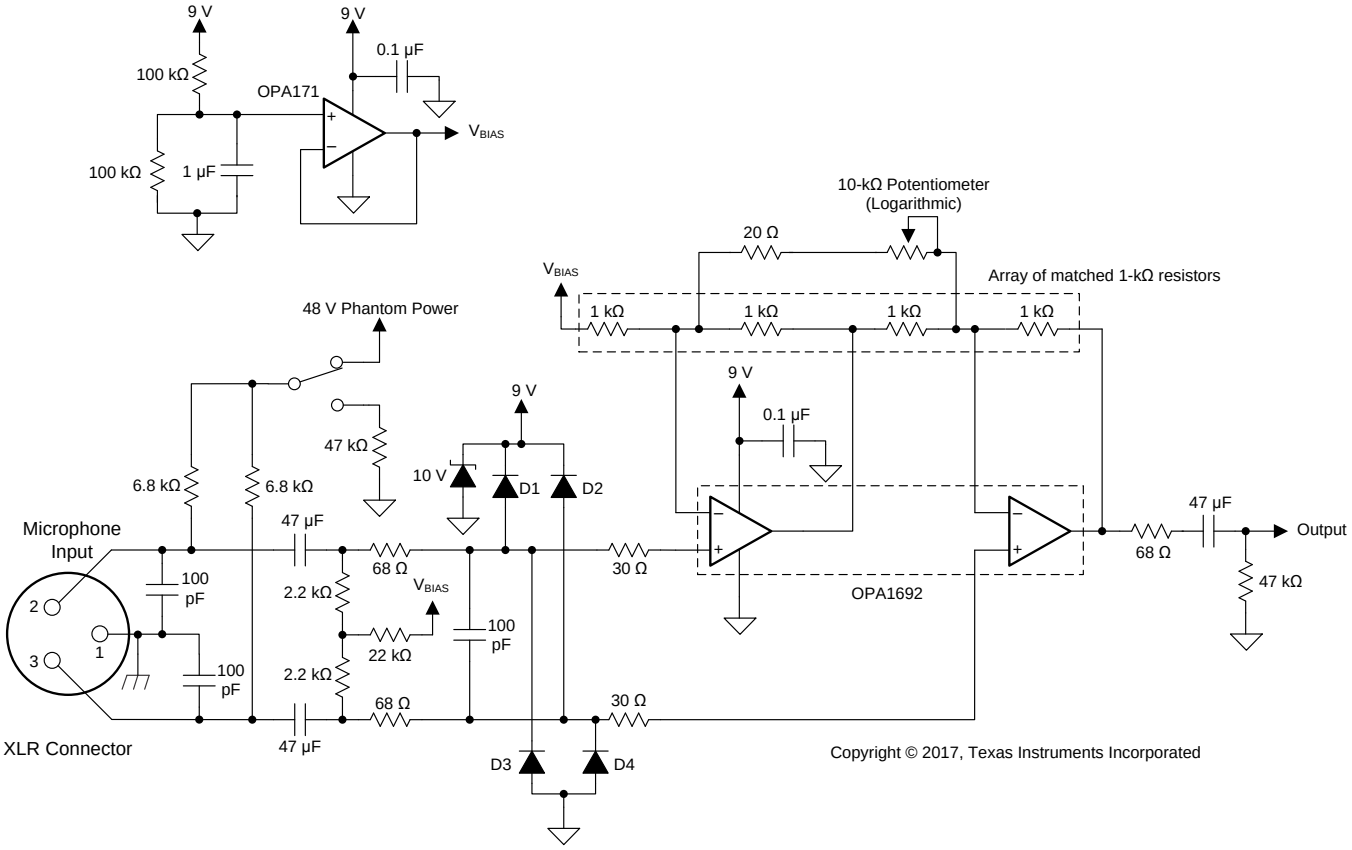


图 63. Preamplifier for Professional Microphones Powered from a 9-V Battery

9 Power Supply Recommendations

The OPA169x are specified for operation from 3.5 V to 36 V (±1.75 V to ±18 V); many specifications apply from –40°C to 125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are shown in the *Typical Characteristics* section. Applications with noisy or high-impedance power supplies require decoupling capacitors close to the device pins. In most cases, 0.1-µF capacitors are adequate.

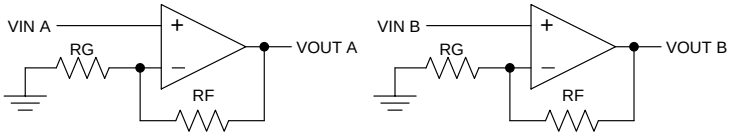
10 Layout

10.1 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 of 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-µF ceramic bypass capacitors between each supply pin and ground, placed as close as possible to the device. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of 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 electromagnetic interference (EMI) noise pickup. Physically separate digital and analog grounds, observing the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away as possible from the supply or output traces. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close as possible to the device. As shown in 图 64, keeping R_F and R_G 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.
- For best performance, TI recommends cleaning the PCB following assembly.
- Any precision integrated circuit can experience performance shifts resulting from moisture ingress into the plastic package. Following any aqueous PCB cleaning process, TI recommends baking the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

10.2 Layout Example



(Schematic Representation)

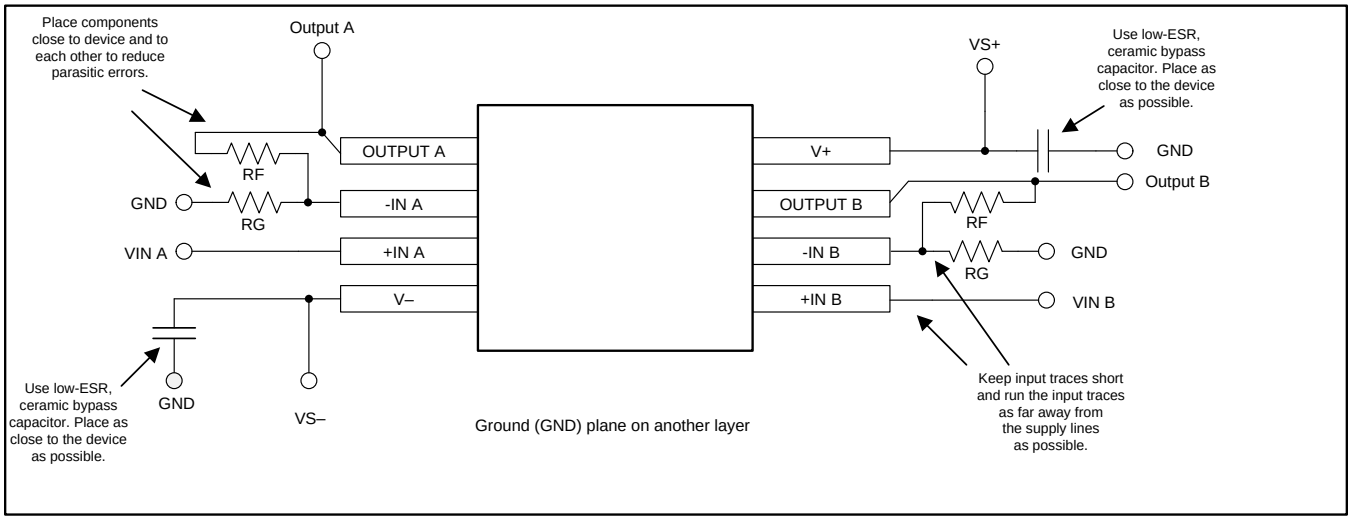


图 64. Operational Amplifier Board Layout for Noninverting Configuration

10.3 Power Dissipation

The OPA169x series op amps are capable of driving 2-kΩ loads with a power-supply voltage up to ±18 V and full operating temperature range. Internal power dissipation increases when operating at high supply voltages. Copper leadframe construction used in the OPA169x series op amps improves heat dissipation compared to conventional materials. Circuit board layouts minimize junction temperature rise. Wide copper traces help dissipate the heat by acting as an additional heat sink. Temperature rise is further minimized by soldering the devices to the circuit board rather than using a socket.

11 器件和文档支持

11.1 器件支持

11.1.1 开发支持

11.1.1.1 TINA-TI™（免费软件下载）

TINA™是一款简单、功能强大且易于使用的电路仿真程序，此程序基于 SPICE 引擎。 TINA-TI™是 TINA 软件的一款免费全功能版本，除了一系列无源和有源模型外，此版本软件还预先载入了一个宏模型库。TINA-TI 提供所有传统的 SPICE 直流 (DC)、瞬态和频域分析以及其他设计功能。

TINA-TI 可从 Analog eLab Design Center（模拟电子实验室设计中心）免费下载，它提供全面的后续处理能力，使得用户能够以多种方式形成结果。虚拟仪器提供选择输入波形和探测电路节点、电压和波形的功能，从而创建一个动态的快速入门工具。

注

这些文件需要安装 TINA 软件（由 DesignSoft™提供）或者 TINA-TI 软件。请从 TINA-TI 文件夹 中下载免费的 TINA-TI 软件。

11.1.1.2 DIP 适配器 EVM

DIP 适配器 EVM 工具提供了一种简单而低成本的方式来针对小型表面贴装 IC 进行原型设计。评估工具适用于以下 TI 封装：D 或 U (SOIC-8)、PW (TSSOP-8)、DGK (VSSOP-8)、DBV（SOT23-6、SOT23-5 和 SOT23-3）、DCK（SC70-6 和 SC70-5）以及 DRL (SOT563-6)。DIP 适配器 EVM 也可搭配引脚排使用或直接与现有电路相连。

11.1.1.3 通用运算放大器评估模块 (EVM)

通用运放 EVM 是一系列通用空白电路板，可简化采用各种 IC 封装类型的电路板原型设计。借助评估模块电路板设计，可以轻松快速地构造多种不同电路。共有 5 个模型可供选用，每个模型都对应一种特定封装类型。支持 PDIP、SOIC、VSSOP、TSSOP 和 SOT-23 封装。

注

这些电路板均为空白电路板，用户必须自行提供 IC。TI 建议您在订购通用运算放大器 EVM 时申请几个运算放大器器件样品。

11.1.1.4 智能放大器扬声器特性鉴定板评估模块

智能放大器扬声器特性鉴定板，与支持的 TI 智能放大器和 PurePath 控制台软件配合使用时，用户可测量扬声器偏移、温度和其它参数以便与 TI 智能放大器产品配合使用。

11.1.1.5 TI 高精度设计

TI 高精度设计的模拟设计方案是由 TI 公司高精度模拟实验室设计 应用 专家创建的模拟解决方案，提供了许多实用电路的工作原理、组件选择、仿真、完整印刷电路板 (PCB) 电路原理图和布局布线、物料清单以及性能测量结果。欲获取 TI 高精度设计，请访问 http://www.ti.com.cn/ww/analog/precision-designs/。

11.1.1.6 WEBENCH®滤波器设计器

WEBENCH® 滤波器设计器是一款简单、功能强大且便于使用的有源滤波器设计程序。借助 WEBENCH 滤波器设计器，用户可使用精选 TI 运算放大器和 TI 供应商合作伙伴提供的无源组件来构建最佳滤波器设计方案。

WEBENCH® 设计中心以基于网络的工具形式提供 WEBENCH® 滤波器设计器。用户通过该工具可在数分钟内完成多级有源滤波器解决方案的设计、优化和仿真。

11.2 文档支持

11.2.1 相关文档

使用 OPA169x 时，建议参考下列相关文档。所有这些文档都可从 www.ti.com.cn 上下载（除非另有说明）。

文档支持 (接下页)

- 《放大器源电阻和噪声注意事项》
- 《运算放大器的单电源操作》
- 《运算放大器性能分析》
- 《在放大器中进行调优》
- 《反馈曲线图定义运算放大器交流性能》
- 《适用于专业音频的有源音量控制》

11.3 相关链接

表 4 列出了快速访问链接。类别包括技术文档、支持与社区资源、工具与软件，以及申请样片或购买产品的快速链接。

表 4. 相关链接

器件	产品文件夹	立即订购	技术文档	工具与软件	支持和社区
OPA1692	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处

11.4 接收文档更新通知

如需接收文档更新通知，请访问 TI.com.cn 上的器件产品文件夹。单击右上角的*通知我* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查阅已修订文档中包含的修订历史记录。

11.5 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 《使用条款》。

TI E2E™ 在线社区 ***TI 的工程师对工程师 (E2E) 社区。*** **此社区的创建目的在于促进工程师之间的协作。在 e2e.ti.com 中，您可以咨询问题、分享知识、拓展思路并与同行工程师一道帮助解决问题。**

设计支持 ***TI 参考设计支持*** **可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。**

11.6 商标

SoundPlus, TINA-TI, E2E are trademarks of Texas Instruments.
WEBENCH is a registered trademark of Texas Instruments.
Bluetooth is a registered trademark of Bluetooth SIG, Inc.
TINA, DesignSoft are trademarks of DesignSoft, Inc.
All other trademarks are the property of their respective owners.

11.7 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。

11.8 术语表

SLYZ022 — *TI 术语表*。

这份术语表列出并解释术语、缩写和定义。

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此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)
OPA1692ID	Active	Production	SOIC (D) | 8	75 | TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OP1692
OPA1692IDGKR	Active	Production	VSSOP (DGK) | 8	2500 | LARGE T&R	Yes	NIPDAUAG | SN	Level-2-260C-1 YEAR	-40 to 125	1692
OPA1692IDGKT	Active	Production	VSSOP (DGK) | 8	250 | SMALL T&R	Yes	NIPDAUAG | SN	Level-2-260C-1 YEAR	-40 to 125	1692
OPA1692IDR	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OP1692

(1) **Status:** For more details on status, see our product life cycle.

(2) **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.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **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.

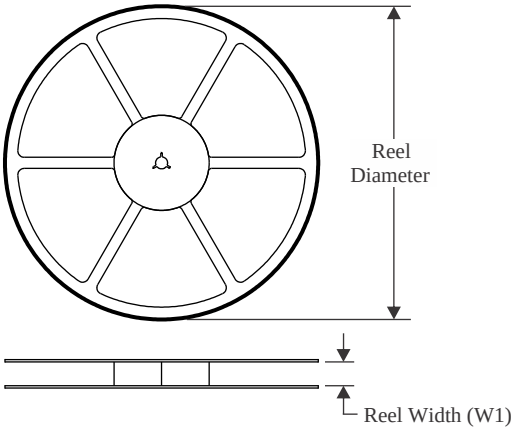
(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will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

(6) **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.

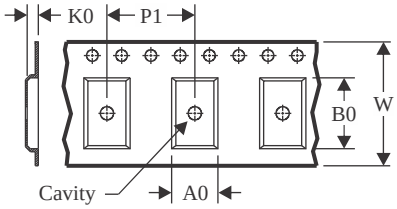
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

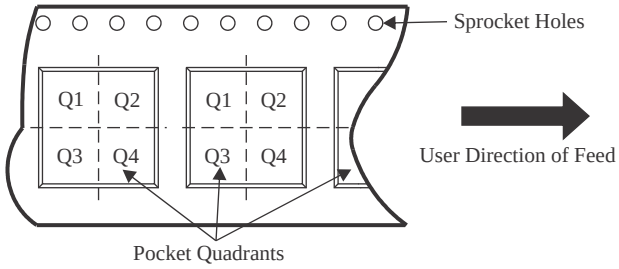


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

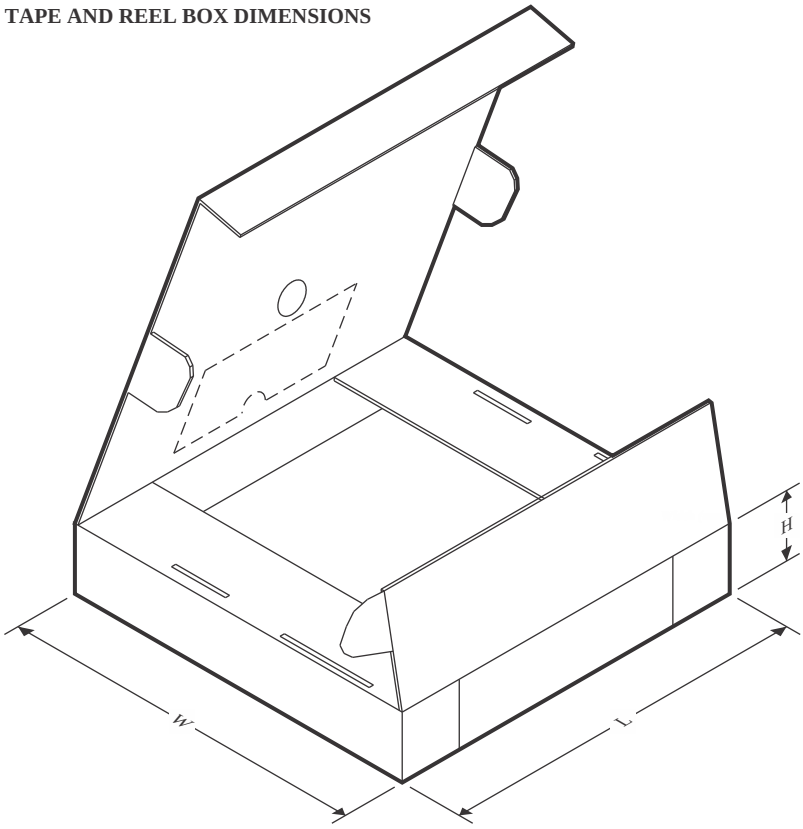
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
OPA1692IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.25	3.35	1.25	8.0	12.0	Q1
OPA1692IDGKT	VSSOP	DGK	8	250	330.0	12.4	5.25	3.35	1.25	8.0	12.0	Q1
OPA1692IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

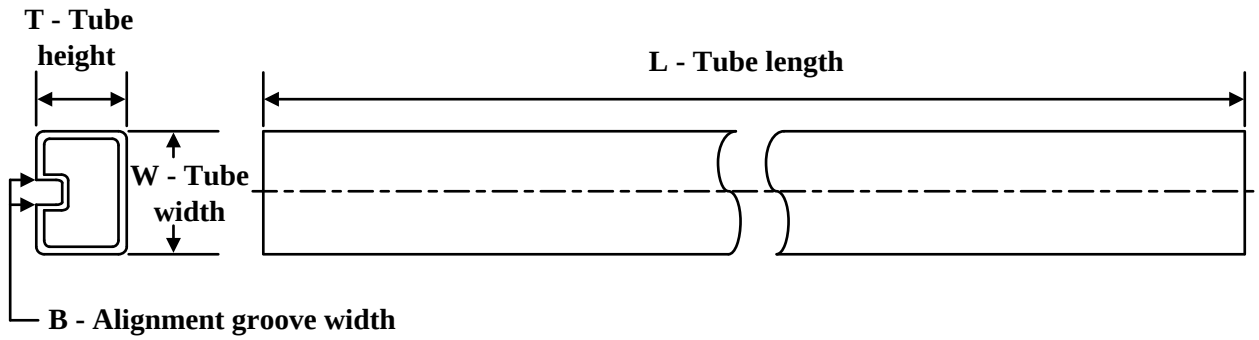
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

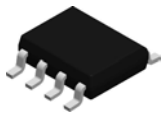
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA1692IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
OPA1692IDGKT	VSSOP	DGK	8	250	366.0	364.0	50.0
OPA1692IDR	SOIC	D	8	2500	356.0	356.0	35.0

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
OPA1692ID	D	SOIC	8	75	506.6	8	3940	4.32

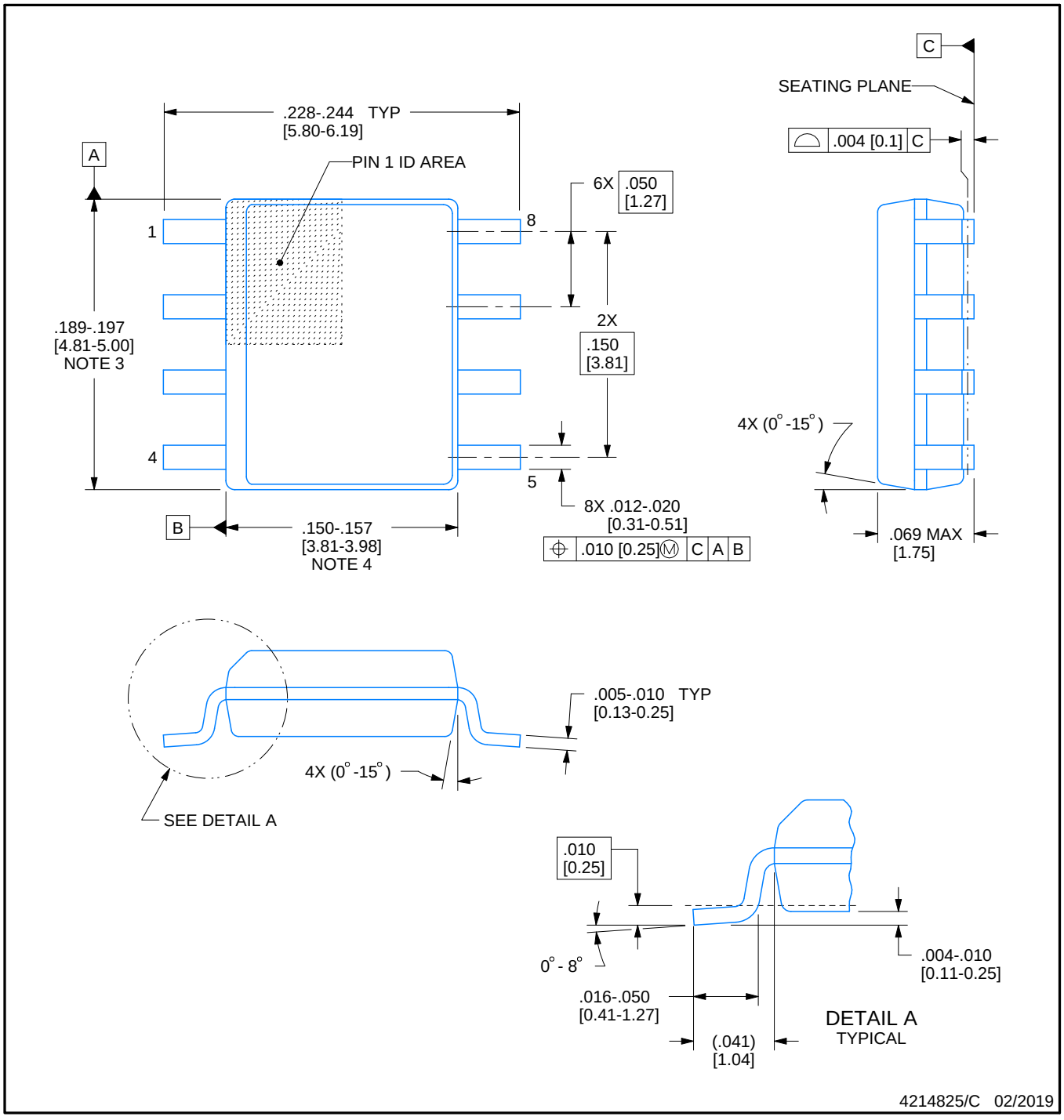


PACKAGE OUTLINE

D0008A

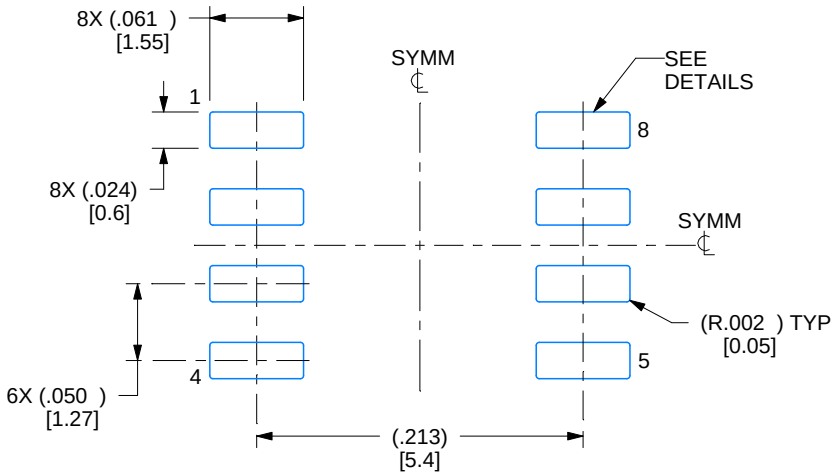
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

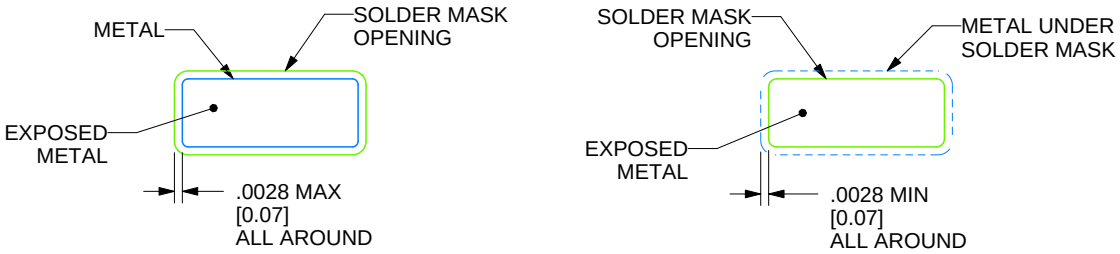


NOTES:

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

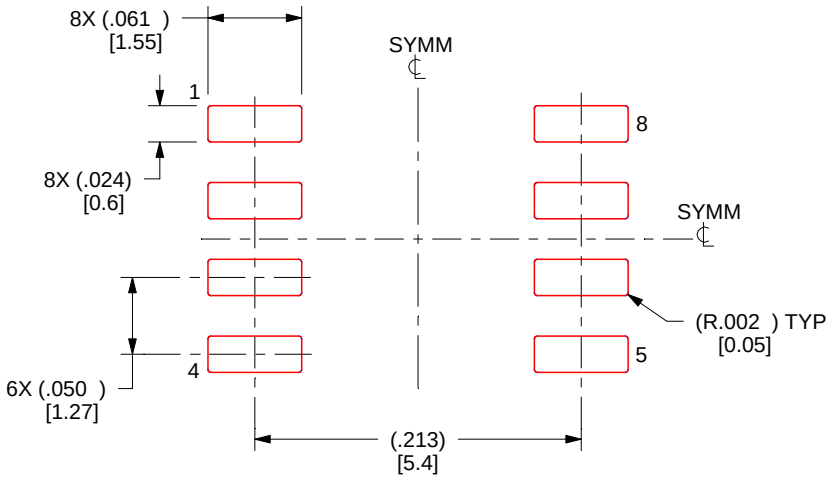
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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)

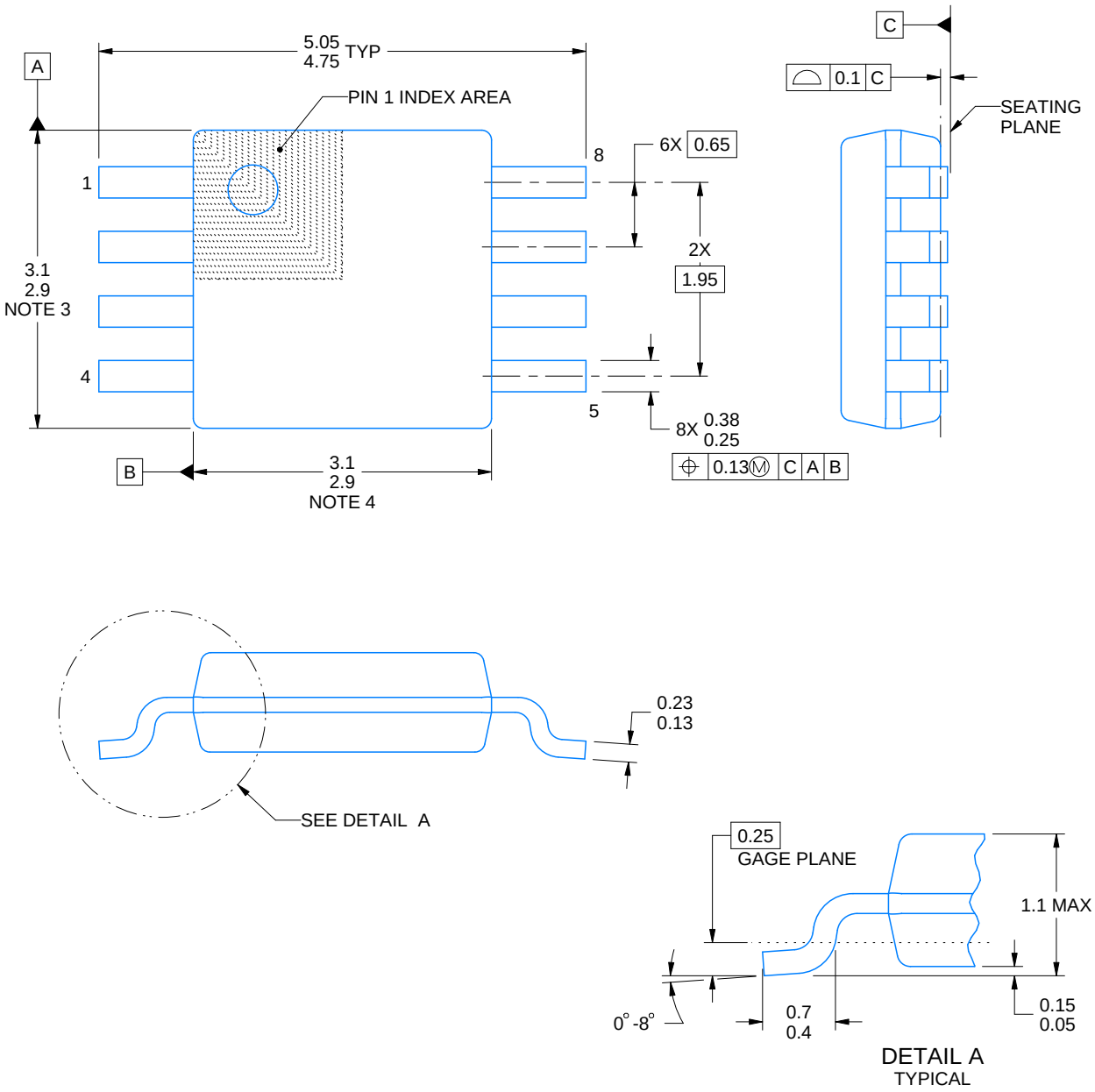
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DGK0008A

VSSOP - 1.1 mm max height

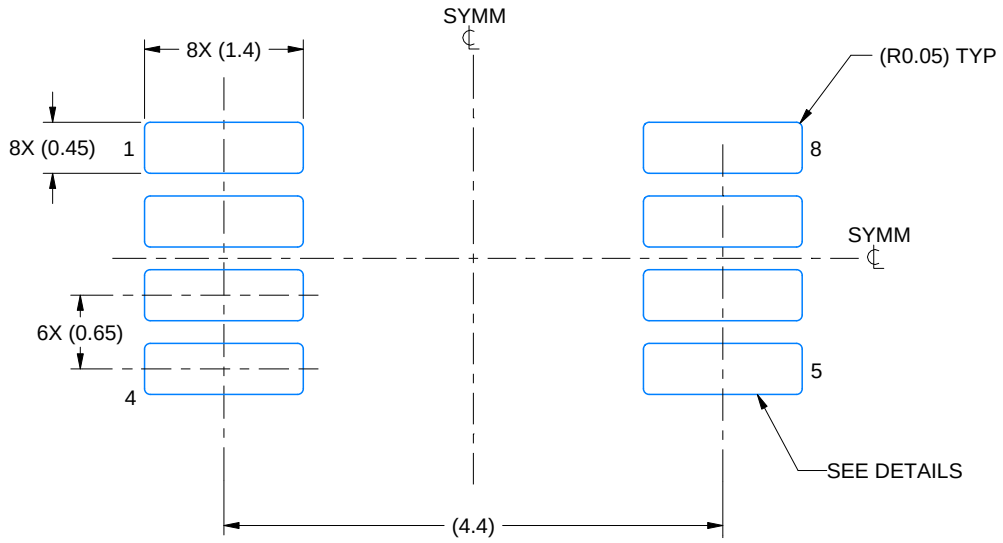
SMALL OUTLINE PACKAGE



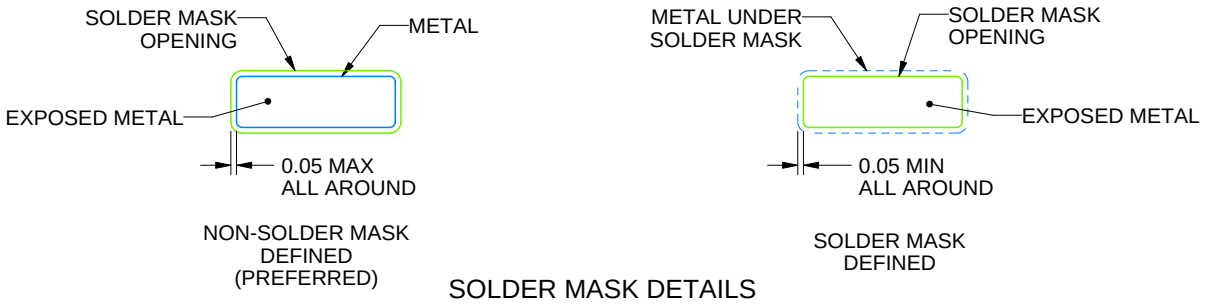
PowerPAD is a trademark of Texas Instruments.

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. 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 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

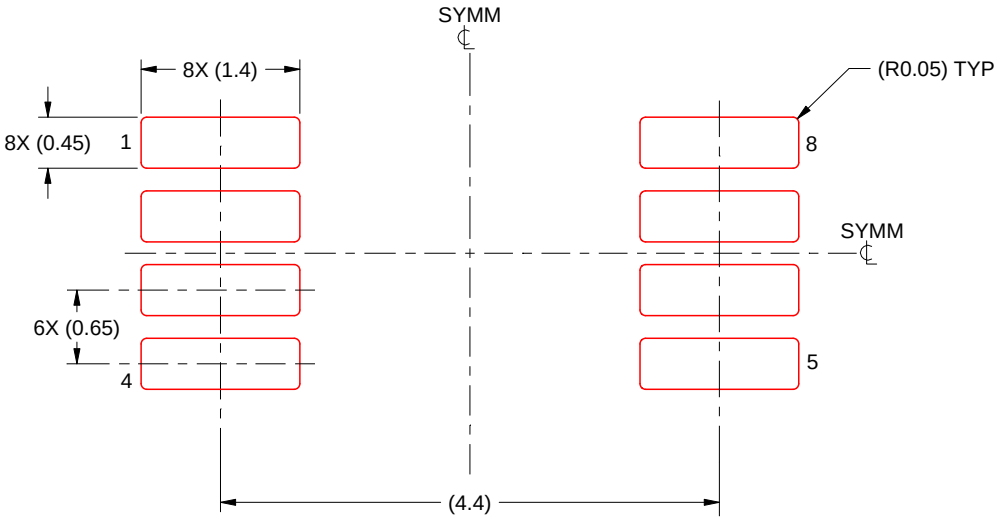


SOLDER MASK DETAILS

4214862/A 04/2023

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.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.



SOLDER PASTE EXAMPLE
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

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

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