# Precision Instrumentation Amplifier

Enhanced Product

# AD8221-EP

## FEATURES

- Specified from −55°C to +125°C
  - 0.9 µV/°C maximum input offset average TC
  - 10 ppm/°C maximum gain vs. temperature (G = 1)
- Excellent ac specifications
  - 80 dB minimum CMRR at 10 kHz (G = 1)
  - −3 dB bandwidth: 825 kHz typical (G = 1)
  - 2 V/µs typical slew rate
- Low noise
  - 8 nV/√Hz, at 1 kHz, maximum input voltage noise
  - 0.25 µV p-p RTI (G = 100 to 1000)
- High accuracy dc performance
  - 80 dB minimum CMRR DC to 60 Hz (G = 1)
  - 70 µV maximum input offset voltage
  - 2 nA maximum input bias current
- Wide power supply range: ±2.3 V to ±18 V
- Available in space-saving MSOP
- Gain set with 1 external resistor (gain range 1 to 1000)

## ENHANCED PRODUCT FEATURES

- Supports defense and aerospace applications (AQEC standard)
- Military temperature range (−55°C to +125°C)
- Controlled manufacturing baseline
- One assembly/test site
- One fabrication site
- Enhanced product change notification
- Qualification data available on request

## APPLICATIONS

- Bridge amplifiers
- Precision data acquisition systems
- Strain gages
- Transducer interfaces

## TYPICAL CONNECTION DIAGRAM

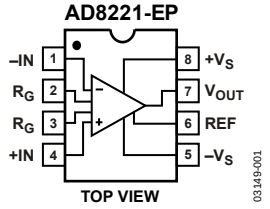


*Figure 1.*

## GENERAL DESCRIPTION

The AD8221-EP is a gain programmable, high performance instrumentation amplifier that delivers the industry's highest CMRR over frequency in its class. The CMRR of instrumentation amplifiers on the market today falls off at 200 Hz. In contrast, the AD8221-EP maintains a minimum CMRR of 80 dB to 10 kHz at G = 1. High CMRR over frequency allows the AD8221-EP to reject wideband interference and line harmonics, greatly simplifying filter requirements.

Possible applications include precision data acquisition, biomedical analysis, and aerospace instrumentation.

Low voltage offset, low offset drift, low gain drift, high gain accuracy, and high CMRR make this device an excellent choice in applications that demand the best dc performance possible, such as bridge signal conditioning.

Programmable gain affords the user design flexibility. A single resistor sets the gain from 1 to 1000. The AD8221-EP operates on both single and dual supplies and is well suited for applications where ±10 V input voltages are encountered.

The AD8221-EP is specified over the −55°C to +125°C military temperature range. It is available in an 8-lead MSOP package.

Additional application and technical information can be found in the AD8221 data sheet.

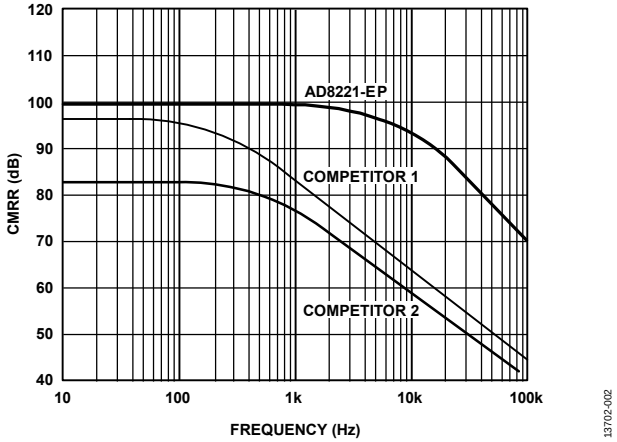


*Figure 2. Typical CMRR vs. Frequency for G = 1*

Rev. 0
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One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700
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## REVISION HISTORY

**4/16—Revision 0: Initial Version**

# SPECIFICATIONS

$V_S$ = ±15 V, $V_{REF}$ = 0 V, $T_A$ = 25°C, G = 1, $R_L$ = 2 kΩ, unless otherwise noted.

**Table 1.**

| Parameter | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| COMMON-MODE REJECTION RATIO (CMRR) | | | | | |
| CMRR DC to 60 Hz with 1 kΩ Source Imbalance | $V_{CM}$ = −10 V to +10 V | | | | |
| G = 1 | | 80 | | | dB |
| G = 10 | | 100 | | | dB |
| G = 100 | | 120 | | | dB |
| G = 1000 | | 130 | | | dB |
| CMRR at 10 kHz | $V_{CM}$ = −10 V to +10 V | | | | |
| G = 1 | | 80 | | | dB |
| G = 10 | | 90 | | | dB |
| G = 100 | | 100 | | | dB |
| G = 1000 | | 100 | | | dB |
| NOISE | RTI noise = $\sqrt{e_{NI}^2 + (e_{NO}/G)^2}$ | | | | |
| Voltage Noise, 1 kHz | | | | | |
| Input Voltage Noise, $e_{NI}$ | $V_{IN+}$, $V_{IN-}$, $V_{REF}$ = 0 | | | 8 | nV/√Hz |
| Output Voltage Noise, $e_{NO}$ | | | | 75 | nV/√Hz |
| Referred to Input (RTI) | f = 0.1 Hz to 10 Hz | | | | |
| G = 1 | | | 2 | | μV p-p |
| G = 10 | | | 0.5 | | μV p-p |
| G = 100 to 1000 | | | 0.25 | | μV p-p |
| Current Noise | f = 1 kHz | | 40 | | fA/√Hz |
| | f = 0.1 Hz to 10 Hz | | 6 | | pA p-p |
| VOLTAGE OFFSET[1] | | | | | |
| Input Offset, $V_{OSI}$ | $V_S$ = ±5 V to ±15 V | | | 70 | μV |
| Over Temperature | $T_A$ = −55°C to +125°C | | | 150 | μV |
| Average Temperature Coefficient (TC) | | | | 0.9 | μV/°C |
| Output Offset, $V_{OSO}$ | $V_S$ = ±5 V to ±15 V | | | 600 | μV |
| Over Temperature | $T_A$ = −55°C to +125°C | | | 1.2 | mV |
| Average TC | | | | 9 | μV/°C |
| Offset RTI vs. Supply (PSR) | $V_S$ = ±2.3 V to ±18 V | | | | |
| G = 1 | | 90 | 100 | | dB |
| G = 10 | | 100 | 120 | | dB |
| G = 100 | | 120 | 140 | | dB |
| G = 1000 | | 120 | 140 | | dB |
| INPUT CURRENT | | | | | |
| Input Bias Current | | | 0.5 | 2 | nA |
| Over Temperature | $T_A$ = −55°C to +125°C | | | 3.75 | nA |
| Average TC | | | 11 | | pA/°C |
| Input Offset Current | | | 0.3 | 1 | nA |
| Over Temperature | $T_A$ = −55°C to +125°C | | | 2.25 | nA |
| Average TC | | | 7 | | pA/°C |
| REFERENCE INPUT | | | | | |
| $R_{IN}$ | | | 20 | | kΩ |
| $I_{IN}$ | $V_{IN+}$, $V_{IN-}$, $V_{REF}$ = 0 | | 50 | 60 | μA |
| Voltage Range | | $-V_S$ | | $+V_S$ | V |
| Gain to Output | | | 1 ± 0.0001 | | V/V |

| Parameter | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| POWER SUPPLY | | | | | |
| Operating Range | $V_S$ = ±2.3 V to ±18 V | ±2.3 | | ±18 | V |
| Quiescent Current | | | 0.9 | 1 | mA |
| Over Temperature | $T_A$ = −55°C to +125°C | | 1 | 1.2 | mA |
| DYNAMIC RESPONSE | | | | | |
| Small Signal −3 dB Bandwidth | | | | | |
| G = 1 | | | 825 | | kHz |
| G = 10 | | | 562 | | kHz |
| G = 100 | | | 100 | | kHz |
| G = 1000 | | | 14.7 | | kHz |
| Settling Time 0.01% | 10 V step | | | | |
| G = 1 to 100 | | | 10 | | µs |
| G = 1000 | | | 80 | | µs |
| Settling Time 0.001% | 10 V step | | | | |
| G = 1 to 100 | | | 13 | | µs |
| G = 1000 | | | 110 | | µs |
| Slew Rate | G = 1 | 1.5 | 2 | | V/µs |
| | G = 5 to 100 | 2 | 2.5 | | V/µs |
| GAIN | G = 1 + (49.4 kΩ/$R_G$) | | | | |
| Gain Range | | 1 | | 1000 | V/V |
| Gain Error | $V_{OUT}$ ± 10 V | | | | |
| G = 1 | | | | 0.1 | % |
| G = 10 | | | | 0.3 | % |
| G = 100 | | | | 0.3 | % |
| G = 1000 | | | | 0.3 | % |
| Gain Nonlinearity | $V_{OUT}$ = −10 V to +10 V | | | | |
| G = 1 to 10 | $R_L$ = 10 kΩ | | 5 | 15 | ppm |
| G = 100 | $R_L$ = 10 kΩ | | 7 | 20 | ppm |
| G = 1000 | $R_L$ = 10 kΩ | | 10 | 50 | ppm |
| G = 1 to 100 | $R_L$ = 2 kΩ | | 15 | 100 | ppm |
| Gain vs. Temperature | | | | | |
| G = 1 | | | 3 | 10 | ppm/°C |
| G > 1[2] | | | | −50 | ppm/°C |
| INPUT | | | | | |
| Input Impedance | | | | | |
| Differential | | | 100‖2 | | GΩ‖pF |
| Common Mode | | | 100‖2 | | GΩ‖pF |
| Input Operating Voltage Range[3] | $V_S$ = ±2.3 V to ±5 V | $-V_S$ + 1.9 | | $+V_S$ − 1.1 | V |
| Over Temperature | $T_A$ = −55°C to +125°C | $-V_S$ + 2.0 | | $+V_S$ − 1.2 | V |
| Input Operating Voltage Range | $V_S$ = ±5 V to ±18 V | $-V_S$ + 1.9 | | $+V_S$ − 1.2 | V |
| Over Temperature | $T_A$ = −55°C to +125°C | $-V_S$ + 2.0 | | $+V_S$ − 1.3 | V |
| OUTPUT | $R_L$ = 10 kΩ | | | | |
| Output Swing | $V_S$ = ±2.3 V to ±5 V | $-V_S$ + 1.1 | | $+V_S$ − 1.2 | V |
| Over Temperature | $T_A$ = −55°C to +125°C | $-V_S$ + 1.4 | | $+V_S$ − 1.3 | V |
| Output Swing | $V_S$ = ±5 V to ±18 V | $-V_S$ + 1.2 | | $+V_S$ − 1.4 | V |
| Over Temperature | $T_A$ = −55°C to +125°C | $-V_S$ + 1.6 | | $+V_S$ − 1.5 | V |
| Short-Circuit Current | | | 18 | | mA |
| TEMPERATURE RANGE | | | | | |
| Specified Performance | | −55 | | +125 | °C |

[1] Total RTI $V_{OS}$ = ($V_{OSI}$) + ($V_{OSO}$/G).
[2] Does not include the effects of external resistor $R_G$.
[3] One input grounded. G = 1.

# ABSOLUTE MAXIMUM RATINGS

**Table 2.**

| Parameter | Rating |
|---|---|
| Supply Voltage | ±18 V |
| Internal Power Dissipation | 200 mW |
| Output Short-Circuit Current | Indefinite |
| Input Voltage (Common-Mode) | $\pm V_S$ |
| Differential Input Voltage | $\pm V_S$ |
| Storage Temperature Range | −65°C to +150°C |
| Operating Temperature Range | −55°C to +125°C |

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

## THERMAL CHARACTERISTICS

Specification for a device in free air.

**Table 3.**

| Package | $\theta_{JA}$ | Unit |
|---|---|---|
| 8-Lead MSOP, 4-Layer JEDEC Board | 135 | °C/W |

## 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.

# PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

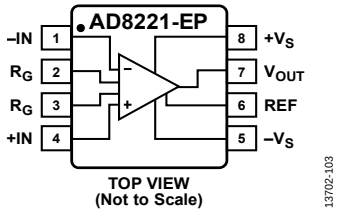


*Figure 3. Pin Configuration*

**Table 4. Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | −IN | Negative Input Terminal. |
| 2, 3 | $R_G$ | Gain Setting Terminal. Place resistor across the $R_G$ pins to set the gain. G = 1 + (49.4 kΩ/$R_G$). |
| 4 | +IN | Positive Input Terminal. |
| 5 | $-V_S$ | Negative Power Supply Terminal. |
| 6 | REF | Reference Voltage Terminal. Drive this terminal with a low impedance voltage source to level-shift the output. |
| 7 | $V_{OUT}$ | Output Terminal. |
| 8 | $+V_S$ | Positive Power Supply Terminal. |

# TYPICAL PERFORMANCE CHARACTERISTICS

T = 25°C, $V_S$ = ±15 V, $R_L$ = 10 kΩ, unless otherwise noted.

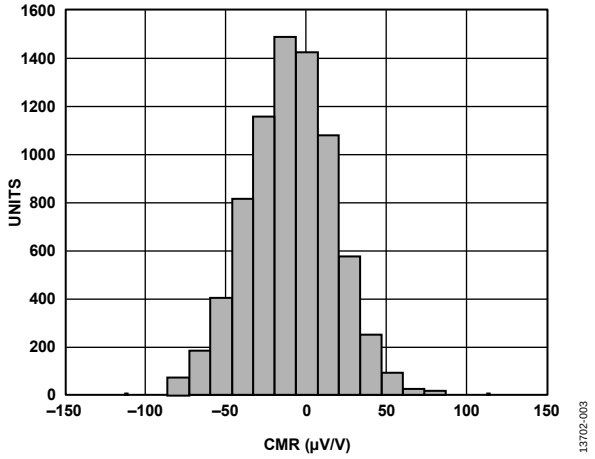


Figure 4. Typical Distribution for CMR (G = 1)

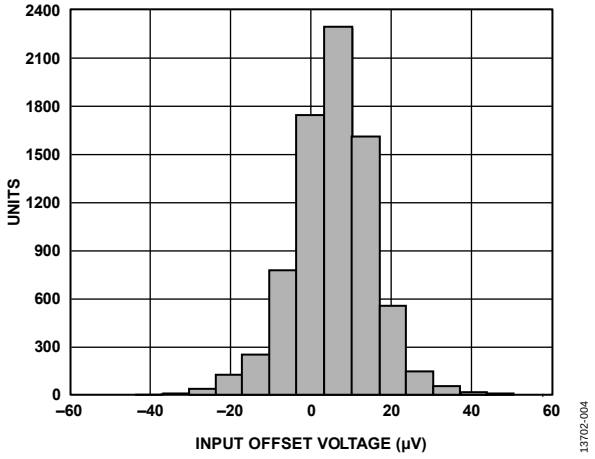


Figure 5. Typical Distribution of Input Offset Voltage

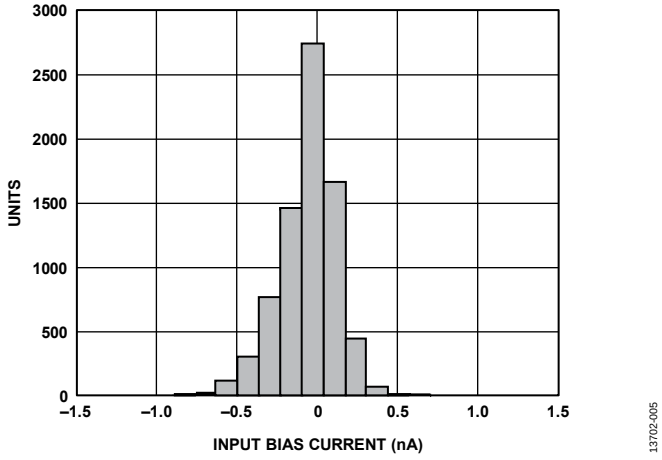


Figure 6. Typical Distribution of Input Bias Current

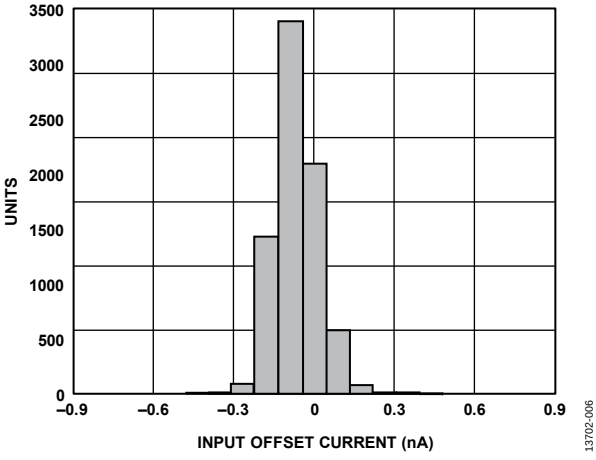


Figure 7. Typical Distribution of Input Offset Current

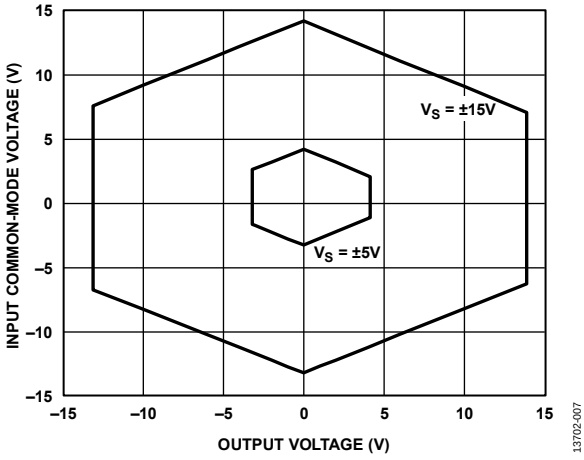


Figure 8. Input Common-Mode Voltage vs. Output Voltage, G = 1

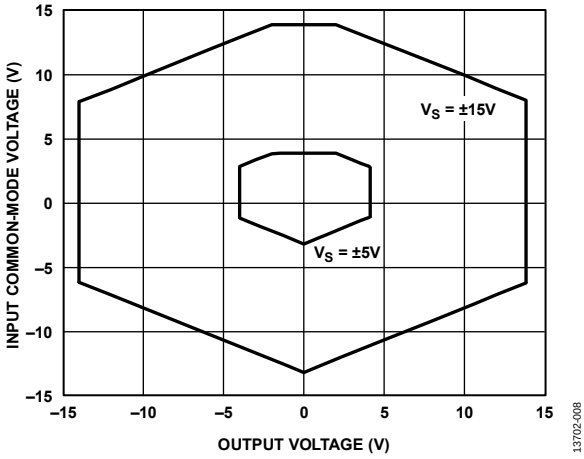


Figure 9. Input Common-Mode Voltage vs. Output Voltage, G = 100

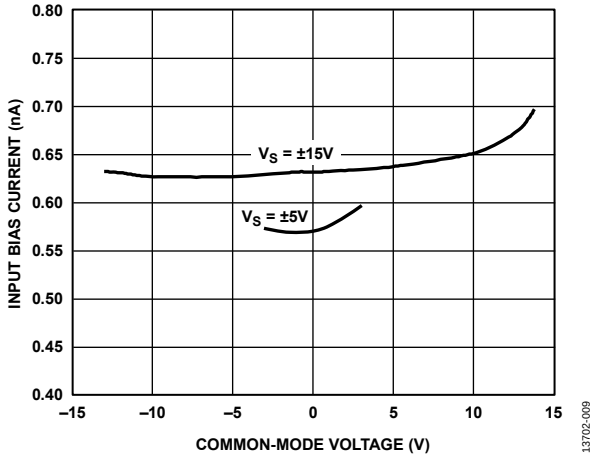


Figure 10. Input Bias Current ($I_{BIAS}$) vs. Common-Mode Voltage (CMV)

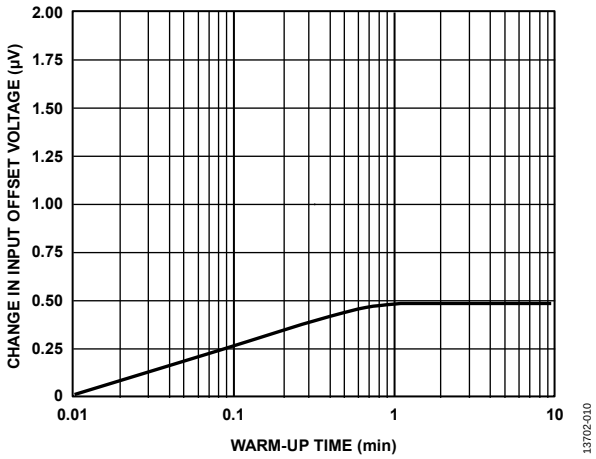


Figure 11. Change in Input Offset Voltage vs. Warm-Up Time

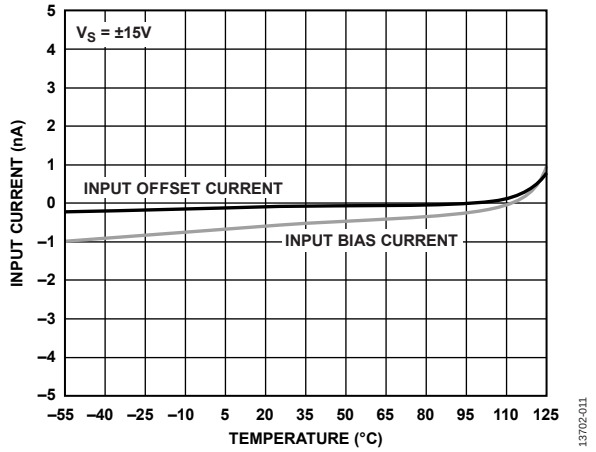


Figure 12. Input Offset Current and Input Bias Current vs. Temperature

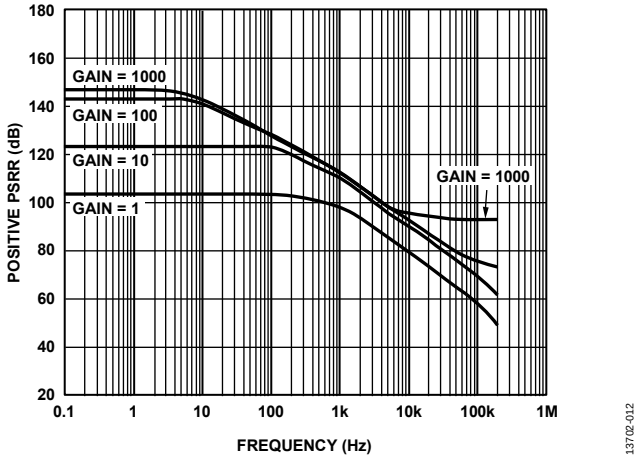


Figure 13. Positive PSRR vs. Frequency, RTI (G = 1 to 1000)

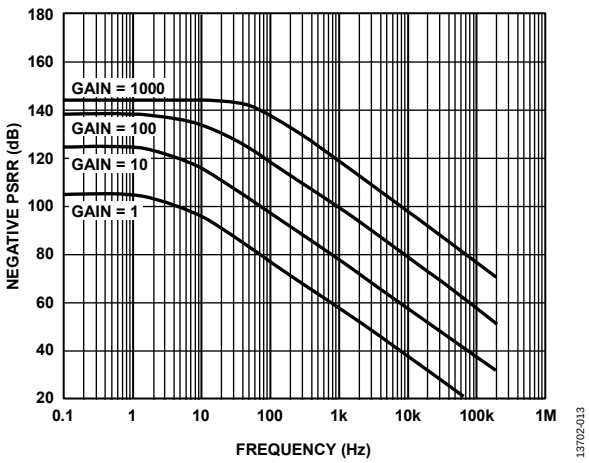


Figure 14. Negative PSRR vs. Frequency, RTI (G = 1 to 1000)

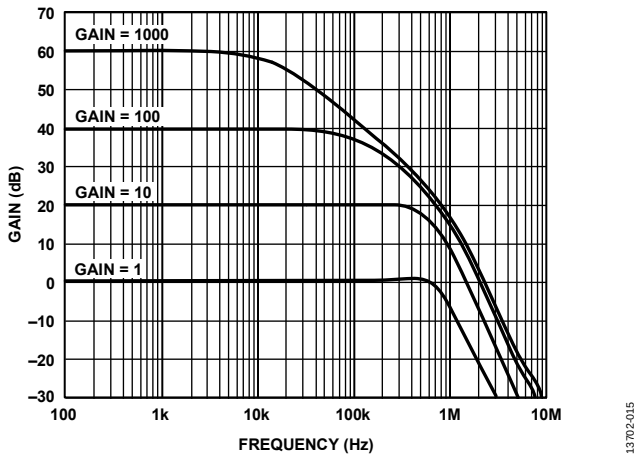


Figure 15. Gain vs. Frequency

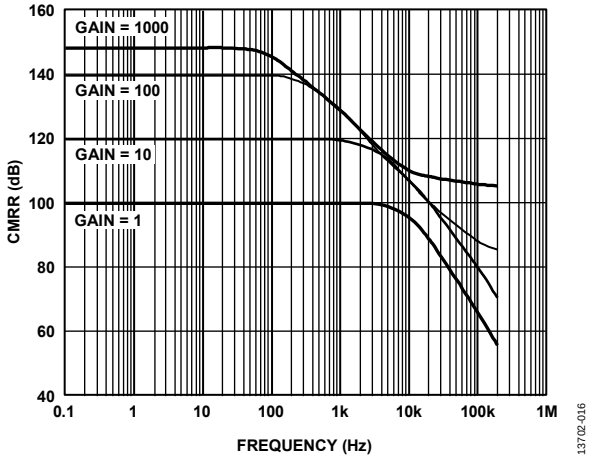


Figure 16. CMRR vs. Frequency, RTI

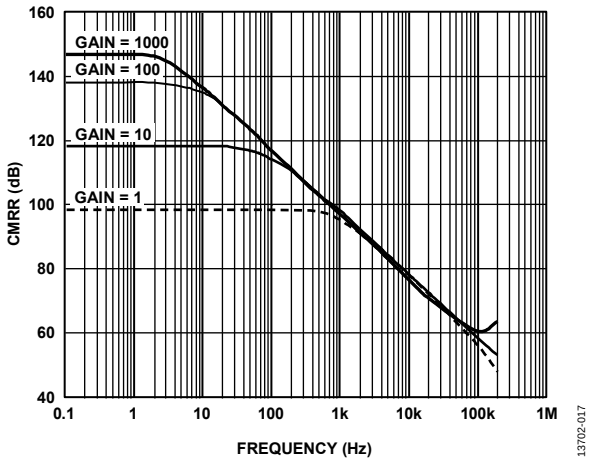


Figure 17. CMRR vs. Frequency, RTI, 1 kΩ Source Imbalance

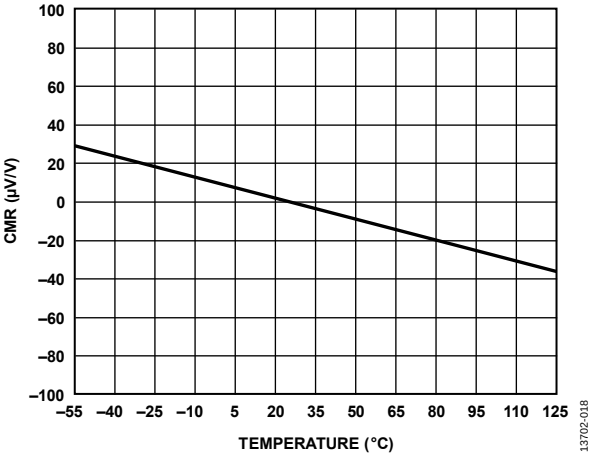


Figure 18. CMR vs. Temperature

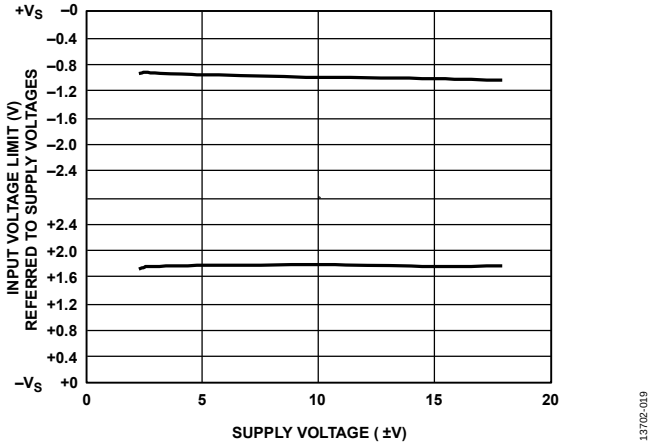


Figure 19. Input Voltage Limit vs. Supply Voltage, G = 1

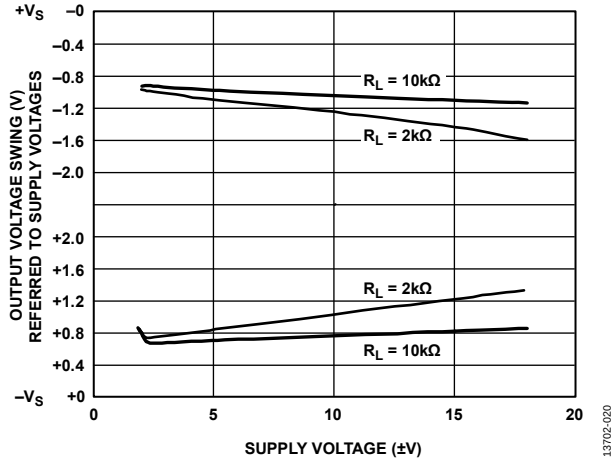


Figure 20. Output Voltage Swing vs. Supply Voltage, G = 1

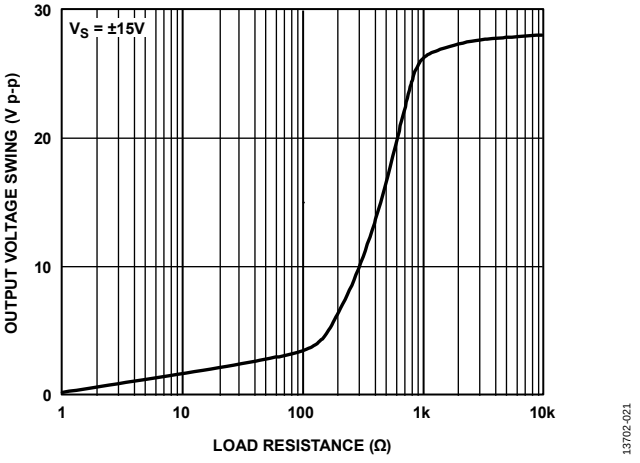


Figure 21. Output Voltage Swing vs. Load Resistance

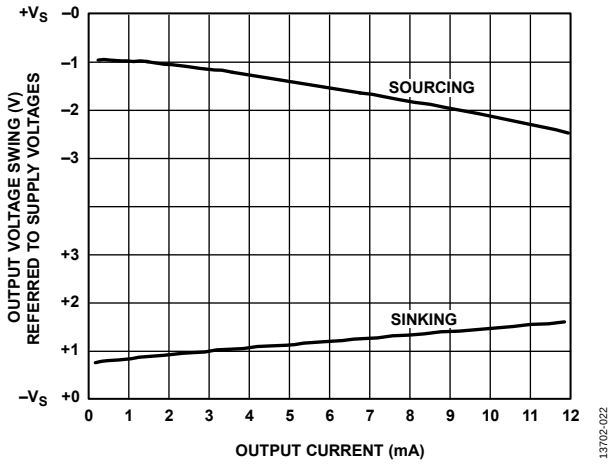


Figure 22. Output Voltage Swing vs. Output Current, G = 1

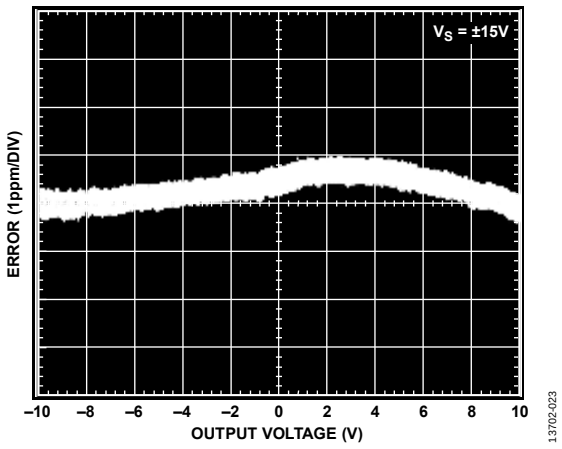


Figure 23. Gain Nonlinearity, G = 1, $R_L$ = 10 kΩ

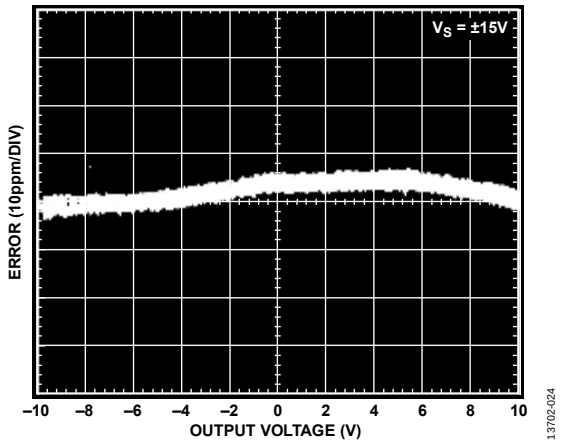


Figure 24. Gain Nonlinearity, G = 100, $R_L$ = 10 kΩ

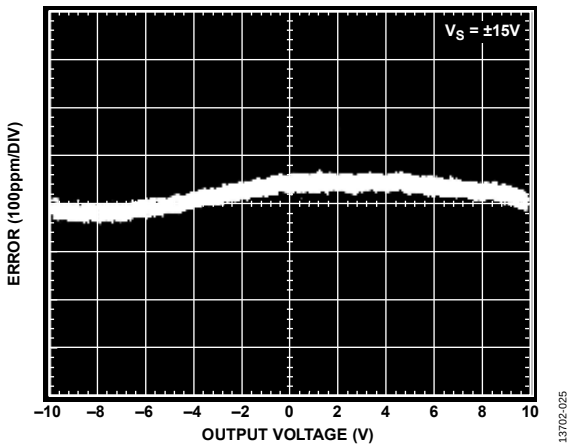


Figure 25. Gain Nonlinearity, G = 1000, $R_L$ = 10 kΩ

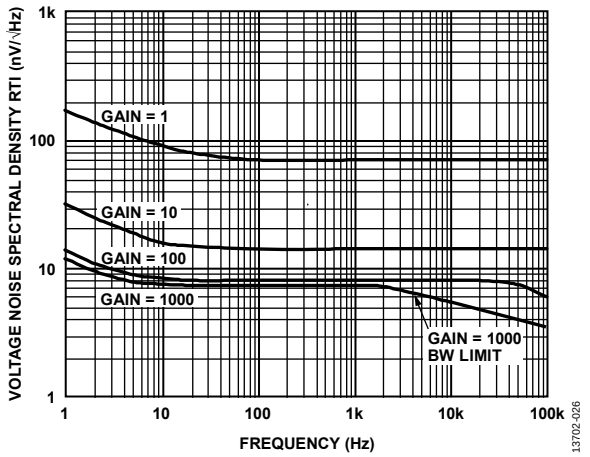


Figure 26. Voltage Noise Spectral Density vs. Frequency (G = 1 to 1000)

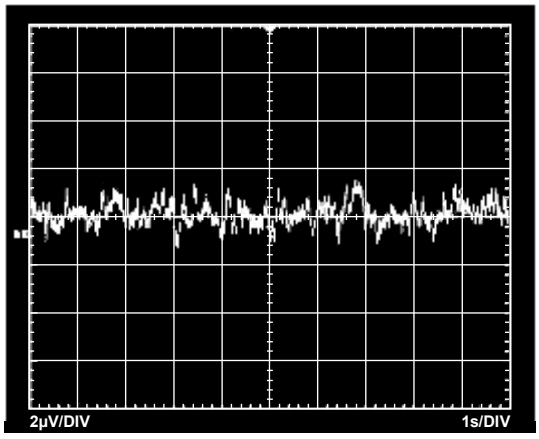


Figure 27. 0.1 Hz to 10 Hz RTI Voltage Noise (G = 1)

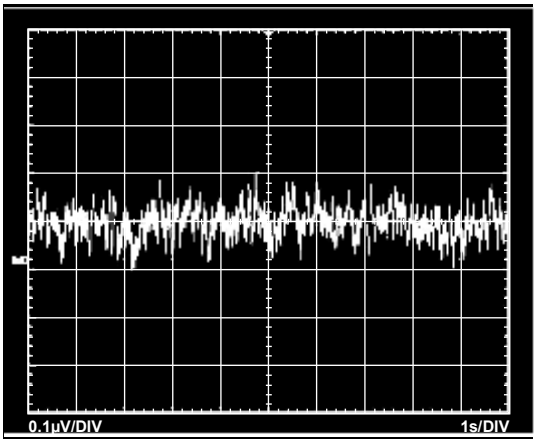


Figure 28. 0.1 Hz to 10 Hz RTI Voltage Noise (G = 1000)

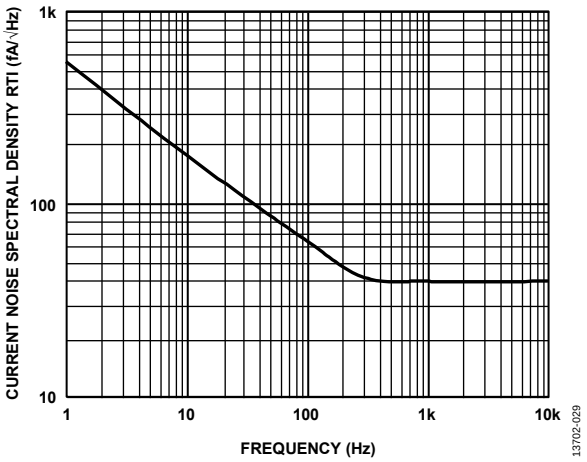


Figure 29. Current Noise Spectral Density vs. Frequency

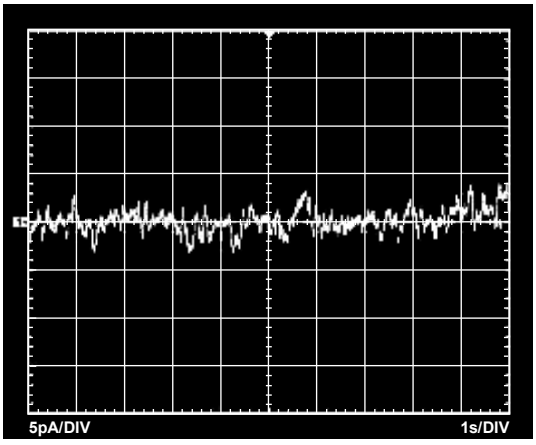


Figure 30. 0.1 Hz to 10 Hz Current Noise

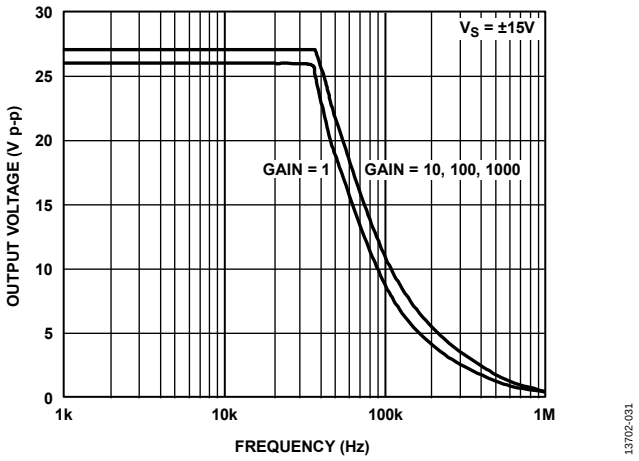


Figure 31. Large Signal Frequency Response

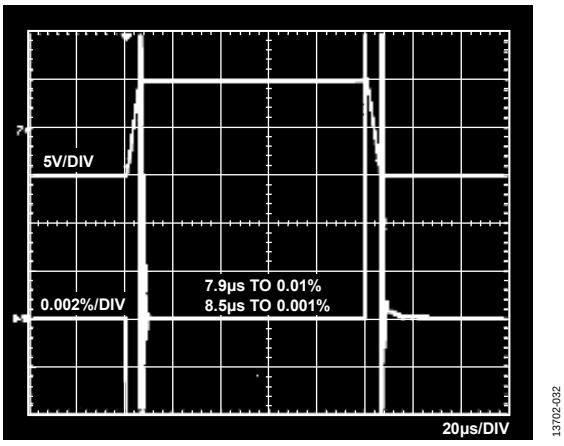


Figure 32. Large Signal Pulse Response and Settling Time (G = 1), 0.002%/DIV

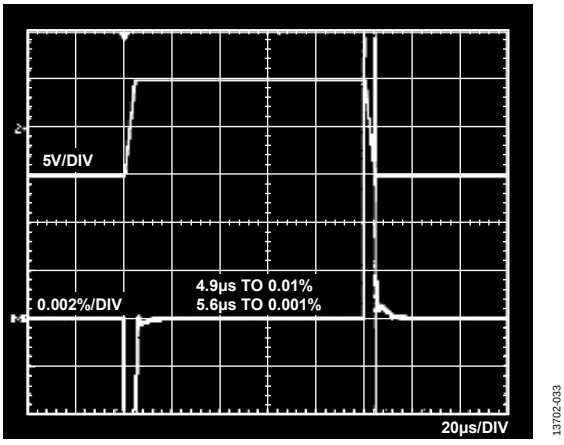


Figure 33. Large Signal Pulse Response and Settling Time (G = 10), 0.002%/DIV

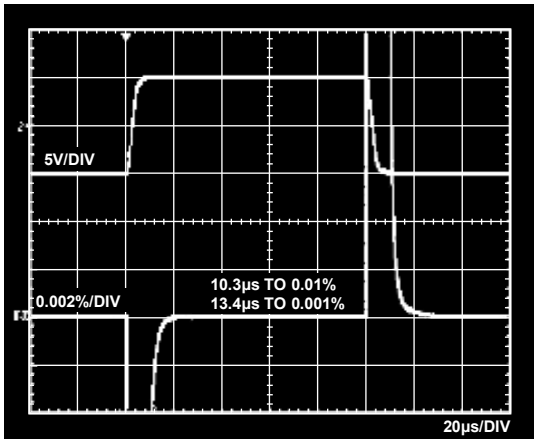


Figure 34. Large Signal Pulse Response and Settling Time (G = 100), 0.002%/DIV

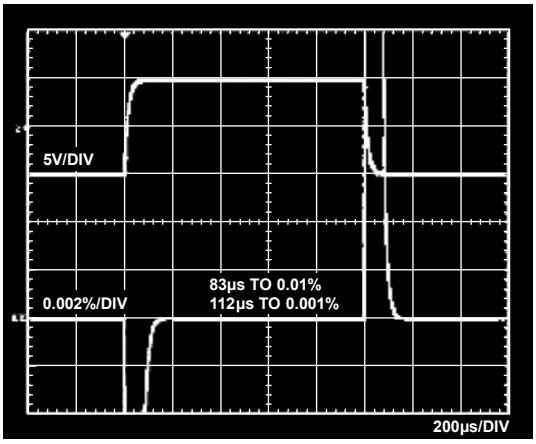


Figure 35. Large Signal Pulse Response and Settling Time (G = 1000), 0.002%/DIV

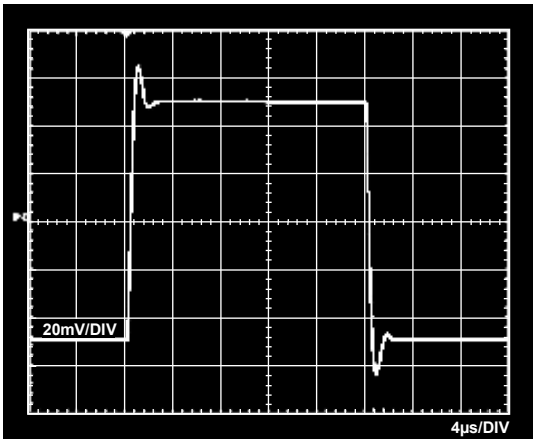


Figure 36. Small Signal Response, G = 1, $R_L$ = 2 kΩ, $C_L$ = 100 pF

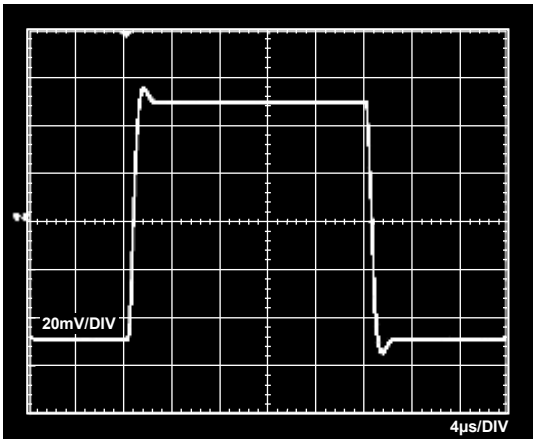


Figure 37. Small Signal Response, G = 10, $R_L$ = 2 kΩ, $C_L$ = 100 pF

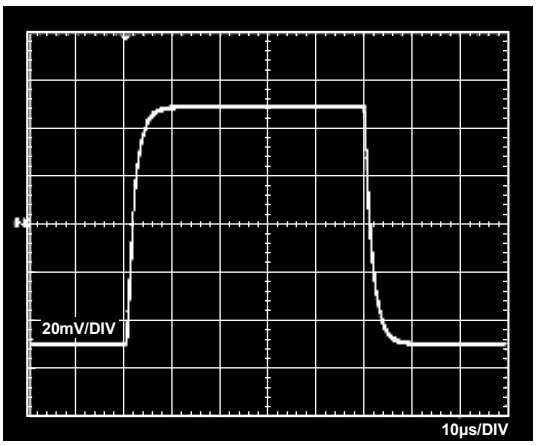


Figure 38. Small Signal Response, G = 100, $R_L$ = 2 kΩ, $C_L$ = 100 pF

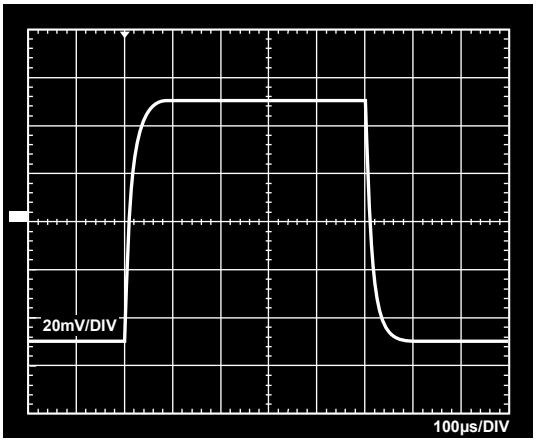


Figure 39. Small Signal Response, G = 1000, $R_L$ = 2 kΩ, $C_L$ = 100 pF

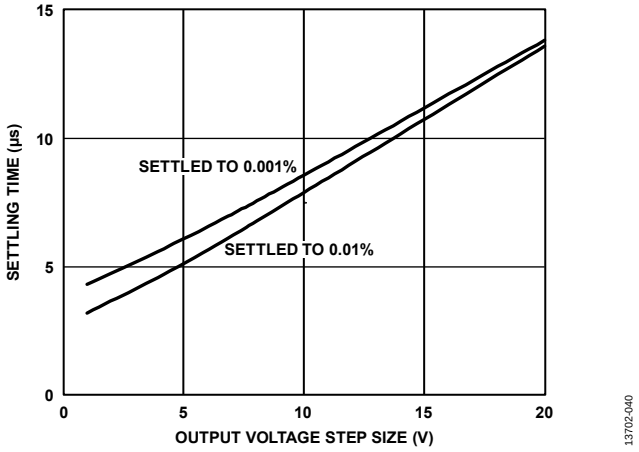


*Figure 40. Settling Time vs. Output Voltage Step Size (G = 1)*

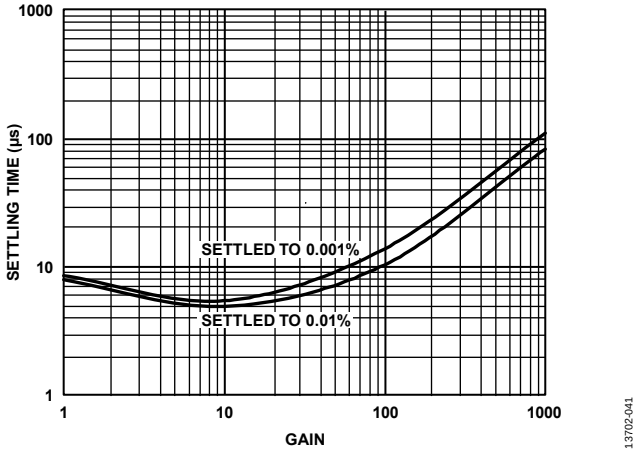


*Figure 41. Settling Time vs. Gain for a 10 V Step*

# OUTLINE DIMENSIONS

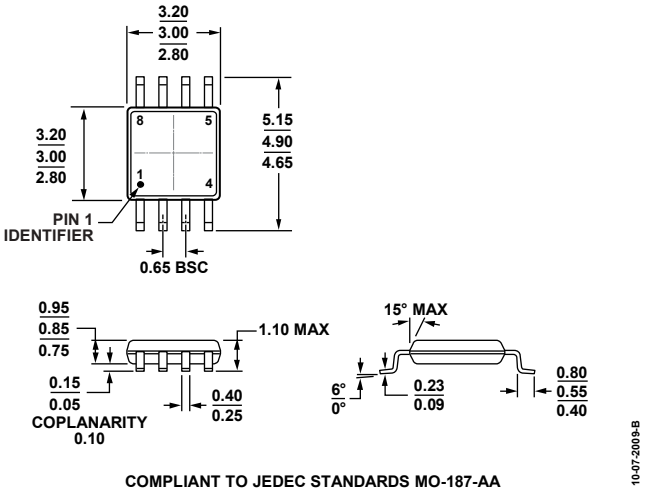


*Figure 42. 8-Lead Mini Small Outline Package [MSOP]*
*(RM-8)*
*Dimensions shown in millimeters*

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Option | Branding |
|---|---|---|---|---|
| AD8221TRMZ-EP | –55°C to +125°C | 8-Lead Mini Small Outline Package [MSOP] | RM-8 | Y67 |
| AD8221TRMZ-EP-R7 | –55°C to +125°C | 8-Lead Mini Small Outline Package [MSOP] | RM-8 | Y67 |

[1] Z = RoHS Compliant Part.

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