

**FEATURES**

- Rail-to-rail input/output**
- Low power: 625  $\mu$ A typical**
- Gain bandwidth product: 15.9 MHz at  $A_v = 100$  typical**
- Unity-gain crossover: 9.9 MHz typical**
- 3 dB closed-loop bandwidth: 13.9 MHz typical at  $\pm 15$  V**
- Low offset voltage: 100  $\mu$ V maximum (SOIC)**
- Unity-gain stable**
- High slew rate: 4.6 V/ $\mu$ s typical**
- Low noise: 3.9 nV/ $\sqrt{\text{Hz}}$  typical at 1 kHz**

**APPLICATIONS**

- Battery-powered instrumentation**
- Power supply control and protection**
- Telecommunications**
- DAC output amplifier**
- ADC input buffer**

**GENERAL DESCRIPTION**

The [ADA4084-2](#) is a dual, single-supply, 10 MHz bandwidth amplifier featuring rail-to-rail inputs and outputs. It is guaranteed to operate from 3 V to 30 V (or  $\pm 1.5$  V to  $\pm 15$  V).

These amplifiers are well suited for single-supply applications requiring both ac and precision dc performance. The combination of wide bandwidth, low noise, and precision makes the [ADA4084-2](#) useful in a wide variety of applications, including filters and instrumentation.

Other applications for these amplifiers include portable telecommunications equipment, power supply control and protection, and use as amplifiers or buffers for transducers with wide output ranges. Sensors requiring a rail-to-rail input amplifier include Hall effect, piezoelectric, and resistive transducers.

The ability to swing rail-to-rail at both the input and output enables designers to build multistage filters in single-supply systems and to maintain high signal-to-noise ratios.

The [ADA4084-2](#) is specified over the industrial temperature range of  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ . The dual [ADA4084-2](#) is available in the 8-lead SOIC and MSOP surface-mount packages.

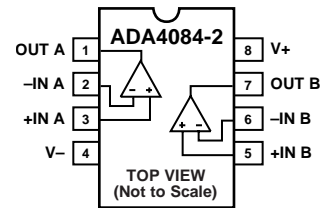
**PIN CONFIGURATIONS**


Figure 1. 8-Lead MSOP (RM)  
8-Lead SOIC (R)

06237-001

The [ADA4084-2](#) is a member of a growing series of high voltage, low noise op amps offered by Analog Devices, Inc., (see Table 1).

For a more complete selection table of low input voltage noise amplifiers, see the [AN-940](#) Application Note, *Low Noise Amplifier Selection Guide for Optimal Noise Performance*, available at [www.analog.com](http://www.analog.com).

**Table 1. Low Noise Op Amps**

Voltage Noise	Single	Dual	Quad
1.1 nV/Hz	<a href="#">AD8597</a>	<a href="#">AD8599</a>	
1.8 nV/Hz	<a href="#">ADA4004-1</a>	<a href="#">ADA4004-2</a>	<a href="#">ADA4004-4</a>
2.8 nV/Hz RRO <sup>1</sup>	<a href="#">AD8675</a>	<a href="#">AD8676</a>	
2.8 nV/Hz	<a href="#">AD8671</a>	<a href="#">AD8672</a>	<a href="#">AD8674</a>
3.2 nV/Hz	<a href="#">OP27/OP37</a>		
3.9 nV/Hz RRIO <sup>2</sup>		<a href="#">ADA4084-2</a>	

<sup>1</sup> Rail-to-rail output.

<sup>2</sup> Rail-to-rail input/output.

**Rev. A**

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices. Trademarks and registered trademarks are the property of their respective owners.

## TABLE OF CONTENTS

Features .....	1	$\pm 15$ V Characteristics .....	15
Applications .....	1	Comparative Voltage and Variable Voltage Graphs.....	19
General Description .....	1	Applications Information .....	20
Pin Configurations .....	1	Functional Description.....	20
Revision History .....	2	Input Protection .....	21
Specifications.....	3	Output Phase Reversal.....	21
Electrical Characteristics .....	3	Designing Low Noise Circuits in Single-Supply	
Absolute Maximum Ratings.....	6	Applications .....	21
Thermal Resistance .....	6	Comparator Operation.....	22
ESD Caution.....	6	Outline Dimensions .....	23
Typical Performance Characteristics .....	7	Ordering Guide .....	23
$\pm 1.5$ V Characteristics.....	7		
$\pm 5$ V Characteristics.....	11		

## REVISION HISTORY

### 2/12—Rev. 0 to Rev. A

Changes to Data Sheet Title .....	1
Changes to Voltage Range in General Description.....	1
Changes to Supply Current/Amplifier Parameter, Table 2.....	3
Changes to Common-Mode Rejection Ratio Parameter, Table 3..	4
Changes to Common-Mode Rejection Ratio Parameter, Table 4..	5
Changes to Figure 2.....	6
Changes to Figure 24.....	10
Changes to Figure 32.....	12
Changes to Figure 47 .....	14
Changes to Figure 55.....	16
Changes to Figure 62.....	17
Changes to Figure 73.....	20

### 10/11—Revision 0: Initial Version

## SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS

$V_{SY} = 3\text{ V}$ ,  $V_{CM} = 1.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 2.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage <sup>1</sup>	$V_{OS}$	SOIC package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			100	$\mu\text{V}$
		MSOP package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			200	$\mu\text{V}$
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.5	1.75	$\mu\text{V}/^\circ\text{C}$
Offset Voltage Matching		Channel A vs. Channel B, $T_A = 25^\circ\text{C}$			150	$\mu\text{V}$
Input Bias Current	$I_B$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		140	300	nA
Input Offset Current	$I_{OS}$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			450	nA
Input Voltage Range			0		3	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to }3\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	64	80		dB
Large Signal Voltage Gain	$A_{VO}$	$R_L = 2\text{ k}\Omega$ , $0.5\text{ V} \leq V_O \leq 2.5\text{ V}$ $R_L = 2\text{ k}\Omega$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	60	104		dB
Input Impedance, Differential				100  1.1		$\text{k}\Omega  \text{pF}$
Input Impedance, Common-Mode				80  2.9		$\text{M}\Omega  \text{pF}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage High	$V_{OH}$	$R_L = 10\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.85	2.95		V
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.8	2.9		V
Output Voltage Low	$V_{OL}$	$R_L = 10\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.7			V
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		10	20	mV
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			40	mV
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			50	mV
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			75	mV
Short-Circuit Current	$I_{SC}$			-17/+10		mA
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR	$V_{SY} = \pm 1.25\text{ V to } \pm 1.75\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	100	110		dB
			90			dB
Supply Current/Amplifier	$I_{SY}$	$I_O = 0\text{ mA}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		565	650	$\mu\text{A}$
					950	$\mu\text{A}$
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 2\text{ k}\Omega$	2.0	2.6		$\text{V}/\mu\text{s}$
Gain Bandwidth Product	GBP	$V_{IN} = 5\text{ mV p-p}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 100$		15.4		MHz
Unity-Gain Crossover	UGC	$V_{IN} = 5\text{ mV p-p}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 1$		8.08		MHz
Phase Margin	$\Phi_M$			86		Degrees
-3 dB Closed-Loop Bandwidth	-3 dB	$A_V = 1$ , $V_{IN} = 5\text{ mV p-p}$		12.3		MHz
<b>NOISE PERFORMANCE</b>						
Voltage Noise	$e_n$ p-p	0.1 Hz to 10 Hz		0.14		$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	$f = 1\text{ kHz}$		3.9		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$	$f = 1\text{ kHz}$		0.55		$\text{pA}/\sqrt{\text{Hz}}$

<sup>1</sup> Offset voltage does not include solder heat resistance.

$V_{SY} = \pm 5.0 \text{ V}$ ,  $V_{CM} = 0 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 3.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage <sup>1</sup>	$V_{OS}$	SOIC package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			100	$\mu\text{V}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			250	$\mu\text{V}$
		MSOP package			130	$\mu\text{V}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			250	$\mu\text{V}$
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.5	1.75	$\mu\text{V}/^\circ\text{C}$
Offset Voltage Matching		Channel A vs. Channel B, $T_A = 25^\circ\text{C}$			150	$\mu\text{V}$
Input Bias Current	$I_B$			140	300	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			450	nA
Input Offset Current	$I_{OS}$				25	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			50	nA
Input Voltage Range			-5		+5	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = \pm 4 \text{ V}$	106	124		dB
		$V_{CM} = \pm 5 \text{ V}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	76			dB
Large Signal Voltage Gain	$A_{VO}$	$R_L = 2 \text{ k}\Omega$ , $-4 \text{ V} \leq V_O \leq 4 \text{ V}$	108	112		dB
		$R_L = 2 \text{ k}\Omega$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	103			dB
Input Impedance, Differential				100  1.1		$\text{k}\Omega  \text{pF}$
Input Impedance, Common-Mode				200  2.5		$\text{M}\Omega  \text{pF}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage High	$V_{OH}$	$R_L = 10 \text{ k}\Omega$ to $V_{CM}$	4.9	4.95		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.8			V
		$R_L = 2 \text{ k}\Omega$ to $V_{CM}$	4.8	4.85		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.7			V
Output Voltage Low	$V_{OL}$	$R_L = 10 \text{ k}\Omega$ to $V_{CM}$		-4.95	-4.9	V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			-4.8	V
		$R_L = 2 \text{ k}\Omega$ to $V_{CM}$		-4.95	-4.8	V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			-4.7	V
Short Circuit Current	$I_{SC}$			-24/+17		mA
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR	$V_{SY} = \pm 2 \text{ V}$ to $\pm 18 \text{ V}$	110	120		dB
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	105			dB
Supply Current/Amplifier	$I_{SY}$	$I_O = 0 \text{ mA}$		595	700	$\mu\text{A}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			1000	$\mu\text{A}$
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 2 \text{ k}\Omega$ to $V_{CM}$	2.4	3.7		$\text{V}/\mu\text{s}$
Gain Bandwidth Product	GBP	$V_{IN} = 5 \text{ mV p-p}$ , $R_L = 10 \text{ k}\Omega$ , $A_V = 100$		15.9		MHz
Unity-Gain Crossover	UGC	$V_{IN} = 5 \text{ mV p-p}$ , $R_L = 10 \text{ k}\Omega$ , $A_V = 1$		9.6		MHz
Phase Margin	$\Phi_M$			85		Degrees
-3 dB Closed-Loop Bandwidth	-3 dB	$A_V = 1$ , $V_{IN} = 5 \text{ mV p-p}$		13.9		MHz
<b>NOISE PERFORMANCE</b>						
Voltage Noise	$e_n$ p-p	0.1 Hz to 10 Hz		0.14		$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	$f = 1 \text{ kHz}$		3.9		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$			0.55		$\text{pA}/\sqrt{\text{Hz}}$

<sup>1</sup> Offset Voltage does not include solder heat resistance.

$V_{SY} = \pm 15.0\text{ V}$ ,  $V_{CM} = 0\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 4.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage <sup>1</sup>	$V_{OS}$	SOIC package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			100	$\mu\text{V}$
		MSOP package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			200	$\mu\text{V}$
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	Channel A vs. Channel B, $T_A = 25^\circ\text{C}$		0.5	1.75	$\mu\text{V}/^\circ\text{C}$
Offset Voltage Matching					150	$\mu\text{V}$
Input Bias Current	$I_B$			140	300	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			450	nA
Input Offset Current	$I_{OS}$				25	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			50	nA
Input Voltage Range			-15		+15	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = \pm 14\text{ V}$	106	124		dB
		$V_{CM} = \pm 15\text{ V}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	85			dB
Large Signal Voltage Gain	$A_{VO}$	$R_L = 2\text{ k}\Omega$ , $-13.5\text{ V} \leq V_O \leq +13.5\text{ V}$	110	117		dB
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	105			dB
Input Impedance, Differential				100  1.1		$\text{k}\Omega  \text{pF}$
Input Impedance, Common-Mode				200  2.5		$\text{M}\Omega  \text{pF}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage High	$V_{OH}$	$R_L = 10\text{ k}\Omega$ to $V_{CM}$	14.8	14.9		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	14.8			V
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$	14.5	14.6		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	14.3			V
Output Voltage Low	$V_{OL}$	$R_L = 10\text{ k}\Omega$ to $V_{CM}$		-14.95	-14.9	V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			-14.8	V
		$R_L = 2\text{ k}\Omega$ to $V_{CM}$		-14.9	-14.8	V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			-14.7	V
Short Circuit Current	$I_{SC}$			$\pm 30$		mA
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR	$V_{SY} = \pm 2\text{ V}$ to $\pm 18\text{ V}$	110	120		dB
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	105			dB
Supply Current/Amplifier	$I_{SY}$	$I_O = 0\text{ mA}$		625	750	$\mu\text{A}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			1050	$\mu\text{A}$
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 2\text{ k}\Omega$	2.4	4.6		$\text{V}/\mu\text{s}$
Gain Bandwidth Product	GBP	$V_{IN} = 5\text{ mV p-p}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 100$		15.9		MHz
Unity-Gain Crossover	UGC	$V_{IN} = 5\text{ mV p-p}$ , $R_L = 10\text{ k}\Omega$ , $A_V = 1$		9.9		MHz
Phase Margin	$\Phi_M$			86		Degrees
-3 dB Closed-Loop Bandwidth	-3 dB	$A_V = 1$ , $V_{IN} = 5\text{ mV p-p}$		13.9		MHz
<b>NOISE PERFORMANCE</b>						
Voltage Noise	$e_n$ p-p	0.1 Hz to 10 Hz		0.1		$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	$f = 1\text{ kHz}$		3.9		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$			0.55		$\text{pA}/\sqrt{\text{Hz}}$

<sup>1</sup> Offset Voltage does not include solder heat resistance.

# ABSOLUTE MAXIMUM RATINGS

Table 5.

Parameter	Rating
Supply Voltage	±18 V
Input Voltage	$V- \leq V_{IN} \leq V+$
Differential Input Voltage <sup>1</sup>	±0.6 V
Output Short-Circuit Duration to GND	Indefinite
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 60 sec)	300°C

<sup>1</sup> For input differential voltages greater than 0.6 V, the input current should be limited to less than 5 mA to prevent degradation or destruction of the input devices.

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.

## THERMAL RESISTANCE

$\theta_{JA}$  is specified for the device soldered on a 4-layer JEDEC standard printed circuit board (PCB) with zero airflow.

Table 6. Thermal Resistance

Package Type	$\theta_{JA}$	$\theta_{JC}$	Unit
8-Lead SOIC	121	43	°C/W
8-Lead MSOP	142	45	°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.

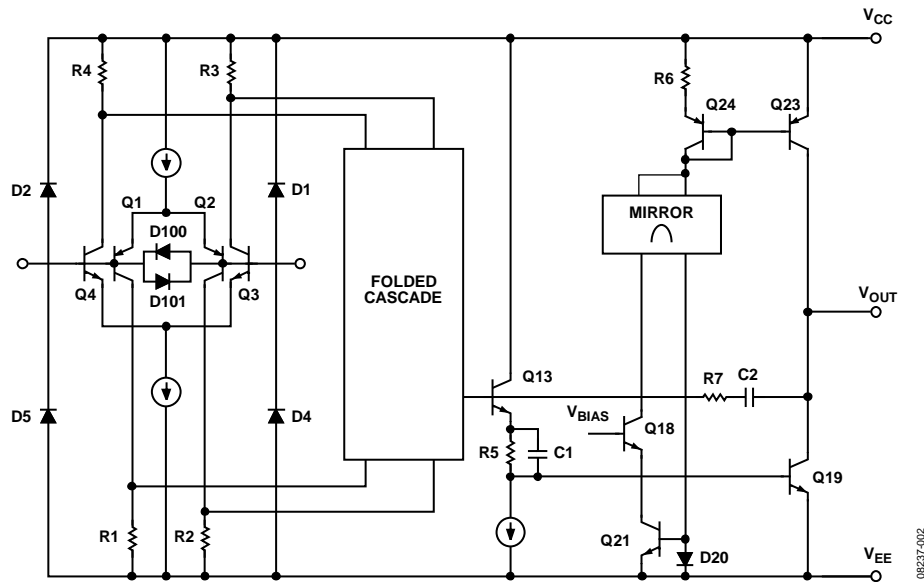


Figure 2. Simplified Schematic

# TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25^\circ\text{C}$ , unless otherwise noted.

## $\pm 1.5\text{ V}$ CHARACTERISTICS

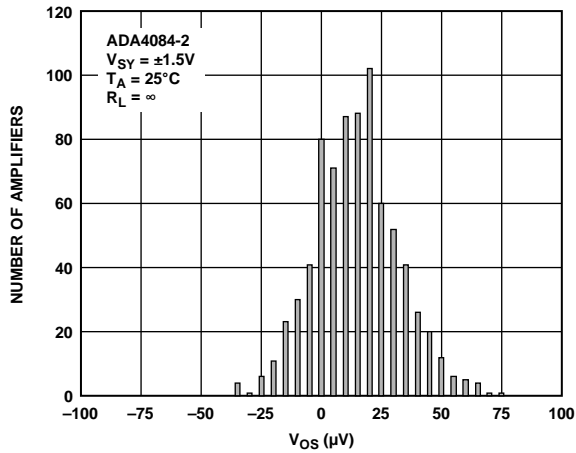


Figure 3. Input Offset Voltage Distribution, SOIC

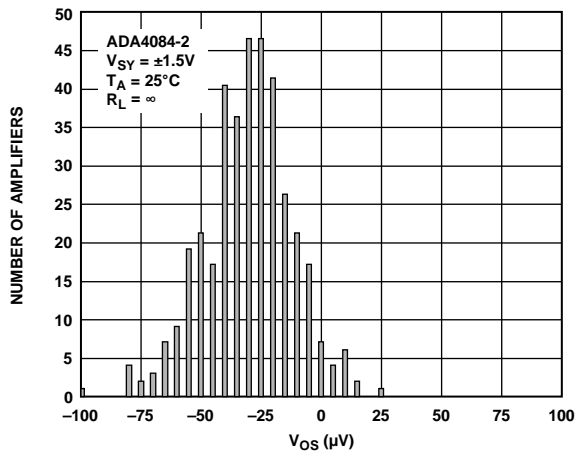


Figure 4. Input Offset Voltage Distribution, MSOP

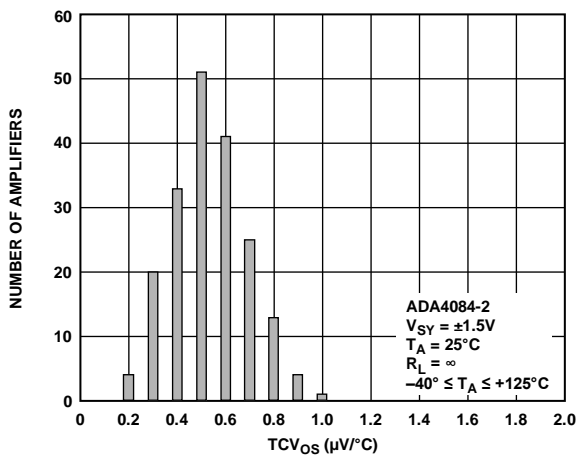


Figure 5.  $TCV_{OS}$  Distribution, SOIC

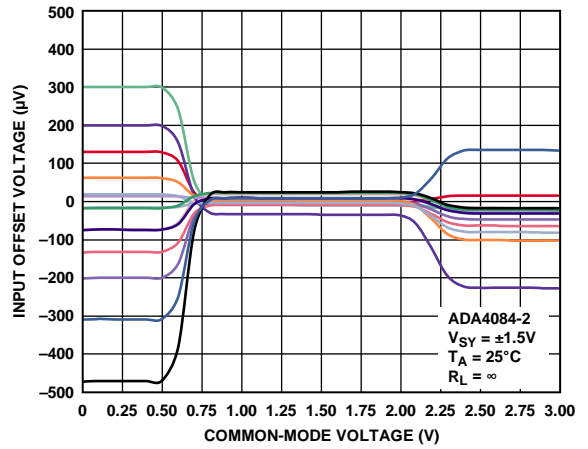


Figure 6. Input Offset Voltage vs. Common-Mode Voltage

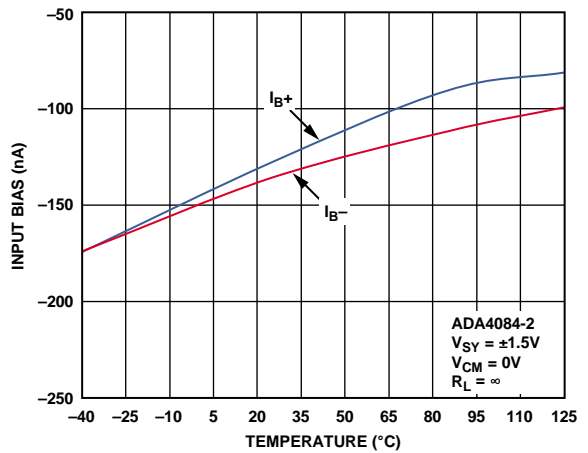


Figure 7. Input Bias Current vs. Temperature

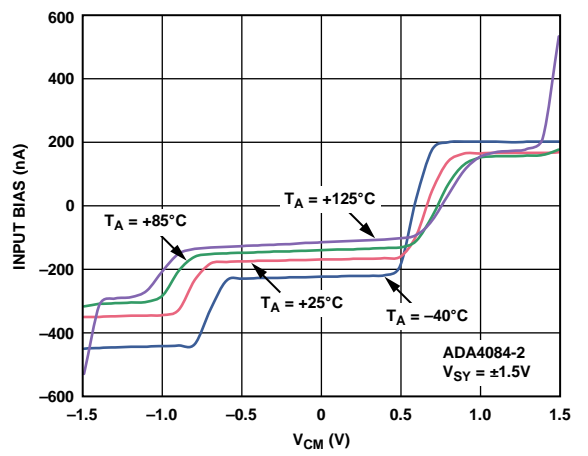


Figure 8. Input Bias Current vs.  $V_{CM}$  and Temperature

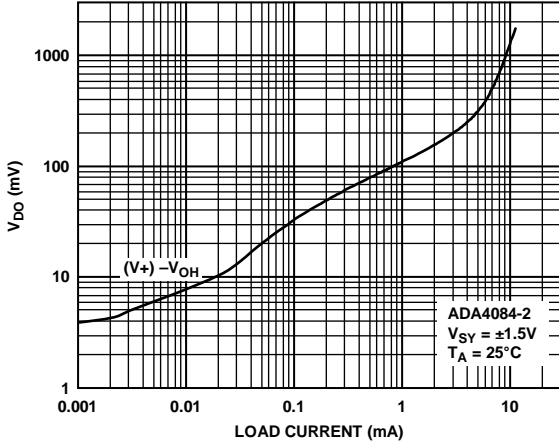


Figure 9. Dropout Voltage vs. Source Current

08237-009

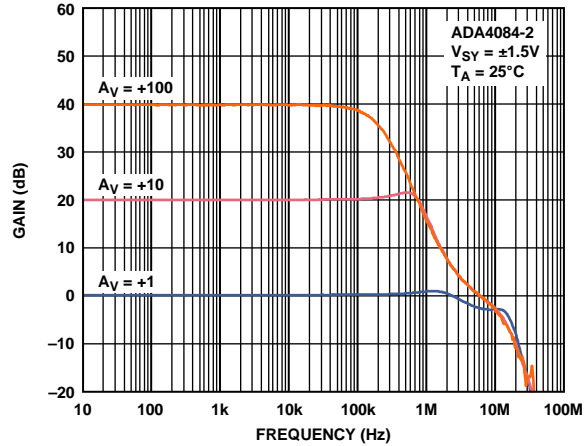


Figure 12. Closed-Loop Gain vs. Frequency

08237-012

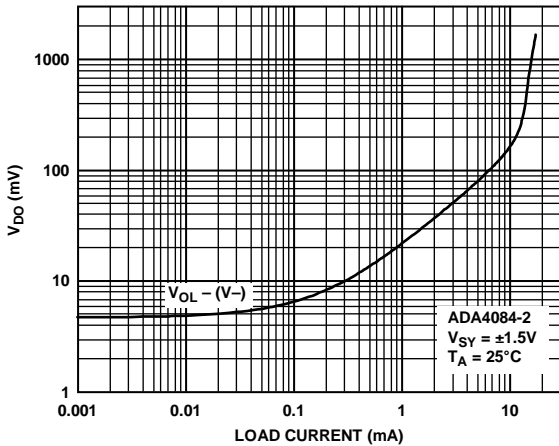


Figure 10. Dropout Voltage vs. Sink Current

08237-010

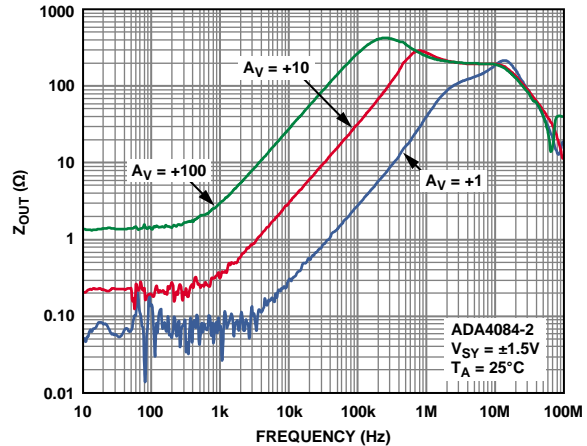


Figure 13. Output Impedance vs. Frequency

08237-013

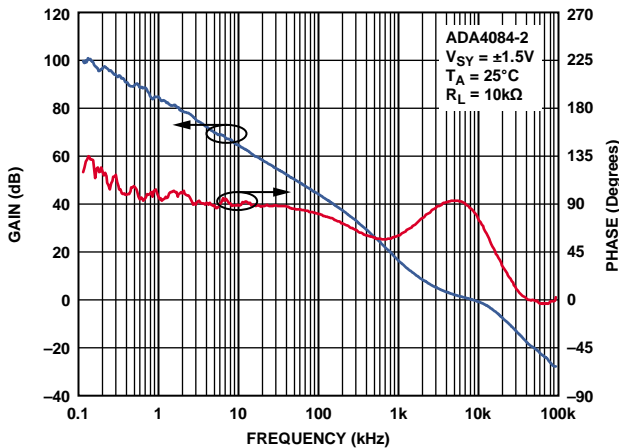


Figure 11. Open-Loop Gain and Phase vs. Frequency

08237-011

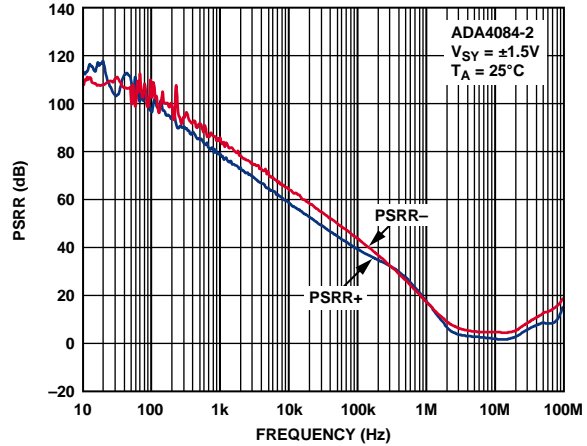


Figure 14. PSRR vs. Frequency

08237-014



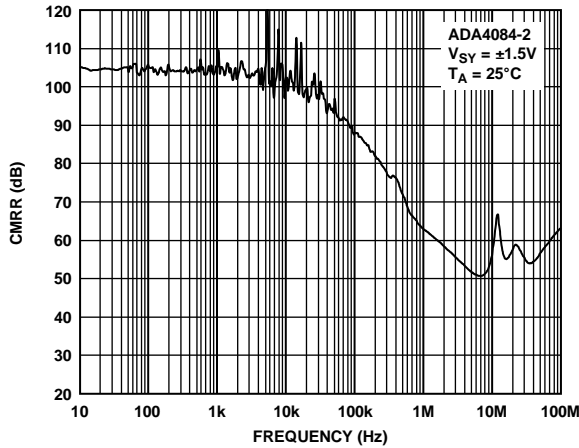


Figure 15. CMRR vs. Frequency

08237-015

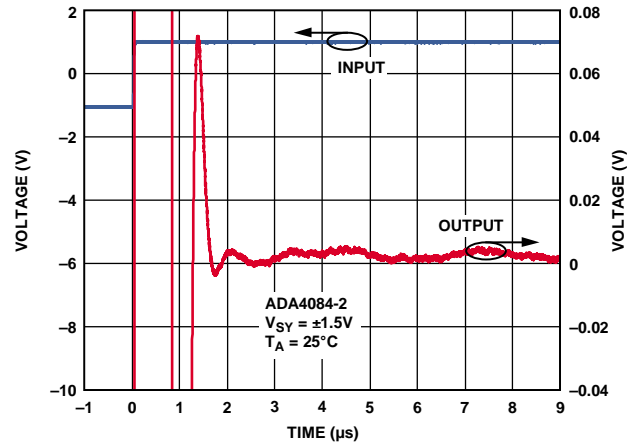


Figure 18. Settling Time

08237-018

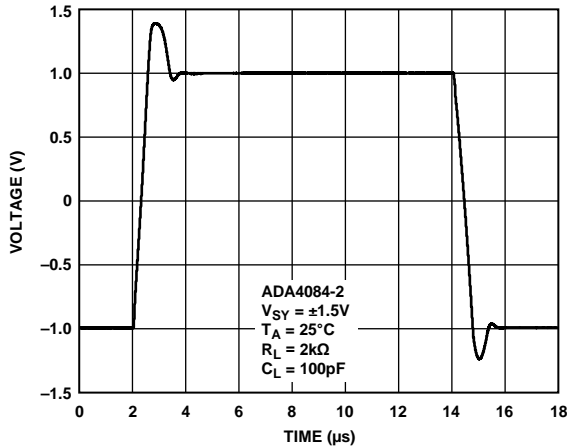


Figure 16. Large Signal Transient Response

08237-016

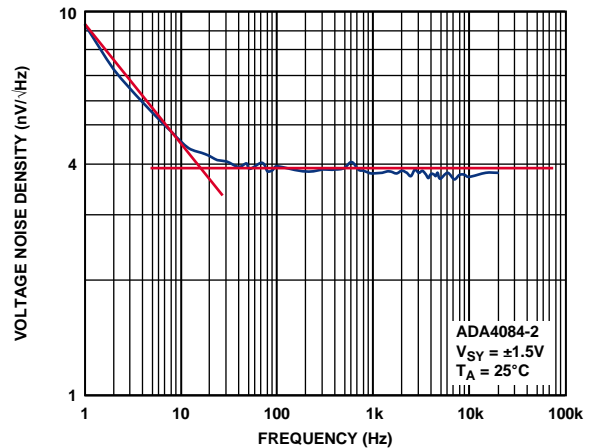


Figure 19. Voltage Noise Density

08237-019

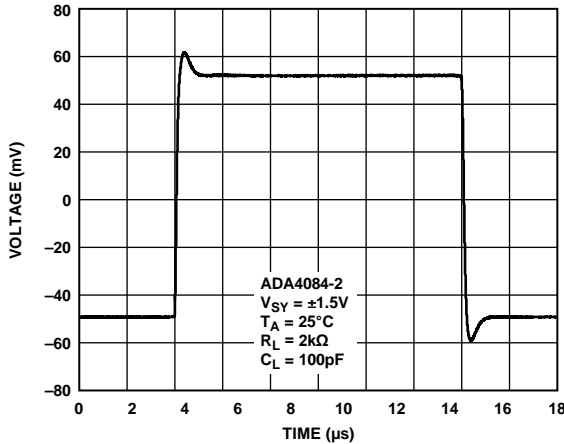


Figure 17. Small Signal Transient Response

08237-017

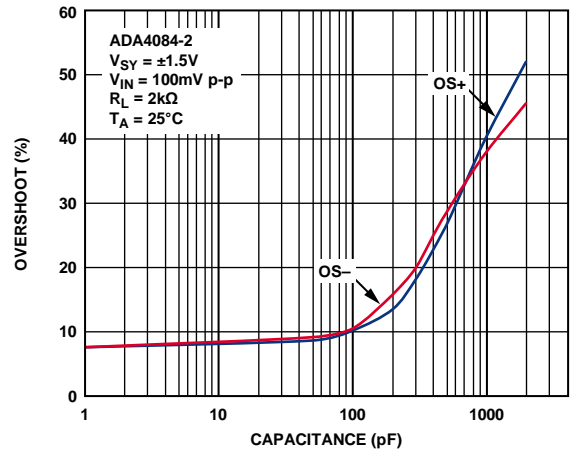


Figure 20. Overshoot vs. Capacitance

08237-020

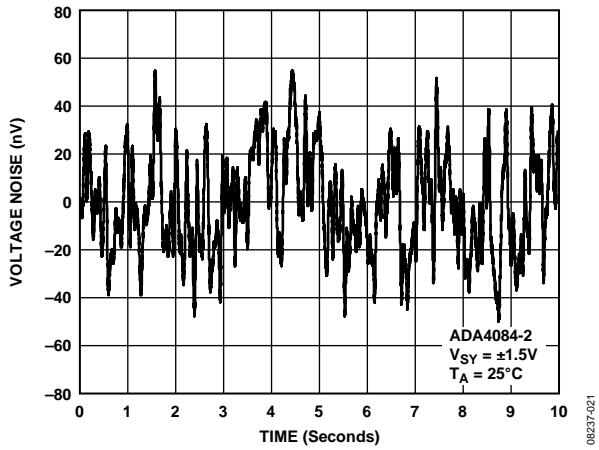


Figure 21. Voltage Noise 0.1 Hz to 10 Hz

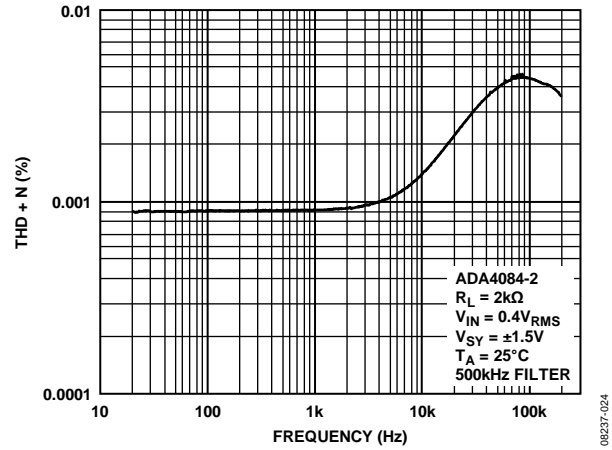


Figure 24. THD + N vs. Frequency

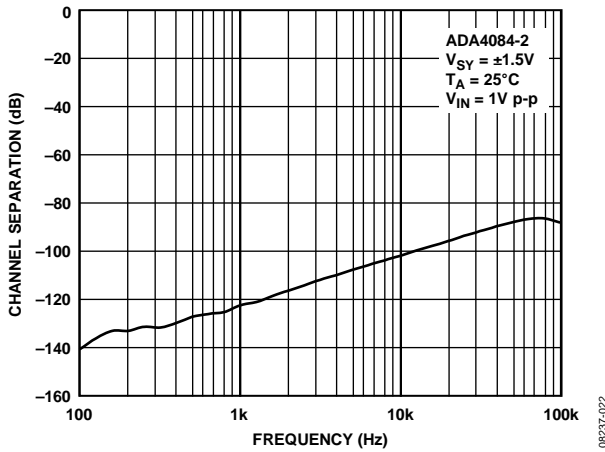


Figure 22. Channel Separation

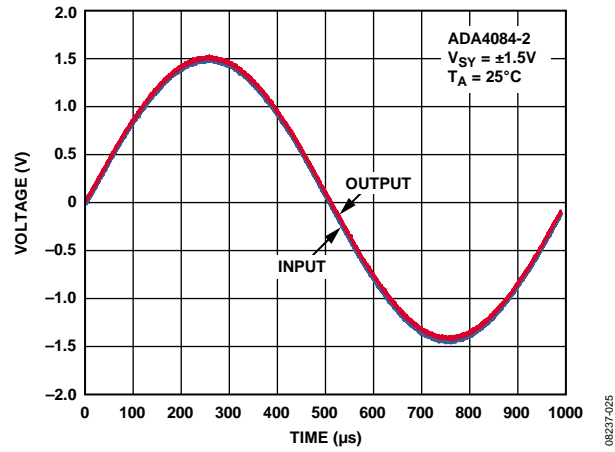


Figure 25. No Phase Reversal

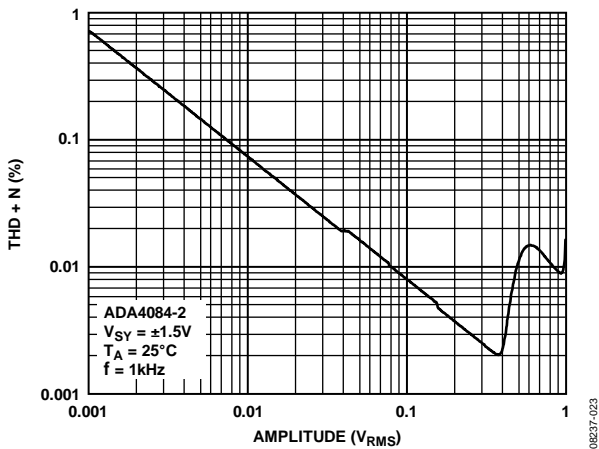


Figure 23. THD + N vs. Amplitude

±5 V CHARACTERISTICS

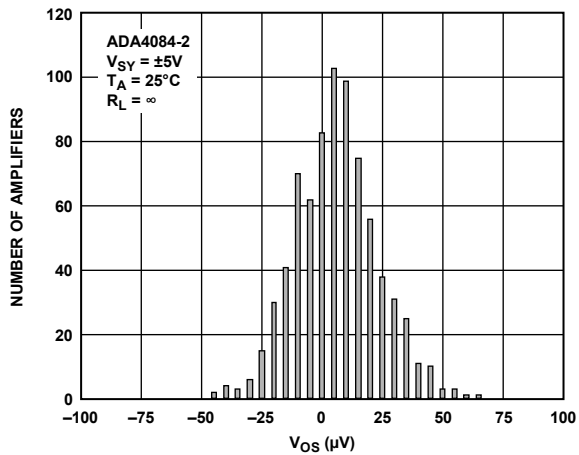


Figure 26. Input Offset Voltage Distribution SOIC

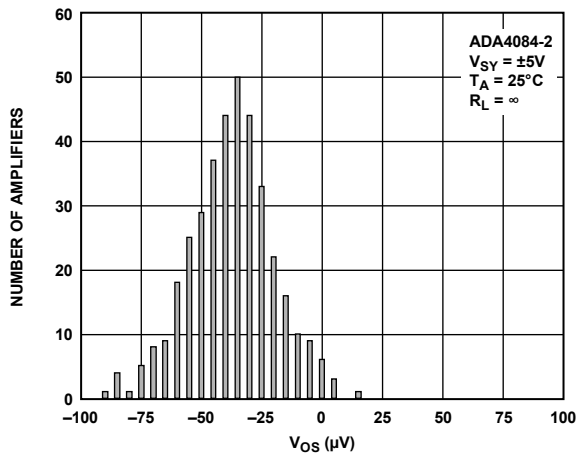


Figure 27. Input Offset Voltage Distribution MSOP

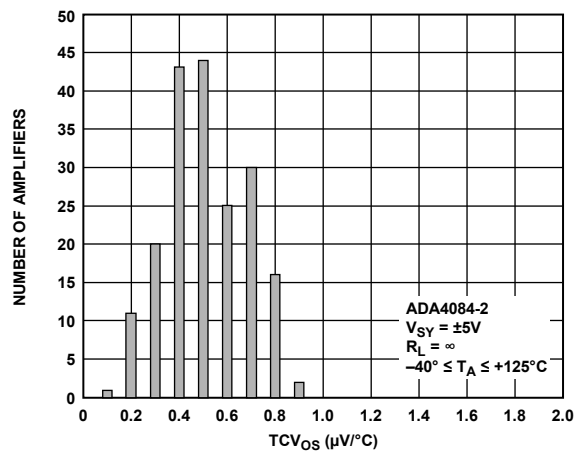


Figure 28. TCVOS Distribution

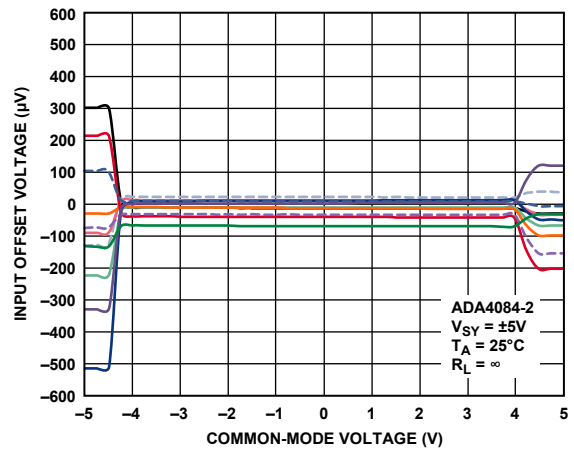


Figure 29. Input Offset Voltage vs. Common-Mode Voltage

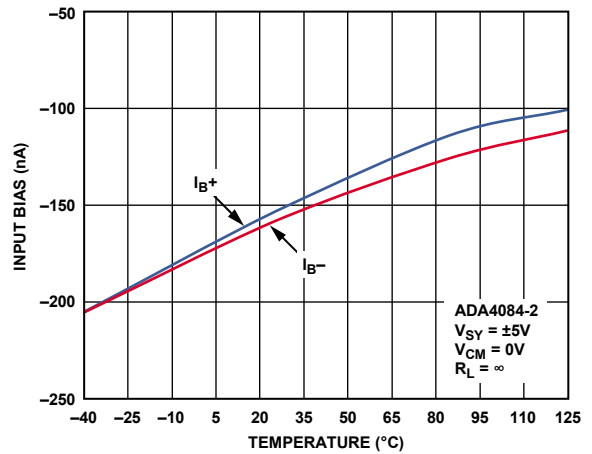


Figure 30. Input Bias Current vs. Temperature

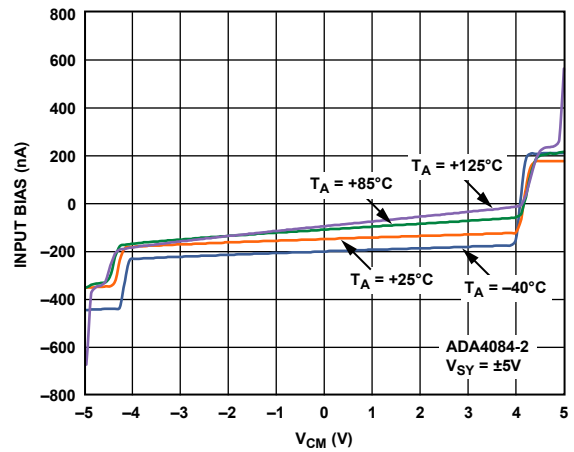


Figure 31. Input Bias Current vs. VCM and Temperature

08237-026

08237-029

08237-027

08237-030

08237-028

08237-031

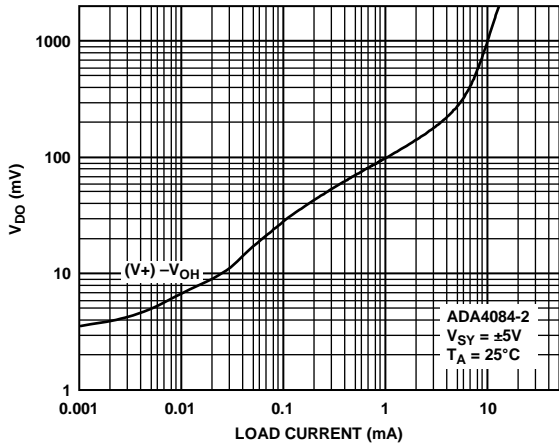


Figure 32. Dropout Voltage vs. Source Current

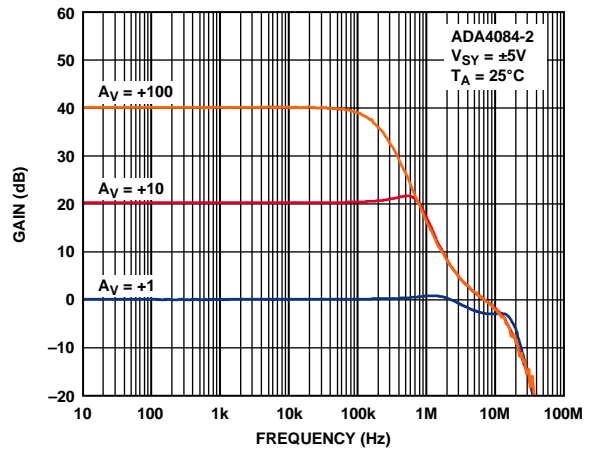


Figure 35. Closed-Loop Gain vs. Frequency

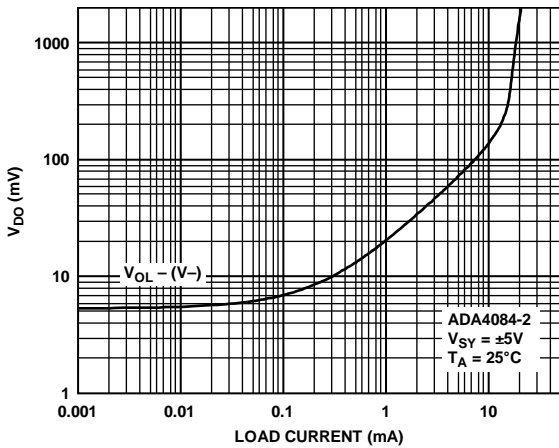


Figure 33. Dropout Voltage vs. Sink Current

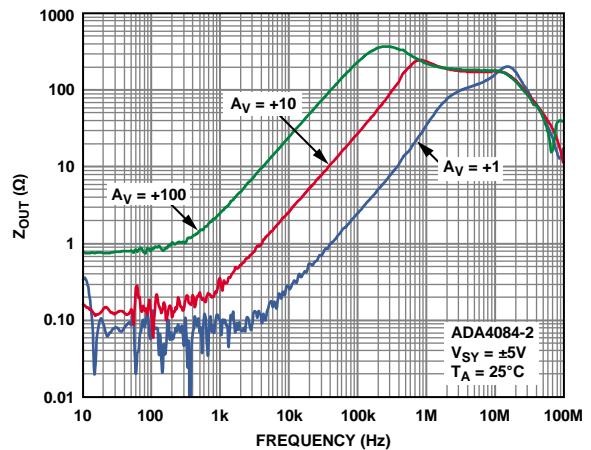


Figure 36. Output Impedance vs. Frequency

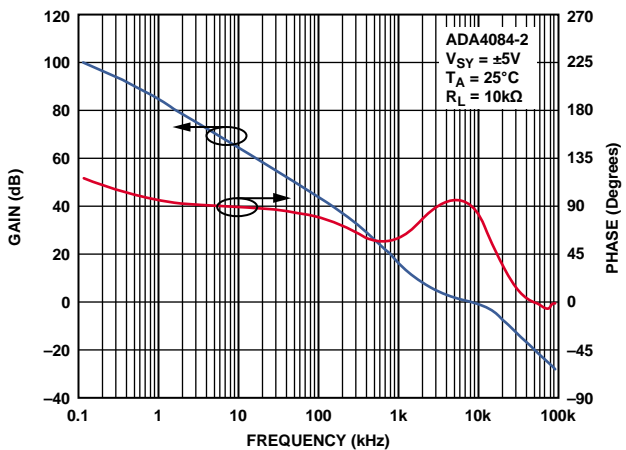


Figure 34. Open-Loop Gain and Phase vs. Frequency

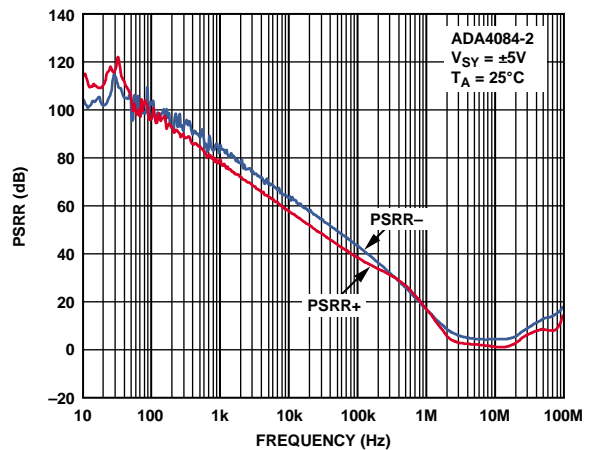


Figure 37. PSRR vs. Frequency

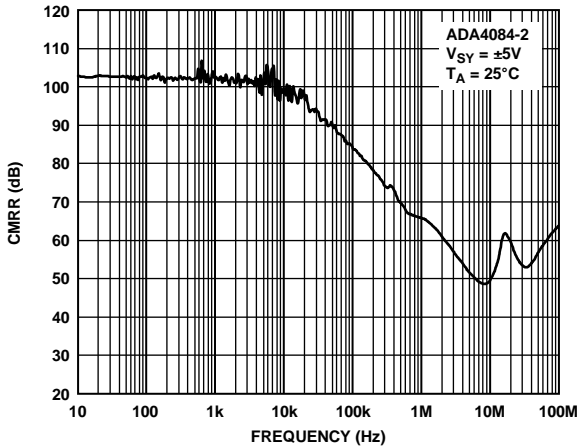


Figure 38. CMRR vs. Frequency

08237-038

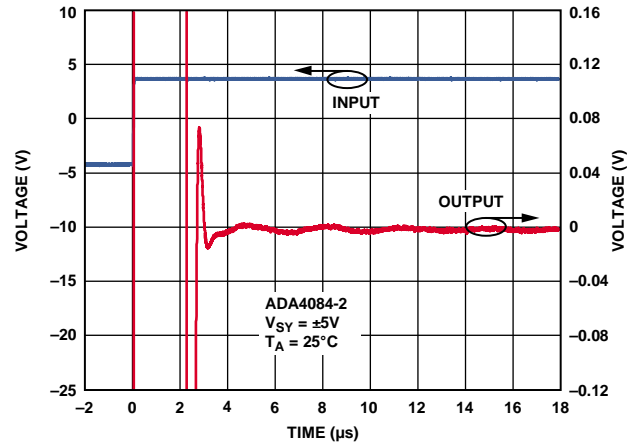


Figure 41. Settling Time

08237-041

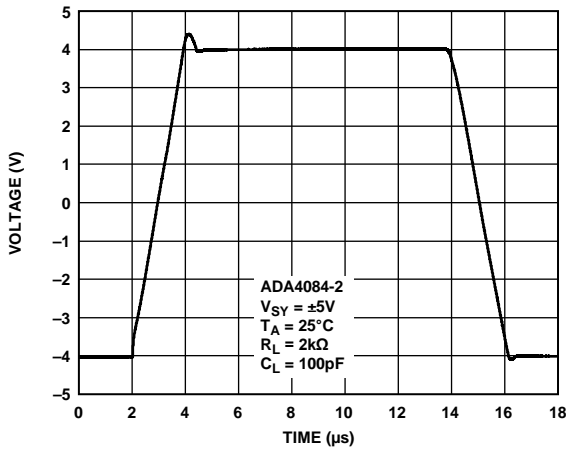


Figure 39. Large Signal Transient Response

08237-039

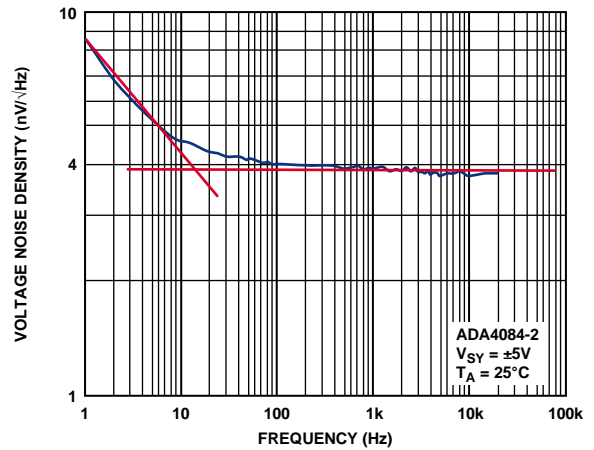


Figure 42. Voltage Noise Density

08237-042

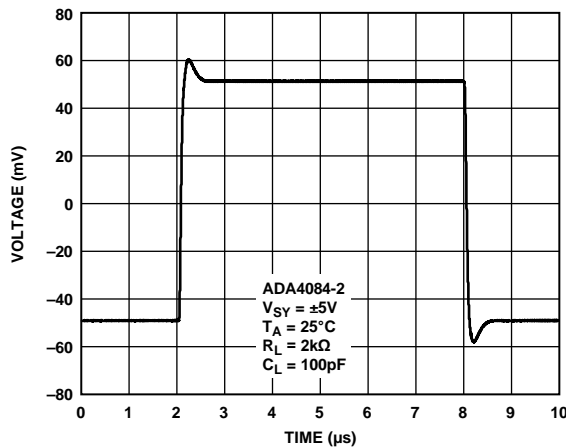


Figure 40. Small Signal Transient Response

08237-040

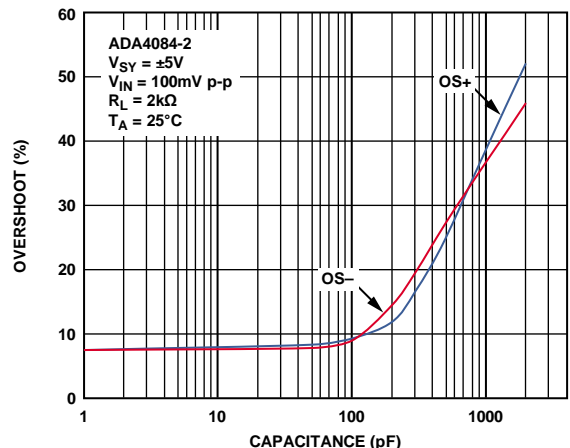


Figure 43. Overshoot vs. Load Capacitance

08237-043

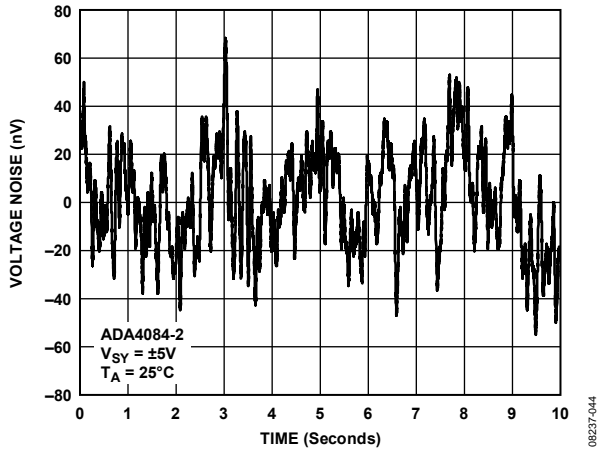


Figure 44. Voltage Noise 0.1 Hz to 10 Hz

08237-044

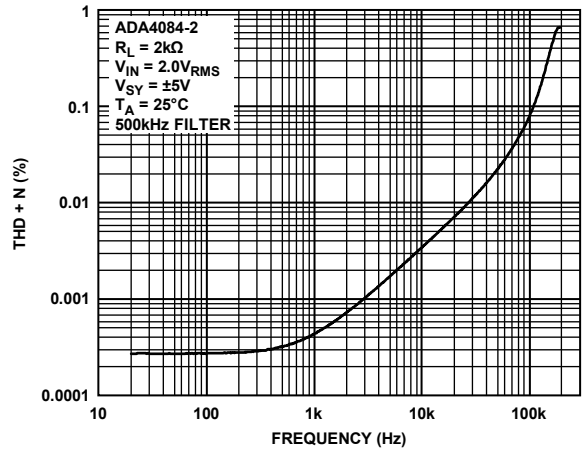


Figure 47. THD + N vs. Frequency

08237-047

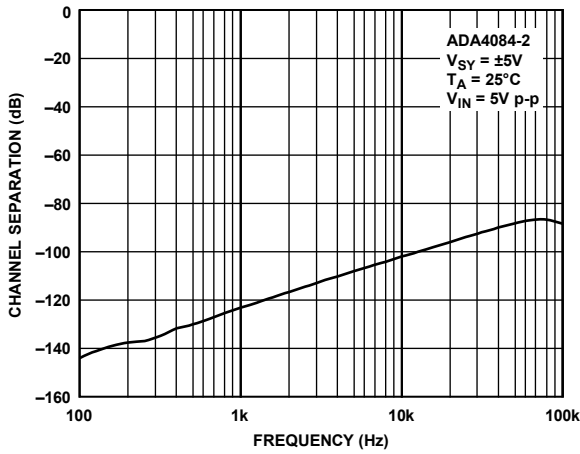


Figure 45. Channel Separation

08237-045

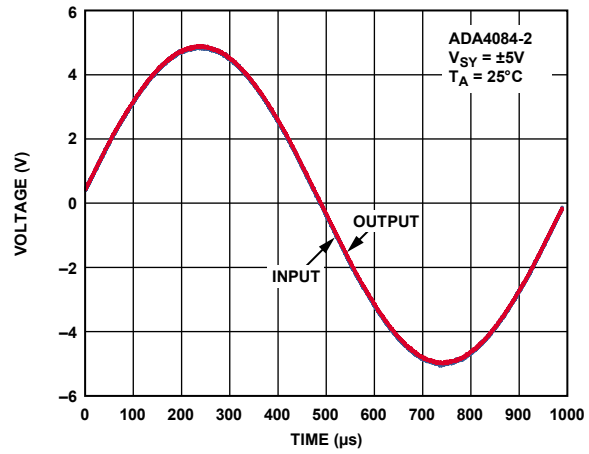


Figure 48. No Phase Reversal

08237-048

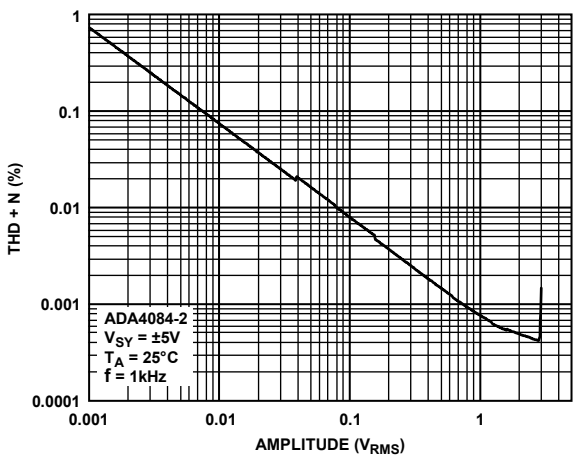


Figure 46. THD + N vs. Amplitude

08237-046

±15 V CHARACTERISTICS

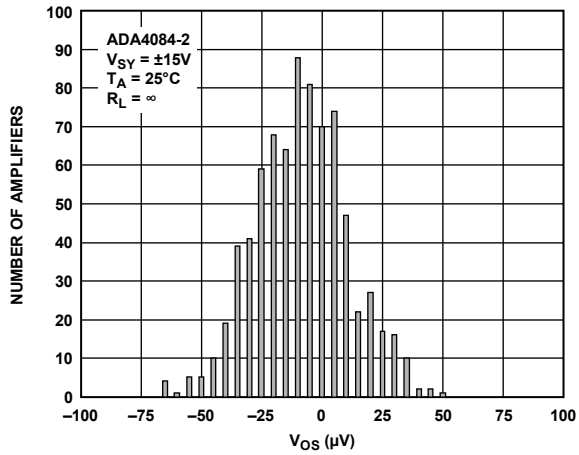


Figure 49. Input Offset Voltage Distribution, SOIC

08237-049

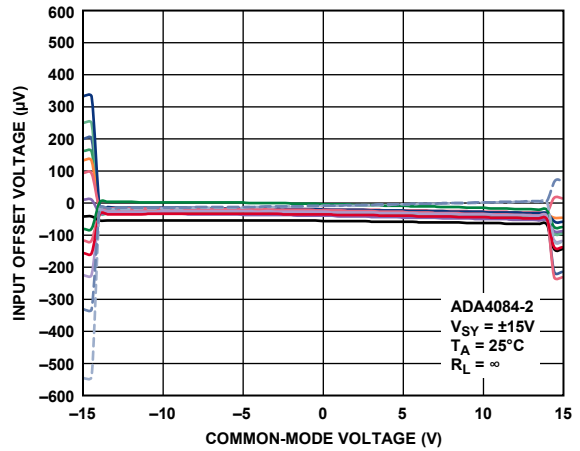


Figure 52. Input Offset Voltage vs. Common-Mode Voltage

08237-052

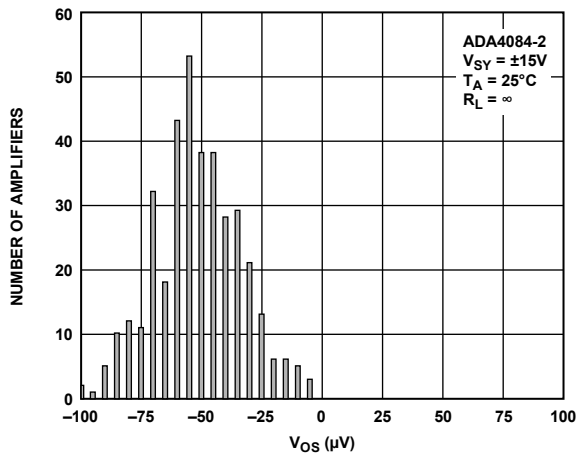


Figure 50. Input Offset Voltage Distribution, MSOP

08237-050

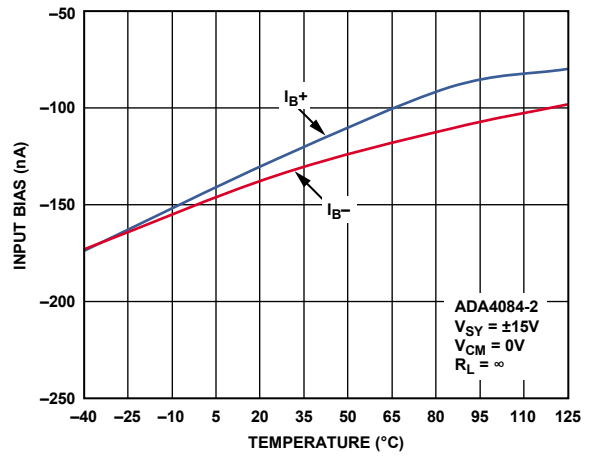


Figure 53. Input Bias Current vs. Temperature

08237-053

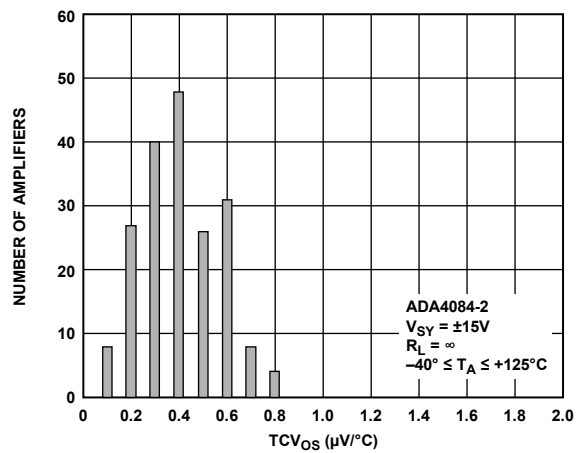


Figure 51. TCV<sub>0s</sub> Distribution

08237-051

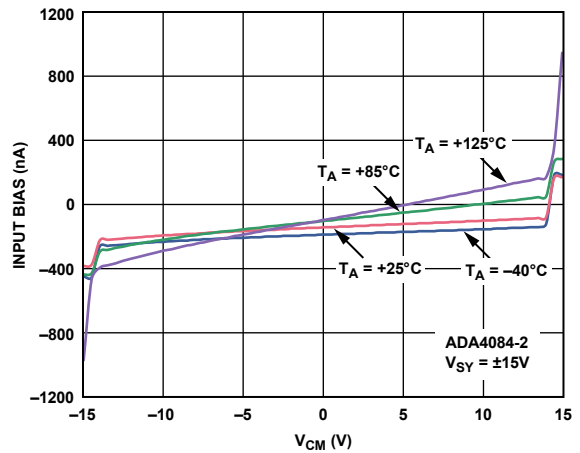


Figure 54. Input Bias Current vs.  $V_{CM}$  and Temperature

08237-054

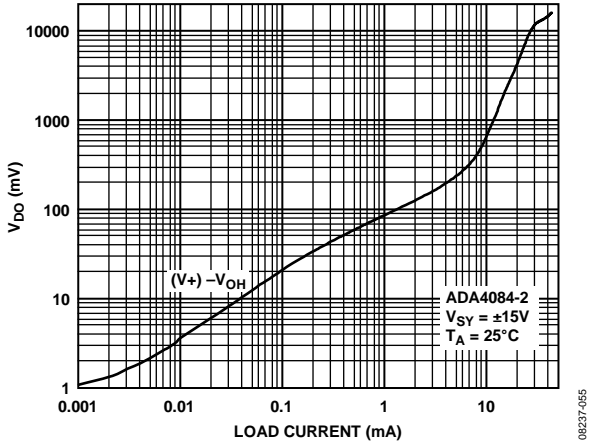


Figure 55. Dropout Voltage vs. Source Current

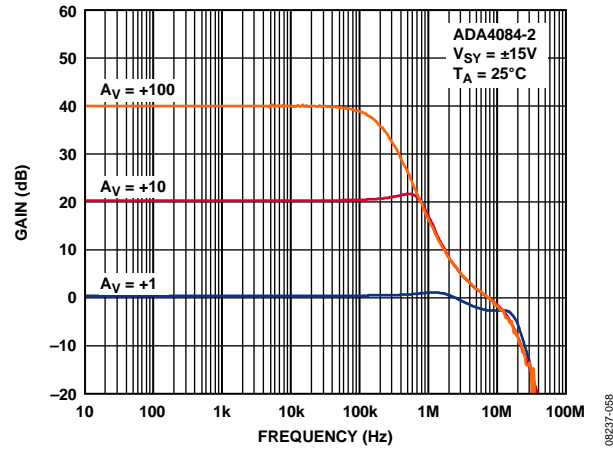


Figure 58. Closed-Loop Gain vs. Frequency

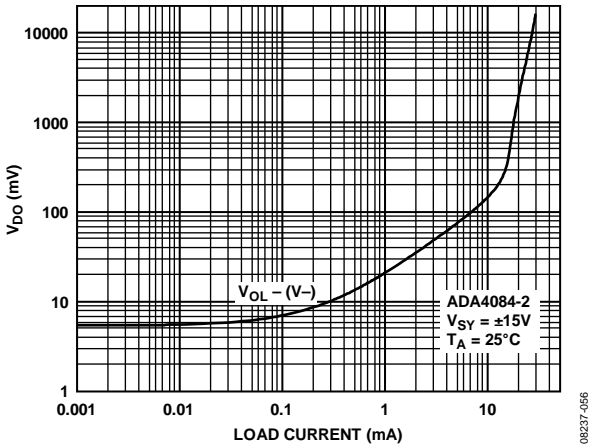


Figure 56. Dropout Voltage vs. Sink Current

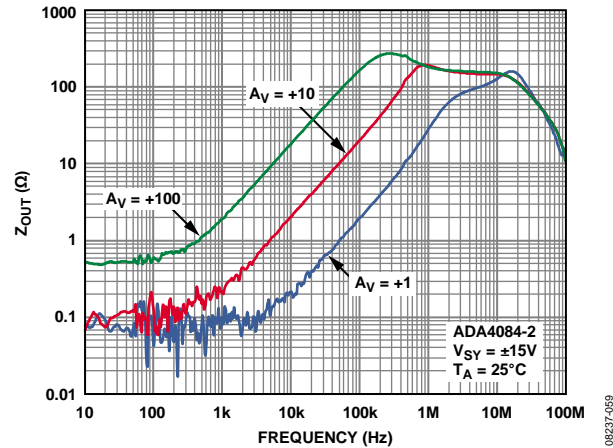


Figure 59. Output Impedance vs. Frequency

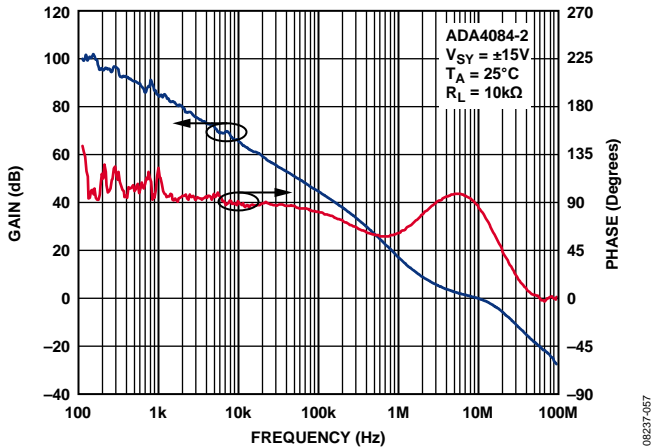


Figure 57. Open-Loop Gain and Phase vs. Frequency

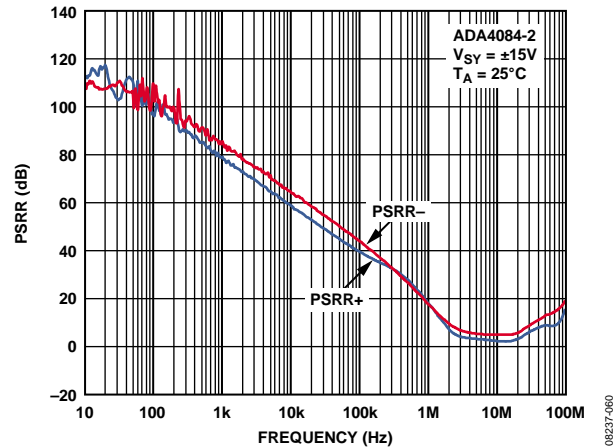


Figure 60. PSRR vs. Frequency



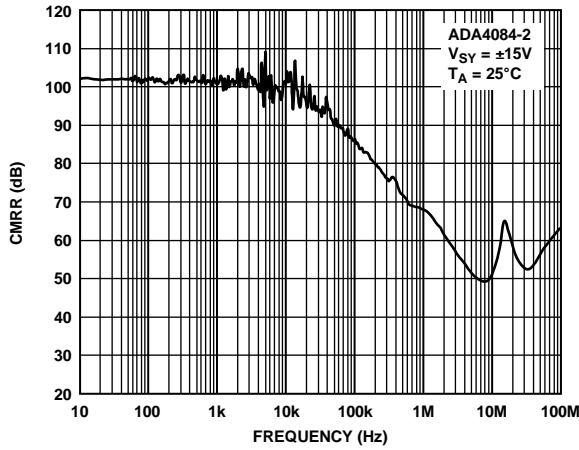


Figure 61. CMRR vs. Frequency

08237-061

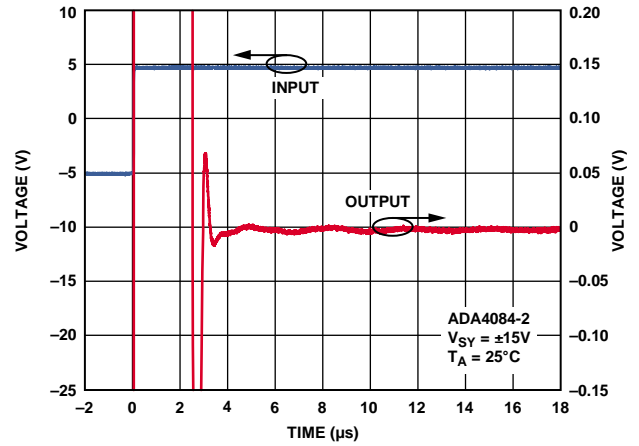


Figure 64. Settling Time

08237-064

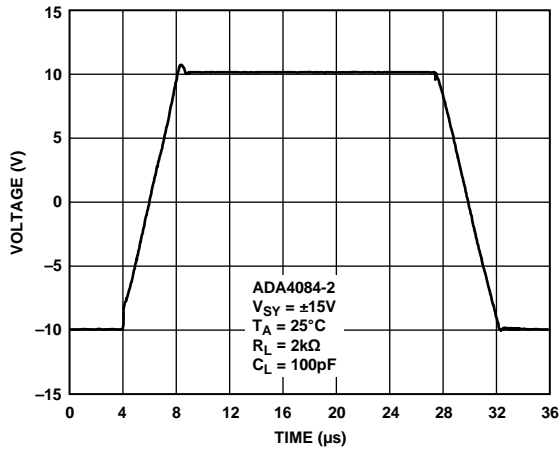


Figure 62. Large Signal Transient Response

08237-062

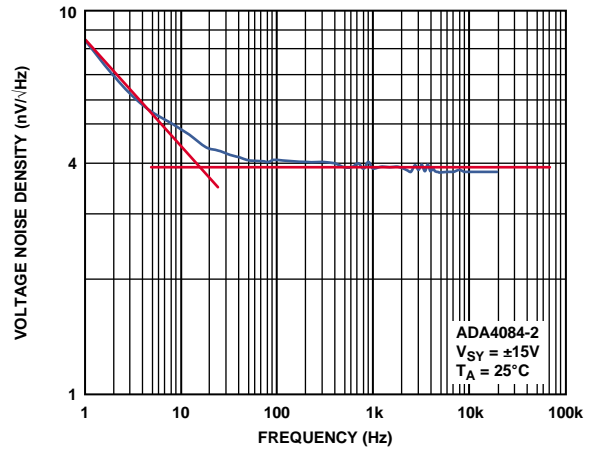


Figure 65. Voltage Noise Density

08237-065

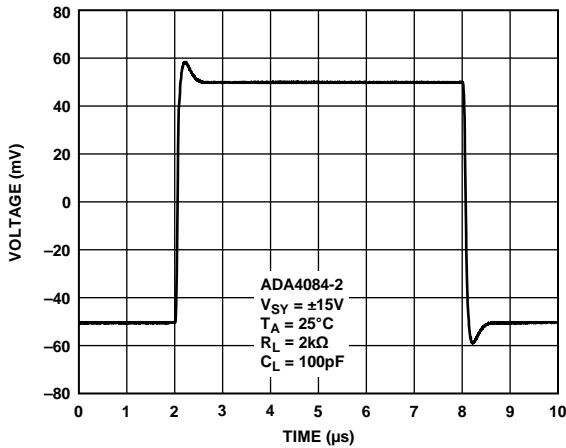


Figure 63. Small Signal Transient Response

08237-063

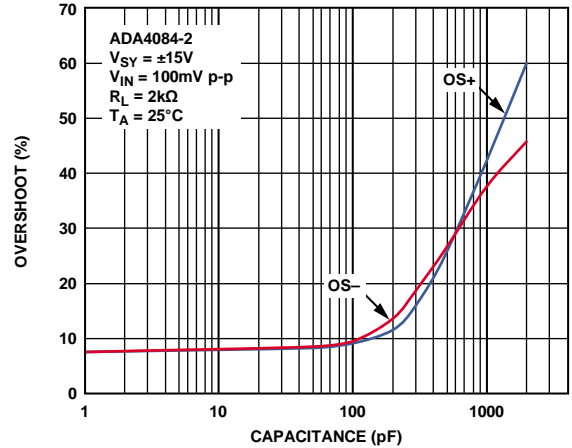


Figure 66. Overshoot vs. Load Capacitance

08237-066

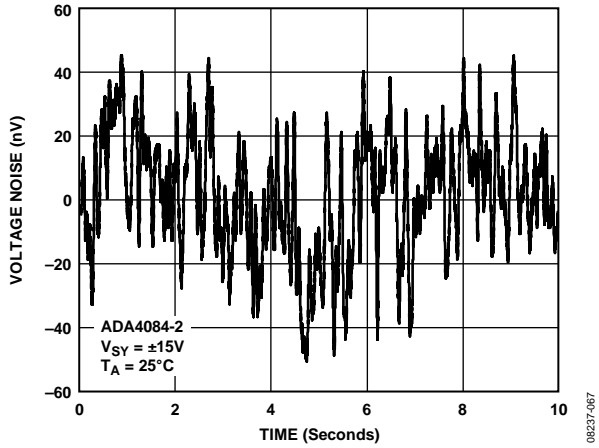


Figure 67. Voltage Noise 0.1 Hz to 10 Hz

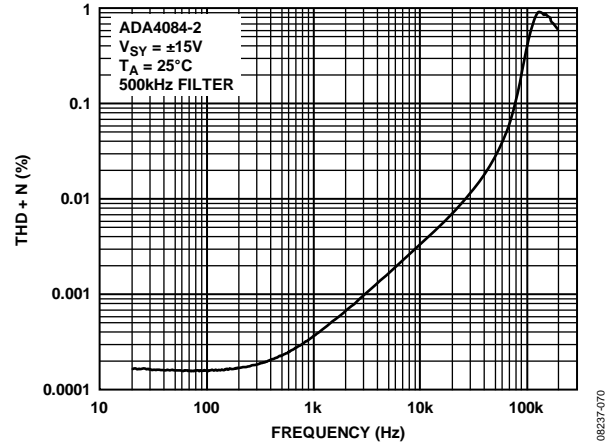


Figure 70. THD + N vs. Frequency

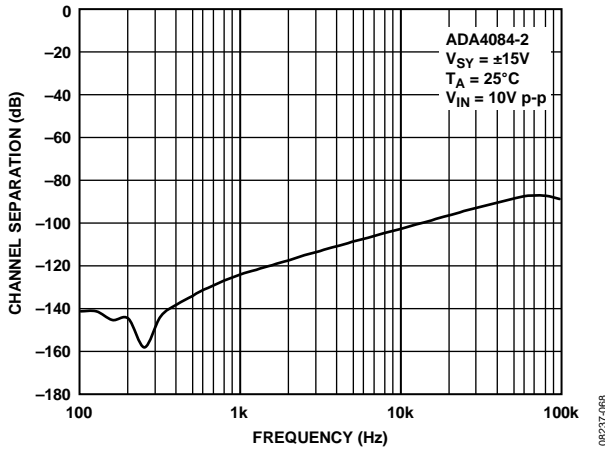


Figure 68. Channel Separation

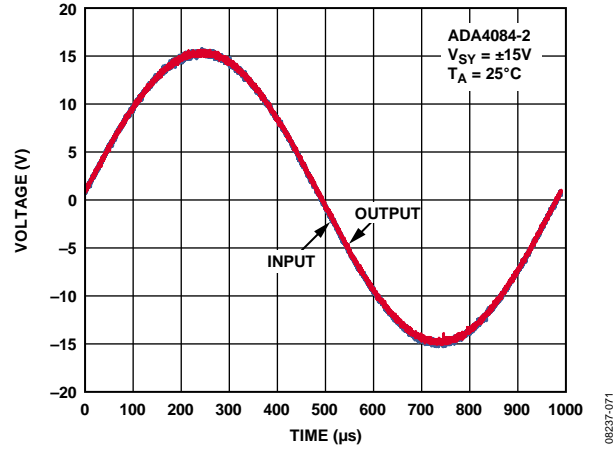


Figure 71. No Phase Reversal

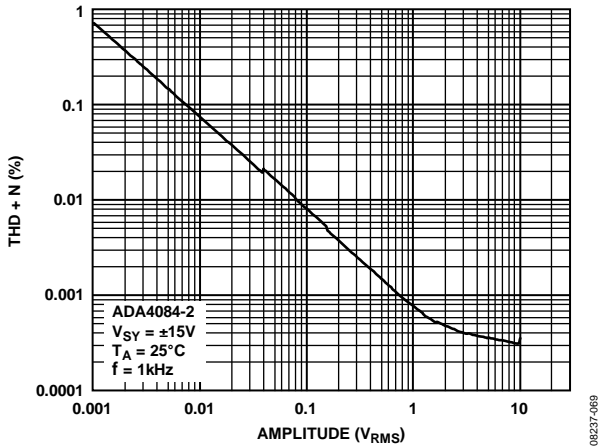


Figure 69. THD + N vs. Amplitude

08237-067

08237-070

08237-068

08237-071

08237-069

COMPARATIVE VOLTAGE AND VARIABLE VOLTAGE GRAPH

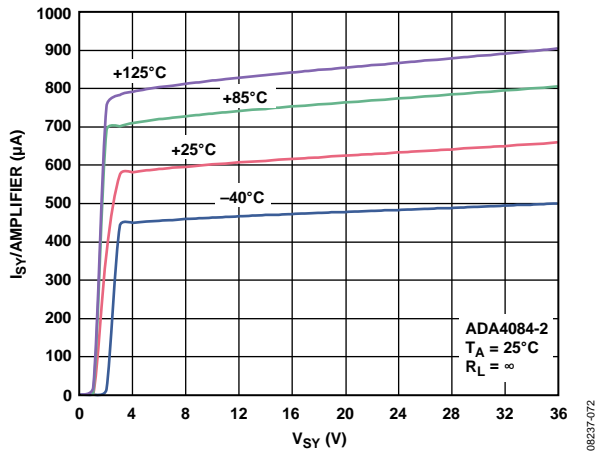


Figure 72. Supply Current vs. Supply Voltage

09237-372

## APPLICATIONS INFORMATION

### FUNCTIONAL DESCRIPTION

The ADA4084-2 is a precision single-supply, rail-to-rail operational amplifier. Intended for portable instrumentation, the ADA4084-2 combines the attributes of precision, wide bandwidth, and low noise to make it an ideal choice in single-supply applications that require both ac and precision dc performance. Other low supply voltage applications for which the ADA4084-2 is well suited are active filters, audio microphone preamplifiers, power supply control, and telecommunications. To combine all of these attributes with rail-to-rail input/output operation, novel circuit design techniques are used.

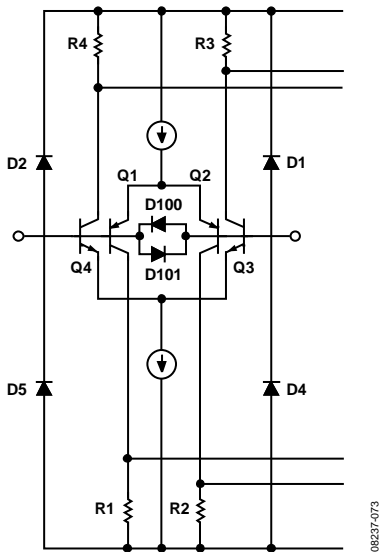


Figure 73. ADA4084-2 Equivalent Input Circuit

For example, Figure 73 illustrates a simplified equivalent circuit for the input stage of the ADA4084-2. It comprises a PNP differential pair, Q1 and Q2, and an NPN differential pair, Q3 and Q4, operating concurrently. Diode D100 and Diode D101 serve to clamp the applied differential input voltage to the ADA4084-2, thereby protecting the input transistors against Zener breakdown of the emitter-base junctions. Input stage voltage gains are kept low for input rail-to-rail operation. The two pairs of differential output voltages are connected to the second stage of the ADA4084-2, which is a modified compound folded cascade gain stage. It is also in the second gain stage, where the two pairs of differential output voltages are combined into a single-ended output signal voltage used to drive the output stage.

A key issue in the input stage is the behavior of the input bias currents over the input common-mode voltage range. Input bias currents in the ADA4084-2 are the arithmetic sum of the base currents in Q1 and Q4 and in Q2 and Q3. As a result of this design approach, the input bias currents in the ADA4084-2 not only exhibit different amplitudes; they also exhibit different polarities. This effect is best illustrated by Figure 7, Figure 8, Figure 30, Figure 31, Figure 53, and Figure 54. It is therefore

important that the effective source impedances connected to the ADA4084-2 inputs be balanced for optimum dc and ac performance.

To achieve rail-to-rail output, the ADA4084-2 output stage design employs a unique topology for both sourcing and sinking current. This circuit topology is illustrated in Figure 74. The output stage is voltage-driven from the second gain stage. The signal path through the output stage is inverting; that is, for positive input signals, Q13 provides the base current drive to Q19 so that it conducts (sinks) current. For negative input signals, the signal path via Q18 → mirror → Q24 provides the base current drive for Q23 to conduct (source) current. Both transistors provide output current until they are forced into saturation.

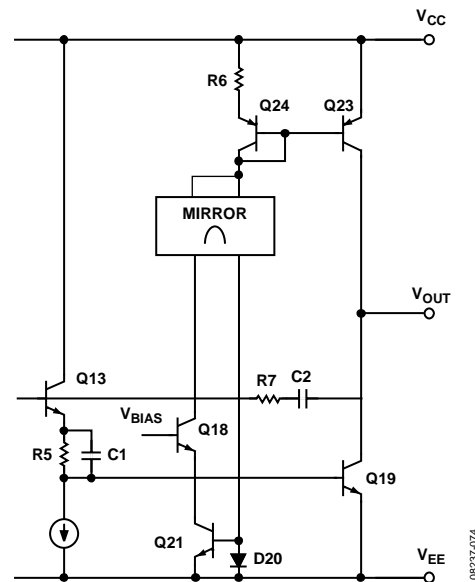


Figure 74. ADA4084-2 Equivalent Output Circuit

Thus, the saturation voltage of the output transistors sets the limit on the ADA4084-2 maximum output voltage swing. Output short-circuit current limiting is determined by the maximum signal current into the base of Q13 from the second gain stage. The output stage also exhibits voltage gain. This is accomplished by the use of common-emitter amplifiers, and, as a result, the voltage gain of the output stage (thus, the open-loop gain of the device) exhibits a dependence on the total load resistance at the output of the ADA4084-2.

**INPUT PROTECTION**

As with any semiconductor device, if conditions exist where the applied input voltages to the device exceed either supply voltage, the input overvoltage I-to-V characteristic of the device must be considered. When an overvoltage occurs, the amplifier may be damaged, depending on the magnitude of the applied voltage and the magnitude of the fault current.

The D1, D2, D4, and D5 diodes conduct when the input common-mode voltage exceeds either supply pin by a diode drop. This varies with temperature and is in the range of 0.3 V to 0.8 V. As illustrated in the simplified equivalent circuit shown in Figure 73, the ADA4084-2 does not have any internal current limiting resistors; thus, fault currents can quickly rise to damaging levels.

This input current is not inherently damaging to the device, provided that it is limited to 5 mA or less. If a fault condition causes more than 5 mA to flow, an external series resistor should be added at the expense of additional thermal noise. Figure 75 illustrates a typical noninverting configuration for an overvoltage-protected amplifier where the series resistance,  $R_s$ , is chosen, such that

$$R_s = \frac{V_{IN(MAX)} - V_{SUPPLY}}{5 \text{ mA}}$$

For example, a 1 kΩ resistor protects the ADA4084-2 against input signals up to 5 V above and below the supplies. Note that the thermal noise of a 1 kΩ resistor at room temperature is 4 nV/√Hz, which exceeds the voltage noise of the ADA4084-2. For other configurations where both inputs are used, each input should be protected against abuse with a series resistor. Again, to ensure optimum dc and ac performance, it is recommended that source impedance levels be balanced.

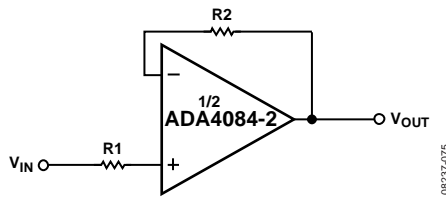


Figure 75. Resistance in Series with Input Limits Overvoltage Currents to Safe Values

To protect Q1-Q2 and Q3-Q4 from large differential voltages that may result in Zener breakdown of the emitter-base junction, D100 and D101 are connected between the two inputs. This precludes operation as a comparator. For a more complete description, see the MT-035 Tutorial, *Op Amp Inputs, Outputs, Single-Supply, and Rail-to-Rail Issues*; the MT-083 Tutorial, *Comparators*, the MT-084 Tutorial, *Using Op Amps As Comparators*; and the AN-849 Application Note, *Using Op Amps as Comparators*, at [www.analog.com](http://www.analog.com).

**OUTPUT PHASE REVERSAL**

Some operational amplifiers designed for single-supply operation exhibit an output voltage phase reversal when their inputs are driven beyond their useful common-mode range. Typically, for single-supply bipolar op amps, the negative supply determines the lower limit of their common-mode range. With these devices, external clamping diodes, with the anode connected to ground and the cathode to the inputs, prevent input signal excursions from exceeding the negative supply of the device (that is, GND), preventing a condition that causes the output voltage to change phase. JFET input amplifiers can also exhibit phase reversal, and, if so, a series input resistor is usually required to prevent it.

The ADA4084-2 is free from reasonable input voltage range restrictions, provided that input voltages no greater than the supply voltages are applied. Although device output does not change phase, large currents can flow through the input protection diodes. Therefore, the technique recommended in the Input Protection section should be applied to those applications where the likelihood of input voltages exceeding the supply voltages is high.

**DESIGNING LOW NOISE CIRCUITS IN SINGLE-SUPPLY APPLICATIONS**

In single-supply applications, devices like the ADA4084-2 extend the dynamic range of the application through the use of rail-to-rail operation. Referring to the op amp noise model circuit configuration illustrated in Figure 76, the expression for an amplifier's total equivalent input noise voltage for a source resistance level,  $R_s$ , is given by

$$e_{nT} = \sqrt{2 [(e_{nR})^2 + (i_{nOA} \times R_s)^2] + (e_{nOA})^2}, \text{ units in } \frac{V}{\sqrt{\text{Hz}}}$$

where:

- $R_s = 2R$ , the effective, or equivalent, circuit source resistance.
- $(e_{nR})^2$  is the source resistance thermal noise voltage power ( $4kTR$ ).
- $k$  is the Boltzmann's constant,  $1.38 \times 10^{-23}$  J/K.
- $T$  is the ambient temperature in Kelvin of the circuit,  $273.15 + T_A$  (°C).
- $(i_{nOA})^2$  is the op amp equivalent input noise current spectral power (1 Hz bandwidth).
- $(e_{nOA})^2$  is the op amp equivalent input noise voltage spectral power (1 Hz bandwidth).

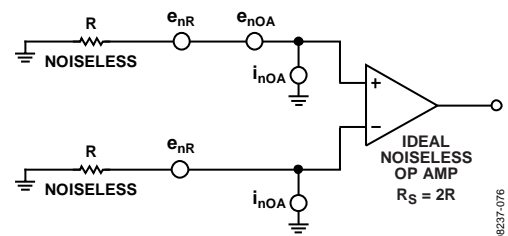


Figure 76. Op Amp Noise Circuit Model Used to Determine Total Circuit Equivalent Input Noise Voltage and Noise Figure

As a design aid, Figure 77 shows the total equivalent input noise of the ADA4084-2 and the total thermal noise of a resistor for comparison. Note that for source resistance less than 1 kΩ, the equivalent input noise voltage of the ADA4084-2 is dominant.

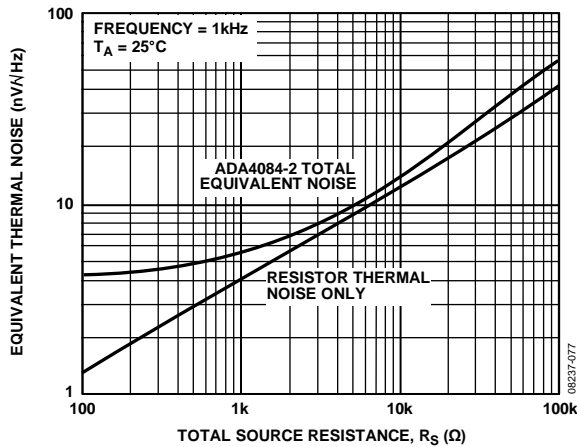


Figure 77. ADA4084-2 Equivalent Thermal Noise vs. Total Source Resistance

Because circuit SNR is the critical parameter in the final analysis, the noise behavior of a circuit is sometimes expressed in terms of its noise figure, NF. The noise figure is defined as the ratio of a circuit's output signal-to-noise to its input signal-to-noise.

Noise figure is generally used for RF and microwave circuit analysis in a 50 Ω system. This is not very useful for op amp circuits where the input and output impedances can vary greatly. For a more complete description of noise figure, see the MT-052 Tutorial, *Op Amp Noise Figure: Don't be Mislead*, available at [www.analog.com](http://www.analog.com).

Signal levels in the application invariably increase to maximize circuit SNR, which is not an option in low voltage, single-supply applications.

Therefore, to achieve optimum circuit SNR in single-supply applications, it is recommended that an operational amplifier with the lowest equivalent input noise voltage be chosen, along

with source resistance levels that are consistent with maintaining low total circuit noise.

**COMPARATOR OPERATION**

Although op amps are quite different from comparators, occasionally an unused section of a dual or a quad op amp can be used as a comparator; however, this is not recommended for any rail-to-rail output op amps. For rail-to-rail output op amps, the output stage is generally a ratioed current mirror with bipolar or MOSFET transistors. With the part operating open loop, the second stage increases the current drive to the ratioed mirror to close the loop. However, it cannot, which results in an increase in supply current. With the op amp configured as a comparator, the supply current can be significantly higher (see Figure 76). An unused section should be configured as a voltage follower with the noninverting input connected to a voltage within the input voltage range. The ADA4084-2 has unique second stage and output stage designs that greatly reduce the excess supply current when the op amp is operating open loop.

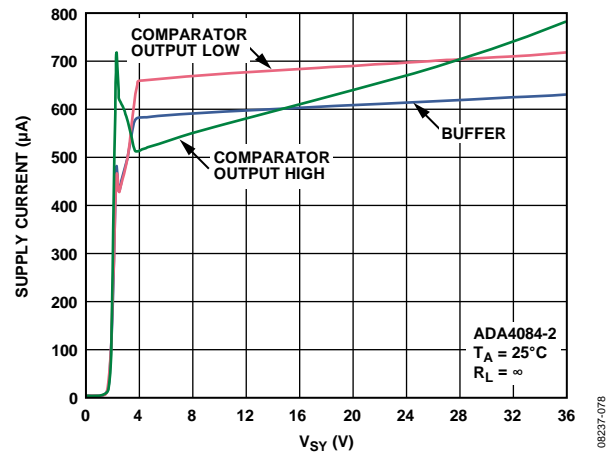
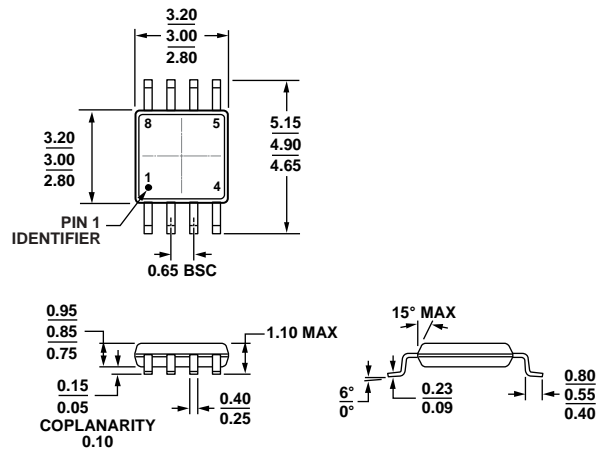


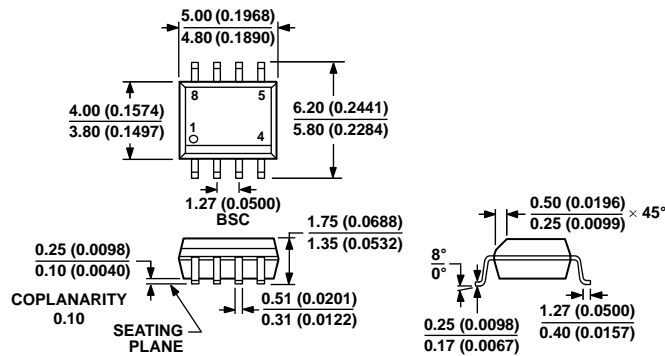
Figure 78. Supply Current vs. Supply Voltage

# OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-187-AA  
 Figure 79. 8-Lead Mini Small Outline Package [MSOP]  
 (RM-8)  
 Dimensions shown in millimeters

10-07-2009-B



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 80. 8-Lead Standard Small Outline Package [SOIC\_N]  
 Narrow Body  
 (R-8)  
 Dimensions shown in millimeters and (inches)

012407-A

## ORDERING GUIDE

Model <sup>1</sup>	Temperature Range	Package Description	Package Option	Branding
ADA4084-2ARMZ	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2Q
ADA4084-2ARMZ-R7	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2Q
ADA4084-2ARMZ-RL	-40°C to +125°C	8-Lead Mini Small Outline Package [MSOP]	RM-8	A2Q
ADA4084-2ARZ	-40°C to +125°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8	
ADA4084-2ARZ-R7	-40°C to +125°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8	
ADA4084-2ARZ-RL	-40°C to +125°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8	

<sup>1</sup> Z = RoHS Compliant Part.

**NOTES**