# Precision, Very Low Noise, Low Input Bias Current, Wide Bandwidth JFET Operational Amplifiers

# AD8510/AD8512/AD8513

## FEATURES

**Fast settling time: 500 ns to 0.1%**
**Low offset voltage: 400 µV maximum**
**Low $T_CV_{OS}$: 1 µV/°C typical**
**Low input bias current: 25 pA typical**
**Dual-supply operation: ±5 V to ±15 V**
**Low noise: 8 nV/√Hz**
**Low distortion: 0.0005%**
**No phase reversal**
**Unity gain stable**

## APPLICATIONS

**Instrumentation**
**Multipole filters**
**Precision current measurement**
**Photodiode amplifiers**
**Sensors**
**Audio**

## PIN CONFIGURATIONS

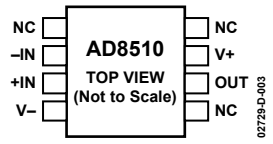


*Figure 1. 8-Lead MSOP (RM Suffix)*

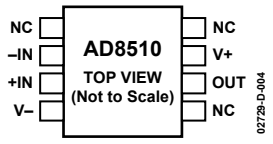


*Figure 2. 8-Lead SOIC_N (R Suffix)*

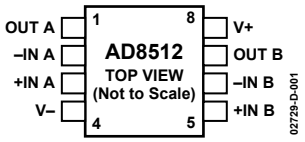


*Figure 3. 8-Lead MSOP (RM Suffix)*

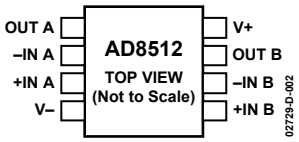


*Figure 4. 8-Lead SOIC_N (R Suffix)*

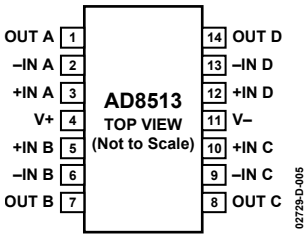


*Figure 5. 14-Lead SOIC_N (R Suffix)*

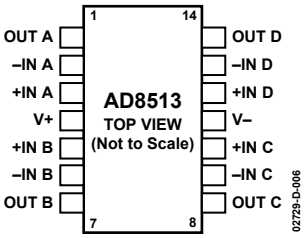


*Figure 6. 14-Lead TSSOP (RU Suffix)*

## GENERAL DESCRIPTION

The AD8510/AD8512/AD8513 are single-, dual-, and quad-precision JFET amplifiers that feature low offset voltage, input bias current, input voltage noise, and input current noise.

The combination of low offsets, low noise, and very low input bias currents makes these amplifiers especially suitable for high impedance sensor amplification and precise current measurements using shunts. The combination of dc precision, low noise, and fast settling time results in superior accuracy in medical instruments, electronic measurement, and automated test equipment. Unlike many competitive amplifiers, the AD8510/AD8512/AD8513 maintain their fast settling performance even with substantial capacitive loads. Unlike many older JFET amplifiers, the AD8510/AD8512/AD8513 does not suffer from output phase reversal when input voltages exceed the maximum common-mode voltage range.

Fast slew rate and great stability with capacitive loads make the AD8510/AD8512/AD8513 a perfect fit for high performance filters. Low input bias currents, low offset, and low noise result in a wide dynamic range of photodiode amplifier circuits. Low noise and distortion, high output current, and excellent speed make the AD8510/AD8512/AD8513 a great choice for audio applications.

The AD8510/AD8512 are both available in 8-lead narrow SOIC_N and 8-lead MSOP packages. MSOP packaged parts are only available in tape and reel. The AD8513 is available in 14-lead SOIC_N and TSSOP packages.

The AD8510/AD8512/AD8513 are specified over the –40°C to +125°C extended industrial temperature range.

**Rev. F**
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# SPECIFICATIONS

@ $V_S$ = ±5 V, $V_{CM}$ = 0 V, $T_A$ = 25°C, unless otherwise noted.

**Table 1.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| INPUT CHARACTERISTICS | | | | | | |
| Offset Voltage (B Grade)[1] | $V_{OS}$ | | | 0.08 | 0.4 | mV |
| | | −40°C < $T_A$ < +125°C | | | 0.8 | mV |
| Offset Voltage (A Grade) | $V_{OS}$ | | | 0.1 | 0.9 | mV |
| | | −40°C < $T_A$ < +125°C | | | 1.8 | mV |
| Input Bias Current | $I_B$ | | | 21 | 75 | pA |
| | | −40°C < $T_A$ < +85°C | | | 0.7 | nA |
| | | −40°C < $T_A$ < +125°C | | | 7.5 | nA |
| Input Offset Current | $I_{OS}$ | | | 5 | 50 | pA |
| | | −40°C < $T_A$ < +85°C | | | 0.3 | nA |
| | | −40°C < $T_A$ < +125°C | | | 0.5 | nA |
| Input Capacitance | | | | | | |
| Differential | | | | 12.5 | | pF |
| Common-Mode | | | | 11.5 | | pF |
| Input Voltage Range | | | −2.0 | | +2.5 | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = −2.0 V to +2.5 V | 86 | 100 | | dB |
| Large Signal Voltage Gain | $A_{VO}$ | $R_L$ = 2 kΩ, $V_O$ = −3 V to +3 V | 65 | 107 | | V/mV |
| Offset Voltage Drift (B Grade)[1] | $\Delta V_{OS}/\Delta T$ | | | 0.9 | 5 | µV/°C |
| Offset Voltage Drift (A Grade) | $\Delta V_{OS}/\Delta T$ | | | 1.7 | 12 | µV/°C |
| OUTPUT CHARACTERISTICS | | | | | | |
| Output Voltage High | $V_{OH}$ | $R_L$ = 10 kΩ | +4.1 | +4.3 | | V |
| Output Voltage Low | $V_{OL}$ | −40°C < $T_A$ < +125°C | | −4.9 | −4.7 | V |
| Output Voltage High | $V_{OH}$ | $R_L$ = 2 kΩ | +3.9 | +4.2 | | V |
| Output Voltage Low | $V_{OL}$ | −40°C < $T_A$ < +125°C | | −4.9 | −4.5 | V |
| Output Voltage High | $V_{OH}$ | $R_L$ = 600 Ω | +3.7 | +4.1 | | V |
| Output Voltage Low | $V_{OL}$ | −40°C < $T_A$ < +125°C | | −4.8 | −4.2 | V |
| Output Current | $I_{OUT}$ | | ±40 | ±54 | | mA |
| POWER SUPPLY | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$ = ±4.5 V to ±18 V | 86 | 130 | | dB |
| Supply Current/Amplifier | $I_{SY}$ | | | | | |
| AD8510/AD8512/AD8513 | | $V_O$ = 0 V | | 2.0 | 2.3 | mA |
| AD8510/AD8512 | | −40°C < $T_A$ < +125°C | | | 2.5 | mA |
| AD8513 | | −40°C < $T_A$ < +125°C | | | 2.75 | mA |
| DYNAMIC PERFORMANCE | | | | | | |
| Slew Rate | SR | $R_L$ = 2 kΩ | | 20 | | V/µs |
| Gain Bandwidth Product | GBP | | | 8 | | MHz |
| Settling Time | $t_S$ | To 0.1%, 0 V to 4 V step, G = +1 | | 0.4 | | µs |
| THD + Noise | THD + N | 1 kHz, G = +1, $R_L$ = 2 kΩ | | 0.0005 | | % |
| Phase Margin | $\Phi_O$ | | | 44.5 | | Degrees |
| NOISE PERFORMANCE | | | | | | |
| Voltage Noise Density | $e_n$ | f = 10 Hz | | 34 | | nV/√Hz |
| | | f = 100 Hz | | 12 | | nV/√Hz |
| | | f = 1 kHz | | 8.0 | 10 | nV/√Hz |
| | | f = 10 kHz | | 7.6 | | nV/√Hz |
| Peak-to-Peak Voltage Noise | $e_n$ p-p | 0.1 Hz to 10 Hz bandwidth | | 2.4 | 5.2 | µV p-p |

[1] AD8510/AD8512 only.

## ELECTRICAL CHARACTERISTICS

@ $V_S$ = ±15 V, $V_{CM}$ = 0 V, $T_A$ = 25°C, unless otherwise noted.

**Table 2.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| INPUT CHARACTERISTICS | | | | | | |
| Offset Voltage (B Grade)[1] | $V_{OS}$ | | | 0.08 | 0.4 | mV |
| | | −40°C < $T_A$ < +125°C | | | 0.8 | mV |
| Offset Voltage (A Grade) | $V_{OS}$ | | | 0.1 | 1.0 | mV |
| | | −40°C < $T_A$ < +125°C | | | 1.8 | mV |
| Input Bias Current | $I_B$ | | | 25 | 80 | pA |
| | | −40°C < $T_A$ < +85°C | | | 0.7 | nA |
| | | −40°C < $T_A$ < +125°C | | | 10 | nA |
| Input Offset Current | $I_{OS}$ | | | 6 | 75 | pA |
| | | −40°C < $T_A$ < +85°C | | | 0.3 | nA |
| | | −40°C < $T_A$ < +125°C | | | 0.5 | nA |
| Input Capacitance | | | | | | |
| Differential | | | | 12.5 | | pF |
| Common-Mode | | | | 11.5 | | pF |
| Input Voltage Range | | | −13.5 | | +13.0 | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = −12.5 V to +12.5 V | 86 | 108 | | dB |
| Large Signal Voltage Gain | $A_{VO}$ | $V_O$ = −13.5 V to +13.5 V | 115 | 196 | | V/mV |
| | | $R_L$ = 2 kΩ, $V_{CM}$ = 0 V | | | | |
| Offset Voltage Drift (B Grade)[1] | $\Delta V_{OS}/\Delta T$ | | | 1.0 | 5 | µV/°C |
| Offset Voltage Drift (A Grade) | $\Delta V_{OS}/\Delta T$ | | | 1.7 | 12 | µV/°C |
| OUTPUT CHARACTERISTICS | | | | | | |
| Output Voltage High | $V_{OH}$ | $R_L$ = 10 kΩ | +14.0 | +14.2 | | V |
| Output Voltage Low | $V_{OL}$ | −40°C < $T_A$ < +125°C | | −14.9 | −14.6 | V |
| Output Voltage High | $V_{OH}$ | $R_L$ = 2 kΩ | +13.8 | +14.1 | | V |
| Output Voltage Low | $V_{OL}$ | −40°C < $T_A$ < +125°C | | −14.8 | −14.5 | V |
| Output Voltage High | $V_{OH}$ | $R_L$ = 600 Ω, $T_A$ = 25°C | +13.5 | +13.9 | | V |
| | | −40°C < $T_A$ < +125°C | +11.4 | | | V |
| Output Voltage Low | $V_{OL}$ | $R_L$ = 600 Ω, $T_A$ = 25°C | | −14.3 | −13.8 | V |
| | | −40°C < $T_A$ < +125°C | | | −12.1 | V |
| Output Current | $I_{OUT}$ | | | ±70 | | mA |
| POWER SUPPLY | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$ = ±4.5 V to ±18 V | 86 | | | dB |
| Supply Current/Amplifier | $I_{SY}$ | | | | | |
| AD8510/AD8512/AD8513 | | $V_O$ = 0 V | | 2.2 | 2.5 | mA |
| AD8510/AD8512 | | −40°C < $T_A$ < +125°C | | | 2.6 | mA |
| AD8513 | | −40°C < $T_A$ < +125°C | | | 3.0 | mA |
| DYNAMIC PERFORMANCE | | | | | | |
| Slew Rate | SR | $R_L$ = 2 kΩ | | 20 | | V/µs |
| Gain Bandwidth Product | GBP | | | 8 | | MHz |
| Settling Time | $t_S$ | To 0.1%, 0 V to 10 V step, G = +1 | | 0.5 | | µs |
| | | To 0.01%, 0 V to 10 V step, G = +1 | | 0.9 | | µs |
| THD + Noise | THD + N | 1 kHz, G = +1, $R_L$ = 2 kΩ | | 0.0005 | | % |
| Phase Margin | $\Phi_O$ | | | 52 | | Degrees |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| NOISE PERFORMANCE | | | | | | |
| Voltage Noise Density | $e_n$ | f = 10 Hz | | 34 | | nV/√Hz |
| | | f = 100 Hz | | 12 | | nV/√Hz |
| | | f = 1 kHz | | 8.0 | 10 | nV/√Hz |
| | | f = 10 kHz | | 7.6 | | nV/√Hz |
| Peak-to-Peak Voltage Noise | $e_n$ p-p | 0.1 Hz to 10 Hz bandwidth | | 2.4 | 5.2 | μV p-p |

[1] AD8510/AD8512 only.

# ABSOLUTE MAXIMUM RATINGS

**Table 3.**

| Parameter | Rating |
|---|---|
| Supply Voltage | ±18 V |
| Input Voltage | $\pm V_S$ |
| Output Short-Circuit Duration to GND | Observe Derating Curves |
| Storage Temperature Range | |
| R, RM Packages | −65°C to +150°C |
| Operating Temperature Range | −40°C to +125°C |
| Junction Temperature Range | |
| R, RM Packages | −65°C to +150°C |
| Lead Temperature (Soldering, 10 sec) | 300°C |
| Electrostatic Discharge (HBM) | 2000 V |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**Table 4. Thermal Resistance**

| Package Type | $\theta_{JA}$[1] | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 8-Lead MSOP (RM) | 210 | 45 | °C/W |
| 8-Lead SOIC_N (R) | 158 | 43 | °C/W |
| 14-Lead SOIC_N (R) | 120 | 36 | °C/W |
| 14-Lead TSSOP (RU) | 180 | 35 | °C/W |

[1] $\theta_{JA}$ is specified for worst-case conditions, that is, $\theta_{JA}$ is specified for device soldered in circuit board for surface-mount packages.

## ESD 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 this product 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.

# TYPICAL PERFORMANCE CHARACTERISTICS

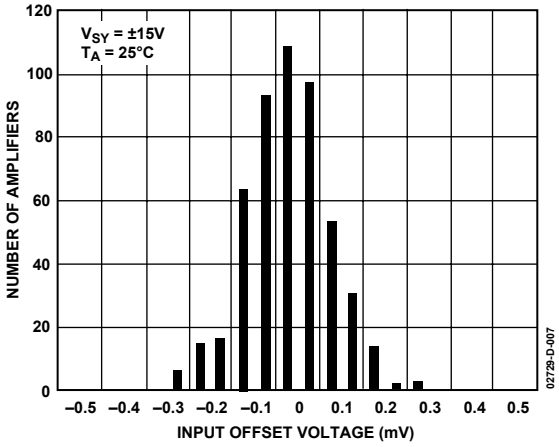


Figure 7. Input Offset Voltage Distribution

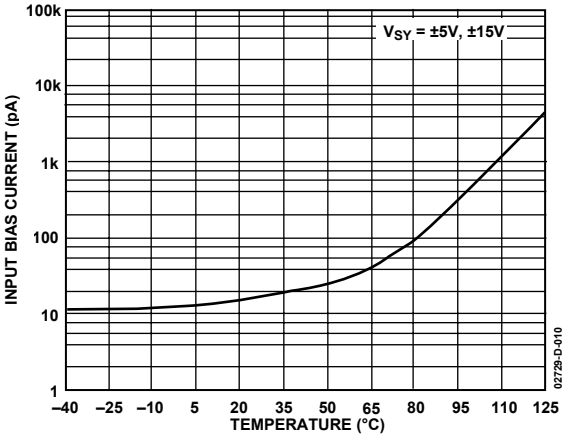


Figure 10. Input Bias Current vs. Temperature

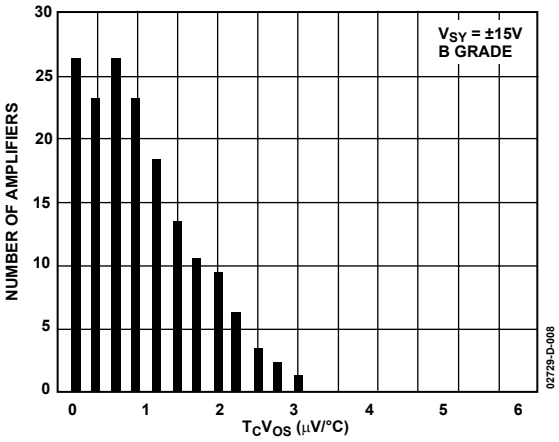


Figure 8. AD8510/AD8512 $T_CV_{OS}$ Distribution

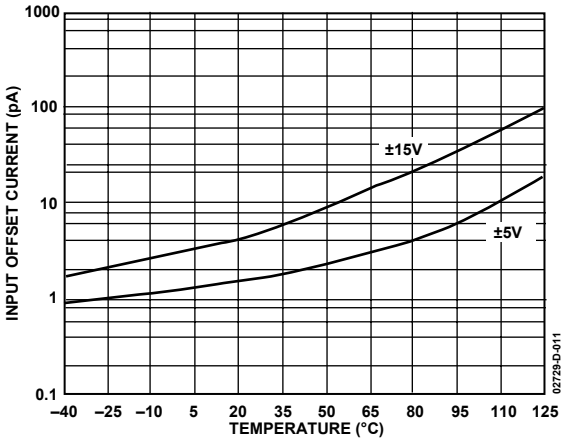


Figure 11. Input Offset Current vs. Temperature

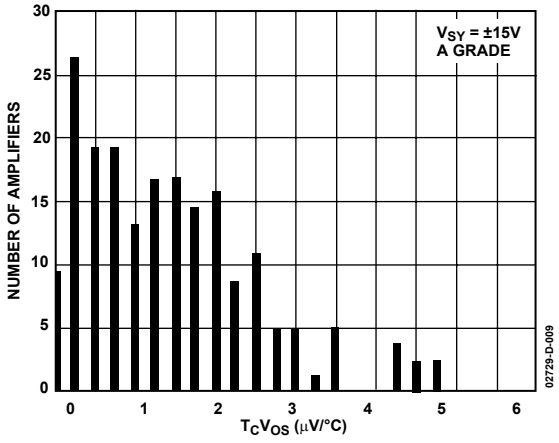


Figure 9. AD8510/AD8512 $T_CV_{OS}$ Distribution

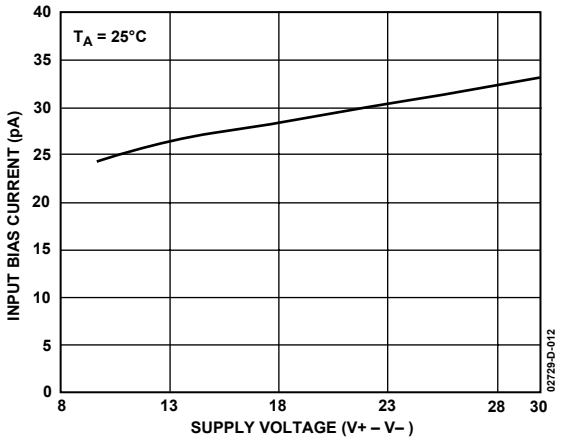


Figure 12. Input Bias Current vs. Supply Voltage

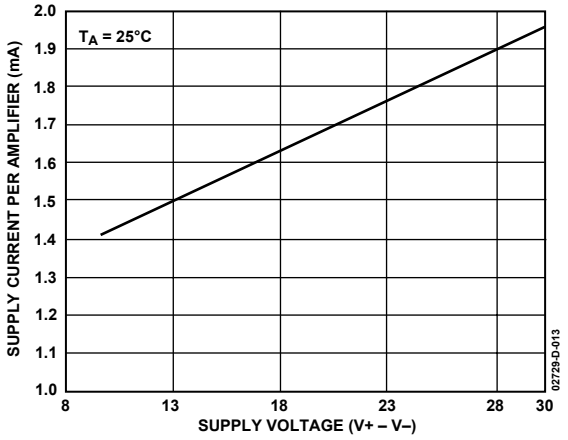


Figure 13. AD8512 Supply Current per Amplifier vs. Supply Voltage

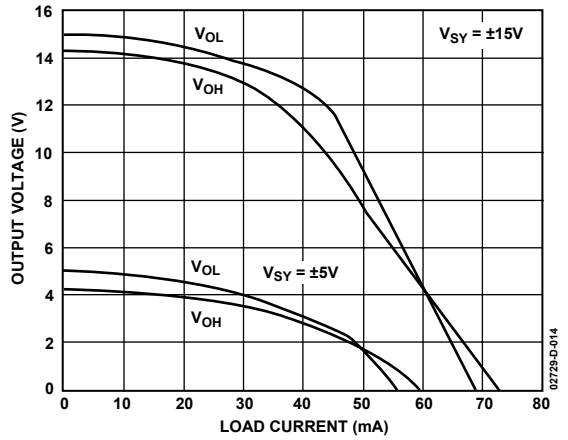


Figure 14. AD8510/AD8512 Output Voltage vs. Load Current

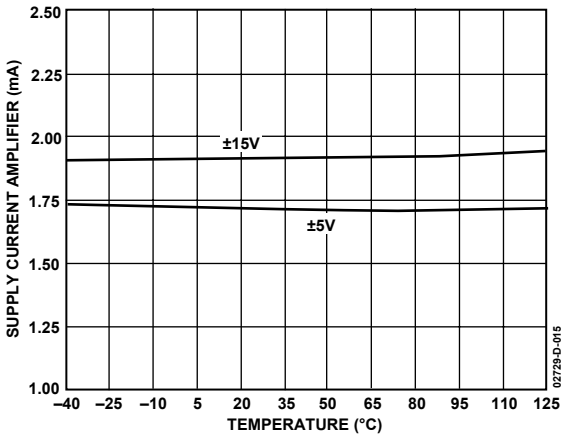


Figure 15. AD8512 Supply Current per Amplifier vs. Temperature

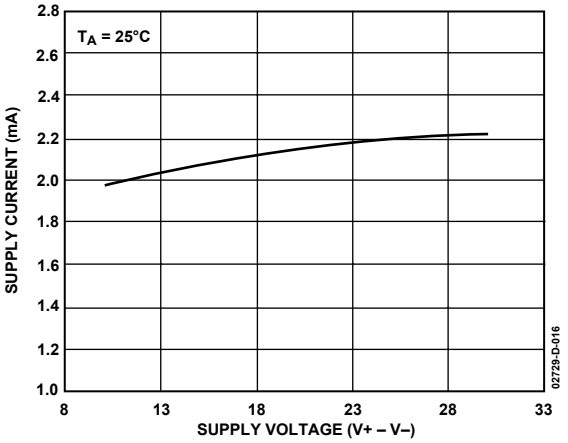


Figure 16. AD8510 Supply Current vs. Supply Voltage

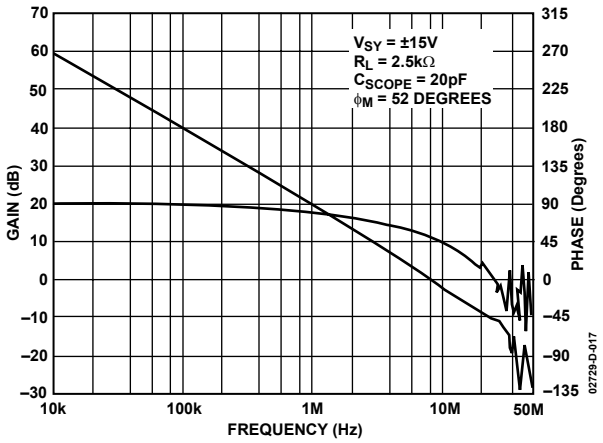


Figure 17. Open-Loop Gain and Phase vs. Frequency

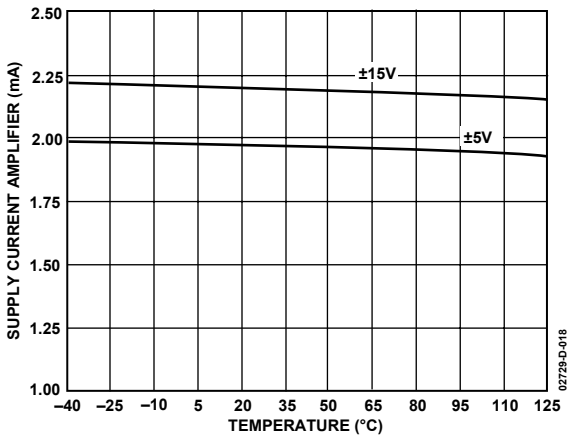


Figure 18. AD8510 Supply Current vs. Temperature

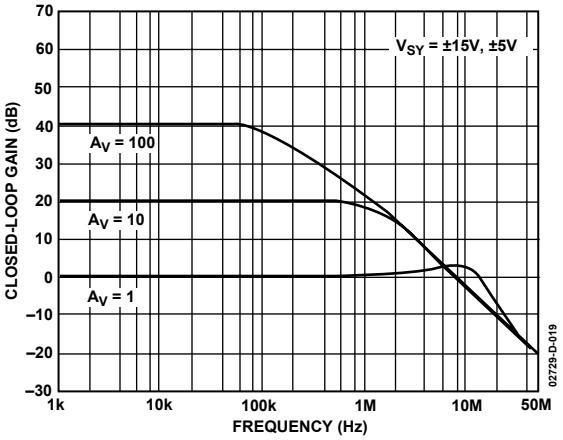


Figure 19. Closed-Loop Gain vs. Frequency

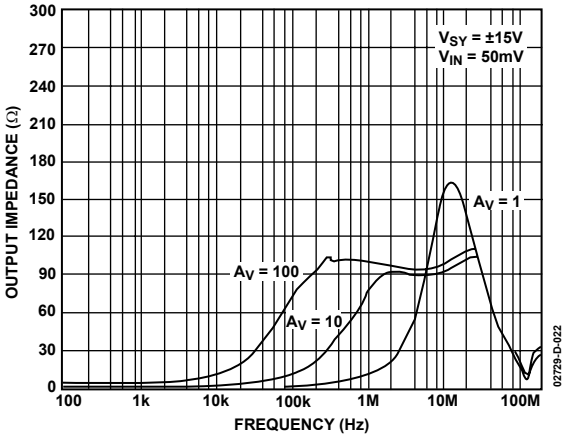


Figure 22. Output Impedance vs. Frequency

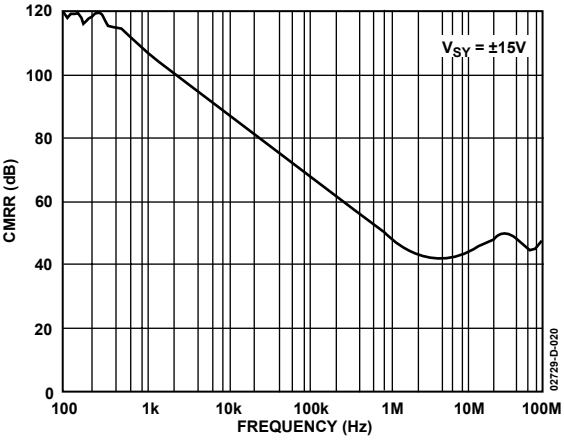


Figure 20. CMRR vs. Frequency

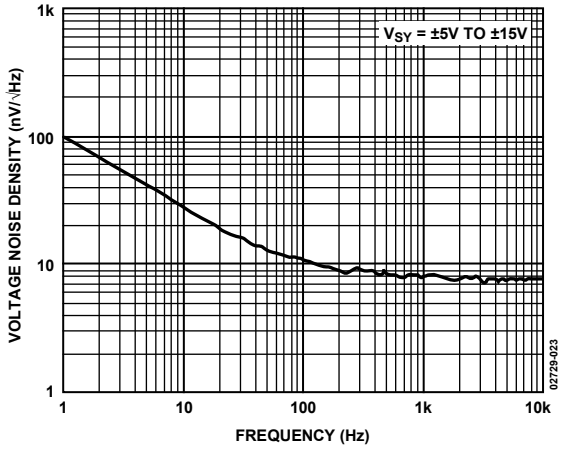


Figure 23. Voltage Noise Density

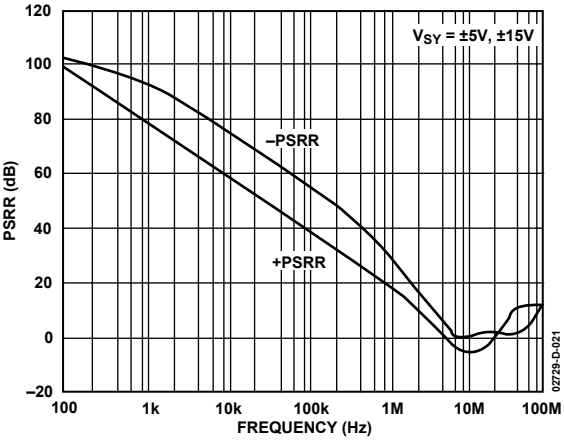


Figure 21. PSRR vs. Frequency

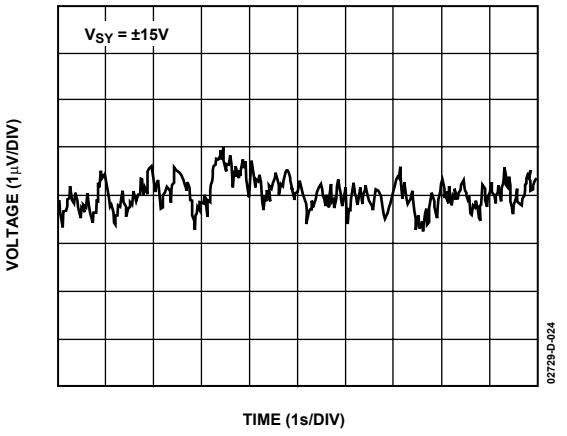


Figure 24. 0.1 Hz to 10 Hz Input Voltage Noise

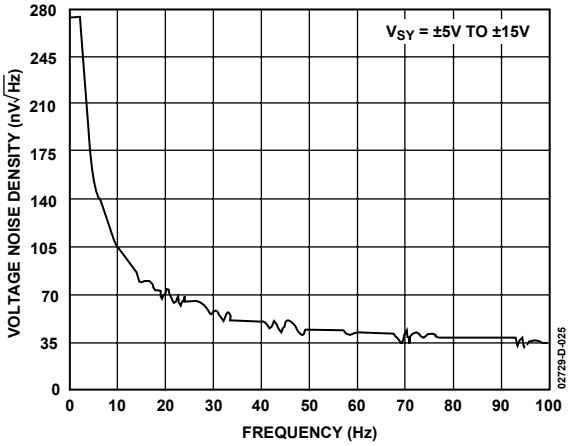


Figure 25. Voltage Noise Density vs. Frequency

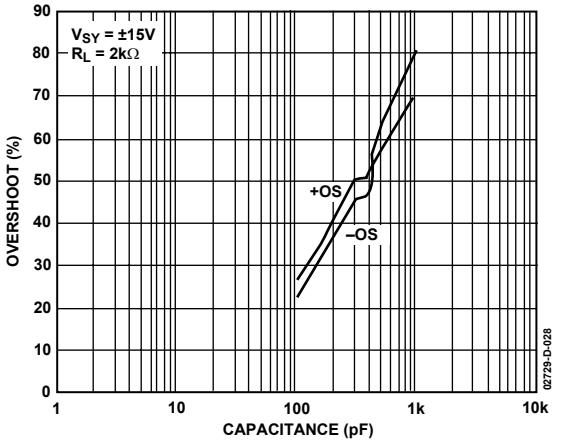


Figure 28. Small Signal Overshoot vs. Load Capacitance

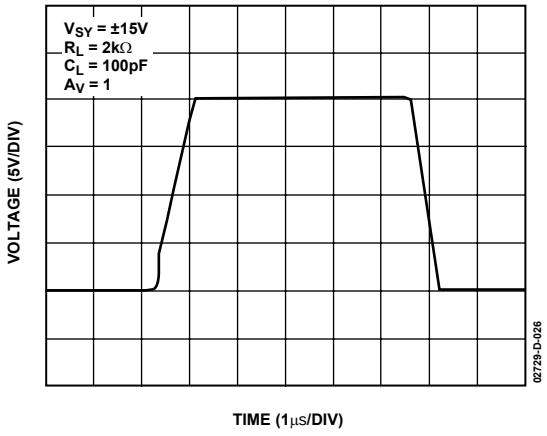


Figure 26. Large Signal Transient Response

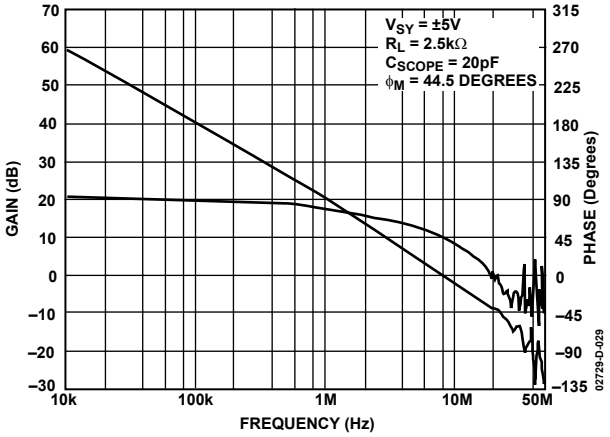


Figure 29. Open-Loop Gain and Phase vs. Frequency

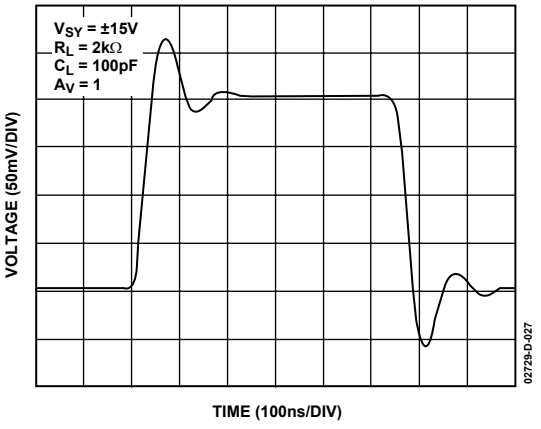


Figure 27. Small Signal Transient Response

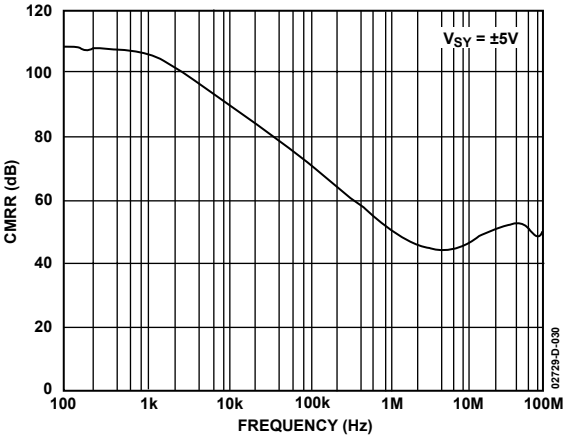


Figure 30. CMRR vs. Frequency

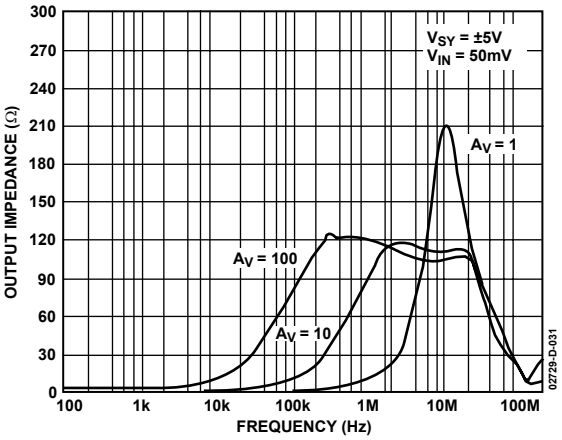


Figure 31. Output Impedance vs. Frequency

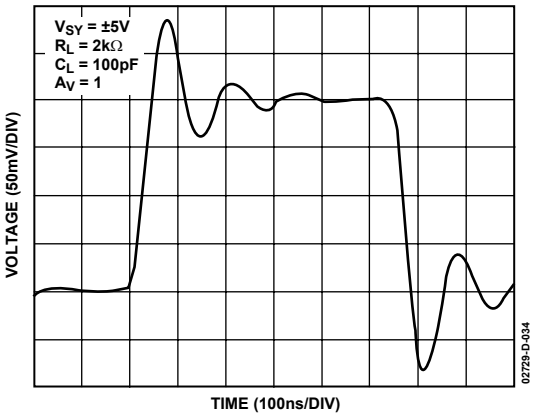


Figure 34. Small Signal Transient Response

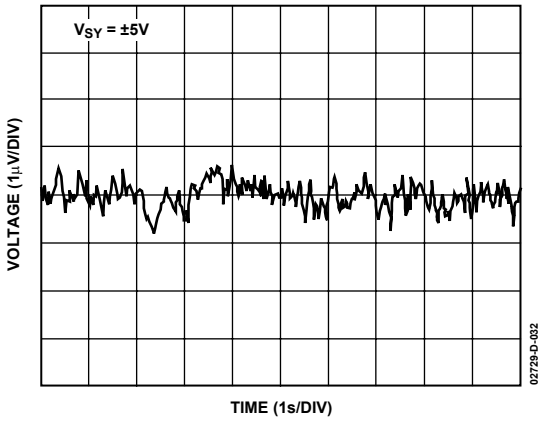


Figure 32. 0.1 Hz to 10 Hz Input Voltage Noise

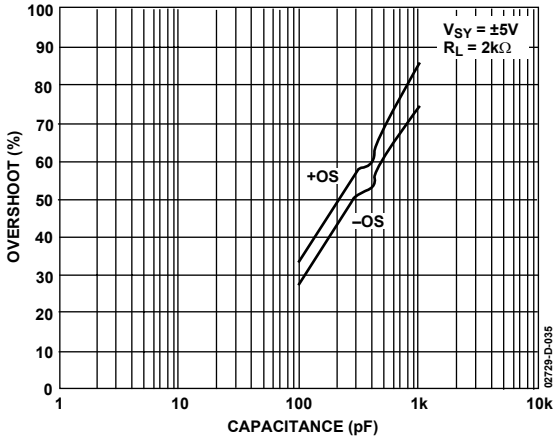


Figure 35. Small Signal Overshoot vs. Load Capacitance

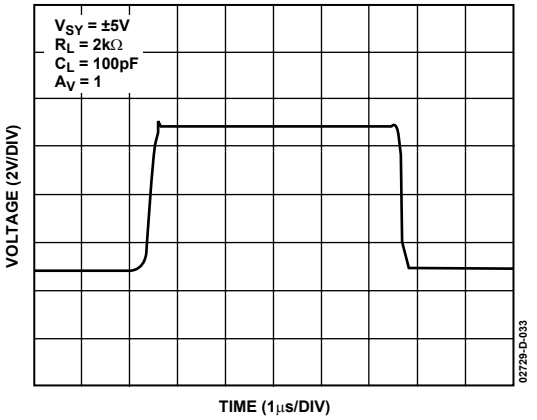


Figure 33. Large Signal Transient Response

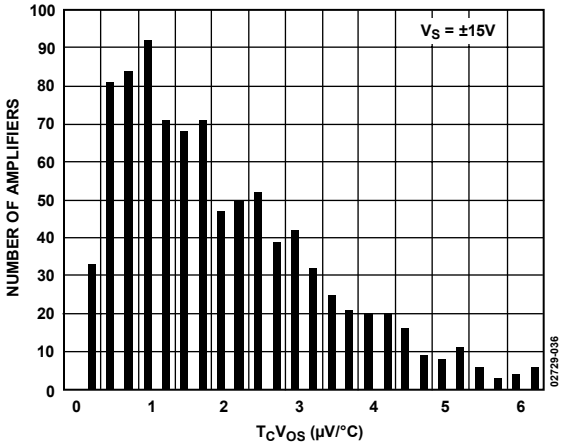


Figure 36. AD8513 $T_CV_{OS}$ Distribution

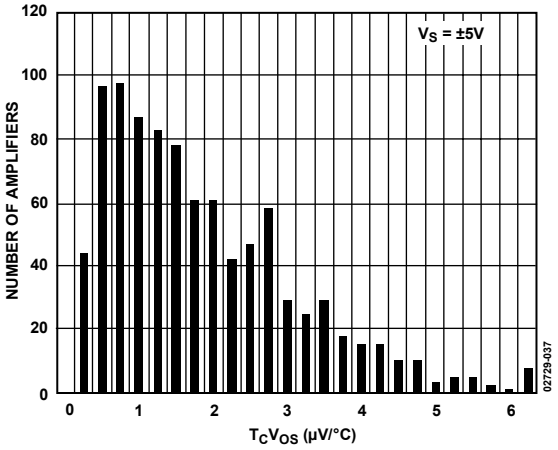


Figure 37. AD8513 $T_CV_{OS}$ Distribution

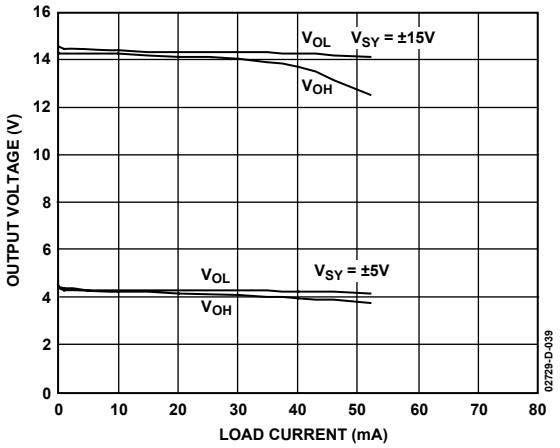


Figure 39. AD8513 Output Voltage vs. Load Current

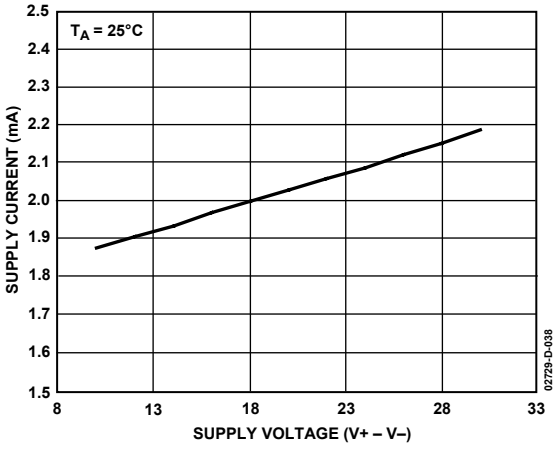


Figure 38. AD8513 Supply Current vs. Supply Voltage

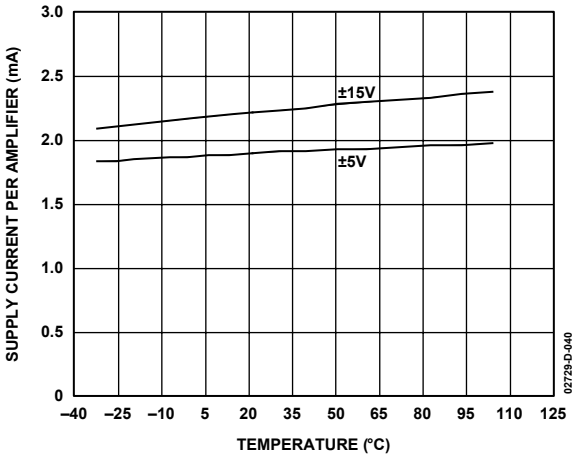


Figure 40. AD8513 Supply Current vs. Temperature

# GENERAL APPLICATION INFORMATION

## INPUT OVERVOLTAGE PROTECTION

The AD8510/AD8512/AD8513 have internal protective circuitry that allows voltages as high as 0.7 V beyond the supplies to be applied at the input of either terminal without causing damage. For higher input voltages, a series resistor is necessary to limit the input current. The resistor value can be determined from the formula

$$\frac{V_{IN} - V_S}{R_S} \leq 5 \text{ mA}$$

With a very low offset current of <0.5 nA up to 125°C, higher resistor values can be used in series with the inputs. A 5 kΩ resistor protects the inputs to voltages as high as 25 V beyond the supplies and adds less than 10 μV to the offset.

## OUTPUT PHASE REVERSAL

Phase reversal is a change of polarity in the transfer function of the amplifier. This can occur when the voltage applied at the input of an amplifier exceeds the maximum common-mode voltage.

Phase reversal can cause permanent damage to the device and can result in system lockups. The AD8510/AD8512/AD8513 do not exhibit phase reversal when input voltages are beyond the supplies.

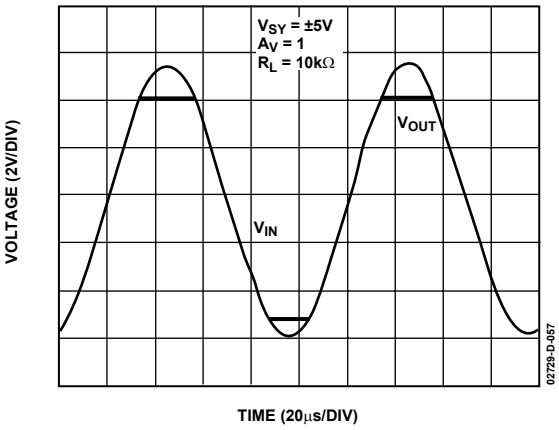


*Figure 41. No Phase Reversal*

## THD + NOISE

The AD8510/AD8512/AD8513 have low total harmonic distortion and excellent gain linearity, making these amplifiers a great choice for precision circuits with high closed-loop gain and for audio application circuits. Figure 42 shows that the AD8510/AD8512/AD8513 have approximately 0.0005% of total distortion when configured in positive unity gain (the worst case) and driving a 100 kΩ load.

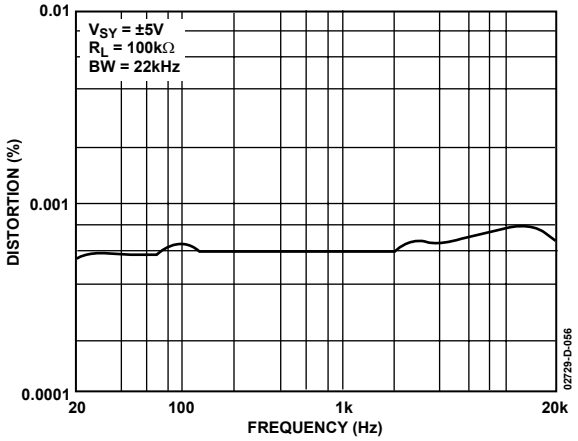


*Figure 42. THD + N vs. Frequency*

## TOTAL NOISE INCLUDING SOURCE RESISTORS

The low input current noise and input bias current of the AD8510/AD8512/AD8513 make them the ideal amplifiers for circuits with substantial input source resistance. Input offset voltage increases by less than 15 nV per 500 Ω of source resistance at room temperature. The total noise density of the circuit is

$$e_{nTOTAL} = \sqrt{e_n^2 + (i_n R_S)^2 + 4kTR_S}$$

where:

$e_n$ is the input voltage noise density of the parts.

$i_n$ is the input current noise density of the parts.

$R_S$ is the source resistance at the noninverting terminal.

$k$ is Boltzman's constant ($1.38 \times 10^{-23}$ J/K).

$T$ is the ambient temperature in Kelvin (T = 273 + °C).

For $R_S$ < 3.9 kΩ, $e_n$ dominates and $e_{nTOTAL} \approx e_n$.

The current noise of the AD8510/AD8512/AD8513 is so low that its total density does not become a significant term unless $R_S$ is greater than 165 MΩ, an impractical value for most applications.

The total equivalent rms noise over a specific bandwidth is expressed as

$$e_{nTOTAL} = e_{nTOTAL}\sqrt{BW}$$

where $BW$ is the bandwidth in Hertz.

Note that the previous analysis is valid for frequencies larger than 150 Hz and assumes flat noise above 10 kHz. For lower frequencies, flicker noise (1/f) must be considered.

## SETTLING TIME

Settling time is the time it takes the output of the amplifier to reach and remain within a percentage of its final value after a pulse is applied at the input. The AD8510/AD8512/AD8513 settle to within 0.01% in less than 900 ns with a step of 0 V to 10 V in unity gain. This makes each of these parts an excellent choice as a buffer at the output of DACs whose settling time is typically less than 1 µs.

In addition to their fast settling time and fast slew rate, their low offset voltage drift and input offset current maintain full accuracy of 12-bit converters over the entire operating temperature range.

## OVERLOAD RECOVERY TIME

Overload recovery, also known as overdrive recovery, is the time it takes the output of an amplifier to recover from a saturated condition to its linear region. This recovery time is particularly important in applications where the amplifier must amplify small signals in the presence of large transient voltages.

Figure 43 shows the positive overload recovery of the AD8510/AD8512/AD8513. The output recovers in approximately 200 ns from a saturated condition.

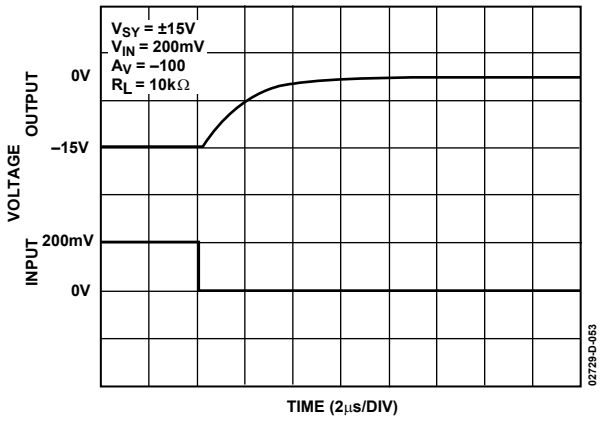


*Figure 43. Positive Overload Recovery*

The negative overdrive recovery time shown in Figure 44 is less than 200 ns.

In addition to the fast recovery time, the AD8510/AD8512/AD8513 show excellent symmetry of the positive and negative recovery times. This is an important feature for transient signal rectification because the output signal is kept equally undistorted throughout any given period.

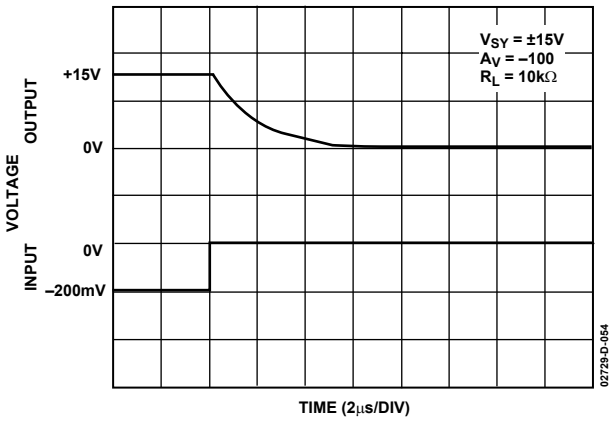


*Figure 44. Negative Overload Recovery*

## CAPACITIVE LOAD DRIVE

The AD8510/AD8512/AD8513 are unconditionally stable at all gains in inverting and noninverting configurations. They are capable of driving up to 1000 pF of capacitive loads without oscillation in unity gain, the worst-case configuration.

However, as with most amplifiers, driving larger capacitive loads in a unity gain configuration can cause excessive overshoot and ringing or even oscillation. A simple snubber network reduces the amount of overshoot and ringing significantly. The advantage of this configuration is that the output swing of the amplifier is not reduced, because $R_S$ is outside the feedback loop.

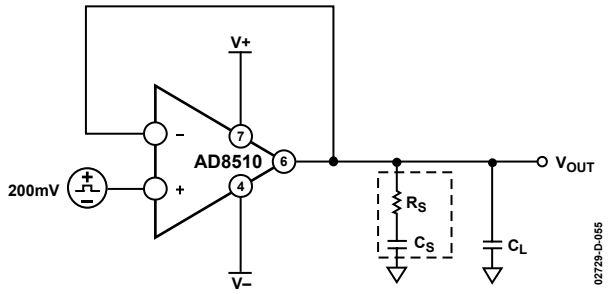


*Figure 45. Snubber Network Configuration*

Figure 46 shows a scope photograph of the output of the AD8510/AD8512/AD8513 in response to a 400 mV pulse. The circuit is configured in positive unity gain (worst-case) with a load experience of 500 pF.

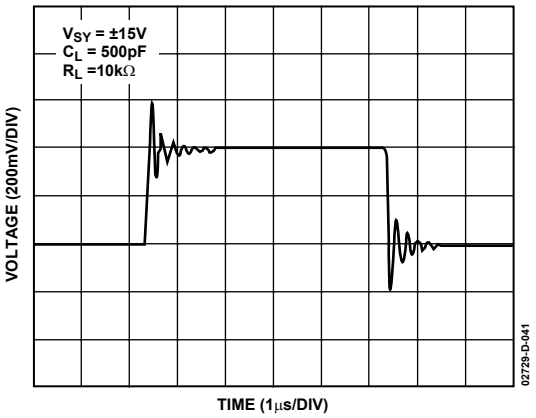


*Figure 46. Capacitive Load Drive without Snubber*

When the snubber circuit is used, the overshoot is reduced from 55% to less than 3% with the same load capacitance. Ringing is virtually eliminated, as shown in Figure 47.

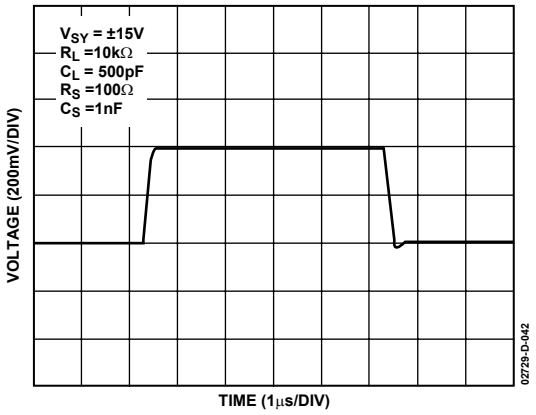


*Figure 47. Capacitive Load with Snubber Network*

Optimum values for $R_S$ and $C_S$ depend on the load capacitance and input stray capacitance and are determined empirically. Table 5 shows a few values that can be used as starting points.

**Table 5. Optimum Values for Capacitive Loads**

| $C_{LOAD}$ | $R_S$ (Ω) | $C_S$ |
|---|---|---|
| 500 pF | 100 | 1 nF |
| 2 nF | 70 | 100 pF |
| 5 nF | 60 | 300 pF |

## OPEN-LOOP GAIN AND PHASE RESPONSE

In addition to their impressive low noise, low offset voltage, and offset current, the AD8510/AD8512/AD8513 have excellent loop gain and phase response even when driving large resistive and capacitive loads. They were compared to the OPA2132 under the same conditions. With a 2.5 kΩ load at the output, the AD8510/AD8512/AD8513 have more than 8 MHz of bandwidth and a phase margin of more than 52°.

The OPA2132, on the other hand, has only 4.5 MHz of bandwidth and 28° of phase margin under the same test conditions. Even with a 1 nF capacitive load in parallel with the 2 kΩ load at the output, the AD8510/AD8512/AD8513 show much better response than the OPA2132, whose phase margin is degraded to less than 0, indicating oscillation.

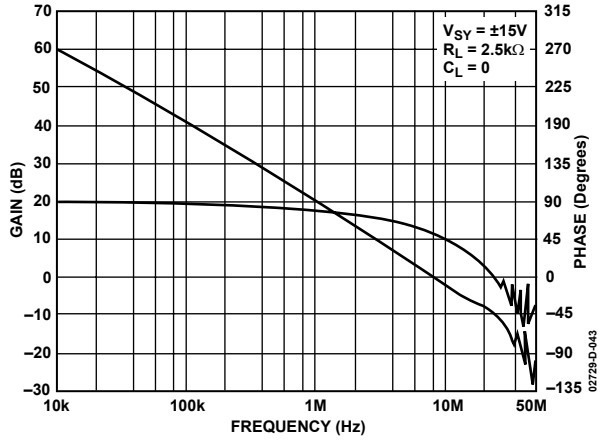


*Figure 48. Frequency Response of the AD8510/AD8512/AD8513*

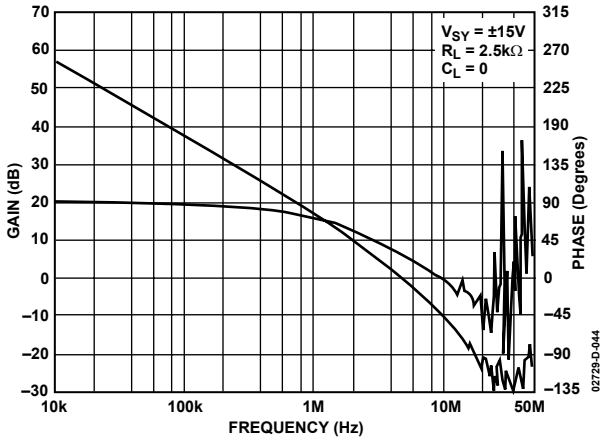


*Figure 49. Frequency Response of the OPA2132*

## PRECISION RECTIFIERS

Rectifying circuits are used in a multitude of applications. One of the most popular uses is in the design of regulated power supplies, where a rectifier circuit is used to convert an input sinusoid to a unipolar output voltage. There are some potential problems with amplifiers used in this manner.

When the input voltage ($V_{IN}$) is negative, the output is zero. The magnitude of $V_{IN}$ is doubled at the inputs of the op amp. This voltage can exceed the power supply voltage, which would damage some amplifiers permanently. The op amp must come out of saturation when $V_{IN}$ is negative. This delays the output signal because the amplifier requires time to enter its linear region.

The AD8510/AD8512/AD8513 have a very fast overdrive recovery time, which makes them great choices for the rectification of transient signals. The symmetry of the positive and negative recovery times is also important in keeping the output signal undistorted.

Figure 50 shows the test circuit of the rectifier. The first stage of the circuit is a half-wave rectifier. When the sine wave applied at the input is positive, the output follows the input response. During the negative cycle of the input, the output tries to swing negative to follow the input, but the power supply restrains it to zero. In a similar fashion, the second stage is a follower during the positive cycle of the sine wave and an inverter during the negative cycle.

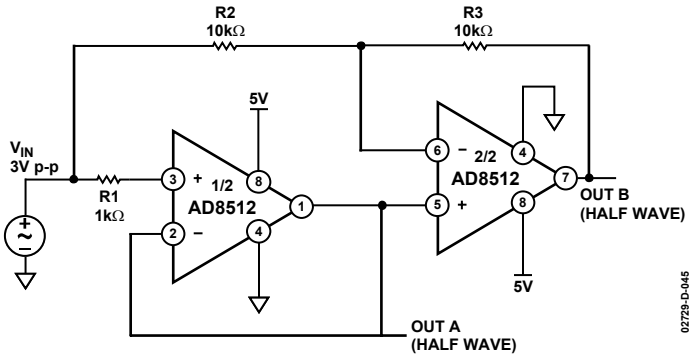


*Figure 50. Half-Wave and Full-Wave Rectifier*

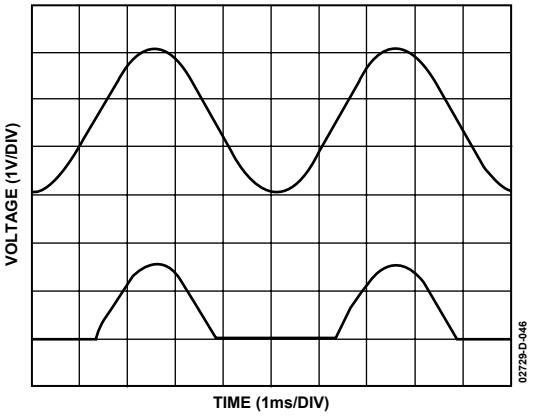


*Figure 51. Half-Wave Rectifier Signal (Out A)*

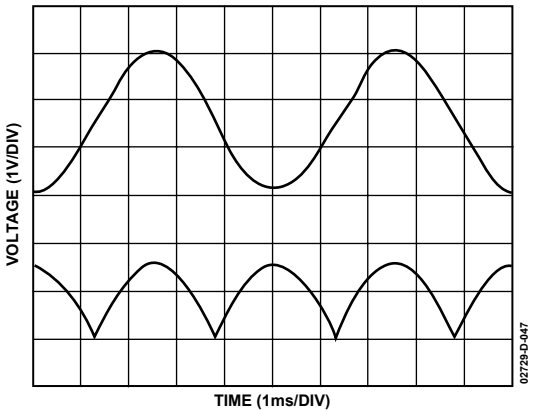


*Figure 52. Full-Wave Rectifier Signal (Out B)*

## I-V CONVERSION APPLICATIONS

### *Photodiode Circuits*

Common applications for I-V conversion include photodiode circuits where the amplifier is used to convert a current emitted by a diode placed at the positive input terminal into an output voltage.

The AD8510/AD8512/AD8513's low input bias current, wide bandwidth, and low noise make them each an excellent choice for various photodiode applications, including fax machines, fiber optic controls, motion sensors, and bar code readers.

The circuit shown in Figure 53 uses a silicon diode with zero bias voltage. This is known as a photovoltaic mode; this configuration limits the overall noise and is suitable for instrumentation applications.

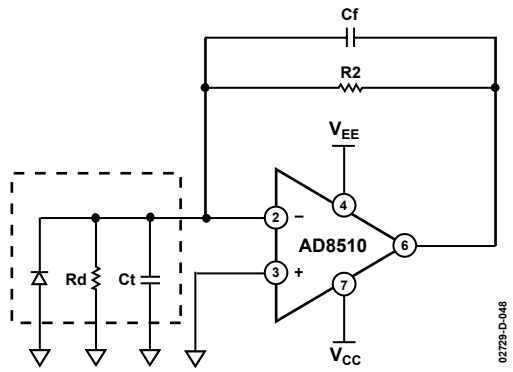


*Figure 53. Equivalent Preamplifier Photodiode Circuit*

A larger signal bandwidth can be attained at the expense of additional output noise. The total input capacitance (Ct) consists of the sum of the diode capacitance (typically 3 pF to 4 pF) and the amplifier's input capacitance (12 pF), which includes external parasitic capacitance. Ct creates a pole in the frequency response that can lead to an unstable system. To ensure stability and optimize the bandwidth of the signal, a capacitor is placed in the feedback loop of the circuit shown in Figure 53. It creates a zero and yields a bandwidth whose corner frequency is 1/(2π(R2Cf)).

The value of R2 can be determined by the ratio

$$V/I_D$$

where:

$V$ is the desired output voltage of the op amp.

$I_D$ is the diode current.

For example, if $I_D$ is 100 µA and a 10 V output voltage is desired, R2 should be 100 kΩ. Rd is a junction resistance that drops typically by a factor of 2 for every 10°C increase in temperature. A typical value for Rd is 1000 MΩ. Since Rd >> R2, the circuit behavior is not impacted by the effect of the junction resistance. The maximum signal bandwidth is

$$f_{MAX} = \sqrt{\frac{ft}{2\pi R2Ct}}$$

where $ft$ is the unity gain frequency of the amplifier.

Using the previous parameters, $Cf \approx 1$ pF, which yields a signal bandwidth of about 2.6 MHz.

$$Cf = \sqrt{\frac{Ct}{2\pi R2\,ft}}$$

where $ft$ is the unity gain frequency of the op amp, and achieves a phase margin, $\Phi_m$, of approximately 45°.

A higher phase margin can be obtained by increasing the value of Cf. Setting Cf to twice the previous value yields approximately $\Phi_m = 65°$ and a maximally flat frequency response but reduces the maximum signal bandwidth by 50%.

### *Signal Transmission Applications*

One popular signal transmission method uses pulse-width modulation. High data rates can require a fast comparator rather than an op amp. However, the need for sharp and undistorted signals can favor using a linear amplifier.

The AD8510/AD8512/AD8513 make excellent voltage comparators. In addition to a high slew rate, the AD8510/AD8512/AD8513 have a very fast saturation recovery time. In the absence of feedback, the amplifiers are in open-loop mode (very high gain). In this mode of operation, they spend much of their time in saturation.

The circuit in Figure 54 compares two signals of different frequencies, namely a 100 Hz sine wave and a 1 kHz triangular wave. Figure 56 shows a scope photograph of the output waveform. A pull-up resistor (typically 5 kΩ) can be connected from the output to $V_{CC}$ if the output voltage needs to reach the positive rail. The trade-off is that power consumption is higher.

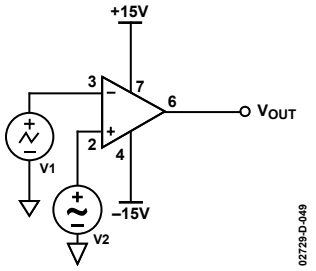


*Figure 54. Pulse-Width Modulator*

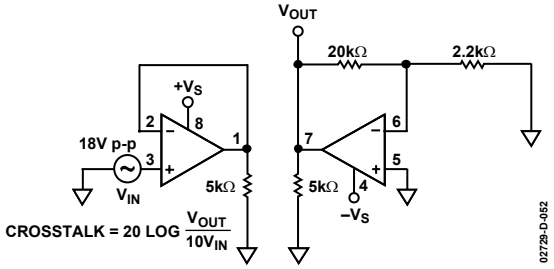


*Figure 55. Crosstalk Test Circuit*

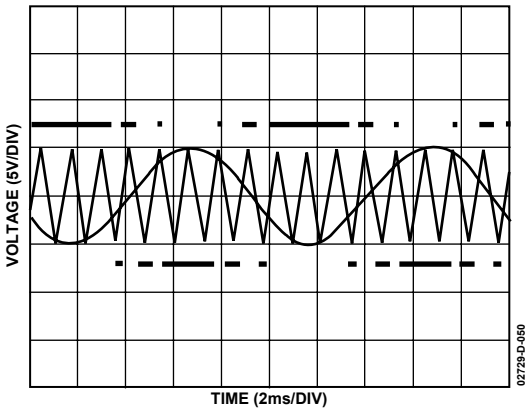


*Figure 56. Pulse-Width Modulation*

### *Crosstalk*

Crosstalk, also known as channel separation, is a measure of signal feedthrough from one channel to the other on the same IC. The AD8512/AD8513 have a channel separation better than −90 dB for frequencies up to 10 kHz and better than −50 dB for frequencies up to 10 MHz. Figure 57 shows the typical channel separation behavior between Amplifier A (driving amplifier), with respect to Amplifier B, Amplifier C, and Amplifier D.

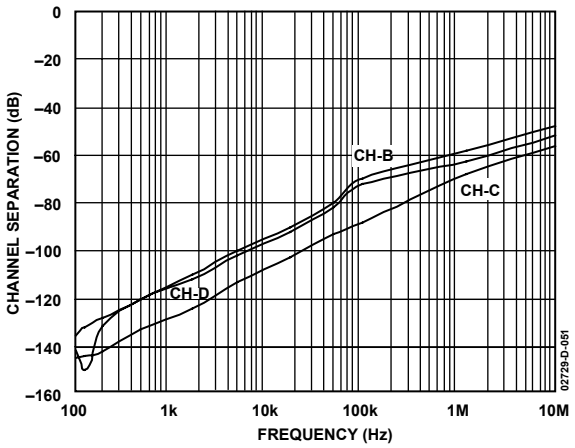


*Figure 57. Channel Separation*

# OUTLINE DIMENSIONS

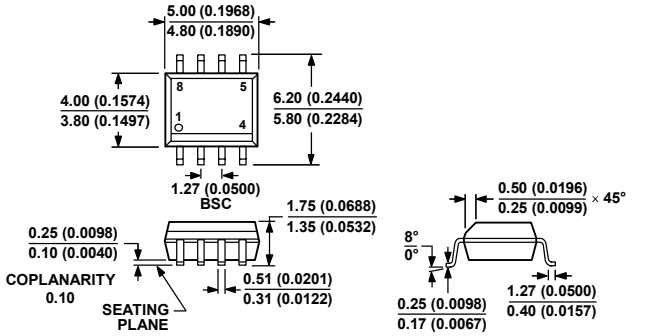


*Figure 58. 8-Lead Standard Small Outline Package [SOIC_N]*
*Narrow Body (R-8)*
*Dimensions shown in millimeters and (inches)*

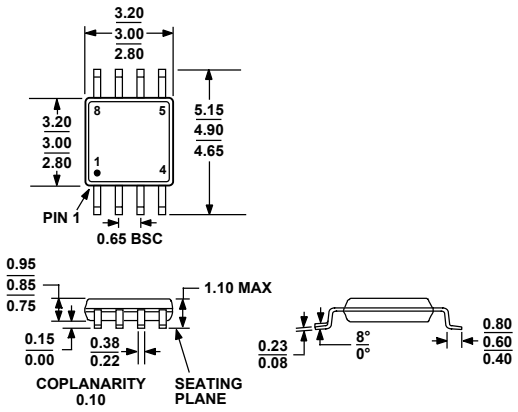


*Figure 59. 8-Lead Mini Small Outline Package [MSOP]*
*(RM-8)*
*Dimensions shown in millimeters*

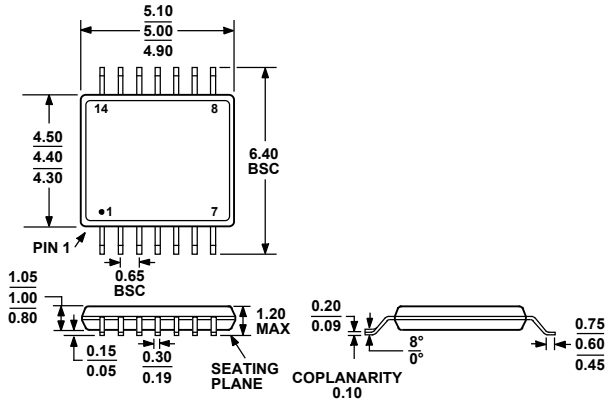


*Figure 60. 14-Lead Thin Shrink Small Outline Package [TSSOP]*
*(RU-14)*
*Dimensions shown in millimeters*

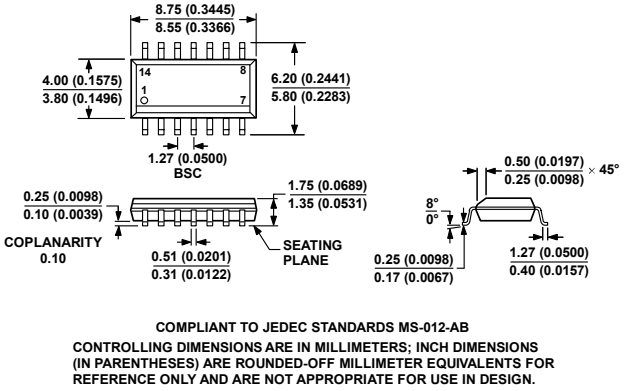


*Figure 61. 14-Lead Standard Small Outline Package [SOIC_N]*
*Narrow Body (R-14)*
*Dimensions shown in millimeters and (inches)*

## ORDERING GUIDE

| Model | Temperature Range | Package Description | Package Option | Branding |
|---|---|---|---|---|
| AD8510ARM-REEL | −40°C to +125°C | 8-Lead MSOP | RM-8 | B7A |
| AD8510ARM-R2 | −40°C to +125°C | 8-Lead MSOP | RM-8 | B7A |
| AD8510ARMZ-REEL[1] | −40°C to +125°C | 8-Lead MSOP | RM-8 | B7A# |
| AD8510ARMZ-R2[1] | −40°C to +125°C | 8-Lead MSOP | RM-8 | B7A # |
| AD8510AR | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510AR-REEL | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510AR-REEL7 | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510ARZ[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510ARZ-REEL[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510ARZ-REEL7[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BR | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BR-REEL | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BR-REEL7 | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BRZ[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BRZ-REEL | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8510BRZ-REEL7[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512ARM-REEL | −40°C to +125°C | 8-Lead MSOP | RM-8 | B8A |
| AD8512ARM-R2 | −40°C to +125°C | 8-Lead MSOP | RM-8 | B8A |
| AD8512ARMZ-REEL[1] | −40°C to +125°C | 8-Lead MSOP | RM-8 | B8A# |
| AD8512ARMZ-R2[1] | −40°C to +125°C | 8-Lead MSOP | RM-8 | B8A# |
| AD8512AR | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512AR-REEL | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512AR-REEL7 | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512ARZ[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512ARZ-REEL[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512ARZ-REEL7[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BR | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BR-REEL | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BR-REEL7 | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BRZ[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BRZ-REEL[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8512BRZ-REEL7[1] | −40°C to +125°C | 8-Lead SOIC_N | R-8 | |
| AD8513AR | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513AR-REEL | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513AR-REEL7 | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513ARZ[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513ARZ-REEL[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513ARZ-REEL7[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 | |
| AD8513ARU | −40°C to +125°C | 14-Lead TSSOP | RU-14 | |
| AD8513ARU-REEL | −40°C to +125°C | 14-Lead TSSOP | RU-14 | |
| AD8513ARUZ[1] | −40°C to +125°C | 14-Lead TSSOP | RU-14 | |
| AD8513ARUZ-REEL[1] | −40°C to +125°C | 14-Lead TSSOP | RU-14 | |

[1] Z = Pb-free part, # denotes lead-free product may be top or bottom marked.

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