

FEATURES

Rail-to-rail input/output

Low power: 0.625 mA typical per amplifier at ± 15 V

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 ± 15 V

Low offset voltage: 100 μ V maximum (SOIC)

Unity-gain stable

High slew rate: 4.6 V/ μ s typical

Low noise: 3.9 nV/ $\sqrt{\text{Hz}}$ typical at 1 kHz

APPLICATIONS

Battery-powered instrumentation

High-side and low-side sensing

Power supply control and protection

Telecommunications

DAC output amplifiers

ADC input buffers

GENERAL DESCRIPTION

The ADA4084-2 (dual) and ADA4084-4 (quad) are single-supply, 10 MHz bandwidth amplifiers featuring rail-to-rail inputs and outputs. They are guaranteed to operate from 3 V to 30 V (or ± 1.5 V to ± 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 and ADA4084-4 useful in a wide variety of applications, including filters and instrumentation.

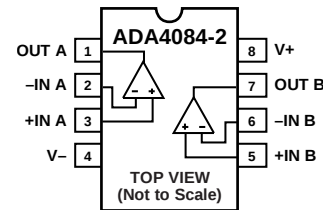
Other applications for these amplifiers include portable telecommunications equipment, power supply control and protection, and use as amplifiers or buffers for transducers with wide output ranges. Sensors requiring a rail-to-rail input amplifier include Hall effect, piezoelectric, and resistive transducers.

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 and ADA4084-4 are specified over the industrial temperature range of -40°C to $+125^\circ\text{C}$. The dual ADA4084-2 is available in the 8-lead SOIC, MSOP, and LFCSP surface-mount packages, and the ADA4084-4 is offered in the 14-lead TSSOP and 16-lead LFCSP.

The ADA4084-2 and ADA4084-4 are members of a growing series of high voltage, low noise op amps offered by Analog Devices, Inc., (see Table 1).

PIN CONFIGURATIONS



NOTES
1. FOR THE LFCSP PACKAGE THE EXPOSED PAD MUST BE CONNECTED TO V-.

08237-001

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

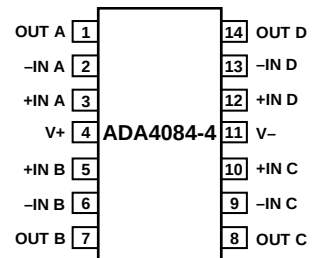
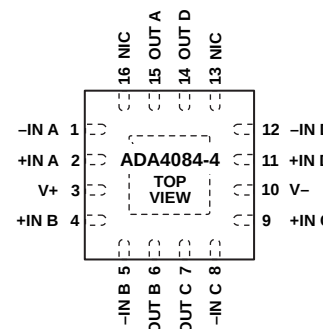


Figure 2. 14-Lead TSSOP (RU)



NOTES
1. NIC = NOT INTERNALLY CONNECTED.
2. FOR THE LFCSP PACKAGE THE EXPOSED PAD MUST BE CONNECTED TO V-.

08237-103

Figure 3. 16-Lead LFCSP (CP)

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.

Table 1. Low Noise Op Amps

Voltage Noise	Single	Dual	Quad
1.1 nV/Hz	AD8597	AD8599	
1.8 nV/Hz	ADA4004-1	ADA4004-2	ADA4004-4
2.8 nV/Hz Rail-to-Rail Output	AD8675	AD8676	
2.8 nV/Hz	AD8671	AD8672	AD8674
3.2 nV/Hz	OP27/OP37		
3.9 nV/Hz Rail-to-Rail Input/Output		ADA4084-2	ADA4084-4

Rev. D

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IMPORTANT LINKS for the [ADA4084-2 4084-4](#)*

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SIMILAR PRODUCTS & PARAMETRIC SELECTION TABLES

[ADA4077-2:](#)

available as a dual channel version in two grades offering lower offset and drift with higher linearity within the Input Voltage Range for dual supply applications.

[ADA4500-2:](#)

offers similar speed and precision in a high linearity, zero-crossover, 5V Op Amp.

[ADA4096-2](#)

a lower power, 30V, rail-to-rail input/output Op Amp.

[Find Similar Products By Operating Parameters](#)

[SAR ADC & Driver Quick-Match Guide](#)

DOCUMENTATION

[AN-940:](#) Low Noise Amplifier Selection Guide for Optimal Noise Performance

[AN-849:](#) Using Op Amps as Comparators

[Op Amp Applications Handbook](#)

[MT-054:](#) Precision Op Amps

[MT-052:](#) Op Amp Noise Figure: Don't Be Mislead

[MT-048:](#) Op Amp Noise Relationships: 1/f Noise, RMS Noise, and Equivalent Noise Bandwidth

[MT-047:](#) Op Amp Noise

[MT-035:](#) Op Amp Inputs, Outputs, Single-Supply, and Rail-to-Rail Issues

DESIGN TOOLS, MODELS, DRIVERS & SOFTWARE

[OpAmp Error Budget Calculator](#)

[ADIsimOpAmp™](#)

[Analog Bridge Wizard](#)

[ADA4084 SPICE Macro Model](#)

EVALUATION KITS & SYMBOLS & FOOTPRINTS

[View the Evaluation Boards and Kits page for the ADA4084-2](#)

[View the Evaluation Boards and Kits page for the ADA4084-4](#)

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REVISION HISTORY

11/13—Rev. C to Rev. D

Added 14-Lead TSSOP and 16-Lead LFCSP Packages	Universal
Added ADA4804-4	Universal
Change to Features Section and Applications Section	1
Added Figure 2 and Figure 3; Renumbered Sequentially	1
Changes to Table 2	3
Changes to Table 3	4
Changes to Table 4	5
Changes to Table 5 and Table 6	6
Changes to Typical Performance Characteristics Section	7
Added Figure 101	27
Added Figure 102; Changes to Ordering Guide	28

4/13—Rev. B to Rev. C

Changes to Figure 48 Caption	15
Updated Outline Dimensions	25

6/12—Rev. A to Rev. B

Added LFCSP Package	Universal
Changes to Figure 1	1
Changes to Output Voltage High Parameter, Table 4	5
Added Figure 5 and Figure 7, Renumbered Sequentially	7
Added Figure 30 and Figure 32	12

Added Figure 55 and Figure 57	17
Added Startup Characteristics Section	23
Moved Figure 78	23
Changes to Output Phase Reversal Section and Comparator Operation Section	24
Updated Outline Dimensions	25
Changes to Ordering Guide	26

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
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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
INPUT CHARACTERISTICS						
Offset Voltage	V _{OS}	SOIC package		20	100	μV
		−40°C ≤ T _A ≤ +125°C			200	μV
		MSOP, TSSOP packages		50	130	μV
		−40°C ≤ T _A ≤ +125°C			250	μV
		ADA4084-2 LFCSP package		80	200	μV
Offset Voltage Drift	ΔV _{OS} /ΔT	−40°C ≤ T _A ≤ +125°C		0.5	1.75	μV/°C
Offset Voltage Matching		T _A = 25°C			150	μV
		ADA4084-4 LFCSP package			200	μV
Input Bias Current	I _B			140	250	nA
Input Offset Current	I _{OS}	−40°C ≤ T _A ≤ +125°C			400	nA
				5	25	nA
		−40°C ≤ T _A ≤ +125°C			50	nA
Input Voltage Range	CMRR		0		3	V
Common-Mode Rejection Ratio		V _{CM} = 0 V to 3 V	64	88		dB
		−40°C ≤ T _A ≤ +125°C	60			dB
Large Signal Voltage Gain	A _{VO}	R _L = 2 kΩ, 0.5 V ≤ V _O ≤ 2.5 V	100	104		dB
		R _L = 2 kΩ, −40°C ≤ T _A ≤ +125°C	97			dB
Input Impedance, Differential				100 1.1		kΩ pF
Input Impedance, Common Mode				80 2.9		MΩ pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V _{OH}	R _L = 10 kΩ to V _{CM}	2.9	2.95		V
		−40°C ≤ T _A ≤ +125°C	2.8			V
		R _L = 2 kΩ to V _{CM}	2.85	2.9		V
		−40°C ≤ T _A ≤ +125°C	2.7			V
Output Voltage Low	V _{OL}	R _L = 10 kΩ to V _{CM}		10	20	mV
		−40°C ≤ T _A ≤ +125°C			40	mV
		R _L = 2 kΩ to V _{CM}		20	30	mV
		−40°C ≤ T _A ≤ +125°C			50	mV
Short-Circuit Current	I _{SC}			−17/+10		mA
Closed-Loop Output Impedance	Z _{OUT}	f = 1 kHz, A = +1		0.1		Ω
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	V _{SY} = ±1.25 V to ±1.75 V	100	110		dB
		−40°C ≤ T _A ≤ +125°C	90			dB
Supply Current/Amplifier	I _{SY}	I _O = 0 mA		0.565	0.650	mA
		−40°C ≤ T _A ≤ +125°C			0.950	mA
DYNAMIC PERFORMANCE						
Slew Rate	SR	R _L = 2 kΩ	2.0	2.6		V/μs
Gain Bandwidth Product	GBP	V _{IN} = 5 mV p-p, R _L = 10 kΩ, A _v = 100		15.4		MHz
Unity-Gain Crossover	UGC	V _{IN} = 5 mV p-p, R _L = 10 kΩ, A _v = 1		8.08		MHz
Phase Margin	Φ _M			86		Degrees
−3 dB Closed-Loop Bandwidth	−3 dB	A _v = 1, V _{IN} = 5 mV p-p		12.3		MHz
Settling Time	t _s	A _v = 10, V _{IN} = 2V p-p; 0.1%		4		μs
Total Harmonic Distortion Plus Noise	THD + N	V _{IN} = 300 mV rms, R _L = 2 kΩ, f = 1 kHz		0.009		%
NOISE PERFORMANCE						
Voltage Noise	e _n p-p	0.1 Hz to 10 Hz		0.14		μV p-p
Voltage Noise Density	e _n	f = 1 kHz		3.9		nV/√Hz
Current Noise Density	i _n	f = 1 kHz		0.55		pA/√Hz

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

Table 3.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}	SOIC package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		30	100	μV
		MSOP, TSSOP packages $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		60	250	μV
		ADA4084-2 LFCSP package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		90	130	μV
					250	μV
					200	μV
					300	μV
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		$T_A = 25^\circ\text{C}$			150	μV
		ADA4084-4 LFCSP package			200	μV
Input Bias Current	I_B			140	250	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			400	nA
Input Offset Current	I_{OS}			5	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	$V_{CM} = \pm 4 \text{ V}$, $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	106	124		dB
		$V_{CM} = \pm 5 \text{ V}$	76			dB
		$V_{CM} = \pm 5 \text{ V}$, $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	70			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		k Ω pF
Input Impedance, Common Mode				200 2.5		M Ω pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	$R_L = 10 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.9	4.95		V
			4.8			V
		$R_L = 2 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	4.8	4.85		V
			4.7			V
Output Voltage Low	V_{OL}	$R_L = 10 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		-4.95	-4.9	V
					-4.8	V
		$R_L = 2 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		-4.95	-4.8	V
					-4.7	V
Short-Circuit Current	I_{SC}			-24/+17		mA
Closed-Loop Output Impedance	Z_{OUT}	$f = 1 \text{ kHz}$, $A = +1$		0.1		Ω
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	$V_{SY} = \pm 2 \text{ V}$ to $\pm 18 \text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	110	120		dB
			105			dB
Supply Current/Amplifier	I_{SY}	$I_O = 0 \text{ mA}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.595	0.700	mA
					1.00	mA
DYNAMIC PERFORMANCE						
Slew Rate	SR	$R_L = 2 \text{ k}\Omega$ to V_{CM}	2.4	3.7		V/ μs
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	Φ_M			85		Degrees
-3 dB Closed-Loop Bandwidth	-3 dB	$A_V = 1$, $V_{IN} = 5 \text{ mV p-p}$		13.9		MHz
Settling Time	t_S	$A_V = 10$, $V_{IN} = 8 \text{ V p-p}$; 0.1%		4		μs
Total Harmonic Distortion Plus Noise	THD + N	$V_{IN} = 2 \text{ V rms}$, $R_L = 2 \text{ k}\Omega$, $f = 1 \text{ kHz}$		0.003		%
NOISE PERFORMANCE						
Voltage Noise	$e_n \text{ p-p}$	0.1 Hz to 10 Hz		0.14		$\mu\text{V p-p}$
Voltage Noise Density	e_n	$f = 1 \text{ kHz}$		3.9		nV/ $\sqrt{\text{Hz}}$
Current Noise Density	i_n			0.55		pA/ $\sqrt{\text{Hz}}$

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

Table 4.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}	SOIC package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ MSOP, TSSOP packages $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ ADA4084-2 LFCSP package $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		40	100	μV
					200	μV
				70	130	μV
					250	μV
				100	200	μV
					300	μV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$			0.5	1.75	$\mu\text{V}/^\circ\text{C}$
Offset Voltage Matching		$T_A = 25^\circ\text{C}$			150	μV
		ADA4084-4 LFCSP package			200	μV
Input Bias Current	I_B			140	250	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$			400	nA
Input Offset Current	I_{OS}			5	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	$V_{CM} = \pm 14 \text{ V}$, $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	106	124		dB
		$V_{CM} = \pm 15 \text{ V}$	85			dB
		$V_{CM} = \pm 15 \text{ V}$, $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	80			dB
Large Signal Voltage Gain	A_{VO}	$R_L = 2 \text{ k}\Omega$, $-13.5 \text{ V} \leq V_O \leq +13.5 \text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	110	117		dB
			105			dB
Input Impedance, Differential				100 1.1		$\text{k}\Omega \text{pF}$
Input Impedance, Common Mode				200 2.5		$\text{M}\Omega \text{pF}$
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	$R_L = 10 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	14.85	14.9		V
			14.8			V
		$R_L = 2 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	14.5	14.6		V
			14.0			V
Output Voltage Low	V_{OL}	$R_L = 10 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		-14.95	-14.9	V
					-14.8	V
		$R_L = 2 \text{ k}\Omega$ to V_{CM} $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		-14.9	-14.80	V
					-14.7	V
Short-Circuit Current	I_{SC}			± 30		mA
Closed-Loop Output Impedance	Z_{OUT}	$f = 1 \text{ kHz}$, $A = +1$		0.1		Ω
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	$V_{SY} = \pm 2 \text{ V}$ to $\pm 18 \text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	110	120		dB
			105			dB
Supply Current/Amplifier	I_{SY}	$I_O = 0 \text{ mA}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.625	0.750	mA
					1.050	mA
DYNAMIC PERFORMANCE						
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	Φ_M			86		Degrees
-3 dB Closed-Loop Bandwidth	-3 dB	$A_V = 1$, $V_{IN} = 5 \text{ mV p-p}$		13.9		MHz
Settling Time	t_s	$A_V = 10$, $V_{IN} = 10 \text{ V p-p}$; 0.1%		4		μs
Total Harmonic Distortion Plus Noise	THD + N	$V_{IN} = 5 \text{ V rms}$, $R_L = 2 \text{ k}\Omega$, $f = 1 \text{ kHz}$		0.003		%
NOISE PERFORMANCE						
Voltage Noise	$e_n \text{ p-p}$	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		$\text{pA}/\sqrt{\text{Hz}}$

ABSOLUTE MAXIMUM RATINGS

Table 5.

Parameter	Rating
Supply Voltage	$\pm 18\text{ V}$
Input Voltage	$V_- \leq V_{IN} \leq V_+$
Differential Input Voltage ¹	$\pm 0.6\text{ V}$
Output Short-Circuit Duration to GND	Indefinite
Storage Temperature Range	-65°C to $+150^\circ\text{C}$
Operating Temperature Range	-40°C to $+125^\circ\text{C}$
Junction Temperature Range	-65°C to $+150^\circ\text{C}$
Lead Temperature (Soldering 60 sec)	300°C
ESD	
Human Body Model ²	4.5 kV
Machine Model ³	1.25 kV
Field-Induced Charged-Device Model (FICDM) ⁴	200 V

¹ For input differential voltages greater than 0.6 V, limit the input current to less than 5 mA to prevent degradation or destruction of the input devices.

² Applicable standard: MIL-STD-883, Method 3015.7.

³ Applicable standard: JESD22-A115-A (ESD machine model standard of JEDEC).

⁴ Applicable standard: JESD22-C101-C (ESD FICDM standard of JEDEC).

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

θ_{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	θ_{JA}	θ_{JC}	Unit
8-Lead SOIC-N (R-8)	121	43	$^\circ\text{C/W}$
8-Lead MSOP (RM-8)	142	45	$^\circ\text{C/W}$
8-Lead LFCSP ^{1,3} (CP-8-12)	84	40	$^\circ\text{C/W}$
14-Lead TSSOP (RU-14)	112	43	$^\circ\text{C/W}$
16-Lead LFCSP (CP-16-26) ^{2,3}	55	30	$^\circ\text{C/W}$

¹ Values are based on 4-layer (2S2P) JEDEC standard PCB, with four thermal vias. Exposed pad soldered to PCB.

² Values are based on 4-layer (2S2P) JEDEC standard PCB, with nine thermal vias. Exposed pad soldered to PCB.

³ θ_{JC} measured on top of package.

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.

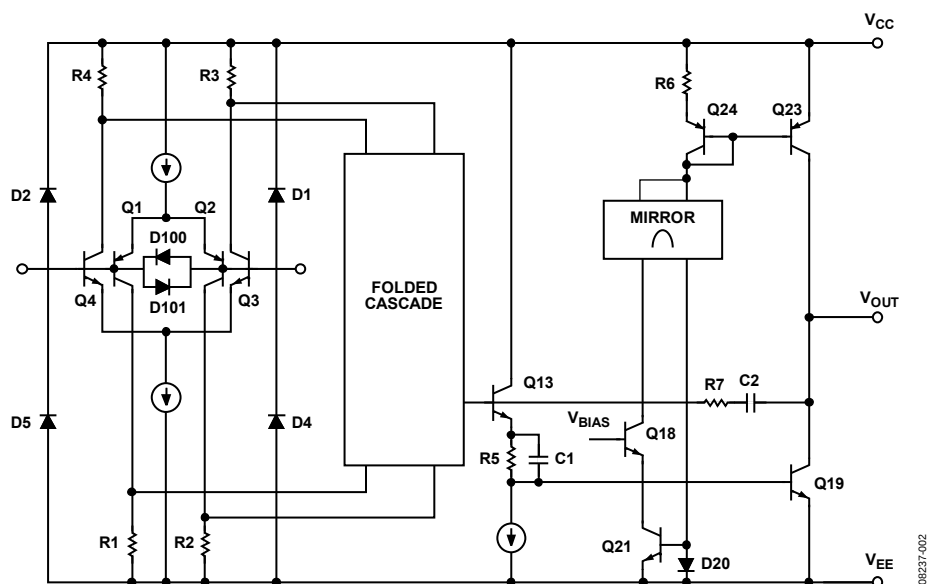


Figure 4. Simplified Schematic

TYPICAL PERFORMANCE CHARACTERISTICS

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

$\pm 1.5\text{ V}$ CHARACTERISTICS

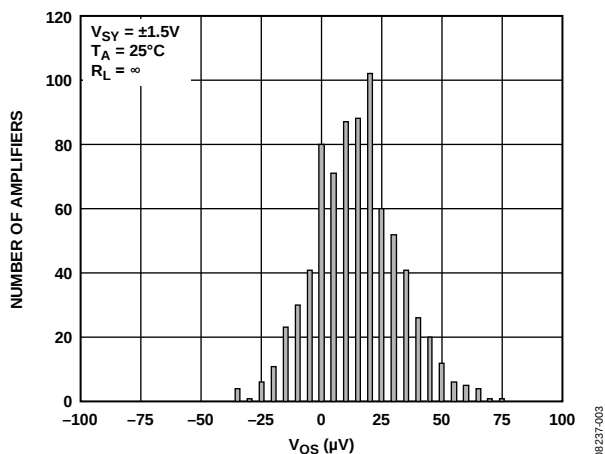


Figure 5. Input Offset Voltage Distribution, SOIC

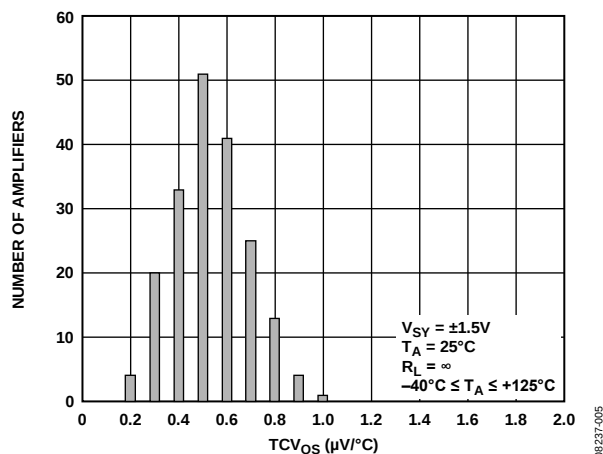


Figure 8. TCV_{OS} Distribution, SOIC, MSOP, and TSSOP

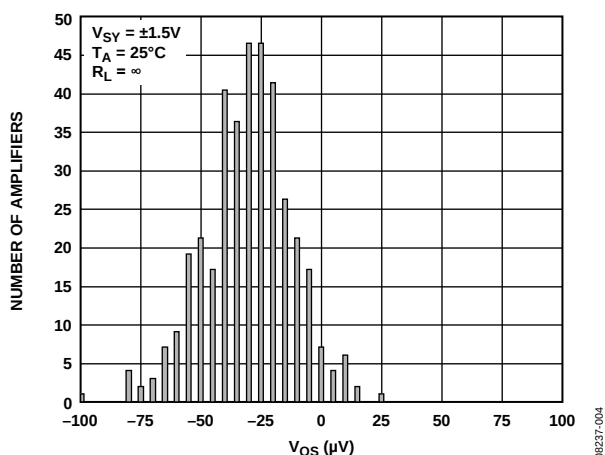


Figure 6. Input Offset Voltage Distribution, MSOP and TSSOP

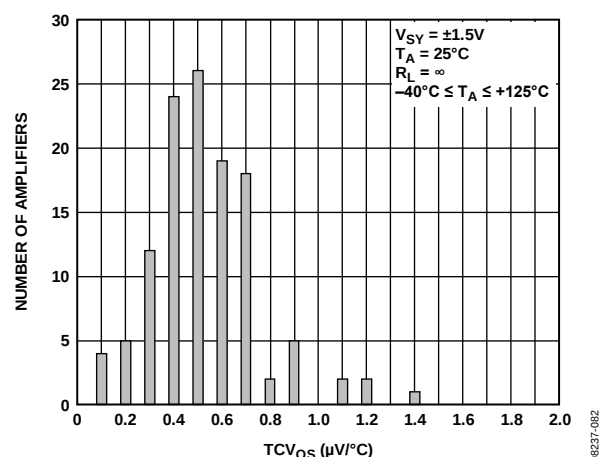


Figure 9. TCV_{OS} Distribution, LFCSP

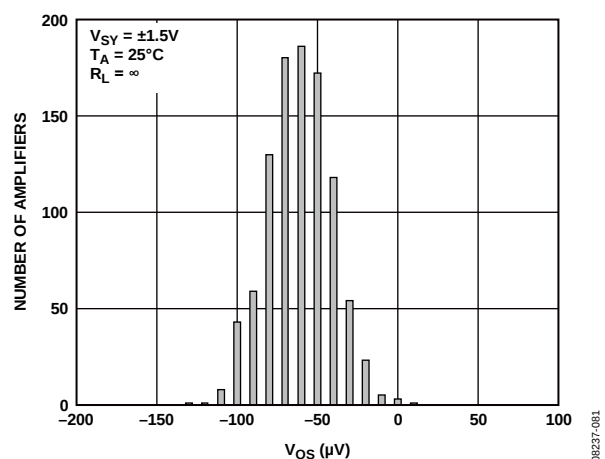


Figure 7. Input Offset Voltage Distribution, ADA4084-2 LFCSP

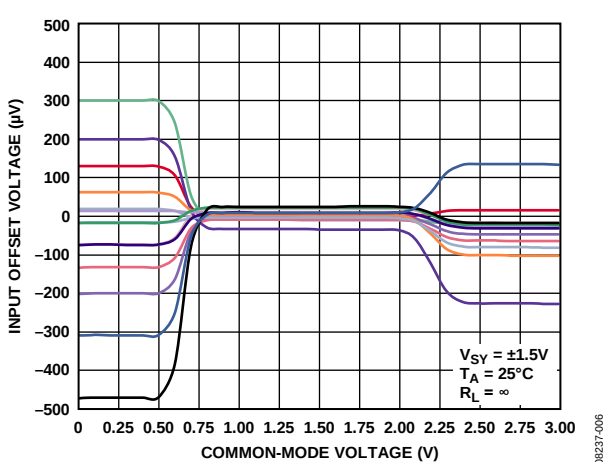


Figure 10. Input Offset Voltage vs. Common-Mode Voltage

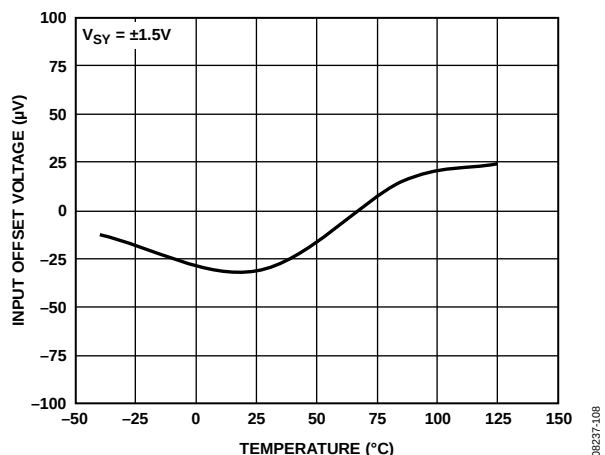


Figure 11. Input Offset Voltage vs. Temperature

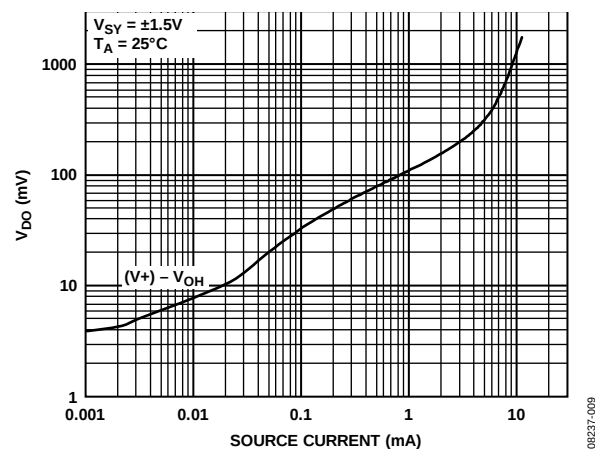


Figure 14. Dropout Voltage vs. Source Current

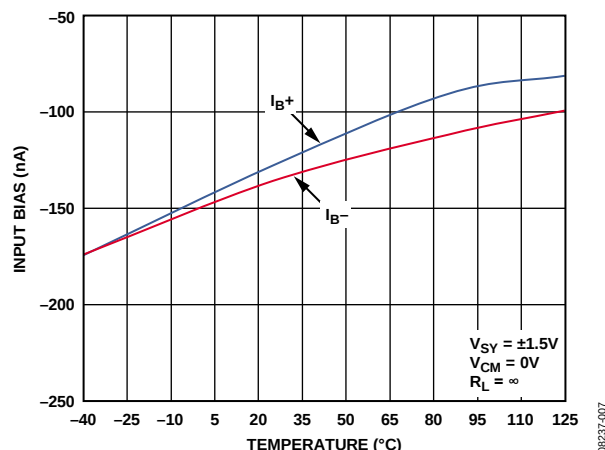


Figure 12. Input Bias Current vs. Temperature

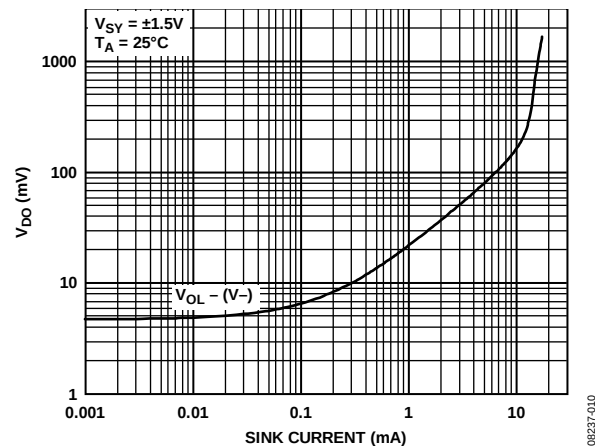


Figure 15. Dropout Voltage vs. Sink Current

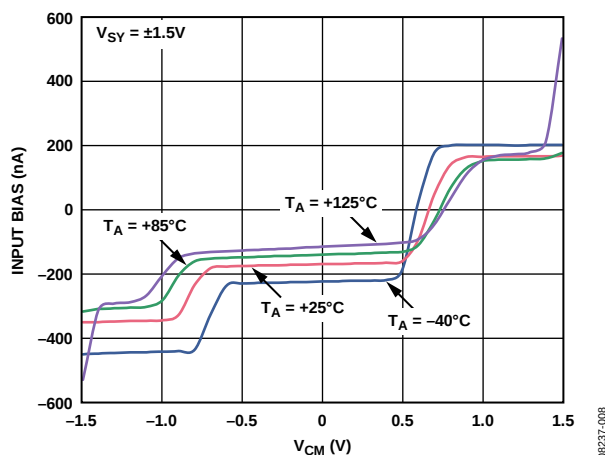


Figure 13. Input Bias Current vs. V_{CM} and Temperature

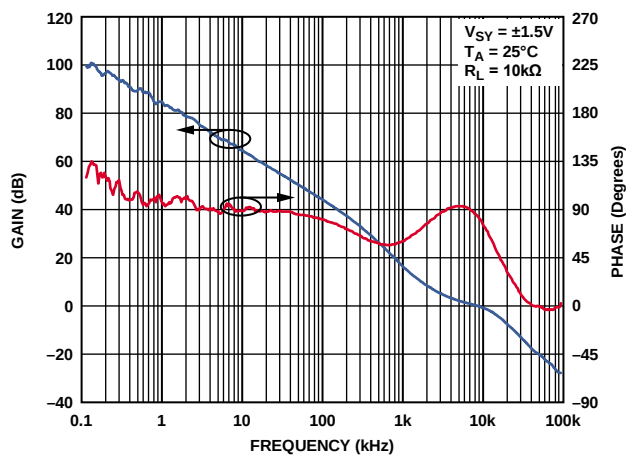


Figure 16. Open-Loop Gain and Phase vs. Frequency

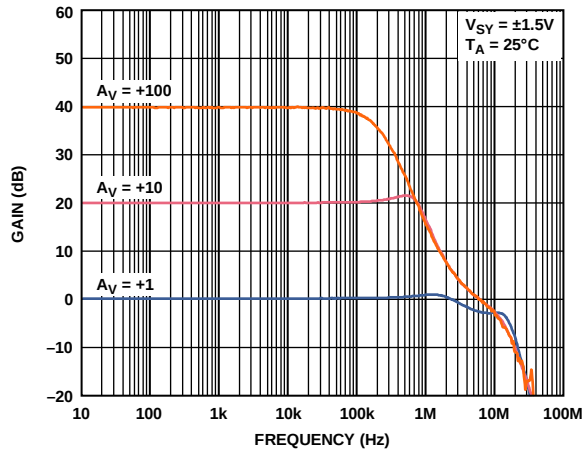


Figure 17. Closed-Loop Gain vs. Frequency

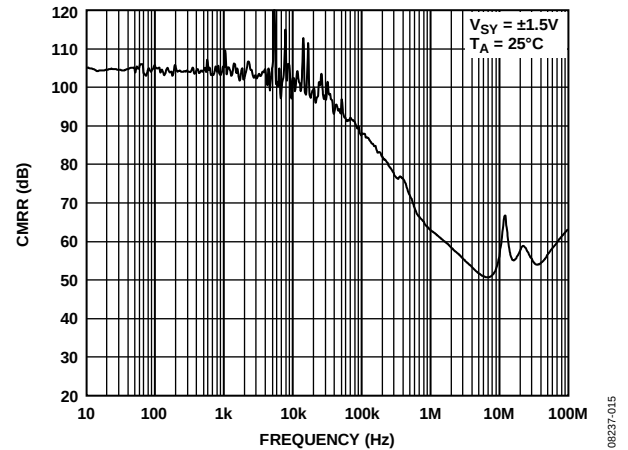


Figure 20. CMRR vs. Frequency

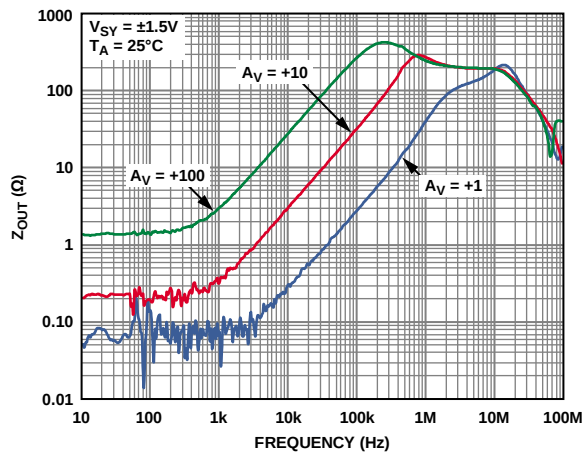


Figure 18. Output Impedance vs. Frequency

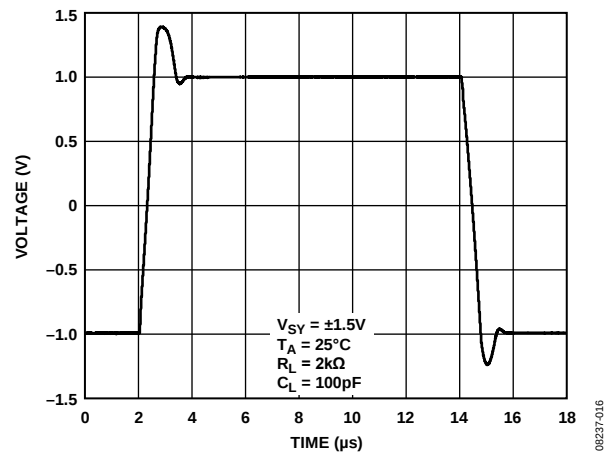


Figure 21. Large Signal Transient Response

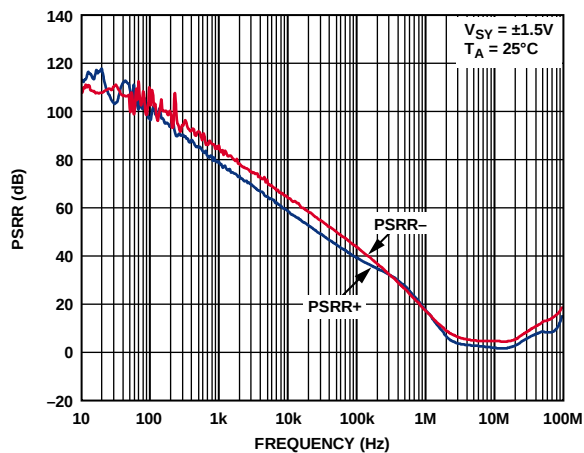


Figure 19. PSRR vs. Frequency

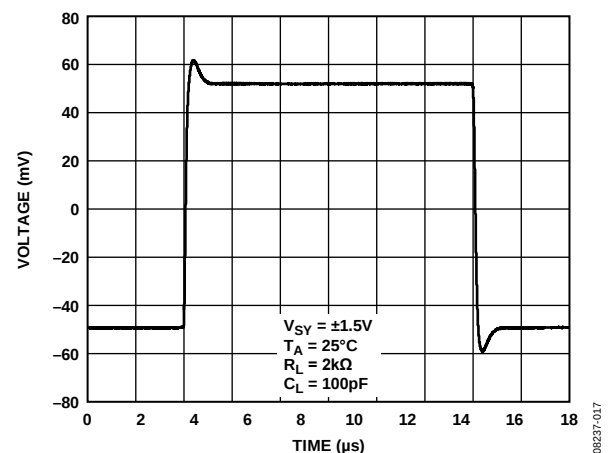


Figure 22. Small Signal Transient Response

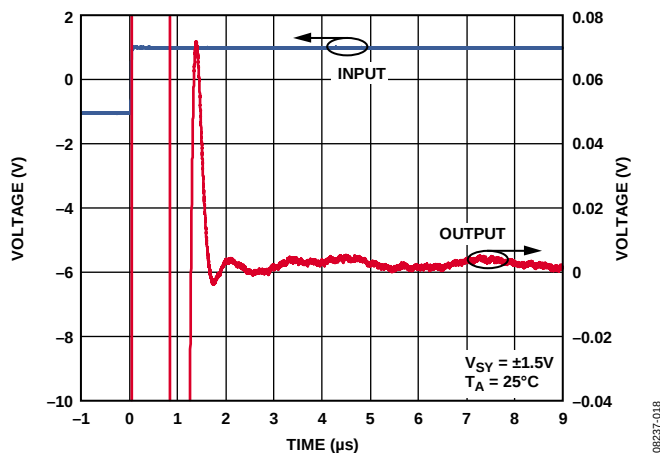


Figure 23. Settling Time

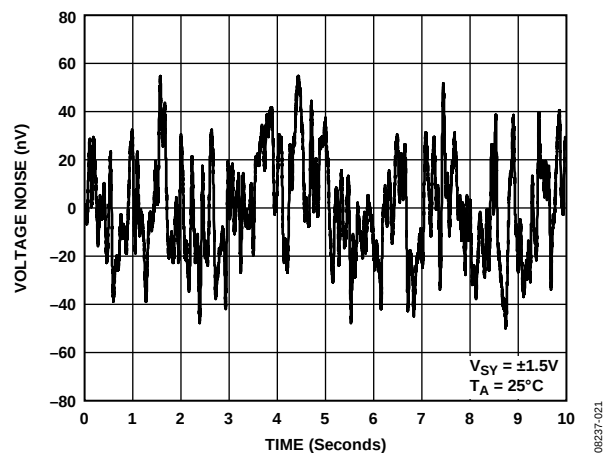


Figure 26. Voltage Noise, 0.1 Hz to 10 Hz

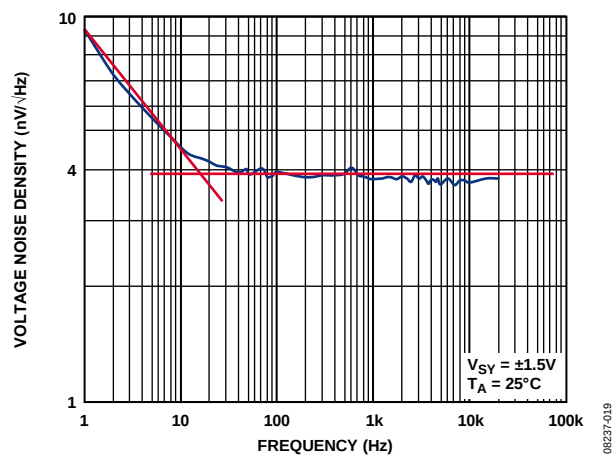


Figure 24. Voltage Noise Density

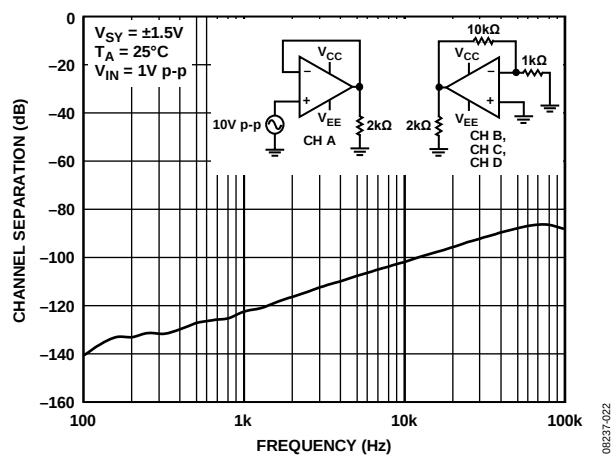


Figure 27. Channel Separation

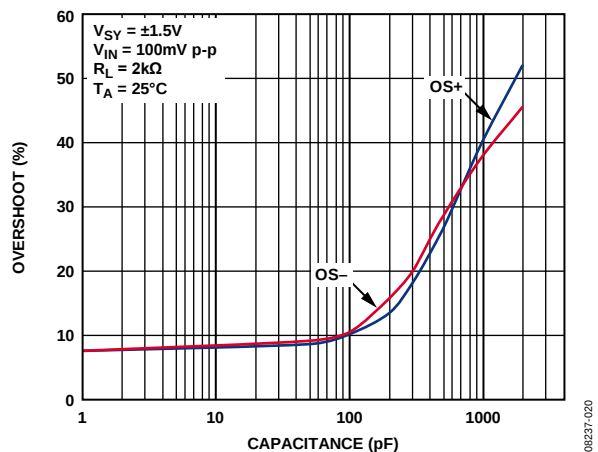


Figure 25. Overshoot vs. Load Capacitance

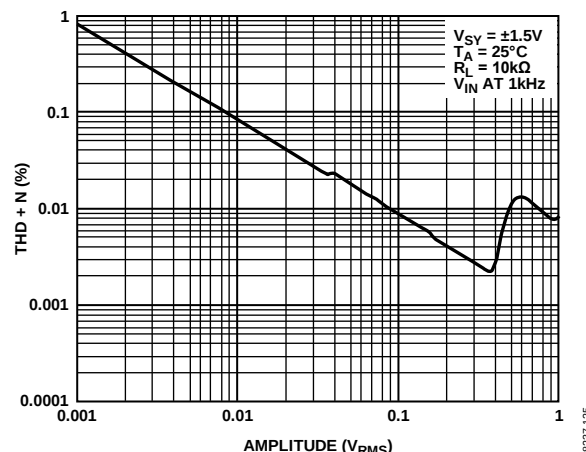


Figure 28. THD + N vs. Amplitude

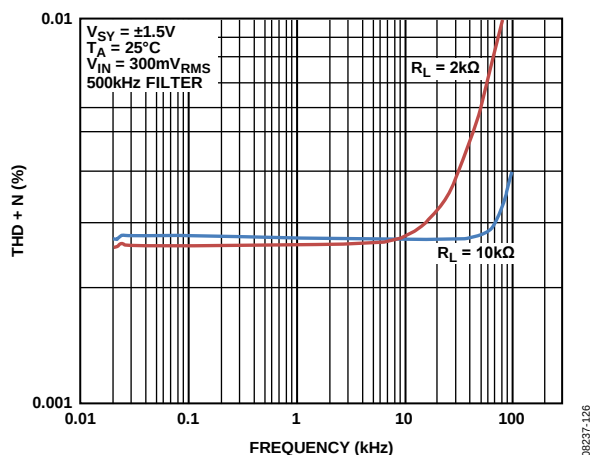


Figure 29. THD + N vs. Frequency

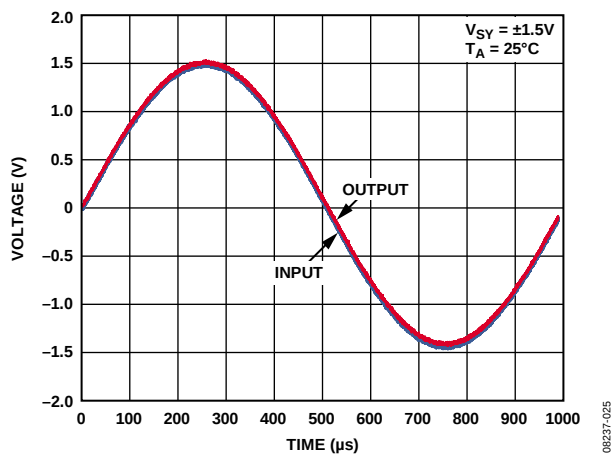


Figure 30. No Phase Reversal

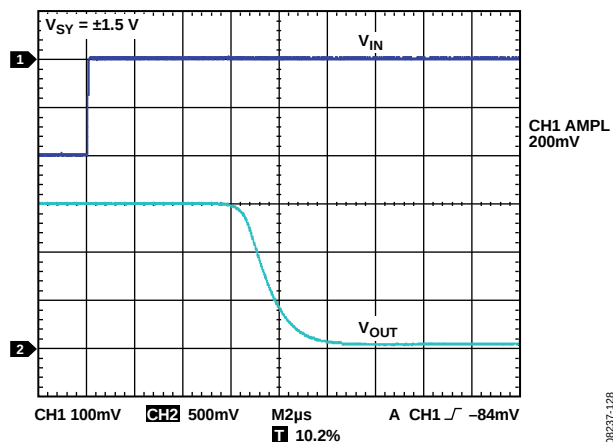


Figure 31. Positive Overload Recovery

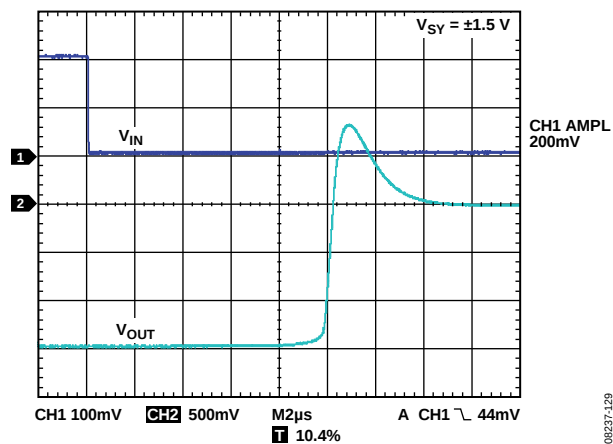


Figure 32. Negative Overload Recovery

±5 V CHARACTERISTICS

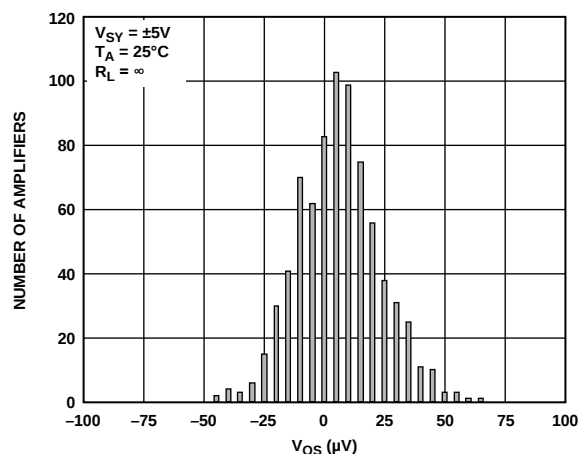


Figure 33. Input Offset Voltage Distribution, SOIC

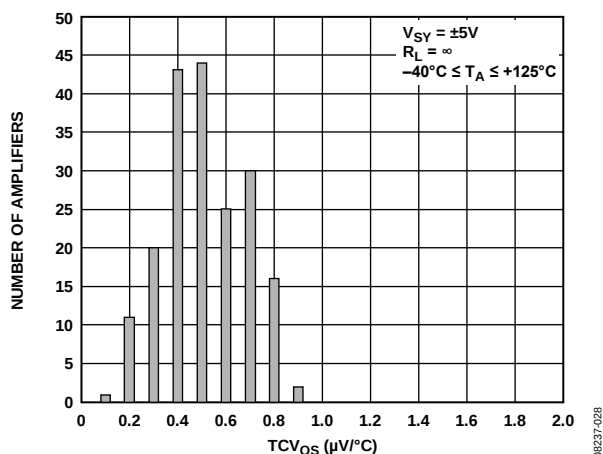


Figure 36. TCV_{OS} Distribution, SOIC and MSOP

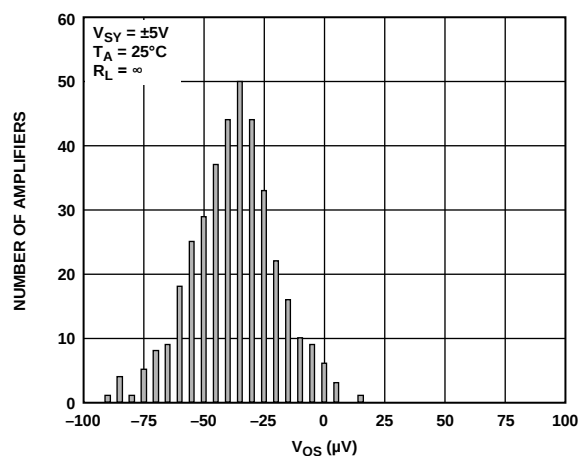


Figure 34. Input Offset Voltage Distribution, MSOP

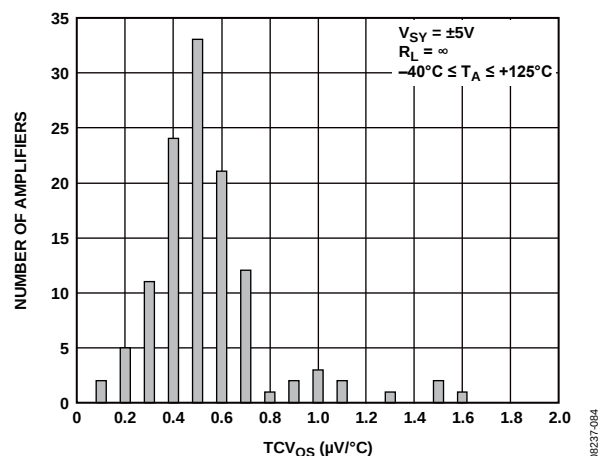


Figure 37. TCV_{OS} Distribution, ADA4084-2 LFCSP

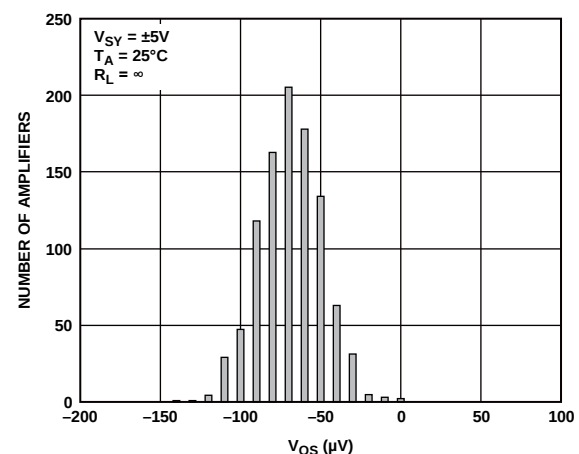


Figure 35. Input Offset Voltage Distribution, ADA4084-2 LFCSP

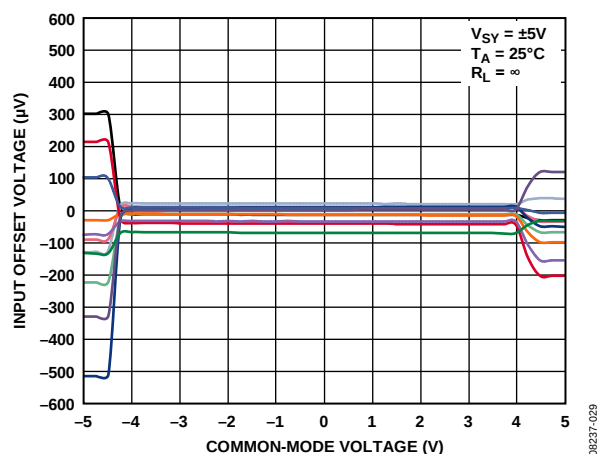


Figure 38. Input Offset Voltage vs. Common-Mode Voltage

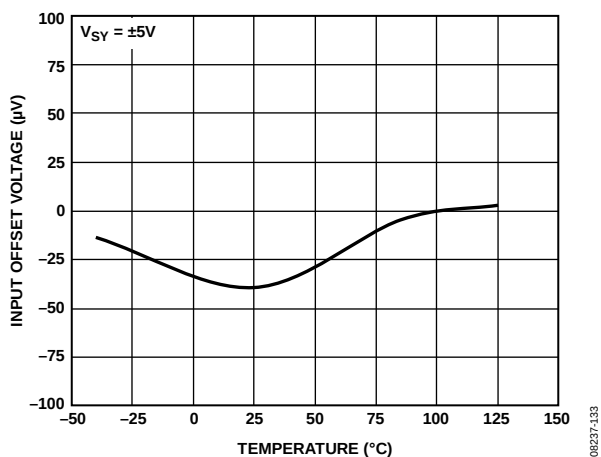


Figure 39. Input Offset Voltage vs. Temperature

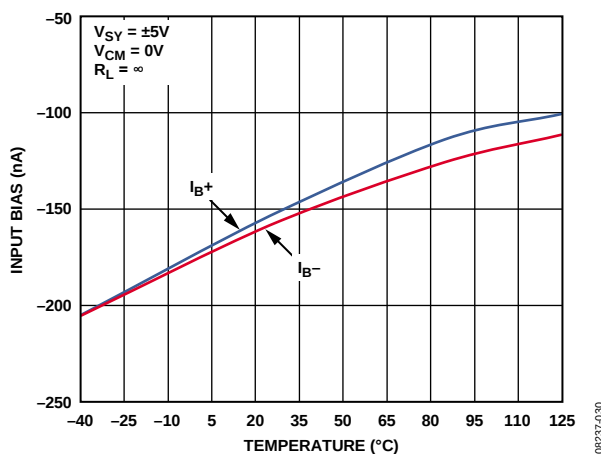


Figure 40. Input Bias Current vs. Temperature

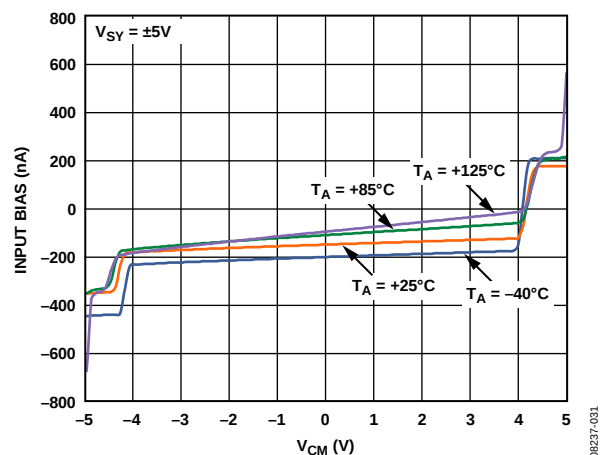
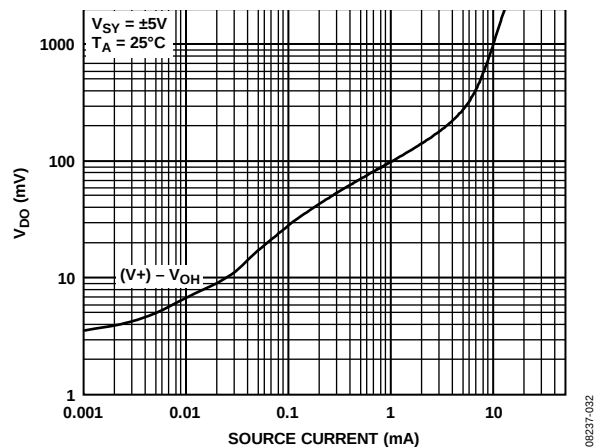
Figure 41. Input Bias Current vs. V_{CM} and Temperature

Figure 42. Dropout Voltage vs. Source Current

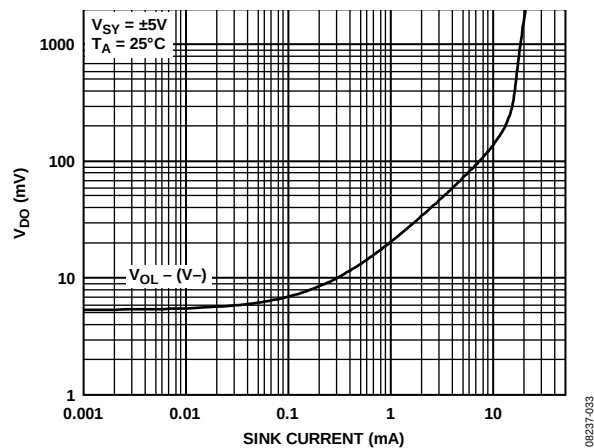


Figure 43. Dropout Voltage vs. Sink Current

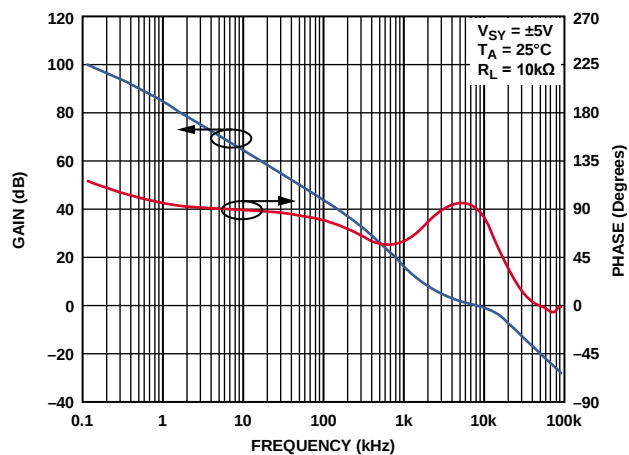


Figure 44. Open-Loop Gain and Phase vs. Frequency

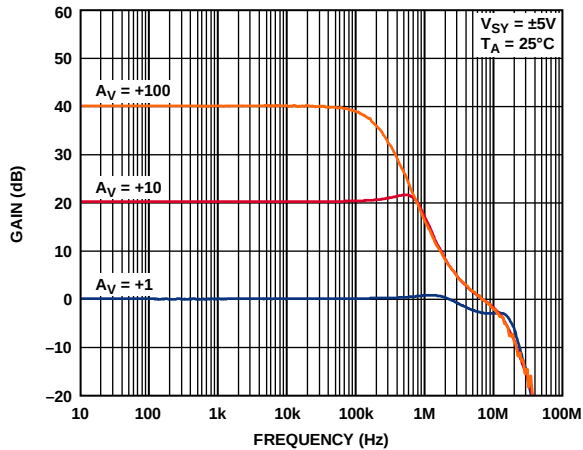


Figure 45. Closed-Loop Gain vs. Frequency

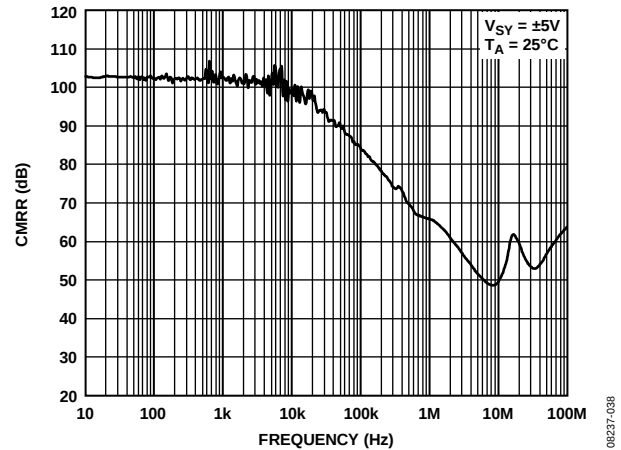


Figure 48. CMRR vs. Frequency

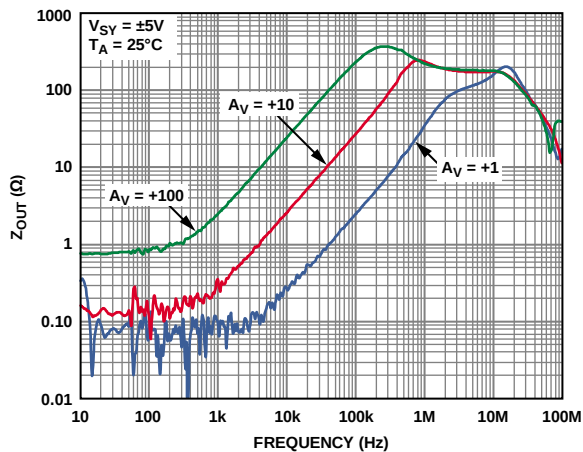


Figure 46. Output Impedance vs. Frequency

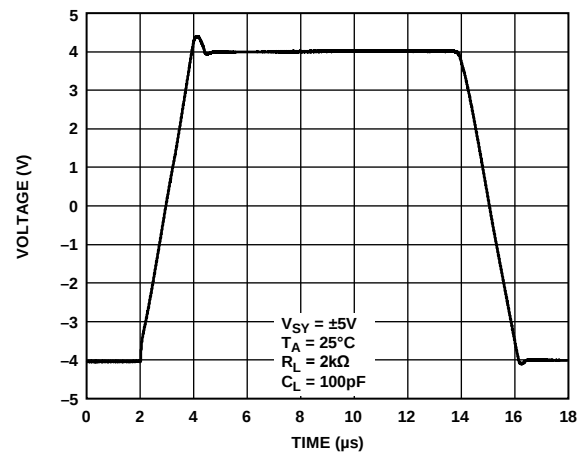


Figure 49. Large Signal Transient Response

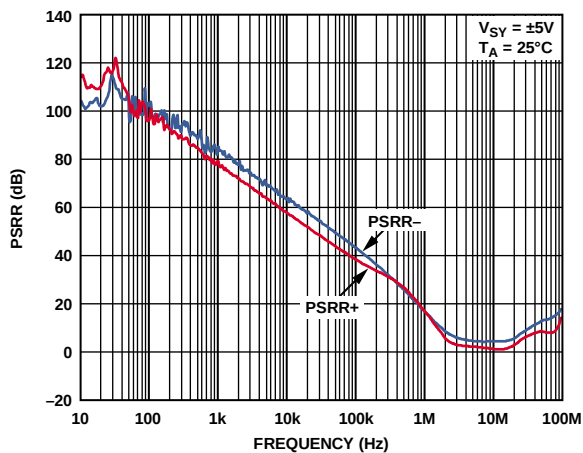


Figure 47. PSRR vs. Frequency

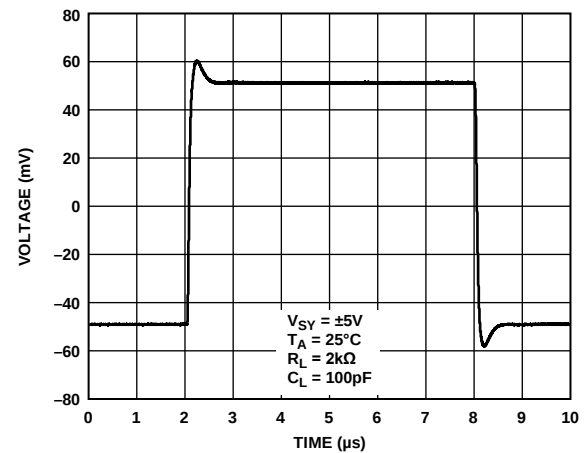


Figure 50. Small Signal Transient Response

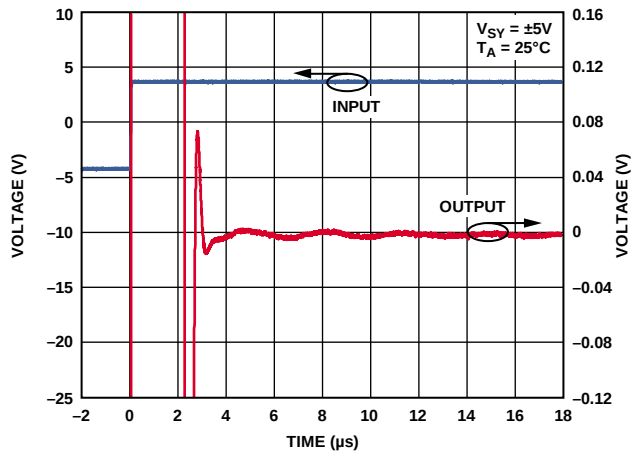


Figure 51. Settling Time

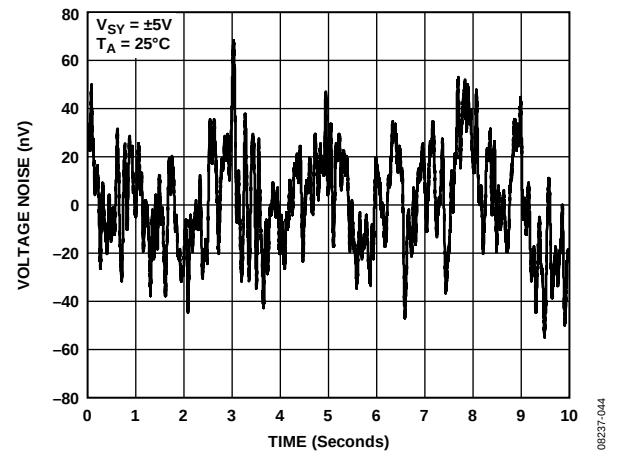


Figure 54. Voltage Noise, 0.1 Hz to 10 Hz

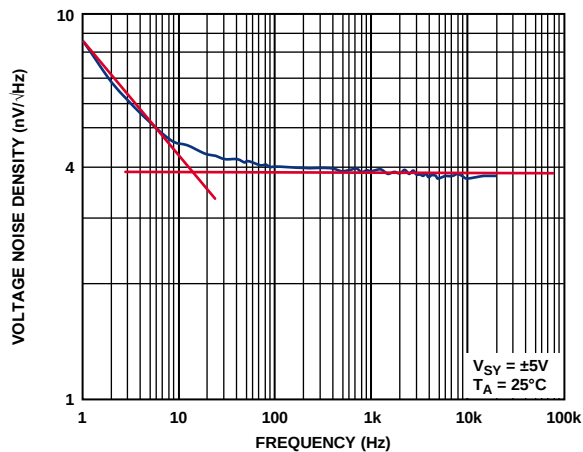


Figure 52. Voltage Noise Density

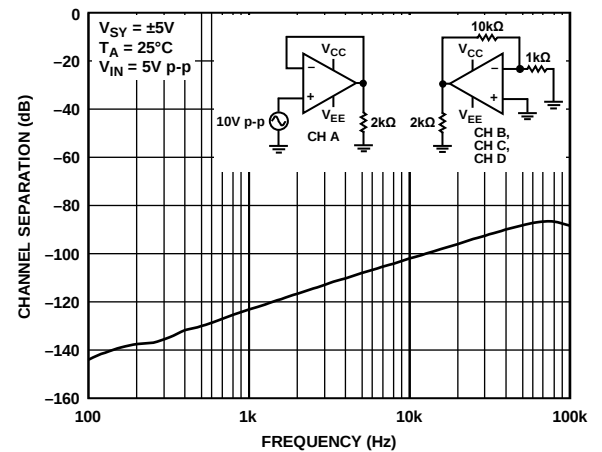


Figure 55. Channel Separation

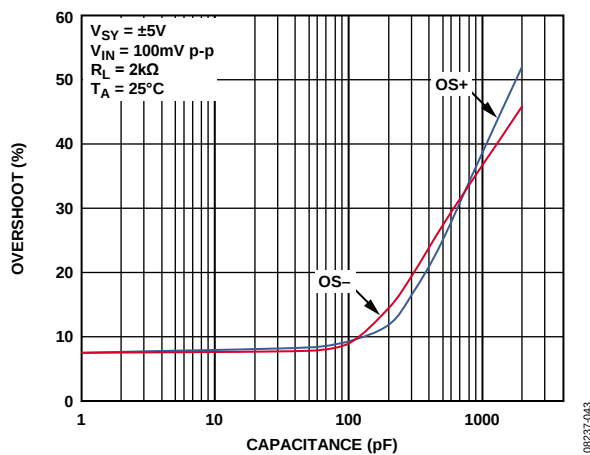


Figure 53. Overshoot vs. Load Capacitance

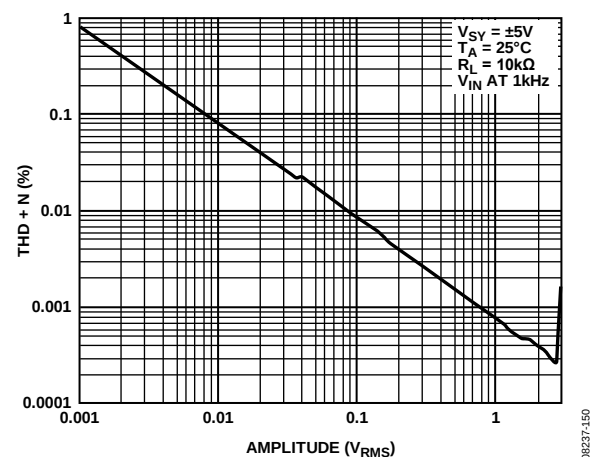


Figure 56. THD + N vs. Amplitude

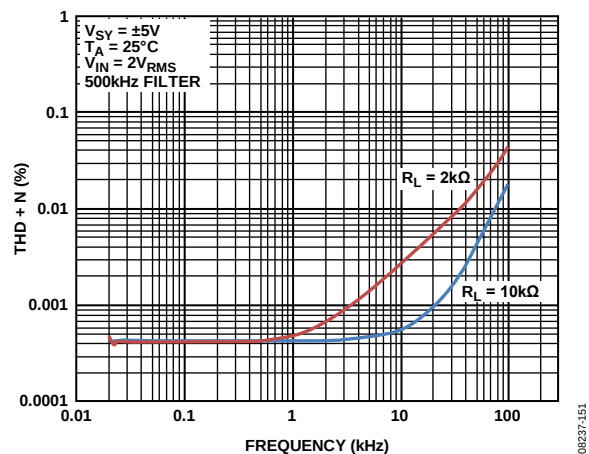


Figure 57. THD + N vs. Frequency

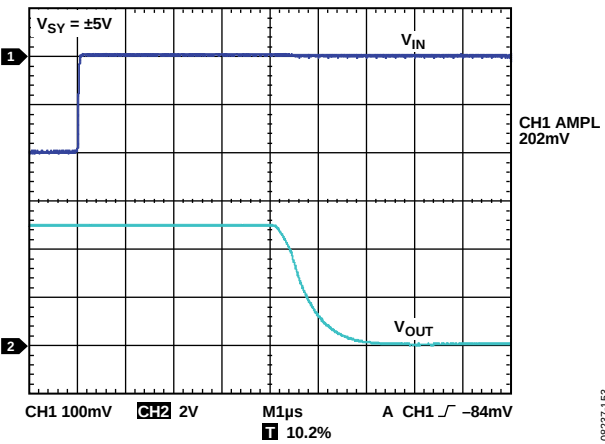


Figure 59. Positive Overload Recovery

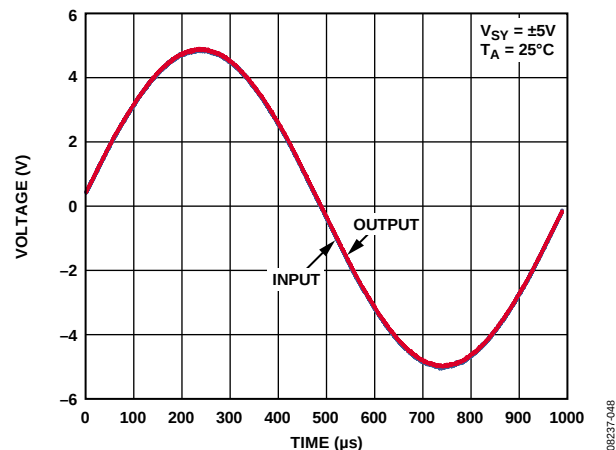


Figure 58. No Phase Reversal

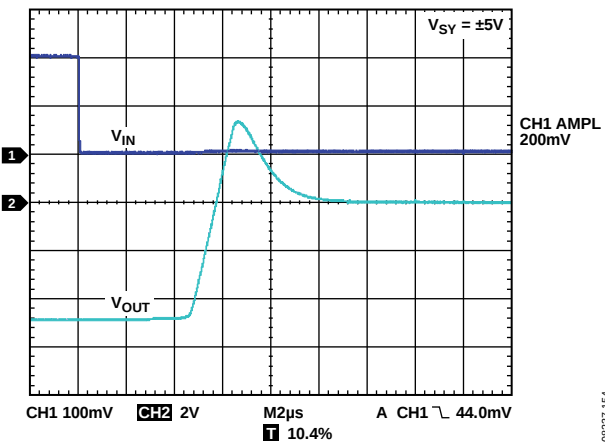


Figure 60. Negative Overload Recovery

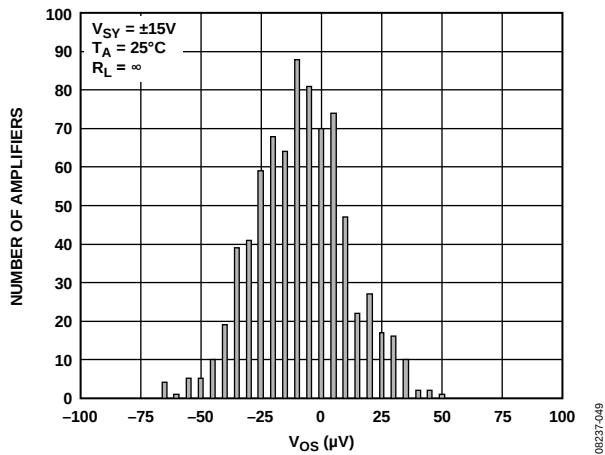
±15 V CHARACTERISTICS

Figure 61. Input Offset Voltage Distribution, SOIC

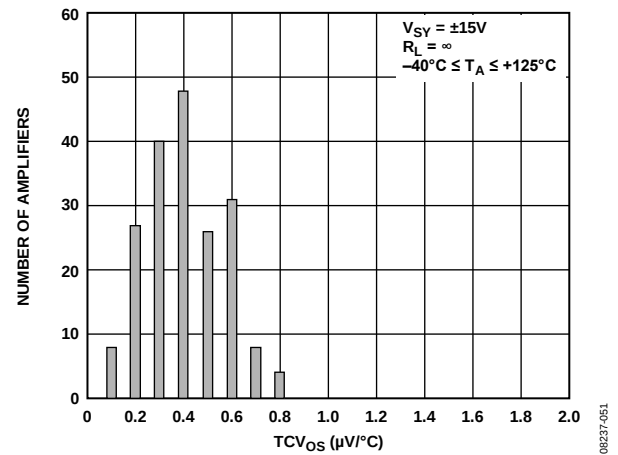
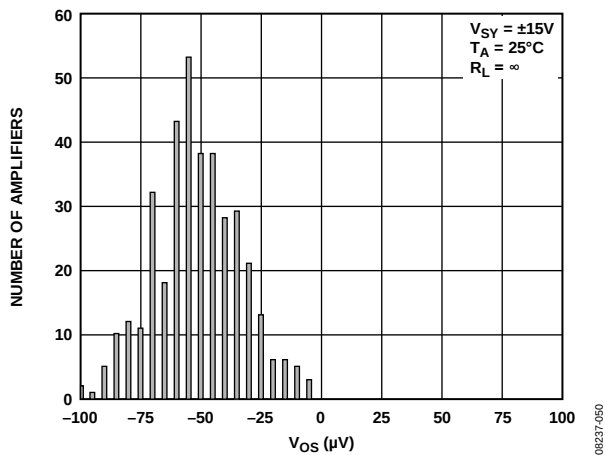
Figure 64. TCV_{OS} Distribution, SOIC and MSOP

Figure 62. Input Offset Voltage Distribution, MSOP

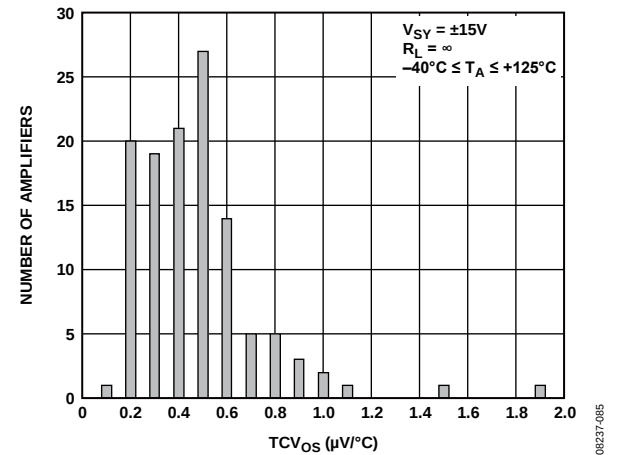
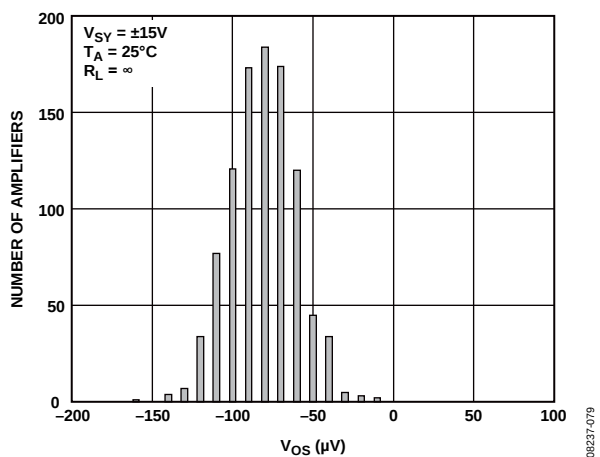
Figure 65. TCV_{OS} Distribution, ADA4084-2 LFCSP

Figure 63. Input Offset Voltage Distribution, ADA4084-2 LFCSP

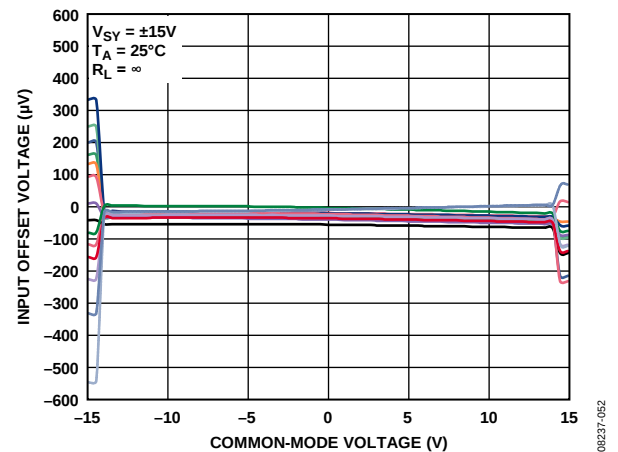


Figure 66. Input Offset Voltage vs. Common-Mode Voltage

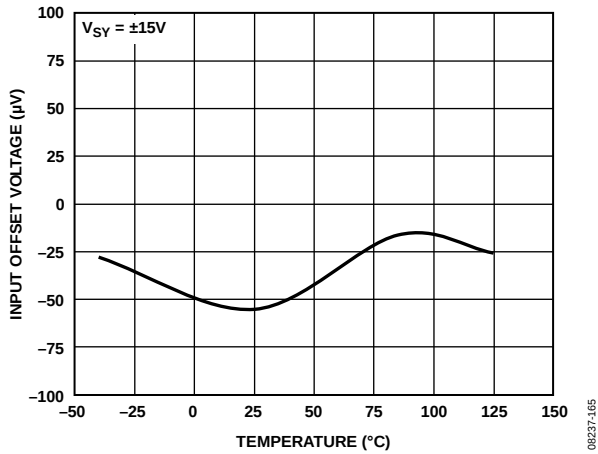


Figure 67. Input Offset Voltage vs. Temperature

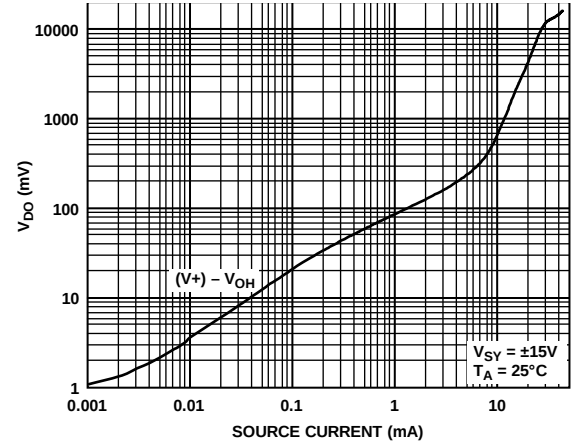


Figure 70. Dropout Voltage vs. Source Current

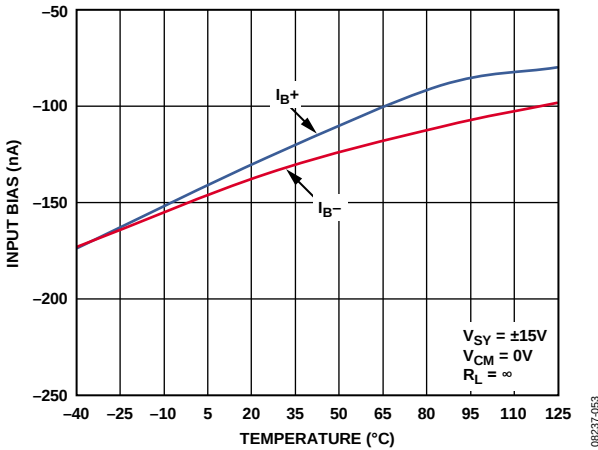


Figure 68. Input Bias Current vs. Temperature

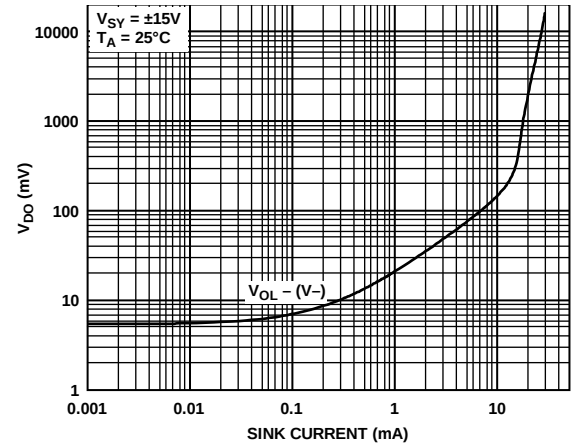


Figure 71. Dropout Voltage vs. Sink Current

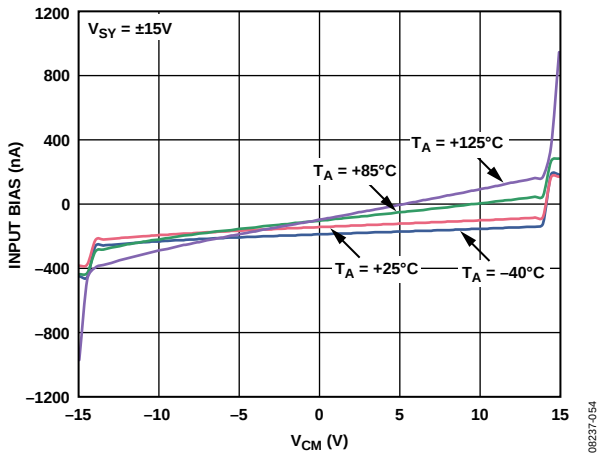


Figure 69. Input Bias Current vs. V_{CM} and Temperature

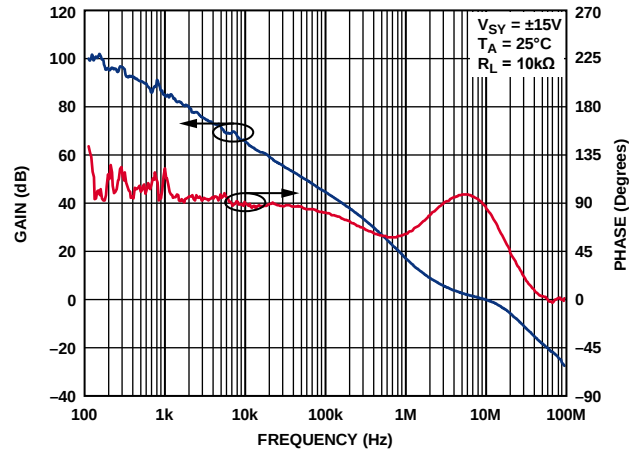


Figure 72. Open-Loop Gain and Phase vs. Frequency

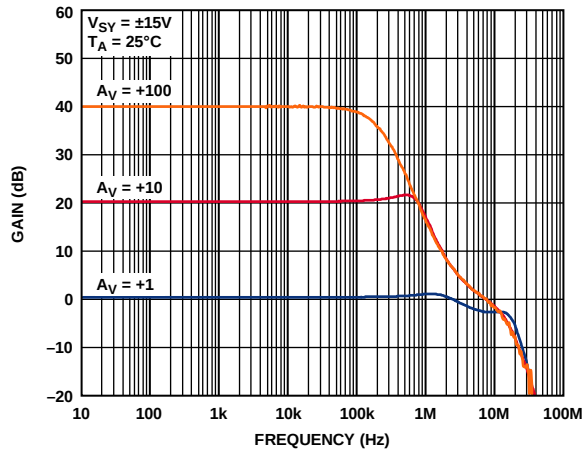


Figure 73. Closed-Loop Gain vs. Frequency

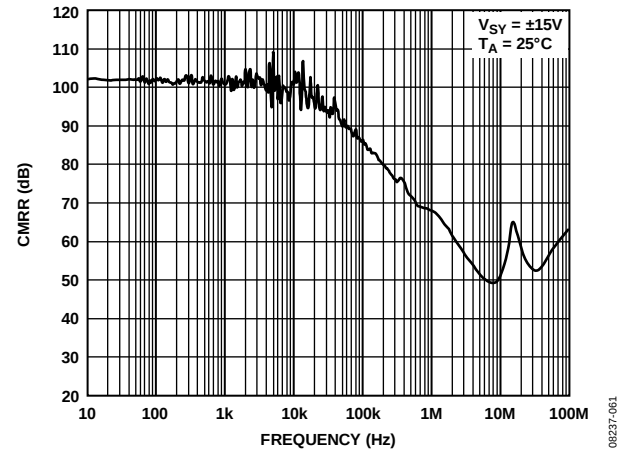


Figure 76. CMRR vs. Frequency

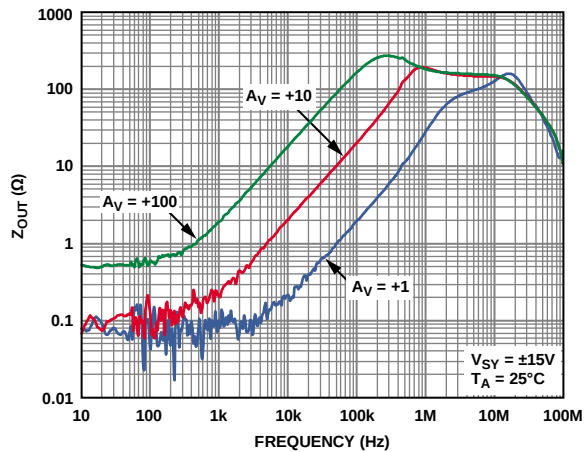


Figure 74. Output Impedance vs. Frequency

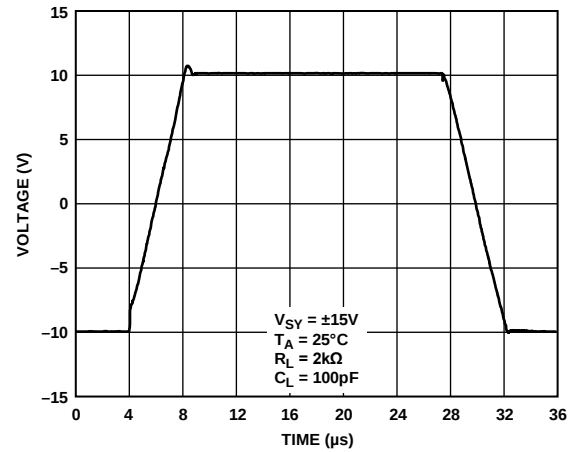


Figure 77. Large Signal Transient Response

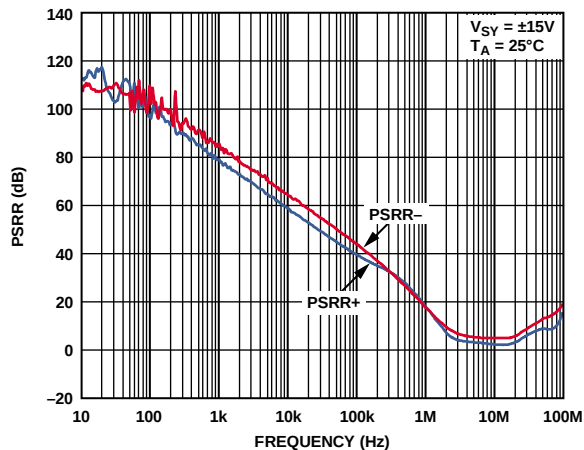


Figure 75. PSRR vs. Frequency

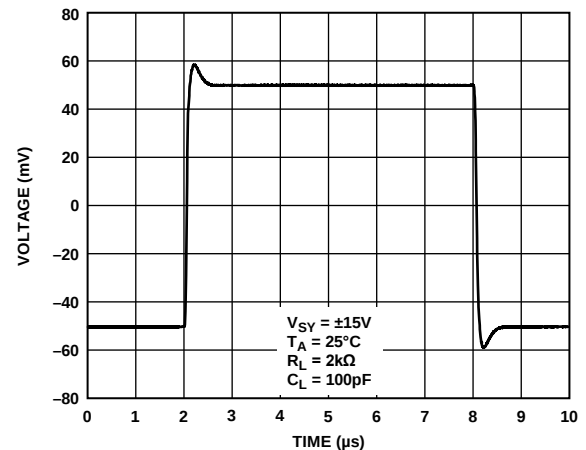


Figure 78. Small Signal Transient Response

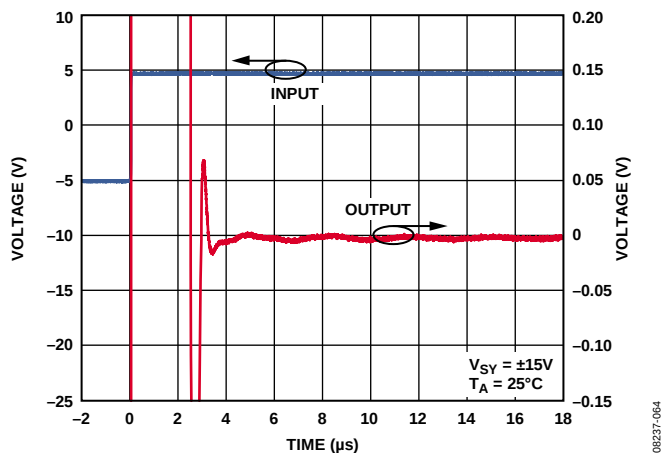


Figure 79. Settling Time

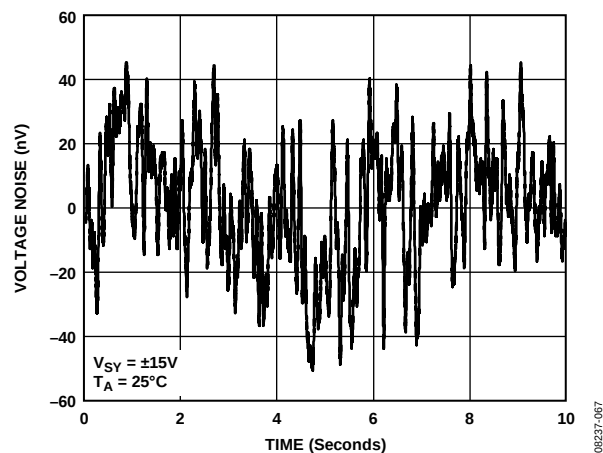


Figure 82. Voltage Noise 0.1 Hz to 10 Hz

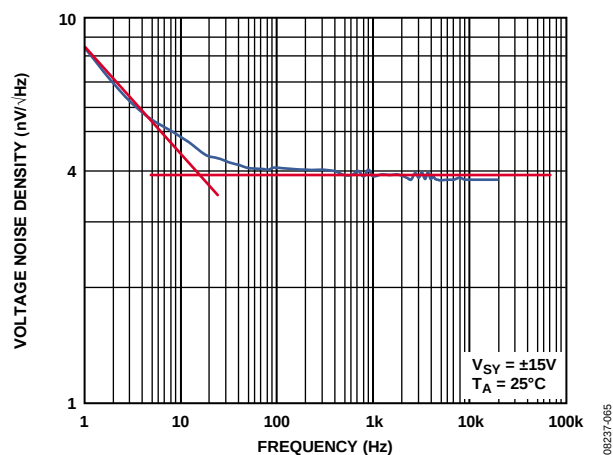


Figure 80. Voltage Noise Density

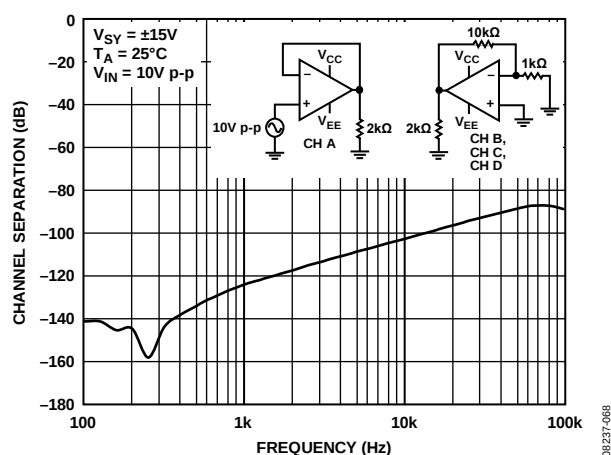


Figure 83. Channel Separation

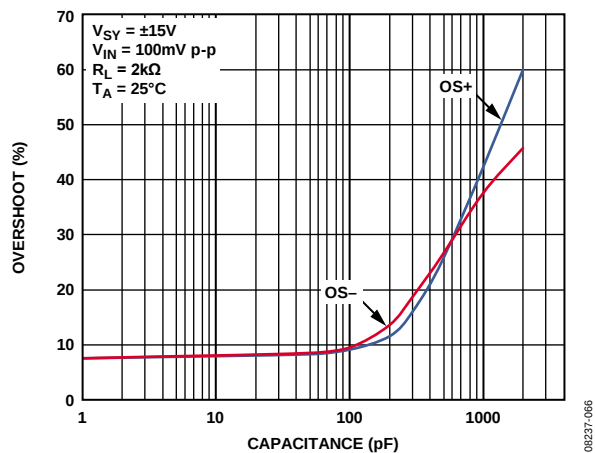


Figure 81. Overshoot vs. Load Capacitance

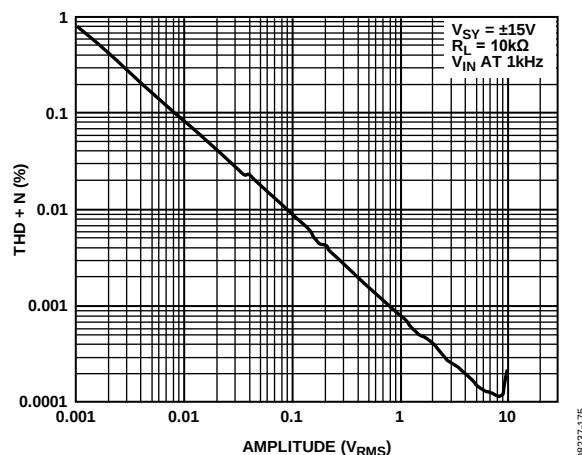


Figure 84. THD + N vs. Amplitude

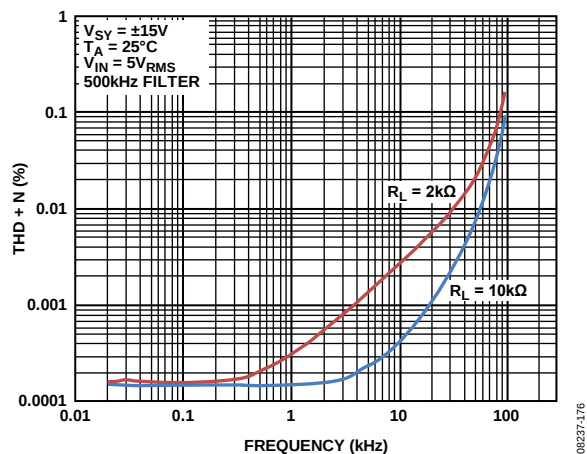


Figure 85. THD + N vs. Frequency

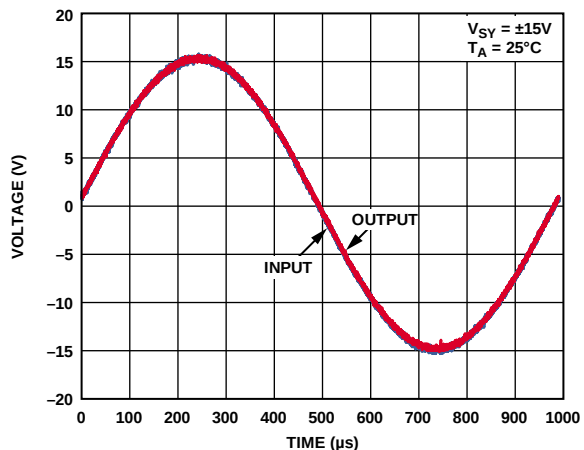


Figure 86. No Phase Reversal

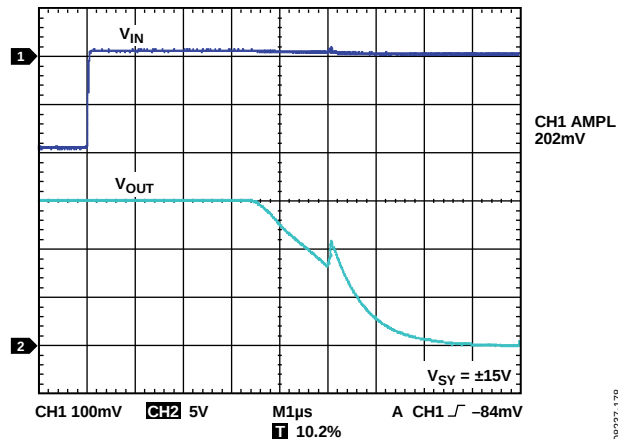


Figure 87. Positive Overload Recovery

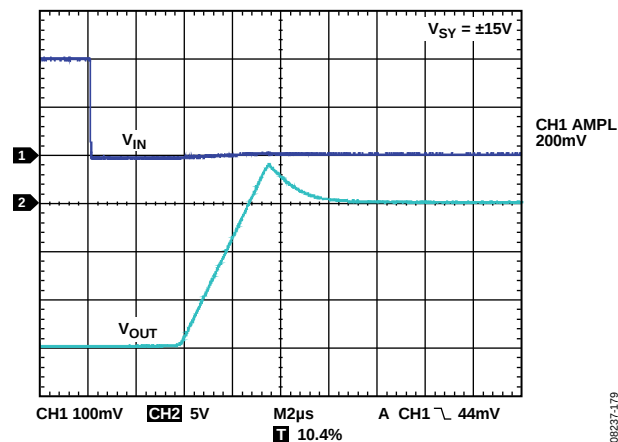


Figure 88. Negative Overload Recovery

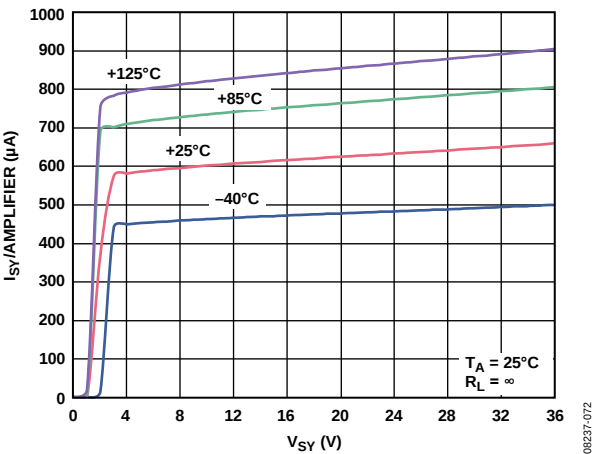


Figure 89. Supply Current vs. Supply Voltage

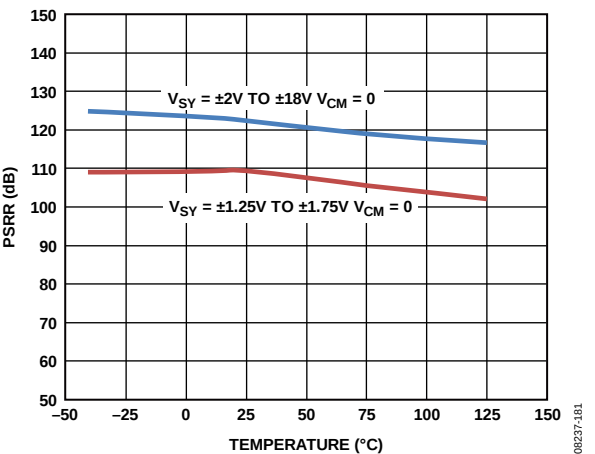


Figure 91. PSRR vs. Temperature

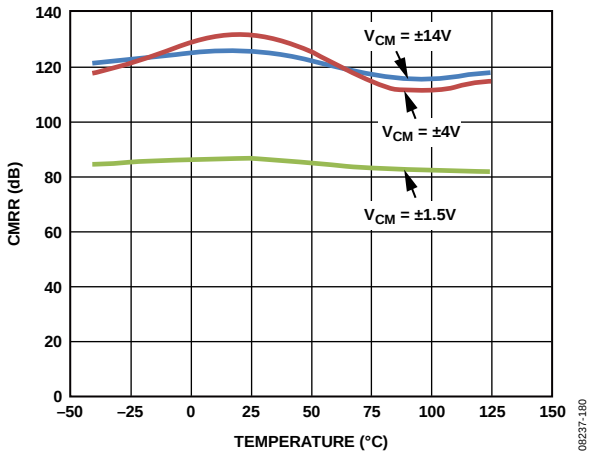


Figure 90. CMRR vs. Temperature

APPLICATIONS INFORMATION

FUNCTIONAL DESCRIPTION

The ADA4084-2/ADA4084-4 devices are precision single-supply, rail-to-rail operational amplifiers. Intended for portable instrumentation, the ADA4084-2/ADA4084-4 devices combine the attributes of precision, wide bandwidth, and low noise, making them 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/ADA4084-4 devices are 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.

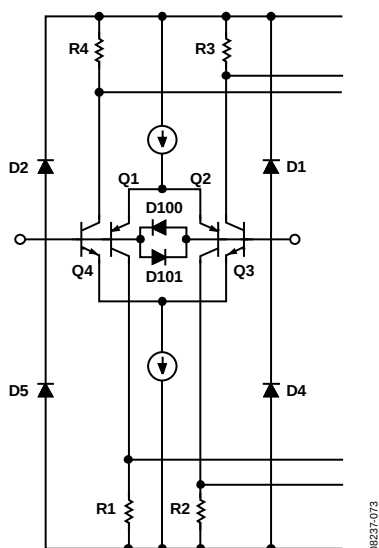


Figure 92. Equivalent Input Circuit

For example, Figure 92 illustrates a simplified equivalent circuit for the input stage of the ADA4084-2/ADA4084-4. 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/ADA4084-4, 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/ADA4084-4, which is a modified compound folded cascade gain stage. It is also in the second gain stage that 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/ADA4084-4 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/ADA4084-4 not only exhibit different amplitudes; they also exhibit different polarities. This effect is best illustrated by Figure 12, Figure 13, Figure 40, Figure 41, Figure 68, and Figure 69. It is,

therefore, important that the effective source impedances that are connected to the ADA4084-2/ADA4084-4 inputs be balanced for optimum dc and ac performance.

To achieve rail-to-rail output, the ADA4084-2/ADA4084-4 output stage design employs a unique topology for both sourcing and sinking current. This circuit topology is shown in Figure 93. 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.

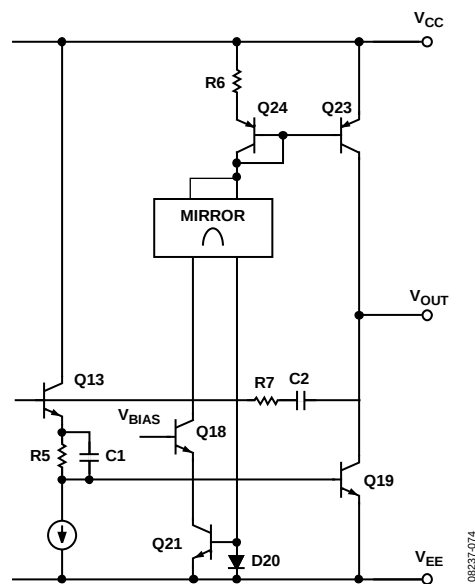


Figure 93. Equivalent Output Circuit

Thus, the saturation voltage of the output transistors sets the limit on the ADA4084-2/ADA4084-4 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/ADA4084-4.

START-UP CHARACTERISTICS

The ADA4084-2/ADA4084-4 are specified to operate from 3 V to 30 V (± 1.5 V to ± 15 V) under nominal power supplies. During power-up as the supply voltage increases from 0 V to the nominal power supply voltage, the supply current (I_{SY}) increases as well, to the point at which it stabilizes and the amplifier is ready to operate. The stabilization varies with temperature, as shown in Figure 89. For example, at -40°C , it requires a higher voltage and stabilizes at a lower supply current than at hot temperatures. At hot temperatures, it requires a lower voltage but stabilizes at a higher current. In all cases, the ADA4084-2/ADA4084-4 are specified to start up and operate at a minimum of 3 V under all temperature conditions.

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 diode drop voltage varies with temperature and is in the range of 0.3 V to 0.8 V. As shown in the simplified equivalent input circuit of Figure 92, the ADA4084-2/ADA4084-4 do 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, add an external series resistor at the expense of additional thermal noise. Figure 94 shows 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 k Ω resistor protects the ADA4084-2/ADA4084-4 against input signals up to 5 V above and below the supplies. Note that the thermal noise of a 1 k Ω resistor at room temperature is 4 nV/ $\sqrt{\text{Hz}}$, which exceeds the voltage noise of the ADA4084-2/ADA4084-4. For other configurations in which both inputs are used, protect each input against abuse with a series resistor. To ensure optimum dc and ac performance, balance the source impedance levels.

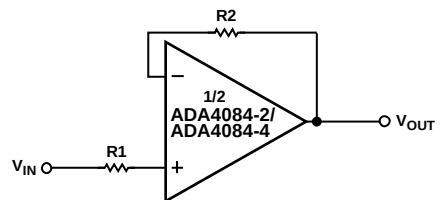


Figure 94. Resistance in Series with Input Limits Overvoltage Currents to Safe Values

To protect the Q1/Q2 and Q3/Q4 pairs 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.

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/ADA4084-4 are free from reasonable input voltage range restrictions, provided that input voltages no greater than the supply voltages are applied (see Figure 30, Figure 58, and Figure 86).

Although device output does not change phase, large currents can flow through the input protection diodes. Therefore, apply the technique recommended in the Input Protection section 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/ADA4084-4](#) 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 95, the expression for the total equivalent input noise voltage of an amplifier 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, 1.38×10^{-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).

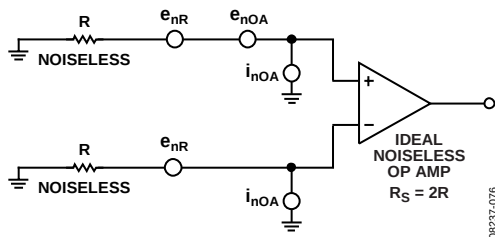


Figure 95. Op Amp Noise Circuit Model Used to Determine Total Circuit Equivalent Input Noise Voltage and Noise Figure

As a design aid, Figure 96 shows the equivalent thermal noise of the [ADA4084-2/ADA4084-4](#) vs. the total source resistance. Note that for source resistance less than 1 kΩ, the equivalent input noise voltage of the [ADA4084-2/ADA4084-4](#) is dominant.

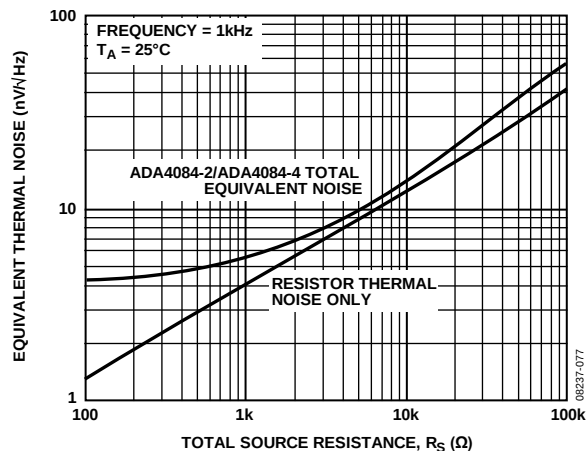


Figure 96. Equivalent Thermal Noise vs. Total Source Resistance

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 the signal-to-noise output of a circuit to its signal-to-noise input.

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.

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, choose an operational amplifier with the lowest equivalent input noise voltage, 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 device operating open loop, the second stage increases the current drive to the ratioed mirror to close the loop. However, the loop cannot close, 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 97). Configure an unused section as a voltage follower with the noninverting input connected to a voltage within the input voltage range. The [ADA4084-2/ADA4084-4](#) have unique second stage and output stage designs that greatly reduce the excess supply current when the op amp is operating open loop.

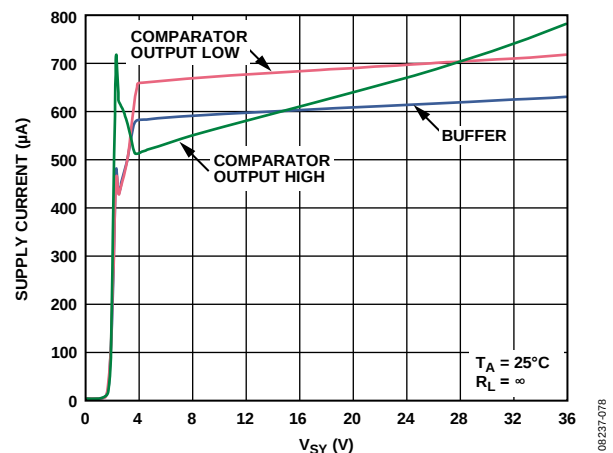
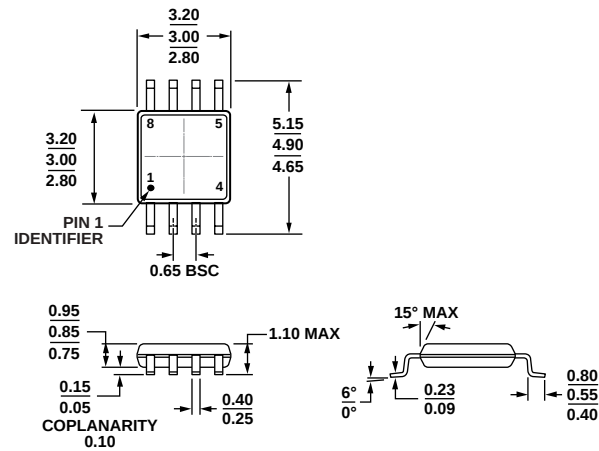


Figure 97. Supply Current vs. Supply Voltage

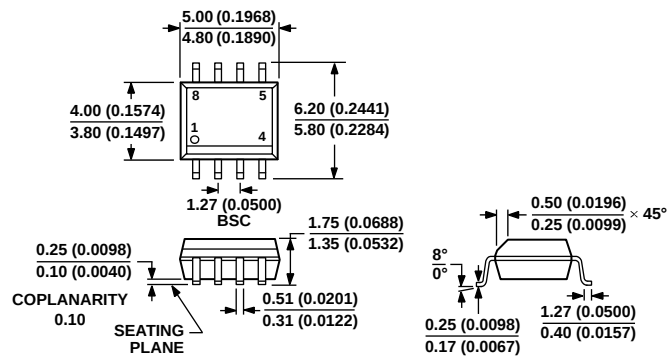
OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-187-AA

Figure 98. 8-Lead Mini Small Outline Package [MSOP]
(RM-8)

Dimensions shown in millimeters



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 99. 8-Lead Standard Small Outline Package [SOIC_N]

Narrow Body

(R-8)

Dimensions shown in millimeters and (inches)

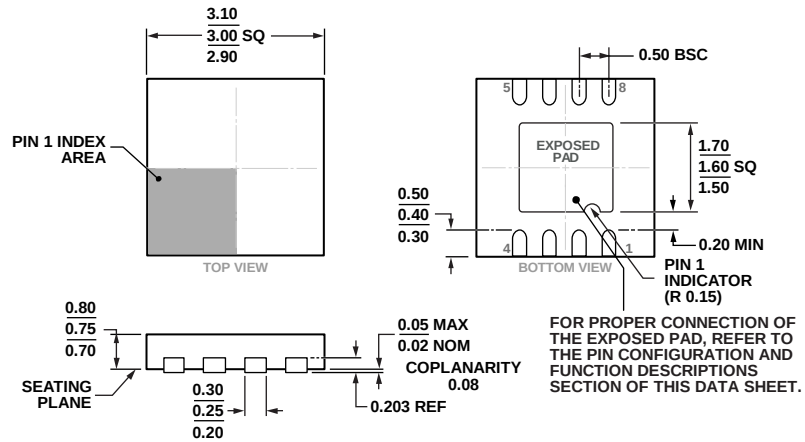


Figure 100. 8-Lead Lead Frame Chip Scale Package [LFCSP_WD]
3 mm × 3 mm Body, Very Very Thin, Dual Lead
(CP-8-12)

Dimensions shown in millimeters

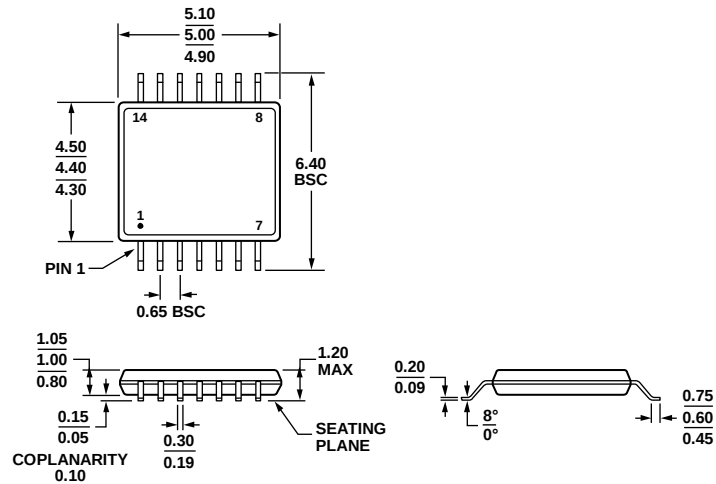
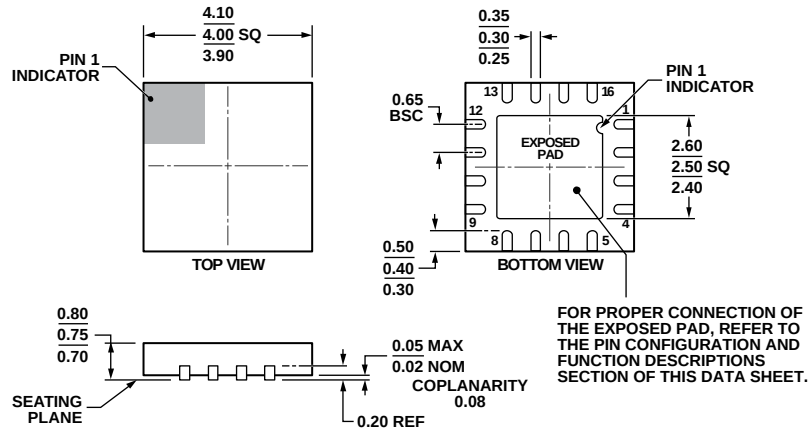


Figure 101. 14-Lead Thin Shrink Small Outline Package [TSSOP]
(RU-14)

Dimensions shown in millimeters



COMPLIANT TO JEDEC STANDARDS MO-220-WGGC.

Figure 102. 16-Lead Lead Frame Chip Scale Package [LFCSP_WQ]
4 mm x 4 mm Body, Very Very Thin Quad
(CP-16-26)
Dimensions shown in millimeters

042708-A

ORDERING GUIDE

Model ¹	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	
ADA4084-2ACPZ-R7	–40°C to +125°C	8-Lead Lead Frame Chip Scale Package [LFCSP_WD]	CP-8-12	A2Q
ADA4084-2ACPZ-RL	–40°C to +125°C	8-Lead Lead Frame Chip Scale Package [LFCSP_WD]	CP-8-12	A2Q
ADA4084-4ACPZ-R7	–40°C to +125°C	16-Lead Lead Frame Chip Scale Package [LFCSP_WQ]	CP-16-26	
ADA4084-4ACPZ-RL	–40°C to +125°C	16-Lead Lead Frame Chip Scale Package [LFCSP_WQ]	CP-16-26	
ADA4084-4RUZ	–40°C to +125°C	14-Lead Thin Shrink Small Outline Package [TSSOP]	RU-14	
ADA4084-4RUZ-RL	–40°C to +125°C	14-Lead Thin Shrink Small Outline Package [TSSOP]	RU-14	

¹ Z = RoHS Compliant Part.