# 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 at $V_S$ = ±15 V**
**Dual-supply operation: ±5 V to ±15 V**
**Low noise: 8 nV/√Hz typical at f = 1 kHz**
**Low distortion: 0.0005%**
**No phase reversal**
**Unity gain stable**

## APPLICATIONS

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

## PIN CONFIGURATIONS

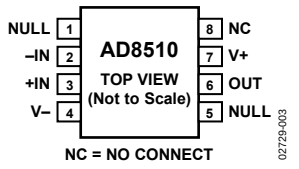



*Figure 1. 8-Lead MSOP (RM Suffix)*

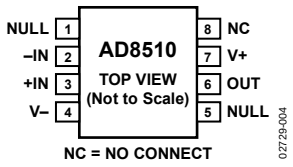



*Figure 2. 8-Lead SOIC_N (R Suffix)*

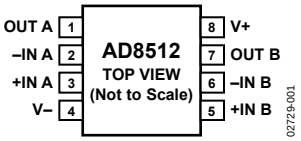



*Figure 3. 8-Lead MSOP (RM Suffix)*

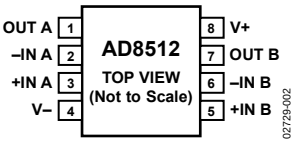



*Figure 4. 8-Lead SOIC_N (R Suffix)*

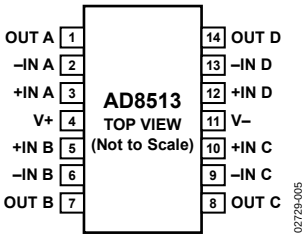



*Figure 5. 14-Lead SOIC_N (R Suffix)*

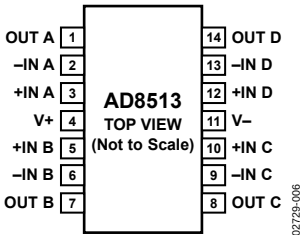



*Figure 6. 14-Lead TSSOP (RU Suffix)*

## 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 do 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 great choices 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.

# 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 | $V_{OL}$ | $R_L$ = 10 kΩ, −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 | $V_{OL}$ | $R_L$ = 2 kΩ, −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 | $V_{OL}$ | $R_L$ = 600 Ω, −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 |
| Total Harmonic Distortion (THD) + Noise | THD + N | 1 kHz, G = +1, $R_L$ = 2 kΩ | | 0.0005 | | % |
| Phase Margin | $\varphi_M$ | | | 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 | $A_{VO}$ | $R_L$ = 2 kΩ, $V_{CM}$ = 0 V, $V_O$ = −13.5 V to +13.5 V | 115 | 196 | | V/mV |
| 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 | $V_{OL}$ | $R_L$ = 10 kΩ, −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 | $V_{OL}$ | $R_L$ = 2 kΩ, −40°C < $T_A$ < +125°C | | −14.8 | −14.5 | V |
| Output Voltage High | $V_{OH}$ | $R_L$ = 600 Ω | +13.5 | +13.9 | | V |
| | | $R_L$ = 600 Ω, −40°C < $T_A$ < +125°C | +11.4 | | | V |
| Output Voltage Low | $V_{OL}$ | $R_L$ = 600 Ω | | −14.3 | −13.8 | V |
| | | $R_L$ = 600 Ω, −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 |
| Total Harmonic Distortion (THD) + Noise | THD + N | 1 kHz, G = +1, $R_L$ = 2 kΩ | | 0.0005 | | % |
| Phase Margin | $\varphi_M$ | | | 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 | −65°C to +150°C |
| Operating Temperature Range | −40°C to +125°C |
| Junction Temperature Range | −65°C to +150°C |
| Lead Temperature (Soldering, 10 sec) | 300°C |
| Electrostatic Discharge (Human Body Model) | 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**

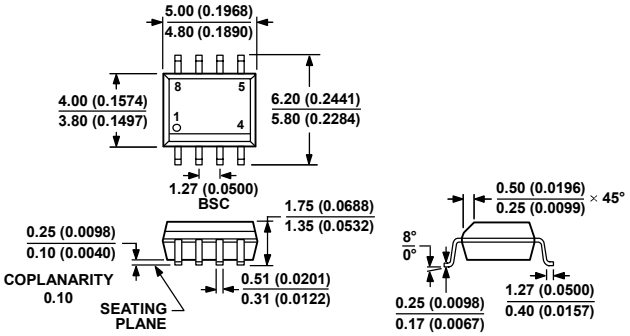
| Package Type | $\theta_{JA}$[1] | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 8-Lead MSOP (RM) | 210 | 45 | °C/W |
| 8-Lead SOIC_N (R) | 158 | 43 | °C/W |
| 14-Lead SOIC_N (R) | 120 | 36 | °C/W |
| 14-Lead TSSOP (RU) | 180 | 35 | °C/W |

[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

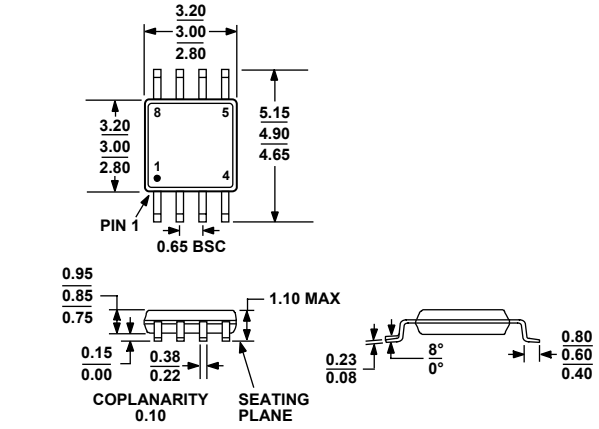
**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

# OUTLINE DIMENSIONS



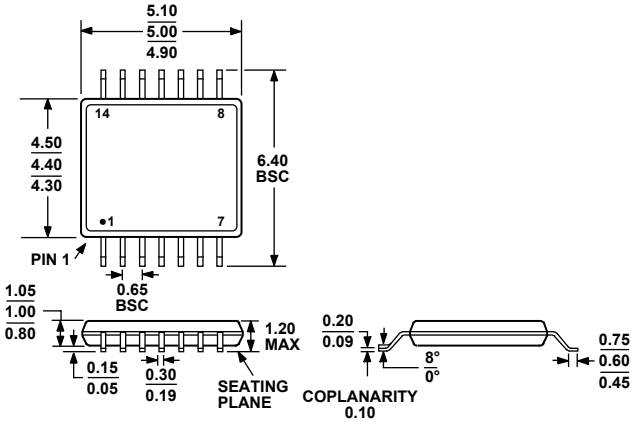

COMPLIANT TO JEDEC STANDARDS MS-012-AA
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

*Figure 59. 8-Lead Standard Small Outline Package [SOIC_N] Narrow Body (R-8) Dimensions shown in millimeters and (inches)*



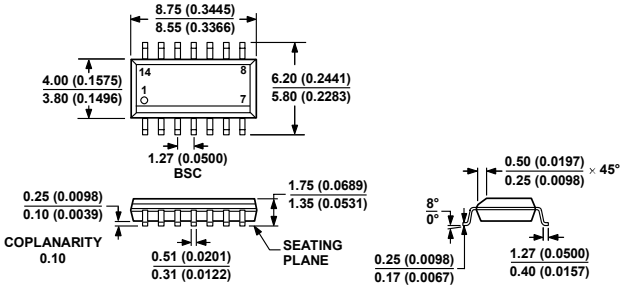

COMPLIANT TO JEDEC STANDARDS MO-187-AA

*Figure 60. 8-Lead Mini Small Outline Package [MSOP] (RM-8) Dimensions shown in millimeters*




COMPLIANT TO JEDEC STANDARDS MO-153-AB-1

*Figure 61. 14-Lead Thin Shrink Small Outline Package [TSSOP] (RU-14) Dimensions shown in millimeters*




COMPLIANT TO JEDEC STANDARDS MS-012-AB
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

*Figure 62. 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[1] | −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 = RoHS Compliant Part, # denotes RoHS compliant product may be top or bottom marked.