## Dual Low Noise Amplifier

The EL2228 is a dual, low-noise amplifier, ideally suited to filtering applications in ADSL and HDSLII designs. It features low noise specification of just $4.9 \mathrm{nV} / \sqrt{ } \mathrm{Hz}$ and $1.2 \mathrm{pA} / \sqrt{ } \mathrm{Hz}$, making it ideal for processing low voltage waveforms.

The EL2228 has a -3dB bandwidth of 80 MHz and is gain-of1 stable. It also affords minimal power dissipation with a supply current of just 4.5 mA per amplifier. The amplifier can be powered from supplies ranging from $\pm 2.5 \mathrm{~V}$ to $\pm 12 \mathrm{~V}$.

The EL2228 is available in a space saving 8-pin MSOP package as well as the industry-standard 8-pin SO. It is specified for operation over the $-40^{\circ} \mathrm{C}$ to $+85^{\circ} \mathrm{C}$ temperature range.

## Ordering Information

| PART <br> NUMBER | PACKAGE |  <br> REEL | PKG. DWG. \# |
| :--- | :---: | :---: | :---: |
| EL2228CY | 8-Pin MSOP | - | MDP0043 |
| EL2228CY-T13 | 8-Pin MSOP | $13 "$ | MDP0043 |
| EL2228CY-T7 | 8-Pin MSOP | $7 \prime \prime$ | MDP0043 |
| EL2228CYZ <br> (See Note) | 8-Pin MSOP <br> (Pb-free) | - | MDP0043 |
| EL2228CYZ-T13 <br> (See Note) | 8-Pin MSOP <br> (Pb-free) | $13 "$ | MDP0043 |
| EL2228CYZ-T7 <br> (See Note) | 8-Pin MSOP <br> (Pb-free) | $7 "$ | MDP0043 |
| EL2228CS | 8-Pin SO | - | MDP0027 |
| EL2228CS-T13 | 8-Pin SO | $13 "$ | MDP0027 |
| EL2228CS-T7 | 8-Pin SO | $7 "$ | MDP0027 |
| EL2228CSZ <br> (See Note) | 8-Pin SO <br> (Pb-free) | - | MDP0027 |
| EL2228CSZ-T13 <br> (See Note) | 8-Pin SO <br> (Pb-free) | $13 " \prime$ | MDP0027 |
| EL2228CSZ-T7 <br> (See Note) | 8-Pin SO <br> (Pb-free) | $7 "$ | MDP0027 |

NOTE: Intersil Pb -free products employ special Pb -free material sets; molding compounds/die attach materials and 100\% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb -free soldering operations. Intersil Pb -free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.

## Features

- Voltage noise of only $4.9 \mathrm{nV} / \mathrm{JHz}$
- Current noise of only $1.2 \mathrm{pA} / \sqrt{\mathrm{Hz}}$
- Bandwidth (-3dB) of $80 \mathrm{MHz}-@ A V=+1$
- Gain-of-1 stable
- Just 4.5mA per amplifier
- 8-pin MSOP package
- $\pm 2.5 \mathrm{~V}$ to $\pm 12 \mathrm{~V}$ operation
- Pb-Free available (RoHS compliant)


## Applications

- ADSL filters
- HDSLII filters
- Ultrasound input amplifiers
- Wideband instrumentation
- Communications equipment
- Wideband sensors


## Pinout

EL2228
(8-PIN SO, MSOP) TOP VIEW


```
Absolute Maximum Ratings \(\left(\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}\right)\)
```



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Input Voltage . . . . . . . . . . . . . . . . . . . . . . . . . . . V \(\mathrm{V}_{\mathrm{S}}-0.3 \mathrm{~V}, \mathrm{~V}_{\mathrm{S}}+0.3 \mathrm{~V}\)
Maximum Continuous Output Current . . . . . . . . . . . . . . . . . . . 40 mA
ESD Voltage. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . \(2 k \mathrm{kV}\)
```

Maximum Die Temperature . . . . . . . . . . . . . . . . . . . . . . . . . . $+150^{\circ} \mathrm{C}$
Storage Temperature . . . . . . . . . . . . . . . . . . . . . . . . $-65^{\circ} \mathrm{C}$ to $+150^{\circ} \mathrm{C}$
Power Dissipation . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . See Curves
Operating Temperature . . . . . . . . . . . . . . . . . . . . . . . . $40^{\circ} \mathrm{C}$ to $+85^{\circ} \mathrm{C}$

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE: All parameters having Min/Max specifications are guaranteed. Typ values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: $T_{J}=T_{C}=T_{A}$
Electrical Specifications $\quad \mathrm{V}_{\mathrm{S}^{+}}=+12 \mathrm{~V}, \mathrm{~V}_{\mathrm{S}^{-}}=-12 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=500 \Omega$ and $\mathrm{C}_{\mathrm{L}}=3 \mathrm{pF}$ to $0 \mathrm{~V}, \mathrm{R}_{\mathrm{F}}=420 \Omega$ and $\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}$ unless otherwise specified.

| PARAMETER | DESCRIPTION | CONDITIONS | MIN | TYP | MAX | UNIT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| INPUT CHARACTERISTICS |  |  |  |  |  |  |
| $\mathrm{V}_{\text {OS }}$ | Input Offset Voltage | $\mathrm{V}_{\mathrm{CM}}=0 \mathrm{~V}$ |  | 0.2 | 3 | mV |
| TCV ${ }_{\text {OS }}$ | Average Offset Voltage Drift | Measured over operating temperature range |  | -4 |  | $\mu \mathrm{V} /{ }^{\circ} \mathrm{C}$ |
| $\mathrm{I}_{\mathrm{B}}$ | Input Bias Current | $\mathrm{V}_{\mathrm{CM}}=0 \mathrm{~V}$ | -9 | -4.5 | -1 | $\mu \mathrm{A}$ |
| $\mathrm{R}_{\mathrm{IN}}$ | Input Impedance |  |  | 8 |  | $\mathrm{M} \Omega$ |
| $\mathrm{C}_{\text {IN }}$ | Input Capacitance |  |  | 1 |  | pF |
| CMIR | Common-Mode Input Range |  | -11.8 |  | +10.4 | V |
| CMRR | Common-Mode Rejection Ratio | for $\mathrm{V}_{\text {IN }}$ from -11.8 V to +10.4 V | 60 | 90 |  | dB |
|  |  | for $\mathrm{V}_{\text {IN }}$ from -10 V to +10 V | 60 | 75 |  | dB |
| AVOL | Open-Loop Gain | $-5 \mathrm{~V} \leq \mathrm{V}_{\text {OUT }} \leq 5 \mathrm{~V}$ | 60 | 75 |  | dB |
| $\mathrm{e}_{\mathrm{N}}$ | Voltage Noise | $\mathrm{f}=100 \mathrm{kHz}$ |  | 4.9 |  | $\mathrm{nV} / \sqrt{ } \mathrm{Hz}$ |
| ${ }^{\mathrm{i}} \mathrm{N}$ | Current Noise | $\mathrm{f}=100 \mathrm{kHz}$ |  | 1.2 |  | $\mathrm{pA} / \sqrt{ } \mathrm{Hz}$ |

## OUTPUT CHARACTERISTICS

| $\mathrm{V}_{\text {OL }}$ | Output Swing Low | $\mathrm{R}_{\mathrm{L}}=500 \Omega$ |  | -10.3 | -10 | V |
| :--- | :--- | :--- | :---: | :---: | :---: | :---: |
|  |  | $\mathrm{R}_{\mathrm{L}}=250 \Omega$ |  | -9.5 | -9 | V |
| $\mathrm{~V}_{\mathrm{OH}}$ | Output Swing High | $\mathrm{R}_{\mathrm{L}}=500 \Omega$ | 10 | 10.3 |  | V |
|  |  | $\mathrm{R}_{\mathrm{L}}=250 \Omega$ | 9.5 | 10 | V |  |
| ISC | Short Circuit Current | $\mathrm{R}_{\mathrm{L}}=10 \Omega$ | 140 | 180 |  | mA |

POWER SUPPLY PERFORMANCE

| PSRR | Power Supply Rejection Ratio | $\mathrm{V}_{\mathrm{S}}$ is moved from $\pm 10.8 \mathrm{~V}$ to $\pm 13.2 \mathrm{~V}$ | 65 | 83 |  | dB |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| IS | Supply Current (per Amplifier) | No load | 4 | 5 | 6 | mA |

## DYNAMIC PERFORMANCE

| SR | Slew Rate (Note 1) | $\pm 2.5 \mathrm{~V}$ square wave, measured $25 \%-75 \%$ | 44 | 65 |  | $\mathrm{~V} / \mu \mathrm{s}$ |
| :--- | :--- | :--- | :---: | :---: | :---: | :---: |
| ts | Settling to $+0.1 \%\left(\mathrm{~A}_{\mathrm{V}}=+1\right)$ | $\left(\mathrm{A}_{\mathrm{V}}=+1\right), \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}$ step |  | 50 | ns |  |
| BW | -3dB Bandwidth |  |  | 80 | MHz |  |
| HD 2 | 2nd Harmonic Distortion | $\mathrm{f}=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{P}-\mathrm{P}}, \mathrm{R}_{\mathrm{L}}=500 \Omega, \mathrm{~A}_{\mathrm{V}}=2$ |  | -86 | dBc |  |
|  | $\mathrm{f}=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{P}-\mathrm{P}}, \mathrm{R}_{\mathrm{L}}=150 \Omega, \mathrm{~A}_{\mathrm{V}}=2$ | -79 | dBc |  |  |  |
| HD3 | 3rd Harmonic Distortion | $\mathrm{f}=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{P}-\mathrm{P},}, \mathrm{R}_{\mathrm{L}}=500 \Omega, \mathrm{~A}_{\mathrm{V}}=2$ | -93 | dBc |  |  |
|  | $\mathrm{f}=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{P}-\mathrm{P}}, \mathrm{R}_{\mathrm{L}}=150 \Omega, \mathrm{~A}_{\mathrm{V}}=2$ |  | -70 | dBc |  |  |

## NOTE:

1. Slew rate is measured on rising and falling edges

Electrical Specifications $\quad \mathrm{V}_{\mathrm{S}^{+}}=+5 \mathrm{~V}, \mathrm{~V}_{\mathrm{S}^{-}}=-5 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=500 \Omega$ and $\mathrm{C}_{\mathrm{L}}=3 \mathrm{pF}$ to $0 \mathrm{~V}, \mathrm{R}_{\mathrm{F}}=420 \Omega$ and $\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}$ unless otherwise specified.

| PARAMETER | DESCRIPTION | CONDITIONS | MIN | TYP | MAX | UNIT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| INPUT CHARACTERISTICS |  |  |  |  |  |  |
| $\mathrm{V}_{\text {OS }}$ | Input Offset Voltage | $\mathrm{V}_{\mathrm{CM}}=0 \mathrm{~V}$ |  | 0.6 | 3 | mV |
| TCV ${ }_{\text {OS }}$ | Average Offset Voltage Drift | Measured over operating temperature range |  | 4.9 |  | $\mu \mathrm{V} /{ }^{\circ} \mathrm{C}$ |
| $\mathrm{I}_{\mathrm{B}}$ | Input Bias Current | $\mathrm{V}_{\mathrm{CM}}=0 \mathrm{~V}$ | -9 | -4.5 | -1 | $\mu \mathrm{A}$ |
| $\mathrm{R}_{\text {IN }}$ | Input Impedance |  |  | 6 |  | $\mathrm{M} \Omega$ |
| $\mathrm{C}_{\text {IN }}$ | Input Capacitance |  |  | 1.2 |  | pF |
| CMIR | Common-Mode Input Range |  | -4.7 |  | +3.4 | V |
| CMRR | Common-Mode Rejection Ratio | for $\mathrm{V}_{\text {IN }}$ from -4.7 V to +3.4 V | 60 | 90 |  | dB |
|  |  | for $\mathrm{V}_{\text {IN }}$ from -2 V to +2 V |  |  |  | dB |
| AVOL | Open-Loop Gain | $-2.5 \mathrm{~V} \leq \mathrm{V}_{\text {OUT }} \leq 2.5 \mathrm{~V}$ | 60 | 72 |  | dB |
| $\mathrm{e}_{\mathrm{N}}$ | Voltage Noise | $\mathrm{f}=100 \mathrm{kHz}$ |  | 4.7 |  | $\mathrm{nV} / \mathrm{JHz}$ |
| ${ }^{\mathrm{N}}$ | Current Noise | $\mathrm{f}=100 \mathrm{kHz}$ |  | 1.2 |  | $\mathrm{pA} / \sqrt{\mathrm{Hz}}$ |
| OUTPUT CHARACTERISTICS |  |  |  |  |  |  |
| $\mathrm{V}_{\mathrm{OL}}$ | Output Swing Low | $\mathrm{R}_{\mathrm{L}}=500 \Omega$ |  | -3.8 | -3.5 | V |
|  |  | $\mathrm{R}_{\mathrm{L}}=250 \Omega$ |  | -3.7 | -3.5 | V |
| $\mathrm{V}_{\mathrm{OH}}$ | Output Swing High | $\mathrm{R}_{\mathrm{L}}=500 \Omega$ | 3.5 | 3.7 |  | V |
|  |  | $\mathrm{R}_{\mathrm{L}}=250 \Omega$ | 3.5 | 3.6 |  | V |
| Isc | Short Circuit Current | $\mathrm{R}_{\mathrm{L}}=10 \Omega$ | 60 | 100 |  | mA |
| POWER SUPPLY PERFORMANCE |  |  |  |  |  |  |
| PSRR | Power Supply Rejection Ratio | $\mathrm{V}_{\mathrm{S}}$ is moved from $\pm 4.5 \mathrm{~V}$ to $\pm 5.5 \mathrm{~V}$ | 65 | 83 |  | dB |
| Is | Supply Current (Per Amplifier) | No load | 3.5 | 4.5 | 5.5 | mA |
| DYNAMIC PERFORMANCE |  |  |  |  |  |  |
| SR | Slew Rate (Note 1) | $\pm 2.5 \mathrm{~V}$ square wave, measured $25 \%-75 \%$ | 35 | 50 |  | V/us |
| ts | Settling to $+0.1 \%\left(\mathrm{~A}_{\mathrm{V}}=+1\right)$ | $\left(\mathrm{A}_{\mathrm{V}}=+1\right), \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}$ step |  | 50 |  | ns |
| BW | -3dB Bandwidth |  |  | 75 |  | MHz |
| HD2 | 2nd Harmonic Distortion | $f=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{P-P}, R_{L}=500 \Omega, A_{V}=2$ |  | -90 |  | dBc |
|  |  | $f=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{P-P}, R_{L}=150 \Omega, A_{V}=2$ |  | -71 |  | dBc |
| HD3 | 3rd Harmonic Distortion | $f=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\text {P-P }}, R_{L}=500 \Omega, A_{V}=2$ |  | -99 |  | dBc |
|  |  | $f=1 \mathrm{MHz}, \mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{P-P}, R_{L}=150 \Omega, A_{V}=2$ |  | -69 |  | dBc |

NOTE:

1. Slew rate is measured on rising and falling edges

## Typical Performance Curves



Non-Inverting Frequency Response (Gain)






## Typical Performance Curves (Continued)






50ns/div




Small Signal Step Response $\mathrm{V}_{\mathrm{S}}= \pm 2.5 \mathrm{~V}$


50ns/div

## Typical Performance Curves (Continued)




CMRR vs Frequency



50ns/div

Diferential Gain/Phase vs DC Input Voltage at 3.58MHz


Closed Loop Output Impedance vs Frequency


PSRR vs Frequency


## Typical Performance Curves (Continued)




Voltage and Current Noise vs Frequency







## Typical Performance Curves (Continued)






## Pin Descriptions

| 8-PIN MSOP | 8-PIN SO | PIN NAME | PIN FUNCTION | EQUIVALENT CIRCUIT |
| :---: | :---: | :---: | :---: | :---: |
| 1 | 1 | $\mathrm{V}_{\text {OUT }} \mathrm{A}$ | Output | CIRCUIT 1 |
| 2 | 2 | $\mathrm{V}_{\text {IN }} \mathrm{A}$ - | Input |  <br> CIRCUIT 2 |
| 3 | 3 | $\mathrm{V}_{\text {IN }} \mathrm{A}^{+}$ | Input | Reference Circuit 2 |
| 4 | 4 | VS- | Supply |  |
| 5 | 5 | $\mathrm{V}_{\text {IN }} \mathrm{B}+$ | Input |  |
| 6 | 6 | $\mathrm{V}_{\text {IN }} \mathrm{B}$ - | Input | Reference Circuit 2 |
| 7 | 7 | $\mathrm{V}_{\text {OUT }}{ }^{\text {B }}$ | Output | Reference Circuit 1 |
| 8 | 8 | $\mathrm{V}_{\mathrm{S}^{+}}$ | Supply |  |

## Applications Information

## Product Description

The EL2228 is a dual voltage feedback operational amplifier designed especially for DMT ADSL and other applications requiring very low voltage and current noise. It also features low distortion while drawing moderately low supply current and is built on Elantec's proprietary high-speed complementary bipolar process. The EL2228 uses a classical voltage-feedback topology which allows them to be used in a variety of applications where current-feedback amplifiers are not appropriate because of restrictions placed upon the feedback element used with the amplifier. The conventional topology of the EL2228 allows, for example, a capacitor to be placed in the feedback path, making it an excellent choice for applications such as active filters, sample-and-holds, or integrators.

## Single-Supply Operation

The EL2228 was designed to have a wide input and output voltage range. This design also makes the EL2228 an
excellent choice for single-supply operation. Using a single positive supply, the lower input voltage range is within 300 mV of ground $\left(R_{L}=500 \Omega\right)$, and the lower output voltage range is within 875 mV of ground. Upper input voltage range reaches 3.6 V , and output voltage range reaches 3.8 V with a 5 V supply and $R_{L}=500 \Omega$. This results in a 2.625 V output swing on a single 5 V supply. This wide output voltage range also allows single-supply operation with a supply voltage as high as 28 V .

## Gain-Bandwidth Product and the -3dB Bandwidth

The EL2228 has a gain-bandwidth product of 40 MHz while using only 5 mA of supply current per amplifier. For gains greater than 1, their closed-loop -3dB bandwidth is approximately equal to the gain-bandwidth product divided by the noise gain of the circuit. For gains of 1 , higher-order poles in the amplifiers' transfer function contribute to even higher closed loop bandwidths. For example, the EL2228 have a -3 dB bandwidth of 80 MHz at a gain of 1 , dropping to 9 MHz at a gain of 5 . It is important to note that the EL2228 is designed so that this "extra" bandwidth in low-gain
application does not come at the expense of stability. As seen in the typical performance curves, the EL2228 in a gain of only 1 exhibited 0.5 dB of peaking with a $500 \Omega$ load.

## Output Drive Capability

The EL2228 is designed to drive a low impedance load. It can easily drive $6 \mathrm{~V}_{\mathrm{P}-\mathrm{P}}$ signal into a $500 \Omega$ load. This high output drive capability makes the EL2228 an ideal choice for RF, IF, and video applications. Furthermore, the EL2228 is current-limited at the output, allowing it to withstand momentary short to ground. However, the power dissipation with output-shorted cannot exceed the power dissipation capability of the package.

## Driving Cables and Capacitive Loads

Although the EL2228 is designed to drive low impedance load, capacitive loads will decreases the amplifier's phase margin. As shown in the performance curves, capacitive load can result in peaking, overshoot and possible oscillation. For optimum AC performance, capacitive loads should be reduced as much as possible or isolated with a series resistor between $5 \Omega$ to $20 \Omega$. When driving coaxial cables, double termination is always recommended for reflectionfree performance. When properly terminated, the capacitance of the coaxial cable will not add to the capacitive load seen by the amplifier.

## Power Dissipation

With the wide power supply range and large output drive capability of the EL2228, it is possible to exceed the $150^{\circ} \mathrm{C}$ maximum junction temperatures under certain load and power-supply conditions. It is therefore important to calculate the maximum junction temperature ( $\mathrm{T}_{\mathrm{JMAX}}$ ) for all applications to determine if power supply voltages, load conditions, or package type need to be modified for the EL2228 to remain in the safe operating area. These parameters are related as follows:

$$
\mathrm{T}_{\mathrm{JMAX}}=\mathrm{T}_{\mathrm{MAX}}+\left(\theta_{\mathrm{JA}} \times P D_{\mathrm{MAXTOTAL}}\right)
$$

where:

- PDMAXTOTAL is the sum of the maximum power dissipation of each amplifier in the package ( $\mathrm{PD}_{\mathrm{MAX}}$ )
- $P D_{\text {MAX }}$ for each amplifier can be calculated as follows:

$$
\mathrm{PD}_{\mathrm{MAX}}=2^{*} \mathrm{~V}_{\mathrm{S}} \times \mathrm{I}_{\text {SMAX }}+\left(\mathrm{V}_{\mathrm{S}}-\mathrm{V}_{\text {OUTMAX }}\right) \times \frac{\mathrm{V}_{\text {OUTMAX }}}{R_{\mathrm{L}}}
$$

where:

- $\mathrm{T}_{\mathrm{MAX}}=$ Maximum ambient temperature
- $\theta_{\mathrm{JA}}=$ Thermal resistance of the package
- $P D_{\text {MAX }}=$ Maximum power dissipation of 1 amplifier
- $\mathrm{V}_{\mathrm{S}}=$ Supply voltage
- $I_{\text {MAX }}=$ Maximum supply current of 1 amplifier
- $V_{\text {OUtMAX }}=$ Maximum output voltage swing of the application
- $R_{L}=$ Load resistance


## Power Supply Bypassing And Printed Circuit Board Layout

As with any high frequency devices, good printed circuit board layout is essential for optimum performance. Ground plane construction is highly recommended. Pin lengths should be kept as short as possible. The power supply pins must be closely bypassed to reduce the risk of oscillation. The combination of a $4.7 \mu \mathrm{~F}$ tantalum capacitor in parallel with $0.1 \mu \mathrm{~F}$ ceramic capacitor has been proven to work well when placed at each supply pin. For single supply operation, where pin $4\left(\mathrm{~V}_{\mathrm{S}^{-}}\right)$is connected to the ground plane, a single $4.7 \mu \mathrm{~F}$ tantalum capacitor in parallel with a $0.1 \mu \mathrm{~F}$ ceramic capacitor across pin $8\left(\mathrm{~V}_{\mathrm{S}^{+}}\right)$.
For good AC performance, parasitic capacitance should be kept to a minimum. Ground plane construction again should be used. Small chip resistors are recommended to minimize series inductance. Use of sockets should be avoided since they add parasitic inductance and capacitance which will result in additional peaking and overshoot.

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