250 MHz, General Purpose Voltage Feedback Op Amps

AD8047/AD8048

FEATURES
Wide Bandwidth AD8047, G = +1 AD8048, G = +2
Small Signal 250 MHz 260 MHz
Large Signal (2 V p-p) 130 MHz 160 MHz
5.8 mA Typical Supply Current
Low Distortion, (SFDR) Low Noise
–66 dBc Typ @ 5 MHz
–54 dBc Typ @ 20 MHz
5.2 nV/√Hz (AD8047), 3.8 nV/√Hz (AD8048) Noise
Drives 50 pF Capacitive Load
High Speed
Slew Rate 750 V/µs (AD8047), 1000 V/µs (AD8048)
Settling 30 ns to 0.01%, 2 V Step
±3 V to ±6 V Supply Operation

APPLICATIONS
Low Power ADC Input Driver
Differential Amplifiers
IF/RF Amplifiers
Pulse Amplifiers
Professional Video
DAC Current to Voltage Conversion
Baseband and Video Communications
Pin Diode Receivers
Active Filters/Integrators

PRODUCT DESCRIPTION
The AD8047 and AD8048 are very high speed and wide bandwidth amplifiers. The AD8047 is unity gain stable. The AD8048 is stable at gains of two or greater. The AD8047 and AD8048, which utilize a voltage feedback architecture, meet the requirements of many applications that previously depended on current feedback amplifiers.

A proprietary circuit has produced an amplifier that combines many of the best characteristics of both current feedback and voltage feedback amplifiers. For the power (6.6 mA max), the AD8047 and AD8048 exhibit fast and accurate pulse response (30 ns to 0.01%) as well as extremely wide small signal and large signal bandwidth and low distortion. The AD8047 achieves –54 dBc distortion at 20 MHz, 250 MHz small signal, and 130 MHz large signal bandwidths.

The AD8047 and AD8048’s low distortion and cap load drive make the AD8047/AD8048 ideal for buffering high speed ADCs. They are suitable for 12-bit/10 MSPS or 8-bit/60 MSPS ADCs. Additionally, the balanced high impedance inputs of the voltage feedback architecture allow maximum flexibility when designing active filters.

The AD8047 and AD8048 are offered in industrial (–40°C to +85°C) temperature ranges and are available in 8-lead PDIP and SOIC packages.

Figure 1. AD8047 Large Signal Transient Response, \( V_o = 4 \) V p-p, \( G = +1 \)
IMPORTANT LINKS for the **AD8047 8048**

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**PARAMETRIC SELECTION TABLES**
Find Similar Products By Operating Parameters
High Speed Amplifiers Selection Table

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**DOCUMENTATION**

**AN-649**: Using the Analog Devices Active Filter Design Tool
**AN-581**: Biasing and Decoupling Op Amps in Single Supply Applications
**AN-402**: Replacing Output Clamping Op Amps with Input Clamping Amps
**AN-417**: Fast Rail-to-Rail Operational Amplifiers Ease Design Constraints in Low Voltage High Speed Systems
**MT-060**: Choosing Between Voltage Feedback and Current Feedback Op Amps
**MT-059**: Compensating for the Effects of Input Capacitance on VFB and CFB Op Amps Used in Current-to-Voltage Converters
**MT-058**: Effects of Feedback Capacitance on VFB and CFB Op Amps
**MT-056**: High Speed Voltage Feedback Op Amps
**MT-053**: Op Amp Distortion: HD, THD, THD + N, IMD, SFDR, MTTR
**MT-052**: Op Amp Noise Figure: Don’t Be Mislead
**MT-050**: Op Amp Total Output Noise Calculations for Second-Order System
**MT-049**: Op Amp Total Output Noise Calculations for Single-Pole System
**MT-048**: Op Amp Noise Relationships: 1/f Noise, RMS Noise, and Equivalent Noise Bandwidth
**MT-047**: Op Amp Noise
**MT-033**: Voltage Feedback Op Amp Gain and Bandwidth
**MT-032**: Ideal Voltage Feedback (VFB) Op Amp
**UG-101**: Evaluation Board User Guide

FOR THE AD8047

**AN-214**: Ground Rules for High Speed Circuits

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**DESIGN TOOLS, MODELS, DRIVERS & SOFTWARE**

- dBm/dBu/dBv Calculator
- Analog Filter Wizard 2.0
- Power Dissipation vs Die Temp
- **ADIsimOpAmp™**
- OpAmp Stability
- AD8047 SPICE Macro-Model

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**AD8048**
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## AD8047/AD8048—SPECIFICATIONS

### ELECTRICAL CHARACTERISTICS

(\( \pm V_S = \pm 5\, V, R_{LOAD} = 100\, \Omega, A_V = 1 \) (AD8047), \( A_V = 2 \) (AD8048), unless otherwise noted.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
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### Notes

\(^\d\) See Absolute Maximum Ratings and Theory of Operation sections.

\(^\d\) Measured at \( A_V = 50 \).

\(^\d\) Measured with respect to the inverting input.

Specifications subject to change without notice.
CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD8047/AD8048 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

MAXIMUM POWER DISSIPATION

The maximum power that can be safely dissipated by these devices is limited by the associated rise in junction temperature. The maximum safe junction temperature for plastic encapsulated devices is determined by the glass transition temperature of the plastic, approximately 150°C. Exceeding this limit temporarily may cause a shift in parametric performance due to a change in the stresses exerted on the die by the package. Exceeding a junction temperature of 175°C for an extended period can result in device failure.

While the AD8047 and AD8048 are internally short circuit protected, this may not be sufficient to guarantee that the maximum junction temperature (150°C) is not exceeded under all conditions. To ensure proper operation, it is necessary to observe the maximum power derating curves.

ORDERING GUIDE

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<td>AD8048AR-REEL7</td>
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<td>SOIC</td>
<td>R-8</td>
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*N = PDIP, R = SOIC
AD8047/AD8048—Typical Performance Characteristics

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TPC 2. AD8047 Large Signal Transient Response; $V_O = 4 \text{ V } p-p$, $G = +1$

TPC 3. AD8047 Small Signal Transient Response; $V_O = 400 \text{ mV } p-p$, $G = +1$

TPC 4. AD8047 Inverting Configuration, $G = -1$

TPC 5. AD8047 Large Signal Transient Response; $V_O = 4 \text{ V } p-p$, $G = -1$, $R_F = R_{IN} = 200 \Omega$

TPC 6. AD8047 Small Signal Transient Response; $V_O = 400 \text{ mV } p-p$, $G = -1$, $R_F = R_{IN} = 200 \Omega$
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TPC 9. AD8048 Small Signal Transient Response; $V_O = 400\,\text{mV\,p-p}$, G = +2, $R_F = R_{IN} = 200\,\Omega$

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TPC 39. AD8047 PSRR vs. Frequency

TPC 42. AD8048 PSRR vs. Frequency, $G = +2$
### THEORY OF OPERATION

#### General

The AD8047 and AD8048 are wide bandwidth, voltage feedback amplifiers. Since their open-loop frequency response follows the conventional 6 dB/octave roll-off, their gain bandwidth product is basically constant. Increasing their closed-loop gain results in a corresponding decrease in small signal bandwidth. This can be observed by noting the bandwidth specification between the AD8047 (gain of 1) and AD8048 (gain of 2).

#### Feedback Resistor Choice

The value of the feedback resistor is critical for optimum performance on the AD8047 and AD8048. For maximum flatness at a gain of 2, $R_F$ and $R_G$ should be set to 200 Ω for the AD8048. When the AD8047 is configured as a unity gain follower, $R_F$ should be set to 0 Ω (no feedback resistor should be used) for the plastic DIP and 66.5 Ω for the SOIC.

For general voltage gain applications, the amplifier bandwidth can be closely estimated as

$$f_{3dB} \approx \frac{\omega_0}{2\pi \left[1 + \left(\frac{R_F}{R_G}\right)^2\right]}$$

This estimation loses accuracy for gains of +2/–1 or lower due to the amplifier’s damping factor. For these low gain cases, the bandwidth will actually extend beyond the calculated value (see Closed-Loop BW plots, TPCs 13 and 25).

#### Pulse Response

Unlike a traditional voltage feedback amplifier, where the slew speed is dictated by its front end dc quiescent current and gain bandwidth product, the AD8047 and AD8048 provide on demand current that increases proportionally to the input step signal amplitude. This results in slew rates (1000 V/µs) comparable to wideband current feedback designs. This, combined with relatively low input noise current (1.0 pA/√Hz), gives the AD8047 and AD8048 the best attributes of both voltage and current feedback amplifiers.

#### Large Signal Performance

The outstanding large signal operation of the AD8047 and AD8048 is due to a unique, proprietary design architecture. In order to maintain this level of performance, the maximum 180 V-MHz product must be observed (e.g., @ 100 MHz, $V_O \leq 1.8$ V p-p) on the AD8047 and the 250 V-MHz product must be observed on the AD8048.

#### Power Supply Bypassing

Adequate power supply bypassing can be critical when optimizing the performance of a high frequency circuit. Inductance in the power supply leads can form resonant circuits that produce peaking in the amplifier’s response. In addition, if large current transients must be delivered to the load, then bypass capacitors (typically greater than 1 µF) will be required to provide the best settling time and lowest distortion. A parallel combination of at least 4.7 µF, and between 0.1 µF and 0.01 µF, is recommended. Some brands of electrolytic capacitors will require a small series damping resistor ≈4.7 Ω for optimum results.

#### Driving Capacitive Loads

The AD8047/AD8048 have excellent cap load drive capability for high speed op amps, as shown in Figures 7 and 9. However, when driving cap loads greater than 25 pF, the best frequency response is obtained by the addition of a small series resistance.
It is worth noting that the frequency response of the circuit when driving large capacitive loads will be dominated by the passive roll-off of $R_{\text{SERIES}}$ and $C_L$.

![Figure 6. Driving Capacitive Loads](image)

![Figure 7. AD8047 Large Signal Transient Response; $V_O = 2 \text{ V p-p, } G = +1, R_F = 0 \Omega, R_{\text{SERIES}} = 0 \Omega, C_L = 27 \text{ pF}$](image)

![Figure 8. Driving Capacitive Loads](image)

![Figure 9. AD8048 Large Signal Transient Response; $V_O = 2 \text{ V p-p, } G = +2, R_F = R_{\text{IN}} = 200 \Omega, R_{\text{SERIES}} = 0 \Omega, C_L = 27 \text{ pF}$](image)

**APPLICATIONS**

The AD8047 and AD8048 are voltage feedback amplifiers well suited for such applications as photodetectors, active filters, and log amplifiers. The devices' wide bandwidth (260 MHz), phase margin (65°), low noise current (1.0 pA/$\sqrt{\text{Hz}}$), and slew rate (1000 V/µs) give higher performance capabilities to these applications over previous voltage feedback designs.

With a settling time of 30 ns to 0.01% and 13 ns to 0.1%, the devices are an excellent choice for DAC I/V conversion. The same characteristics along with low harmonic distortion make them a good choice for ADC buffering/amplification. With superb linearity at relatively high signal frequencies, the AD8047 and AD8048 are ideal drivers for ADCs up to 12 bits.

**Operation as a Video Line Driver**

The AD8047 and AD8048 have been designed to offer outstanding performance as video line drivers. The important specifications of differential gain (0.01%) and differential phase (0.02°) meet the most exacting HDTV demands for driving video loads.

**Active Filters**

The wide bandwidth and low distortion of the AD8047 and AD8048 are ideal for the realization of higher bandwidth active filters. These characteristics, while being more common in many current feedback op amps, are offered in the AD8047 and AD8048 in a voltage feedback configuration. Many active filter configurations are not realizable with current feedback amplifiers.

A multiple feedback active filter requires a voltage feedback amplifier and is more demanding of op amp performance than other active filter configurations such as the Sallen-Key. In general, the amplifier should have a bandwidth that is at least 10 times the bandwidth of the filter if problems due to phase shift of the amplifier are to be avoided.

Figure 11 is an example of a 20 MHz low-pass multiple feedback active filter using an AD8048.
Choose

\[ F_0 = \text{Cutoff Frequency} = 20 \text{ MHz} \]
\[ \alpha = \text{Damping Ratio} = 1/Q = 2 \]
\[ H = \text{Absolute Value of Circuit Gain} = \frac{-R_4}{R_1} = 1 \]

Then,

\[ k = 2\pi F_0 C_1 \]
\[ C_2 = \frac{4 C_1 (H + 1)}{\alpha^2} \]
\[ R_1 = \frac{\alpha}{2HK} \]
\[ R_3 = \frac{\alpha}{2K(H + 1)} \]
\[ R_4 = H(R_1) \]

A/D Converter Driver

As A/D converters move toward higher speeds with higher resolutions, there becomes a need for high performance drivers that will not degrade the analog signal to the converter. It is desirable from a system’s standpoint that the A/D be the element in the signal chain that ultimately limits overall distortion. This places new demands on the amplifiers used to drive fast, high resolution A/Ds.

With high bandwidth, low distortion, and fast settling time, the AD8047 and AD8048 make high performance A/D drivers for advanced converters. Figure 12 is an example of an AD8047 used as an input driver for an AD872A, a 12-bit, 10 MSPS A/D converter.

Layout Considerations

The specified high speed performance of the AD8047 and AD8048 requires careful attention to board layout and component selection. Proper RF design techniques and low-pass parasitic component selection are mandatory.

The PCB should have a ground plane covering all unused portions of the component side of the board to provide a low impedance path. The ground plane should be removed from the area near the input pins to reduce stray capacitance.

Chip capacitors should be used for the supply bypassing (see Figure 12). One end should be connected to the ground plane and the other within 1/8 inch of each power pin. An additional large (0.47 µF to 10 µF) tantalum electrolytic capacitor should be connected in parallel, though not necessarily so close, to the supply current for fast, large signal changes at the output.

The feedback resistor should be located close to the inverting input pin in order to keep the stray capacitance at this node to a minimum. Capacitance variations of less than 1 pF at the inverting input will significantly affect high speed performance.

Stripline design techniques should be used for long signal traces (greater than about 1 inch). These should be designed with a characteristic impedance of 50 Ω or 75 Ω and be properly terminated at each end.

Figure 12. AD8047 Used as Driver for an AD872A, a 12-Bit, 10 MSPS A/D Converter
OUTLINE DIMENSIONS

8-Lead Plastic Dual In-Line Package [PDIP] (N-8)
Dimensions shown in inches and (millimeters)

8-Lead Standard Small Outline Package [SOIC] (R-8)
Dimensions shown in millimeters and (inches)
## AD8047/AD8048

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<td>Updated ORDERING GUIDE</td>
<td>3</td>
</tr>
<tr>
<td>Updated OUTLINE DIMENSIONS</td>
<td>15</td>
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