OPA2604-Q1
DUAL FET-INPUT, LOW DISTORTION OPERATIONAL AMPLIFIER

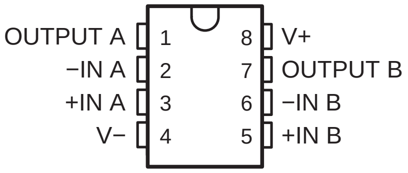
SGLS209 − NOVEMBER 2003

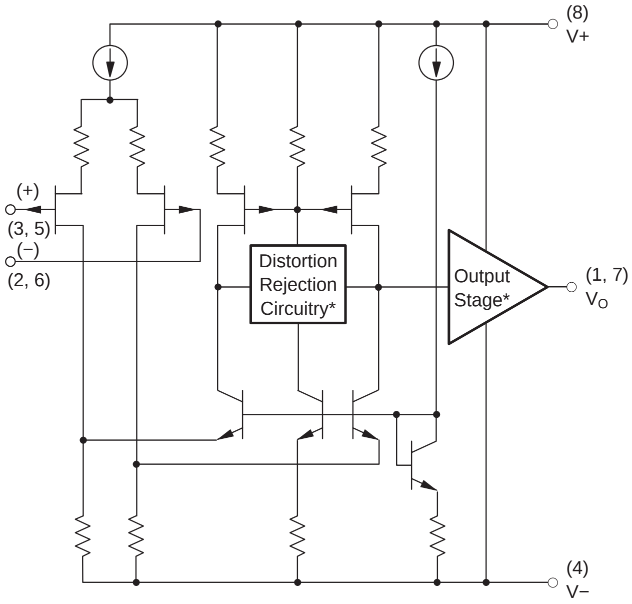
features

- **Qualification in Accordance With AEC-Q100**[†]
- **Qualified for Automotive Applications**
- **Customer-Specific Configuration Control Can Be Supported Along With Major-Change Approval**
- **Low Distortion: 0.0003% at 1 khz**
- **Low Noise: 10 nV/$\sqrt{\text{Hz}}$**
- **High Slew Rate: 25 V/μs**
- **Wide Gain-Bandwidth: 20 MHz**
- **Unity-Gain Stable**
- **Wide Supply Range: $V_S = \pm4.5$ to ±24 V**
- **Drives 600 Ω Loads**

[†] Contact factory for details. Q100 qualification data available on request.

D PACKAGE
(TOP VIEW)





* Patents Granted:
#5053718, 5019789

applications

- **Professional Audio Equipment**
- **PCM DAC I/V Converter**
- **Spectral Analysis Equipment**
- **Active Filters**
- **Transducer Amplifier**
- **Data Acquisition**

description

The OPA2604 is a dual, FET-input operational amplifier designed for enhanced AC performance. Very low distortion, low noise and wide bandwidth provide superior performance in high quality audio and other applications requiring excellent dynamic performance.

New circuit techniques and special laser trimming of dynamic circuit performance yield very low harmonic distortion. The result is an op amp with exceptional sound quality. The low-noise FET input of the OPA2604 provides wide dynamic range, even with high source impedance. Offset voltage is laser-trimmed to minimize the need for interstage coupling capacitors.

The OPA2604 is available in a SO-8 surface-mount package, specified for the −40°C to +85°C temperature range.

ORDERING INFORMATION

T_A	PACKAGE[‡]		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 85°C	SOIC - D	Tape and reel	OPA2604IDRQ1	2604Q1

[‡] Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Power supply voltage	±25 V
Input voltage, V_{IN}	⟨V−) − 1 V to (V+) + 1 V
Output short circuit to ground	Continuous
Operating free-air temperature range, T_A	−40°C to 100°C
Storage temperature range, T_{stg}	−40°C to 125°C
Package thermal impedance, θ_{JA} (see Note 1): D package	90°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 3 seconds	260°C
Junction temperature, T_J	150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Operating voltage	±4.5	±15	±24	V
Operating free-air temperature	−40		85	°C

electrical characteristics, T_A = 25°C, V_S = ±15 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Offset Voltage					
Input offset voltage (V_{IO})			±1	±5	mV
Average drift			±8		μV/°C
Power supply rejection ratio (PSRR)	V_S = ±5 V to ±24 V	70	80		dB
Input Bias Current (See Note 1)					
Input bias current (I_{IB})	V_{CM} = 0 V		100		pA
Input offset current (I_{IO})	V_{CM} = 0 V		±4		pA
Noise					
Input noise, voltage noise density	f = 10 Hz		25		$\mathrm{nV}/\sqrt{\mathrm{Hz}}$
	f = 100 Hz		15		
	f = 1 kHz		11		
	f = 10 kHz		10		
Voltage noise	BW = 20 Hz to 20 kHz		1.5		μV_{p-p}
Input bias current noise density	f = 0.1 Hz to 20 kHz		6		$\mathrm{fA}/\sqrt{\mathrm{Hz}}$
Input Voltage Range					
Common-mode input voltage range (V_{ICR})		±12	±13		V
Common-mode rejection ratio (CMRR)	V_{CM} = ±12 V	80	100		dB
Input Impedance					
Input impedance, differential mode			10^{12} 8		Ω pF
Input impedance, common mode			10^{12} 10		Ω pF
Open-loop Gain					
Open-loop voltage gain (A_{VOL})	V_O = ±10 V, R_L = 1 kΩ	80	100		dB
Frequency Response					
Gain bandwidth product	G = 100		20		MHz
Slew rate	20 V_{p-p}, R_L = 1 kΩ	15	25		V/μs
Settling time to 0.01%	G = −1, 10 V step		1.5		μs
Settling time to 0.1%			1		μs
Total Harmonic Distortion + Noise (THD+N)	G = 1, f = 1 kHz, V_O = 3.5 Vrms, R_L = 1 kΩ		0.0003		%
Channel separation	f = 1 kHz, R_L = 1 kΩ		142		dB
Output					
Output voltage range (V_{OH}, V_{OL})	R_L = 600 Ω	±11	±12		V
Output current (I_O)	V_O = ±12 V		±35		mA
Output short circuit current (I_{OS})			±40		mA
Open-loop output resistance			25		Ω
Power Supply					
Total current. both amplifiers (I_{CC})	I_O = 0		±10.5	±12	mA

NOTE 1: Typical performance, measured fully warmed-up.

TYPICAL CHARACTERISTICS

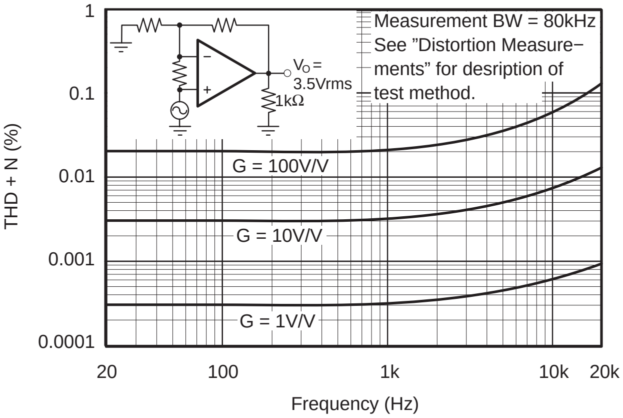

TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY

Figure 1

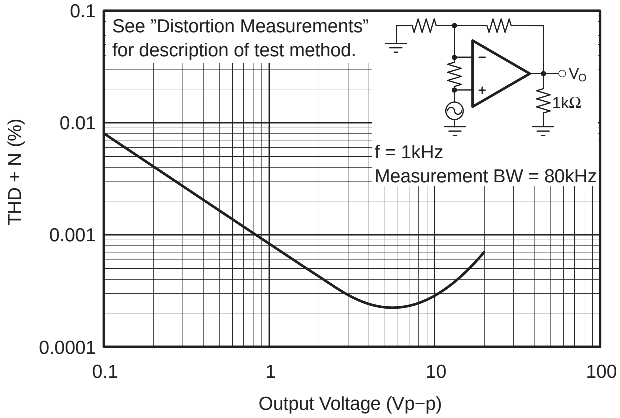

TOTAL HARMONIC DISTORTION + NOISE vs OUTPUT VOLTAGE

Figure 2

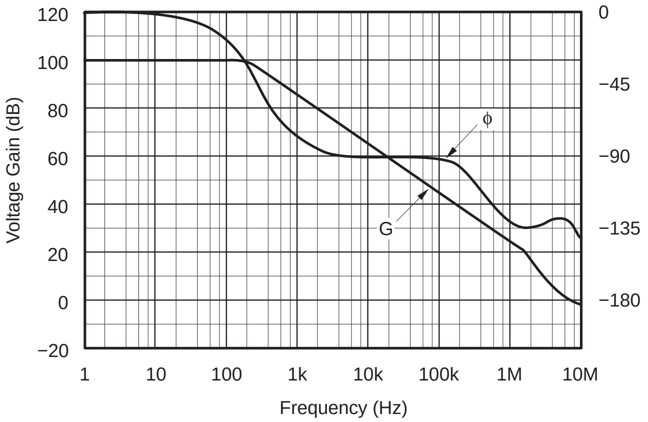

OPEN−LOOP GAIN/PHASE vs FREQUENCY

Figure 3

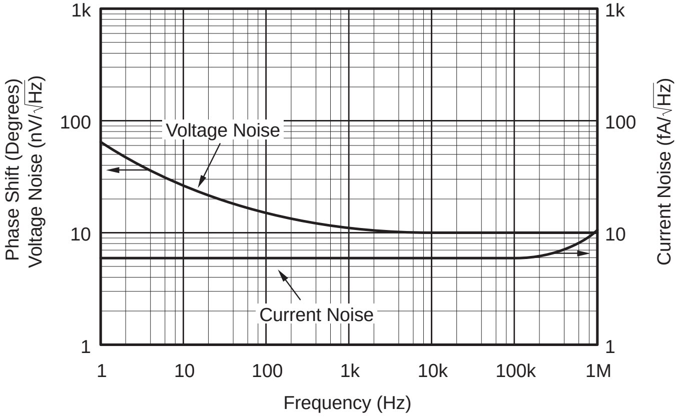

INPUT VOLTAGE AND CURRENT NOISE SPECTRAL DENSITY vs FREQUENCY

Figure 4

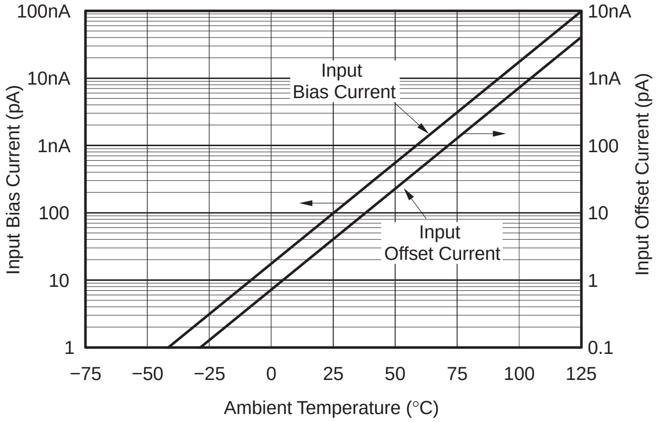

INPUT BIAS AND INPUT OFFSET CURRENT vs TEMPERATURE

Figure 5

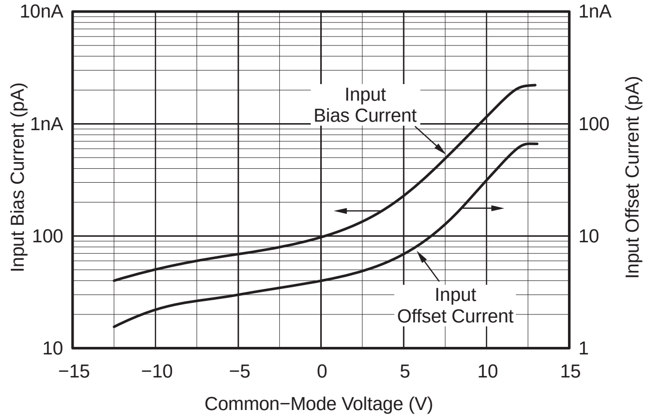

INPUT BIAS AND INPUT OFFSET CURRENT vs INPUT COMMON−MODE VOLTAGE

Figure 6

TYPICAL CHARACTERISTICS

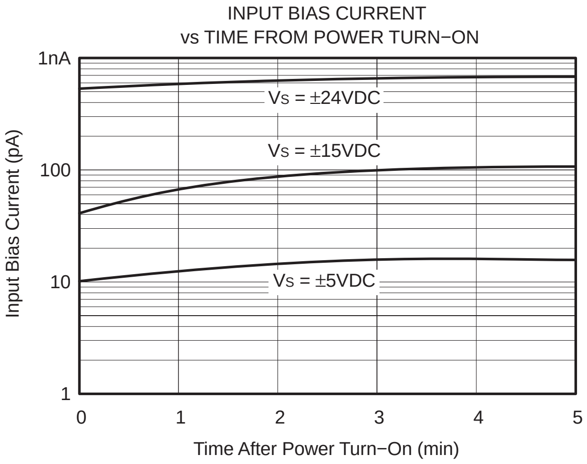


Figure 7

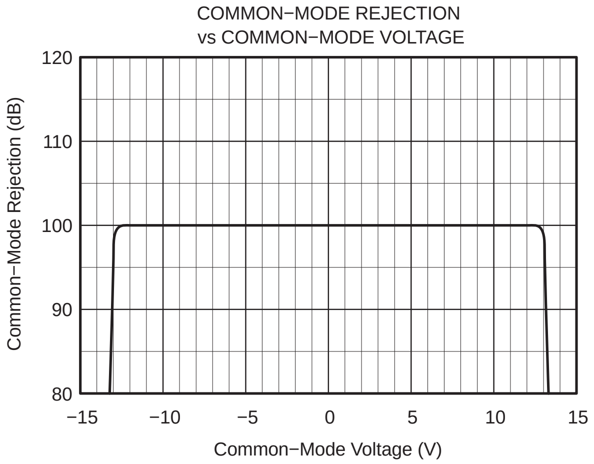


Figure 8

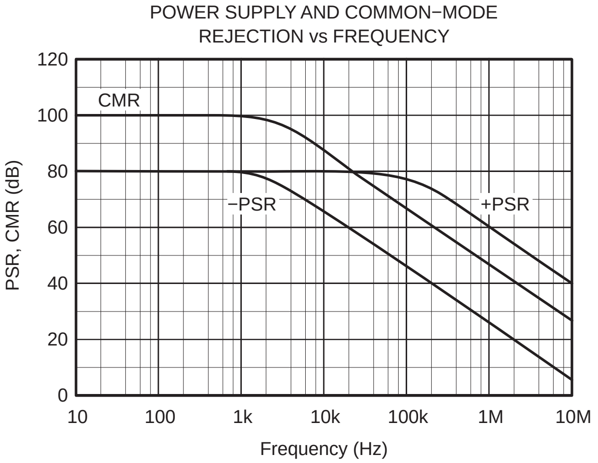


Figure 9

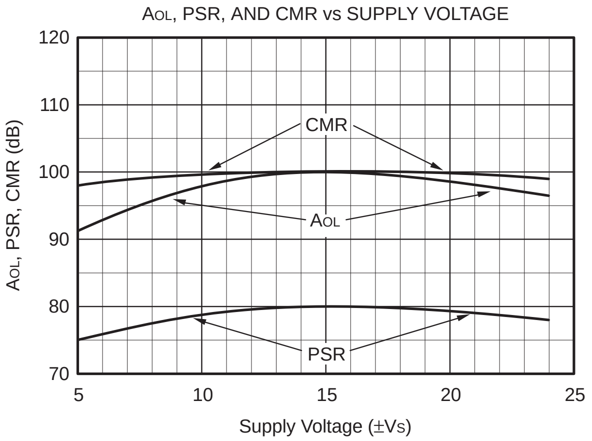


Figure 10

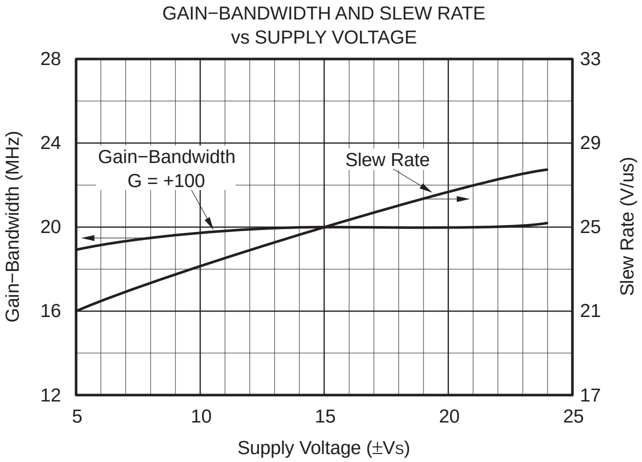


Figure 11

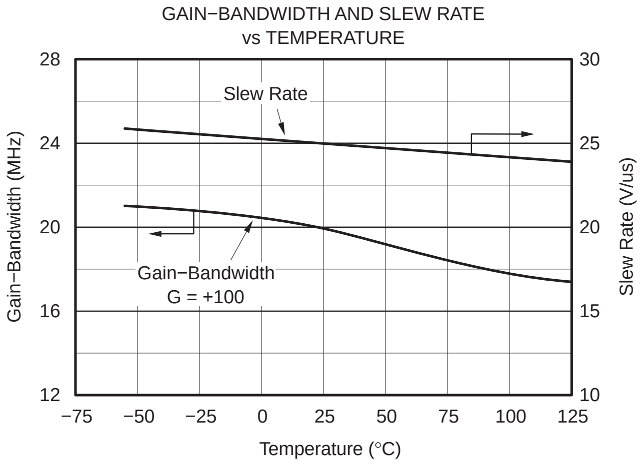


Figure 12

TYPICAL CHARACTERISTICS

SETTLING TIME vs CLOSED−LOOP GAIN

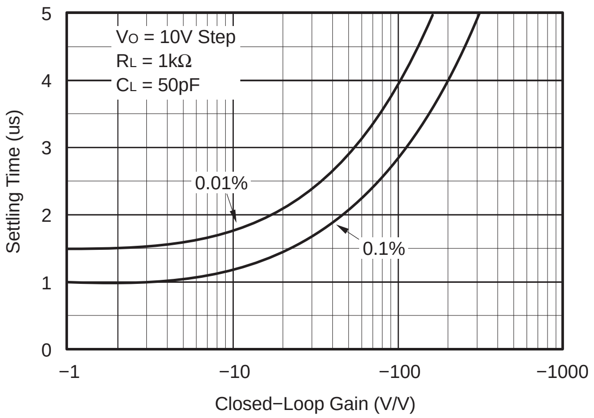


Figure 13

CHANNEL SEPARATION vs FREQUENCY

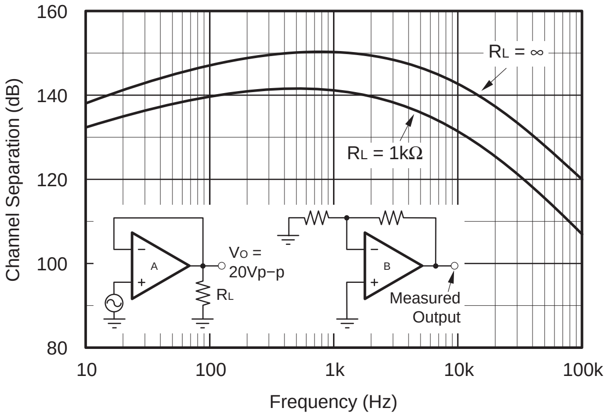


Figure 14

MAXIMUM OUTPUT VOLTAGE SWING vs FREQUENCY

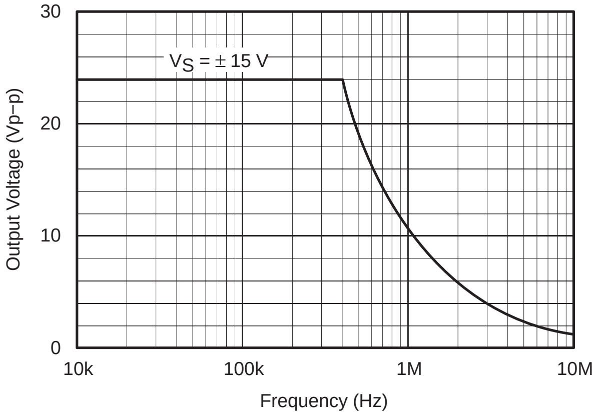


Figure 15

SUPPLY CURRENT vs TEMPERATURE

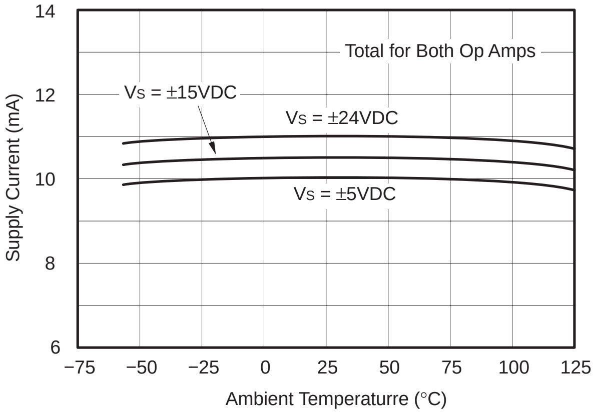


Figure 16

LARGE−SIGNAL TRANSIENT RESPONSE

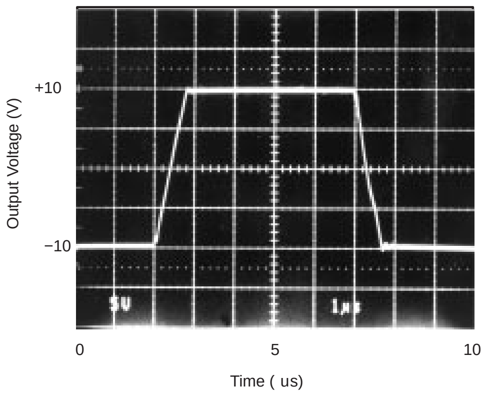


Figure 17

SMALL−SIGNAL TRANSIENT RESPONSE

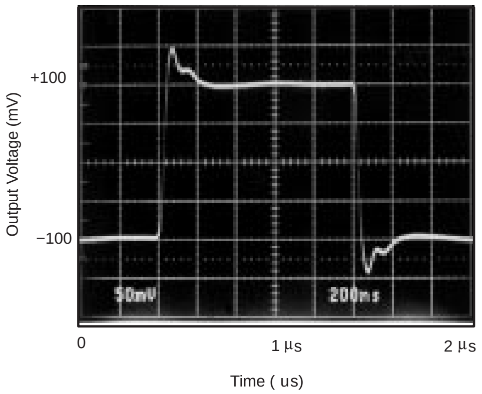


Figure 18

TYPICAL CHARACTERISTICS

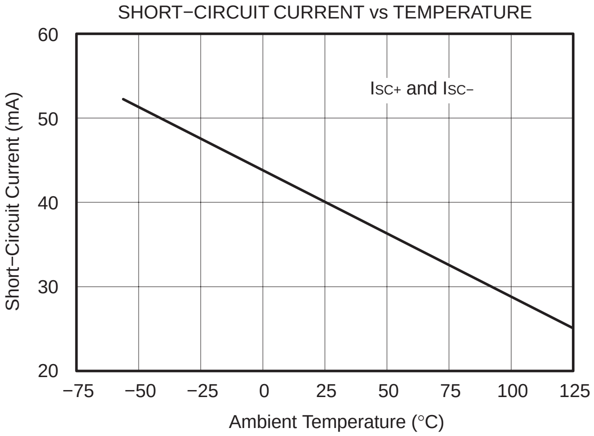


Figure 19

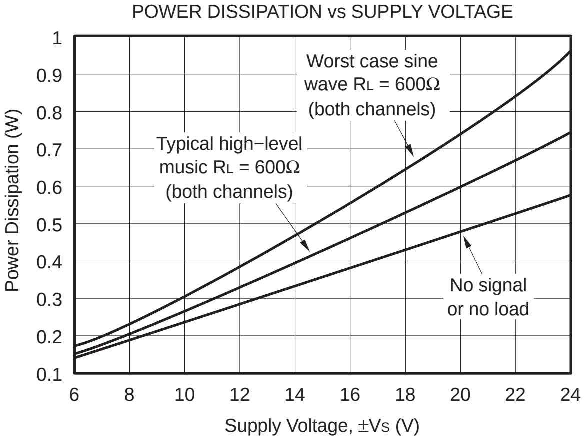


Figure 20

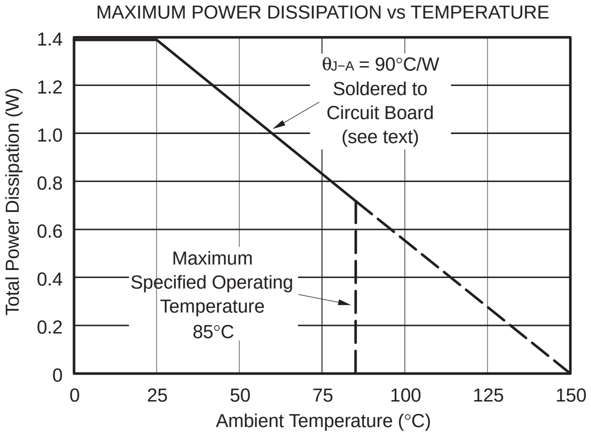


Figure 21

APPLICATION INFORMATION

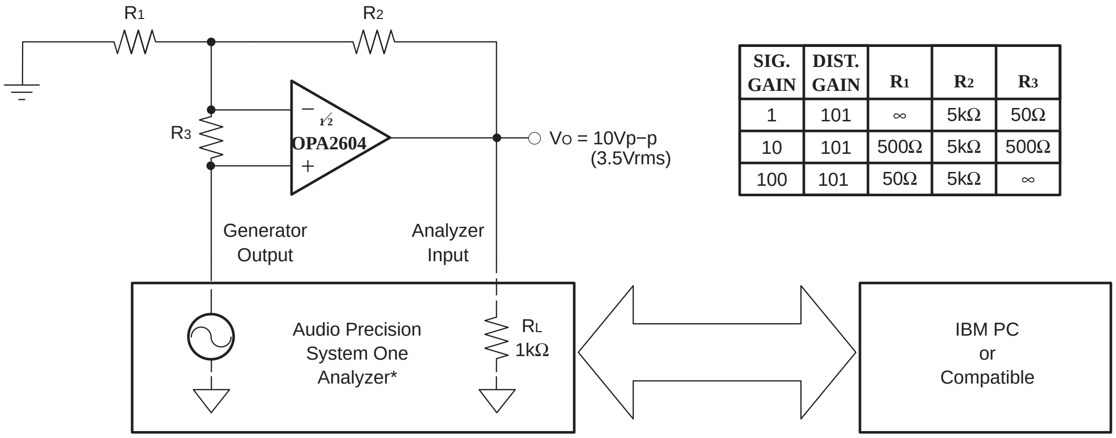
The OPA2604 is unity-gain stable, making it easy to use in a wide range of circuitry. Applications with noisy or high impedance power supply lines may require decoupling capacitors close to the device pins. In most cases 1 µF tantalum capacitors are adequate.

distortion measurements

The distortion produced by the OPA2604 is below the measurement limit of virtually all commercially available equipment. A special test circuit, however, can be used to extend the measurement capabilities.

Op amp distortion can be considered an internal error source which can be referred to the input. Figure 22 shows a circuit which causes the op amp distortion to be 101 times greater than normally produced by the op amp. The addition of R_3 to the otherwise standard non-inverting 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. This extends the measurement limit, including the effects of the signal-source purity, by a factor of 101. Note that the input signal and load applied to the op amp are the same as with conventional feedback without R_3.

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 the Audio Precision System One which greatly simplifies such repetitive measurements. The measurement technique can, however, be performed with manual distortion measurement instruments.



SIG. GAIN	DIST. GAIN	R_1	R_2	R_3
1	101	∞	5kΩ	50Ω
10	101	500Ω	5kΩ	500Ω
100	101	50Ω	5kΩ	∞

* Measurement BW = 80kHz

Figure 22. Distortion Test Circuit

capacitive loads

The dynamic characteristics of the OPA2604 have been optimized for commonly encountered gains, loads and operating conditions. The combination of low closed-loop gain and capacitive load will decrease the phase margin and may lead to gain peaking or oscillations. Load capacitance reacts with the op amp’s open-loop output resistance to form an additional pole in the feedback loop. Figure 23 shows various circuits which preserve phase margin with capacitive load. Request Application Bulletin AB-028 for details of analysis techniques and applications circuits.

For the unity-gain buffer, Figure a, stability is preserved by adding a phase-lead network, R_C and C_C. Voltage drop across R_C will reduce output voltage swing with heavy loads. An alternate circuit, Figure b, does not limit the output with low load impedance. It provides a small amount of positive feed-back to reduce the net feedback factor. Input impedance of this circuit falls at high frequency as op amp gain rolloff reduces the bootstrap action on the compensation network.

Figures c and d show compensation techniques for noninverting amplifiers. Like the follower circuits, the circuit in Figure d eliminates voltage drop due to load current, but at the penalty of somewhat reduced input impedance at high frequency.

Figures e and f show input lead compensation networks for inverting and difference amplifier configurations.

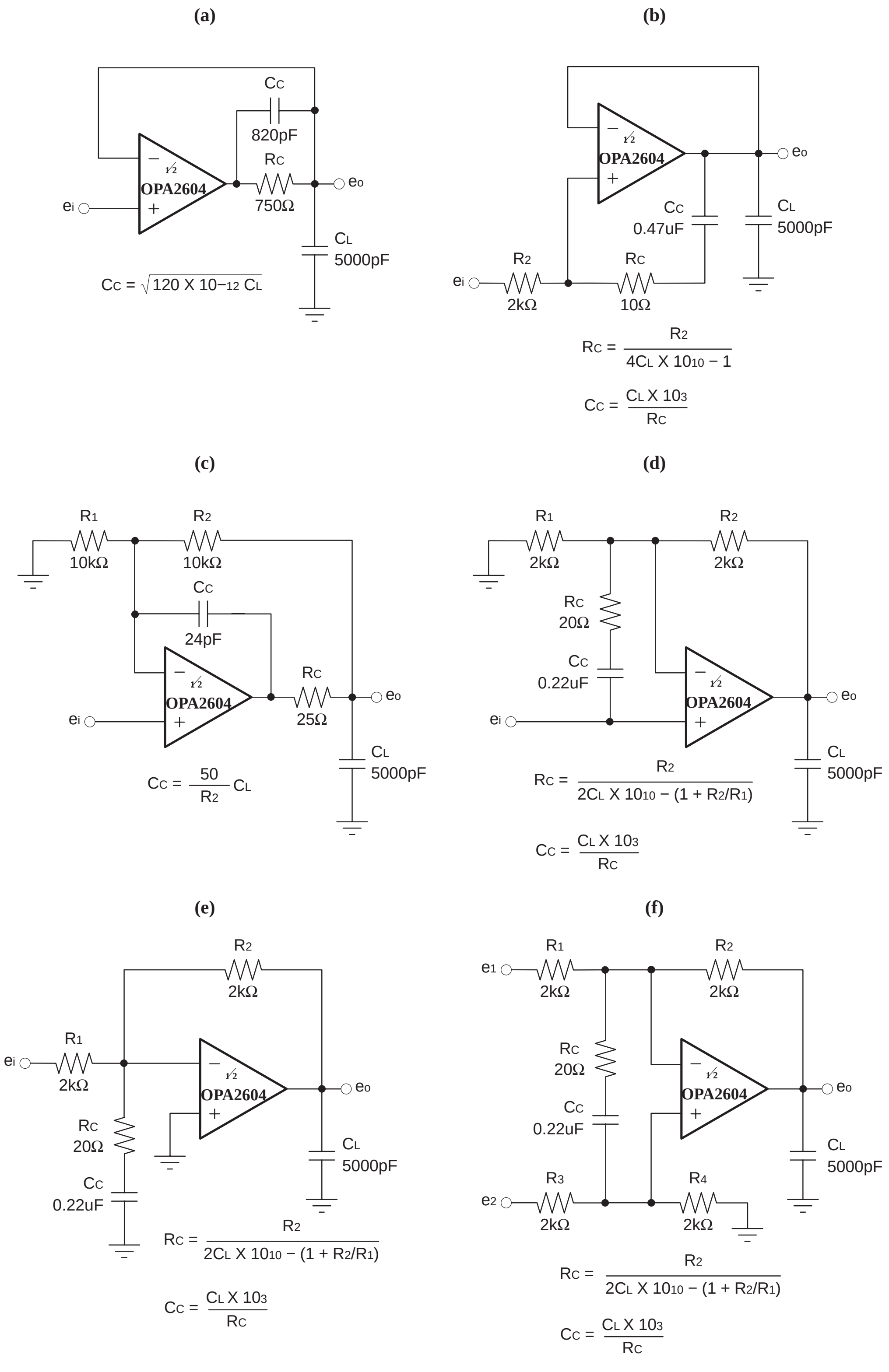


Figure 23. Driving Large Capacitive Loads

noise performance

Op amp noise is described by two parameters − noise voltage and noise current. The voltage noise determines the noise performance with low source impedance. Low noise bipolar-input op amps such as the OPA27 and OPA37 provide very low voltage noise. But if source impedance is greater than a few thousand ohms, the current noise of bipolar-input op amps react with the source impedance and will dominate. At a few thousand ohms source impedance and above, the OPA2604 will generally provide lower noise.

power dissipation

The OPA2604 is capable of driving 600 Ω loads with power supply voltages up to ±24 V. Internal power dissipation is increased when operating at high power supply voltage. The typical performance curve, Power Dissipation vs Power Supply Voltage, shows quiescent dissipation (no signal or no load) as well as dissipation with a worst case continuous sine wave. Continuous high-level music signals typically produce dissipation significantly less than worst case sine waves.

Copper leadframe construction used in the OPA2604 improves heat dissipation compared to conventional plastic packages. To achieve best heat dissipation, solder the device directly to the circuit board and use wide circuit board traces.

output current limit

Output current is limited by internal circuitry to approximately ±40 mA at 25°C. The limit current decreases with increasing temperature as shown in the typical curves.

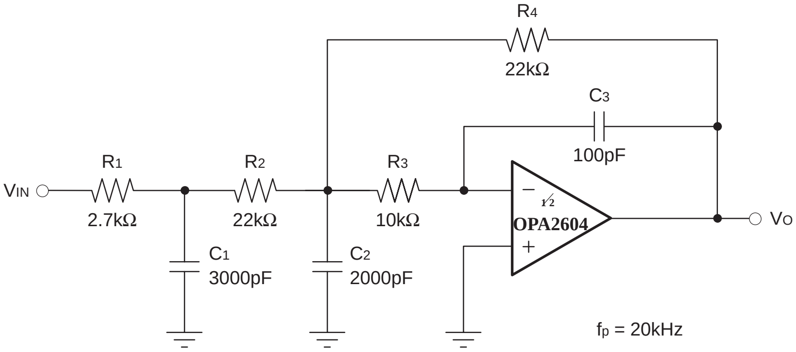
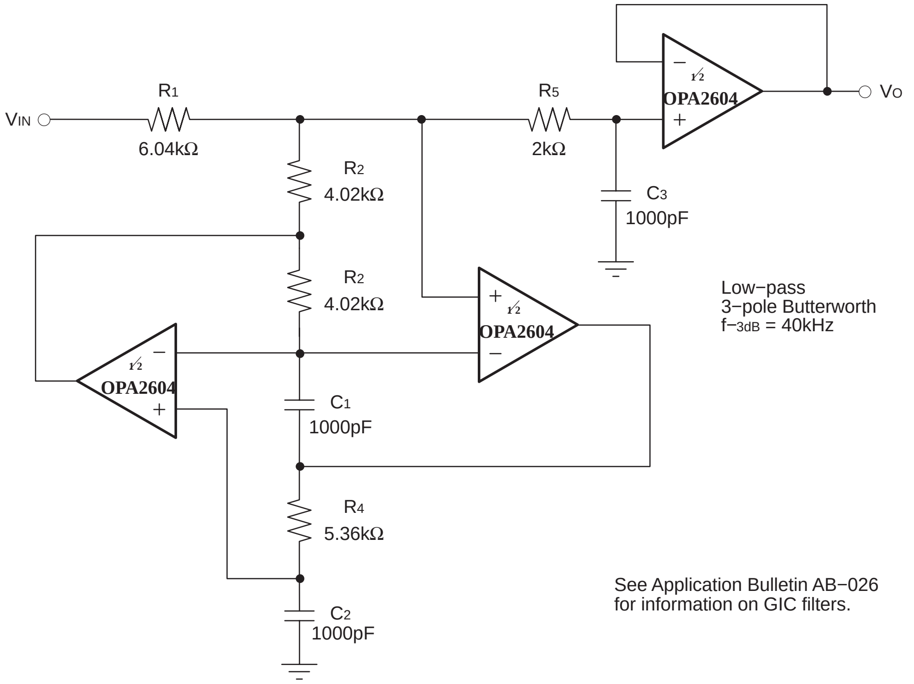


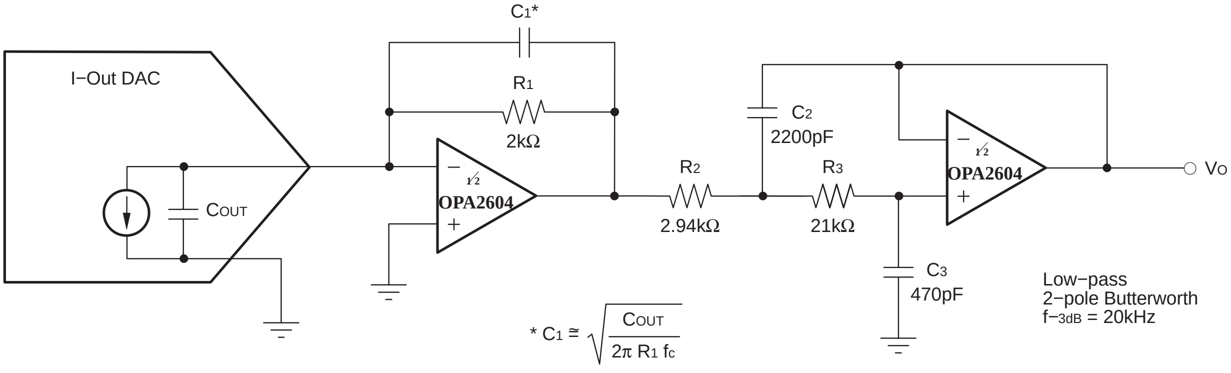
Figure 24. Three-Pole Low-Pass Filter



Low−pass
3−pole Butterworth
f_{-3dB} = 40kHz

See Application Bulletin AB−026
for information on GIC filters.

Figure 25. Three-Pole Generalized Immittance Converter (GIC) Low-Pass Filter



Low−pass
2−pole Butterworth
f_{-3dB} = 20kHz

$$* \ C_1 \cong \sqrt{\frac{C_{OUT}}{2\pi R_1 f_c}}$$

R_1 = Feedback resistance = 2kΩ
f_c = Crossover frequency = 8MHz

Figure 26. DAC I/V Amplifier and Low-Pass Filter

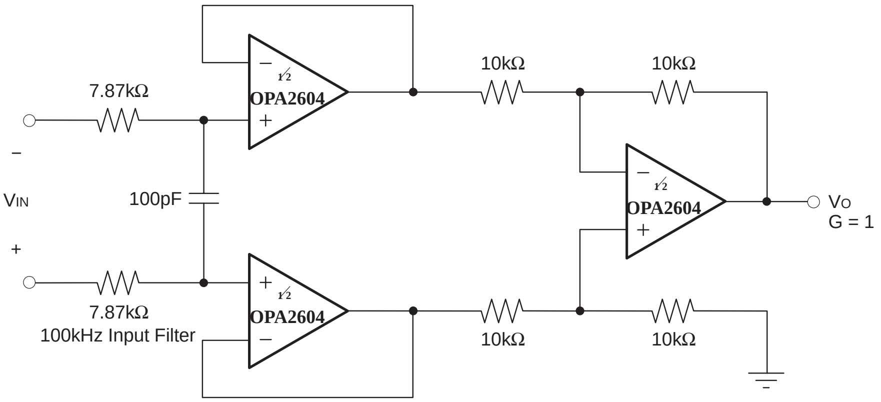


Figure 27. Differential Amplifier with Low-Pass Filter

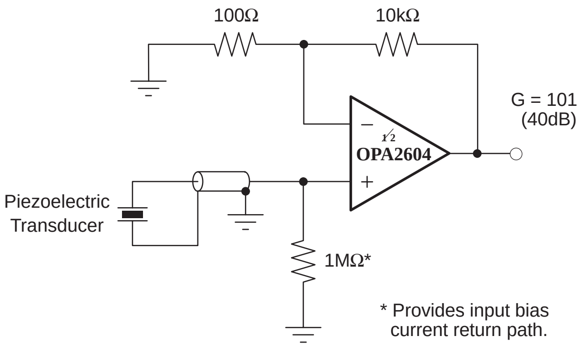


Figure 28. High Impedance Amplifier

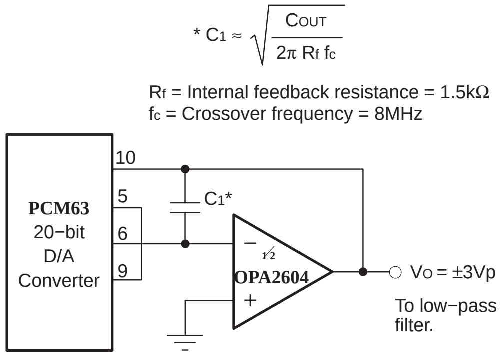


Figure 29. Digital Audio DAC I-V Amplifier

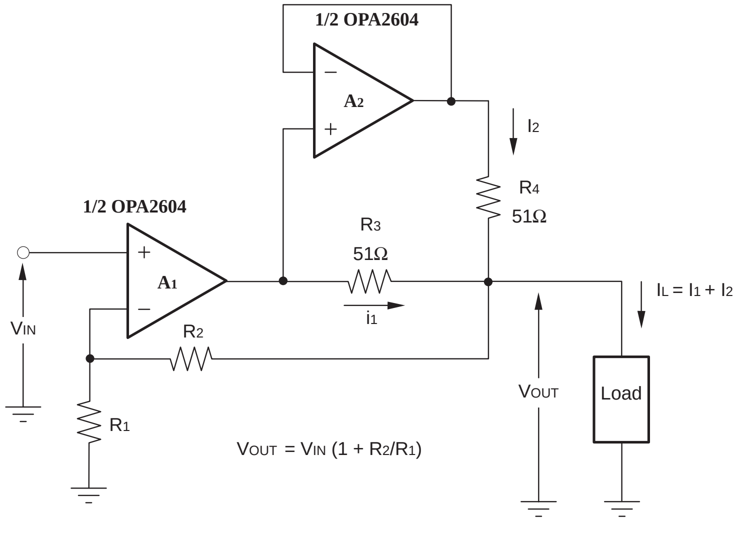


Figure 30. Using the Dual OPA2604 Op Amp to Double the Output Current to a Load

PACKAGE OPTION ADDENDUM

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
OPA2604IDRQ1	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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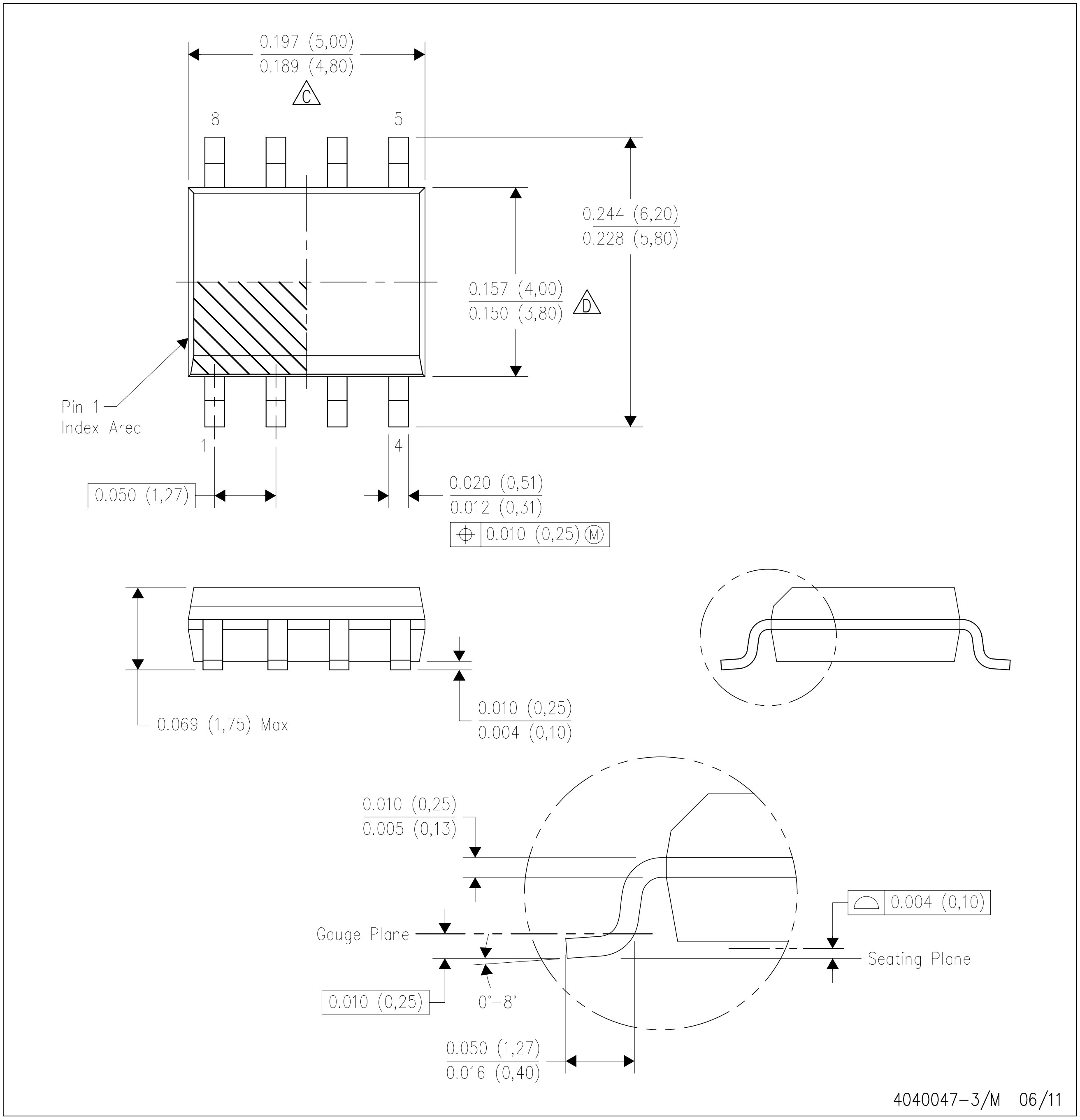
OTHER QUALIFIED VERSIONS OF OPA2604-Q1 :
- Catalog: OPA2604

NOTE: Qualified Version Definitions:
  - Catalog - TI's standard catalog product

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- △C Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- △D Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS–012 variation AA.

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