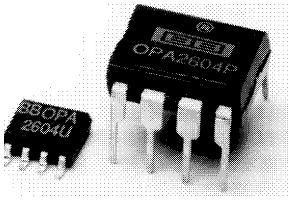
BURR - BROWN®

OPA2604



Dual FET-Input, Low Distortion OPERATIONAL AMPLIFIER

FEATURES

- LOW DISTORTION: 0.0003% at 1kHz
- LOW NOISE: 10nV/√Hz
- HIGH SLEW RATE: 25V/µs
- WIDE GAIN-BANDWIDTH: 20MHz
- UNITY-GAIN STABLE
- WIDE SUPPLY RANGE: V_S = ±4.5 to ±24V
- DRIVES 600Ω LOADS

APPLICATIONS

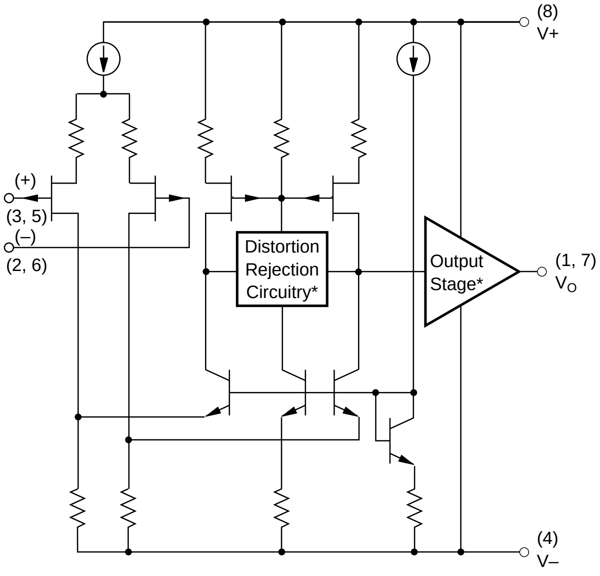
- PROFESSIONAL AUDIO EQUIPMENT
- PCM DAC I/V CONVERTER
- SPECTRAL ANALYSIS EQUIPMENT
- ACTIVE FILTERS
- TRANSDUCER AMPLIFIER
- DATA ACQUISITION

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 8-pin plastic mini-DIP and SO-8 surface-mount packages, specified for the –25°C to +85°C temperature range.



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PDS-1069D

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SPECIFICATIONS

ELECTRICAL

T_A = +25°C, V_S = ±15V unless otherwise noted.

		OPA2604AP, AU			
PARAMETER	**CONDITION**	**MIN**	**TYP**	**MAX**	**UNITS**
OFFSET VOLTAGE					
Input Offset Voltage			±1	±5	mV
Average Drift			±8		µV/°C
Power Supply Rejection	V_S = ±5 to ±24V	80	100		dB
INPUT BIAS CURRENT(1)					
Input Bias Current	V_{CM} = 0V		100		pA
Input Offset Current	V_{CM} = 0V		±4		pA
NOISE					
Input Voltage Noise					
Noise Density: f = 10Hz			25		nV/√Hz
f = 100Hz			15		nV/√Hz
f = 1kHz			11		nV/√Hz
f = 10kHz			10		nV/√Hz
Voltage Noise, BW = 20Hz to 20kHz			1.5		µVp-p
Input Bias Current Noise					
Current Noise Density, f = 0.1Hz to 20kHz			6		fA/√Hz
INPUT VOLTAGE RANGE					
Common-Mode Input Range		±12	±13		V
Common-Mode Rejection	V_{CM} = ±12V	80	100		dB
INPUT IMPEDANCE					
Differential			10^{12} || 8		Ω || pF
Common-Mode			10^{12} || 10		Ω || pF
OPEN-LOOP GAIN					
Open-Loop Voltage Gain	V_O = ±10V, R_L = 1kΩ	80	100		dB
FREQUENCY RESPONSE					
Gain-Bandwidth Product	G = 100		20		MHz
Slew Rate	20Vp-p, R_L = 1kΩ	15	25		V/µs
Settling Time: 0.01%	G = –1, 10V Step		1.5		µs
0.1%			1		µs
Total Harmonic Distortion + Noise (THD+N)	G = 1, f = 1kHz V_O = 3.5Vrms, R_L = 1kΩ		0.0003		%
Channel Separation	f = 1kHz, R_L = 1kΩ		142		dB
OUTPUT					
Voltage Output	R_L = 600Ω	±11	±12		V
Current Output	V_O = ±12V		±35		mA
Short Circuit Current			±40		mA
Output Resistance, Open-Loop			25		*W*
POWER SUPPLY					
Specified Operating Voltage			±15		V
Operating Voltage Range		±4.5		±24	V
Current, Total Both Amplifiers			±10.5	±12	mA
TEMPERATURE RANGE					
Specification		–25		+85	°C
Storage		–40		+125	°C
Thermal Resistance(2), θ_{JA}			90		°C/W

NOTES: (1) Typical performance, measured fully warmed-up. (2) Soldered to circuit board—see text.

ABSOLUTE MAXIMUM RATINGS

Power Supply Voltage	±25V
Input Voltage	(V–)–1V to (V+)+1V
Output Short Circuit to Ground	Continuous
Operating Temperature	–40°C to +100°C
Storage Temperature	–40°C to +125°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s) AP	+300°C
Lead Temperature (soldering, 3s) AU	+260°C

PACKAGING INFORMATION

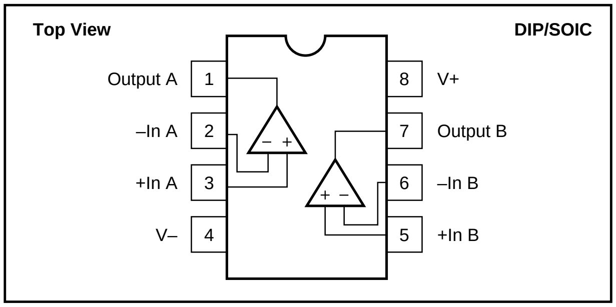
MODEL	PACKAGE	PACKAGE DRAWING NUMBER(1)
OPA2604AP	8-Pin Plastic DIP	006
OPA2604AU	SO-8 Surface-Mount	182

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

ORDERING INFORMATION

MODEL	PACKAGE	TEMP. RANGE
OPA2604AP	8-Pin Plastic DIP	–25°C to +85°C
OPA2604AU	SO-8 Surface-Mount	–25°C to +85°C

PIN CONFIGURATION



ELECTROSTATIC DISCHARGE SENSITIVITY

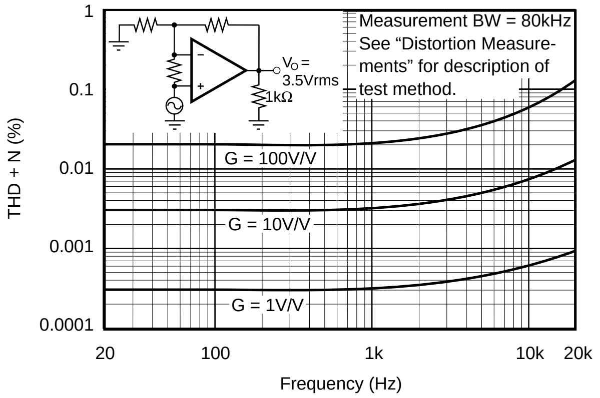
Any integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet published specifications.

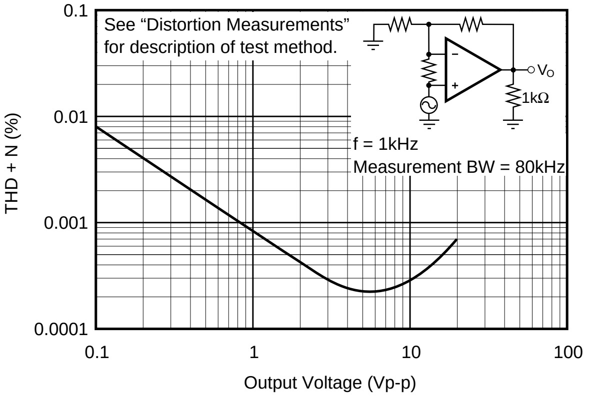
TYPICAL PERFORMANCE CURVES

T_A = +25°C, V_S = ±15V unless otherwise noted.

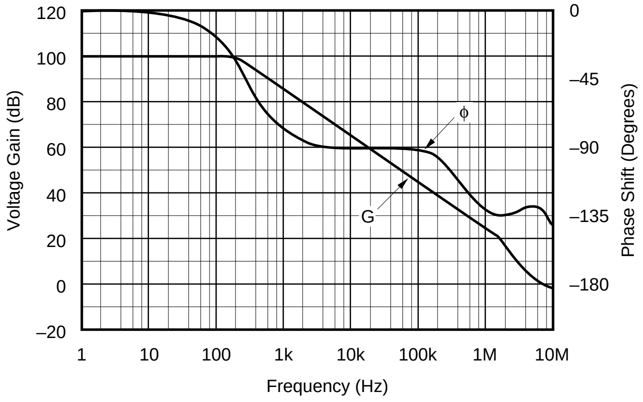
TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



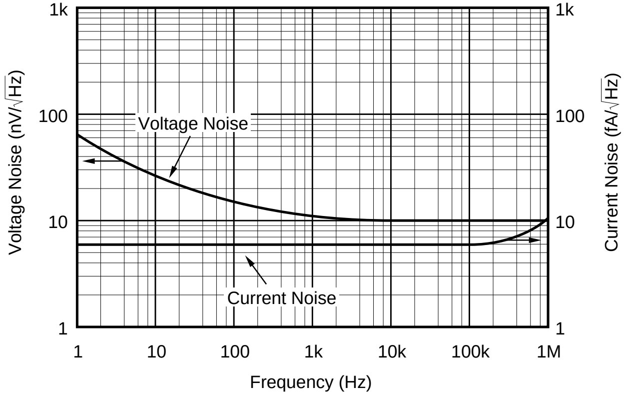
TOTAL HARMONIC DISTORTION + NOISE vs OUTPUT VOLTAGE



OPEN-LOOP GAIN/PHASE vs FREQUENCY

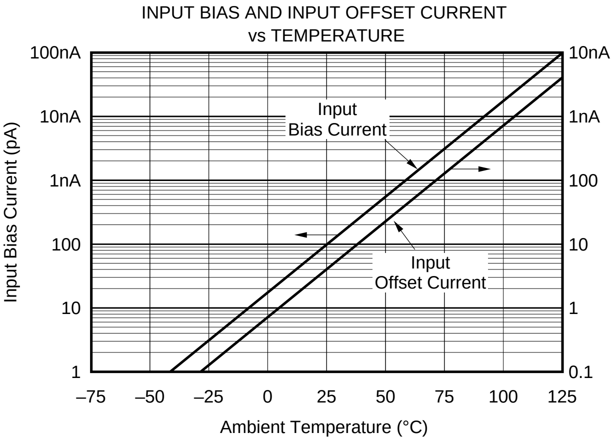


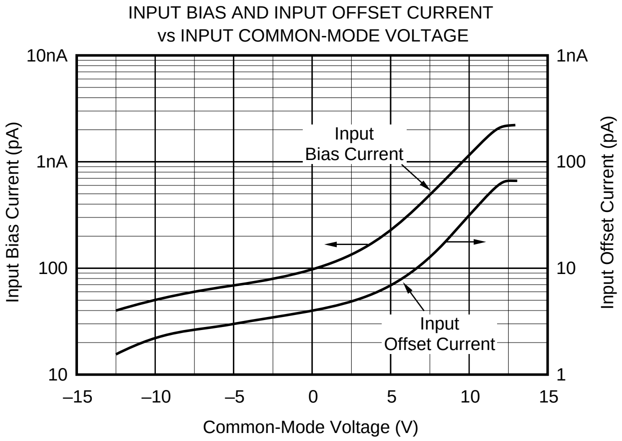
INPUT VOLTAGE AND CURRENT NOISE SPECTRAL DENSITY vs FREQUENCY

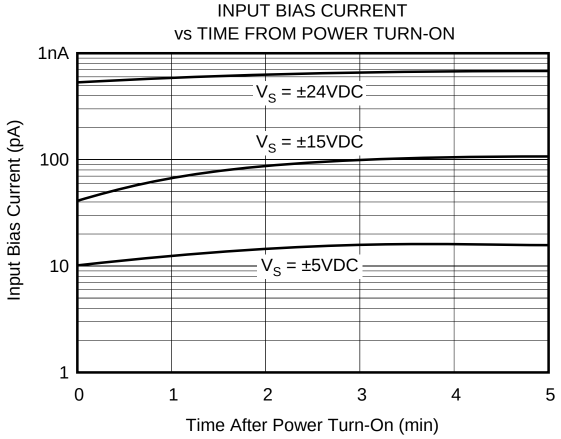


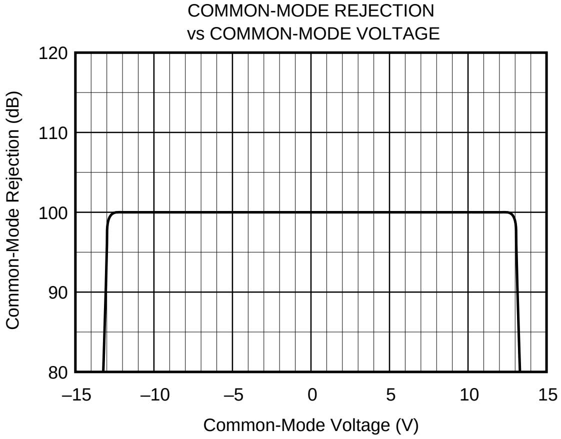
TYPICAL PERFORMANCE CURVES (CONT)

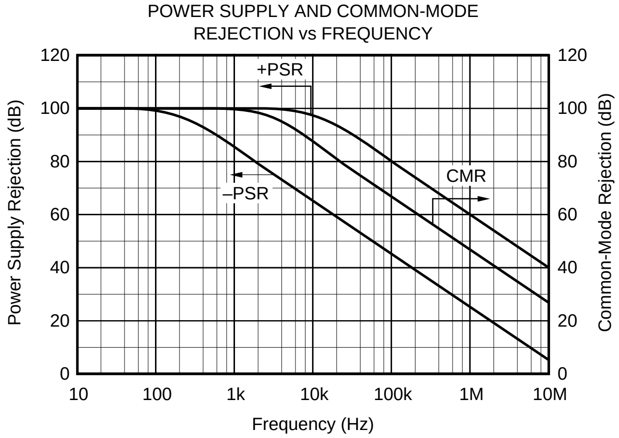
T_A = +25°C, V_S = ±15V unless otherwise noted.

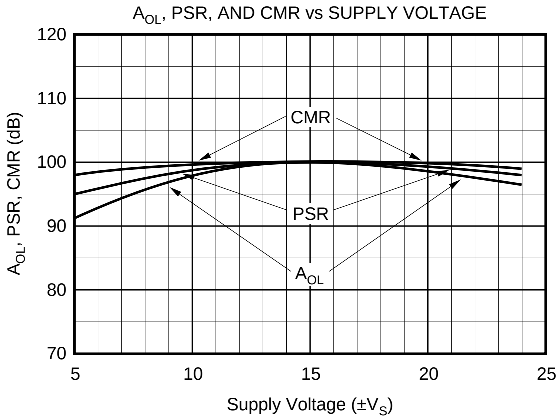








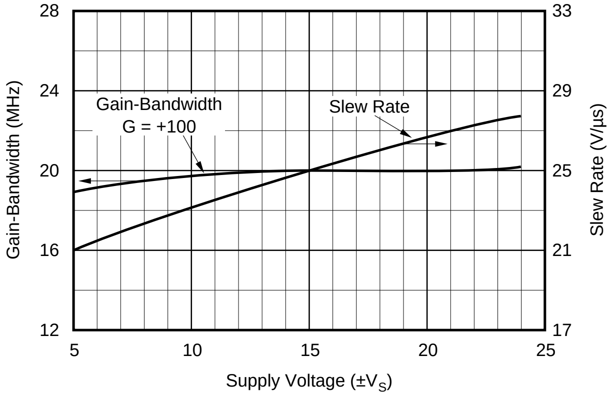




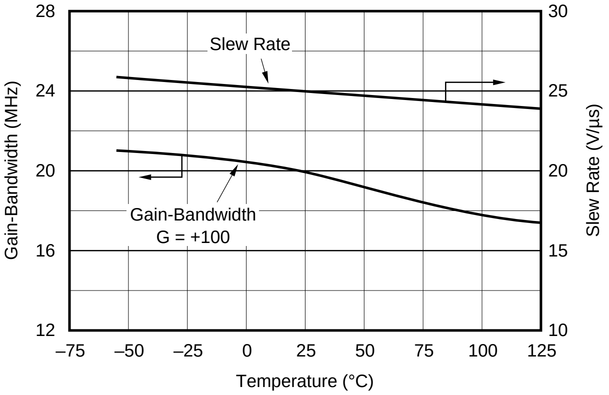
TYPICAL PERFORMANCE CURVES (CONT)

T_A = +25°C, V_S = ±15V unless otherwise noted.

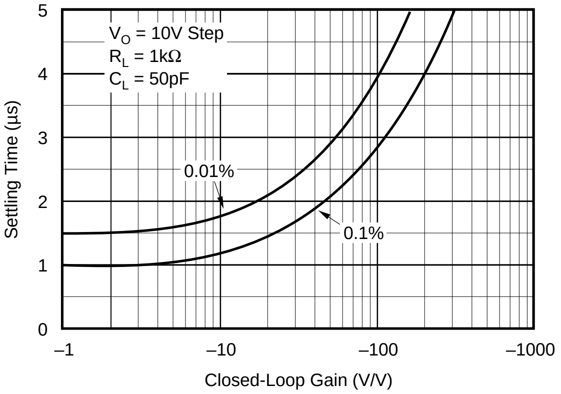
GAIN-BANDWIDTH AND SLEW RATE vs SUPPLY VOLTAGE



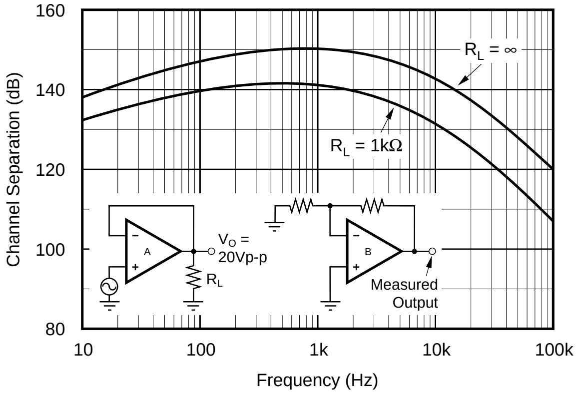
GAIN-BANDWIDTH AND SLEW RATE vs TEMPERATURE



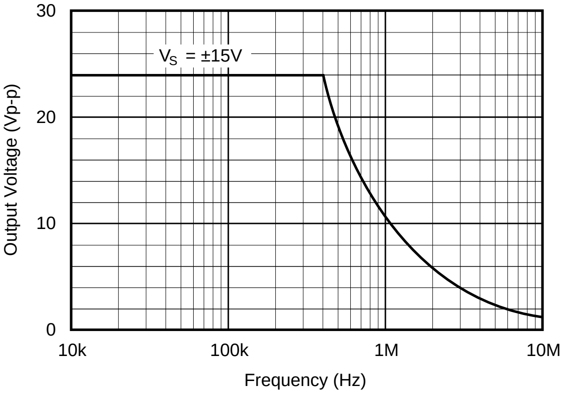
SETTLING TIME vs CLOSED-LOOP GAIN



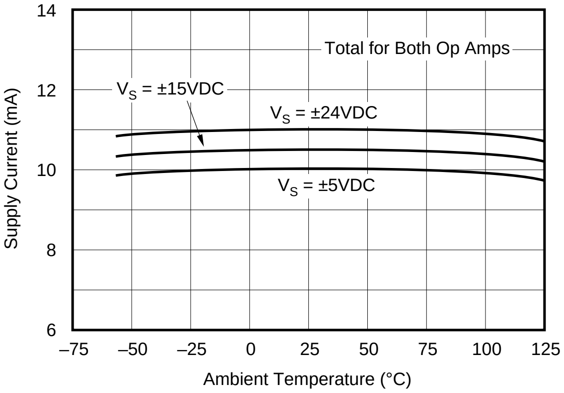
CHANNEL SEPARATION vs FREQUENCY



MAXIMUM OUTPUT VOLTAGE SWING vs FREQUENCY



SUPPLY CURRENT vs TEMPERATURE



TYPICAL PERFORMANCE CURVES (CONT)

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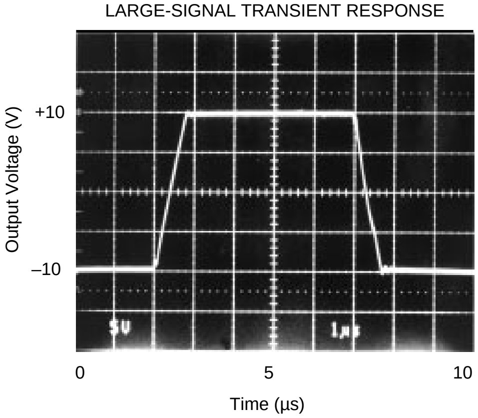
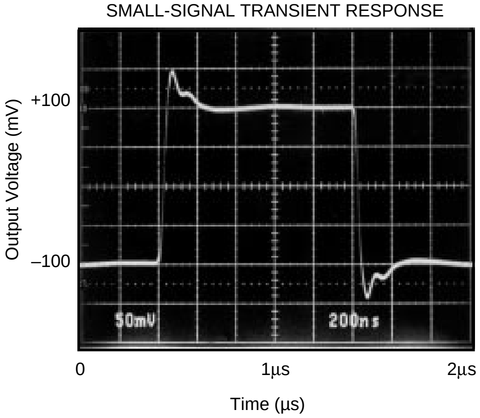
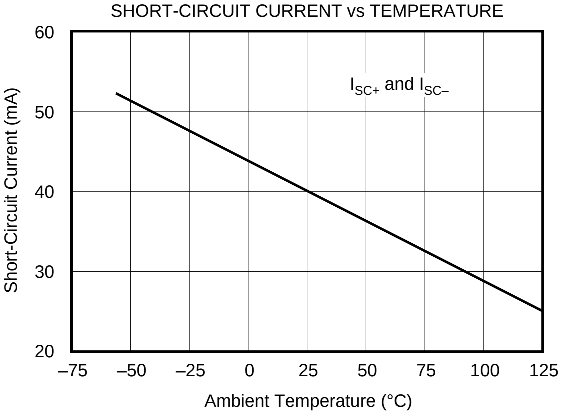
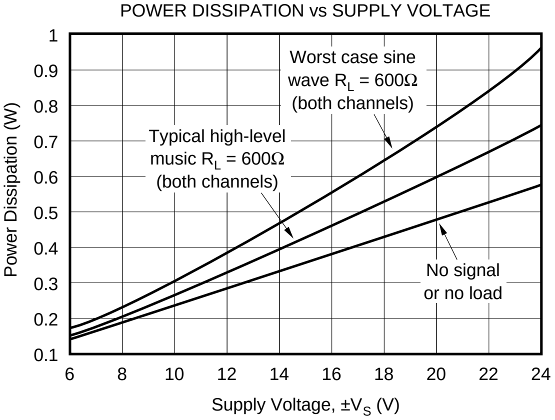
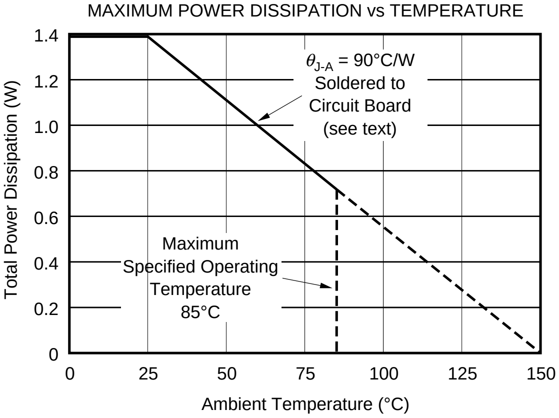










APPLICATIONS INFORMATION

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 1µF 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 1 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.

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 2 shows various circuits which preserve phase margin with capacitive load. Request Application Bulletin AB-028 for details of analysis techniques and applications circuits.

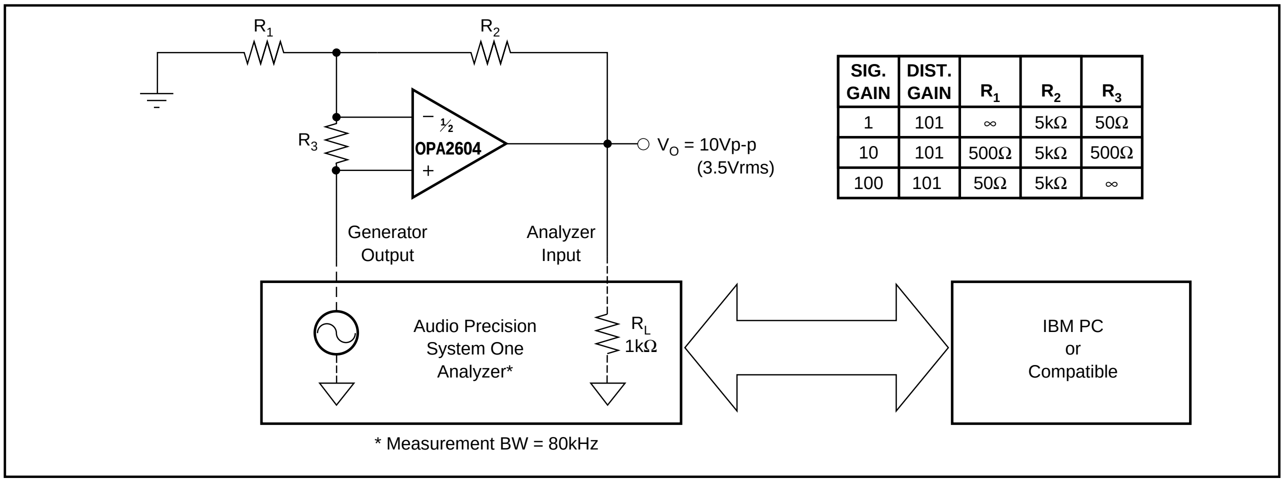
For the unity-gain buffer, Figure 2a, stability is preserved by adding a phase-lead network, R_C and C_C. Voltage drop across R_C will reduce output voltage swing with heavy loads. An alternate circuit, Figure 2b, does not limit the output with low load impedance. It provides a small amount of positive feedback 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 2c and 2d show compensation techniques for noninverting amplifiers. Like the follower circuits, the circuit in Figure 2d eliminates voltage drop due to load current, but at the penalty of somewhat reduced input impedance at high frequency.

Figures 2e and 2f show input lead compensation networks for inverting and difference amplifier configurations.

NOISE PERFORMANCE

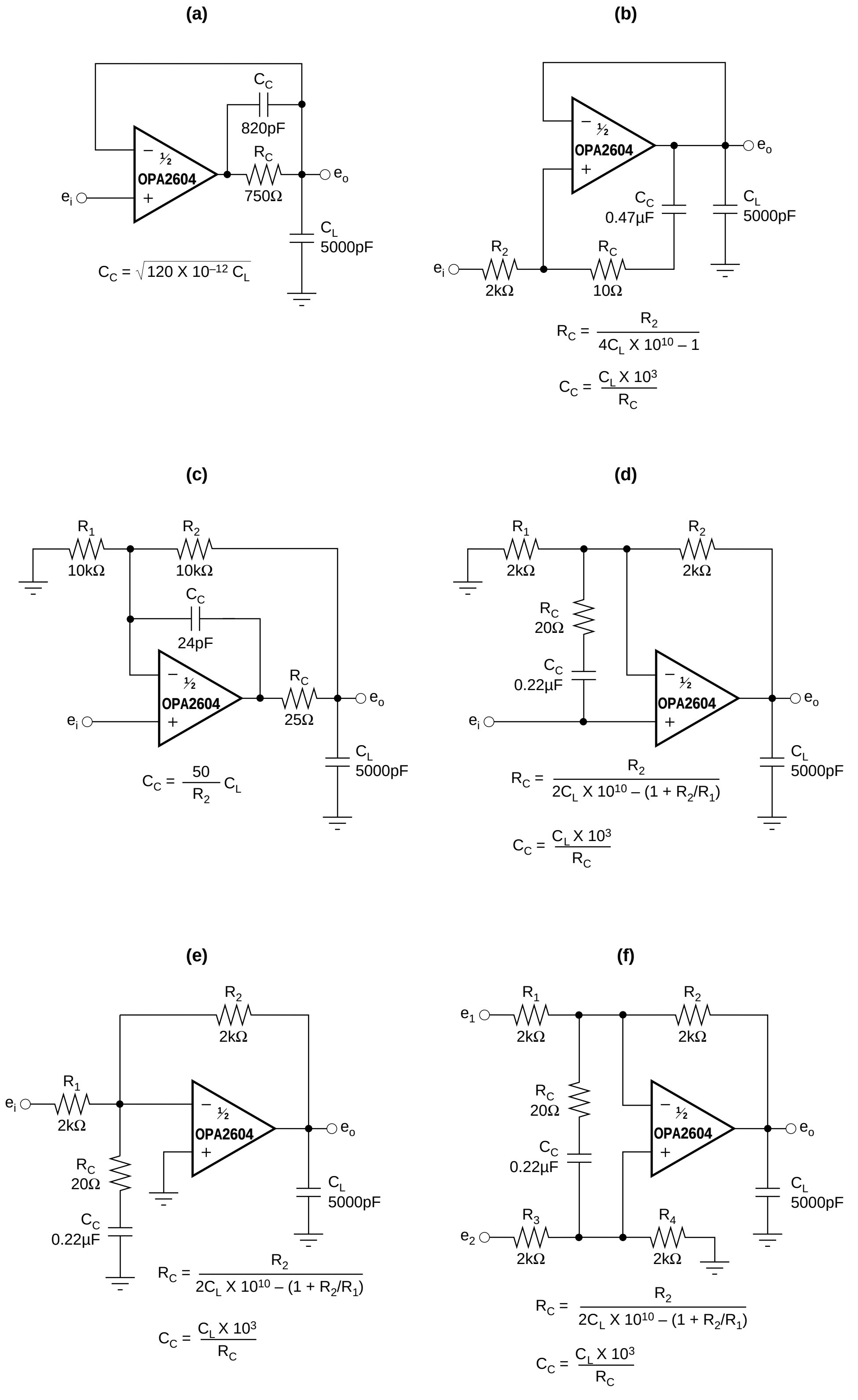
Op amp noise is described by two parameters—noise voltage and noise current. The voltage noise determines the noise performance with low source impedance. Low noise bipolar-input op amps such as the OPA27 and OPA37 provide very low voltage noise. But if source impedance is greater than a few thousand 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.



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 1. Distortion Test Circuit.



(a)

$$C_C = \sqrt{120 \times 10^{-12}\, C_L}$$

(b)

$$R_C = \frac{R_2}{4C_L \times 10^{10} - 1}$$

$$C_C = \frac{C_L \times 10^3}{R_C}$$

(c)

$$C_C = \frac{50}{R_2} C_L$$

(d)

$$R_C = \frac{R_2}{2C_L \times 10^{10} - (1 + R_2/R_1)}$$

$$C_C = \frac{C_L \times 10^3}{R_C}$$

(e)

$$R_C = \frac{R_2}{2C_L \times 10^{10} - (1 + R_2/R_1)}$$

$$C_C = \frac{C_L \times 10^3}{R_C}$$

(f)

$$R_C = \frac{R_2}{2C_L \times 10^{10} - (1 + R_2/R_1)}$$

$$C_C = \frac{C_L \times 10^3}{R_C}$$

NOTE: Design equations and component values are approximate. User adjustment is required for optimum performance.

FIGURE 2. Driving Large Capacitive Loads.

POWER DISSIPATION

The OPA2604 is capable of driving 600Ω loads with power supply voltages up to ±24V. 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 ±40mA at 25°C. The limit current decreases with increasing temperature as shown in the typical curves.

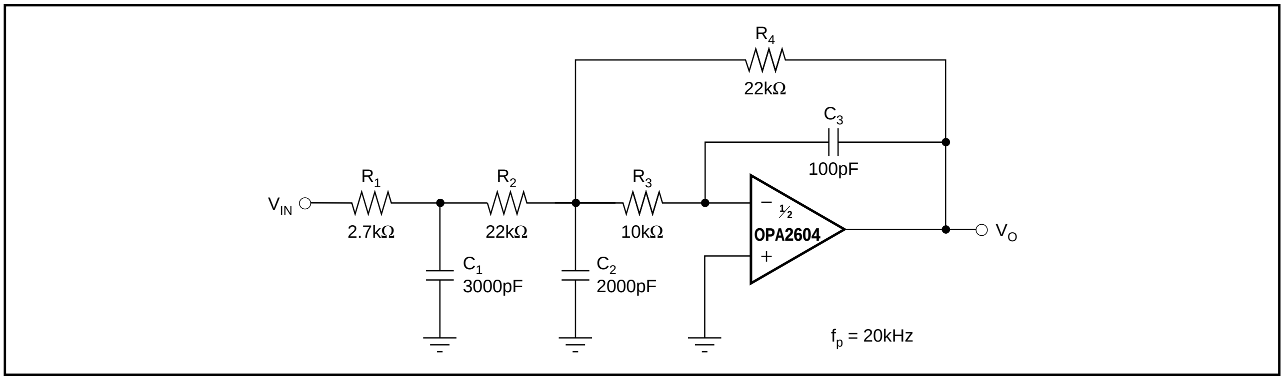


FIGURE 3. Three-Pole Low-Pass Filter.

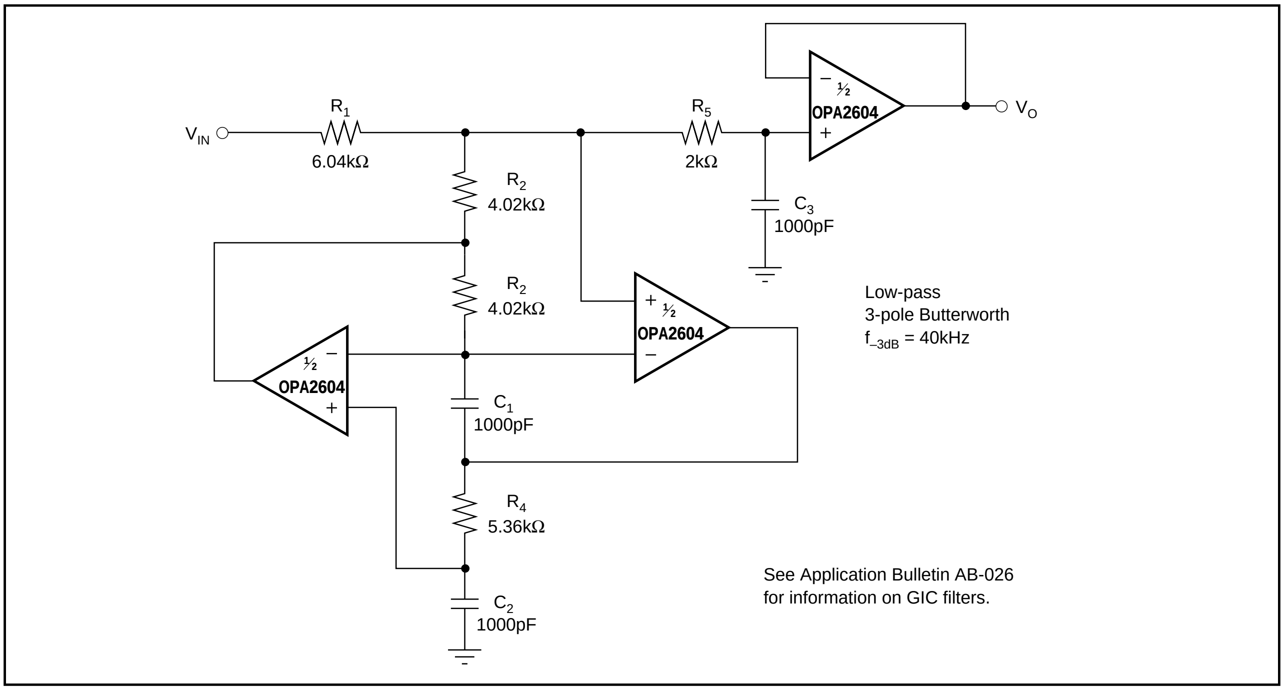
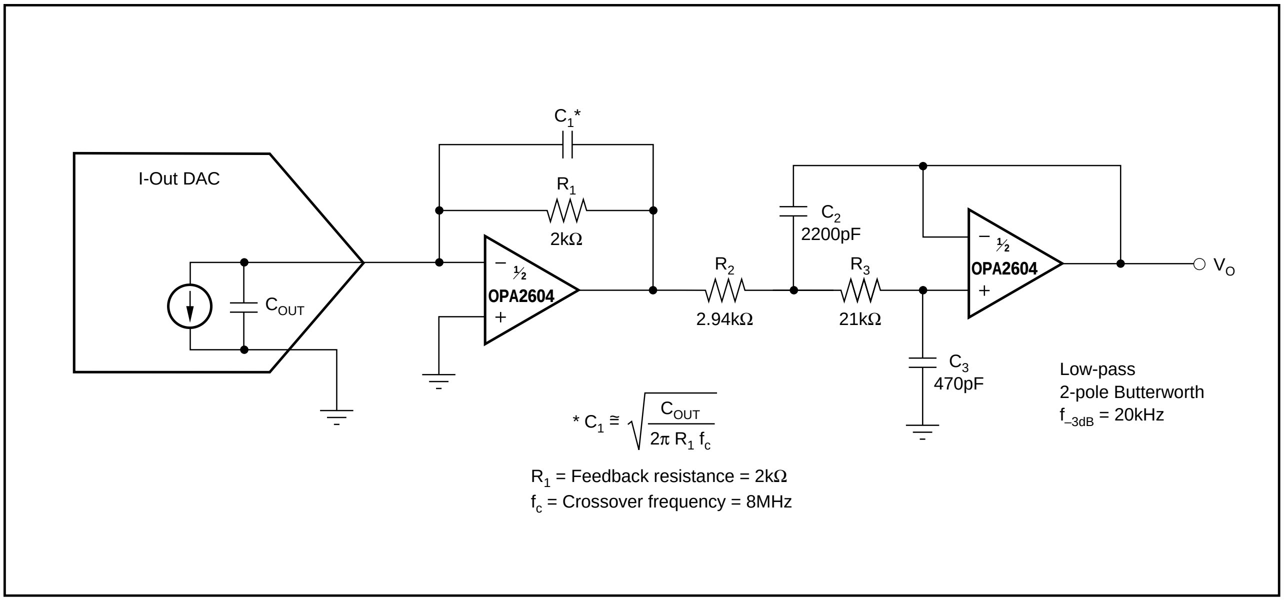


FIGURE 4. Three-Pole Generalized Immittance Converter (GIC) Low-Pass Filter.



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

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

FIGURE 5. DAC I/V Amplifier and Low-Pass Filter.

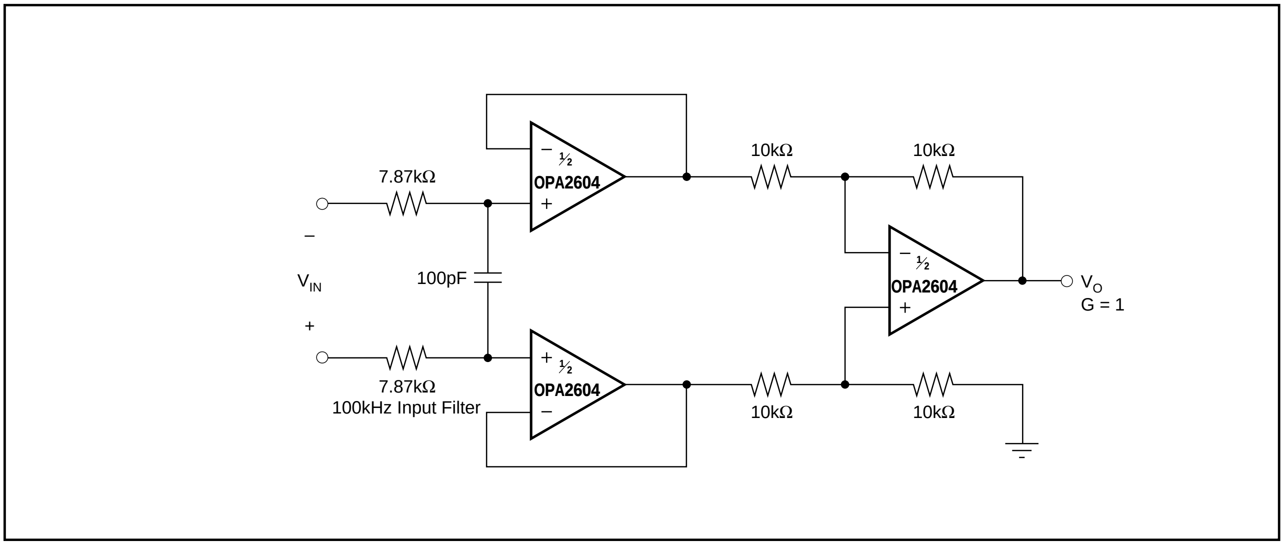


FIGURE 6. Differential Amplifier with Low-Pass Filter.

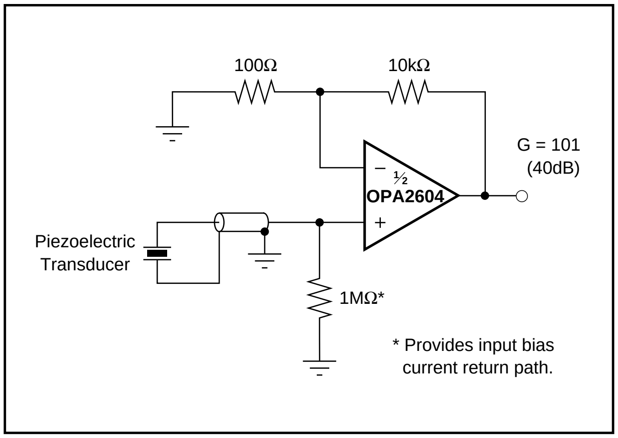


FIGURE 7. High Impedance Amplifier.

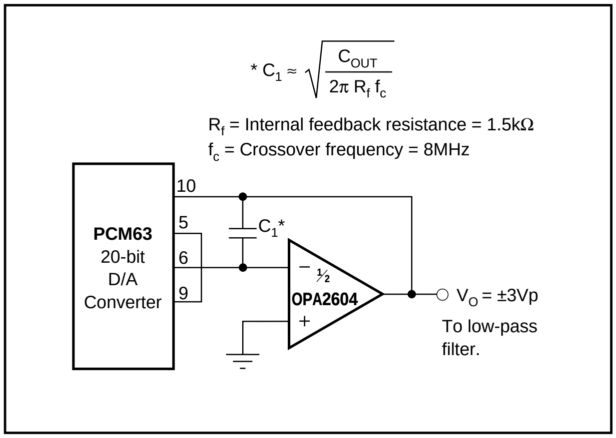


FIGURE 8. Digital Audio DAC I-V Amplifier.

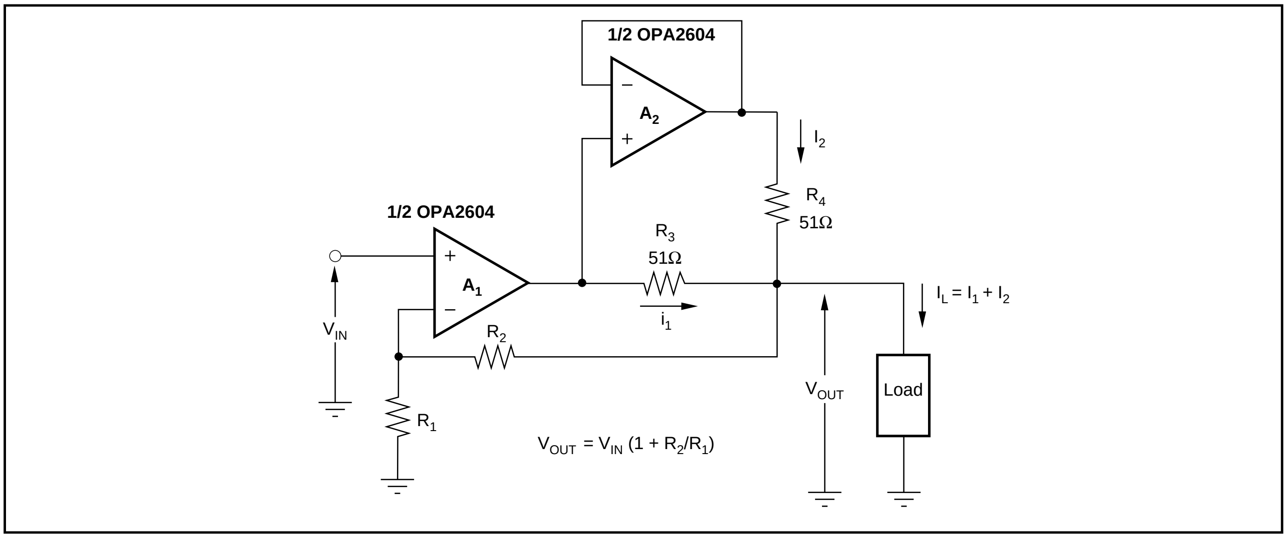


FIGURE 9. Using the Dual OPA2604 Op Amp to Double the Output Current to a Load.

SOUND QUALITY

The following discussion is provided, recognizing that not all measured performance behavior explains or correlates with listening tests by audio experts. The design of the OPA2604 included consideration of both objective performance measurements, as well as an awareness of widely held theory on the success and failure of previous op amp designs.

SOUND QUALITY

The sound quality of an op amp is often the crucial selection criteria—even when a data sheet claims exceptional distortion performance. By its nature, sound quality is subjective. Furthermore, results of listening tests can vary depending on application and circuit configuration. Even experienced listeners in controlled tests often reach different conclusions.

Many audio experts believe that the sound quality of a high performance FET op amp is superior to that of bipolar op amps. A possible reason for this is that bipolar designs generate greater odd-order harmonics than FETs. To the human ear, odd-order harmonics have long been identified as sounding more unpleasant than even-order harmonics. FETs, like vacuum tubes, have a square-law I-V transfer function which is more linear than the exponential transfer function of a bipolar transistor. As a direct result of this square-law characteristic, FETs produce predominantly even-order harmonics. Figure 10 shows the transfer function of a bipolar transistor and FET. Fourier transformation of both transfer functions reveals the lower odd-order harmonics of the FET amplifier stage.

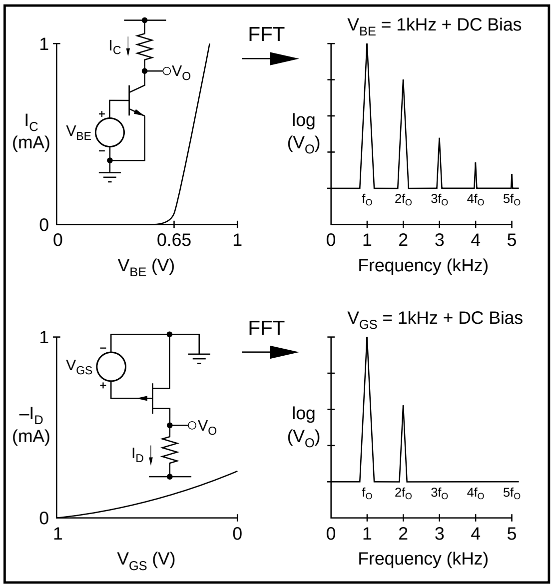
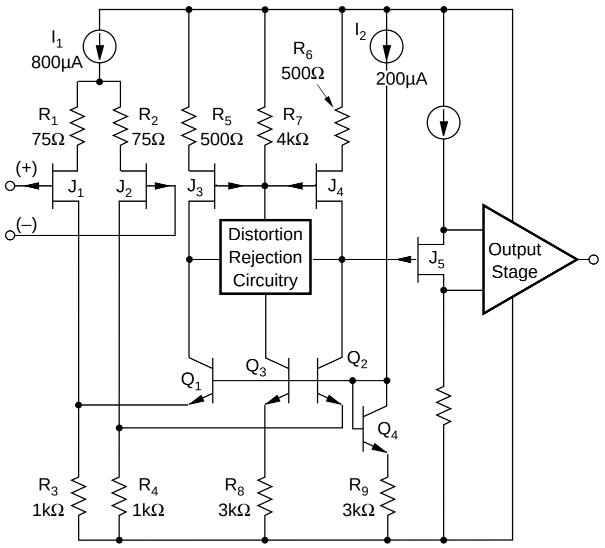


FIGURE 10. I-V and Spectral Response of NPN and JFET.



THE OPA2604 DESIGN

The OPA2604 uses FETs throughout the signal path, including the input stage, input-stage load, and the important phase-splitting section of the output stage. Bipolar transistors are used where their attributes, such as current capability are important and where their transfer characteristics have minimal impact.

The topology consists of a single folded-cascode gain stage followed by a unity-gain output stage. Differential input transistors J_1 and J_2 are special large-geometry, P-channel JFETs. Input stage current is a relatively high 800µA, providing high transconductance and reducing voltage noise. Laser trimming of stage currents and careful attention to symmetry yields a nearly symmetrical slew rate of ±25V/µs.

The JFET input stage holds input bias current to approximately 100pA, or roughly 3000 times lower than common bipolar-input audio op amps. This dramatically reduces noise with high-impedance circuitry.

The drains of J_1 and J_2 are cascoded by Q_1 and Q_2, driving the input stage loads, FETs J_3 and J_4. Distortion reduction circuitry (patent pending) linearizes the open-loop response and increases voltage gain. The 20MHz bandwidth of the OPA2604 further reduces distortion through the user-connected feedback loop.

The output stage consists of a JFET phase-splitter loaded into high speed all-NPN output drivers. Output transistors are biased by a special circuit to prevent cutoff, even with full output swing into 600Ω loads.

The two channels of the OPA2604 are completely independent, including all bias circuitry. This eliminates any possibility of crosstalk through shared circuits—even when one channel is overdriven.