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/\sqrt{Hz} (AD8047), 3.8 nV/\sqrt{Hz} (AD8048) Noise
Drives 50 pF Capacitive Load
High Speed
Slew Rate 750 V/\mu s (AD8047), 1000 V/\mu s (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 band-
width 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 require-
ments 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,
\( V_o = 4 \ V \ p-p, \ G = +1 \)
## AD8047/AD8048—SPECIFICATIONS

### ELECTRICAL CHARACTERISTICS

(±V<sub>s</sub> = ±5 V, R<sub>LOAD</sub> = 100 Ω, A<sub>V</sub> = 1 (AD8047), A<sub>V</sub> = 2 (AD8048), unless otherwise noted.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>AD8047A</th>
<th>AD8048A</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DYNAMIC PERFORMANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bandwidth (–3 dB)</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; ≤ 0.4 V p-p</td>
<td>170</td>
<td>250</td>
<td>180</td>
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<td></td>
<td>Large Signal&lt;sup&gt;1&lt;/sup&gt;</td>
<td>100</td>
<td>130</td>
<td>135</td>
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<tr>
<td>Bandwidth for 0.1 dB Flatness</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 300 mV p-p</td>
<td>AD8047, R&lt;sub&gt;F&lt;/sub&gt; = 0 Ω; AD8048, R&lt;sub&gt;F&lt;/sub&gt; = 200 Ω</td>
<td>35</td>
<td>50</td>
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<tr>
<td>Slew Rate, Average +/-</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 2 V p-p</td>
<td>100</td>
<td>130</td>
<td>135</td>
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<tr>
<td></td>
<td>Rise/Fall Time</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 0.5 V Step</td>
<td>1.1</td>
<td>1.2</td>
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<tr>
<td></td>
<td></td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 4 V Step</td>
<td>4.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Settling Time</td>
<td>To 0.1%</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 2 V Step</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>To 0.01%</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 2 V Step</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>HARMONIC/NOISE PERFORMANCE</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Second Harmonic Distortion</td>
<td>2 V p-p; 20 MHz</td>
<td>R&lt;sub&gt;LOAD&lt;/sub&gt; = 1 kΩ</td>
<td>–54</td>
<td>–48</td>
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<tr>
<td></td>
<td></td>
<td>R&lt;sub&gt;LOAD&lt;/sub&gt; = 2 kΩ</td>
<td>–64</td>
<td>–60</td>
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<tr>
<td>Third Harmonic Distortion</td>
<td>2 V p-p; 20 MHz</td>
<td>R&lt;sub&gt;LOAD&lt;/sub&gt; = 1 kΩ</td>
<td>–60</td>
<td>–56</td>
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<tr>
<td>Input Voltage Noise</td>
<td>f = 100 kHz</td>
<td>5.2</td>
<td>3.8</td>
<td>nV/√Hz</td>
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<tr>
<td>Input Current Noise</td>
<td>f = 100 kHz</td>
<td>1.0</td>
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<td>pA/√Hz</td>
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<td>Average Equivalent Integrated Input Noise Voltage</td>
<td>0.1 MHz to 10 MHz</td>
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<td>Differential Gain Error (3.58 MHz)</td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 150 Ω, G = +2</td>
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<td>0.01</td>
<td>%</td>
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<td>Differential Phase Error (3.58 MHz)</td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 150 Ω, G = +2</td>
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<td><strong>DC PERFORMANCE</strong>&lt;sup&gt;2&lt;/sup&gt;, R&lt;sub&gt;L&lt;/sub&gt; = 150 Ω</td>
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<td>Input Offset Voltage&lt;sup&gt;3&lt;/sup&gt;</td>
<td>T&lt;sub&gt;MIN&lt;/sub&gt; to T&lt;sub&gt;MAX&lt;/sub&gt;</td>
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<td>3</td>
<td>1</td>
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<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td>mV</td>
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<td>Offset Voltage Drift</td>
<td>T&lt;sub&gt;MIN&lt;/sub&gt; to T&lt;sub&gt;MAX&lt;/sub&gt;</td>
<td>±5</td>
<td>±5</td>
<td>μV/°C</td>
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<td>Input Bias Current</td>
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<td>3.5</td>
<td>1</td>
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<td>Input Offset Current</td>
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<td>2</td>
<td>0.5</td>
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<td>Common-Mode Rejection Ratio</td>
<td>V&lt;sub&gt;CM&lt;/sub&gt; = ±2.5 V</td>
<td>74</td>
<td>80</td>
<td>74</td>
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<td>Open-Loop Gain</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = ±2.5 V</td>
<td>58</td>
<td>62</td>
<td>65</td>
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<td></td>
<td>T&lt;sub&gt;MIN&lt;/sub&gt; to T&lt;sub&gt;MAX&lt;/sub&gt;</td>
<td>54</td>
<td>56</td>
<td>dB</td>
</tr>
</tbody>
</table>

### INPUT CHARACTERISTICS

| Parameter | | | | |
|-----------|-----------|-----------|-----------|
| Input Resistance | | | 500 | 500 | kΩ |
| Input Capacitance | | | 1.5 | 1.5 | pF |
| Input Common-Mode Voltage Range | | | ±3.4 | ±3.4 | V |

### OUTPUT CHARACTERISTICS

| Parameter | | | | |
|-----------|-----------|-----------|-----------|
| Output Voltage Range, R<sub>L</sub> = 150 Ω | | | ±2.8 | ±3.0 | ±2.8 | ±3.0 | V |
| Output Current | 50 | 50 | mA |
| Output Resistance | | | 0.2 | 0.2 | Ω |
| Short-Circuit Current | 130 | 130 | mA |

### POWER SUPPLY

| Parameter | | | | |
|-----------|-----------|-----------|-----------|
| Operating Range | | | ±3.0 | ±5.0 | ±5.0 | ±6.0 | V |
| Quiescent Current | T<sub>MIN</sub> to T<sub>MAX</sub> | 5.8 | 6.6 | 5.9 | 6.6 | mA |
| Power Supply Rejection Ratio | | | 72 | 78 | 72 | 78 | dB |

### NOTES

1<sup>See Absolute Maximum Ratings and Theory of Operation sections.</sup>
2<sup>Measured at A<sub>V</sub> = 1.</sup>
3<sup>Measured with respect to the inverting input.</sup>

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.

WARNING!

ESD SENSITIVE DEVICE
TPC 1. AD8047 Noninverting Configuration, $G = +1$

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

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

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

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

TPC 6. AD8047 Small Signal Transient Response; $V_O = 400 \, mV \, p-p$, $G = -1$, $R_F = R_{IN} = 200 \, \Omega$
TPC 7. AD8048 Noninverting Configuration, $G = +2$

TPC 10. AD8048 Inverting Configuration, $G = -1$

TPC 8. AD8048 Large Signal Transient Response; $V_O = 4 \, V \, p-p, \, G = +2, \, R_F = R_{IN} = 200 \, \Omega$

TPC 11. AD8048 Large Signal Transient Response; $V_O = 4 \, V \, p-p, \, G = -1, \, R_F = R_{IN} = 200 \, \Omega$

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

TPC 12. AD8048 Small Signal Transient Response; $V_O = 400 \, mV \, p-p, \, G = -1, \, R_F = R_{IN} = 200 \, \Omega$
TPC 13. AD8047 Small Signal Frequency Response, $G = +1$

TPC 16. AD8047 Large Signal Frequency Response, $G = +1$

TPC 14. AD8047 0.1 dB Flatness, $G = +1$

TPC 17. AD8047 Small Signal Frequency Response, $G = -1$

TPC 15. AD8047 Open-Loop Gain and Phase Margin vs. Frequency

TPC 18. AD8047 Harmonic Distortion vs. Frequency, $G = +1$
TPC 19. AD8047 Harmonic Distortion vs. Frequency, G = +1

TPC 20. AD8047 Harmonic Distortion vs. Output Swing, G = +1

TPC 21. AD8047 Differential Gain and Phase Error, G = +2, $R_L = 150\, \Omega$, $R_F = 200\, \Omega$, $R_{IN} = 200\, \Omega$

TPC 22. AD8047 Short-Term Settling Time, G = +1

TPC 23. AD8047 Long-Term Settling Time, G = +1

TPC 24. AD8047 Noise vs. Frequency
TPC 25. AD8048 Small Signal Frequency Response, G = +2

TPC 26. AD8048 0.1 dB Flatness, G = +2

TPC 27. AD8048 Open-Loop Gain and Phase Margin vs. Frequency

TPC 28. AD8048 Large Signal Frequency Response, G = +2

TPC 29. AD8048 Small Signal Frequency Response, G = –1

TPC 30. AD8048 Harmonic Distortion vs. Frequency, G = +2
TPC 31. AD8048 Harmonic Distortion vs. Frequency, G = +2

TPC 32. AD8048 Harmonic Distortion vs. Output Swing, G = +2

TPC 33. AD8048 Differential Gain and Phase Error, G = +2, R_L = 150 Ω, R_F = 200 Ω, R_IN = 200 Ω

TPC 34. AD8048 Short-Term Settling Time, G = +2

TPC 35. AD8048 Long-Term Settling Time 2 V Step, G = +2

TPC 36. AD8048 Noise vs. Frequency
AD8047/AD8048

TPC 37. AD8047 CMRR vs. Frequency

TPC 40. AD8048 CMRR vs. Frequency

TPC 38. AD8047 Output Resistance vs. Frequency, G = +1

TPC 41. AD8048 Output Resistance vs. Frequency, G = +2

TPC 39. AD8047 PSRR vs. Frequency

TPC 42. AD8048 PSRR vs. Frequency, G = +2
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TPC 45. AD8047/AD8048 PSRR vs. Temperature

TPC 46. AD8047/AD8048 CMRR vs. Temperature

TPC 47. AD8047/AD8048 Supply Current vs. Temperature

TPC 48. AD8047/AD8048 Input Offset Voltage vs. Temperature
AD8047/AD8048

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\textsubscript{F} and R\textsubscript{G} should be set to 200 $\Omega$ for the AD8048. When the AD8047 is configured as a unity gain follower, R\textsubscript{F} should be set to 0 $\Omega$ for optimum flatness (<1 dB peaking) and settling time can be estimated as

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

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).

As a general rule, capacitor C\textsubscript{F} will not be required if $(R_F/R_G) \times C_I \leq \frac{NG}{4 \omega_o}$

where NG is the Noise Gain $(1 + R_F/R_G)$ of the circuit. For most voltage gain applications, this should be the case.

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

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

where $\omega_o$ is the unity gain bandwidth product of the amplifier in rad/sec, and $C_I$ is the equivalent total input capacitance at the inverting input. Typically, $\omega_o = 800 \times 10^6$ rad/sec (see Open-Loop Frequency Response curve, TPC 15).

As an example, choosing $R_F = 10 \, \text{k}\Omega$ and $C_I = 5 \, \text{pF}$ requires $C_F$ to be 1.1 $\text{pF}$ (Note: $C_I$ includes both source and parasitic circuit capacitance). The bandwidth of the amplifier can be estimated using the $C_F$ calculated as

$$f_{3 dB} = \frac{1.6}{2\pi R_F C_F}$$

where $C_F$ is the equivalent total input capacitance at the inverting input.

As an example, choosing $R_F = 10 \, \text{k}\Omega$ and $C_I = 5 \, \text{pF}$ requires $C_F$ to be 1.1 $\text{pF}$ (Note: $C_I$ includes both source and parasitic circuit capacitance). The bandwidth of the amplifier can be estimated using the $C_F$ calculated as

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where $C_F$ is the equivalent total input capacitance at the inverting input.

When the AD8047 is configured as a unity gain follower, R\textsubscript{F} should be set to 0 $\Omega$ (no feedback resistor should be used) for optimum results. 

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\textsubscript{F} and R\textsubscript{G} should be set to 200 $\Omega$ for the AD8048. When the AD8047 is configured as a unity gain follower, R\textsubscript{F} should be set to 0 $\Omega$ for optimum flatness (<1 dB peaking) and settling time can be estimated as

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$$f_{3 dB} = \frac{1.6}{2\pi R_F C_F}$$

where $C_F$ is the equivalent total input capacitance at the inverting input.

When the AD8047 is configured as a unity gain follower, R\textsubscript{F} should be set to 0 $\Omega$ (no feedback resistor should be used) for optimum flatness (<1 dB peaking) and settling time can be estimated as

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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).

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

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where $\omega_o$ is the unity gain bandwidth product of the amplifier in rad/sec, and $C_I$ is the equivalent total input capacitance at the inverting input. Typically, $\omega_o = 800 \times 10^6$ rad/sec (see Open-Loop Frequency Response curve, TPC 15).

As an example, choosing $R_F = 10 \, \text{k}\Omega$ and $C_I = 5 \, \text{pF}$ requires $C_F$ to be 1.1 $\text{pF}$ (Note: $C_I$ includes both source and parasitic circuit capacitance). The bandwidth of the amplifier can be estimated using the $C_F$ calculated as

$$f_{3 dB} = \frac{1.6}{2\pi R_F C_F}$$

where $C_F$ is the equivalent total input capacitance at the inverting input.
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**

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

**Figure 7. AD8047 Large Signal Transient Response;**

$V_O = 2 \text{ V p-p, } G = +1, R_F = 0 \text{ }\Omega, R_{\text{SERIES}} = 0 \text{ }\Omega, C_L = 27 \text{ pF}$

**Figure 8. Driving Capacitive Loads**

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

**Figure 9. AD8048 Large Signal Transient Response;**

$V_O = 2 \text{ V p-p, } G = +2, R_F = R_{\text{IN}} = 200 \text{ }\Omega, R_{\text{SERIES}} = 0 \text{ }\Omega, C_L = 27 \text{ pF}$

**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 ($65^\circ$), low noise current ($1.0 \text{ pA/}\sqrt{\text{Hz}}$), and slew rate ($1000 \text{ V/}\mu\text{s}$) 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 ($0.02^\circ$) meet the most exacting HDTV demands for driving video loads.

**Figure 10. Video Line Driver**

![Figure 10. Video Line Driver](image)

**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.

**Figure 11. Active Filter Circuit**

![Figure 11. Active Filter Circuit](image)
AD8047/AD8048

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

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

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

Revision History

<table>
<thead>
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